

BIODIESEL

Handling and Use Guidelines



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Biodiesel Handling and Use Guidelines

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BIODIESEL HANDLING AND USE GUIDELINES

1 Introduction

This document is a field guide for end-users (firms and individuals that are using biodiesel or blends of biodiesel and diesel fuel), distributors, (firms and individuals who are purchasing biodiesel for blending, storage, or distribution to others), and those involved in related activities. These guidelines cover fuel use and handling issues that could be anticipated or encountered in the field. Put this document where employees can access it and be sure to use it as a reference when questions are raised by your customers or your employees.

2 Biodiesel Fuel

Biodiesel is a fuel manufactured from vegetable oils, recycled cooking grease, or animal fats. The fuel typically contains up to 14 different types of fatty acids (Table 1) that are chemically transformed into fatty acid methyl esters (FAME). Different fractions of each type of FAME present in various feedstocks (Table 2) influence some of the properties of the fuel (Table 3). High levels of saturates (C14:0, C16:0, C18:0) raise cloud point, raise Cetane number, reduce NO_x, and improve stability. More polyunsaturates (C18:2, C18:3) will reduce cloud point and Cetane, reduce stability (unless stability additives are used), and raise NO_x.

Biodiesel always refers to the pure fuel. Biodiesel blends or BXX refers to a fuel that is composed of XX% biodiesel and 1-XX% diesel fuel. For example, B100 is pure biodiesel and B20 is a blend of 20% biodiesel and 80% diesel fuel. The diesel fuel can be No. 1, No. 2, or JP8. Some biodiesel blends may not meet ASTM D975 standards depending on how much biodiesel is present. Biodiesel blends stay mixed in the presence of water.

Biodiesel and biodiesel blends should only be used in compression-ignition (CI) engines that were designed to be operated on diesel fuel as described by ASTM D 975 or related military specifications. Do not put biodiesel fuels or blends into gasoline engines. Biodiesel and biodiesel blends can be used in CI engines in diesel-powered cars, trucks, tractors, boats, shipping equipment, irrigation systems, mining equipment, electrical generators, and in most applications where diesel is typically used. More detail is provided in the following sections.

Biodiesel has a specific gravity of 0.88 compared to 0.85 for diesel fuel. Because it is slightly heavier than diesel fuel, splash blending biodiesel on **top** of diesel fuel is the common mixing procedure. Rack blending is being considered in some states where B2 blends are being considered. B2 is a high-lubricity diesel fuel made with 2% biodiesel.

Biodiesel contains no nitrogen or aromatics and typically contains less than 15 ppm sulfur. Biodiesel contains 11% oxygen by weight, which accounts for its slightly lower heating value (energy content) and its characteristically low carbon monoxide, particulate, soot, and hydrocarbon emissions. The energy content of biodiesel is roughly 10% less than diesel No. 2 and comparable to diesel No.1. Fuel efficiency is the same as diesel fuel. Fuel economy, power, and torque are proportional to the heating value of biodiesel or the biodiesel blend. For example,

B20 tends to reduce power, torque, and fuel economy by slightly less than 2%.

Table 1. Structural Formula for Fatty Acids used in Biodiesel

Fatty Acid Name	No. Of Carbons & Double Bonds	Chemical Structure (= denotes double bond placement)
Caprylic	C8	$\text{CH}_3(\text{CH}_2)_6\text{COOH}$
Capric	C10	$\text{CH}_3(\text{CH}_2)_8\text{COOH}$
Lauric	C12	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Myristic	C14	$\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$
Palmitic	C16:0	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Palmitoleic	C16:1	$\text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Stearic	C18:0	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
Oleic	C18:1	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Linoleic	C18:2	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Linolenic	C18:3	$\text{CH}_3(\text{CH}_2)_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Arachidic	C20:0	$\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$
Eicosenoic	C20:1	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_9\text{COOH}$
Behenic	C22:0	$\text{CH}_3(\text{CH}_2)_{20}\text{COOH}$
Eurcic	C22:1	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_{11}\text{COOH}$

Table 2. Weight Percent of Fatty Acids in Fat and Oil Feedstocks

Fatty Acid Fat or Oil	C8:0	C10:0	C12:0	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0 C22:0	C20:1 C22:1	Other
Tallow	--	--	0.2	2-3	25-30	2-3	21-26	39-42	2	--	0.4-1	0.3	0.5
Lard	--	--	--	1	25-30	2-5	12-16	41-51	4-22	--	-	2-3	0.2
Coconut	5-9	4-10	44-51	13-18	7-10	--	1-4	5-8	1-3	--	--	--	--
Palm Kernal	2-4	3-7	45-52	14-19	6-9	0-1	1-3	10-18	1-2	--	1-2	--	--
Palm	--	--	--	1-6	32-47	--	1-6	40-52	2-11	--	--	--	--
Safflower	--	--	--	--	5.2	--	2.2	76.3	16.2	--	--	--	--
Peanut	--	--	--	0.5	6-11	1-2	3-6	39-66	17-38	--	5-10	--	--
Cottonseed	--	--	--	0-3	17-23	--	1-3	23-41	34-55	--	--	2-3	--
Corn	--	--	--	0-2	8-10	1-2	1-4	30-50	34-56	--	--	0-2	--
Sunflower	--	--	--	--	6.0	--	4.2	18.7	69.3	0.3	1.4	--	--
Soybean	--	--	--	0.3	7-11	0-1	3-6	22-34	50-60	2-10	5-10	--	--
Rapeseed	--	--	--	--	2-5	0.2	1-2	10-15	10-20	5-10	.9	50-60	--
Linseed	--	--	--	0.2	5-9	--	0-1	9-29	8-29	45-67	--	--	--
Mustard	--	--	--	--	3.0	--	1.5	15-60	12	5-10	--	10-60	--

