Surfactants and Biodiesel Expand the Use of Vegetable Oils

The use of agriculturally based surfactants is increasing in existing products and processes and in newer applications. U.S. transit operations will be able to use biodiesel to meet air-quality regulations, without any change in operability and maintenance, if it is approved as a certified technology for the Urban Bus Retrofit Rebuild Program. In the European Union, biodiesel production and commercial use expanded in 1994 and is expected to intensify in 1995. Crambe growers in North Dakota have contracted with the Archer Daniels Midland plant in Enderlin, North Dakota, to toll process their 1996 crop.

Surfactants Use Increasing in Traditional and New Applications

Surfactants are compounds that change the surface and interfacial tension of materials. As ingredients in soaps and detergents, they increase the wetting ability of water so that it can more easily penetrate fabric and remove dirt particles. In paints, they improve adhesion of paint particles to the surface being painted. Surfactants were first manufactured by the soaps and detergents industry for their products. As more uses were discovered, an independent industry arose.

Driven both by environmental regulations and expanding niche markets, the use of surfactants is increasing both in existing products and processes and in newer applications. With 23 States either partially or completely banning phosphates in laundry detergents and 7 others contemplating bans, detergent manufacturers are turning to environmentally friendly, surfactant-based systems to achieve maximum cleaning characteristics. The industry is meeting consumer demands for biodegradable products with the use of surfactants derived from vegetable oils and fats. The current popularity of superconcentrated detergents also has boosted the demand for these surfactants.

Surfactants can be made using either petrochemical feedstocks or agricultural materials, such as vegetable oils, animal fats, and starches. Many different vegetable oils are, or can be, used to make surfactants (table 5). Coconut and palm kernel oils are popular feedstocks. Coconut oil prices have ranged from 30.5 to 35.6 cents per pound during the first 7 months of 1995 (table 35), while palm kernel oil prices varied from 31 to 37 cents per pound (table 42). Ethylene, a major petroleum feedstock for surfactants, sells for 20 to 22 cents per pound.

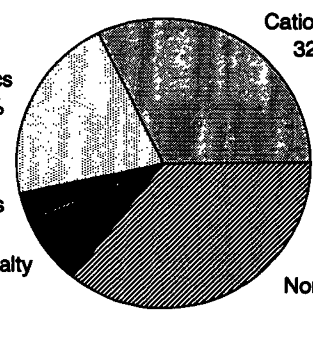
Table 5--Vegetable oils that are, or can be, used by U.S. surfactant manufacturers

Currently used	Potentially feasible	
Castor	Bladderpod	Linseed
Coconut	Buffalo gourd	Meadowfoam
Palm	Crambe	Safflower
Palm kernel	Cuphea	Vernonia
Rapeseed	Euphorbia	
Soybean	Jojoba	
Sunflower	Lesquerella	

There are four major types of surfactants: nonionics, cationics, anionics, and amphoterics (figure 2). About 15 percent of anionics come from plant and animal sources, while over 30 percent of nonionics are made from these natural feedstocks. Overall, an estimated 20 percent of all surfactants are derived from natural raw materials. In many applications, such as laundry detergents, surfactants derived from agricultural and petroleum feedstocks are interchangeable. Industrial grade surfactants usually sell for under 50 cents per pound, while specialty surfactants with applications in cosmetics and textiles go for $1 per pound and higher.

While surfactants have long been considered environmentally neutral products, recent studies have found traces of carcinogens—such as nitrosamines, dioxanes, and ethylene oxides—in some surfactants derived from petrochemical feedstocks. These concerns have spurred the replacement in detergents of surfactants containing petrochemical-derived branched-chain alcohols with surfactants containing straight-

Figure 2
Market Share in 1994 by Type of Surfactant 1/



1/ Approximately 7.5 billion pounds of surfactants were used in 1994.
Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., Mclean, VA, August 1995.

chain fatty alcohols derived from vegetable oils. Straight-chain alcohols also biodegrade more easily than branched chain compounds.

