

What's So Different about Biodiesel Fuel?

Introduction

Biodiesel is a liquid fuel that is created by chemically processing vegetable oil and altering its properties to make it perform more like petroleum diesel fuel. It was first evaluated seriously in the late 1970s but was not widely adopted at that time.

The topic of biodiesel fuel has been receiving a great deal of interest recently, and both large- and small-scale manufacturers have started production at locations throughout the state. However, many people are still uncertain about whether biodiesel is a reliable, safe fuel to use for diesel engines.

This fact sheet explains the major differences between biodiesel and petroleum diesel (also called petrodiesel), including information about biodiesel additives and blends. The companion fact sheet in this series *Using Biodiesel Fuel in Your Engine* explains the performance you can expect when running an engine on biodiesel.

Properties of Biodiesel Versus Petroleum Diesel

The sizes of the molecules in biodiesel and petroleum diesel are about the same, but they differ in chemical structure. Biodiesel molecules consist almost entirely of chemicals called fatty acid methyl esters (FAME), which contain unsaturated "olefin" components. Low-sulfur petroleum diesel, on the other hand, consists of about 95 percent saturated hydrocarbons and 5 percent aromatic compounds.¹

The differences in chemical composition and structure between petroleum diesel and biodiesel result in several notable variations in the physical properties of the two fuels. The seven most significant differences are as follows:

1. Biodiesel has higher lubricity (it is more "slippery") than petroleum diesel. This is a good thing, as it can be expected to reduce engine wear.
2. Biodiesel contains practically no sulfur. This is also a good thing, as it can be expected to result in reduced pollution from engines using biodiesel.
3. Biodiesel has a higher oxygen content (usually 10 to 12 percent) than petroleum diesel. This should result in lower pollution emissions. But, relative to petroleum diesel, it causes slightly reduced peak engine power (~4 percent).
4. Biodiesel tends to thicken and "gel up" at low temperatures more readily than petroleum diesel. Some types of oil are more of a problem than others. This is a concern, especially for the cold winters that are typical to Pennsylvania.

1. If the biodiesel is made using ethanol rather than methanol, the resulting molecules are "fatty acid ethyl esters" (FAEE).



5. Biodiesel is more likely to oxidize (react with oxygen) to form a semisolid gel-like mass. This is a concern, especially for extended fuel storage and when using engines that are only operated occasionally (such as standby power generators). A good method for storage is to use a dry, semi-sealed, cool, light-tight container.
6. Biodiesel is more chemically active as a solvent than petroleum diesel. As a result, it can be more aggressive to some materials that are normally considered safe for diesel fuel.
7. Biodiesel is much less toxic than petroleum diesel. This can be a real benefit for spill cleanups.

The quality of petroleum diesel fuel tends to be more uniform and reliable, especially when compared to small-scale production of biodiesel where quality control may or may not have been good. Petroleum diesel can vary in quality from plant to plant or from region to region, but the variations are typically much smaller. Poor-quality biodiesel fuel can lead to many problems in engine performance, and care should be taken to ensure that your fuel is of good quality (see the *Renewable and Alternative Energy Fact Sheet: Using Biodiesel Fuel in Your Engine*). Biodiesel that conforms to ASTM standard D6751 should be of a consistent, high quality.

In all fairness, we should mention that petroleum diesel has also demonstrated problems with oxidative stability and low-temperature performance, although biodiesel, at present, seems to be more susceptible.

Does the Type of Vegetable Oil Used Matter?

A common question regarding biodiesel that comes up is “which oil crop results in the best biodiesel?” There are definite differences from crop to crop, but it’s not a straightforward matter to choose a “best” one, especially when the cost of growing or buying oil can vary quite a bit from crop to crop as well.

Different vegetable oils have higher or lower concentrations of different chemical components (fatty acids, for the most part), which affects their performance when they are made into biodiesel. In addition, the chemical structure of the alcohol that is reacted with the oil to create biodiesel can also affect the properties of the fuel. In general, the chemical properties that matter the most are the length of the biodiesel molecule, the amount of “branching” in the chain, and the degree of “saturation” of the molecule.

As shown in Table 1, these properties have both positive and negative effects on biodiesel, so it is not really possible to choose a “perfect” oil for biodiesel. As if this wasn’t complicated enough, we need to also remember that cold-starting properties might be vital during winter in cold climates but unimportant in summertime or in warm parts of the world. On top of all that, it is possible to buy additives that improve some of the less-than-ideal properties of biodiesel.