Table 3. Selected Fuel Properties for Diesel and Biodiesel Fuels

<u>Fuel Property</u>	<u>Diesel</u>	<u>Biodiesel</u>
Fuel Standard	ASTM D975	ASTM PS 121
Fuel composition	C10-C21 HC	C12-C22 FAME
Lower Heating Value, Btu/gal	131,295	117,093
Kin. Viscosity, @ 40 °C	1.3-4.1	1.9-6.0
Specific Gravity kg/l @ 60 °F	0.85	0.88
Density, lb/gal @ 15°C	7.079	7.328
Water, ppm by wt	161	.05% max
Carbon, wt %	87	77
Hydrogen, wt %	13	12
Oxygen, by dif. wt %	0	11
Sulfur, wt %	.05 max	0.0 - 0.0024
Boiling Point, °C	188-343	182-338
Flash Point, °C	60-80	100-170
Cloud Point, °C	-15 to 5	-3 to 12
Pour Point, °C	-35 to -15	-15 to 10
Cetane Number	40-55	48-65
Stoichiometric Air/Fuel Ratio wt./wt.	15	13.8
BOCLE Scuff, grams	3,600	>7,000
HFRR, microns	685	314

3 Biodiesel Fuel Quality

ASTM PS 121 (Table 4) provides the standards to ensure good fuel quality. PS 121 is a provisional standard; a final standard should be available by winter, 2001. The standard is independent of any manufacturing process or feedstock. ASTM PS 121 is designed to ensure that biodiesel has the fuel properties for safe operation in a compression ignition engine and ensures that poor processing has not contaminated the fuel with products that will create engine damage.

Key fuel-quality issues are described below:

- Biodiesel flash point is typically high (greater than 150°C). FAMEs are not volatile. The limit for D93 is set at 100 °C to ensure that the manufacturer has removed excess methanol used in the manufacturing process. Residual methanol in the fuel is a safety issue because very small amounts reduce the flash point. Methanol can also affect fuel pumps, seals, elastomers, and can result in poor combustion properties.
- The Sulfated ash test ensures the removal of all the manufacturing catalysts. High levels of manufacturing catalysts in the fuel can result in injector deposits or filter plugging.
- Acid numbers will become elevated if the fuel ages, or if it was not properly manufactured. Acid numbers higher than 0.10 have been shown to be associated with fuel system deposits, and reduce the life of fuel pumps and filters.

Table 4. ASTM PS 121 Biodiesel for B20

Property	ASTM Method	Limits	Units
Flash Point	D93	100.0 min	Degrees C
Water & Sediment	D2709	0.050 max.	% vol.
Kinematic Viscosity, 40 C	D445	1.9 - 6.0	mm ² /sec.
Sulfated Ash	D874	0.020 max.	% mass
Sulfur	D5453	0.0015 max.	% mass
Copper Strip Corrosion	D130	No. 3 max.	
Cetane Number	D613	46 min.	
Cloud Point	D2500	Report to Customer	Degrees C
Carbon Residue, 100% sample	D4530**	0.050 max.	% mass
Carbon Residue, Ramsbottom	D524	0.090 max	% mass
Acid Number	D664	0.80 max.	mg KOH/gm
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass

- Free and total glycerin numbers measure the complete conversion of the fats and oils into FAMES. If these numbers are too high, the manufacturing process is inadequate and engine fouling will occur. **Never** use fuel that exceeds the free and total glycerin limit. Return the fuel to the fuel provider.
- Oxidative stability test methods are under development which will allow a customer to determine if the fuel will remain stable in storage over extended periods of time and to test fuels to determine if they have degraded during storage. ASTM PS 121 does not contain any test methods for stability at this time. High acid numbers coupled with high viscosity numbers indicate a degraded fuel.
- Cloud point does not have a limit, but should be reported to the customer. Cold filter plug point is a more accurate test of biodiesel's cold weather performance. If you are using a biodiesel blend, an accurate estimate of how the biodiesel will perform in the winter months will require mixing the biodiesel with the winter diesel typically delivered in your area and testing the mixture.
- Biodiesel generally contains less than 15 ppm sulfur and the test for low sulfur fuel (ASTM D 5453) should be used for accurate results instead of D 2622.
- Biodiesel requires the Cetane Number test because the Cetane Index test methods provide inaccurate results.
- The aromatics test for diesel fuel will provide inaccurate results for biodiesel. Biodiesel does not contain any aromatics.
- Biodiesel should be clear, although it may come in a variety of colors. Biodiesel color does not predict fuel quality.
- A milky layer of material on the bottom of a fuel tank can have several meanings. If the fuel was frozen or chilled, the layer may contain the saturated FAMES with high cloud points. If the material returns to a clear form after heating to 100°F, it is probably composed of biodiesel saturates. If the material remains milky or jelly-like at 100°F, it may be poorly

processed fuel residues, water, or other contaminants and the fuel shipment should be returned to the manufacturer.

