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Stability of Biodiesel and Biodiesel Blends: Interim Report

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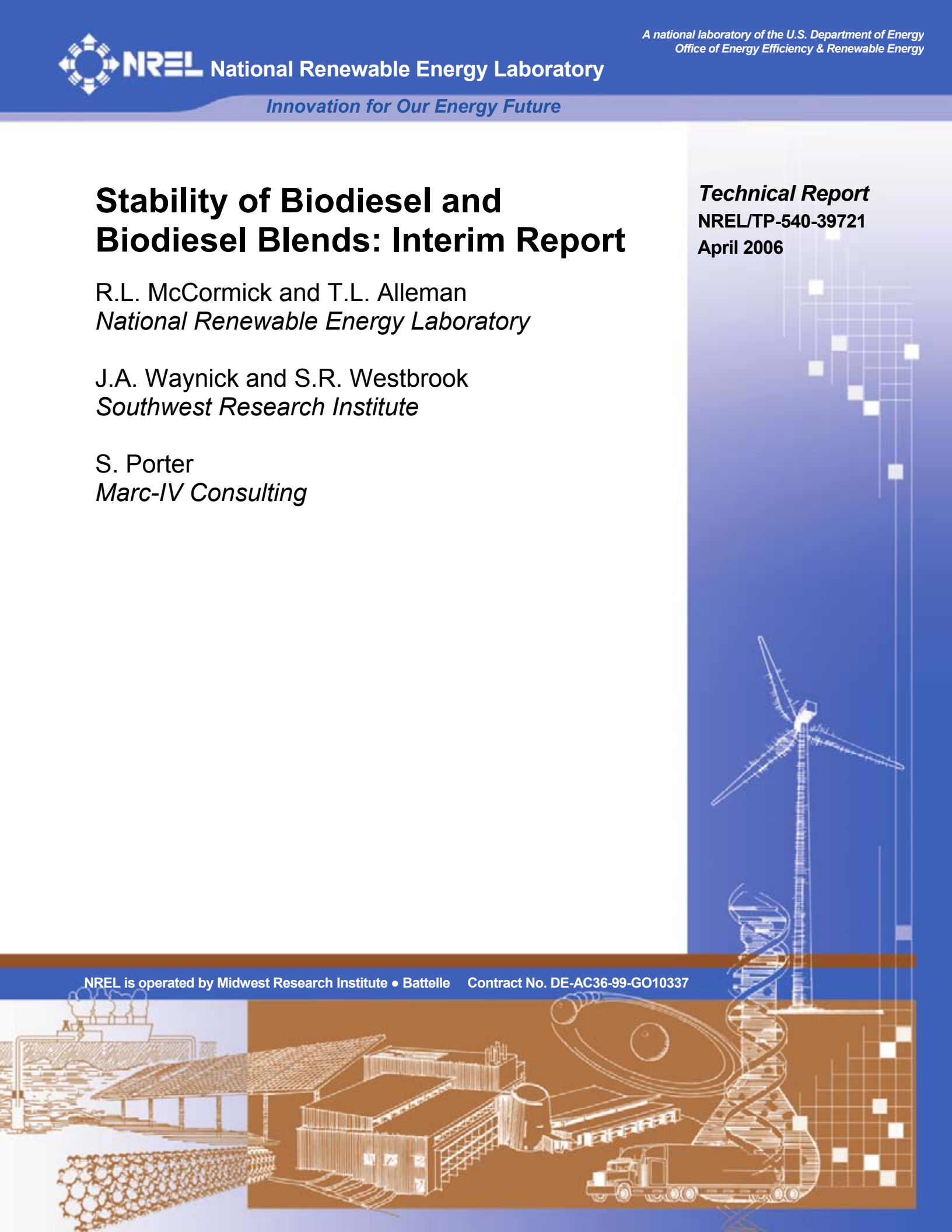
Technical Report
NREL/TP-540-39721
April 2006



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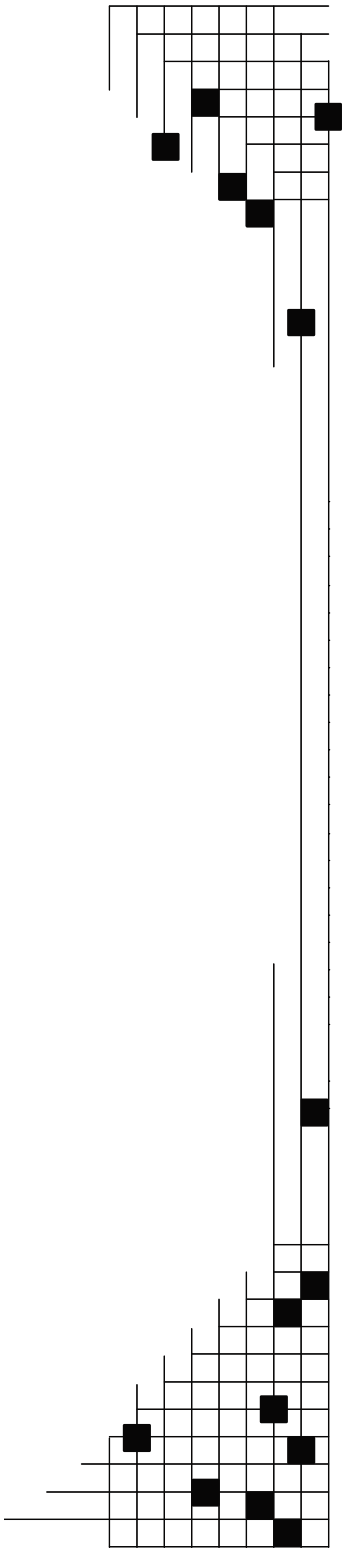

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
B100	100% biodiesel
B20	20% biodiesel, 80% petrodiesel
B5	5% biodiesel, 95% petrodiesel
FAME	fatty acid methyl esters
mg KOH/g	milligrams of potassium hydroxide per gram
mg	milligram
ml	milliliter
NREL	National Renewable Energy Laboratory
ppm	parts per million
ULSD	Ultra-low sulfur diesel (petrodiesel having 15 ppm or less sulfur)

Executive Summary

In support of the U.S. Department of Energy, Fuels Technologies Program Multiyear Program Plan Goal of identifying fuels that can displace 5% of petroleum diesel by 2010, the National Renewable Energy Laboratory is performing a study of biodiesel oxidative stability. The objective of this work is to develop a database that supports specific proposals for a stability test and a specification for biodiesel and biodiesel blends. The overall study includes the following steps:

1. Collection of 19 B100 samples and six diesel samples
2. Preliminary B100 characterization and measurement of B100 stability using accelerated tests
3. Down selection from 19 B100 samples to eight that cover the range of stability observed in accelerated tests and the range of feedstocks
4. Preparation of B5 and B20 blends from all eight biodiesel fuels and all six diesel fuels
5. Measurement of the stability of the B5 and B20 blends using accelerated tests
6. Down selection from 48 B5 and 48 B20 blends to eight of each blend
7. Testing of the eight B100 samples for stability in a simulated storage environment for 12 weeks
8. Testing of the eight B5 and eight B20 blends for stability in a simulated storage environment for 12 weeks, and in a simulated vehicle fuel tank for 1 week followed by high-temperature stability testing
9. Selection of two B100 and two diesel fuels for tests of antioxidant additives in all testing scenarios.

