Fill 'Er Up . . . With Veggie Oil

Vegetable oils are moving from the kitchen table to the car engine

By CORINNA WU

Oil from plants—such as these sunflowers growing in a field near Davis, Calif.—can serve as an environmentally friendly substitute for petroleum-based products.

Stephen Buchmann

Asked to name a striking image from the 1970s, some might think of President Nixon making his resignation speech, a news photo from the Vietnam War, or even a young John Travolta striking a pose.

Others might recall the long lines of cars at gas stations during the oil embargo. From October 1973 to March 1974, Arab nations banned oil exports to the United States in retaliation for U.S. support of Israel during the Arab-Israeli War. Gasoline became a rare and precious commodity.

Those lean days made it all too clear how heavily the United States had come to depend on imported petroleum and how easily its supply could be cut off. The energy crisis of the 1970s, followed by high oil prices in the early 1980s, sparked widespread interest in alternative energy sources.

Today, gasoline is again plentiful and cheap, and the long lines at gas stations are a fading memory. Research into alternatives, however, continues. Some geologists predict that petroleum production will peak within 2 decades, then diminish, triggering a sharp rise in oil prices (SN: 10/31/98, p. 278).

Hoping to develop technologies that could lessen U.S. dependence on imported oil, some scientists are looking to a homegrown solution, literally. They are developing diesel fuels and lubricants based on vegetable oils—the same vegetable oils that people drizzle on salads and use to cook french fries. Oils from soybeans, corn, canola, and sunflowers all have the potential to move from the kitchen to the garage, researchers say.

In some applications, fuels and lubricants made from vegetable oils actually perform better and pollute less than their petroleum counterparts. Their big drawback, however, is that they're two to three times more expensive. For that reason, researchers are adapting vegetable oil for those fuel markets where its advantages might justify its cost.

The idea of using vegetable-based products as fuel is not new. German engineer Rudolf Diesel reportedly employed peanut oil to power one of his engines at the Paris Exposition of 1900. In the late 1970s, petroleum makers stretched limited fuel supplies by mixing gasoline with ethanol from fermented corn. This formed a cleaner-burning concoction known as gasohol (SN: 10/29/77, p. 280) that is still available. Gasohol burns more completely than petroleum, producing less carbon monoxide and hydrocarbons.

To some researchers, vegetable oils seem like a natural choice for an alternative fuel since the United States grows an abundance of agricultural crops. In Europe, strict environmental regulations have made vegetable oil–based products an even more attractive choice, since they present less of a problem if accidentally spilled. Seventy to 80 percent of a vegetable oil biodegrades to small organic molecules, carbon dioxide, and water in standardized tests compared with only 20 to 40 percent of a conventional lubricant, says André L. Boehman of the Pennsylvania State University in State College.

In a junkyard, a car leaking canola oil won't contaminate the soil as badly as one leaking conventional gasoline or oil. A boat that inadvertently dumps soybean-based diesel fuel into a lake won't foul the water as much as one releasing regular fuel.

Farmers also look to the oil research as a way to increase the market for their crops, says Lowell Norland, director of community and business services for the Ag-Based Industrial Lubricants Research Program at the University of Northern Iowa in Waverly. Toward this goal, scientists in the oil research group at the Department of Agriculture's National Center for Agricultural Utilization Research (NCAUR) in Peoria, Ill., are studying the properties of biodiesel, a type of fuel derived from vegetable oil. It may someday serve as an alternative to the diesel fuel used in many trucks and boats.

Ordinary diesel fuel is a mixture of hydrocarbon molecules of differing lengths and structures. These molecules contain no oxygen atoms. Some hydrocarbons consist of long, straight carbon chains; others branch like a tree or form rings.

They may have double-bonded carbons that cause the chains to bend. The characteristics of the hydrocarbons affect how they burn.