In general, longer molecules with more branching are beneficial to the performance of biodiesel but are seldom present in FAME. High unsaturation (high iodine number) leads to poor oxidative stability and is undesirable in biodiesel. Of the many types of fatty acid found in vegetable oils, oleic acid is probably best, while linoleic is less desirable and linolenic acid is most undesirable.

With all this in mind, it appears that canola oil, with its high proportion of long, unsaturated fats (lots of oleic acid), may be slightly better for biodiesel fuel quality than some of the other oilseed crops, although this has not been conclusively confirmed with careful testing. Tropical oils such as palm oil, with their high proportion of saturated fats, tend to have significant problems with cold-weather performance, as they tend to solidify more readily than many other oils.

Making Biodiesel Better with Additives

Some of the properties of biodiesel fuel are not ideal from an engine performance point of view. Thankfully, additives can be used to counteract these problems and improve the overall quality of the fuel.

- Cold-flow improvers: these additives improve the cold-weather performance of biodiesel by limiting its ability to gel. They tend to only improve the operating range by about 5 degrees.
- Fuel stabilizers: these additives act as “antioxidants” to reduce the possibility of oxidation degradation of the fuel.
- Antimicrobial additives: it is possible for microbes to grow in biodiesel, resulting in clogged lines and fouled equipment. Antimicrobial additives prevent this by killing off any existing microbes and preventing them from returning.
- Detergent additives: these help reduce the formation of deposits on engine parts by forming a protective layer on the parts and dissolving existing deposits from the surfaces within the engine.
- Corrosion inhibitors: these also protect the engine by forming a protective layer on the components, thus preventing corrosive chemicals from reaching the surface.

A wide array of additives is available on the market today, and they can be purchased at an automotive shop or on the Internet. Often, a single product can be purchased that combines many or all of the above additives. The actual composition of these additives is usually a closely guarded trade secret, and not all additives perform the same. Users should keep track of how well a specific additive is working for them and take care to follow the manufacturer’s recommendations for the concentration and proper use of the additive. Keep in mind that there are many “snake oil” salesmen in the market today. Only deal with reputable companies and suppliers that are approved by your engine’s manufacturer.

Table 1. General comparison of different oil chemical properties related to their use as biodiesel.

Property	Positive effects	Negative effects
Length of molecule	Increases the cetane number, heat of combustion; decreases NOx emissions	Increases viscosity
Amount of branching	Decreases the gel point	Decreases the cetane number
Saturation	Decreases NOx emissions, improves oxidative stability, reduces deposition	Increases melting point and viscosity; reduces lubricity*

*Technically, the reduction in lubricity is due to the removal of polar compounds containing sulfur that are natural additives by hydrogenation and the formation of saturated compounds.

What about Blends?

Biodiesel fuel blends very easily with petroleum diesel. These blends are described by their percentage of biodiesel (e.g., “B20” has 20 percent biodiesel, 80 percent petroleum diesel). In general, the properties of a blend will lie somewhere between the properties of the biodiesel and the petroleum diesel. Blends are sometimes used to improve the lubricity of petroleum diesel or reduce its sulfur content.

Probably the most useful reason for a biodiesel producer to blend would be to improve cold-operating characteristics during the winter. A mix of 70 percent biodiesel and 30 percent petroleum diesel has been reported to be effective for mild winter conditions. Kerosene, also known as #1 diesel fuel, is blended with standard (#2) petroleum diesel during winter months (usually ~40 percent kerosene, 60 percent #2 diesel) to improve its cold-weather performance. This approach is probably the easiest way to make biodiesel usable during harsh midwinter conditions in Pennsylvania. However, keep in mind that only low-sulfur kerosene that is approved as an engine fuel should be used.

Summary

Biodiesel and petroleum diesel are very similar fuels, but they are not identical. However, the differences are remarkably small when we consider the radically different procedure for making biodiesel as compared to petroleum diesel. Many additives are available that can modify the properties of biodiesel fuel, and biodiesel can be easily blended with petroleum diesel fuel if desired.

For additional information, please refer to the following Penn State Cooperative Extension fact sheets and reports:

- *Biodiesel: A Renewable, Domestic Energy Resource*
- *Renewable and Alternative Energy Fact Sheet: Using Biodiesel Fuel in your Engine*
- *Making Your Own Biodiesel: Brief Procedures and Safety Precautions*
- *Biodiesel Safety and Best Management Practices for Small-Scale Noncommercial Production*



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