Agriculture and Industry Explore New Crop and Market Opportunities

Castor and lesquerella, both potential U.S. oilseed crops, are sources of hydroxy fatty acids that are used by industry in a variety of applications. Glycerine markets are tight as expected supplies have not developed and demand remains strong. Biodiesel research and testing continues.

Native to Africa, castor is grown throughout the world. In temperate climates, it is an annual crop, while in tropical climates, it is a perennial. Castor seeds contain a high amount of oil--over 50 percent on a dry-weight basis--that is used in a variety of ways. Ancient Egyptians burned it in their lamps. Modem manufacturers have developed many products using castor oil and its derivatives, ranging from lipstick to jet-engine lubricants. The United States has imported an average of 40,630 metric tons of castor oil per year since domestic production ceased in 1972 (figure 3). India is the major U.S. supplier, followed by Brazil.

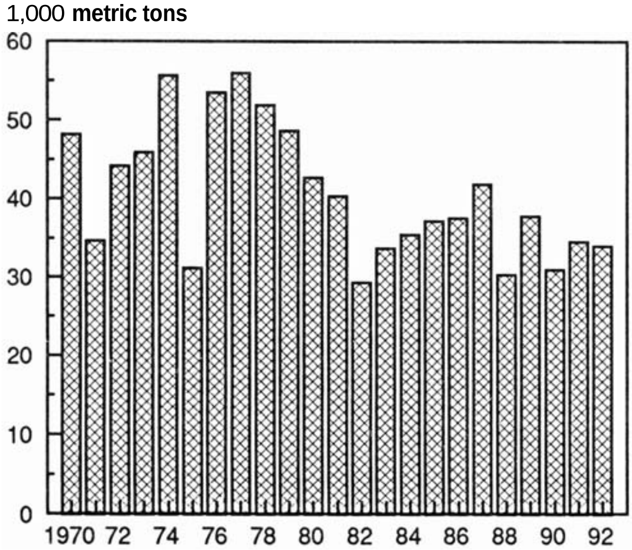
Because of widely fluctuating world supplies and the structure of the world market, prices for castor oil vary considerably. These supply and price instabilities impact cash flow, make corporate planning difficult, and discourage research and investment in castor products. Therefore, major castor oil buyers--Union Camp, CasChem, Alnor, and Atochem--have expressed interest in U.S. castor production. In response, Browning Seed, Inc. (Plainview, TX) and National Sun Industries (Minneapolis, MN) are working with scientists and farmers to reestablish castor as a domestic crop. During the 1950's and 1960's, about 80,000 acres of castor were grown in Texas.

Lesquerella, an experimental crop, may also provide U.S. manufacturers with a domestic source of hydroxy fatty acids and U.S. farmers with a new source of income. A consortium of industrial, university, and government organizations has come together to commercialize lesquerella. USDA's Alternative Agricultural Research and Commercialization Center has committed $776,110 to the project and USDA's Cooperative State Research Service, Office of Agricultural Materials is supporting research to increase yields in 10 U.S. locations.

Figure 3

U.S. Imports of Castor Oil

1,000 metric tons



Plants of the genus Lesquerella are native to North and South America. Of the 85 species, 23 have been examined for agronomic potential and seed composition. Species native to the southwestern United States and northern Mexico are generally rich in lesquerolic acid. Of these species, Lesquerella fendleri--a winter annual--appears to have the best agronomic potential. Its tiny seeds contain over 25-percent oil on a dry-weight basis.

Considerable genetic variation has been observed both within the genus and in L. fendleri, which appears to be highly cross-pollinated. These characteristics provide plant breeders with opportunities to improve yield, the oil content of the seed, the amount of hydroxy fatty acids in the oil, its growth habit (so the plants stand more upright), and other traits needed in a commercial oilseed crop.

The primary fatty acids in castor and lesquerella oils are hydroxy fatty acids. The hydroxyl group (an oxygen atom and a hydrogen atom) gives a fatty acid special properties, such as higher viscosity and reactivity compared with other fatty acids. Ricinoleic acid is the dominant fatty acid in castor oil; it accounts for almost 90 percent of castor's fatty acids. Researchers have identified three principal hydroxy fatty acids in the Lesquerella species examined thus far--lesquerolic, densipolic, and auricolic acids. Depending on the species, one of the fatty acids is dominant. Some species also contain up to 15 percent ricinoleic acid. About 55 percent of L. fendleri's oil is lesquerolic acid.

