To increase the amount of rubber in guayule plants, ARS chemist Charles De Benedict sprays bioregulators on the plants. 0584X712-11A

Rubber production first started in the Americas. When guayule rubber is commercially produced in the United States, the natural-rubber source will have finally returned to its place of origin.

Rapeseed and Crambe: Developing Useful Products From Oils That Are High in Erucic Acid

The use of rapeseed oil dates back to antiquity. Ancient (2000 to 1500 B.C.) writing from Greece, Rome, India, and China refer specifically to oilseed rape, its medicinal value, and its use as a cooking oil. The focus of this chapter, however, is not on the edibility of oils but on the industrial use of high erucic acid (industrial) rapeseed and crambe oils.
This artist's rendering illustrates crambe, a member of the mustard family. The crop requires fewer purchased inputs and has relatively low production costs. Also, conventional wheat machinery can be used to plant and harvest crambe.

Until the development of the steam engine, rapeseed oil had rather limited industrial use. Then, users found that it clung to water- and steam-washed metal surfaces better than any other lubricant. But use of rapeseed oil declined when internal combustion engines that required petroleum replaced steam engines. Today, however, the extraordinary lubricating properties and other functional attributes of rapeseed oil are again gaining favor. More rapeseed oil is being used because people in developed countries are placing increased emphasis on environmental improvement and the use of renewable resources. Some bread wraps, garbage bags, and lubricants now contain rapeseed or crambe oils and therefore possess the functional properties of the oil’s primary fatty acid, erucic acid. Recently, crambe has emerged as a source of high erucic acid oil.

Why the Interest in Oils High in Erucic Acid?

Considerable private sector interest exists both in use of erucic acid and in agricultural production of industrial rapeseed and crambe. Erucic acid has unique chemical properties that chemists can use to make useful products. High erucic acid oils and their derivatives have excellent lubricating properties, as well as special attributes for manufacturing nylons, paints, and coatings that do not shrink or swell with changes in moisture. These products also possess excellent electrical insulation properties, and provide good strength.

The economics of growing high erucic acid oilseed crops in the Northern Plains compare favorably with those of growing wheat, as equipment needs are similar to those used in producing and harvesting small grains. In addition, the United States has the capacity to grow and process more oilseed crops. Success in producing crambe and industrial rapeseed could decrease the need for imports.

Primary concerns affecting expanded commercialization of these crops center around improving winterhardiness in rapeseed, gaining acceptance of crambe meal as a feed, managing pest problems (including approval to use safe chemicals when necessary), developing new products that use erucic acid, and selling to existing and new markets.
Production of Crambe and Industrial Rapeseed

Rapeseed (both *Brassica napus* and *B. campestris*) and crambe (*Crambe abyssinica*) have emerged as commercially viable alternative oil crops. Rapeseed appears to be native to the Himalayan region, and crambe is native to the arid regions of the Middle East, yet both are adapted to a broad range of growing regions in the United States and the world. Both are attractive, not only for their products, but also for their potential to diversify cropping systems, thereby reducing pest problems and conserving soil. Farmers can rotate these crops with traditional crops or with lesser known species that offer the promise of botanical diversity for the future. Nature has even provided some natural pest resistance mechanisms in crambe.

Rapeseed (industrial and canola) ranks third or fourth in volume of vegetable oil produced worldwide, depending on the year. Rapeseed is grown in northern Europe, Asia, and Canada, as well as in the U.S. North-west and Midsouth. Except in Canada, most rapeseed grown for industrial oil (high in erucic acid) is of the winter type, which is sown in fall and harvested in summer. U.S. production of industrial rapeseed generally has remained under 15,000 acres annually.

The principal spring-seeded crop that is high in erucic acid is crambe. This crop was introduced into the United States in the early 1940’s. In 1957, researchers at the New Crops Research Program of ARS in Peoria, IL, reported that up to 60 percent of the crambe seed oil was erucic acid. They also indicated that crambe appeared to be broadly adapted. During the next 30 years, research interest in the crop increased, but by 1985 there was no sustained commercial production because the oil cost was not competitive with that of imported rapeseed oil.

