Low Temperature Storage Test Phase 2 - Identification of Problem Species

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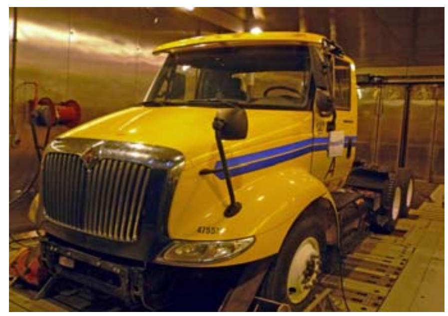

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SUMMARY

The use of renewable fuels, such as biodiesel, in motor vehicle fuels is expected to grow rapidly in North America as a result of government mandates, both federal and state/provincial. Biodiesel is a fuel component made from plant or animal feedstocks through an esterification process. The resulting fatty acid methyl esters (FAME) have a large variation in cloud point from -5° C to +15° C, depending upon the source. In Canada where a large geographic area experiences a cold climate, the poor low temperature properties of FAME and blends containing same (wax, gelling, and phase separation above the Cloud Point) must be well understood to avoid operability issues. The need for this understanding is underscored by reports of field issues that have occurred in the United States and Europe. Investigations of these issues have implicated saturated mono-glycerides (SMG) as the cause of filter plugging.

To gain a better understanding of the saturated mono-glyceride issue, the low temperature storage stability of fifty seven bio-diesel fuels comprising essentially B5 and B20 made with canola, soybean, tallow and palm methyl esters was examined. The laboratory program was designed to address the phase separation of the FAME impurities above the cloud point of the blended fuel. The storage stability was assessed using the filter blocking tendency test (ASTM D2068-08). The deposits from selected B20 blends were analyzed by Gas Chromatography/ Mass Spectrometry (GC-MS) to identify the problem species.

The study showed that precipitates form in the fuel after ten days of storage at 2 - 4 °C above its Cloud Point or at 1°C. Analysis of the selected precipitates by gas GC/MS show them to be enriched in SMG content. The filter blocking tendency (FBT) test was found to correlate fairly well ($R^2 = 0.71$) with the SMG content of the fuel. The correlation can be used to indicate the level of SMG in the renewable diesel that would result in a FBT value of <1.4 similar to conventional diesel fuels. Additional work to improve the correlation between SMG and FBT as well as a fundamental study of the kinetics of SMG precipitation and re-dissolution, including the impact of base fuel aromatic content, would be very valuable.

The results of this study further confirm the previous reports in the literature regarding the deleterious impact of saturated mono-glycerides in FAME on the low temperature operability of filters in fuel handling systems. This is a very important consideration when formulating renewable diesel fuels for a Canadian climate. The information generated by this study may be used to direct future renewable diesel blending formulations (e.g. seasonal bio-diesel for winter per current practice) and by standard-setting bodies to set specifications that will ensure "fit for service" fuel products.

1. INTRODUCTION

The use of renewable fuels, such as biodiesel, in motor vehicle fuels is expected to grow rapidly in North America as a result of government mandates, both federal and state/provincial. Biodiesel is a fuel component made from plant or animal feedstocks through a trans-esterification process. The resulting fatty acid methyl esters (FAME) have a large variation in cloud point from -5° C to +15° C, depending upon the source. In Canada where a large geographic area experiences a cold climate, the poor low temperature performance of FAME and blends containing same (wax, gelling, and phase separation above the Cloud Point) must be well understood to avoid operability issues. The need for this understanding is underscored by reports of field issues that have occurred in the United States and Europe.

Unexpected filter plugging issues occurred in vehicles and dispensing filters during the winter of 2005 - 2006 in Minnesota (1-3). The filter plugging was attributed by several sources to biodiesel that exceeded the <0.24 wt% total glycerin limit of the ASTM D6571 standard (4). Analysis of the plugged filters identified "...a preponderance of saturated monoglycerides in the organic component."(2). In response to these problems, a cold soak filtration test consisting of chilling the B100 bio-diesel to 4.4°C for 16 hours and then allowing warming up to room temperature prior to filtering was developed and incorporated into the ASTM D6751-08 Standard. Biodiesel produced to the new standard achieved a dramatic reduction in filter plugging issues during the winter of 2006 - 2007. However, Flint Hill Resources reported the plugging of dispensing filters at -18°C caused by B2.5 soybean methyl ester (SME) in December 2006 (1). Analysis of the material on the filters showed a substantial elevation of the saturated monoglycerides monopalmatin and monostearin.

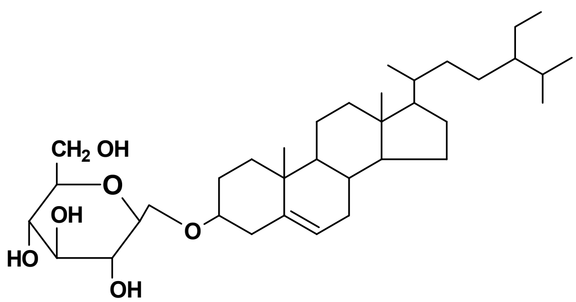
During the winter of 2007 Sweden experienced cold temperatures for long periods of time which resulted in filter blocking in vehicles and precipitates in customer above ground tanks at temperatures above the cloud point of the fuel (5). Analyses of the precipitated material showed it to be saturated monoglycerides. B5 blends had been introduced into the market in the summer of 2006. B2 had been successfully used in the Swedish market. Lab tests showed that the solubility of saturated monoglycerides in Swedish diesel to be low (i.e < 50 ppm @ 4°C). The monoglyceride specification was reduced to 0.3 wt% in Sweden versus 0.8 wt% in EN 14214.

Filter plugging operability issues (3/day/service station) were reported in France during the winter of 2008 - 2009 (6). The first episode was attributed to the fuel not meeting the EN590 specification. During the second episode all fuels tested met EN590 specs. The fuel filters were found to contain high levels of saturated monoglycerides. The authors pointed out that once formed, the saturated monoglyceride crystals do not re-dissolve in the fuel. They also pointed out that tests such as CFPP will not detect the problem due to the fast cooling rate used and that a cold filterability or other test methods need to be developed to address the issue.

There have also been several research studies in this area. Infineum has also reported precipitation of saturated monoglycerides, above the cloud point, in Bxx biodiesel fuels. This was demonstrated by saturated monoglycerides (SMG) add-back experiments using IP 387 filter blocking tendency test method (7). Cosmo Oil Ltd examined the low temperature storage [laboratory as well as All Weather Chassis Dynamometer (AWCD) testing] of biodiesel fuel blends

(8). Their study showed that B5 palm methyl ester (PME) stored at 10°C produced crystals of C_{14} to C_{18} saturated monoglycerides.

The properties of the various individual fatty acid methyl esters that comprise bio-diesel determine the overall fuel properties of the bio-diesel fuel. Structural features that influence the physical and fuel properties of the fatty acid methyl ester molecule are mainly the chain length and the degree of unsaturation of the chain. While the cold flow properties of the fatty acid methyl esters are governed by the unsaturation of the chain, the presence of impurities consisting mainly of sterol glucosides (I) and monoglycerides (II) have been found to have significant impact on the low temperature storage stability and filter blocking tendency.



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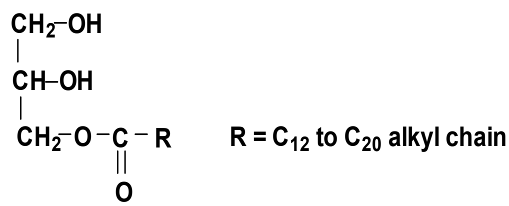


II

Due to their high melting point (240°C) and insolubility in bio-diesel, the presence of these sterol glucosides in the bio-diesel could contribute to filterability problems. The impact of sterol glucosides on filter plugging has been investigated by ADM (9). Using the Filter Blocking Tendency (FBT) test ASTM D2068 it was determined that 32ppm of sterol glucoside dissolved in SME can cause a FBT failure (FBT = 1.47).The filterability problems due to sterol glucosides can be overcome by ensuring that the B100 bio-diesel has a cold soak filtration time of 200 seconds maximum for operability temperature below -12°C. Sterol glucosides have been found particularly abundant in soybean oil.

To gain a better understanding of the saturated mono-glyceride issue, the low temperature storage stability of fifty seven bio-diesel fuels comprising essentially B5 and B20 made with canola methyl ester (CME), SME, tallow methyl ester (TME) and PME was examined. The laboratory program was designed to address the phase separation of the FAME impurities above the cloud point of the fuel. The storage stability was assessed using the filter blocking tendency (FBT) test ASTM D2068-08 (10). The deposits from selected B20 blends were analyzed by a modified ASTM 6584 Gas Chromatography method which included detection and speciation by Mass Spectrometry (GC-MS) to identify the problem species.

Note that the NRDDI program funded the "Low Temperature Storage Test: Phase II - Identification of problem species" project. This report includes results from Phase I- Stability Testing of the Low Temperature Storage Test project to provide context for the Phase II results.