Vegetable oils, on the other hand, are mixtures of fatty acids—molecules that contain carbon, hydrogen, and oxygen atoms. The fatty acids may be saturated, monounsaturated, or polyunsaturated, meaning they contain zero, one, or multiple double bonds between carbons, respectively. The greater the number of double bonds, the more easily the compound reacts with oxygen from the air and goes bad, as kitchen fats and oils do after months on the shelf.

Saturated fats, such as those in lard, have another disadvantage as a fuel or lubricant. They turn solid at low temperatures, while mono- and polyunsaturated oils remain liquid. Researchers have their eye on polyunsaturated soybean oil, in particular, because many of its properties, such as viscosity and combustibility, are similar to those of petroleum-based oils.

To produce biodiesel, chemists treat a vegetable oil in a process called transesterification. This turns the oil into methyl ester compounds, which burn more cleanly than diesel fuel and leave fewer engine deposits than untreated vegetable oil.

When burned in an engine, biodiesel emits smaller amounts of pollutants, including particulates, volatile organic compounds, carbon dioxide, and polyaromatic hydrocarbons, than regular diesel fuel does, says Gerhard Knothe, a scientist at NCAUR. Notable exceptions are the nitrogen oxides, major contributors to smog, which biodiesel generates more of than does petroleum diesel.

On the other hand, biodiesel contains no sulfur, unlike regular diesel, so acid-rain-producing sulfur oxides aren't a problem (SN: 8/27/94, p. 134).

"You can smell the difference," Knothe observes. "The fumes from biodiesel are less obnoxious."

An advantage of biodiesel over other alternatives to petroleum is that it works in existing diesel engines. Other clean-burning fuels such as natural gas have combustion properties so different from those of diesel fuel that they can't be used in conventional engines.

Natural gas must also be stored differently. "The fuel [itself] may be cheaper, but the engine and infrastructure changes are so expensive, they outweigh that advantage," says Knothe.

In terms of performance, however, biodiesel isn't yet up to par. Because of its unsaturated fatty compounds, vegetable oil reacts with oxygen more easily than diesel does, and so its properties can change. Biodiesel can also leave more gummy deposits in engines than regular diesel does.

And just like cooking oil placed in the freezer, biodiesel thickens and forms solid crystals—mostly of saturated fats—at low temperatures, plugging fuel lines. At 0°C, components of biodiesel begin to crystallize. Lower the temperature a few degrees more, and the fuel no longer flows. "Here in the Midwest, we'd be in trouble," says Knothe.

The fix is rather simple: The scientists can winterize the fuel by cooling it until the crystals form, then filtering them out. The resulting biodiesel can start an engine at –15°C, a temperature comparable to petroleum-based diesel.

Some of the fats filtered out, such as methyl palmitate and methyl stearate, tend to have the best combustion properties, however. "It's a tradeoff," says Knothe. "You improve one property, but you have to be careful about the other."

Legislative activity may drive the acceptance of vegetable oil–based fuels and lubricants, whatever their price

Biodiesel can be combined with conventional diesel fuels, says Knothe. Several companies manufacture a blend known as B20 because it contains 20 percent biodiesel and 80 percent regular diesel fuel.

Biodiesel improves the slipperiness, or lubricity, of diesel fuel. When sulfur is removed during refining of conventional diesel, the lubricity goes down. "If you add [biodiesel] in, you get the lubricity back," says Knothe. As an additive to a fuel tank, biodiesel could potentially reduce wear on moving engine parts.

In a similar way, vegetable oil added to an engine's oil pan can do the duty of motor oil while polluting less. Boehman, Joseph M. Perez, and their colleagues at Penn State are studying an engine lubricant made from sunflowers genetically modified to produce oil with a high concentration of monounsaturated oleic acid. To test a formula made by Renewable Lubricants in Hartville, Ohio, they compared it with a 10W-30 petroleum-based oil.

In the lab, Boehman explains, he puts lubricant in a small diesel engine, which he runs at a variety of temperatures and engine speeds. He passes the exhaust through a filter and collects particles of soot and other pollutants.