Henkel Corporation of Gulph, Pennsylvania, a leading surfactant manufacturer, is producing a new line of vegetable oil-based surfactants for the soaps and detergents industry. The surfactants are made from corn, coconut, and palm kernel oils, and are marketed under the trade name Plantaren. Henkel's Cincinnati, Ohio, plant produces 27,500 tons of Plantaren per year.

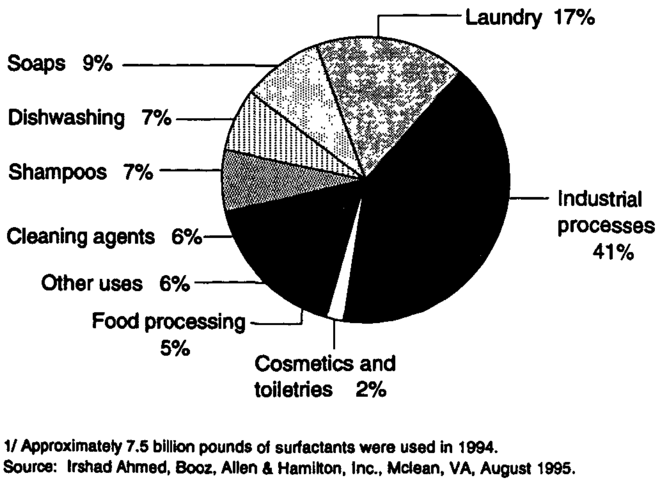
More than 10 large surfactant manufacturers are using natural feedstocks to commercially produce a wide variety of surfactants with potential to supply almost all segments of the organic chemicals industry. For example, Hoechst Celanese produces a group of ethoxylate-type surfactants, called Grenapol 26-L, at its Charlotte, North Carolina, specialty chemicals plant that are made from coconut and palm kernel oils. Leading surfactant manufacturers that use natural raw materials include Witco Corporation, Henkel Corporation, Ethyl Corporation, and Proctor & Gamble Company.

In 1994, U.S. surfactant industry shipments were valued at $19 billion, an increase of over 3 percent in constant dollars from 1993. U.S. surfactant consumption in 1994 was roughly 7.5 billion pounds. Industrial processes accounted for the largest market share, followed by laundry and soap (figure 3). The industry employs over 9,000 people in the United States. In 1995, surfactant markets are expected to exceed $20 billion.

New Markets Are Being Developed

One of the fastest growing segments of surfactant markets is specialty surfactants, which are designed with properties to meet specific end-product requirements. The introduction of two-in-one and three-in-one products—such as shampoos that combine shampoo, conditioner, and coloring agents in one formulation—has opened up new markets for surfactants derived from natural materials. The markets for specialty surfactants has been growing at a rate of 10 percent per year since 1990. In 1994, 1.5 billion pounds of specialty surfactants, valued at $1.7 billion, were consumed in the United States.

Figure 3
Utilization of Surfactants in 1994 by Type of End Product[1/]



1/ Approximately 7.5 billion pounds of surfactants were used in 1994.
Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., Mclean, VA, August 1995.

Surfactant-based systems are increasingly being used as a substitute for solvents, bleaches, and other processing chemicals in the pulp and paper, metal cleaning, and chemical processing industries where the key property requirements are bleaching, hydrolysis, and/or surface chemistry. For example, Interchem Industries, Inc., of Overland Park, Kansas, has developed several methyl ester-based solvents that are effective as degreasers and cleaning agents for machinery and removing graffiti from walls and sidewalks. Surfactant-based techniques also are being developed for replacing lubricating systems. Surfactants derived from vegetable oils nearly eliminate toxic pollutants when used as an alternative to conventional boron-based petrochemical equivalents.

The surfactant industry is forecast to grow 3 to 4 percent annually during the next 5 years. Manufacturers will attempt to satisfy the demand for more effective cleaning agents by introducing new all-purpose cleaners. Environmental concerns will force producers to look for natural substitutes, such as agricultural-based surfactants, for fluorocarbons and chlorinated hydrocarbons used as degreasers. (See the Specialty Plant Products Sections for other natural alternatives.)