2. EXPERIMENTAL

2.1 Properties of the Petroleum Base Fuels

Six Canadian commercial ultra low sulphur diesel fuels having low cloud points (ULSD-Cloud Point ,°C) which represent typical winter fuels were selected for this study: a ULSD-46, a ULSD-45, a ULSD-29, a ULSD-29 (-29.4°C) referred as ULSD-29B, and a ULSD-48 obtained from Imperial Oil refineries. A ULSD-25 containing zero aromatics was obtained from another Canadian refiner. This diesel fuel is produced by severe hydro-processing and is sold commercially, neat or co-mingled with other diesel fuels. These petroleum diesel fuels were used as blend stock for the preparation of laboratory bio-diesel fuel blends. The diesel fuels did not contain any flow improver but some contained cetane improver and Stadis 450 conductivity improver. The aromatic content of these fuels ranges from 0 to 42.7%. The properties of the diesel fuels are presented in Table 1. All the fuels met the CAN/CGSB-3.517 Standard.

2.2 Properties of the Fatty Acid Methyl Esters (FAME)

Four typical FAME or B100 bio-diesels consisting of CME, SME, TME and PME were selected for this study. FAME samples were acquired from two different suppliers to get some insight into source variability. The PME could only be acquired from one supplier. In the case of the CME, a blend of two CME's (80vol%: 20vol%) having a low (100 sec.) and a high (>720 sec.) cold soak filtration time was made to produce a CME having a cold soak filtration time between 200 and 360 seconds. This blend has been referred as CME2 in this study. The properties of the FAME taken from the C's of A (Appendices 1 to 7) are presented in Table 2. The cold soak filtration was determined by IOL using the test method described in ASTM D6751-08, Annex 1 (4). All the biodiesel samples met the ASTM D6751 standard except the PME, and the second CME, which had cold soak filtration times >720 seconds.

2.3 Low Temperature Storage Stability of the Bio-Diesel Fuels

The fifty seven bio-diesel fuels were blended and used for the low temperature storage stability study. The B0 fuels which did not contain FAME were used as a reference. A first set of fuel samples were stored in a 500 ml clear glass bottle at 2-4°C above their cloud point for a period of 10 days. Visual examination was made after 1, 2, 5 and 10 days. After that period, the fuels were allowed to warm-up to ambient temperature (20-24°C), and homogenized by swirling the bottle prior to the determination of the FBT by ASTM D2068-08 test method (8). A second set of fuel samples were stored in a 500 mL clear glass bottle at 1°C for a period of 10 days using the same procedure as above. The low temperature storage stability test protocol is summarized in the Appendix 8. The low temperature storage stability results are presented in Tables 3 to 6. The results of the visual examination of the samples are tabulated in Appendix 9.

The haze and/or precipitate in the fuel at test temperature start to appear after the first few days (Appendix 9). Wax crystals were observed in B0 fuels when stored at 2 to 4°C above the cloud point. For the majority of the fuels, the visible haze and/or precipitate disappeared upon warming up to ambient temperature indicating an association with water and/or wax that re-solublizes. The FBT test was found to be a good tool to discriminate between "good" and "bad" fuels. The cloud point did not predict the temperature at which phase separation occurred. Considering that the repeatability of the FBT test of is 0.277 (FBT-1), similar filter blocking tendency results were obtained from storage temperature at 2 to 4°C above the cloud point and at 1°C (Tables 3 - 6). The storage stability results at 2 to 4°C above cloud point will be used in the following sections to discuss the effect of various variables on filter blocking tendency.

3. RESULTS AND DISCUSSION

3.1 Analysis of the precipitate from selected B20 fuel blends

Three B20 bio-diesel fuels (Test Fuels # 29, 34 and 25) containing SME, TME and PME respectively and showing a precipitate at the bottom of the glass bottle after storage at 2-4°C above cloud point for 10 days, were selected for analysis. The B20 CME fuels did not show any significant precipitate for analysis. The clear portion of the fuel was decanted and the enriched fuel/ precipitate fraction was filtered through a 0.45µm Sep-Pak filter, flushed with a stream of nitrogen and sent to for analysis. The samples were analyzed by gas chromatography according to ASTM D6584 test procedure which involves derivatization with a silylating agent N-methyl-N-trimethylsilyltrifluoroacetamide (MSTFA). The peaks were identified by using a mass spectrometer. The spectra are shown in Figures 1 - 3 and confirm that the precipitates causing the filter plugging were significantly enriched in SMG (Note that the spectra for the precipitates from B20 SME and PME contain residual fuel). The monoglycerides present in the precipitates were identified as 1-monopalmitin, 2-monopalmitin, 1-monostearin and 2-monostearin. The unsaturated monoglycerides such as 1-monoolein and 1-palmitolein, which have high concentrations in the base B100, were not detected which confirmed that unsaturated monoglycerides in bio-diesel fuels remain dissolved in the fuel.