This interim report describes characterization and accelerated stability test results for the 19 B100 samples and six diesel fuels obtained. The B100 samples underwent an initial characterization for acid value as well as free and total glycerin content. The samples were then tested for stability using the following accelerated stability test methods:

- Rancimat (EN14112)
- Stability (modified ASTM D2274, including measurement of iso-octane insolubles)
- Stability (modified ASTM D6468 150°C for 180 minutes, 350 ml sample, gravimetric deposit determination)
- Stability (ASTM D525).

Based on the results of these tests, eight samples were selected for a more detailed study and for studies as B5 and B20 blends (see Table 5 on page 15).

Two B100 samples were treated with two commercial antioxidants at different treatment levels and characterized by accelerated stability tests. Both antioxidants were effective for increasing induction time and reducing deposit formation.

Five ultra-low sulfur diesel (<15 ppm S) and one low-sulfur diesel (<500 ppm S) were also obtained for use in preparing B5 and B20 blends. These were characterized for aromatic content because of its potential impact on the solubility of oxidized biodiesel, as well as other properties.

Introduction

In support of the U.S. Department of Energy, Fuels Technologies Program Multiyear Program Plan Goal of identifying fuels that can displace 5% of petroleum diesel by 2010, the National Renewable Energy Laboratory (NREL) is performing a study of biodiesel oxidation stability. The objective of this work is to develop a database that supports specific proposals for a stability test and specification for biodiesel and biodiesel blends. The overall study includes the following steps:

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9. Selection of two B100 and two diesel fuels for tests of antioxidant additives in all testing scenarios.

The total data set will be analyzed to determine if any of the accelerated tests are able to predict storage stability for B100, along with the effects of antioxidants. The accelerated stability test results for the B100 samples will also be used in conjunction with the biodiesel blend stability data to determine if a B100 stability specification can ensure the stability of blends. If not, the accelerated stability test results for the blends will be assessed to determine if they can predict stability on any of the longer-term tests.

This interim report describes characterization and accelerated stability test results for the 19 B100 samples and six diesel fuels obtained.

Experimental Methods

B100 and Diesel Samples

A single drum of B100 was obtained from 14 biodiesel production sites in the United States and two more from Canadian production facilities. Additionally, three drums of European rapeseed derived biodiesel were obtained. The B100 drums were nitrogen purged/blanketed and stored in a dark room at room temperature. The samples were tested for acid value (ASTM D664), and for free and total glycerin (ASTM D6584) shortly after receipt. Detailed characterization will only be performed on a subset of these fuels that is selected for more detailed testing.

In addition, six samples (two drums each) of petroleum-derived diesel fuel were obtained from petroleum refiners in the United States and Canada. These include one 500 ppm sulfur fuel, and five others meeting the 15 ppm sulfur limit [ultra-low sulfur diesel (ULSD)]. The diesel fuels have been characterized using the following tests:

- Total particulate contamination, ASTM D6217
- Flash point, ASTM D93
- Sulfur, ASTM D5453
- T90/Carbon Residue, ASTM D86/D524
- Acid Number, ASTM D664
- Peroxide Number, ASTM D3703
- Ash Content, ASTM D482
- SFC Aromatics, ASTM D5186
- Oxidation Stability, ASTM D2274 with additional measurement of iso-octane insolubles
- Thermal Stability, ASTM D6468 (150ºC, 180 minutes).

B100 Stability

All B100 samples were tested using the following accelerated stability tests:

> *EN14112:* Fatty Acid Methyl Esters (FAME) – Determination of oxidation stability (accelerated oxidation test). EN14112 was run using the Rancimat apparatus.
>
> *ASTM D525:* Standard Test Method for Oxidation Stability of Gasoline (Induction Period Method). D525 is a gasoline stability test method measuring an induction time for the start of oxygen consumption. This test was shown in a recent study[1] to correlate well with Rancimat, but may provide better discrimination between fuels with short Rancimat induction times.

[1] Miyata, I.; Takei, Y; Tsurutani, K.; Okada, M. "Effects of Bio-Fuels on Vehicle Performance: Degradation Mechanism Analysis of Bio-Fuels," *SAE Technical Paper No. 2004-01-3031* (2004).

ASTM D2274: Standard Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method). D2274 is modified to use glass fiber filters and to include iso-octane insolubles and acid value.

ASTM D6468: Standard Test Method for High-Temperature Stability of Distillate Fuels. This test was run at 150°C for 180 minutes and modified to utilize 350 ml sample size and the same gravimetric insolubles procedures used for D2274.

Results

B100 Samples

Table 1 lists the 19 B100 samples obtained, their feedstock, and preliminary characterization results. These samples appear to cover the full range of feedstocks currently used in North America. Two samples failed the ASTM D6751 specification for biodiesel: one due to high acid value and a second due to high total glycerin. While these samples are included in the accelerated stability tests, they will not be considered for down selection and blending because of their poor quality. The samples that are down selected will be characterized much more extensively.

Table 1. Biodiesel Samples Obtained and Preliminary Characterization

Sample Identification	**Feedstock**	**Total Acid Number, mg KOH/g**	**Total Glycerin, %(mass)**	**Free Glycerin, %(mass)**
		ASTM D664	ASTM D6584	ASTM D6584
ASTM D6751-03a Limit:		*0.80*	*0.24*	*0.02*
AL-27128-F	Canola	0.23	0.103	0.009
AL-27129-F	Palm Stearin	0.41	0.081	<0.001
AL-27137-F	Soy	0.05	0.144	0.002
AL-27138-F	Soy	0.33	0.016	0.002
AL-27140-F	Soy	0.20	0.022	0.015
AL-27141-F	Soy	0.13	0.121	0.005
AL-27142-F	Soy	0.07	0.216	0.003
AL-27144-F	Soy	0.39	0.221	0.004
AL-27145-F	Soy	0.49	0.192	0.005
AL-27146-F	Rapeseed	0.08	0.161	<0.001
AL-27148-F	Grease	0.69	0.121	<0.001
AL-27152-F	Rapeseed	0.09	0.15	0.001
AL-27153-F	Rapeseed	0.08	0.15	0.001
AL-27154-F	Grease	***1.31***	0.132	0.003
AL-27155-F	Soy	0.29	***0.298***	0.007
AL-27157-F	Soy	0.11	0.225	0.015
AL-27158-F	Soy	0.51	0.158	0.001
AL-27160-F	Tallow	0.46	0.188	0.002
AL-27161-F	Grease	0.37	0.151	0.003