Regulations and Environmental Benefits Boost Biodiesel's Prospects

Twin Rivers Technology, Inc., of Quincy, Massachusetts, has submitted a certification package to the U.S. Environmental Protection Agency (EPA) that includes the use of biodiesel fuel for approval as a "certified technology" for the Urban Bus Retrofit Rebuild Program. Finalized in 1993, the program is designed to reduce particulate-matter exhaust emissions from older-model urban buses (model year 1993 and earlier). (See the special article on biodiesel for more information on the program.) To date, only an oxidation catalyst developed by Engelhard, a New Jersey-based technology company, has achieved certification. Twin Rivers' proposed technology uses a straight 20/80-percent biodiesel/diesel blend, a 20-percent blend with a minor engine timing change, or the blend in conjunction with an oxidation catalyst.

Urban transit operators will be making their decision on compliance options for the retrofit program by the end of 1995. If approved, biodiesel's certification will enable transit operators to meet Clean Air Act regulations without any significant change in operations or maintenance. In a recent survey of urban transit managers, one-fifth indicated that biodiesel is their number one alternative fuel. Biodiesel ranked second in the survey behind compressed natural gas as the alternative fuel of choice for urban bus systems (*1*).

The Energy Policy Act of 1992 (EPACT) affects virtually all aspects of U.S. energy markets. Under the auspices of the U.S. Department of Energy (DOE), EPACT provisions encourage increased use of renewable energy and more efficient use of fossil fuels and nuclear energy, which will increase the competitiveness of these sectors. Under the umbrella of renewable energy, biodiesel is covered under several sections of the law, such as Alternative Fuels Utilization, Biofuels User Facility, and Biofuels Renewables. DOE's Biofuels Systems Program views biofuels as a win-win strategy that could provide energy security, improve the environment, increase farm income, and promote rural development (2).

On July 31, 1995, DOE published a notice in the *Federal Register* announcing a limited reopening of the public comment period for EPACT's Alternative Transportation Fuels Program. During the original public comment period from February 28 to May 1, 1995, many respondents requested that biodiesel specifically be included in DOE's regulatory definition of "alternative fuel." DOE is considering amending the proposed definition to include neat biodiesel, with a caution that this proposal does not relieve alternative fuel producers from complying with other federal, state, or automobile manufacturer requirements. DOE also is considering comments urging the inclusion of biodiesel blends in the definition of "alternative fuel." EPACT Section 301 authorizes such an addition for fuels that are "substantially not petroleum and would yield substantial energy security and environmental benefits."

One of EPACT's advantages is its complementarity with federal environmental regulations and programs. For example, biodiesel can help reduce tailpipe emissions of hydrocarbons, carbon monoxide, and particulate matter. It does not contain sulphur or harmful aromatics. Plus, it is nontoxic and biodegradable. Thus, it could help diesel users comply with Clean Air Act regulations, such as the Urban Bus Retrofit Rebuild Program and the Clean Fuel Fleet Program. EPACT's biofuels provisions also complement the U.S. Climate Change Action Plan, which aims to mitigate the greenhouse effect caused by the build up of carbon dioxide (CO_2) and other trace gases in the atmosphere.

Test Results Further Quantify Biodiesel's Environmental Benefits

Test results from two independent studies further validate biodiesel's reputation as a health- and environmentally friendly fuel for mining and marine applications. In the first study, the French Oilcrop Association ONIDOL, together with the Government of France, conducted engine-durability and emissions-level testing using biodiesel produced from rapeseed oil. Results show that unregulated exhaust emissions of gaseous polycyclic aromatic hydrocarbons (PAH's) declined significantly with increased percentages of rapeseed biodiesel in the fuel blend (table 6). Particulate PAH's decline as well for a 30-percent biodiesel blend. PAH's are organic compounds adsorbed on diesel particulate matter that have received considerable attention because of their potential mutagenic and carcinogenic properties.

The second study, which was conducted by the University of Idaho for USDA's Cooperative State Research, Education, and Extension Service (CSREES), demonstrates that biodiesel fuels are readily biodegradable in an aquatic environment. Biodegradability is an issue for water quality and ecosystem effects in case the fuel enters an aquatic environment in the course of its use or disposal. Not only are oil spills a hazard to natural waterways, diesel-fueled vessels and equipment operating in an aquatic environment often leak small amounts of fuel into the surrounding ecosystem.