Figure 1
GC/MS Spectra of Precipitate from Test Fuel # 29 - B20 SME

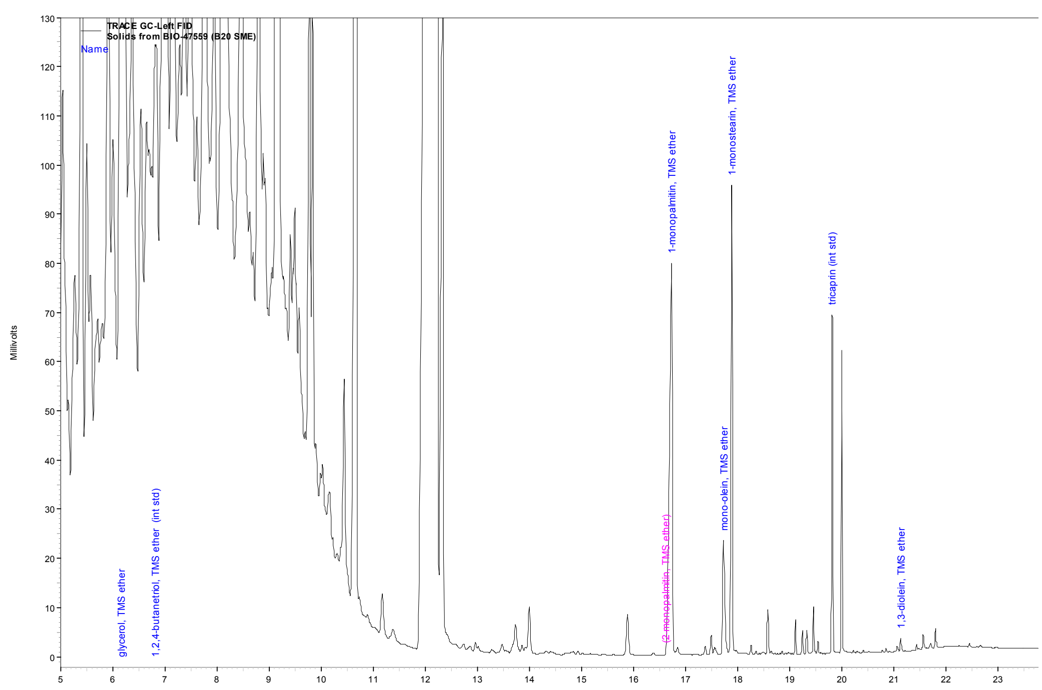


Figure 2
GC/MS Spectra of Precipitate from Test Fuel # 25 - B20 PME

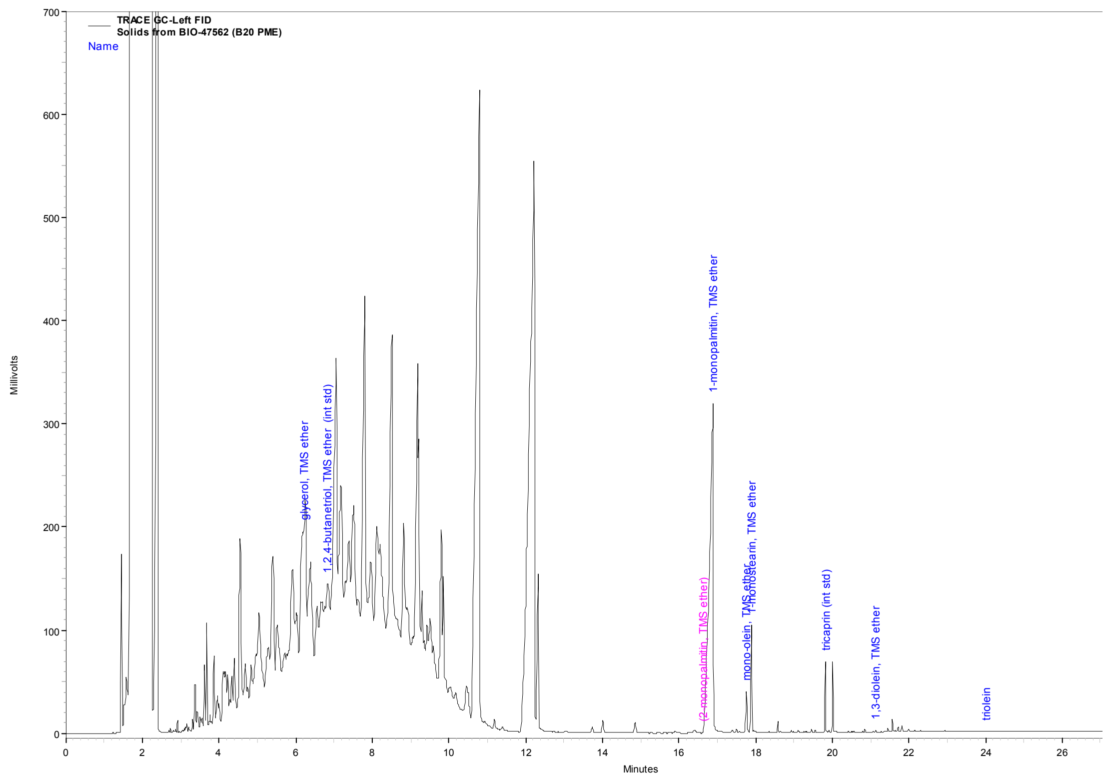
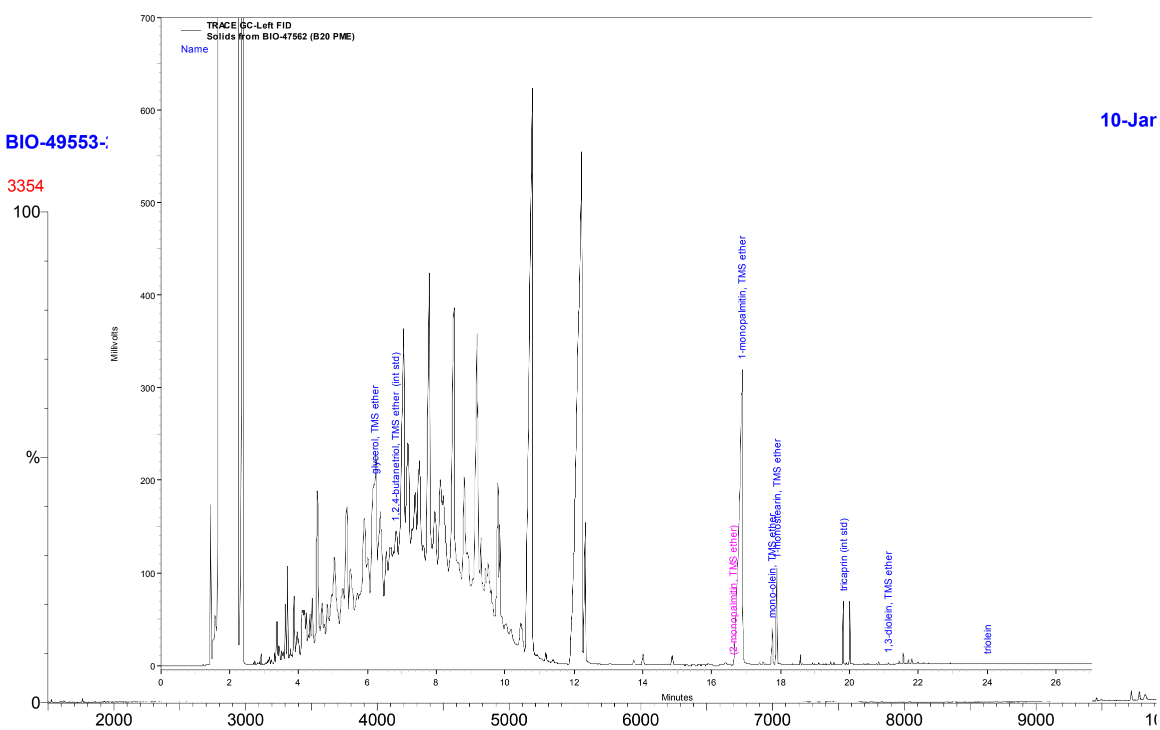


Figure 3
GC/MS Spectra of Precipitate from Test Fuel # 34 - B20 TME



3.2 Quantification of the Saturated Monoglycerides in the FAME

The above results combined with those reported from the literature (1, 5, 6) confirmed that the saturated monoglycerides can cause filter plugging issues. In view of defining a specification limit of the saturated monoglycerides in the FAME and establishing a correlation between the FBT and saturated monoglycerides, the quantification of the monoglycerides in the FAME used in this study was required. The analysis was performed according to the ASTM D6584 test procedure with peak identification using a mass spectrometer. The following table provides a complete compositional analysis of the FAME. The unsaturated monoglycerides were obtained from the difference between the total monoglycerides and the saturated monoglycerides.

Supplier			A	C	D	F
	Carbon	m.p.	CME	SME	TME	PME
FAME	Chain	°C	wt%	wt%	wt%	wt%
methyl caprate	C10:0	-13	0.1	0	0.1	0
methyl laurate	C12:0	4	0	0	0.1	0.3
methyl myristate	C14:0	19	0	0.1	2.1	1.0
methyl myristoleate	C14:1	-52	0	0	0.3	0.0
methyl palmitate	C16:0	32	3.8	10.8	23.8	40.0
methyl palmitoleate	C16:1	-34	0.2	0.2	3.3	0.2
methyl stearate	C18:0	39	1.7	4.5	14.8	4.1
methyl oleate	C18:1	-20	56.2	20.2	37.1	39.7
methyl elaidate	C18:1	-20	3.4	1.7	3.1	1.8
methyl linoleate	C18:2	-35	18.5	51.3	7.9	10.6
methyl γ-linolenate	C18:3	-52	8.0	7.4	0.6	0.2
methyl α-linolenate	C18:3	-52	0.8	0.2	0.1	0.2
methyl arachidate	C20:0	46	1.3	0.1	0.3	0.1
methyl behenate	C22:0	55	0.3	0.1	0	0
others	-	-	2.2	0.1	3.4	0.4
Total, wt%			96.5	96.7	97.0	98.6
Monoglycerides			mg/kg	mg/kg	mg/kg	mg/kg
1-monopalmitin	C16:0	71	109	596	649	1682
2-monopalmitin	C16:0	-	21	83	64	154
1-monostearin	C18:0	81	106	261	250	183
Total Sat. Monoglycerides		-	236	940	963	2019
Unsat. Monoglycerides		-	2593	4663	1095	2501
Total Monoglycerides		-	2829	5603	2058	4520
Sat. Monoglycerides, wt%			8.34	16.78	46.80	44.67

The results show that the CME contains the least (8.34wt% of total monoglycerides) saturated monoglycerides. Although the TME contained only 2058 mg/kg total monoglycerides, 46.8wt% are saturated monoglycerides. The amount of saturated monoglycerides in these FAME samples is in the following order.

CME < SME ~ TME < PME

Low ⟶ High

It is interesting to note that the percentage of the saturate monoglycerides to the total monoglycerides is almost proportional to the percentage of the methyl palmitate and methyl stearate, in the FAME, from which they are derived. These numbers are highlighted in blue. One should bear in mind that the level of saturated monoglycerides in the FAME can vary from one supplier to another and from one batch to another. These variations in composition are due to the manufacturing processes used as well as the geographic source of the feedstock.

Additional CME (Supplier B), SME (Supplier B) and TME (Supplier E) samples obtained were analyzed for the saturated monoglycerides content. The monoglycerides compositions are highlighted in the following table.

FAME	Supplier	CSFT, sec	MG, mg/kg	SMG, mg/kg	SMG/MG,%
CME	A	100	2829	236	8.3
CME	B	> 720	5669	658	11.6
SME	C	96	5603	940	16.8
SME	B	180	6504	1370	21.0
TME	D	111	2058	963	46.8
TME	E	114	606	277	45.7
PME	F	> 720	4520	2019	44.7

The table shows that the level of saturated and unsaturated monoglycerides can vary widely from FAME to FAME. It is interesting to note that the ratio of SMG to MG is somewhat similar. The TME from supplier E contained significantly lower saturated monoglycerides than that from supplier D. The lower saturated monoglycerides content is explained by the distillation method used in the production of the TME by supplier E and suggests a method to remove/reduce the level of saturated monoglycerides in the FAME.

