

Soybean Meal and Oil Make Inroads in New Industrial Applications

Soybean meal is being used to make adhesives and composites. Soybean oil is finding its way into plastics, inks, and solvents. In 1996, 305.2 million pounds of soybean oil were used in inedible applications, accounting for about 2.5 percent of total consumption.

Soybeans contain both meal and oil. Soybean meal is currently the more valuable component obtained from processing soybeans, although this can change when relative prices of commodities change. Over 90 percent of soybean meal is used as a high-protein ingredient in livestock feed. A small portion of soybean meal is milled into flour or grits, primarily for edible applications, or used in the preparation of protein concentrates and isolates, which have food and industrial applications.

Soybean oil is the most widely used and least costly domestic vegetable oil, so it is frequently used in industrial applications. It is a source of fatty acids that are used to produce surfactants, emulsifiers, and alkyd resins for paints. One major industrial use is as epoxidized soy oil for a plasticizer in polyvinyl chloride (PVC) and other plastics. In 1996, 305.2 million pounds of soybean oil were used in nonfood applications, such as livestock feed and the manufacture of resins, plastics, paints, inks, and soaps. This constituted roughly 2.5 percent of all soybean oil consumed in 1996, with the remaining 12 billion pounds going into edible uses (table 25).

Soybean oil accounts for about 75 percent of the vegetable oil produced in the United States. Due to the abundance of domestic soybean production, research and development of industrial uses of vegetable oils have tended to concentrate mainly on soybean oil. For example, research on biodiesel has focused on using soybean oil as a major feedstock. Most biodiesel production today is used for testing and demonstration projects, but demand could increase in coming years (see the August 1996 issue of this report for more information on biodiesel).

A variety of public and private research on finding new uses for soybeans is underway. Much of this research is funded by a checkoff program in which farmers pay for promotion, research, and market development through an assessment on the sale of their crop. The United Soybean Board (USB), which distributes a portion of the earmarked money, has approved more than \$6.6 million for new-product research and development from fiscal 1997 funds. The money is being used to fund 34 new projects with 1- and 2-year grants to universities, private companies, and public research facilities. Many of the new applications use soybean oil, but new uses for soybean meal also are being pursued. This arti-

cle highlights examples of recent market successes and ongoing research projects.

Soy-Based Composites Are on the Market

One of the most successful new soybean-based products recently brought to market is a composite material that looks like granite and works like wood. Environ is comprised of 45-percent soybean flour and 45-percent old newspapers, with inks, oils, and other materials accounting for the remaining 10 percent. It is manufactured by Phenix Biocomposite, Inc., of Mankato, Minnesota, into 3-by-6-foot boards, which are used to make furniture, paneling, flooring, and other wood-like products. The company cites studies that the product has a potential market of \$1.8 billion a year by 2000. Construction has begun on a new 150,000-square-foot production facility in Mankato. The \$29-million plant should be operational in early 1998.

Commercialization of New Wood Adhesives And Composites Is Imminent

Research on new soybean-based wood adhesives promises performance, economic, and environmental benefits. One product, developed by Kriebich and Associates of Seattle, Washington, is an adhesive specifically developed for use in finger-jointing lumber. The process takes short scrap pieces of lumber and glues them end-to-end to make longer, more marketable lumber. The soy-based adhesive works in tandem with a traditional adhesive. The soy-based adhesive is applied to one piece of wood and the traditional adhesive to the other piece. When the pieces are joined, a strong bond forms in seconds. The water- and boil-proof bond is created without the use of heat, saving energy and time compared with traditional adhesives. The soy-based adhesive has a high tensile strength, which exceeds the minimum standards for finger joints. Using short lengths of lumber to make marketable products supplements scarce supplies of saw logs. Additional mill trials are planned for this year. If the tests are successful, commercial sale of the adhesive is anticipated to begin in 1998.

Other soy-adhesive research has focused on making composites, such as plywood, particleboard, and oriented-strand board (OSB) or chipboard. University of Minnesota researchers are conducting tests to make OSB using soy flour and methylene diphenyl diisocyanate (MDI) adhesive. MDI is commonly used in OSB production. Researchers

combine the two adhesives to make a powder that is applied to wood chips. The chips are coated with the adhesive mixture and fed into a press. Heat and pressure bond them to one another to form a high-quality OSB. The soy-based adhesive could replace half of the more expensive MDI, resulting in less expensive OSB. Four other research projects in the wood products area are testing the use of different forms of soy derivatives from whole meal to protein concentrates and isolates.

