U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

Straight Vegetable Oil as a Diesel Fuel?

Biodiesel, a renewable fuel produced from animal fats or vegetable oils, is popular among many vehicle owners and fleet managers seeking to reduce emissions and support U.S. energy security. Questions sometimes arise about the viability of fueling diesel vehicles with straight vegetable oil (SVO), or waste oils from cooking and other processes, without intermediate processing. But SVO and waste oils differ from biodiesel (and conventional diesel) in some important ways and are generally not considered acceptable vehicle fuels.

Straight vegetable oil is not the same as biodiesel and is generally not recommended for long-term vehicle use. *Photo by Dennis Schroeder, NREL 21940.*

Performance of SVO

Research has shown there are several technical barriers to use of SVO as a vehicle fuel.[1]

The published engineering literature strongly indicates using SVO leads to reduced diesel engine life[2] caused by the buildup of carbon deposits inside the engine and the accumulation of SVO in the engine lubricant. These issues are attributable to SVO's high viscosity and high boiling point relative to the required boiling range for diesel fuel. The carbon buildup doesn't necessarily happen immediately upon use of SVO; it typically takes place over the long term. However, even at concentrations as low as 1%, the use of SVO can cause long-term engine deposits. These findings are consistent across a substantial body of technical literature, including an SAE technical paper that reviewed published data on the use of SVO in diesel engines.[3] The SAE paper states:

- Compared to No. 2 diesel fuel, all of the vegetable oils are much more viscous, are much more reactive to oxygen, and have higher cloud point and pour point temperatures.
- Diesel engines with vegetable oils offer acceptable engine performance and emissions for short-term operation. Long-term operation results in operational and durability problems.

Some investigators explored modifying vehicles to preheat SVO prior to injection into the engine. Others examined blends of vegetable oil with conventional diesel. These techniques may mitigate the problems to some degree but don't eliminate them entirely. Studies show carbon buildup (coking) continues over time, resulting in higher engine maintenance costs and/or shorter engine life. Figure 1 shows the tendency to form carbon deposits increases with increasing proportions of vegetable oil blended into the fuel.[4]

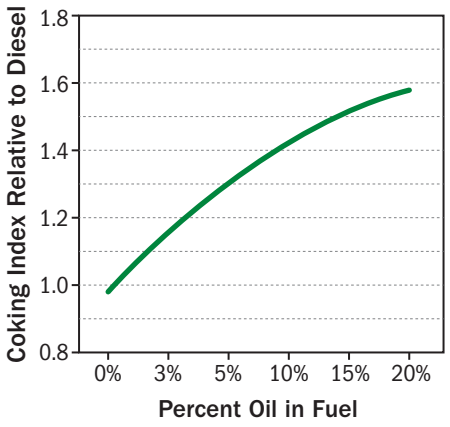

Figure 1. Buildup of carbon deposits in the engine as a function of the proportion of oil in the fuel.

Viscosity (the thickness, or measure of a fuel's resistance to flow) is another important consideration related to the use of SVO. The viscosity of SVO is much higher than that of diesel fuel at

[1] Alleman, T.L.; R.L. McCormick; E.D. Christensen; G. Fioroni; K. Moriarty; J. Yanowitz. *Biodiesel Handling and Use Guide (Fifth Edition).* (2016). afdc.energy.gov/files/u/publication/biodiesel_handling_use_guide.pdf

[2] Sidibé, S.S.; J. Blin; G. Vaitilingom; Y. Azoumah. "Use of Crude Filtered Vegetable Oil as a Fuel in Diesel Engines State of the Art: Literature Review." *Renew Sust Energ Rev* 14(9):2748-2759 (2010).

[3] Babu, A.K.; G. Devaradjane. *Vegetable Oils and Their Derivatives as Fuels for CI Engines: An Overview.* SAE Technical Paper No. 2003-01-0767.

[4] Figure 1 adapted from Jones, S.T.; C.L. Peterson; J.C. Thompson. Biological and Agricultural Engineering Department, University of Idaho, Moscow, Idaho. "Used Vegetable Oil Fuel Blend Comparisons Using Injector Coking in a DI Diesel Engine." Presented at 2001 ASAE Annual International Meeting, Sacramento, Calif., July 30– August 1, 2001. SAE Paper No. 01-6051.