Oxidation stability data for the 19 B100 samples are tabulated in the Appendix. Figure 1 shows a frequency plot for Rancimat induction time measured for these 19 samples. The samples show a broad distribution with results ranging from less than 1 to over 9 hours. Figure 2 shows a frequency plot for ASTM D525 induction time, which also reveals a wide range of values. We anticipated that these tests would be somewhat correlated with one another, and this relationship is shown in Figure 3. The circled data points indicate

that no oxidation was observed after 780 minutes, and the results are simply plotted as 780 minutes. Figure 3 indicates only an approximate correlation between these methods (r^2 of 0.4).

Figures 4 through 6 show results for the ASTM D2274 deposit test. Ten out of the 19 samples tested show deposits of less than 2 mg/100 ml; deposits for the other nine fuels cover the range up to nearly 18 mg/100 ml. The filtrate from this test was also mixed with iso-octane to precipitate materials that are insoluble in non-polar solvents. Fourteen of the samples exhibited less than 20 mg/100 ml, with the balance ranging up to 200 mg/100 ml. Finally, the acid value of the filtered liquid was also measured and ranged from less than 1 to over 5 mg KOH/g.

Table 2 lists results for the ASTM D6468 thermal stability test modified for gravimetric measurement of deposits. All samples produced low levels of deposits, and there is little discrimination among the samples.