Table 6--Exhaust emissions of polycyclic aromatic hydrocarbons (PAH'S) from urban buses burning diesel and biodiesel blends

Pollutant	Amount of biodiesel in the fuel 1/		
	0 percent	30 percent	50 percent
		ug/cycle	
Gaseous PAH's			
Napthalene	331,654	253,398	384
Methyl-2 napthalene	10,280	3,841	329
Acanapthylene	1,268	376	268
Fluorene	1,864	463	368
Methyl-1 fluorene	2,380	297	584
Anthracene	4,301	904	873
Fluoranthene	783	172	128
Pyrene	816	121	80
Particulate PAH's			
Fluoranthene	144	105	124
Pyrene	139	105	162
Benzo (ghi) fluoranthene	42	32	59
Benzo (a) anthracene	19	15	29
Chrysene + triphanylene	69	42	74
Benzo (k) fluoranthene	23	12	20
Benzo (b) fluoranthene	8.2	3.4	6.7
Benzo (c) pyrene	18	15	20
Benzo (a) pyrene	5.1	5.4	9.7
Benzo (ghi) perylene	11	7.2	23
Dibenzo (ah) anthracene	3	0.89	1.9

1/ The biodiesel used was rapeseed methyl ester.

Source: Frederic Staat and Paul Gateau, "The Effects of Rapeseed Oil Methyl Ester on Diesel Engine Performance, Exhaust Emissions and Long-Term Behavior--A Summary of 3 Years of Experimentation," paper presented at the SAE International Congress and Exposition, February 27-March 2, 1995, in Detroit, MI, SAE International, Warrendale, PA, technical paper 950053.

Using CO_2 evolution tests in a shaker flash system, various biodiesel fuels and petroleum diesel were added to distilled water containing small amounts of organic-matter-rich soil, raw sewage water, yeast, and a nutrient supply (nitrogen and phosphorus). The amount of CO_2 given off indicates how much of the substrate has been metabolized. Results show that rapeseed- and soybean-oil-based biodiesel degraded at about the same rate as dextrose and three times faster than petroleum-based diesel (table 7). In addition, more biodiesel disappeared after 28 days than had raw soybean or rapeseed oil. In tests of biodiesel/diesel blends, the presence of biodiesel prompted and accelerated the degradation of the entire blend (table 8). After 7 days, 25 percent of a 20-percent biodiesel blend had degraded into CO_2 and water, versus 12 percent for diesel fuel.

European Biodiesel Production Expands

Unlike the limited use of biodiesel in the United States, biodiesel production and commercial use in the European Union (EU) expanded in 1994 and is expected to intensify in 1995. Rapeseed (mostly canola) grown for biodiesel production amounted to approximately 1.2 million metric tons in 1994, almost a three-fold increase over 1993. This expansion is due to EU agricultural policies that allow farmers to grow oilseeds and certain other crops for industrial uses, such as biodiesel production, on set-aside land. The EU's Common

Table 7--Biodegradability of various types of biodiesel, rapeseed oil, soybean oil, diesel fuel, and dextrose 1/

Days	Rapeseed ethyl ester	Rapeseed methyl ester	Soybean ethyl ester	Soybean methyl ester	Rapeseed oil	Soybean oil	Diesel fuel	Dextrose
	Percent CO2 evolution 2/							
0	0	0	0	0	0	0	0	0
7	69.01	66.32	67.68	68.40	58.39	60.57	13.20	59.84
14	79.15	80.72	78.40	77.83	70.47	70.12	21.04	80.19
28	86.92	88.49	86.40	85.54	78.48	75.95	26.24	87.79

1/ Rapeseed and soybean methyl and ethyl esters are types of biodiesel. Dextrose was included for comparison. 2/ Biodegradability is measured by the percent of CO2 given off as microbes degrade the substrate.

Source: Xiulin Zhang, Charles L. Peterson, Daryl Reece, Gregory Moller, and Randal Haws, "Biodegradability of Biodiesel in the Aquatic Environment," paper presented at the 1995 ASAE Meeting, June 18-23, 1995, Chicago, IL, American Society of Agricultural Engineers, St. Joseph, MI, paper no. 956742.