3.3 Effect of the Saturated Monoglycerides on Filter Blocking Tendency

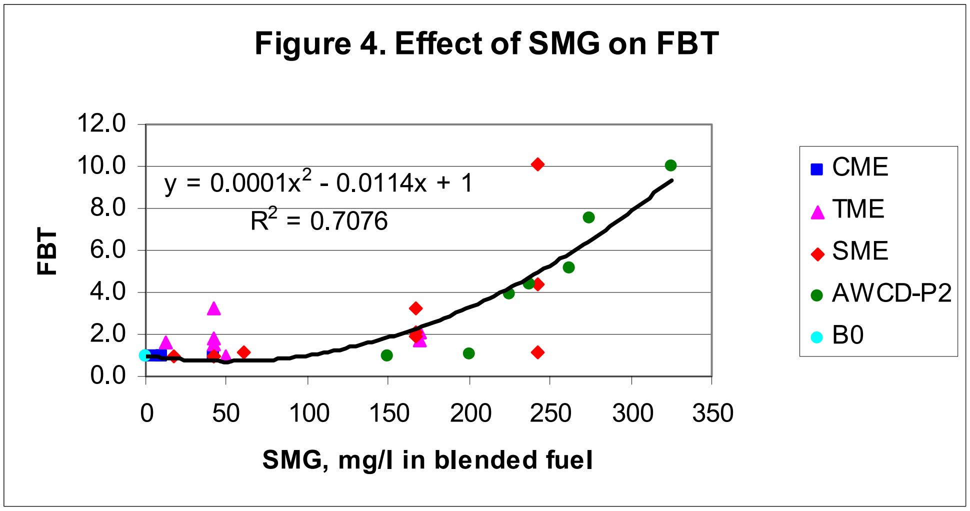
The amount of saturated monoglycerides in the bio-diesel fuel blends was calculated by using the following formula:

$$SMG_{mg/L} = FAME_{vol\%} \text{ x } d_{FAME} \text{ x } SMG_{mg/kg} \quad \text{Equation 1}$$

Where

$SMG_{mg/L}$ = SMG in the fuel
d_{FAME} = density of the FAME (Table 2)
$SMG_{mg/kg}$ = SMG in the FAME
$FAME_{vol\%}$ = volume percent of FAME in the fuel

The amount of saturated monoglycerides in the bio-diesel fuel blends is presented in Table 7. Figure 4 shows that the FBT correlates fairly well ($R^2 = 0.71$) with the level of SMG in the fuel. The bio-diesel fuel blends containing CME2 was not used in the correlation as the cold soak filtration time for one its components had a CSFT > 720 seconds. Similarly, the PME data was not used. The bio-diesel fuel blends using the ULSD-25 (0% aromatics) was also not used in the correlation as the absence of the aromatics in the fuel gave significantly higher FBT for the TME blends. The effect of fuel type on the filter blocking tendency is discussed later in this section. The data (AWCD-P2: SMG spiked B5 CME fuel) from Reference 11 was included.



Using the above correlation, a saturated monoglycerides level of 145 mg/L in the fuel translates to a 1.4 filter blocking tendency. The ASTM D2068 test method suggests a limit of 1.4 (105 kPa or 300 mL) as defined by the following Equations 2 and 3.

$$\mathbf{FBT} = \sqrt{1 + \left[\frac{P}{105}\right]^2} \quad \text{or} \quad \sqrt{1 + \left[\frac{300}{V}\right]^2} \qquad \textbf{Equations 2 \& 3}$$

P = maximum pressure reading obtained for 300 ml of fuel to pass filter, kPa
V = volume of fuel in ml, passed prior to pressure rising to 105 kPa

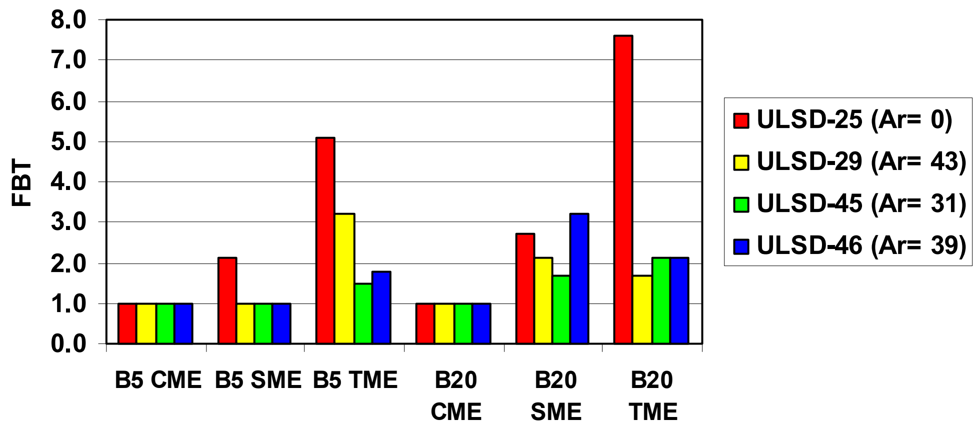
Assuming a maximum limit of 145 mg/L of SMG in the fuel and B20 as the highest FAME content, Equation 1 can be used to back calculate a maximum SMG content for the FAME of 820 mg/kg.

Note that the above correlation was based on B100 samples with SMG content up to 2000 mg/kg and should not be extrapolated beyond this range.

3.4 Effect of Fuel Type on the Filter Blocking Tendency

The amount of aromatics in the base fuel was found to impact the filter blocking tendency of the fuel. Significantly higher filter blocking tendency results were obtained for the B5 and B20 TME in the zero aromatics base fuel (ULSD-25). This is illustrated in Figure 5.

Figure 5. Effect of Fuel Type on the FBT



All other base fuels shown in Figure 5 contain from 30.5 wt% to 42.7 wtl% aromatics (Table 1). Although the ULSD-25 was obtained commercially, the zero aromatics content fuel is not typical of diesel fuels. These results suggested that the solubility of the SMG decreases with decreasing aromatic content of the fuel.

4. CONCLUSIONS and RECOMMENDATIONS

1. The 10-days storage stability study of bio-diesel fuels at 2-4°C above cloud point and at 1°C resulted in the formation of precipitates. Analysis of precipitates for selected B20 fuel blends show them to be significantly enriched in SMG (but not unsaturated mono-glycerides).

2. The filter blocking tendency test (ASTM D2068-08) was found to correlate fairly well (R^2 = 0.71) with the SMG content of the fuel. The correlation indicates that a SMG level of 145 mg/l in the renewable diesel fuel blend translates to a FBT value of <1.4, similar to that of conventional diesel fuel.

3. B5 and B20 TME blends in a zero aromatic base fuel had unexpectedly high FBT results suggesting that the solubility of SMG in the base fuel decreases with decreasing aromaticity.

The results of this study further confirm the previous reports in the literature regarding the deleterious impact of saturated mono-glycerides in FAME on the low temperature operability of filters in fuel handling systems. This is a very important consideration when formulating renewable diesel fuels for a Canadian climate. The information generated by this study may be used to direct future renewable diesel blending formulations (e.g. seasonal bio-diesel for winter per current practice) and by standard-setting bodies to set specifications that will ensure "fit for service" fuel products.

Additional work to improve the correlation between SMG and FBT as well as a fundamental study of the kinetics of SMG precipitation and re-dissolution, including the impact of base fuel aromatic content, would be very valuable.

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6. TABLES

Table 1. Properties of the Petroleum Diesel Fuels

Sample ID	47306	47424	47497	48269	48270	48909				
Product	ULSD-45	ULSD-29	ULSD-46	ULSD-48	ULSD-29B	ULSD-25				
CGSB Type	Type A	Type B	Type B	Type A	Type B	Type B	**Type A Limits**		**Type B Limits**	
ULSD No.	1	2	2	1	2	2				
Properties							Min	Max	Min	Max
Appearance	C&B	C&B	C&B	C&B	C&B	C&B				
Density, kg/m3	819	844	845	818	847	843				
Flash Point,°C	51	64	51	54	64	81	40.0		40.0	
Viscosity @ 40°C, mm^2/s	1.43	2.05	2.04	1.42	2.13	3.16	1.3	3.6	1.3[1]	3.6
Aromatics, wt%	30.5	42.7	39.3	31.4	35.3	0				
Sulphur, mg/kg	5.1	5	3.1	5.7	3.8	< 1.2		15		15
Cetane Index	42.9	44.3	42.5	42.8	42.9	49.1	40.0		40.0	
Cloud Point, °C	-45.0	-28.7	-46.0	-48.0	-29.4	-24.7				
Conductivity @ 20°C, pS/m	1830	750	1750	1119	800	292	25		25	
Distillation D86										
IBP	156.8	173.3	156.7	157.0	176.5	201.5				
5%	170.7	197.2		171.0	201.5	211.1				
10%	174.2	208.4	183.6	174.4	210.1	216.3				
20%	183.9	221.2		183.1	220.1	223.0				
30%	192.2	232.5	214.1	191.0	228.5	231.5				
40%	202.3	243.0		200.0	236.6	243.5				
50%	211.8	251.1	245.8	210.2	244.6	261.1				
60%	222.3	258.9		219.9	253.6	288.8				
70%	233.1	267.1		231.3	263.9	317.4				
80%	245.7	275.6		244.2	276.0	335.8				
90%	263.3	286.5	306.8	260.7	294.1	351.4		290.0		360.0
95%	279.7	295.5	321.1	273.2	310.3	363.0				
FBP	291.1	304.9	331.0	292.0	323.7	364.6				

1) For a fuel designed for an operability temperature colder than -20°C.