The researchers see a reduction in particle emissions with the sunflower oil, although they want to confirm those results with additional tests, says Boehman. He presented some of the group's recent findings in August at a Boston meeting of the American Chemical Society.

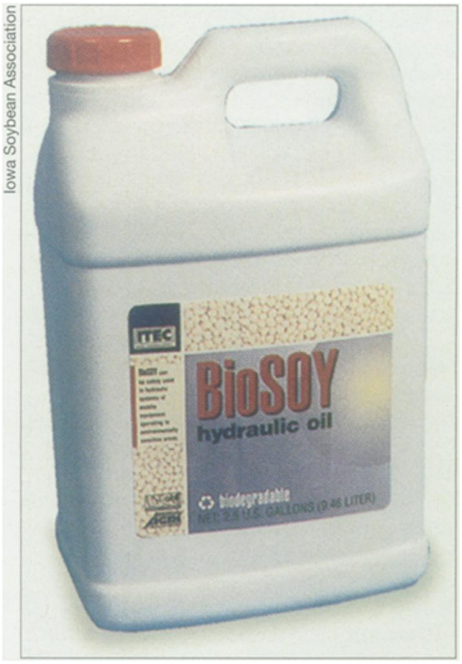
In regular engine operations, "most of the emissions come from the lubricant," he says. Oil vapors that don't get burned condense on the solid particles of soot that fly out through the exhaust pipe. Vegetable oil doesn't evaporate as easily as petroleum-based oil, so less finds its way out of the engine.

Because oleic acid has only one double bond, it doesn't react with oxygen as readily as polyunsaturated oils do. Adding antioxidants to sunflower oil improves its stability, to resemble that of 10W-30 motor oil.

As foods, monounsaturated oils such as olive and canola oil may have health benefits (SN: 11/21/98, p. 328). Therefore, many agricultural seed companies are genetically modifying plants to increase their proportion of monounsaturated oils, says Norland. "What seed companies are developing for human consumption is also very good for industrial lubricants."

If vegetable oil–based fuels and lubricants are to compete with conventional ones, their price will have to drop considerably.

"Biodiesel will not be able to replace all conventional diesel," says Knothe. "If you took all the vegetable oil in the world and made biodiesel out of it, you'd only replace a few percent of the whole conventional diesel market. That's the reason why the National Biodiesel Board [a trade organization] is targeting niche markets." These markets would include urban bus fleets, mining equipment, and marine vessels. Mine and marine environments face



Iowa Soybean Association

Iowa lawmakers are encouraging state agencies to use BioSOY, a hydraulic fluid made from soybean oil, in vehicles and heavy machinery.

particular threats from fuel spills.

One factor that would reduce the price is an increase in supply spurred by changing patterns of consumption, Norland suggests. Soybean products, for example, are gaining recognition for their heart-healthy qualities (SN: 5/30/98, p. 348). "As soybean flour is used more and more, oil becomes a by-product," he notes.

Legislative activity may drive the acceptance of vegetable oil–based fuels and lubricants, whatever their price. The omnibus spending bill recently passed by Congress recognizes B20 as an alternative fuel. The Clean Air Act of 1990 and the Energy Policy Act of 1992 also create markets for these products.

In Germany's Black Forest region, environmental protection laws require farm machinery to use only biodegradable fuels and lubricants, thereby instituting "almost a requirement to use veggie oil," says Boehman. Several products based on canola oil are used in Europe.

At the University of Northern Iowa, Lou Honary and his colleagues developed a vegetable oil replacement for hydraulic fluid used in heavy machinery such as forklifts and garbage trucks. An Iowa bill passed this year requires all state agencies to purchase as much of this fluid, called BioSOY, as allowed by their budgets and manufacturer warranties on equipment.

Oil companies themselves don't see vegetable-based products as a threat, according to Honary. Instead, they have already jumped on the bandwagon. "I don't know of any petroleum company that doesn't have a green program running," he says. "They are all trying to find some way to promote the use of vegetable oils. They'd like to have this alternative for certain applications."