Currently, you can test for biodiesel fuel quality before it is blended, but not after it is blended with diesel fuel. There is an experimental technique for testing B20 or other blends, but it does not detect free glycerin and thus cannot perform a complete ASTM PS 121 test. Once biodiesel is blended, it is very difficult to determine if it was a good quality fuel to begin with. Therefore, the person or organization that actually blends the biodiesel into the diesel fuel is responsible for ensuring that the biodiesel meets ASTM standards.

Biodiesel production is currently a batch process in the U.S. and fuel quality varies from batch to batch. Check the product specification sheet for batch number, production date, testing date, and other information. For marketers that are blending large biodiesel volumes, be proactive and test one gallon of fuel from each delivery, or at least save a gallon for future testing in case some customer concerns arise. Williams Laboratory Services in Kansas City is the only commercial laboratory with extensive field experience in testing biodiesel fuel quality. Marketers and blenders should be especially careful with new biodiesel producers or marketers, since their track record on fuel quality has yet to be established. The biodiesel industry is largely self-policing but not effectively so.

The biodiesel industry has developed a fuel certification program to ensure fuel quality throughout the production and distribution chain. At this time, the program has not been fully implemented and is voluntary. Firms that receive accreditation will have the highest assurance of fuel quality possible.

4 The “Right” Blend

Biodiesel can be used pure or mixed in any proportion with diesel #2 or diesel #1 (kerosene). The military has its own biodiesel specifications and guidelines, including blends with JP8. Military users need to use the guidelines adopted by their organization. These guidelines are for general use. Most customers use a 20% blend of biodiesel with 80% diesel fuel called B20 for a variety of reasons:

- B20 minimizes the impact of the biodiesel cost on the customer.
- Federal EPAAct guidelines require a minimum 20% blend, although higher blends are acceptable.
- A 20% blend keeps NO_x increases small (1-4%) and within the legal emission limits for engines.
- A 20% blend still gives good emission benefits by reducing soot, particulates, hydrocarbons, carbon monoxide, and carbon dioxide by more than 10% each.
- B20 does not create major problems with filter plugging and deposit formation that can result from the interaction between biodiesel and the accumulated sediments and sludge that form in diesel storage tanks. See the section on solvency for more details.
- B20 controls the increase in cloud and pour point by a manageable level that cold flow additives can control. See the section on cold weather issues for more details.
- Few material compatibility problems arise with B20. Higher blend levels will cause more

problems with rubber seals, gaskets, and hoses unless these have been replaced with biodiesel resistant materials. (See material compatibility.)

B20 is basically a trade off between cost, emissions, cold weather, material compatibility, and solvency issues. It is a good starting point for new users because B20 users rarely encounter problems. Users should be careful when moving from B20 to higher blends since the risk of encountering problems increase. These problems can be managed but you need to anticipate them and develop strategies for managing them. Higher blends have been used over extended periods of time and some commercial fleets are using B100.

Blends of 35%, 50%, and higher can provide significant emission reduction benefits for carbon monoxide, particulates, soot, and hydrocarbons (Table 5). Higher blend levels of biodiesel significantly reduce polycyclic aromatic hydrocarbons and other toxic or carcinogenic compounds found in diesel exhaust. Higher blend levels also provide significant reductions in greenhouse gas emissions and increase the renewable content of the fuel.

Table 5. Tailpipe Emission Changes with Biodiesel Fuels

Emission	B100*	B20**
Carbon Monoxide	-43.2%	-12.6%
Hydrocarbons	-56.3%	-11.0%
Particulates	-55.4%	-18.0%
Nitrogen oxides	+5.8%	+1.2%
Air toxics	-60% to -90%	-12% to -20%
Mutagenicity	-80% to -90%	-20%
Carbon dioxide***	-78.3%	-15.7%

*Average of data from 14 EPA FTP Heavy Duty Test Cycle tests, variety of stock engines

**Average of data from 14 EPA FTP Heavy Duty Cycle tests, variety of stock engines

***Life cycle emissions

One downside of higher blend levels is an increase in nitrogen oxides emissions (NOx). Biodiesels with high levels of polyunsaturates produce more NOx than biodiesels with high levels of saturates. The flip side to this issue is that fuels with high levels of polyunsaturates have good cold weather properties, and fuels with high levels of saturates have poor cold weather properties. Summer blends and winter blends may be one strategy for the customer, but this is not a standard practice for the biodiesel industry at this time. Research has identified one additive that provides a limited amount of control on NOx emissions. One percent DTBP (ditertiary butyl peroxide) by volume in B20 can make B20 NOx neutral with diesel fuel. The effect of five percent DTBP in B100 has different effects on different biodiesels. This problem may be resolved in the near future as other additives or solutions are identified.