Researchers Attempt To Increase Soy Use In Plastics

In 1996, approximately 121.1 million pounds of soybean oil were used in plastics and resins, the largest category of inedible uses (table 25). Much of this was used to make epoxidized soybean oil, a plasticizer used to modify the properties of PVC and other plastic resins (see the June 1994 issue of this report for more information on vegetable oil-based plasticizers). Soybean oil currently accounts for only 3 percent of the plasticizers used to make PVC pipes and other products. If too much soybean oil is used in the formulation, the oil causes the PVC to become brittle and degrade. Research is being conducted in an attempt to modify soybean oil, enabling manufacturers to use up to 25 percent soybean oil in the plasticizing process. The majority of the plasticizers used in forming PVC resins are petroleum-based or generic phthalic esters, which sell for approximately 56 cents per pound. In comparison, the price of soybean oil has averaged 25 cents per pound during the last 5 years (table 36). Finding practical ways to modify the oil while maintaining its lower price is critical to the success of the project.

Another area of plastics research sponsored by the USB is the use of soybean meal or flour in the manufacture of biodegradable foams and films. Scientists at the University of Missouri at Rolla have developed prototype materials that are being tested for such uses as rigid insulation boards and agricultural mulching films. Planned field testing will help researchers to refine formulations for improved performance.

Inks Now a Large User of Soy Oil

Soybean oil is used in ink formulations as a vehicle, which, as defined by the ink industry, is any media that acts as a solvent, carrier, or binder for pigments to the substrate. Developed by the American Newspaper Publishers Association in response to the oil shocks of the 1970's, soybean oil-based inks were first marketed in 1987. Since then, soybean oil has been incorporated into a number of ink formulations. The amount of soybean oil used varies among manufacturers and types of ink. For an ink manufacturer to claim its product is soy ink, soybean oil must make up a minimum percent of the ink's total formula weight (table 4). Newer formulations have higher amounts of soybean oil; for example, some black news inks contain up to 75 percent soy oil.

Table 4—Percentage of soybean oil in printing inks, by type

Type of ink	Minimum soybean	Maximum current
	oil content	soybean oil usage
Percent		
Black news ink	40	up to 75
Color news ink	30	up to 50
Sheet-fed ink	20	30
Heat-set ink	7	less than 20
Cold-set ink	30	30
Business-form ink	20	50

The newspaper industry is a large user of soy inks. Soy inks account for more than 90 percent of all colored inks and about one-third of black inks used by U.S. newspapers. Soy inks produce better colors and provide greater clarity with reduced rub-off on readers' hands. The lighter color of soybean oil makes it ideal for color inks because the true color of the pigments can show through. Newspaper pictures are composed of a pattern of dots, which with petroleum-based inks increase in size during the press run, reducing the clarity of the picture. With soy inks, the dots remain relatively the same size, keeping picture clarity constant throughout the press run. Moreover, soy inks can be used for printing newspapers without a change in equipment or printing methods. Soy ink has been found to be a better carrier of pigments, driers, and other agents than other ink vehicles, which can result in less press time, lower cost, and higher quality results.

Color soy inks have taken over much of the market not only because of their superior properties, but also due to their competitive price. Color inks contain less oil, and prices are based primarily on the cost of the pigments. On the other hand, the price of black inks, which are 70 to 80 percent oil, is driven by the cost of the vehicle oil. Currently, the price of refined soybean oil is higher than that for petroleum-based mineral oil, making black soy inks more expensive than their conventional counterparts. (See the June 1993 issue of this report for more information on soy ink development.)

The U.S. Department of Agriculture's (USDA) Agricultural Research Service (ARS) has patented a 100-percent vegetable oil ink that replaces the petroleum-based vehicle and resins used in conventional inks with vegetable oil derivatives. The ARS formulation represents an improvement over most soy oil inks that replaced only the mineral oil carrier with soy oil, but not the resins. USDA issued its first license on the patent in 1992 to Franks Research Laboratories, Inc., of Oklahoma City, Oklahoma, giving the company the right to make ink products for sale in five states. The Department continues to explore other licensing opportunities. ARS scientists also developed sheet-fed and heat-set inks containing up to 60 percent soybean oil by eliminating the petroleum oil and resin. Patents are pending for these technologies.

In addition to their other attributes, soy inks are more environmentally friendly than traditional petroleum-based inks.

Soy inks can help improve air quality since they emit almost no volatile organic compounds (VOC's) into the air. Petroleum inks typically have VOC ratings of 25 to 40 percent, while soy ink manufacturers report VOC ratings under 10 percent, with many soy inks registered at 2 to 4 percent. Soy ink also enhances paper recycling since soy ink is easier to remove from paper pulp than petroleum-based ink, so there is less damage to pulp fibers during deinking. Finally, soy inks are more biodegradable than petroleum-based inks. In a study to test the biodegradability of various inks, ARS scientists found that 90 percent of USDA's 100-percent vegetable oil inks biodegraded, compared with 60 percent for regular soy-based formulations that contain about 30-percent vegetable oil and 20-percent biodegradation for petroleum-based inks. All inks, including the 100-percent vegetable oil formulations, utilize pigments, which are derived from either petrochemicals or metallic oxides, that preclude complete biodegradability.