In response to a dwindling supply of petroleum, a consortium of land-grant universities and USDA’s Cooperative State Research Service and ARS came together in late 1986 to expand commercial use of crops like crambe and rapeseed. Today, the consortium consists of land-grant universities in Idaho, Illinois, Iowa, Kansas, Missouri, Nebraska, New Mexico, and North Dakota; the Kansas Board of Agriculture; and several private firms. The consortium has emphasized the production and processing of crops, product development, and marketing. They have found that crambe performs better than rapeseed north of Missouri and Kansas. Rapeseed tends to be the better crop south of this line.

In 1990, a collaborative partnership was formed. Thirty-eight North Dakota farmers, National Sun Industries, and the consortium joined to share the risk of commercializing crambe. During this first year, farmers grew 2,200 acres of crambe under contract to National Sun Industries, which successfully processed and marketed the crambe. In 1991, farmers grew nearly 5,000 acres of crambe, and they planted 23,000 acres in 1992.

Processing Rapeseed and Crambe Seeds

When crambe and rapeseed are processed, the results are oil and coproduct meal. Most crambe and
rapeseed are usually processed, like other high-oil seeds such as sunflower, cottonseed, and peanuts, by prepress solvent extraction methods. However, two other processing methods exist: screw pressing and direct solvent extraction.

**Screw Pressing.** This simple mechanical process squeezes oil from seeds using screw presses, also called expellers. Seeds are cracked, or flaked, and cooked before they enter the expeller. The meal, or press cake, contains 6-14 percent oil. This processing method generally leaves too much valuable oil in the less valuable meal to be really cost-effective. However, rapeseed press cake meal from the expeller processing can be used as a protein supplement in beef cattle rations.

**Prepress Solvent Extraction.** This method is most common and recovers much more of the oil than does the screw pressing method. The screw presses used to collect part of the oil do not squeeze the seed as hard in this method, so the resulting press cake then goes to the solvent extraction unit to remove the remaining oil. The solvent is recovered and recycled back to the extractor. Sometimes the resulting press oil and solvent oil are kept in separate containers because some buyers prefer press oil. Mills in Tennessee, Ohio, North Dakota, and Montana have processed rapeseed or crambe by this method. The meal, containing about 1 percent oil, provides an economical source of protein supplement for beef cattle rations.

**Direct Solvent Extraction.** Managers of some U.S. mills have retrofitted their facilities with extruders (similar to screw presses) to prepare oilseed for solvent extraction. These machines remove little or no oil but simply pelletize the seed material. The pellets, or collets, are highly porous and keep their integrity during direct solvent extraction, despite oil content as high as 40-45 percent for some seeds.

Most mills employing this technology crush 2,000-3,000 tons of seed per day. Thus, these mills are too large to process the small quantities of crambe or rapeseed grown to date. Researchers have processed both crops using a pilot plant extruder at Texas A&M University with excellent results. The defatted meal would be appropriate for use in beef cattle rations.

**Other Processing Considerations.** Crambe seed’s high-fiber hull is 24 percent of the seed’s weight and an even larger percentage of its volume. Hence, a bushel of crambe weighs only about 22 pounds. Commercial cracking rollers and air aspiration can remove about 85 percent of the hull material. Dehulling reduces fiber content of crambe from 20-25 percent to 8-15 percent and provides a high-protein (47-53 percent) meal. Small quantities of crambe have been dehulled on several occasions, demonstrating that this is technically feasible if it proves economically so. Rapeseed has a lower initial fiber content (7-12 percent) than crambe, so dehulling is unnecessary.

Both crambe seeds and some rape-seeds contain glucosinolates, which are undesirable substances for livestock consumption. When enzymes in
the stomach come in contact with glucosinolates, they form compounds that are potentially antinutritional, especially in single-stomached animals. Hence, the meal from defatted seeds is most appropriate for use in beef cattle rations. Scientists have shown that water-washing these meals will remove glucosinolates and increase their potential as poultry feed. Research is under way to further develop this technology for removing glucosinolates, as lack of acceptance of the meal has slowed the growth of crambe and industrial rapeseed as commercial crops.

**Products That Use Erucic Acid**

For crambe and industrial rapeseed to succeed as crops, the use of their oils in industrial products must be expanded. Though they are currently used in several products, development is needed to transform more potential uses into marketplace realities.