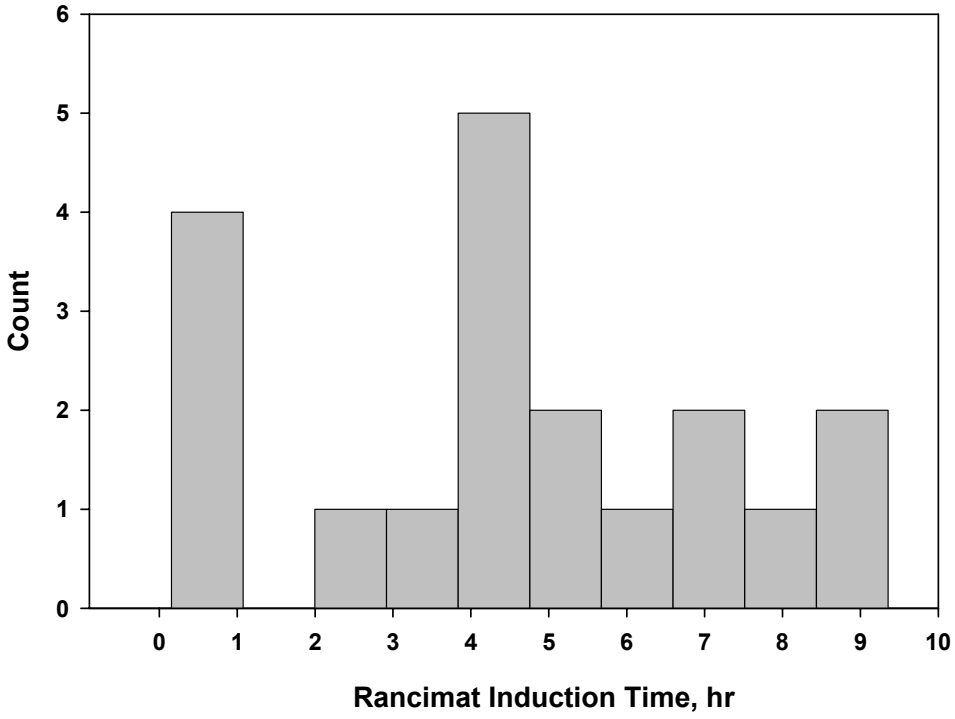


Figure 1. Histogram for B100 Rancimat induction time

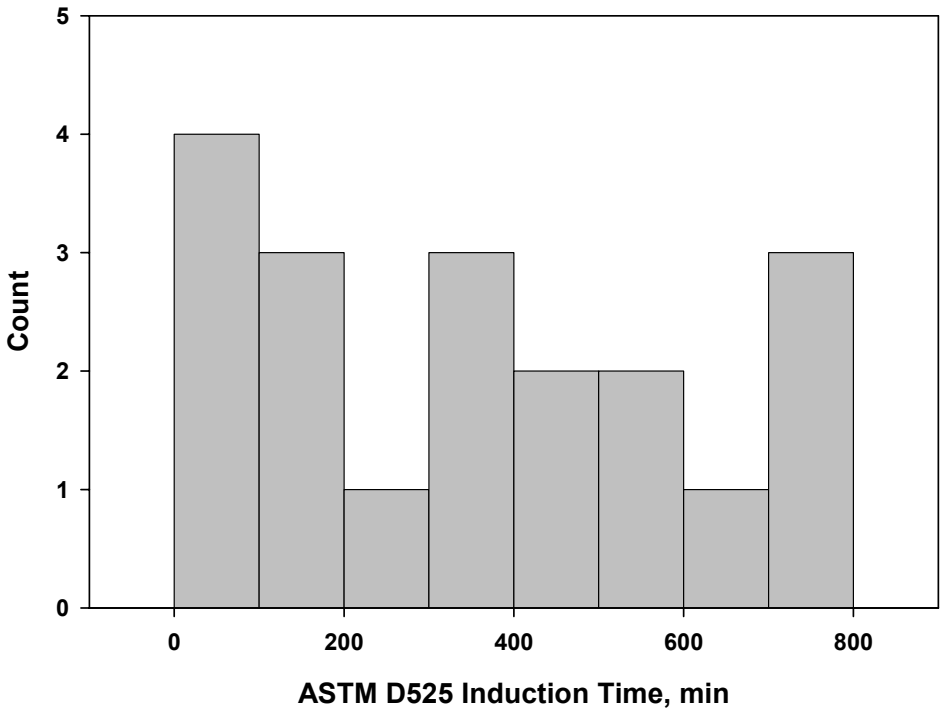


Figure 2. Histogram for B100 ASTM D525 induction time

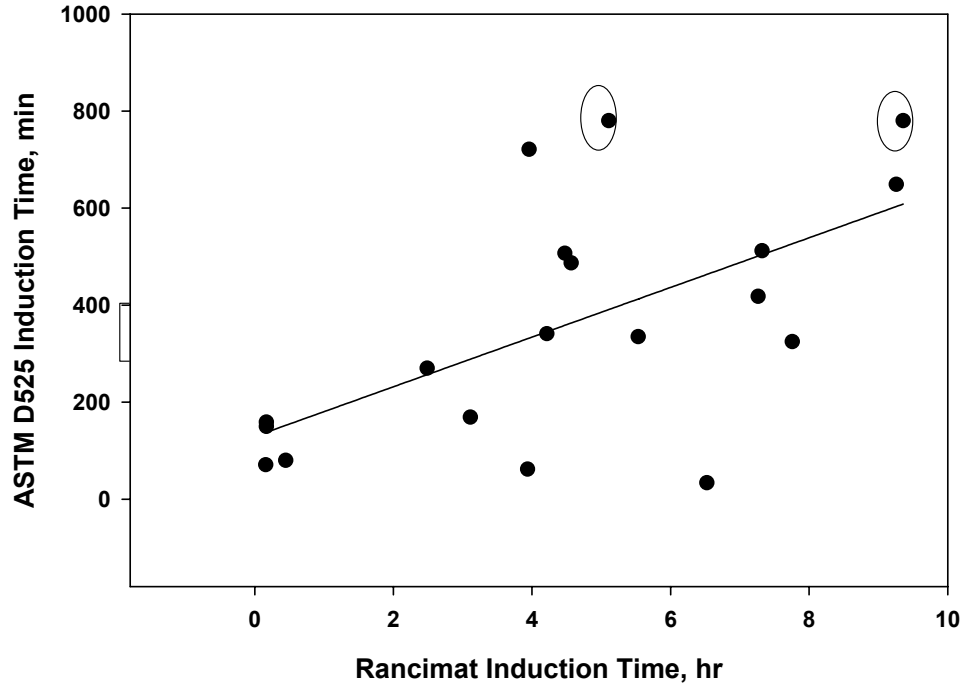


Figure 3. Relationship between Rancimat and ASTM D525 results (Circled data points indicate that no oxidation was observed after 780 minutes, and the results are simply plotted as 780 minutes.)