Table 2. Properties of the FAMEs

Sample ID	BIO-47404	BIO-47242	BIO-47435	BIO-48272	BIO-48274	BIO-47453	BIO-47499				
Supplier	A	B	C	B	E	D	F				
								ASTM D6751		EN 14214	
Properties	**CME**	**CME**	**SME**	**SME**	**TME**	**TME**	**PME**	**Min**	**Max**	**Min**	**Max**
Density @ 15°C, kg/m3	883.3	882.6	885.4	884.7	875.8	876.5	875.0	-	-	860	900
KV @ 40°C, mm^2/s	4.4	4.5	4.1	4.1	4.5	4.55	4.4	1.9	6.0	3.5	5.0
Total sulphur,mg/kg	2.6	4.8	< 1.0	0	1.3	4.8	1.4		15		10
Water & Sediment, vol%	0	0.02	< 0.01	0.000	<0.025	< 0.005	-		0.050	-	-
Water, mg/kg	-	-					315	-	-		500
Cloud Point, °C	-2.8	-3	-1	1	9.9	13.5	11.6	-	-	-	-
Flash Point, °C	163	> 120	129	150	165	175	> 150	93		120	
Acid Number, mg KOH/g	0.16	0.12	0.25	0.34	0.21	0.29	0.14		0.50		0.50
Carbon Residue, wt%	0.000	-	< 0.03	0.05	<0.002	0.001	-		0.050	-	-
Carbon Residue, 10% distillation residu, wt%					-		0.13	-	-		0.30
Copper Corrosion	1a	1a	1a	1a	1a	1a	1a		3		
Cetane Number	51.5	-	49.3	48.7	61.8	63	60	47		51	
Oxidation Stability, hours	6.2	14.5	5.6	10.2	> 3	5.1.7	> 8	3		6.0	
Sulfated Ash, wt%	0.000	0.000	< 0.002	0.000	0.0019	0.009	0.001		0.020		0.02
Free Glycerin, wt%	0.004	0.000	0.004	0.001	0.003	0.001	< 0.005		0.020		0.02
Total Glycerin, wt%	0.112	0.16	0.168	0.133	0.151	0.057	0.13		0.240		0.25
Monoglycerides, wt%	0.350	0.601	0.546	0.485	-	-	0.41	-	-		0.80
Diglycerides, wt%	0.119	0.046	0.127	0.077	-	-	0.08	-	-		0.20
Triglycerides, wt%	< 0.001	0.000	0.038	0.031	-	-	0.04	-	-		0.20
Cold Soak Filtration, sec[1]	100	> 720	96	180	114	111	> 720		200[2]	-	-

1) CSFT determined by IOL. 2) For operability < -12°C

Table 3. Storage Stability of the CME Bio-Diesel Fuels

Test Fuel #	Base Fuel	Aromatics, wt%	Vol%FAME	FAME	Supplier	FAME CSF, sec	Finished CP, °C	Storage Temp., °C	FBT, 2-4°C Above CP, °C	FBT, 1°C
4	ULSD-46	39.3	5	CME	A	100	-41.8	-38	1.0	1.0
20	ULSD-46	39.3	5	CME2	AB	275	-41.6	-38	1.0	1.0
3	ULSD-45	30.5	5	CME	A	100	-41.2	-38	1.0	1.0
19	ULSD-45	30.5	5	CME2	AB	275	-41.0	-38	1.0	1.0
47	ULSD-29+ ULSD-46	40.4	2	CME	A	100	-36.5	-33	1.0	1.0
46	ULSD-29+ ULSD-46	39.8	5	CME	A	100	-36.4	-33	1.0	1.0
24	ULSD-46	39.3	20	CME	A	100	-29.2	-25	1.0	1.0
23	ULSD-45	30.5	20	CME	A	100	-28.3	-24	1.0	1.0
40	ULSD-46	39.3	20	CME2	AB	275	-27.6	-24	2.1	1.6
39	ULSD-45	30.5	20	CME2	AB	275	-27.1	-24	1.7	1.0
1	ULSD-29	42.7	5	CME	A	100	-26.3	-24	1.0	1.0
17	ULSD-29	42.7	5	CME2	AB	275	-26.0	-24	1.0	1.0
42	ULSD-29+ULSD-45	40.3	20	CME	A	100	-24.4	-21	1.0	1.0
37	ULSD-29	42.7	20	CME2	AB	275	-23.2	-19	1.4	1.5
21	ULSD-29	42.7	20	CME	A	100	-22.8	-19	1.0	1.0
2	ULSD-25	0	5	CME	A	100	-20.3	-16	1.0	1.0
18	ULSD-25	0	5	CME2	AB	275	-20.2	-16	1.0	1.0
38	ULSD-25	0	20	CME2	AB	275	-17.1	-12	1.8	1.6
22	ULSD-25	0	20	CME	A	100	-16.8	-12	1.0	1.0

Table 4. Storage Stability of the TME Bio-Diesel Fuels

Test Fuel #	Base Fuel	Aromatics, wt%	Vol%FAME	FAME	Supplier	FAME CSF, sec	Finished CP, °C	Storage Temp., °C	FBT, 2-4°C Above CP, °C	FBT, 1°C
16	ULSD-46	39.3	5	TME	D	111	-27.7	-24	1.8	3.2
15	ULSD-45	30.5	5	TME	D	111	-24.9	-21	1.5	1.9
56	ULSD-29B	41.7	5	TME	E	114	-21.7	-18	1.6	1.0
13	ULSD-29	42.7	5	TME	D	111	-21.3	-18	3.2	1.9
14	ULSD-25	0	5	TME	D	111	-17.6	-8	5.1	1.9
57	ULSD-48 + ULSD-29B	39.9	20	TME	E	114	-11.2	-8	1.0	1.0
33	ULSD-29	42.7	20	TME	D	111	-7.9	-4	1.7	1.0
36	ULSD-46	39.3	20	TME	D	111	-6.9	-4	2.1	2.9
35	ULSD-45	30.5	20	TME	D	111	-5.5	-2	2.1	1.0
34	ULSD-25	0	20	TME	D	111	-5.2	-2	7.6*	5.1

* GC/MS analysis of precipitate

Table 5. Storage Stability of the SME Bio-Diesel Fuels

Test Fuel #	Base Fuel	Aromatics, wt%	Vol%FAME	FAME	Supplier	FAME CSF, sec	Finished CP, °C	Storage Temp., °C	FBT, 2-4°C Above CP, °C	FBT, 1°C
11	ULSD-45	30.5	5	SME	C	96	-36.6	-33	1.0	1.3
43	ULSD-29 + ULSD-46	40.3	2	SME	C	96	-36.5	-33	1.0	1.0
12	ULSD-46	39.3	5	SME	C	96	-34.9	-33	1.0	1.1
9	ULSD-29	42.7	5	SME	C	96	-24.9	-21	1.0	1.0
50	ULSD-29B	41.7	5	SME	B	180	-24.7	-21	1.1	1.3
31	ULSD-45	30.5	20	SME	C	96	-22.2	-19	1.7	1.9
58	ULSD-48	38.0	20	SME	B	180	-21.8	-18	10.1	10.1
53	ULSD-48 + ULSD-29B	39.9	20	SME	B	180	-21.4	-18	1.1	1.2
32	ULSD-46	39.3	20	SME	C	96	-21.3	-18	3.2	1.9
10	ULSD-25	0	5	SME	C	96	-19.9	-16	2.1	1.0
29	ULSD-29	42.7	20	SME	C	96	-18.8	-16	2.1*	2.0
55	ULSD-29B	41.7	20	SME	B	180	-18.0	-16	4.4	6.1
30	ULSD-25	0	20	SME	C	96	-15.2	-12	2.7	2.0

* GC/MS analysis of precipitate

Table 6. Storage Stability of the PME and B0 Bio-Diesel Fuels

Test Fuel #	Base Fuel	Aromatics, wt%	Vol%FAME	FAME	Supplier	FAME CSF, sec	Finished CP, °C	Storage Temp., °C	FBT, 2-4°C Above CP, °C	FBT, 1°C
7	ULSD-45	30.5	5	PME	F	> 720	-27.7	-24	3.2	2.1
8	ULSD-46	39.3	5	PME	F	> 720	-27.3	-24	1.9	1.6
44	ULSD-29 + ULSD-45	32.9	5	PME	F	> 720	-26.5	-24	1.1	1.9
5	ULSD-29	42.7	5	PME	F	> 720	-21.9	-18	2.9	4.4
6	ULSD-25	0	5	PME	F	> 720	-18.3	-16	2.9	2.5
25	ULSD-29	42.7	20	PME	F	> 720	-5.3	-2	10.1*	7.6
28	ULSD-46	39.3	20	PME	F	> 720	-4.8	-2	6.1	3.9
27	ULSD-45	30.5	20	PME	F	> 720	-3.6	-2	10.1	4.4
26	ULSD-25	0	20	PME	F	> 720	-1.1	4	6.1	7.6
45	ULSD-29 + ULSD-46	40.7	0	None	None	NA	-37.4	-33	1.0	1.0
48	ULSD-29B	41.7	0	None	None	NA	-29.4	-25	1.0	1.0
41	ULSD-29	42.7	0	None	None	NA	-28.7	-25	1.0	1.0
59	ULSD-25	0	0	None	None	NA	-24.7	-21	1.0	1.0
60	ULSD-46	39.3	0	None	None	NA	-46.0	-42	1.0	1.0
61	ULSD-45	30.5	0	None	None	NA	-45.0	-42	1.0	-