Higher blends of biodiesel are popular with users in pristine or vulnerable environments, because they are biodegradable and reduce the toxicity of diesel fuel. B100 is used in commercial fleets, marine vessels, and in mining equipment. Extra precautions may be required to resolve solvency

concerns or to protect the customer from cold weather. Modifications may be required to replace materials with compatibility concerns. If customers want to use B100 or higher blends, the sections on solvency, cold weather, and material compatibility are mandatory reading.

5 Splash Blending

Biodiesel is slightly heavier than petroleum diesel. Biodiesel has a specific gravity of 0.88 compared to petroleum diesel at 0.85. Biodiesel should be splash blended on **top** of petroleum diesel, otherwise, the fuels may not mix properly. If you've made a mistake and added the biodiesel to the bottom of the tank and it did not mix with the petroleum diesel, you have several options:

- Find a way to agitate the fuels together,
- Pump the fuels out into a tank truck and then pump them back down together,
- You can ignore the problem if you are not worried about solvency, material compatibility, or cold weather, since biodiesel can be burned as a 100% pure fuel.

Biodiesel blends will not separate in the presence of water, however, for good housekeeping and tank/fuel maintenance, water in the storage systems should be monitored and minimized.

Biodiesel can be stored in standard diesel storage tanks. Copper, brass, zinc, lead, and tin parts should be replaced with aluminum or steel since these metals oxidize both diesel and biodiesel fuels. Please read the sections on cold weather storage issues and solvency before proceeding with B100 storage!

6 Cold Weather Blending and Storage

Like any diesel fuel, biodiesel can gel at low temperatures. Some types of biodiesel freeze at higher temperatures than others, depending on the level of saturated components in the fuel.

- Pure biodiesel should be stored at temperatures at least 15 degrees higher than the pour point of the fuel (30°F to 56°F). A storage temperature of 45°F to 50°F is fine for most B100.
- Blends of biodiesel and diesel should be stored at temperatures of at least 15 degrees above the pour point of the blended fuel.
- Pure biodiesel can be stored underground in most cold climates, but above ground fuel systems should be protected with insulation, agitation, heating systems, or other measures if freezing weather is common. This precaution includes tanks, pumping equipment, and the vehicles themselves.
- Blended fuels can be stored below ground in most climates. Above ground storage should consider special precautions if temperatures routinely fall below the pour point of the blended fuel.
- Biodiesel can be splash blended with no problems if the diesel fuel temperature is 50°F or higher. If biodiesel is blended with cold diesel fuel (fuel temperature is less than 45°F to 50°F), the saturated compounds in the biodiesel can crystallize and plug fuel filters and fuel lines. If crystals have already formed the solutions include:
 - See if they disappear as the fuel warms with ambient weather conditions

- Heat the fuel to above 100°F or until the crystals dissolve
- Filter the solid fuel crystals out. They can be reused when they melt.
- To prevent forming crystals, blend biodiesel with kerosene in a 50:50 mix first (make sure the temperature of the kerosene is above 45°F), then blend the biodiesel-kerosene mix into the cold diesel fuel. Do not forget to adjust your blending formula so that you end up with a 20% blend of biodiesel in the final fuel.
- Pure biodiesel is difficult to ship in cold weather. In the winter, most biodiesel is shipped one of three ways:
 - hot in tank cars for immediate delivery,
 - frozen in tank cars equipped with steam coils (the tank cars are melted at the final destination with steam),
 - in 20% blends with available winter diesel, or
 - in a 50% blend with diesel No. 1 (kerosene). A 50:50 blend of soy biodiesel and kerosene has a pour point of 0°F in most cases.
- Adjusting the blend of kerosene in the diesel fuel can modify the cloud and pour point temperatures of B20. Figure 1 shows the cloud and pour point for several different types of B100 and the impact on cloud and pour when B20 is produced from different diesel fuels. B20 with D2 is a blend of 20% biodiesel with 80% straight diesel No. 2. The other two B20 blends shown are blends of 20% biodiesel with 80% winterized diesel fuel. In one case the winterized diesel consists of 80% No. 2 and 20% No. 1 and in the other case the winterized diesel consists of 60% No. 2 and 40% No. 1. The cloud and pour points of the No. 2, No. 1, and the two winterized diesel fuels are also shown for comparison. The point of the chart is to show that you can produce a B20 fuel that has the desired cloud and pour points by adjusting the amount of No. 1 diesel in the diesel fraction of the mix.
- No. 1 diesel (kerosene) and pour point depressants have been used with good results in B20. Pour point depressants work on the diesel part of a biodiesel blend and can reduce the gel and cloud properties of blended fuels. No additives have been shown to be effective on B100.