Table 8--Biodegradability of biodiesel/diesel blends

Days	Biodiesel 1/	Percent biodiesel/diesel 80/20	50/50	80/20	Diesel
	Percent C02 evolution 2/				
0	0	0	0	0	0
7	64.09	52.33	37.85	25.24	12.08
14	77.51	61.26	45.74	31.59	14.96
28	84.37	67.82	51.90	35.67	18.18

1/ Rapeseed ethyl ester. 2/ Biodegradability is measured by the percent of CO2 given off as microbes degrade the substrate.

Source: Xiulin Zhang, Charles L. Peterson, Daryl Reece, Gregory Moller, and Randal Haws, "Biodegradability of Biodiesel in the Aquatic Environment," paper presented at the 1995 ASAE Meeting, June 18-23, 1995, Chicago, IL, American Society of Agricultural Engineers, St. Joseph, MI, paper no. 956742.

Agricultural Policy requires producers of arable crops (grains, oilseeds, and protein crops) to set aside a portion of their arable crop base to receive support payments. Farmers receive a set-aside premium for industrial oilseeds production in addition to payments from seed sales. The average set-aside premium for arable crops in 1994 was about $138 per acre.

The amount of set-aside land on which industrial oilseeds were grown for the production of biodiesel increased from 204,000 hectares in 1993, the first year of the program, to 621,000 hectares in 1994. In 1995, the forecast is around 900,000 hectares (table 9). The main beneficiaries of the set-aside program for biodiesel are EU rapeseed and sunflowerseed producers. In Austria, an early leader in European biodiesel development, farmers plant both rapeseed and sunflowers, while rapeseed is popular in France and Germany and sunflowers in Italy.

Although most biodiesel in Europe is used in urban public bus and truck fleets, it is also used to fuel farm equipment, as a heating fuel, solvent, hydraulic oil, and lubricant. Since biodiesel has less of an environmental impact compared with petroleum-based products, most European countries that commercially produce biodiesel—France, Germany, Italy, and Austria—offer some form of tax break to reduce production costs to make biodiesel competitive at the pump. High European excise taxes on petroleum products raise the retail price of diesel fuel to a level that allows higher cost biodiesel that is exempt from excise taxes to compete. For instance, if 85 percent of the excise tax were removed, the prices of diesel and biodiesel would be competitive (figure 4).

Greater biodiesel production also has been made possible by an expansion in processing capacity. In 1994, EU crushing plants could process approximately 350,000 tons of oilseeds. This capacity is expected to double in the near future due to continued program assistance from national governments, oil companies, producer cooperatives, and oilseed promotion boards. Despite the expected capacity expansion, production is restrained by uncertainty over limits on industrial oilseed production agreed upon by the EU and the United States.

Concerned about the competition for soybean exports from oilseed meals produced as coproducts, the United States sought limits on the amount of oilseeds grown on European set-aside land. Under the Blair House Agreement, signed by the EU and United States in 1992, the EU agreed to limit the production of industrial oilseeds on set-aside land to the equivalent of 1 million tons of soybean meal, which is roughly equal to 2.3 million tons of rapeseed. With the EU likely to reach its industrial-oilseed production limit this year and the uncertainty on how these limits will be administered, biodiesel producers are hesitant to further increase productive capacity.

Crambe Farmers Search for Crushing Facility

During the past few years, farmers in North Dakota, in cooperation with National Sun Industries, began developing a significant crambe industry. Like many farmers across the United States, these farmers were attempting to diversify crop production and market opportunities. Crambe acreage increased from 2,200 in 1990 to 55,500 in 1993, then declined to 43,900 acres in 1994 (table 10). No commercial acreage was planted in 1995, primarily because much of the crambe oil produced last year had not been sold by the spring planting date. However, a few fields of crambe were planted and harvested in 1995 for seed stock. As with many new crops, it is difficult to match supply and demand. In the case of crambe, crop production grew faster than the demand for the oil as an industrial feedstock. Most crambe oil is processed into erucamide, which is used as a slip agent for plastic wraps and bags.