Hydroxy Fatty Acids Have a Wide Range of Uses

Because of their special chemical attributes, hydroxy fatty acids are used in a wide range of products, including cosmetics, waxes, nylons, plastics, and coatings. Furthermore, they are used in grease formulations for military and industrial equipment. These latter uses have prompted the Department of Defense to include ricinoleic and sebacic acids, castor-oil derivatives, in their stockpile of strategic and critical materials.

Castor oil is used directly in many products, such as transparent soaps, waxes and polishes, hydraulic fluids, inks, and metal drawing oils. However, most castor oil is further processed. The resulting derivatives are used in a wide range of applications. For example, hydrogenated castor fatty acids are an ingredient in lubricating greases for cars, trucks, boats, railcars, aircraft, and industrial equipment. Nylon-11 is used in engineering plastics and powder coatings. Dehydrated castor oil and its fatty acids are components of coatings, inks, and sealants. Polyurethanes are used in electrical and telecommunication casting resins and coatings.

Polymer scientists at the University of Southern Mississippi have used *L. fendleri* oil to make urethane foams, wood stains, and alkyd resins, a common component of paints and coatings. Polyurethane foams are frequently used in dashboards, car seats, and similar items.

In addition, the known properties of fatty acids indicate that lesquerella should be a good raw material in other applications. Ricinoleic and lesquerolic acids have similar chemical structures. This means that both common and different products may be derived from the two hydroxy acids. Where higher molecular weights are important for the chemical properties of the products, lesquerolic acid could be superior. For example, precursors for nylon-13 and nylon-1212 can be produced from lesquerolic acid. Nylon-1212 now comes from petrochemicals, while nylon-11 and sebacic acid are derived from ricinoleic acid.

The remainder of *L. fendleri* oil is composed of oleic, linoleic, and linolenic acids. These fatty acids are commonly found in other fats and oils used for animal feeds and industrial raw materials. Scientists, processors, and manufacturers are faced with the challenge of finding uses that utilize the entire oil or ways to economically separate lesquerolic acid from these other fatty acids. Researchers at USDA's Agricultural Research Service (ARS), National Center for Agricultural Utilization Research (NCAUR) have developed two methods--enzymatic and physical--to concentrate lesquerolic acid to 85 to 90 percent. Another alternative, which is currently being investigated, is to increase the amount of hydroxy fatty acids in the oil.

Lesquerella meal and treated castor meal could be used as protein supplements in livestock rations, primarily for beef cattle. Feeding trials with lesquerella meal are currently underway, and preliminary results are encouraging. Treating lesquerella meal may not be necessary, depending upon the level used in the feed. Texas A&M University has developed technology to detoxify castor meal, which has been proven commercially in Thailand. This process improves the feed value compared with the detoxified castor meal that was fed to Texas cattle during the 1960's and early 1970's.

The Next Steps for Castor and Lesquerella

With domestic production of both castor and lesquerella, U.S. supplies of hydroxy fatty acids would not depend on

Coconut and Castor Oil Prices Forecast to Rise

According to times-series forecasting models, coconut and castor oil prices are expected to rise moderately through January 1994 (table 2). By January, coconut oil prices are to increase 2.9 percent and castor oil prices are forecast at 4.3 percent above October 1993 levels.

The forecasts published in the June 1993 issue of this report are also in the table, as are the actual values. Last issue's coconut oil price forecasts were accurate, while forecasts of castor oil prices generally fell below actual values. Castor oil prices took a sudden 16-percent jump from 32 cents per pound in April to 37 cents in May. This is credited to drought conditions in Brazil's castor production areas, causing a shift to Indian supplies. Prices rose further by about 4 percent in September and 14 percent in October due to concerns over the Indian crop. When making the forecasts for November through January, the castor-oil-price model was adjusted to account for the two large price increases in May and October.

The single-equation time-series models used here were estimated with monthly price data from January 1977 through October 1993. Prices from the previous 2 months and seasonal factors are used to explain each month's price. These models capture the historical regularities in these two markets. Forecasts are based on historical patterns. These forecasts do not account for random and atypical events, such as political unrest and violent weather during the forecast period. Ronald A. Babula (202) 219-0785]

Table 2--Price forecasts for castor and coconut oil, 1993194

	Castor oil		Coconut oil	
Month	Forecast 1/	Actual	Forecast 11	Actual
	--Cents/pound--			
May	31.8	37.0	23.7	24.1
Jun	30.6	37.0	25.5	25.0
Jul	31.5	37.0	26.1	25.4
Aug	33.5	37.0	25.4	25.6
Sep	N.A.	38.5	N.A.	24.4
Oct	N.A.	44.0	N.A.	24.0
Nov	44.9	N.A.	24.1	N.A.
Dec	45.7	N.A.	24.0	N.A.
Jan	45.9	N.A.	24.7	N.A.