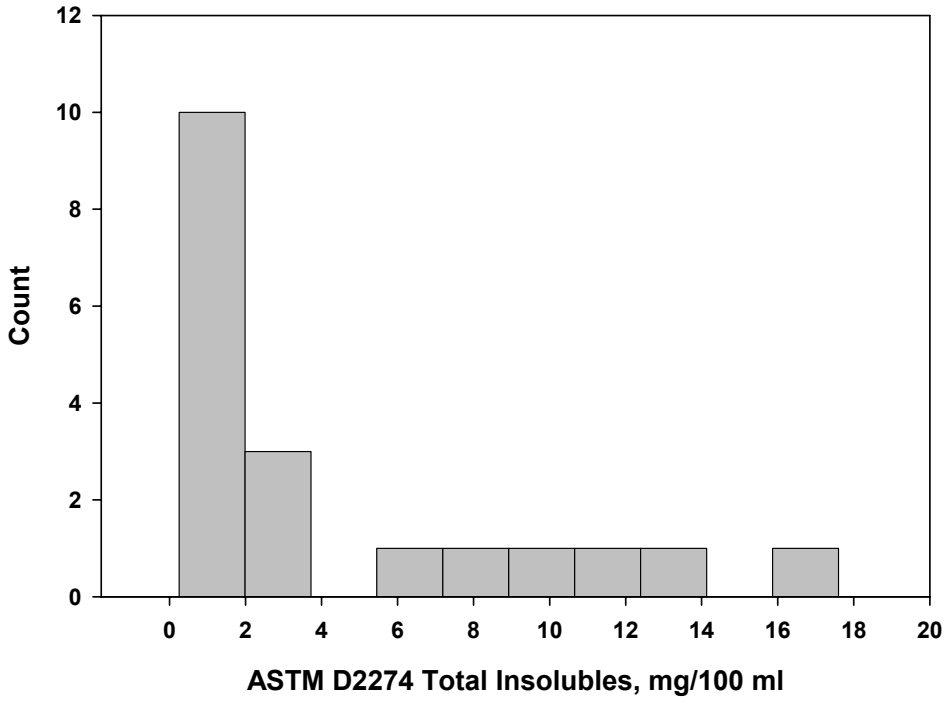


Figure 4. Histogram for B100 ASTM D2274 total insolubles

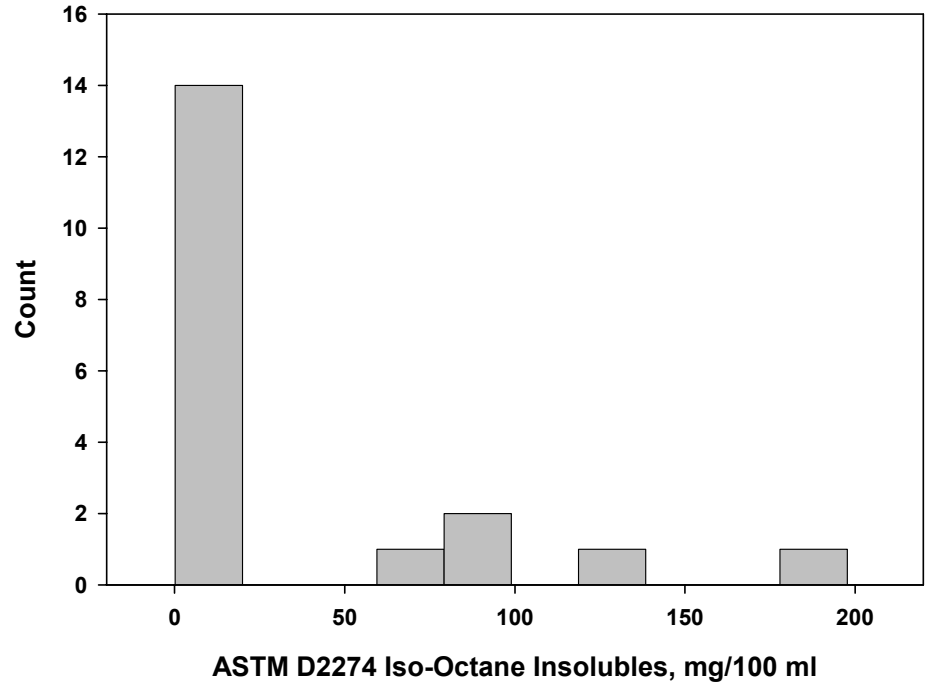


Figure 5. Histogram for B100 ASTM D2274 iso-octane insolubles

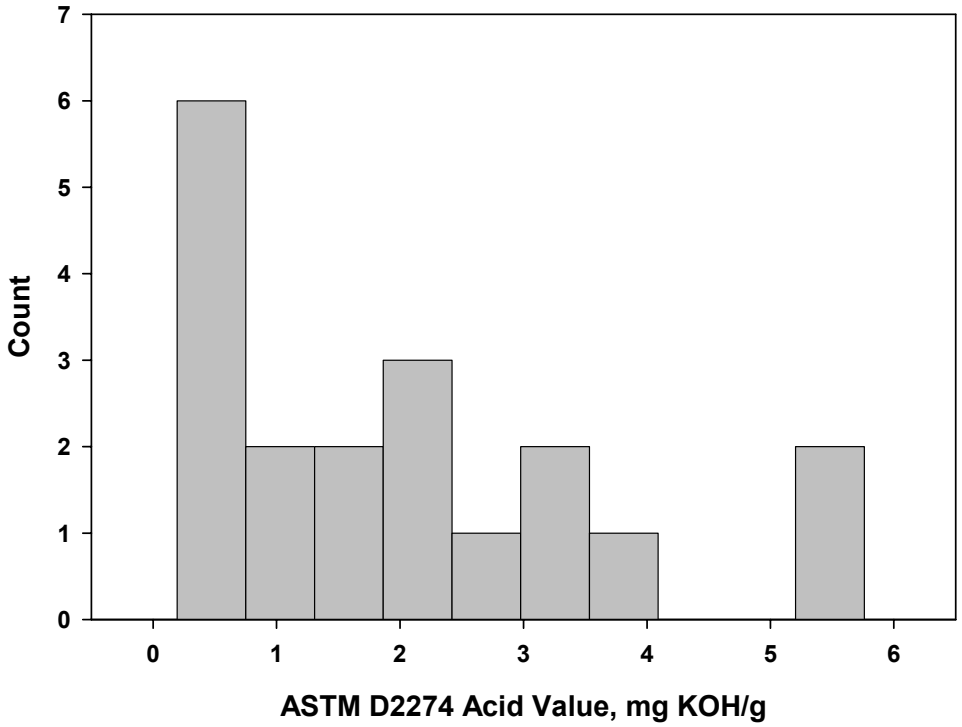


Figure 6. Histogram for B100 ASTM D2274 acid value

Table 2. Results of ASTM D6468 Performed at 150°C/180 Minutes/350 ml Sample Size with Gravimetric Determination of Deposits

Sample Identification	ASTM D6468 Modified
	Thermal Stability, deposit, mg
AL-27128-F	0.3
AL-27129-F	0.1
AL-27137-F	0.3
AL-27138-F	0.3
AL-27140-F	0.4
AL-27141-F	0.2
AL-27142-F	0.3
AL-27144-F	0.4
AL-27145-F	0.4
AL-27146-F	0.5
AL-27148-F	0.4
AL-27152-F	0.1
AL-27153-F	0.5
AL-27154-F	0.1
AL-27155-F	0.3
AL-27157-F	0.3
AL-27158-F	0.6
AL-27160-F	0.5
AL-27161-F	0.2

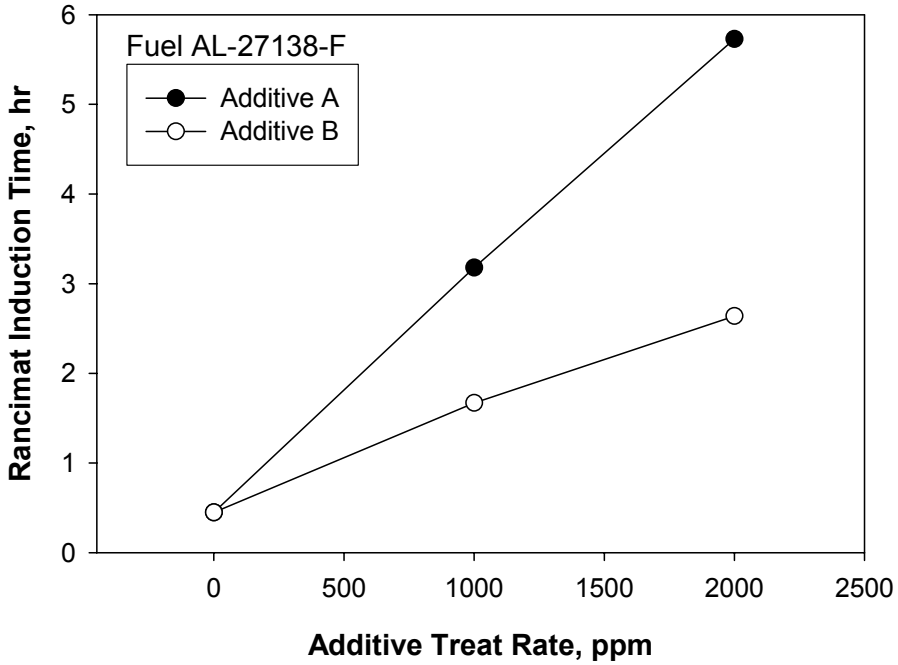
B100 Antioxidant Testing

Biodiesel sample AL-27129-F and AL-27138-F were treated with two commercial antioxidants. Antioxidant treat rates as well as Rancimat induction times and total insolubles from ASTM D2274 are given in Table 3. Both additives are highly effective at increasing Rancimat induction time and reducing insoluble formation for these samples. The biodiesel fuels were selected to represent unstable fuel (AL-27138-F) with Rancimat of 0.45 hr and moderately stable fuel (AL-27129-F) with Rancimat of 3.11 hr. Additive response curves for the unstable biodiesel fuel are shown in Figure 7. For increasing induction time, additive A seems to be more effective; while for reducing total deposits, additive B may be slightly more effective. Both additives were effective for reducing iso-octane insoluble formation. For the moderately stable curve only one treat rate was tested for each additive, and results are shown in Figure 8. In this fuel, additive A is also more effective at increasing induction time. For insoluble formation these data are not sufficient to distinguish between the additives, but both are effective.

These biodiesel samples are currently being tested using ASTM D4625—the 12-week, storage-stability test. In addition, B5 and B20 blends are being prepared using two of the ULSD fuels, and these will also be subjected to accelerated stability tests and real-world aging simulations.