According to the National Soy Information Center, the use of soybean oil in printing inks grew nearly 27 percent between 1994 and 1995, from 46 million pounds to 58.2 million pounds. However, industry analysts suggest that growth in U.S. vegetable oil-based inks will begin to flatten out, primarily because most of the environmentally proactive users have already switched from petroleum-based inks and demand will stay constant. In contrast, interest is expanding overseas. For example, soy inks are being tested in the Asian market. South Korea's two largest newspapers are using and actively promoting soy ink. Major newspapers in both Japan and Taiwan are considering making the switch to soy.

Soybean Solvents Are Cleaning Up

A new soy-based industrial solvent, now being marketed by several companies, is a direct substitute for petroleum distillate as a cleaner and carrying agent. Soy solvents help cut grease, oil, tar, hydrocarbons, and a variety of oil-based paints and rubber compounds. Other benefits of using soy solvents are that they have no harsh fumes or unpleasant odors, they do not irritate skin, and they are recyclable.

Using USB funding, Cyto Culture International, Inc., of Point Richmond, California, has developed a process that uses methyl soyate to clean up oil spills. The solvent is sprayed on sand and contaminated rocks, and the oil is separated and recovered by conventional skimming technology. In many cases, more than 90 percent of the oil can be removed by the soy solvent. The remaining crude oil then biodegrades more quickly after exposure to the methyl soyate. This new method is far less expensive than older methods of cleaning oil spills that usually require high transport and storage costs of moving the soiled sand to a landfill. In 1997, the U.S. Environmental Protection Agency listed the product and process for use as a surface cleaning agent.

Promising Research in Soy-Based Lubricants

USB is funding research on soy-based lubricants with the goal of commercial use in 3 to 5 years. Soybean oil is biodegradable, which gives it an advantage over petroleum lubricants in instances where the lubricant is lost into the environment and may contaminate water supplies. Soybean oil also protects metal better than petroleum lubricants and costs less than canola or industrial rapeseed oils, which are already being used in lubricant formulations. However, soybean oil has technical and economic barriers to overcome before commercial use is feasible. The oil gels up under pressure and high temperatures. Researchers at the University of Delaware may alleviate these performance problems by using oils from genetically modified soybeans. Also, soybean oil is more expensive than petroleum lubricants, which will relegate soy-based lubricants to niche markets where users would be willing to pay a price premium.

Developing commercially viable soy-based lubricants is primarily focused on hydraulic fluids, crankcase oils, and total-loss lubricants. A niche market for biodegradable hydraulic fluids has already formed in Europe, where many localities ban the use of nondegradable hydraulic fluid to protect water supplies. Industry analysts expect similar requirements to reach the United States sometime in the near future. A prototype biodegradable, soy-based hydraulic fluid has passed year-long development tests at the University of Northern Iowa's Agricultural-Based Industrial Lubricants Research Program and is ready for market introduction.

Scientists at Agro Management Group, Inc., of Colorado Springs, Colorado, are testing soybean oil in conjunction with canola oil in the crankcases of small engines, such as lawnmowers and snowblowers. Renewable Lubricants of Hartsville, Ohio, is researching the use of soybean oil as a crankcase lubricant in automobile engines. Soybean oil-based lubricants also can fill a need in situations where oils and greases are routinely lost into sensitive environmental areas. These include uses in railroads and offshore-drilling equipment. Soy lubricants are also safer for workers in industrial situations like metal-working factories where workers are exposed to fumes from quenching and cutting oils. International Lubricants, Inc., of Seattle, Washington, is evaluating soy-based total-loss lubricants. Total-loss lubricants, which include oil for lawnmowers and other machines with two-cycle engines, drop directly to the ground or water through normal use. Omni Tech International of Midland, Michigan, estimates that certain crankcase oils and hydraulic fluids made with soybean oil could be on the market in 2 to 3 years. The company expects soy-based lubricants will eventually capture 10 to 15 percent of the lubricants market.

Creative Efforts of Students Result in New Uses

Professional researchers have not been the only ones in recent years investigating new uses for soybeans. Other innovative uses have been developed by students. Two Purdue University students developed a soy-based fire-starter log. The log is a flat, brownish bar made from sawdust and fully hydrogenated soybean oil under pressure. Two commercial companies have expressed interest in the product.

Other student projects at Purdue have found ways to substitute hydrogenated soybean oil for paraffin, a petroleum-

based wax. The first project developed a set of soy-based crayons. The crayons, which are 80-percent soybean oil, are nontoxic and washable. Already in commercial production, soy-based crayons could require the oil from up to 200 tons of soybeans a year. The market for crayons is large, about 2 billion annually. Another group created birthday candles, made with edible wax. The candles are 83-percent hydrogenated soybean oil and come in seven flavors. The candles reportedly drip less and burn an average of 25 seconds longer with a shorter flame than paraffin birthday candles. [Jacqueline Salsgiver, ERS, (202) 501-7107, jsalsgiv@econ.ag.gov]