N.A. = Not available.
1/ May to August forecasts were published in the June 1993 issue of this report.

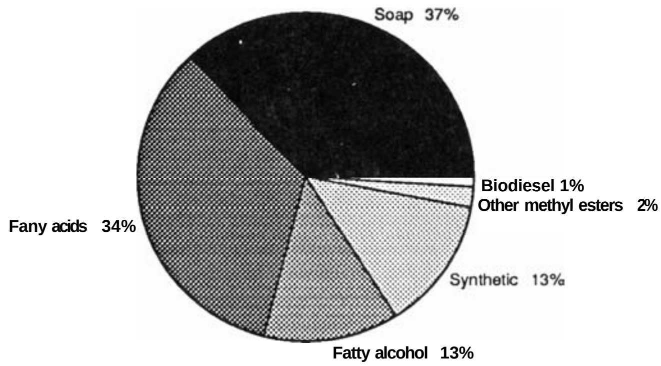
a single commodity. The two crops would be grown in different seasons; lesquerella is planted in the fall and harvested in late spring, while castor is planted in the spring and harvested in late fall. Also, due to disparate requirements for water, temperature, and other climatic conditions, the crops will probably be grown in different parts of the country. Multiple production regions would provide a more reliable domestic supply. This in turn could encourage further product research and development, thus opening additional markets for both crops.

The lack of a crushing facility has been the major obstacle impeding domestic castor production. Plans to produce 10,000 metric tons of castor seed in the Texas High Plains in 1991 stalled when negotiations for crushing the crop failed. Some farmers in the area were also wary of growing castor because of the possibility of contaminating adjacent crops, particularly food-grade corn. However, plans are now underway to crush castor at National Sun's facility in western Kansas. The parties are exploring funding options.

Much work still needs to be done on lesquerella's crop and product development. The consortium, led by Mycogen Corporation (San Diego, CA), has signed a Cooperative Research and Development Agreement with ARS's Water Conservation Laboratory (Phoenix, AZ) to explore lesquerella's growing requirements and other agronomic characteristics. The lab will also work on germplasm collection, evaluation, and enhancement. Mycogen will conduct plant breeding, variety development, and biotechnology research. NCAUR (Peoria, IL) will evaluate a variety of potential applications. International Flora Technologies, Ltd. (Apache Junction, AZ) will develop oil processing technology and high-value applications for the cosmetic industry. The collaborators expect that it will take 5 to 7 years to develop a commercial variety for large-scale production.

Figure 4

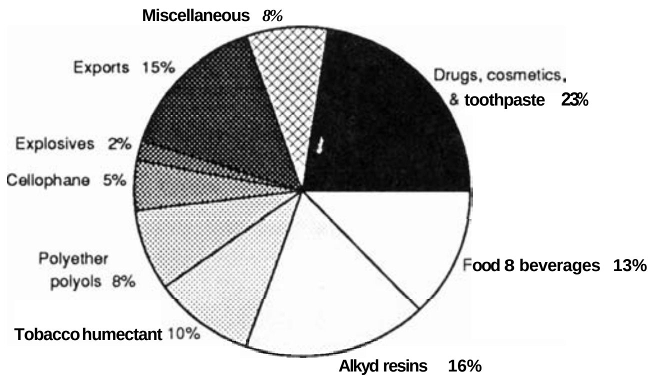
World Production Sources of Glycerine by Primary Product or Process, 1992 1/



1/1992 world production of glycerine is estimated at 1.2 billion pwnds.
Source: Institute for Local Sell-Reliance. Washington. DC.

Figure 5

Estimated End Uses of Glycerine in the United States 1/



1/Annual consumption is estimated at 300 million pounds per year.
Source: Institute for Local Self-Reliance. Washington. DC.

Glycerine Markets Are Tight

Glycerine is a byproduct of producing soaps, fatty acids, and fatty alcohols from the triglycerides in vegetable oils and animal fats (figure 4). Lower cost synthetic glycerine has provided stiff competition since its development around the turn of the century. During the last decade, however, glycerine recovery has been a significant factor in the economics of producing soaps and surfactants from renewable resources. The glycerine credit from biodiesel production has similarly increased the competitiveness of that renewable fuel (see the special article).

