AE-1240

Biodiesel Fuel

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North Dakota farmers use a considerable amount of diesel fuel in their farming operations. An alternate fuel supply could be extremely helpful to stabilize fuel prices, especially when fuel prices are fluctuating.

Biodiesel could be an excellent renewable fuel for diesel engines. It is derived from vegetable oils that are chemically converted into biodiesel. As the name implies, it is similar to diesel fuel except that it is produced from crops commonly grown in North Dakota, including canola, soybean, sunflower and safflower. These crops are all capable of producing several gallons of fuel per acre that can power an unmodified diesel engine. Vegetable oil is converted into biodiesel through a chemical process that produces methyl or ethyl ester. After washing and filtering to meet American Society for Testing and Materials (ASTM) standards, it is usable as an alternate renewable fuel.

Biodiesel

Biodiesel is composed of long-chain fatty acids with an alcohol attached, often derived from vegetable oils. It is produced through the reaction of a vegetable oil with methyl alcohol or ethyl alcohol in the presence of a catalyst. Animal fats are another potential source. Commonly used catalysts are potassium hydroxide (KOH) or sodium hydroxide (NaOH). The chemical process is called transesterification which produces biodiesel and glycerin.

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Chemically, biodiesel is called a methyl ester if the alcohol used is methanol. If ethanol is used, it is called an ethyl ester. They are similar and currently, methyl ester is cheaper due to the lower cost for methanol. Biodiesel can be used in the pure form, or blended in any amount with diesel fuel for use in compression ignition engines. **Figure 1** shows basic transesterification technology.

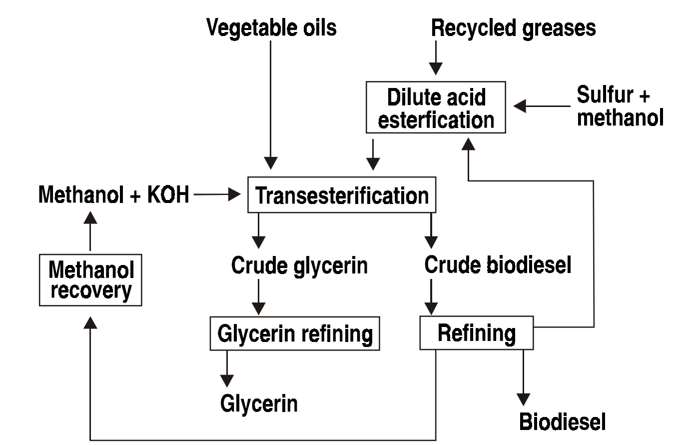


Figure 1. Basic transesterification technology.

The transesterification process of converting vegetable oils to biodiesel is shown in **Figure 2**. The "R" groups are the fatty acids, which are usually 12 to 22 carbons in length. The large vegetable oil molecule is reduced to about 1/3

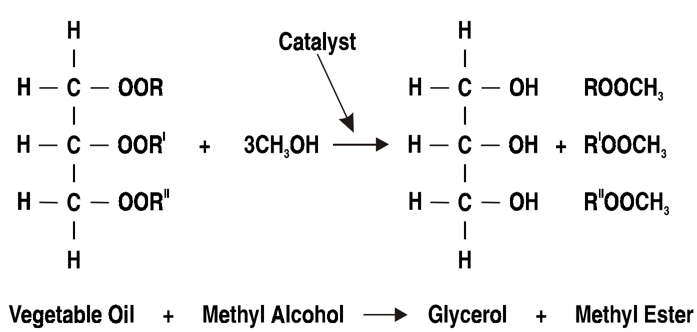


Figure 2. Transesterification of vegetable oils.

its original size, lowering the viscosity making it similar to diesel fuel. The resulting fuel operates similar to diesel fuel in an engine. The reaction produces three molecules of an ester fuel from one molecule of vegetable oil.

Some properties of various fuels are shown in **Table 1**. They include diesel fuel, biodiesel, and vegetable oil. The main differences between diesel fuel, an ester fuel, and vegetable oil are the viscosity, cetane number and heat of combustion. The viscosity of a fuel is important because it affects the atomization of the fuel being injected into the engine combustion chamber. A small fuel drop is desired so complete combustion occurs. A high viscosity fuel, such as raw vegetable oil, will produce a larger drop of fuel in an engine combustion chamber which may not burn as clean as a fuel that produces a smaller drop. Unburned oxidized fuel will build up in the engine around valves, injector tips and on piston sidewalls and rings. Previous NDSU tests using sunflower and other oils mixed with diesel fuel found significant buildup on piston sidewalls, stuck rings and in a few cases, broken rings. Biodiesel has a viscosity much closer to diesel fuel than vegetable oil. This helps produce a much smaller drop, which burns cleaner.