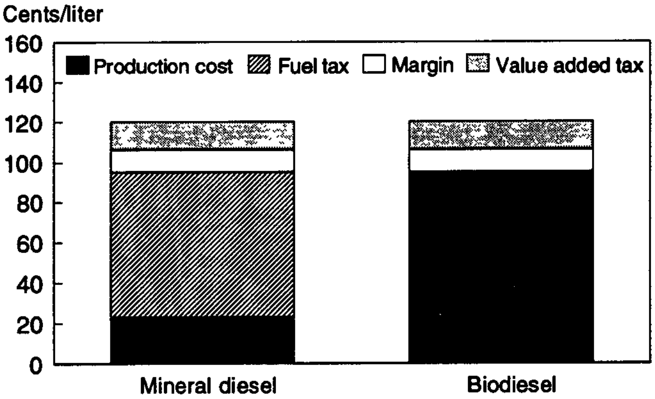
Despite the lack of commercial acreage in 1995, the crambe growers, organized as the American Renewable Oilseed Association (AROA), continue their efforts to commercialize and market crambe. Previously, National Sun Industries processed crambe in their plant in Enderlin, North Dakota. However, the company decided in 1994 to discontinue crushing operations and concentrate on value-added processing of oilseed products. As a result, National Sun leased the Enderlin plant to Archer Daniels Midland Company (ADM), which is using it to process sunflowers. AROA personnel expect to produce about 40,000 acres of crambe in 1996, with the crop

Table 9--Area and production of industrial oilseeds in the European Union 1/

Crop	Area 1993-94	Area 1994-95	Area 1995-96 2/	Production 1993-94	Production 1994-95	Production 1995-96 2/
		Hectares			Metric tons	
Rapeseed	172,000	482,000	800,000	472,000	1,236,000	2,328,000
Sunflowerseed	32,000	139,000	100,000	64,000	243,000	134,000
Total	204,000	621,000	900,000	536,000	1,479,000	2,462,000

1/ Refers to oilseeds produced for nonfood uses on set-aside land. 2/ Forecast.

Figure 4
Price of European Biodiesel Is Competitive at 85-Percent Tax Reduction



Source: Tadashi Murayama, "Evaluating Vegetable Oils as a Diesel Fuel," Inform, Vol. 5, No. 10, October 1994, pp. 1138-45.

Table 10--Crambe acreage, United States, 1990-95 1/

Year	Area	Yield 2/
	Acres	Pounds/acre
1990	2,200	1,300
1991	4,500	1,338
1992	24,000	1,138
1993	55,500	1,011
1994	43,900	1,300 3/
1995	0	0

1/ Commercial acreage. 2/ North Dakota only. 3/ Estimated

to be toll processed by ADM at their Enderlin plant. AROA has contracted with Witco Chemical to buy the crambe oil and will market the meal on its own.

HEADE Provided Crambe with Crucial Support

Because of the market potential for products containing, or derived from, erucic acid (the major fatty acid in crambe and industrial rapeseed oils), an effort by universities, government, and private industry was initiated in December 1986 to help develop crambe as a major crop in the United States. Participants recognized that, since erucic acid was used only in minor quantities in the United States, any attempt to develop a large-scale commercial industry would need to coordinate crop production, processing, and product/market development. The Crambe Project, as the effort was called, was supported by Iowa State University, the Kansas Board of Agriculture, Kansas State University, the University of Missouri, and New Mexico State University, plus USDA's Agricultural Research Service and CSREES. A special effort was made to involve private industry.

The Crambe Project became the High Erucic Acid Development Effort (HEADE) in 1990 and research was expanded to include industrial rapeseed. Eventually, consortium members also included the land grant universities of Georgia, Idaho, Illinois, Nebraska, and North Dakota. While it was never incorporated or organized as a legal entity, it was a very effective multistate group whose scientists operated in multidisciplinary teams.

Some of HEADE's funding came from a Special Grant appropriation, which was administered by CSREES. Federal funds were matched by state funding on approximately a dollar-for-dollar basis. Federal appropriations for the project reached $500,000 in the early 1990's, but funding was discontinued in fiscal 1995. Thus, HEADE lost funding and its primary private sector proponent at about the same time.