In the end, researchers hope that vegetable oils will perform well enough to convince people to use them. Honary looks to the example of Sandia National Laboratories in Albuquerque, N.M. The facility tested BioSOY in 20 of its own vehicles from 1996 to 1997. This hydraulic fluid worked so well that Sandia decided to use it in all of its vehicles.

Iowa Soybean Association

Biodiesel fuel made from processed soybean oil emits fewer pollutants when burned and is less harmful to the environment if accidentally spilled.

Biology

Geraniums intoxicate Japanese beetles

Several bites of a garden-variety geranium, and a Japanese beetle falls to the ground in a stupor that lasts some 8 hours. It's hardly a great way to avoid predators or get on with beetle business, like reproduction. Yet researchers now find that the beetles never learn. They choose geraniums over perfectly good linden leaves and get paralyzed day after day.

Researchers described the knockout effect on Japanese beetles in 1929, notes Daniel A. Potter. He and David W. Held, both of the University of Kentucky in Lexington, have studied beetle learning and the sad effects of geranium intoxication on family life. Their results will appear in an upcoming issue of the journal ENTOMOLOGIA EXPERIMENTALIS ET APPLICATA.

In theory, insects with wide-ranging tastes are the most likely to learn to avoid noxious foods, according to the few studies that have tested this idea, Potter says. However, Japanese beetles eat nearly 300 U.S. plant species but don't avoid geraniums.

The flower petals, especially from plants in full sunlight, seem the most narcotic, Potter reports. His most extensive tests were of red geraniums, but flowers of white, coral, and other colors also slammed the beetles. So did a water-soluble leaf extract.

A geranium "is like candy to them," Potter says. Beetle pairs offered a choice picked geranium flowers so often that they laid just half as many eggs as pairs provided only with linden leaves. Intoxication is dangerous for the beetle, but is it fun? Potter won't speculate. —*S.M.*

Ravens' memories can lead to thievery

Ravens not only remember where they hid their own food; there's evidence they remember—and steal—caches of other ravens.

As far as Bernd Heinrich is aware, his raven studies at the University of Vermont in Burlington are the first to show that a bird's memory for caches extends to somebody else's hoard.

Ravens don't just sniff out hidden meat, report Heinrich and John W. Pepper of the University of Michigan in Ann Arbor. When Heinrich, unseen by the birds, hid 40 caches in snow in a large, outdoor aviary, the ravens failed to find even one.

Yet when nine ravens hid food at the same time and looked for it the next day, they found 58 out of 85 caches. Fifteen of these were thefts. The ravens appeared to search deliberately in specific spots, Heinrich says. He has also observed that a raven changes its hiding strategies, going farther to stash booty, if others are watching. Results appear in the November ANIMAL BEHAVIOUR. —*S.M.*

Diverse fungi underlie plant success

There's a hidden side to plant diversity that people had better start paying attention to, warn two research teams.

Their experiments demonstrate the major importance of soil fungi in shaping plant communities, say Marcel G.A. van der Heijden of the University of Basel in Switzerland, John N. Klironomos of the University of Guelph in Ontario, and their colleagues. Yet the possible loss of diversity in soil fungi has hardly been studied, they lament in the Nov. 5 NATURE.

Most soils have so-called arbuscular mycorrhizal fungi, which grip roots and boost nutrients for an estimated 80 percent of land plant species. A forest might have 30 of these fungal species, but crop fields typically have few, Klironomos says.

The Swiss researchers grew greenhouse pots of 11 plants with different soil fungi. Plant growth varied depending on the fungus. "This was a surprise," Klironomos notes. Researchers had assumed that any of the fungi could partner with any plant.

Outdoors, Klironomos' group seeded each of 70 tubs with the same combination of 15 plants but different fungi, from a lone species to a mix of 14. All the plants sprouted, but in some tubs, a few species took over. Plant communities were most diverse in tubs with eight or more fungal species. —*S.M.*