Table 1. Fuel properties.

	Fuel Weight	Heat of Combustion	Cetane Number	Viscosity Centistokes
	Lbs./gal.	BTU/gal.		
No. 2 diesel	7.05	140,000	48	3.0
100% Biodiesel (B100)				
Methyl or ethyl ester	7.3	130,000	55	5.7
B20 mix (20/80)	7.1	138,000	50	3.3
Raw vegetable oil	7.5	130,000	35 to 45	40 to 50

Cetane rating varies considerably among the listed fuels (table 1) and is a measure of the self-ignition quality of the fuel. No. 2 diesel fuel usually has a cetane rating between 45 and 50 while vegetable oil is 35 to 45. Biodiesel is usually 50 to 60. The ignition quality affects engine performance, cold starting, warm up and engine combustion roughness. Cetane rating is related to the volatility of the fuel where more volatile fuels have higher ratings. A high cetane fuel also may lead to incomplete combustion and smoke if the fuel ignites too soon by not allowing enough time for the fuel to mix with air for complete combustion.

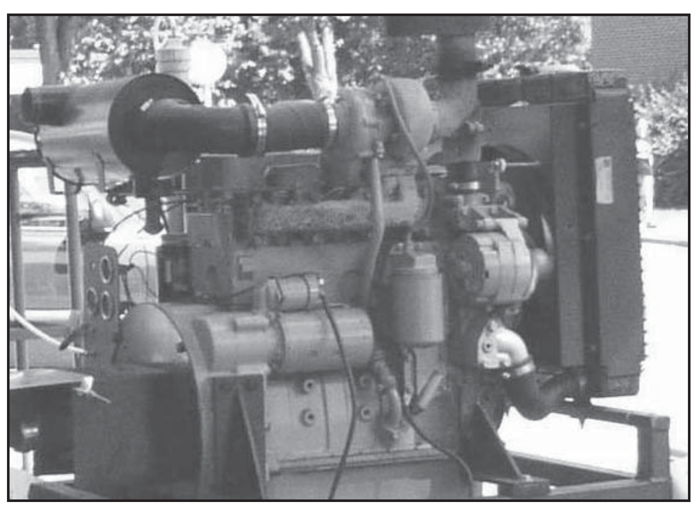
The energy content of the fuels also vary. No. 2 diesel fuel typically contains about 140,000 BTU's per gallon while vegetable oil and biodiesel contain about 130,000 BTU/gal. A "BTU" stands for British Thermal Unit which is defined as the energy required to raise the temperature of water one degree fahrenheit. Fuels with a high heat of combustion will usually produce more power per pound of fuel than fuels with lower energy. As a result, an engine using a lower energy fuel will require more fuel to produce the same power as diesel fuel. As a result of the lower energy content, biodiesel will require about 1.1 gallons of fuel to do the same work as a gallon of diesel fuel.

Engine Studies

Several studies show biodiesel can run in a conventional diesel engine for an extended time. Researchers in several states including Missouri and Idaho, have run diesel engines in pickups, city buses, large trucks and tractors on various mixes of biodiesel/diesel fuel. These mixtures have ranged from 2/98% (B2), 20/80% (B20) up to 100%(B100). The results of these studies look very promising.

Standard diesel engines will operate on 100% biodiesel. In cold weather, biodiesel begins to cloud and thicken at about 30F. Biodiesel thickens at warmer temperatures than No. 2 diesel fuel, but additives are available that will lower the pour point. Pour point is the point at which flow of the fuel ceases. Mixing biodiesel with No.1 diesel as is currently done with No. 2 will lower the pour point. Installing an in-tank or fuel line heater may also be needed to keep the fuel flowing in cold weather. A blend of biodiesel/diesel fuel has a lower pour point than 100% biodiesel, but gelling may still occur unless care as mentioned earlier is taken.

New lower diesel engine emission requirements that dictate a reduction of sulfur in fuel is causing a reduction in the lubricating ability of fuel. This will shorten the operating life of the injection system and engine. Biodiesel blends,



Various mixtures of biodiesel have been used to operate this 4 cylinder Cummings engine.

even at low rates (2%), indicate improved lubricating ability over diesel which should reduce wear and extend fuel system and engine life.