Erucamide is a chemical made from erucic acid produced from industrial rapeseed or crambe oils. Plastic film manufacturers have used erucamide for decades in bread wraps, garbage bags, and sandwich bags. Erucamide lubricates the extruding machine during manufacturing of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together.

International Lubricants, Inc. (ILI), of Seattle, WA, markets an automatic transmission fluid (ATF) supplement and a metal-cutting oil based on derivatives of rapeseed oil. In independent third party tests where USDA’s Cooperative State Research Service was a partner, the ATF fluid supplement decreased wear by more than 50 percent when compared to the wear associated with factory-fill ATF fluid. The ATF supplement also produced 24 percent fewer acids that break down ATF fluids. The tests identified no detrimental impacts. Users of the ILI cutting fluid report that it causes much less dermatitis on workers’ hands than other cutting oils, and also extends tool life. The cutting oil contains no toxic material, so it is less expensive overall and does not harm the environment.

Recently, a firm patented and introduced a low-calorie chocolate substitute that contains over 50 percent behenic acid, a derivative of erucic acid. Another firm is test-marketing this chocolate substitute in one of its candy bars.

In 1991, Mobil Oil began marketing a biodegradable, nontoxic, anti-wear hydraulic fluid. Ninety-seven percent of this product is canola oil (edible rapeseed) and the other 3 percent also consists of natural materials. This fluid has environmental advantages, especially for machinery used near water such as hydraulic equipment at barge and ship loading docks and at hydroelectric plants.

A pharmaceutical product known as Lorenzo’s Oil uses an extremely small volume of rapeseed oil. Lorenzo’s Oil is used to treat adrenoleukodystrophy (ALD), a rare but debilitating disease in young males.

**New Products Being Developed**

Industrial bake-on paints using derivatives of rapeseed or crambe oils show...
promise. The key feature of the coatings is their increased flexibility and impact resistance. Properly formulated paints using derivatives of these oils could find a market niche. About one-third of the 1 billion gallons of paint used annually in the United States is industrial bake-on paint used on automobiles, household appliances, and machinery.

Nylon 13,13 can be made from the erucic acid in rapeseed and crambe oils. This nylon offers superior performance characteristics that enhance the likelihood of its commercialization: it absorbs only 0.75 percent moisture compared to 10.5 percent for nylon 6, a typical commercial nylon; it has excellent electrical insulating properties; and it is durable, yet flexible. Polymers such as nylon 13,13 could serve as insulators for high-voltage electrical lines, as fuel tanks and fuel lines in autos, and as lightweight yet durable parts for aerospace and marine applications.

But no one has yet commercialized nylon 13,13. A major hindrance has been the lack of a cost-effective method of achieving the first step—producing brassylic acid from erucic acid. The only commercial process for this chemical cutting of erucic acid into two fatty acids (brassylic and pelargonic acids) is a process known as ozonolysis, which is costly and potentially dangerous.

Recently, North Dakota State Uni-
iversity chemists and University of Nebraska chemical engineers developed a new, lower cost, and safer catalytic method of making brassylc acid. This method offers new promise for commercializing nylon 13,13 and other products. Jet engine lubricants and some synthetic automobile lubricants use the coproduct, pelargonic acid.

These and other as-yet-unforseen applications for oils high in erucic acid hold great promise for the future use of crambe and industrial rapeseed. However, for a significant increase in their use to occur, that promise must be transformed into commercial reality. With persistence and dedication, opportunity exists for researchers and business specialists to expand commercial markets for industrial products that use erucic acid, and thereby reap many benefits for American agriculture and industry.

Castor and Lesquerella: Sources of Hydroxy Fatty Acids

Recorded use of castor oil dates back at least 4,000 years to when the ancient Egyptians used it in their lamps. In modern times, manufacturers have developed many products, ranging from lipstick to jet-engine lubricants, using castor oil and its derivatives.

Among commercial vegetable and petroleum oils, castor oil has unusual characteristics. Its chemical structure and hydroxy fatty acid content make it valuable for industrial applications.

During the 1950's and 1960's, about 80,000 acres of castor were grown annually on the High Plains of Texas. But domestic production decreased, and was finally abandoned altogether in 1972 when castor oil buyers and the farmer cooperative involved in crushing castor seed were unable to agree on their annual contract because of low world prices for castor oil and high local farm prices for competing crops. Since then, the United States...