* GC/MS analysis of precipitate

Table 7. Saturated Monoglycerides Content and FBT

Test Fuel #	Base Fuel	Vol%FAME	FAME	Supplier	SMG, mg/L	FBT, 2-4°C Above CP, °C
4	ULSD-46	5	CME	A	10	1.0
3	ULSD-45	5	CME	A	10	1.0
47	ULSD-29+ ULSD-46	2	CME	A	4	1.0
46	ULSD-29+ ULSD-46	5	CME	A	10	1.0
24	ULSD-46	20	CME	A	42	1.0
23	ULSD-45	20	CME	A	42	1.0
1	ULSD-29	5	CME	A	10	1.0
42	ULSD-29+ULSD-45	20	CME	A	42	1.0
21	ULSD-29	20	CME	A	42	1.0
16	ULSD-46	5	TME	D	42	1.8
15	ULSD-45	5	TME	D	42	1.5
13	ULSD-29	5	TME	D	42	3.2
56	ULSD-29B	5	TME	E	12	1.0
33	ULSD-29	20	TME	D	169	1.7
36	ULSD-46	20	TME	D	169	2.1
35	ULSD-45	20	TME	D	169	2.1
57	ULSD-48 + ULSD-29B	20	TME	E	49	1.0
11	ULSD-45	5	SME	C	42	1.0
43	ULSD-29+ ULSD-46	2	SME	C	17	1.0
12	ULSD-46	5	SME	C	42	1.0
9	ULSD-29	5	SME	C	42	1.0
50	ULSD-29B	5	SME	B	61	1.3
31	UULSD-45	20	SME	C	167	1.7
32	ULSD-46	20	SME	C	167	3.2
29	ULSD-29	20	SME	C	167	2.1
58	UULSD-48	20	SME	B	242	10.1
53	ULSD-48 + ULSD-29B	20	SME	B	242	1.2
55	ULSD-29B	20	SME	B	242	6.1
45	ULSD-29+ ULSD-46	0	None	NA	0	1.0
41	ULSD-29	0	None	NA	0	1.0
60	ULSD-46	0	None	NA	0	1.0
61	ULSD-45	0	None	NA	0	1.0
*	AWCD-P2: ULSD-29	5	CME+SMG	A	100	1.0
*	AWCD-P2: ULSD-29	5	CME+SMG	A	200	1.0
*	AWCD-P2: ULSD-29	5	CME+SMG	A	225	3.9
*	AWCD-P2: ULSD-29	5	CME+SMG	A	237	4.4
*	AWCD-P2: ULSD-29	5	CME+SMG	A	264	5.1
*	AWCD-P2: ULSD-29	5	CME+SMG	A	275	7.6
*	AWCD-P2: ULSD-29	5	CME+SMG	A	325	10.0
*	Reference 11					

7. APPENDICES

Appendix 1
SUPPLIER A - Canola Methyl Ester
Alberta Research Council ~ Fuels & Lubricants

250 Karl Clark Road, Edmonton, Alberta, Canada T6N1E4
Certified by the Standards Council of Canada as an Accredited Testing Organization complying with the requirements oflSO/IEC 17025 for specific tests registered -with the Council

Report of Analysis

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Report GO-2007-4489

Client:

Attention:

Laboratory Sample Number: GO-2007-4489 **Product:** B100 Biodiesel
Specification: ASTM D6751-07a B100 Grade S15 **Date Received:** 22-Oct-2007

Sample Reference
Lot # RBD-OCT-2007, 18/10/07

Analysis	Method			Results	Notes
		Minimum	Maximum		
Cetane Number	ASTM D613	47		51.5	
Cloud Point, °C	ASTM D5773			-28	
Particulate Contamination in Biodiesel by Laboratory Filtration	ASTM D621 7 (modified), Procedure B				1,2
Filtration Time, seconds			360	105.5	
Water, mg/kg	ASTM D6304, Procedure A		500	1011	3
Water and Sediment, Volume %	ASTM D2709		0.050	0.000	
Density, kg/m^s, @ 15 °C	ASTM D4052			883.3	
Flash Point, °C	ASTM D93, Procedure A	93.0		163.0	
Oxidation Stability, 1 10"C, hours	EN 141 12	3.0		6.2	
Kinematic Viscosity, mm2/s(cSt)	ASTMD445				
Clear, at 40 °C		1.9	6.0	4.408	
Ash, Sulfated, Mass %	ASTM D874		0.020	0.000	
Total Sulfur by Ultraviolet Fluorescence, mg/kg	ASTM D5453		15	2.6	
Copper Corrosion	ASTM D130		No. 3	1a	
.Carbon Residue, Mass %	ASTM D4530		0.050	0.000	4
Acid Number, mg KOH/g	ASTMD664		0.50	0.16	
Test Method for Determination of Free and Total Glycerine in B-100 Biodiesel Methyl Ester by Gas Chromatography	ASTM D6684				-
Free Glycerin, mass %			0.020	0.004	
Total Glycerin, mass %			0.240	0.112	
Monoglycerides, mass%				0.350	
Diglycerides, mass %				0.119	
Trigfycerides, mass %				<0.001	
Inductively Coupled Argon Plasma	EN 14107 modified				5,6
Group I Metals (Na + K), mg/kg			5.0	<0.5	
Group II Metals (Ca + Mg), mg/kg			5.0	<0.5	
Phosphorus Content, mg/kg			10.0	<0.5	

Appendix 2
SUPPLIER B - Canola Methyl Ester

PRODUCT NAME: 006100 **BIODIESEL,** B100, CANOLA
SHIP DATE: 12/12/2007
LOT NUMBER: **5012 12/10/2007**

ANALYSIS	METHOD	LIMIT	UNIT	RESULT
Visual	ASTMD4176	Clear, Bright, Free		C,B&F
Ester Content	EN 14103	96.5 min.	%mass	Pending independent analysis
Density @15°C	EN ISO 121 85	860 - 900	kg/m^3	.8826
Viscosity @ 40°C	EN ISO 3 104	3.50-5.00	mm^2/s	4.5023
Flash Point	ISO/DIS 3679	120.0 min.	°C	PASS
Sulfur Content	EN ISO 20846	10.0 max.	mg/kg	4.76
Sulfated Ash Content	ISO 3987	0.02 max.	%mass	0.000
Water Content	EN ISO 12937	500 max.	mg/kg	135
Total Contamination	EN 12662 '	24 max.	mg/kg	21.57
Copper Strip Corrosion 3hrat50°C	EN ISO 2160	1 max.		la
Oxidation Stability, 110°C	EN 141 12	6.0 min.	hours	14.50
Acid Value	EN 14104	0.50 max.	mgKOH/g	.1178
Iodine Value	EN 141 11	120 max.		117.81
Linolenic acid methyl ester	EN 14103	12.0 max.	%mass	Pending independent analysis
Polyunsaturated methyl esters >=4 double bonds	EN 14103	1 max.	%mass	<1
Methanol	EN 141 10	0.20 max.	%mass	0.028
Monoglyceride Content	EN 14105	0.80 max.	%mass	0.601
Diglyceride Content	EN 14105	0.20 max.	%mass	0.046
Triglyceride Content	EN 14105	0.20 max.	%mass	0.000
Free Glycerol	EN 14105	0.02 max.	%mass	0.000
Total Glycerol	EN 14105	0.24 max.	%mass	0.160
Group I metals, (Na + K)	EN 14538	5.0 max.	mg/kg	0.000
Group II metals, (Ca + Mg)	EN 14538	5.0 max.	mg/kg	0.000
Phosphorous Content		10.0 max.	mg/kg	0.00007
Water & Sediment	ASTMD2709	0.050 max.	% volume	0.02
Cloud Point	ASTMD2500		°C	-3.0
Flash Point	ASTMD93	93 min.	°C	N/A
TYPICAL ANALYSIS				
ANALYSIS	METHOD	LIMIT	UNIT	RESULT
Cetane Number	EN ISO 5165	5 1.0 min.		Pending independent analysis
Carbon Residue On 10% distillation residue	EN ISO 10370	0.30 max.	%mass	Pending independent analysis
Cold Filter Plugging Point	EN 116		°C	-3.0
Distillation Temperature	ASTMD1160	360 max.	°C	N/A
Carbon Residue	ASTMD4530	0.050 max.	%mass	N/A
Cold-Soak Filtration			seconds	N/A

Appendix 3
SUPPLIER C - Soybean Methyl Ester

Biodiesel Certificate of Analysis

Date Reported:	10-23-07	Product Description:	8100
Lot Number	11BD071021T004	Tank Seal Number	3347
Order Number . "	-		
Shipping Date:	S/VJ6 Bl*o	Rail/Truck Number:	
Customer	6»0-HTH3S	Attention:	

ASTM D 6751-07b Specification Analysis of Biodiese!