End uses for glycerine include diverse products like drugs and cosmetics, resins, polymers, and explosives. Glycerine's chief end uses are drugs, cosmetics, toothpaste, alkyd resins, and tobacco (figure 5). However, it has over 1,500 commercial and industrial applications (table 3). The primary function of glycerine in many cases is that of a humectant (a substance for retaining moisture and, in turn, softness). It also acts as a solvent, sweetener, and preservative in food and beverages, and as a carrier and emollient in cosmetics. Glycerine's properties as a plasticizer and lubricant give it wide applicability, particularly for food processing machinery because it is nontoxic. Glycerine also is used in alkyd resin manufacture to assure flexibility. Alkyd resins find their way into products such as paints and inks where brittleness is undesirable.

Specific examples of glycerine based products that have recently been introduced into U.S. markets include a 100-percent glycerine bar soap that is marketed by Jason Natural Cosmetics (Culver, CA), under the brand name Jason Natural Aromatherapy. Wal-Mart has introduced its own line of glycerine liquid soap under the Sam's American Choice label. And St. Ives Laboratories (Chatsworth, CA) is in the process of introducing a glycerine-based extra mild facial cleansing liquid under the brand name St. Ives Swiss Formula. 3

Table 3--Uses of glycerine by industry

Product category	Uses
Food and beverages	Humectant, solvent, sweetener, and preservative.
Pharmaceuticals	Solvent, moistener, humectant, and bodying agent in tinctures, elixirs, ointments, and syrups; plasticizer for medicine capsules; other uses include suppositories, ear infection remedies, anesthetics, cough remedies, lozenges, gargles, and carrier for antibiotics and antiseptics.
Cosmetics and toiletries	Humectant, vehicle, and emollient in toothpaste, skin creams and lotions, shaving preparations, deodorants, and makeup.
Tobacco	Keeps tobacco moist and soft to prevent breaking and crumbling during processing; ensures freshness in packaged cigarettes and other tobacco products.
Surface coatings	Used in the manufacture of alkyd resins, which are an important component of surface coatings.
Paper and printing	Plasticizer, humectant, and lubricant in the manufacture of paper; used with other ingredients in specialty treatments such as grease-proofing; alkyd resins also an important constituent of many printing inks.
Lubricants	Because of its nontoxic character, used in lubricants for food and other machinery where product purity is essential.
Textiles	Conditioning agent used widely in lubricating, sizing, and softening yarn and fabric; lubricates many kinds of fibers in spinning, twist setting, knitting, and weaving operations.
Rubber and plastics	Lubricant and plasticizer for plastic.
Urethane polymers	Fundamental chemical component of polyethers for urethane foams.
Electrical and electronics	Widely employed in manufacturing electrolytes for electrolytic condensers, which are used in radios and neon lights, and in processes for electrodeposition and treatment of metals.
Nitration	Used to make nitroglycerine, which is the usual explosive in dynamite and a cardiovascular agent.

Source: Glycerine: An Overview, Soap and Detergent Association, Glycerine and Oleochemical Division, New York, NY, undated.

More applications of glycerine are being discovered. Substituting glycerine for polyols is a rapidly growing area. Among the candidates for further substitution are personal-care products, pharmaceuticals, alkyd resins, and detergents.

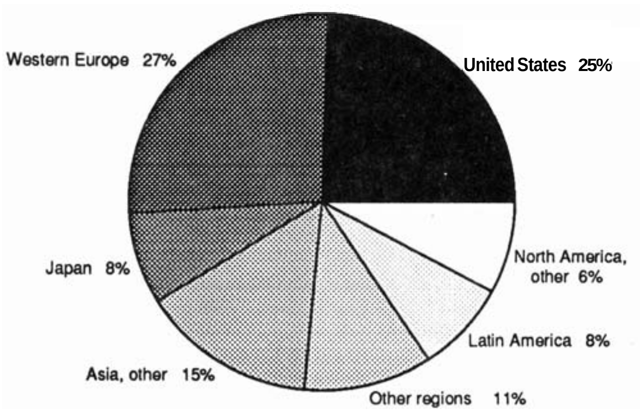
Currently, total world consumption of glycerine is estimated at 1.2 billion pounds annually (figure 6). The United States accounts for 25 percent or 300 million pounds. A 2- to 3-percent annual growth is expected through 1997. If glycerine prices fall to 1991 levels, annual demand could grow 5 to 6 percent.

Analysts are having fits trying to pin down the volatile glycerine market. Last year, prices were expected to fall because of projected increases in supply resulting from greater biodiesel production in Europe and new fatty alcohol production facilities in Asia. These projections, however, have not panned out due to the recession in Europe that lowered fatty acid production, the over-estimation of biodiesel industry expansion, and the slower than expected market entry by new Southeast Asian producers.