Table 3. Results of Accelerated Stability Tests for Biodiesel Treated with Antioxidant Additives

Sample Number	Description	Rancimat Induction Time	ASTM D2274		
			Total Insoluble	i-Octane Insoluble	Acid Value
		hr	mg/100 ml	mg/100 ml	mg KOH/g
	AL-27138 with no additive	0.45	7.6	4.4	3.01
06-0077	AL-27138 plus 1000 ppm additive A	3.18	6.5	1.0	2.35
06-0078	AL-27138 plus 2000 ppm additive A	5.73	0.3	1.6	0.40
06-0079	AL-27138 plus 1000 ppm additive B	1.67	3.0	0.6	2.49
06-0080	AL-27138 plus 2000 ppm additive B	2.64	0.8	0.3	1.28
	AL-27129 with no additive	3.11	1.9	2.6	2.50
06-0081	AL-27129 plus 1000 ppm additive A	22.82	0.1	0.5	0.45
06-0082	AL-27129 plus 1000 ppm additive B	6.87	0.2	0.1	0.47



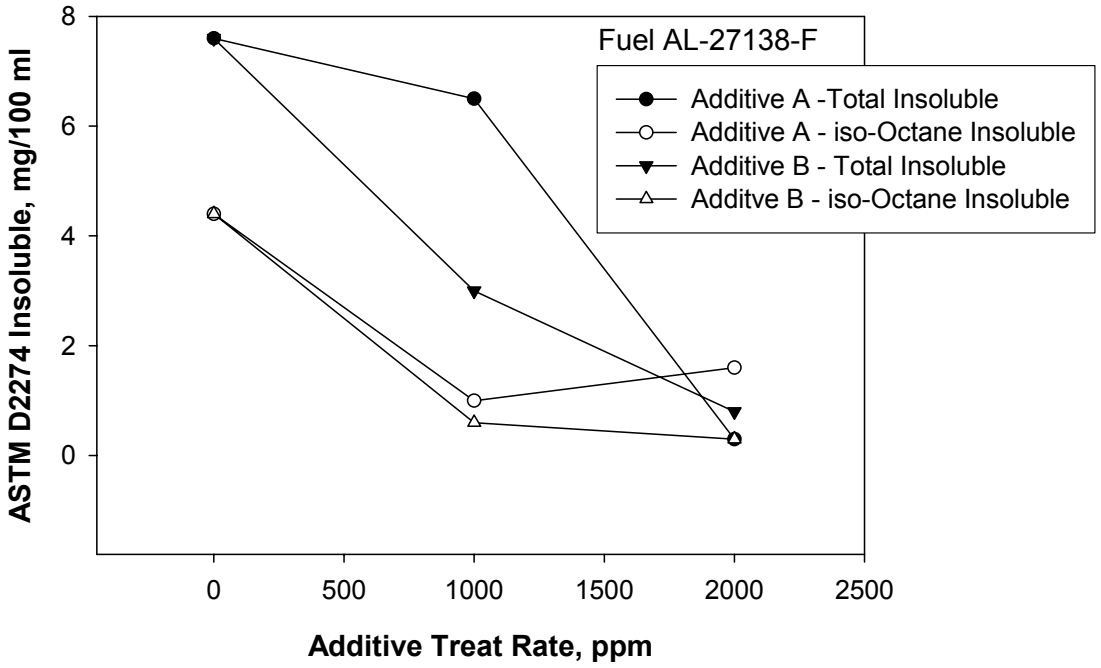
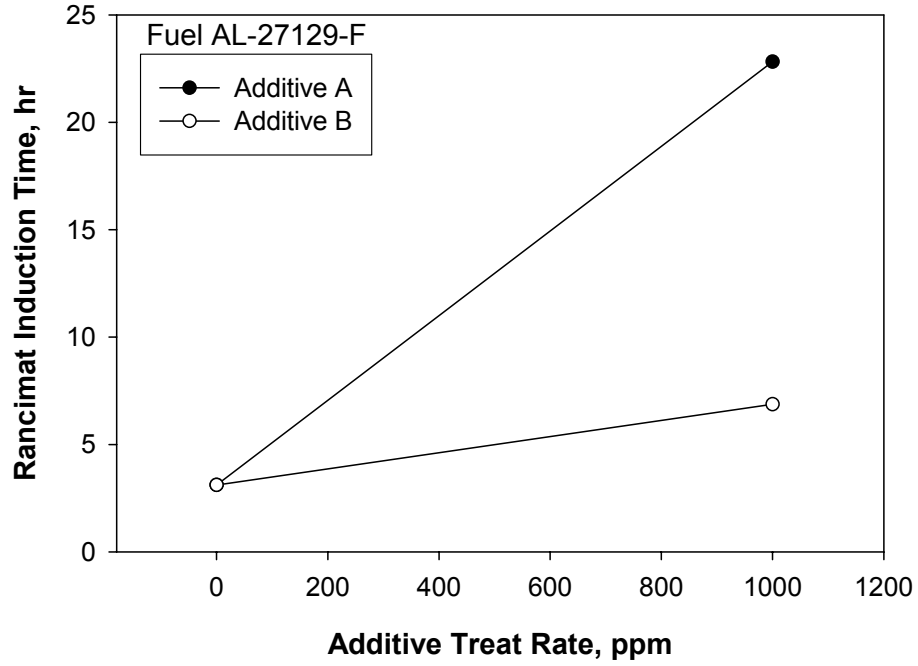