Test Parameter	Results	Limits	Units	ASTM Method
Free Glycerin:	0.004	0.020 max.	%Mass	D 85844)7
Total Glycerin:	0.16B	0.240 max.	%Mass	D 6584-07
Monoglycerldes[1]:	0.546	n/a	%Mass	D 6584-07
Dlglycerides[2]:	0.127	n/a	•/.Mass	D 8564-07
Triglycerides[1]:	0.038	n/a	%Mass	DB584-07
Cloud point;	(-1)°	Report	•c ,	D 2500-05
Waters Sediment	«X01	0.050 max	% Volume	D 2709-86(2006)
Acid Number	0.251	0.50 max.	mgKOH/g	D 664-07
Visual Inspection:	1	2 max	Haze	D 4176-04" Procedure 2
Relative Density @60»F:	0.8854	n/a	n/a	D 1288-99(2005}
Oxidatrve Stability:	5.64	3min.	hrs	EN 14112:2003
Flashpoint Option A- PMCC :	n/a	130 min.	•C	093-07
Flashpoint Option B- PMCC :	129	93m)n.	•C	D 93-07
Option B- Methanol:	- 0.12	0.2 max.	% Volume	EN 141 10:2003
Moisture[4]:	0.013.	n/a	% Volume	E203-01
Cold Soak Filtration[5]:	82	360 max.	seconds	06217-98(2003)01 Modified
Sulfur:	<1.0	15	ppm	D 5453-08
Phosphorus:	<0.0005*	0.001 max.	ttMass	D 4951-06
Sodium & Potassium Combined:	<0.9*	5 max.	ppm (M9/0)	EN 14538 BS2000-547
Calcium & Magnesium Combined:	<0.4*	5 max.	ppm (uo/fl)	EN 14538 BS2000-547
Carbon Residue:	<0.03*	0.050 max.	•AMass	D 4530-06"
SulfatedAsh:	<0.002*	0.020 max.	%Mass	D 874-06
Kinematic Viscosity at 40 *C:	4.128*	1.9-8.0	imnVsec. .	D 445-06
Copper Corrosion:	1a*	No. 3 max •	n/a	D130O**[1]
Cetarte Number: • _	48.3*	47mln.	n/a	D 613-05
Distillation at 90% Recovered:	357*	360 max.	C	D 1160-06

MhM* «re **not ASTM D 875i-
0?a** nor BQMOO Tfcnote*
Avwage Typfc»l

Prenared by: Quality Assurance Coordinator WIE l* - i s - « 7
•Name Title Company Date

Appendix 4
SUPPLIER B - Soybean Methyl Ester

PRODUCT NAME: 006600 BIODIESEL, B100, SOYB
APPROVAL DATE: 10/20/2007 8:10:00 PM
LOT NUMBER: spt!01907
TANK NUMBER: South
TANK VOLUME: 76736

ANALYSIS	METHOD	LIMIT	UNIT	RESULT
VISUAL	ASTMD4I76	CLEAR,BRIGHT,FREE		PASS
FLASHPOINT	ASTM D93	93.00 MIN.	DegC	150.0
METHANOL	EN141IO	0,20 MAX.	%Ma$s	0-098
WATER AND SEDIMENT	ASTM D2709	0.050 MAX.	d/o Volume	0.000
CLOUD POINT	ASTMD2500	REPORT	DegC	I
SULFUR	ASTM D5453	0.001 5 MAX.	% Mass	0.0000
ACID NUMBER	ASTM D664	0.50 MAX.	mgKOH/g	0,34
FREE GLYCERIN	ASTM D6584	0.020 MAX.	% Mass	0.001
TOTAL GLYCERIN	ASTM D6584	0.240 MAX.	%Mass	0.133
OXIDATION STABILITY	EN141I2	3.0 MIN.	Hour	10.2
COLD SOAK 16 HOUR	0.7 MICRON AT RT	1 50 SECONDS MAX.	Seconds	121
FILTER BLOCKING TENDENCY				1.010

TYPICAL ANALYSIS

ANALYSIS	METHOD	LIMIT	UNIT	RESULT
HOMOGENEITY	ASTM D4052	HOMOGENEOUS		PASS
CALCIUM AND MAGNESIUM	EN 14538	5 MAX.	PPM	0,19
VISCOSITY @40OC	ASTM D445	1.9-6,0	mm2/s	4.100
SULFATED ASH CONTENT	ASTM D874	0.020 MAX.	% Mass	0.000
COPPER STRIP CORROSION	ASTM 130	NO. 3 MAX.		1
CETANE NUMBER	ASTM D6 13	47 MIN.		48.7
CARBON RESIDUE	ASTM D4530	0.050 MAX.	%Mass	0.050
PHOSPHORUS	ASTMD4951	0.001 MAX.	% Mass	0.0000
DISTILLATION TEMPERATURE	ASTM Dl 160	360 MAX.	DegC	353
SODIUM AND POTASSIUM	EN 14538	5 MAX,	PPM	0.25

Certified By: Mexico Quality Control Laboratory

Appendix 5
SUPPLIER E - Tallow Methyl Ester

Lot Number Sample **80101506**

ID Production Dates

12/14/07 to **01/01/08**

Analysis

Parameter	Reported Result	Unit	Analytical Method	Sjbecificatlon
Workmanship	1	.	ASTM 041 76	<2
Acid Number	0.21-	mg KOH/gm	ASTM D664	<0.50
Water & Sediment	< 0.025	% vol	ASTM 02709	<0.05
Free Glycerin	0.003	%mass	ASTM 06584	< 0.020
Total Glycerin	0.151	%mass	ASTM D6584	< 0.240
Flash Point	165.0	•c	ASTM 093	>130'
Cloud Point	9.9	•c	ASTM D2500	*
Sulfur	1.3	ppm	ASTM D5453	15
Specific Gravity 4	f15" 30.2	API	ASTMD1298	.
Copper Corrosion	1A	.	ASTM 0130	<3
Kinematic Viscocity	4.53	mm2/sec	ASTMP445	1.9-6.0
Oxidative Stability	>3	hrs	EN14112	>3
'Cetane	61.8	.	ASTM 0613	>47
"Calcium	<0.1	ppm	UOP389	<5
"Magnesium	<0.1	ppm	UOP389	<5
•Sodium	1.0	ppm	UOP391	<5
"Potassium	0.1	ppm	UOP391	<5
'Phosphorus	< 0.001	% mass	ASTM 04951	<5
"Carbon Residue	< 0.002	% mass	ASTM D4530	< 0.001
*Sulfated Ash	0.0019	% mass	ASTM 0874	<0.05
*Distillation Temp	331.9	%mass	ASTM 0874	<680

Reslts typical

I *signature:*

\RobertBrylski

Appendix 6
SUPPLIER D - Tallow Methyl Ester

Product NamerBiodiesel based Tallow B100	Product meets ASTM D6751-7a Specification	
Manufacturer:	Lot number: A0024	
Blend: 1 00 % "agri" Biodiesel	Production date: January 07 , 2008	
Customer: Imperial Oil	Loading date: January 8, 2008	
Order number: SAMPLE	Train #: N/A	Trailer #: N/A

PROPERTIES	METHOD	RESULTS	UNITS	LIMITS	
				Min	Max
Flash point*	D93	174.5	°C	130	-
Flash point(closed cup)*	D93	178	°C	93	-
Water and sediment *	D2709	< 0.005	%vol.	-	0.050
Kinematic Viscosity @ 40 °C*	D445	4.5549	mm/s	1.9	6.0
Sulphated Ash[1]	D874	<0,009>	%mass.	-	0.020
Sulphur content	D5453	0.00048	%mass.	-	0.0015
Phosphorous Content[1]	D4951	<0,0002>	%mass.	-	0.001
Copper Corrosion, 3hrs @ 50 "C[1]	D130	<la>	-	-	No.3
Cetane number[1]	D613	<63>	minute	47	-
Cloud point*	D2500	13.5	°C	Report to customer	
Distillation @ 90%'	D1160	<350>	°C	-	360
Carbon Residue[1]	D4530	<0,001>	%mass.	-	0.050
Acid number*	D664	0.293	mgKOH/g	-	0.50
Free Glycerin*	D6584	0.0009	%mass.	-	0.020
Total Glycerin*	D6584	0.0565	%mass.	-	0.240
Calcium and Magnesium, combined[1]	EN 14538	<0,3>	ppm	-	5
Sodium and Potassium, combined[1]	EN 14538	<1,6>	ppm	-	5
Oxidation Stability*	Enl4112	5.14	hours	3	-