B20 may be stored in above ground tanks, depending on the cloud and pour points of the blended fuel and the local ambient weather conditions. For example, a B20 blend made with No. 2 diesel will raise cloud point by 2 °F to 7°F. B20 made with No. 1 diesel will have a cloud point of -15°F to 0°F depending on the properties of the biodiesel fuel. There are no lubricity issues with kerosene and biodiesel blends. Since biodiesel is a lubricant, 1%-2% would be enough to lubricate kerosene.

User experience with cold weather varies. B20 blends are used in some very cold climates such as northern Minnesota and Wyoming where temperatures routinely fall below -40°F in the winter. B20 was used in an airport shuttle fleet for four years in Boston with no problems. Some users have reported using B100 in extremely cold climates such as in Yellowstone National Park. The vehicles were equipped with winterization packages and no other precautions were noted. Since widespread experience with B100 and higher blends in cold climates is lacking in the United States, users should be alert to potential problems and take reasonable steps to prevent them if possible. We can only conclude that laboratory tests appear to be more conservative than field experience.

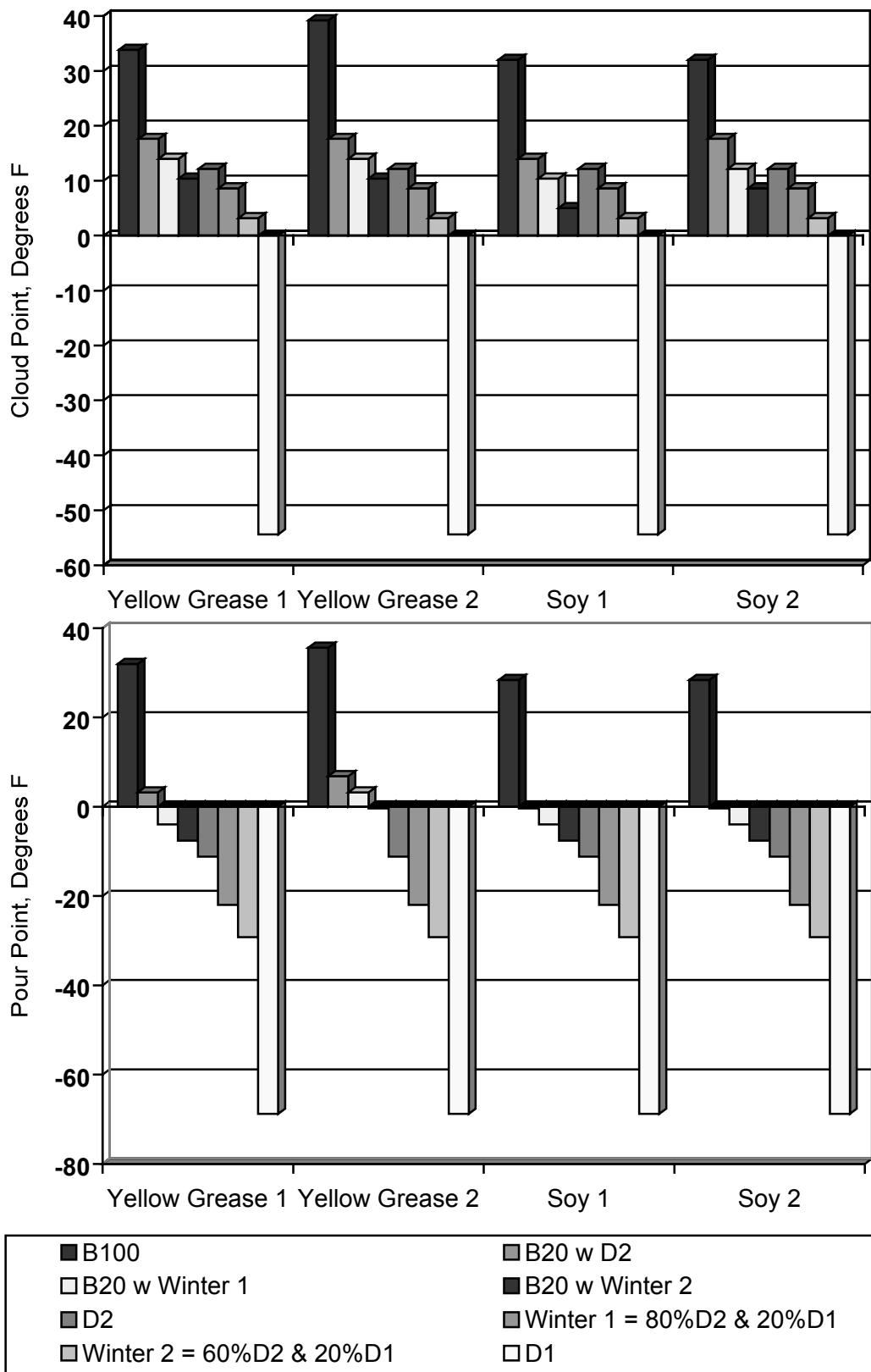


Figure 1. Cold Weather Properties of Biodiesel Fuels and Blends

7 Stability

Oxidative stability is a major industry issue for diesel and biodiesel fuels. Some biodiesels are more stable than others and some unstable biodiesel contain stability additives that perform very well (Table 6). The tendency of a fuel to be unstable can be predicted by the Iodine number (ASTM D 1510) but the test method may not pick up the presence of stability additives. Iodine number actually measures the presence of C=C bonds that are prone to oxidation. The general rule of thumb is that instability increases by a factor of 1 for every C=C bond on the fatty acid chain; thus, 18:3 are three times more reactive than C18:0. Stability can be predicted from knowledge of the feedstock only if you know the proportion of C18:2 and C18:3 fatty acids present in the fuel and know whether or not the fuel has been treated for stability. High fractions of those two types of fatty acids can adversely affect fuel stability if additives are not used. The accelerated stability test—ASTM D 2274—can provide an idea of whether the fuel stability is poor, average, or good.

Table 6 Modified ASTM D 2274*

<u>Biodiesel Fuel</u>	<u>Additives</u>	<u>Total Insolubles, Mg/L**</u>
Soy 1	No additive	13.60
Soy 2	No additive	14.32
Soy 1	Tenox 21	0.09
Soy 3	Tocopherol	1.87
Yellow grease 1	No additive	0.89
Yellow grease 2	No additive	12.37

*Data from Southwest Research Institute under contract to the National Renewable Energy Lab.

**High levels of insolubles indicate unstable fuels.

Poor stability can lead to increasingly high acid numbers, increasing viscosity, and the formation of gums and sediments that can clog filters. Comparing the fuel's acid number and viscosity over time can provide some idea about whether or not the fuel is oxidizing, but you need to take a sample at the beginning when the fuel is fresh and then sample on a regular basis after that.

