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Biodiesel Distillation Temperature, Cetane Number, and Viscosity vs. Fatty Acid Profile

Synopsis:

Finished biodiesel intended for retail must meet certain quality criteria. These are specified under the American Society for Testing and Materials ASTM D 6751, the technical standard for biodiesel. Several quality tests are required under ASTM D 6751 (version 12 as of this printing) to ensure that biodiesel used at 100% strength, or blended with petroleum-based diesel, remains a consistent, high quality alternative fuel and can run in unmodified diesel engines without problems.

In this Biodiesel TechNote, we discuss three particular ASTM quality standards: the distillation temperature of biodiesel, its cetane number, and its measurement of viscosity. Our testing demonstrates that certain feedstocks with long chain fatty acids are destined to fail these standards, regardless of steps taken by the producer.

As biodiesel becomes a more widely used fuel, supplies of feedstock oils and fats are becoming harder to find. Oils that might not have been considered for use as fuels are getting serious attention. Some of these oils contain fatty acid profiles that are different from the common oils like soybean oil or canola oil. Oils such as mustard oil, industrial rapeseed oil, and camelina contain fatty acids with chain lengths that are longer than those found in other oils. Common oils have fatty acid chain lengths that are usually 16 to 18 carbons long. These other oils contain substantial amounts of fatty acids with 20, 22 or even 24 carbons. These longer chains can have a dramatic effect on biodiesel properties although we have no indication they do not produce high quality fuels. However, because they were not envisioned as biodiesel feedstocks when the specifications were developed, they may not comply with some of the requirements of the ASTM D 6751 specification for biodiesel (or the European specification EN14214). The specifications of greatest concern with longer chain fatty acids are the T-90 temperature, the cetane number, and the viscosity. Some of these oils, such as camelina, also have high levels of polyunsaturates which can lower the cetane number, a key indicator of diesel fuel quality.

Distillation Temperature (ASTM D 1160)

The biodiesel specification for the vacuum distillation procedure is described in ASTM D 1160. The biodiesel specification, ASTM D 6751, specifies 360°C as the maximum T-90 temperature; the temperature at which 90% of a 200 ml sample has been distilled. This test was developed to determine the distillation characteristics of petroleum products and was chosen by ASTM to be included in the biodiesel specification. A sample is distilled under vacuum and the temperature at which each 10% increment has been distilled is noted until 90% of the sample is boiled off and condensed (see Table 1). Thus, a distillation curve or boiling range is produced. This boiling range is directly related to viscosity, vapor pressure, heating value, average molecular weight, as well as other chemical, physical, and mechanical properties.

Vacuum distillation apparatus

Viscosity (ASTM D 445)

Kinematic viscosity is measured at 40°C using the procedure described in ASTM D 445. The ASTM biodiesel specification sets an acceptable range of between 1.9 and 6.0 mm^2/sec for the viscosity. EN14214 stipulates an upper limit for the viscosity of 5.0 mm^2/sec. Like the T-90 temperature, this property is

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www.BiodieselEducation.org biodiesel@uidaho.edu 208-885-7626

directly related to the fatty acid profile of the oil or fat used to make the biodiesel and can also be influenced by the alcohol used.

Cetane Number (ASTM D 613)

Cetane Number is measured using ASTM D 613. The ASTM specification D 6751 requires a minimum of 47 and EN14214 requires a minimum of 51. Both of these specifications set much higher limits than the minimum level of 40 required for No. 2 diesel fuel in ASTM D 975.

Results

Thirteen samples were tested for cetane number, distillation temperature, viscosity, and fatty acid profile (see Tables 1 and 2). Notice that five of the various oils were made into fuel using both methanol and ethanol.

Table 1. Cetane Number, T-90, & Viscosity of Biodiesel

	Cetane	T-90	Viscosity
Sample		°C	mm^2/s
Rapeseed Methyl Esters	60.1	399	5.60
Rapeseed Ethyl Esters	61.0	419	6.13
Mustard Methyl Esters - PG	49.8	392	5.04
Mustard Ethyl Esters - IG	58.1	403	5.70
Canola Methyl Esters - Distilled	50.1	351	4.79
Canola Methyl Esters - RBD	56.2	359	4.57
Canola Ethyl Esters - RBD	59.8	364	4.80
Soy Methyl Esters - RBD	51.8	355	4.18
Soy Ethyl Esters - RBD	51.5	361	4.44
Camelina Methyl Esters	48.9	368	4.34
Camelina Ethyl Esters	52.8	379	5.02
Palm Methyl Esters	63.0	348	4.24
Coconut Methyl Esters	63.7	337	2.81

Notes:

PG-Pacific Gold and IG-Ida Gold are mustard varieties developed at the University of Idaho.

RBD-Refined, bleached, deodorized.

Table 2. Fatty Acid Profile

FATTY ACID	16:0	18:0	18:1	18:2	18:3	20:1	22:1	24:0
Rapeseed	2.7	1.0	14.2	11.7	7.3	7.3	48.4	1.2
Mustard - PG	2.8	1.4	17.5	20.5	12.8	12.0	24.9	1.8
Mustard - IG	2.8	1.1	27.8	10.45	9.15	9.6	32.75	
Canola	4.0	1.9	61.9	19.3	9.3	1.2		
Soy	10.2	4.2	21.7	53.1	7.0			
Camelina	6.1	2.9	18.2	24.8	24.3	12.8	2.6	
Palm	41.1	5.3	40.3	10.8				
Coconut*	10.9	3.2	7.8	1.4				

**Coconut oil contains over 70% fatty acid chain lengths from 8 to 14 carbons, including 6.7% of 8:0, 5.4% of 10:0, 44.8% of 12:0 and 19.1% of 14:0.*

Discussion

Table 1 shows the measured values of cetane number, T-90 temperature, and viscosity for the 13 fuels. It can be seen from these tables that fuels made with feedstocks containing a high percentage of long chain fatty acids may not meet the specification for T-90 temperature and viscosity. For example, rapeseed, mustard, and camelina methyl esters have T-90 temperatures above 360°C. All of the methyl esters met the 6.0 mm^2/sec viscosity requirement of ASTM D 6751, but rapeseed and mustard methyl esters do not meet the lower viscosity requirement of 5.0 mm^2/sec in the European specification EN14214. It can be seen that biodiesel made with ethanol (it being a heavier molecule than methanol) is consistently more viscous and has a higher T-90 temperature than the methyl esters. All of the ethyl esters tested did not meet the T-90 specification, and rapeseed ethyl ester had a viscosity that exceeded the limit of 6.0 mm^2/sec. All of the fuels tested met the ASTM specification of 47 for the cetane number, although camelina methyl ester at 48.9 was within the test-to-test variability of the method. Three of the fuels failed the higher standard of 51 in EN14214.

So what can be done to rectify the situation? Short of lobbying all stakeholders, including ASTM, to change the standards; blending with lower molecular weight oils or fats may be the easiest way to overcome this obstacle.

Contributor to this TechNote: Dr. Joe Thompson, biodiesel production specialist at the University of Idaho Biological and Agricultural Engineering Department.

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