Comments: these tests were subcontracted by IMS Analytical Services

*':-CP.W^' ~rr<i" 'say lab

< > Typical result

Appendix 7
SUPPLIER F - Palm Methyl Ester

Report Date: 01/10/2008 **Sample Received:** 01/10/2008

Sample ID: ME01-157 **Collected By:** Chris Lee

Sample Description: GEFH PME Tk 20-1 Product Sample

GEFH FAME Export Specification

Test	Method	\ Limit	Typical	; Units
Ester Content	; EN 14103	: £ 96,5	98,7	; % m/m
Density @ 15°C	EN ISO 3675	860 - 900	875	kg/m[3]
i Viscosity @ 40°C	EN ISO 3104	3,50 - 5,00	4,408	] mm[2]/s
Flash point	EN ISO 3679	> 120 i	>150	°C
Sulfur Content	EN ISO 20846	< 10,0	M	mg/kg
Carbon Residue (10% distillation residue)	EN ISO 10370	i <> 0,30	0,13	i % m/m
Cetane Number	i EN ISO 5165	> 51,0 j	60	
Sulfated Ash Content	ISO 3987	< 0,02 ;	0,001	%m/m
i Water Content	EN ISO 12937	S500 i	315	mg/kg
; Total Contamination	EN 12662	<24 ;	13	mg/kg
Copper Strip Corrosion (3h @ 50°C)	EN ISO 2160	Class 1 I	la	
\ Oxidation Stability, 110°C	EN 14112	S6,0 1	>8,0	hours
\ Acid Value	EN 14104	< 0,50	0,14	mg KOH/g
i Iodine Value	EN 14111	<120 i	55,1	gr iodine/IOOg
j Linolenic Acid Methyl Ester	EN 14103	< 12,0 j	0,21	% m/m .
1 Polyunsaturated (>=4 double bonds) I Methy|_Esters		< 1,0 j	<0,10	% m/m
! Methanol Content	EN 14110	< 0,20 j	0,09	%m/m
j Monoglyceride Content	EN 14105	< 0,80 |	0,41	%m/m
! Diglyceride Content	EN 14105	<> 0,20 !	0,08	%m/m
; Triglyceride Content	EN 14105	< 0,20 i	0,04	%m/m
FreeGlycerol	EN 14105	£ 0,02	<0,005	% m/m
Total Glycerol	EN 14105	< 0,25 !	0,13	% m/m

Appendix 8

Low Temperature Storage Stability Test Protocol

Storage Stability Test #1 **10 Days at fixed Temperature**

Cold storage stability at 2-4°C above cloud point of the fuel and below cloud point of the FAME. Fuels were classified into categories.

	Fuel CP, °C	Test Temperature
Category 1	-10.5 to -12.5	-9°C
Category 2	-19.5 to -21.5	-18°C
Category 3	-21.5 to -23.5	-20°C
Category 4	-23.5 to -25.5	-22°C
Category 5	-25.5 to -27.5	-24°C
Category 6	-27.5 to -29.5	-26°C
Category 7	-34.5 to -36.5	-33°C
Category 8	-36.5 to -38.5	-35°C
Category 9	-38.5 to -40.5	-37°C

Volume: 1L to 2L
Appearance After 1,2,5 and 10 days.

Storage Stability Test #2 **10 Days at Fixed Temperature**

All the fuels stored at 1°C for 10 days.

Volume: 1L to 2L
Appearance: After 1, 2, 5 and 10 days.

Appendix 9

Test Fuel #	Base Fuel	Vol%FAME	FAME	Appearance @ 2-4°C Above CP				Appearance at 1°C			
			Days -->	1	2	5	10	1	2	5	10
4	ULSD-46	5	CME A	H&P	H&P	H&P	H&P	H	H	H	C
20	ULSD-46	5	CME2 AB	H&P	H&P	H&P	C&P	C	C	C	C
3	ULSD-45	5	CME A	C&P	C&P	C&P	C&P	C	C	C	C
19	ULSD-45	5	CME2 AB	C&P	C&P	C&P	C&P	C	C	C	C
47	ULSD-29+ ULSD-46	2	CME A	C	C&P	C&P	C&P	C	C	C	C
46	ULSD-29+ ULSD-46	5	CME A	C	C&P	C&P	C&P	C	C	C	C&P
24	ULSD-46	20	CME A	H	H&P	H&P	H&P	H	H	H&P	H&P
23	ULSD-45	20	CME A	H&P	C&P	C&P	C&P	C	C	H&P	H&P
40	ULSD-46	20	CME2 AB	H	H	H&P	H&P	C&P	C&P	C&P	C&P
39	ULSD-45	20	CME2 AB	H	C&P	C&P	C&P	C&P	C&P	C&P	C&P
1	ULSD-29	5	CME A	C	C&P	C&P	C&P	C	C	C	C
17	ULSD-29	5	CME2 AB	C	C	C&P	C&P	C	C	C	C
42	ULSD-29+ULSD-45	20	CME A	C	C	C&P	C&P	C	C	C	C&P
37	ULSD-29	20	CME2 AB	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
21	ULSD-29	20	CME A	H&P	H&P	H&P	H&P	C	C	C&P	C&P
2	ULSD-25	5	CME A	C	C&P	C&P	C&P	C	C	C	C
18	ULSD-25	5	CME2 AB	H	H	C&P	C&P	C	C	C	C
38	ULSD-25	20	CME2 AB	C	C&P	C&P	C&P	C	H&P	H&P	C&P
22	ULSD-25	20	CME A	C	C	C	C&P	H	H	H&P	H&P
16	ULSD-46	5	TME D	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
15	ULSD-45	5	TME D	C	C	C	C&P	C&P	C&P	C&P	C&P
56	ULSD-29B	5	TME E	C	C&P	C&P	C&P	C	C	C	C
13	ULSD-29	5	TME E	C	C&P	C&P	C&P	C	C&P	C&P	C&P
14	ULSD-25	5	TME D	C	C	C&P	C&P	C&P	C&P	C&P	C&P
57	ULSD-48+ ULSD-29B	20	TME E	C	C	C	C	C	C	C	C
33	ULSD-29	20	TME D	C	C&P	C&P	C&P	C&P	C&P	C&P	C&P
36	ULSD-46	20	TME D	C	H	H&P	H&P	H&P	H&P	H&P	H&P
35	ULSD-45	20	TME D	H	H&P	H&P	H&P	H&P	H&P	H&P	H&P
34	ULSD-25	20	TME D	H	H&P	H&P	H&P	H&P	H&P	H&P	H&P
11	ULSD-45	5	SME C	C	C&P	C&P	C&P	C	C&P	C&P	C&P
43	ULSD-29+ ULSD-46	2	SME C	C	C&P	C&P	C&P	C	C	C	C&P
12	ULSD-46	5	SME C	C&P	C&P	C&P	C&P	C	C	C	C&P
9	ULSD-29	5	SME C	C	C	C&P	C&P	C	C&P	C&P	C&P
50	ULSD-29B	5	SME C	C	C	C&P	C&P	C	C	C&P	C&P
31	ULSD-45	20	SME C	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
58	ULSD-48	20	SME C	H&P	H&P	C&P	C&P	C&P	C&P	C&P	C&P
53	ULSD-48+ ULSD-29B	20	SME C	C	C&P	C&P	C&P	C	C	C	C&P
32	ULSD-46	20	SME C	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
10	ULSD-25	5	SME C	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
29	ULSD-29	20	SME C	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
55	ULSD-29B	20	SME C	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
30	ULSD-25	20	SME C	C&P	C&P	C&P	H&P	C&P	C&P	C&P	C&P

Appendix 9 (continued)

Test Fuel #	Base Fuel	Vol%FAME	FAME	Appearance @ 2-4°C Above CP				Appearance at 1°C			
		Days -->		1	2	5	10	1	2	5	10
7	ULSD-45	5	PME F	C	C&P	C&P	C&P	C&P	C&P	C&P	C&P
8	ULSD-46	5	PME F	C	C&P	C&P	C&P	C&P	C&P	C&P	C&P
44	ULSD-29 + ULSD-45	5	PME F	C	C	C&P	C&P	C&P	C&P	C&P	C&P
5	ULSD-29	5	PME F	C	C&P	C&P	C&P	C&P	C&P	C&P	C&P
6	ULSD-25	5	PME F	C	C&P	C&P	C&P	C&P	C&P	C&P	C&P
25	ULSD-29	20	PME F	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
28	ULSD-46	20	PME F	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
27	ULSD-45	20	PME F	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
26	ULSD-25	20	PME F	C&P	C&P	C&P	C&P	C&P	C&P	C&P	C&P
45	ULSD-29 + ULSD-46	0	None	C&P	C&P	C&P	C&P	C	C	C	C
48	ULSD-29B	0	None	C	C	C	C&P	C	C	C	C
41	ULSD-29	0	None	C	C&P	C&P	C&P	C	C	C	C
59	ULSD-25	0	None	C	C&P	C&P	C&P	C	C	C	C
60	ULSD-46	0	None	H	H	H	H&P	C	C	C	C
61	ULSD-45	0	None	H	H	H&P	C&P	C	C	C	C

C&P = Clear + Precipitate **C** = Clear **H&P** = Hazy + Precipitate