Long-term storage in the presence of diesel fuel, diesel additives, water, sediments, heat, and air has not been adequately documented in the field. Biodiesel and blends of biodiesel and diesel fuel should not be stored for longer than 6 months in either storage tanks or vehicles until better field data is available. If it becomes necessary to store biodiesel longer than 6 months, or the storage conditions are poor, use antioxidants. The common antioxidants that work with biodiesel are TBHQ (t-butyl hydroquinone), Tenox 21, and tocopherol (Vitamin E). Most of these are sold by food additive firms. Powdered antioxidants are difficult to mix into biodiesel. A trick used is to heat a small amount of biodiesel (1 gal or so) up to 100°F or until all the powdered antioxidant is dissolved. Then mixed the treated biodiesel into the bulk biodiesel fuel.

Biocides are recommended wherever biological growth in the fuel has been a problem. If biological contamination is a problem, housekeeping needs to be improved and water contamination needs to be reduced, since the algae grows in the water and not in the fuel itself.

8 Solvency

Biodiesel is a mild solvent. On prolonged contact with painted surfaces, it may deface some paints. Always wipe up spills and dispose of rags in a safe manner. Biodiesel soaked rags can self-combust if not handled properly.

The most commonly encountered problem with solvency is biodiesel's tendency to "clean out" storage tanks, including the vehicle fuel tanks and systems. No. 2 diesel tends to form sediments that stick to and accumulate in storage systems, forming layers of sludge or slime in the fuel systems. The older the system, and the poorer the maintenance, the thicker the accumulated sediments become. Biodiesel will dissolve these sediments and carry the dissolved solids into the fuel systems of vehicles. Fuel filters will catch most of it, but in severe cases, the dissolved sediments have caused fuel injector failure.

Few problems have been encountered with B20 in typical diesel storage situations. The effect is very similar to switching from diesel No. 2 diesel to No. 1. The solvency effect of the biodiesel in B20 is sufficiently diluted so that most problems encountered are minor. These problems include an occasional plugged fuel filter. Drivers should be aware that sediments in the vehicle system may plug fuel filters during the first few weeks using B20 and that they should keep some extra filters in the glove box. Do not remove the fuel filter if it becomes plugged without replacing it.

When using B20, the problem typically goes away after the first few tanks of fuel. If the problem does not disappear, send the fuel filters to Williams Laboratory for analysis, since you may have a problem with biodiesel fuel quality or biological growth in the fuel.

The solvency problems occur most often when customers try to put higher blends or even pure biodiesel into aged and dirty systems that previously held No. 2 diesel fuel. If you do not clean out the diesel fuel storage tanks before using biodiesel blends of 30% or higher, there is a strong risk that excessive fuel filter plugging and fuel injector failure may occur. We recommend cleaning fuel storage tanks (remove water and accumulated sediments) before using higher blend levels or B100.

Consumers that did not encounter any problems with B20 assume they can switch to higher blends without any concern because they think the B20 already cleaned their tanks. B20 doesn't really clean the tanks, it's too diluted. Once again, tanks should be cleaned before switching to higher blend or B100 fuels.

If you have been using biodiesel for a while (3 months or more) and a sudden problem with plugged fuel filters arises, it is probably the result of a bad batch of biodiesel or a bad batch of diesel fuel. Notify the supplier immediately and retain a fuel sample and the filters for testing.

