K-STATE Research and Extension
Biological and Agricultural Engineering

Biodiesel Fundamentals

Edwin Brokesh, specialist, machinery systems, Kansas State University

Logan Joos, K-State Biodiesel Initiative Lab Assistant

Introduction

High fuel prices, commodity grain prices, political unrest in the Middle East, a desire to go green, and global warming are all reasons people give when they consider alternative fuels. Historically, ethanol is the fuel people think of most often as an alternative fuel. However, ethanol does not work as well for agriculture and other industries because diesel is the fuel that powers many of the engines that make these segments of the economy move. Is there an alternative to petroleum diesel? Yes — it is biodiesel.

Biodiesel Is Diesel Fuel

Biodiesel is not vegetable oil, although it is made from vegetable oils. Many people have heard that simple vegetable oil or used cooking oil can be burned in a diesel engine. Though there is an element of truth to this thought, practically speaking it is not a good idea. Modern diesel engines need diesel fuel. New or used vegetable oil burned in an un-modified diesel engine ultimately will "gunk" up the engine, leading to expensive repairs for damage such a fuel filter plugging and clogged injectors.

Biodiesel can be made from vegetable oils (soy, canola, peanut, etc.) and animal fats (such as lard and tallow) in a reaction called **transesterification**. This reaction combines fatty oils with an alcohol in the presence of a catalyst. The products of this reaction are biodiesel, glycerin, and some excess alcohol. The process is relatively simple and can be performed by individuals with specialized, but relatively simple, equipment. Fuel material produced by this process must meet the ASTM International Standard D6751 to be called biodiesel. Any biodiesel conforming to this standard is safe for use in a modern diesel engine.

ASTM provides numerous standards and test methods specifically for biodiesel properties such as oxidation, particulates, and glycerin content. Diesel fuel's specification ASTM D 975 provides minimum values

for properties, such as flash point, Cetane number, and viscosity. However, many fuel suppliers implement additional standards such as density and pour point when transporting large amounts of fuel. Biodiesel conforming to ASTM D6751 can be used safely in any diesel engine. The use of biodiesel will not void a manufacturer's warranty, because manufacturers do not warrant ANY fuel-related problems.

Biodiesel is defined as "mono-alkyl esters of long chain fatty acids derived from plant or animal fats." It shares many similar physical properties with traditional petroleum-based diesel fuel and has roughly the same combustion quality and viscosity. Biodiesel is slightly heavier than standard No. 2 diesel. It will not separate from petroleum diesel fuel when the two fuels are mixed properly.

Chemically, biodiesel contains 11 percent oxygen by weight. This oxygen content makes biodiesel a cleaner combusting fuel than regular diesel. A higher biodiesel fuel blend contains more excess oxygen, which will help reduce pollutants the most by improving combustion. Commonly used B20 reduces particulates and carbon monoxide by more than 12 percent and unburned hydrocarbons by about 20 percent. Consequently, biodiesel is highly recommended in applications where diesel engines will be operated in confined spaces, such as mines and warehouses, where there are concerns over air quality.

With respect to greenhouse gas emissions, the actual combustion of biodiesel produces the same amount of carbon as petroleum diesel fuel. However, because the carbon in biodiesel originated from plant materials, which captured the carbon from the atmosphere to begin with, the carbon in biodiesel is considered "carbon neutral." Therefore, it does not increase the carbon dioxide content of the atmosphere. Compared to petroleum diesel, B100 reduces carbon dioxide emissions by 57 to 86 percent, and B20 by more than 15 percent depending on the feedstock and production process used.

Biodiesel Availability

Biodiesel is available in about 50 locations in Kansas. It is generally found as a blend with traditional diesel, ranging from 2 to 20 percent. Pumps that distribute biodiesel are labeled as B2, B5, B10, and so on. B2 is a fuel with 2 percent biodiesel; B5 is 5 percent biodiesel, etc. B100 is pure biodiesel and is available at only a few stations in Kansas.

Most commercially available Ultra Low Sulfur Diesel (ULSD) likely contains1 to 2 percent biodiesel. It can contain up to 5 percent even if it isn't labeled as containing biodiesel. Why does petroleum diesel contain biodiesel? It is because the sulfur content in diesel fuel must be maintained below 15ppm to meet the current ultra-low sulfur fuel standard. During the refining process to meet the ultra-low sulfur standard, the lubricity of petro diesel decreases. It decreases enough that unacceptable wear in the diesel engine injector pump is possible. Biodiesel, because of its chemical composition, has high lubricity and a sulfur content of less than 15 ppm. Because of these two properties, biodiesel is used as an additive in ultra-low sulfur diesel fuel to protect engine components from wear, while maintaining a low sulfur concentration.

Using Biodiesel

Engines manufactured after 1993 use fuel injection equipment that will generally tolerate high concentrations of biodiesel. In engines manufactured prior to 1993, the elastomers in the engine's fuel system may break down with high concentrations of biodiesel in the fuel. However, biodiesel blends of up to B20 are considered a "drop in" alternative fuel, meaning the biodiesel can be used in place of petroleum diesel without any modifications to fuel systems or handling equipment. Blends up to B5 have been approved by all original equipment manufacturers (OEMs) for their on-highway vehicles. Higher blends are sometimes approved for use in farm equipment. Referencing the OEM's website is recommended before choosing to switch from petroleum diesel to regular biodiesel use in high concentrations.