In fact, Procter & Gamble Co. (P&G), the largest U.S. producer of natural glycerine, estimates that since 1990, 120 million pounds of glycerine capacity and 85 million pounds of actual production have disappeared from the world market due to plant shutdowns, flat fatty acid production,

Figure 6

World Glycerine Consumption 1/



1/Worldwide use of glycerine is estimated at 1.2 billion pounds per year.
Source: institute for Local Self-Reliance. Washington. DC.

and revised manufacturing processes. This sharp decline in supply prompted P&G to raise prices of glycerine 16 to 20 cents per pound this year. Although many industry experts doubted that the price increase would hold, most of the major producers followed P&G's lead and raised their prices.

The outlook for the glycerine market is still uncertain. Increased interest in natural sources for soaps and surfactants--driven by both cheap vegetable oil supplies and greater demand for "green" cleaners--has resulted in a greater supply of natural glycerine. And an upturn in the biodiesel industry worldwide, coupled with new fatty alcohol production in Malaysia and Indonesia, may further expand glycerine supplies.

These supply increases may be met by an equally large demand expansion. More glycerine uses are being developed each year. And even with the recent price hikes, glycerine is less expensive than its main competitor, propylene glycol.

Biodiesel Research and Testing Continues

Government, industry, and trade associations continue to research and test biodiesel. For example, the National Institute for Petroleum Energy Research recently completed biodiesel engine exhaust emissions tests. Blends of diesel and biodiesel–processed from soybean oil, beef tallow, and/or waste grease (used fats and oils discarded by foodservice operations)--were run in diesel engines commonly found in buses and pickup trucks. The results indicate that the more biodiesel used in the blend, the lower the emissions of hydrocarbons (HC) and carbon monoxide (CO) compared to low-sulfur diesel fuel. However, nitrousoxide (NOx) emissions rose as the amount of biodiesel in the blend increased.

ORTECH, an engine-testing laboratory in Canada, recently completed timing change tests on a Detroit Diesel 6V-92 engine using a diesel fuel blend containing 20-percent biodiesel. Previous research suggested that 20 percent may be the optimum biodiesel blend for city buses using the 6V-92 engine. Results show that a 3-degree timing change decreased NOx exhaust emissions slightly and maintained lower emissions of CO, HC, and particulate matter (table 4).

Numerous demonstration projects are underway in the United States. Most of the demonstrations are being conducted on mass transit fleets in major cities where meeting Clear Air Act standards may be an issue. Many are sponsored by the National SoyDiesel Development Board (table 5). In addition, testing will soon begin at the U.S. Bureau of Mines Twin Cities Research Center (Minneapolis, MN). In order to meet pending regulations, the bureau has been researching strategies to reduce exhaust emissions in mines.

MFA Oil Company, Inc. (Columbia, MO) is the first commercial petroleum distributor to handle biodiesel in the United States. MFA o i l is marketing a biodiese/diese l blend to four rural electric cooperatives in Missouri. The cooperatives will use the fuel in their truck fleets. Eewrene Glaser (202) 219-0085, David Pace (606) 257-7272, Irshad Ahmed (202) 232-4108, and Alan Weber (314) 882-4512]

Table 4--ORTECH emissions test results

Test with a Detroit diesel 6v-92 engine	Emissions: Nitrous oxides	Carbon monoxide	Hydrocarbons	Particulates
	--Grams per brake horsepower hour--			
Blend of 80-percent #2 diesel and 20-percent biodiesel with a 3degree timing change	4.25	1.50	0.38	0.216
#2 diesel fuel	4.46	1.67	0.45	0.261

Source: ORTECH International, Report No. 93-E14-36. addendum to Final Report No. 93-E14-21,1993.

Table 5--Biodiesel demonstrations sponsored by the National SoyDiesel Development Board and/or State soybean boards

Location	Type of vehicle	Number of vehicles	Status
Lambert International Airport St. Louis, MO	Ground vehicles	100	complete
Bi-State Transit St. Louis, MO	Buses	50	ongoing
Sioux Falls, SD	Buses	16	ongoing
Cincinnati, OH	Buses	6	ongoing
Topeka, KS	Trolley buses	3	ongoing
Gardena, CA	Buses	2	ongoing
Spokane, WA	Buses	18	ongoing
Oakland, CA	Mass transit vehicles	114	ongoing
Santa Cruz, CA	Boats, trucks, and a dredge	7	ongoing
New Jersey	State highway equipment	10	ongoing
Illinois	Mass transit vehicles, farm equipment, truck fleets, and individual trucks	over 100	ongoing

Source: Biodiesel Alert. September 1993.