Figure 7. Additive response curves for unstable biodiesel AL-27138-F



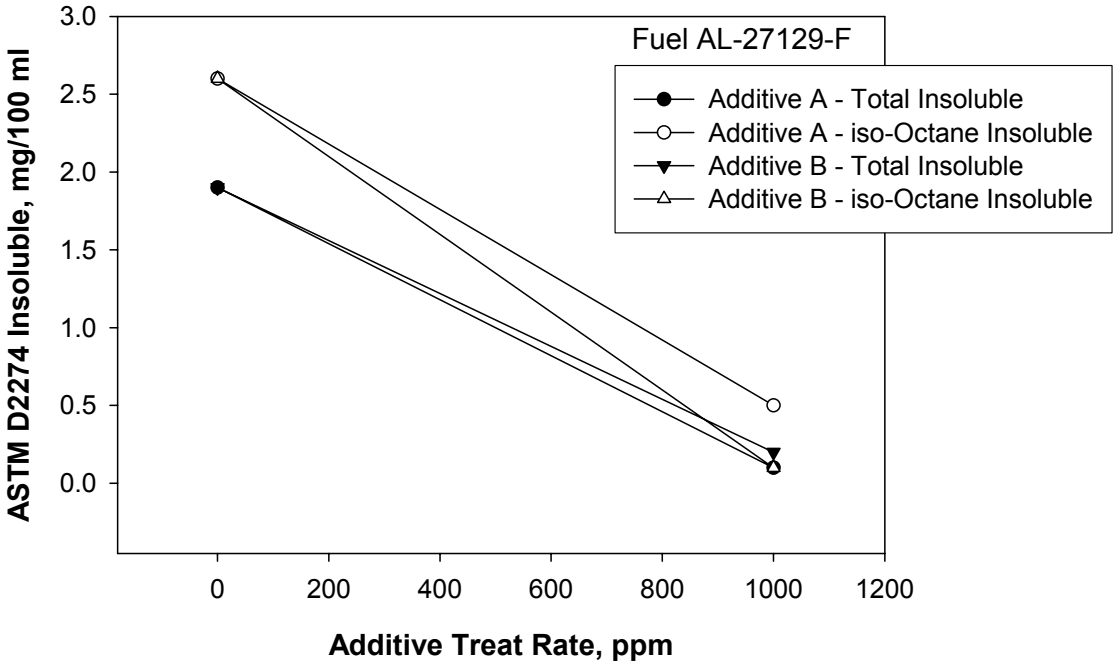


Figure 8. Additive response curves for moderately stable biodiesel AL-27129-F

Diesel Fuel Samples

Characterization results for the six diesel fuel samples are shown in Table 4. Five are ULSD, and one is a current on-road diesel fuel. Based on the distillation T90, samples AL2715F, AL27166F, and AL27176F are No. 1 diesel fuels; the others are No. 2 diesel fuels. Aromatic content is regarded as an important parameter for this study because fuels with higher aromatic content may be able to more readily solvate oxidized biodiesel molecules, which would otherwise precipitate as deposits in fuels with lower aromatic content. Total aromatics for the ULSD samples range from 8.2 to 22.1 mass percent. There is great uncertainty as to exactly what commercial ULSD will look like when introduced in October 2006. Thus, these ULSD fuels might not be representative of commercial ULSD. However, these are the ULSD fuels that the petroleum refining industry supplied to NREL in December 2005. All samples exhibited good stability on both D2274 and D6468.

Table 4. Characterization Results for Petroleum Diesel Samples to be Used in Preparation of B5 and B20 Blends

	Sample:	ASTM D975 Limit (No. 2 Diesel)	AL27150F	AL27151F	AL27166F	AL27171F	AL27175F	AL27176F
ASTM D93	Flash Point, ºC	52	56	69	59	73	59	69
ASTM D5453	Sulfur, ppm	15 or 500	7.4	6.7	5.8	339.6	2.9	7.4
ASTM D86	T90, ºC	282 min 338 max	274	313	269	319	333	236
ASTM D524	Carbon Residue (10%), mass%	0.35	0.07	0.04	0.06	0.13	0.05	0.08
ASTM D664	Acid Number, mg KOH/g	none	0.01	0.03	0.01	0.01	0.01	0.01
ASTM D3703	Peroxide Number	none	<1	<1	<1	<1	<1	<1
ASTM D2709	Water and Sediment, vol%	0.05	0.01	0.01	0.01	0.01	0.01	0.01
ASTM D482	Ash Content, mass%	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ASTM D5186	Total Aromatics, mass%	none	15.7	22.1	18.1	36.2	8.2	19.3
	Monoaromatics, mass%	none	14.4	19.9	17.1	27.6	7	17.4
	Polynuclear Aromatics, mass%	none	1.3	2.1	1	8.7	1.2	1.9
ASTM D2274	Total Insolubles, mg/100 ml	none	0.25	0.25	0.5	0.2	0.1	0.05
ASTM D6468	Thermal Stability, 150ºC/180 min % Reflectance	none	100	100	100	--	95	100
ASTM D6217	Particulate Contamination, mg/L	none	0.5	0.4	0.8	0.8	1.2	0.3

Discussion and Recommendations

There are 19 B100 samples, and our intent is to select eight for long-term storage tests (D4625 for 12 weeks) and for preparation of B5 and B20 blends. The down selection was based on covering the full range (high, medium, low) of values for each of the accelerated tests (see Appendix) and to include the full range of feedstocks. However, results for D6468 showed low levels of deposits (gravimetric) for all samples, so that test is not considered here. Additionally, the two B100 samples—which were out of spec for either acid value or total glycerin—are not considered further. The samples selected are shown in Table 5. Obviously some compromises were made to meet all of the study objectives, including covering all feedstocks. If questions arise at a later date, other samples can be added to the test matrix.

Table 5. B100 Samples Selected for Long-Term Storage and Blending Studies

	Feedstock	Rancimat	D525	D2274 Total	D2274 i-Octane
Observed Range:		0.2 – 9.4 hr	34 - >780 min	0.3 – 17.6 mg/100 ml	0.2 – 198 mg/100 ml
AL-27128-F	Canola	4.2 (med)	341 (med)	6.5 (med)	198 (high)
AL-27129-F	Palm Stearin	3.1 (med)	169 (med)	1.9 (low)	2.6 (low)
AL-27137-F	Soy	6.5 (high)	retesting	1.0 (low)	2.6 (low)
AL-27138-F	Soy	0.5 (low)	80 (low)	7.6 (med)	4.4 (low)
AL-27141-F	Soy	5.5 (high)	335 (med)	0.3 (low)	0.6 (low)
AL-27148-F	Grease	7.8 (high)	325 (med)	0.9 (low)	19 (med)
AL-27152-F	Rapeseed	7.3 (high)	418 (med)	0.5 (low)	6.4 (low)
AL-27160-F	Tallow	0.2 (low)	159 (low)	17.6 (high)	124 (high)

Appendix: Oxidation Stability Test Data

Sample Identification	Method	AL-27128-F	AL-27129-F	AL-27137-F	AL-27138-F	AL-27140-F	AL-27141-F
Oxidation Stability, hours	EN 14112						
Replicate 1		4.22	3.09	6.41	0.13	0.17	5.74
Replicate 2		4.18	3.10	6.55	0.62	0.17	5.75
Replicate 3		4.24	3.14	6.61	0.59	0.13	5.11
Mean		4.21	3.11	6.52	0.45	0.16	5.53
Oxidation Stability, mg/ 100 ml	Modified ASTM D2274						
Replicate 1							
Filterable insolubles		4.7	1.3	0.7	6.1	7.6	0.2
Adherent Insolubles		1.6	1.0	1.1	0.9	2.1	0.1
Total Insolubles		6.3	2.3	1.8	7.0	9.7	0.3
Iso-Octane Insolubles		197.4	4.7	2.4	4.0	64.1	0.7
Replicate 2							
Filterable insolubles		5.0	1.0	0.2	6.9	10.5	0.2
Adherent Insolubles		1.6	0.5	0.0	1.3	2.0	0.1
Total Insolubles		6.6	1.5	0.2	8.2	12.5	0.3
Iso-Octane Insolubles		198.0	0.4	2.8	4.8	73.0	0.5
Mean Total Insolubles		6.5	1.9	1.0	7.6	11.1	0.3
Mean Iso-Octane Insolubles		197.7	2.6	2.6	4.4	68.6	0.6
Oxidation Stability, Pressure Vessel	ASTM D525						
Induction Period Method, minutes		341	169	34	80	71	335
Thermal Stability, deposit, mg	ASTM D6468 Modified	0.3	0.1	0.3	0.3	0.4	0.2
Total Acid Number, mg KOH/g	ASTM D664	0.23	0.41	0.05	0.33	0.2	0.13
Total Acid Number after D2274, mg KOH/g							
Replicate 1		1.84	2.92	0.24	2.75	3.83	0.79
Replicate 2		2.03	2.07	0.15	3.26	4.22	0.64
Mean		1.94	2.50	0.20	3.01	4.03	0.72
Total Glycerin, %(mass)	ASTM D6584	0.103	0.081	0.144	0.016	0.022	0.121
Free Glycerin, %(mass)	ASTM D6584	0.009	<0.001	0.002	0.002	0.015	0.005