Studies show that some older engine fuel systems (engines built prior to 1993) may show fuel pump seal deterioration. They may have rubber or nitrile seals in the fuel pump and fuel system that could fail if 100% biodiesel is used. It may be best to replace them with Viton or other non-rubber seals if 100% biodiesel is used. A blend of 20% biodiesel can be used in older engines with no changes, but it is recommended to watch for leaks. Also, biodiesel studies indicate some cleaning action of the fuel system, so a fuel filter may need replacement soon after switching to biodiesel.

Biodiesel and Air Pollution

Research with biodiesel show reductions in several contributors to air pollution. **Table 2** is a summary of engine tests completed at the University of Idaho.

These tests were performed with a 100% and a 20% mix of ethyl and methyl ester of rapeseed oil. A U.S. Deptartment of Energy publication indicates reductions in most emission components except for an increase in nitrous oxide. Biodiesel use could provide reductions in several air pollutants. This could provide significant improvements in cities where air quality is a concern.

Table 2. Engine emission results from the University of Idaho.

Emission	100% Ester Fuel (B100)	20/80 Mix (B20)
Hydrocarbons	- 52.4%	-19.0%
Carbon Monoxide	- 47.6%	-26.1%
Nitrous Oxides	- 10.0%	-3.7%
Carbon Dioxide	+ 0.9%	+.7%
Particulates	+ 9.9%	-2.8%

Mixing and Storage of Biodiesel

Biodiesel mixes well with diesel fuel in any proportion and stays blended even in cold temperatures. A storage study completed over a 24-month period at the University of Idaho found that biodiesel tends to store about as well as diesel fuel. This study found that engine power decreased about 2% and viscosity, density, peroxide and acid value increased for biodiesel. Usually it is recommended not to store biodiesel longer than 6 months or at the most, a year. This recommendation is similar to diesel fuel storage periods.

Biodiesel Cost

The cost of biodiesel is higher than diesel fuel. Currently, there are seven producers of biodiesel in the United States. Pure biodiesel (100%) sells for about $1.50 to $2.00 per gallon before taxes. Fuel taxes will add approximately $0.50 per gallon. A mix of 20% biodiesel and 80% diesel will cost about 15¢ to 20¢ more per gallon over the cost of 100% diesel. Some suppliers are selling a 2% biodiesel mix at the same price as diesel, but this price will probably not continue into the future. A more realistic price would be about 1 to 2 cents more per gallon than diesel. These prices would be more attractive to people. The U.S. Department of Energy is working with the biodiesel industry to reduce the cost of biodiesel. A subsidy for the industry similar to that for other alternate fuels may be needed to promote the fuel. Improvements in processing along with the use of waste cooking oil as a raw material may help reduce costs.

Currently, there are several service stations selling a mix of biodiesel and diesel in North Dakota.

Potential Fuel From Oil Crops

Currently, diesel fuel use in North Dakota is about 165 million gallons per year. About 85 million gallons are used on farms in crop production. In 2001, about 2.1 million acres of soybeans were produced in the state with an average yield of about 33 bushels per acre. Soybeans contain about 18% oil so the average oil production per acre is about 49 gallons. If this oil were converted to an ester fuel, more than 100 million gallons of fuel could be produced. Soybean ester fuel could replace all the on-farm diesel fuel needs in the state. Other oil crops grown in the state could be used to produce additional fuel. **Table 3** shows the production potential of biodiesel from the main oil crops grown in North Dakota.

Every gallon of vegetable oil will produce about 1 gallon of biodiesel. The total input/output energy ratio shows a very positive return. For every BTU of energy used to produce the crop and process the oil, about 3.3 BTU's is produced as fuel.

Table 3. Potential fuel from North Dakota oil crops (2001).

Crop	Acres in State	Yield	Oil	Gallons
	(millions)		(%)	(per Acre)
Soybean	2.1	33 bu/acre	18	49
Sunflower	1.1	1400 lb/ac	44	84
Canola	1.2	1300 lb/ac	43	76

Engine Warranties

Some people are concerned that using a new fuel in an engine may cause damage. Several engine manufacturers guarantee their engines the same when using biodiesel as for diesel fuel as long as the amount of biodiesel does not exceed 20% and the fuel must meet ASTM D6751 specifications.

More Information

A web site that contains links to a number of private, university and government locations is:

www.missouri.edu/~pavt0689/index.html

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Any standard diesel engine will operate well on biodiesel.

For more information on this and other topics, see: www.ag.ndsu.nodak.edu

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