9 Material Compatibility

Brass, bronze, copper, lead, tin, and zinc will oxidize diesel and biodiesel fuels and create sediments. Lead solders and zinc linings should be avoided, as should copper pipes, brass regulators, and copper fittings. The fuel or the fittings will tend to change color and sediments may form, resulting in plugged fuel filters. Affected equipment should be replaced with stainless steel or aluminum. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, and Teflon. Table 7 has some information on specific materials.

Table 7. Material Compatibility with Biodiesel Fuels

<u>Material</u>	<u>BXX</u>	<u>Effect compared to diesel fuel</u>
Teflon	B100	Little change
Nylon 6/6	B100	Little change
Nitrile	B100	Hardness reduced 20%
	B100	Swell increased 18%
Viton A401-C	B100	Little change
Viton GFLT	B100	Little change
Fluorosilicon	B100	Little change in hardness
	B100	Swell increased 7%
Polyurethane	B100	Little change in hardness
	B100	Swell increased 6%
Polypropylene	B100	Hardness reduced 10%
	B100	Swell increased 8-15%
Polyvinyl	B100	Much Worse
	B50	Worse
	B40	Worse
	B30	Worse
	B20	Comparable
	B10	Comparable
Tygon	B100	Worse

The effect of B20 on vulnerable materials is diluted compared to higher blends. Some slow oxidation can occur, although it may take longer to materialize. Biodiesel also can affect some seals, gaskets, and adhesives, particularly those made before 1993 and those made from natural or nitrile rubber. It is primarily for these reasons that vehicle and storage equipment are modified. Most engines made after 1994 have been constructed with gaskets and seals that are generally biodiesel resistant. Earlier engine models or rebuilds may use older gasket and seal materials and present a risk of swelling, leaking, or failure. Fuel pumps may contain rubber valves that may fail. The typical approach is to create a maintenance schedule that checks for potential failures. Users can also contact engine manufacturers for more information.

10 Warrantees

The landscape is littered with different engine warrantees depending on the engine manufacturer. No consistency exists at this time. Caterpillar offers a B100 warrantee on most of their newer engines that is feedstock neutral if fuels meet either ASTM PS 121 or the CAT standards. Caterpillar has tested various types of biodiesel and examined the underlying chemistry of the fuels. John Deere offers B100 warrantees on some equipment. Other firms (Cummins, DDC, etc.) offer B20 warrantees that may or may not be feedstock specific. Feedstock specificity is based on a lack of information or a misunderstanding of biodiesel chemistry. In some cases, feedstock limitations are proxies for fuel properties that are not included in the ASTM PS 121 for biodiesel. Feedstock specifications may be an attempt to limit variations in fuel properties and thus, limit risks associated with using a new fuel. Biodiesel fuel properties vary just as much as diesel fuel properties, so some of this concern may be unnecessary. This issue will become less important as engine manufacturers improve their understanding of biodiesel chemistry and more data becomes available. Until then, the smart thing to do is to contact the engine manufacturer for information.

To further complicate matters, no engine warrantee covers fuels. Engines are warranted for materials and workmanship only, regardless of the fuels used, although they are designed to operate on diesel fuel that meets ASTM D 975. Most B20 and higher blends do not meet D 975.

Limits on engine warrantees are meant to discourage consumers from engaging in risky behaviors that may lead to engine damage. Thus, to some extent, the limitations on warrantees are moot. Nonetheless, in order to prevent misunderstandings, the warrantee limitations should always be considered before biodiesel fuels are implemented.

Damage caused by poorly processed biodiesel or biodiesel that does not meet ASTM standards will not be covered by the engine warrantee, but may be covered under general liability insurance carried by the biodiesel producer or broker. New users should make sure that their biodiesel suppliers provide general liability coverage.

11 Safety and Environmental Regulation

Composition Information: Biodiesel contains no hazardous materials. Biodiesel contains a variety of fatty acid methyl esters with carbon chain lengths varying between 12 and 22, where 18 carbon chains are the most common. Small quantities (less than 1%) of other materials may be present and should not exceed fuel quality standards.

Handling and Storage: Store in clean, dry, approved diesel equipment between 50° F and 120°F. Keep away from oxidizing agents, excessive heat, and ignition sources. Store and use in well-ventilated areas. Do not store or use near heat, spark, or flame. Store out of the sun. Do not puncture, drag, or slide drums or totes. Drum and totes are not pressure vessels; never use pressure to empty.

Inhalation: Negligible danger unless heated to produce vapors. Vapors or finely misted

materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. If this occurs remove to fresh air. If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

Eye Contact: May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist. Safety glasses, goggles, or face shield are recommended to protect eyes from mists or splashing.

Acute Oral Toxicity/Rates: Biodiesel is nontoxic and there are no hazards anticipated from ingestion incidental to industrial exposure. If ingested, give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.) Effects are similar to those associated with laxatives. The acute oral LD50 (lethal dose) is greater than 17.4 g/Kg body weight. By comparison, table salt (NaCL) is nearly 10 times more toxic.