Sample Identification	Method	AL-27142-F	AL-27144-F	AL-27145-F	AL-27146-F	AL-27148-F	AL-27152-F
Oxidation Stability, hours	EN 14112						
Replicate 1		4.56	3.69	3.70	9.28	7.82	7.24
Replicate 2		4.46	4.02	4.01	9.33	7.76	7.24
Replicate 3		4.40	4.10	4.16	9.16	7.69	7.31
Mean		4.47	3.94	3.96	9.26	7.76	7.26
Oxidation Stability, mg/ 100 ml	Modified ASTM D2274						
Replicate 1							
Filterable insolubles		0.9	2.0	2.0	0.3	0.8	0.4
Adherent Insolubles		0.2	0.3	0.4	0.1	0.1	0.1
Total Insolubles		1.1	2.3	2.4	0.4	0.9	0.5
Iso-Octane Insolubles		0.3	1.4	2.7	0.4	22.1	6.2
Replicate 2							
Filterable insolubles		0.9	2.2	2.0	0.2	0.7	0.3
Adherent Insolubles		0.2	0.1	0.2	0.0	0.1	0.2
Total Insolubles		1.1	2.3	2.2	0.2	0.8	0.5
Iso-Octane Insolubles		0.7	1.3	0.7	0.4	15.7	6.5
Mean Total Insolubles		1.1	2.3	2.3	0.3	0.9	0.5
Mean Iso-Octane Insolubles		0.5	1.4	1.7	0.4	18.9	6.4
Oxidation Stability, Pressure Vessel	ASTM D525						
Induction Period Method, minutes		507	62	721	649	325	418
Thermal Stability, deposit, mg	ASTM D6468 Modified	0.3	0.4	0.4	0.5	0.4	0.1
Total Acid Number, mg KOH/g	ASTM D664	0.07	0.39	0.49	0.08	0.69	0.09
Total Acid Number after D2274, mg KOH/g							
Replicate 1		1.11	1.91	2.18	0.19	1.56	0.73
Replicate 2		0.90	1.83	2.13	0.20	1.37	0.68
Mean		1.01	1.87	2.16	0.20	1.47	0.71
Total Glycerin, %(mass)	ASTM D6584	0.216	0.221	0.192	0.161	0.121	0.15
Free Glycerin, %(mass)	ASTM D6584	0.003	0.004	0.005	<0.001	<0.001	0.001

Sample Identification	Method	AL-27153-F	AL-27154-F	AL-27155-F	AL-27157-F	AL-27158-F	AL-27160-F
Oxidation Stability, hours	EN 14112						
Replicate 1		9.36	0.14	2.60	4.67	7.18	0.18
Replicate 2		9.36	0.18	2.59	4.56	7.26	0.14
Replicate 3		9.35	0.18	2.27	4.47	7.52	0.18
Mean		9.36	0.17	2.49	4.57	7.32	0.17
Oxidation Stability, mg/ 100 ml	Modified ASTM D2274						
Replicate 1							
Filterable insolubles		0.2	12.3	9.4	1.5	0.2	11.0
Adherent Insolubles		0.1	1.3	1.5	0.5	0.1	2.1
Total Insolubles		0.3	13.6	10.9	2.0	0.3	13.1
Iso-Octane Insolubles		0.2	87.6	94.6	2.8	0.5	120.9
Replicate 2							
Filterable insolubles		0.2	11.1	8.5	1.5	0.2	18.0
Adherent Insolubles		0.0	1.5	1.3	0.8	0.1	4.1
Total Insolubles		0.2	12.6	9.8	2.3	0.3	22.1
Iso-Octane Insolubles		0.2	ND	95.8	2.8	0.0	126.7
Mean Total Insolubles		0.3	13.1	10.4	2.2	0.3	17.6
Mean Iso-Octane Insolubles		0.2	87.6	95.2	2.8	0.3	123.8
Oxidation Stability, Pressure Vessel	ASTM D525						
Induction Period Method, minutes		>780	150	270	487	512	159
Thermal Stability, deposit, mg	ASTM D6468 Modified	0.5	0.1	0.3	0.3	0.6	0.5
Total Acid Number, mg KOH/g	ASTM D664	0.08	**1.31**	0.29	0.11	0.51	0.46
Total Acid Number after D2274, mg KOH/g							
Replicate 1		0.21	5.54	3.21	1.05	0.70	5.12
Replicate 2		0.27	ND	2.93	1.19	0.69	6.40
Mean		0.24	5.54	3.07	1.12	0.70	5.76
Total Glycerin, %(mass)	ASTM D6584	0.15	0.132	**0.298**	0.225	0.158	0.188
Free Glycerin, %(mass)	ASTM D6584	0.001	0.003	0.007	0.015	0.001	0.002

Sample Identification	Method	AL-27161-F
Oxidation Stability, hours	EN 14112	
Replicate 1		5.13
Replicate 2		5.11
Replicate 3		5.09
Mean		5.11
Oxidation Stability, mg/ 100 ml	Modified ASTM D2274	
Replicate 1		
Filterable insolubles		1.0
Adherent Insolubles		0.1
Total Insolubles		1.1
Iso-Octane Insolubles		0.60
Replicate 2		
Filterable insolubles		0.8
Adherent Insolubles		0.2
Total Insolubles		1.0
Iso-Octane Insolubles		0.80
Mean Total Insolubles		1.1
Mean Iso-Octane Insolubles		0.7
Oxidation Stability, Pressure Vessel	ASTM D525	
Induction Period Method, minutes		>780
Thermal Stability, deposit, mg	ASTM D6468 Modified	0.2
Total Acid Number, mg KOH/g	ASTM D664	0.37
Total Acid Number after D2274, mg KOH/g		
Replicate 1		1.63
Replicate 2		1.50
Mean		1.57
Total Glycerin, %(mass)	ASTM D6584	0.151
Free Glycerin, %(mass)	ASTM D6584	0.003

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This is an interim report for a study of biodiesel oxidative stability. It describes characterization and accelerated stability test results for 19 B100 samples and six diesel fuels.

15. SUBJECT TERMS
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