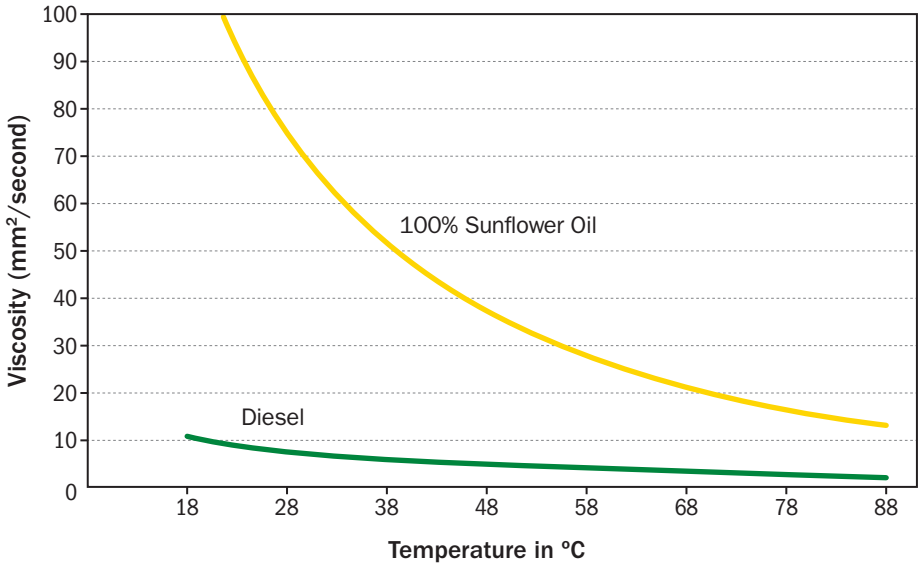

Figure 2. Viscosities of sunflower oil and conventional diesel fuel as a function of temperature.

normal operating temperatures.[2] Figure 2 illustrates the viscosities of diesel fuel and of 100% sunflower oil over a range of temperatures. High fuel viscosity can cause premature wear of the fuel pumps and injectors. It can also dramatically alter the structure of the fuel spray coming out of the injectors by increasing droplet size, decreasing spray angle, and increasing spray penetration. These effects tend to increase wetting of the engine's internal surfaces, thereby diluting the engine lubricant and increasing the tendency for coking.

The long-term effect of using SVO in diesel engines equipped with modern emission control systems is also a matter of concern. Buildup of fuel in the lubricant is more significant in these engines—even for petroleum diesel—and would likely be severe with SVO. In general, these systems were not originally designed to accommodate the properties of SVO, and they can be seriously damaged or poisoned by out-of-spec or contaminated fuel.

Biodiesel: Fuel Made From SVO

Biodiesel is an alternative fuel that can be made from SVO or other fats in a chemical process called transesterification (or esterification), which involves a reaction with methanol using caustic soda (sodium hydroxide) as a catalyst. Through the process of converting plant oils or greases to biodiesel by transesterification, the viscosity and boiling point of the fuel are reduced to values more similar to conventional diesel fuel. Biodiesel has substantially different properties than SVO and results in better engine performance. In particular, biodiesel has a lower boiling point and viscosity than SVO.

Biodiesel is most commonly used as a blend with petroleum diesel fuel. All manufacturers of diesel vehicles and engines have approved the use of B5 (a blend containing 5% biodiesel and 95% petroleum diesel), and some approve the use of blends up to B20 (20% biodiesel and 80% petroleum diesel) or higher. Visit the National Biodiesel Board website for information on OEM approvals of biodiesel use in vehicles (biodiesel.org/using-biodiesel/oem-information).

To ensure good performance in engines, biodiesel must meet quality specifications developed by ASTM International. ASTM Specification D6751 (astm.org/Standards/D6751.htm) is for pure biodiesel (B100) used for blending with petroleum diesel fuel. Biodiesel that meets ASTM D6751 is legally registered with the U.S. Environmental Protection Agency. Blends up to B5 may be found in conventional diesel fuel without additional labeling at the pump. Properties of these low-level blends are covered by the diesel fuel ASTM Specification D975 (astm.org/Standards/D975.htm). A separate specification, ASTM D7467 (astm.org/Standards/D7467.htm), exists for blends of biodiesel ranging from B6 to B20, and pump labeling is required to inform the consumer that a biodiesel blend is being sold.

For a complete list of ASTM biodiesel requirements, see the Biodiesel Handling and Use Guide (Fifth Edition) at afdc.energy.gov/files/u/publication/biodiesel_handling_use_guide.pdf. In addition, the biodiesel industry created a quality assurance program for biodiesel producers and marketers. To learn more about the BQ-9000 program, visit bq-9000.org. ■

Where can I get more information?

- The U.S. Department of Energy's Alternative Fuels Data Center, at afdc.energy.gov, contains a vast collection of information on alternative fuels and alternative fuel vehicles.
- The National Biodiesel Board is the national trade association representing the biodiesel industry. Its website, biodiesel.org, serves as a clearinghouse of biodiesel-related information.

Clean Cities
U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For more information, visit:
afdc.energy.gov

DOE/GO-102021-5649 • December 2021