A review of HEADE's structure, activities, and progress show how the consortium was successful in its development efforts and how it may be an appropriate model for the development of other new crops. The HEADE structure included a management committee, plus subcommittees for production, processing, and marketing/economics. HEADE's priorities were reviewed annually by the management committee, with significant input from subcommittee members, private-industry participants, others knowledgeable about high-erucic-acid oils and their products, and those knowledgeable about the agronomics of crambe and industrial rapeseed.

Once priorities and the level of federal funding were identified, a request for proposals was issued. The proposals received were evaluated and prioritized by peer review panels for each of the subcommittees. The subcommittees' ranked proposals were then collectively considered and ranked by the management committee, according to quality, potential for contribution to the HEADE project mission, and the potential to dramatically increase the level of production of these crops and use of high-erucic-acid oils in the United States. Those receiving the highest ranking were funded. Typically, 15 to 20 projects were funded annually, at levels ranging from $5,000 to $20,000 each.

Production advances outpaced those in processing and product development. The combined efforts of National Sun Industries and North Dakota State University expanded crambe acreage in North Dakota from test plots in 1989 to 55,500 acres in 1993. While this was a prime example of private-public cooperation, the failure to develop additional markets for high-erucic-acid oils resulted in excess supplies.

Significant advances have been made in plant breeding. A major breeding program for crambe is underway at North Dakota State University, while the industrial rapeseed work is located at the University of Idaho. The University of Georgia also expanded their breeding program for industrial rapeseed and canola. These programs, plus activities by agronomists and plant scientists at each of the member universities, have resulted in significantly higher yields, improved winter hardiness, and better knowledge of planting and harvesting dates, fertilizer needs, harvesting methods, and other relevant factors.

The processing subcommittee conducted pilot-scale tests and determined that extrusion processing of whole and dehulled crambe and rapeseed provided excellent seed preparation for solvent extraction of both crops. The subcommittee provided advice to National Sun when the company began crushing crambe by prepress-solvent extraction in their Enderlin mill. Research on the uses of defatted crambe meal in beef cattle rations aided marketing of the meal to feeders and feed formulators. The subcommittee also sought to increase the value of crambe meal by examining ways to extract glucosinolates from the meal. Projects were funded to evaluate glucosinolates as potential herbicides, nematicides, insecticides, fungicides, and chemoprotectants/antitumor agents.

Product development efforts were restricted by the level of HEADE funding, but numerous research proposals were considered and a number funded. The types of products explored include surfactants, lubricants, paints and coatings, and various polymer types and applications. Some of these projects are ongoing and may result in new uses for high-erucic-acid oils. For instance, scientists continue to research a catalytic process for cleaving erucic acid to brassylic and pelargonic acids, which may make these two products accessible to the chemical intermediates market for use in polymers, coatings, lubricants, and other functional fluids. Research on developing polymer composites from high-erucic-acid-oil derivatives also continues.

International Lubricants, Inc. (ILI), of Seattle, Washington, developed automatic transmission fluid additives based on vegetable oils, including high-erucic-acid oils. Such additives are currently used by five automobile manufacturers in Europe and are widely used in transmission repair shops in the United States and other countries. Subsequent products developed by ILI include cutting oils, hydraulic oils, power steering fluids, and, recently, a telomer that modifies the viscosity of oil-based products so they can be used in a wide range of applications. HEADE worked closely with ILI early on, and funded product testing by certified laboratories to assure product acceptance.

HEADE succeeded in promoting significant commercial production of crambe and industrial rapeseed in a relatively short time, and helped develop information about these crops, their oils, and current and potential products. The HEADE experience shows that limited Federal and state funding encouraged private sector investment and commercialization of high-erucic-acid-oil crops in the United States, and significantly expanded the body of knowledge available for future development. HEADE's multidisciplinary approach to research and development is an appropriate model for future Federal-state collaborations. It is expected that the associations and affiliations developed as the result of HEADE will continue. [Donald Van Dyne, (314) 882-0141; Irshad Ahmed, (703) 917-2060; Anton Raneses, (202) 219-0742; Alan Weber, (314) 635-3893; and Maryanne Normile, (202) 219-0774]

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