Table 1. Cloud points of biodiesel and diesel fuel

Fuel	Chemical Structure	Energy Content (BTU's/Gallon)	Cloud Point (°F)
Methyl soyate (biodiesel)	$C_{19}H_{36}O_2$	118,170	32° F
Diesel fuel	$C_{16}H_{34}$	129,050	0° F

Although biodiesel blends may be approved for use, there are a few characteristics that make using it in diesel engines slightly different when compared to petroleum diesel fuel.

First, biodiesel has different energy content. Pure biodiesel, B100, has 8 percent less energy per gallon than petroleum-based No. 2 diesel fuel. Energy content per gallon in biodiesel blends, B10 to B20, is about 1 to 2 percent less than petroleum diesel. At these blend levels, the energy content difference will not be noticeable. The B100 energy content difference will be noticeable at full, sustained engine load conditions, where an increase in fuel consumption could occur.

Second, biodiesel has higher lubricity when compared to petroleum diesel. This extra lubricity improves the service life of key engine components, such as injector pumps and cylinders. The extra lubricity is evident even when a small percentage of biodiesel is blended with traditional petroleum diesel. Research has shown diesel fuel containing as little as 2 percent biodiesel has measurable improvement in wear protection over unblended diesel fuel, which is why it is used as a fuel additive in ultra-low sulfur diesel fuel.

Third, biodiesel has a much higher cloud point temperature than petroleum diesel fuel. Biodiesel begins clouding as much as 30 degrees warmer than petroleum-based diesel fuel (depending on the feed stock, some biodiesel fuels can begin to cloud at 32 degrees F). This is the reason B100 fuel is not commonly available in colder climates. The cloud point temperature of blended biodiesel fuel up to B20 is roughly the same as pure petroleum diesel. Blends higher than B20 become more problematic in colder temperatures. For best cold weather performance, it is recommended to use a B20 blend mixed with No. 2 diesel fuel, and then add a "de-icer" additive into the diesel fuel blend. Another option is to store vehicles in a warm dry space for easy start up.

Aftermarket kits are becoming available to allow engines to run on B100 during the coldest months. One such kit features a heated fuel tank for biodiesel, a small fuel tank for conventional diesel fuel, and an electric control system that will automatically switch between B100 and conventional diesel fuel. The kit works by starting the engine on conventional diesel fuel; once the fuel system reaches a certain operating temperature, the system will switch over to running B100 fuel. Then, during engine shut down, the control system will automatically switch back to conventional diesel fuel, leaving unheated portions of the fuel system with conventional diesel fuel in them for cold storage. This technology is readily available for medium- to heavy-duty diesel vehicles and can be found on snow removal trucks in some northeastern cities.

Storing Biodiesel

Biodiesel can be stored successfully for the same period of time as conventional diesel fuel (six months to a year). Like any fuel that is stored for a long period of time, biodiesel will begin to change as it ages. As biodiesel ages, it can react with the surrounding engine fuel system and storage tank materials. An open container of biodiesel will react with oxygen and acidify over time. Acidic biodiesel can loosen or dissolve varnish and sediments found in older fuel systems and form a scum at the bottom of a storage tank, which in turn may clog fuel system filters. If a diesel engine that has been using biodiesel needs to be stored for a long period of time, it is recommended that fuel in the system be changed back to petroleum diesel before storage.

Biodiesel, like conventional diesel fuel, attracts water, which will settle at the bottom of vehicle and storage fuel tanks. Water sediment produces a habitat for microbes that feed on biodiesel. As microbes consume biodiesel they form a smelly slime that can clog fuel filters. Microbes will also grow in water found in conventional diesel fuel tanks. However, because conventional diesel contains many non-organic compounds (sulphur, for example) it will not support strong microbial growth the same as biodiesel.

In high concentrations (greater than B20) biodiesel can be an effective solvent. Biodiesel tends to soften certain rubber compounds such as buna-N, nitrile, and natural rubber. These compounds can be found in supply hoses and gaskets in fuel storage and distribution equipment and some older (pre-1993) engine fuel systems.

Biodiesel will degrade and form sediments if it remains in contact with a copper or copper-containing metal such as brass or bronze. At lower blends of biodiesel, the likelihood of this occurring decreases. Conventional diesel fuels will also react with these metals when exposed over long periods of time.

The solvent behavior of biodiesel can also cause an initial release of fuel systems deposits when it is first introduced into an older fuel system. The release of these deposits can clog filters. It is recommended to change fuel system filters (engine and storage system filters) frequently when switching to biodiesel. For the first two to three months, filters should be changed monthly, then every other month until the six months mark is reached. Once the deposits have been cleaned out of the fuel system, a regular yearly fuel filter replacement schedule can be resumed.

Conclusion

Biodiesel is an alternative fuel that can be safely used in modern diesel engines. It has several advantages over petroleum diesel fuel, including reduced emissions and greater engine protection. Biodiesel differs from petroleum diesel in cloud point, energy content, and solvent tendencies. Differences should be understood when using the fuel in either its pure state or as a high percentage blend.

Beyond fuel performance, biodiesel represents an opportunity for farmers to grow and process a crop for their own fuel needs. Increased fuel demand from a growing population and greater acceptance of alternative fuels, such as biodiesel, supports farmers and local business and industry while minimizing agriculture's carbon footprint.

Resources

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