Skin Irritation – Humans: A 24-hr. human patch test indicated that undiluted biodiesel produced very mild irritation. The irritation was less than the result produced by a 4 percent soap and water solution. Wash with soap and water. Avoid contact with hot fuel as it may cause burns. PVC coated gloves are recommended to prevent skin contact. May soften skin.

Aquatic Toxicity: A 96-hr. lethal concentration of biodiesel for bluegills was greater than 1000 mg/L. Lethal concentrations at these levels are generally deemed "insignificant" according to NIOSH (National Institute for Occupational Safety and Health) guidelines in its *Registry of the Toxic Effects of Chemical Substances*.

Biodegradability: Biodiesel degrades about four times faster than petroleum diesel. Within 28 days, pure biodiesel degrades 85% to 88% in water. Dextrose (a test sugar used as the positive control when testing biodegradability) degraded at the same rate. Blending biodiesel with diesel fuel accelerates its biodegradability. For example, blends of 20% biodiesel and 80% diesel fuel degrade twice as fast as #2 diesel alone.

Flash Point: The flash point of a fuel is defined as the temperature at which it will ignite when exposed to a spark or flame. Biodiesel's flash point is over 150°F, well above petroleum based diesel fuel's flash point of around 125° Fahrenheit. Testing has shown the flash point of biodiesel blends increases as the percentage of biodiesel increases. Therefore, biodiesel and blends of biodiesel with petroleum diesel are safer to store, handle, and use than conventional diesel fuel.

Fire Fighting Measures: Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor. Combustion produces carbon monoxide and carbon dioxide along with thick smoke. Fires may be extinguished with dry chemical, foam, halon, CO₂, or water spray (fog). Use water spray to cool drums exposed to heat or flames. (Caution-Water stream may splash the burning liquid and spread fire.) Oil soaked rags can cause spontaneous combustion if not handled properly. Before disposal, wash rags with soap and water and dry in well ventilated area.

Accidental Release/Spills: Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels, "Oil Dry," sand, or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

Regulatory:

UN HAZARD CLASS: N/A

NMFC (National Motor Freight Classification):

PROPER SHIPPING NAME: Fatty acid ester

IDENTIFICATION NUMBER: 144920

SHIPPING CLASSIFICATION: 65

OSHA: This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in fire fighting section.

TSCA: This product is listed on TSCA.

CERCLA: (Comprehensive Response Compensation and Liability Act). NOT reportable.

SARA TITLE III: (Superfund Amendments and Reauthorization Act), Section 312 Extremely Hazardous Substances, None. Section 311/312 Hazard Categories, Non-hazardous under Section 311/312. Section 313 Toxic Chemicals, None.

RCRA: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal whether a material containing the product or derived from the product should be classified as a hazardous waste (40 CFR 261.20-24).

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California Safe Drinking Water and Toxic Enforcement Act of 1986. This product contains no chemicals known to the state of California to cause cancer.

12 Taxes

At this time, biodiesel is not exempt from federal excise taxes and it is not exempt from most state or local taxes. That means that biodiesel and biodiesel blends are taxed at the same rate as diesel fuel and the taxes are handled in the same manner. Some states have passed legislation that either reduces fuel excise taxes or provides other incentives. For local exceptions to this statement, please contact the local tax authorities.

13 Incentives

At the present, there are no national financial incentives such as excise tax credits or government subsidies for purchasing biodiesel. Some states or local communities may offer incentives for

specific blends or for special groups of users. Please check with the local energy office or other transportation agencies for up to date information for your state and city.

The City of Cincinnati qualified for a grant from the Dept. of Transportation Congestion Mitigation and Air Quality Program in 2000 that paid the difference between the cost of biodiesel and the cost of diesel fuel. These grants are available to other communities through the Clean Cities Program. For more information contact the Clean Cities Hotline at 1-800-CCITIES (1-800-224-8437).

The Energy Policy Act of 1992 (EPAct) provides an indirect incentive program to federal and state fleets which may be applied to municipal fleets and large commercial fleets in the near future. The EPAct regulation requires federal and state fleets to purchase alternative fueled vehicles. The regulation sets the requirements for a percentage of each year's purchases, so that some fraction of that year's vehicle purchases must be able to run on alternative fuels. Unfortunately, the government is not willing to claim that all diesel vehicles are alternative fueled vehicles just because biodiesel can be used in all existing diesel vehicles. Therefore, a special exemption was created for biodiesel. The government will give the fleet an "alternative vehicle credit" (a paper credit, not a financial credit) to a qualified customer (federal or state governments and some utilities) that purchases 450 gallons of pure biodiesel and uses it in a blend of at least 20% (B20) in a heavy-duty vehicle with a gross weight of 8,500 pounds or more. There is no requirement to use B20 year round. For multiple credits, multiple purchases of 450 gallons of B100 are all that is required, and they can be burned in one or more vehicles as long as the mixture used exceeds 20%. Most federal and state fleets have started to shift a large part of their heavy-duty fleets to biodiesel on a regular basis. Some fleets in northern climates limit purchases in winter months, but resume again in the spring and use B20 throughout the spring, summer, and fall months. For more information on EPACT, contact the Lee Slezak, U.S. Department of Energy, (202) 586-2335.

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