



Assessment of BQ-9000 Biodiesel Properties for 2019

Teresa L. Alleman

National Renewable Energy Laboratory

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Technical Report
NREL/TP-5400-76840
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Acknowledgments

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List of Acronyms

ASTM	ASTM International
B100	neat (100% by volume) biodiesel
CSFT	cold soak filterability test
NREL	National Renewable Energy Laboratory

Executive Summary

This is the third report in the series documenting the annual quality of neat biodiesel (B100) produced and sold in the United States and Canada in calendar year 2019. The data only includes companies that participate in the industry's voluntary quality program, BQ-9000. Each company that agreed to provide monthly data did so voluntarily to a third-party group. This third-party group of industry experts removed any identifying information and randomized the data prior to providing the data to the National Renewable Energy Laboratory (NREL) for statistical analysis. The quality parameters covered in this report are: sodium and potassium (Na+K); calcium and magnesium (Ca+Mg); phosphorus (P); flash point or alcohol control; water and sediment; cloud point; acid number; free and total glycerin; monoglycerides; sulfur; oxidation stability; visual appearance, and cold soak filterability test (CSFT). The results are summarized in Table ES-1.

Table ES-1. BQ-9000 Critical Parameter Summary Table, Calendar Year 2019

BQ-9000 Parameter	# of Values Reported	Minimum	Maximum	Average	Median	Standard Deviation	95th Percentile
Na+K, ppm	383	0	5	0.588	0.260	0.857	2.423
Ca+Mg, ppm	381	0	3.397	0.206	0.047	0.437	1.069
P, ppm	361	0	10	0.465	0	1.593	3.000
Flash Point, °C	479	95	200	152	157	25	105 ^a
Alcohol Control, mass%	197	0	0.200	0.072	0.070	0.048	0.140
Water and Sediment, vol%	295	0	0.025	0.002	0	0.004	0.010
Cloud Point, °C	523	-6.0	15.8	0.956	0	3.848	10
Acid Number, mg KOH/g	521	0.070	0.490	0.266	0.270	0.103	0.431
Free Glycerin, mass%	490	0	0.020	0.005	0.005	0.004	0.013
Total Glycerin, mass%	523	0	0.228	0.094	0.101	0.045	0.171
Monoglycerides, mass%	511	0.008	0.666	0.269	0.309	0.123	0.418
Sulfur, ppm	501	0	15	4.081	2.800	3.938	11.800
Oxidation Stability, hr.	523	3.800	24.200	9.107	8.446	2.930	5.3 ^a
Cold Soak Filterability Test, sec	523	61	330	101	95	25	153

a: Data is for 5th percentile

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1 Introduction

The National Renewable Energy Laboratory (NREL) has a long collaboration with the biodiesel industry and has leveraged this relationship to acquire data for this report. This report, the third in an ongoing series, summarizes the quality of biodiesel produced and sold in the United States and Canada. This report covers calendar year 2019, with previous reports for 2017 and 2018 (Alleman 2020a; Alleman 2020b). The analysis was limited to producers that participate in the voluntary biodiesel industry quality program, BQ-9000.¹

The BQ-9000 program requires analysis of many critical fuel quality parameters: sodium and potassium (Na+K), calcium and magnesium (Ca+Mg), phosphorus (P), flash point or alcohol control, water and sediment, cloud point, acid number, free and total glycerin, monoglycerides, sulfur (S), oxidation stability, visual appearance, and cold soak filterability test (CSFT). This report covers 6,211 individual data points for calendar year 2019.

2 Methods

Similar to previous reports, Mr. Scott Fenwick of the National Biodiesel Board, Mr. Steve Howell of M4 Consulting, and Dr. Richard Nelson of Enersol Resources contacted participants in the BQ-9000 program and requested their monthly fuel quality data. Fuel quality data were provided voluntarily to this third-party team for calendar year 2019.

The data set was anonymized by removing identifying information such as company name, location, and production lot. To further ensure confidentiality of participants, each parameter was independently randomized, and the resulting “clean” data set provided to NREL for statistical analysis. The analysis included minimum and maximum, average and median, standard deviation, and 95th percentile. The 5th percentile was reported for flash point and oxidation stability.

The participating producers were asked to provide data “as-is,” which meant that data fell into two categories (similar to previous years): actual values, or values provided as “greater than” or “less than.” In the case where actual values were provided by the producer, these values were used in the analysis. Data reported as “greater than” and “less than” were removed from the data set presented in the body of the report. For example, a flash point reported as >130°C was removed from the main body of the report but was included in the Appendix and assumed to have a flash point of 130°C.

3 Results

The property limitations for biodiesel are set in ASTM International (ASTM) D6751, *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels* (ASTM 2020). ASTM D6751 also lists applicable test methods and discusses the significance of the test parameters.

¹ Additional discussion of the BQ-9000 program is available at bq-9000.org and in Alleman 2020a.

Following are the results from analysis of the 2019 data set by critical parameter.

3.1 Sodium and Potassium

Na+K averaged 0.6 parts per million (ppm) for 2019 (Figure 1). The 95th percentile was 2.42 ppm and the median was 0.26 ppm.

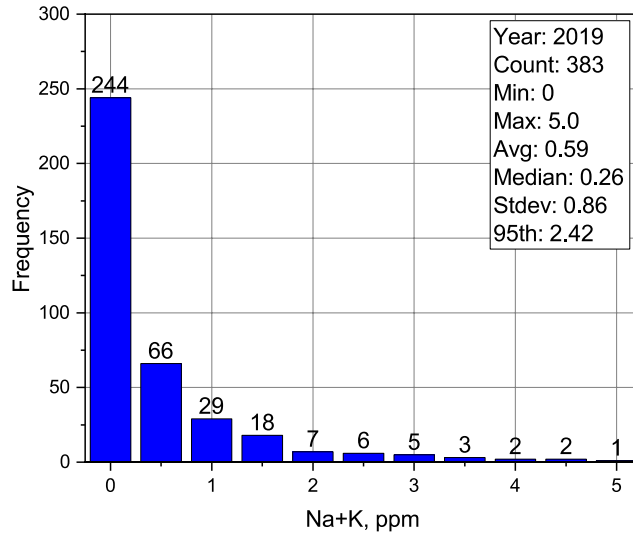


Figure 1. Sodium and potassium content for biodiesel samples produced January–December 2019

3.2 Calcium and Magnesium

The average Ca+Mg for biodiesel produced in 2019 was 0.21 ppm and the median was 0.05 ppm, as shown in Figure 2. The 95th percentile of the data was 1.10 ppm.

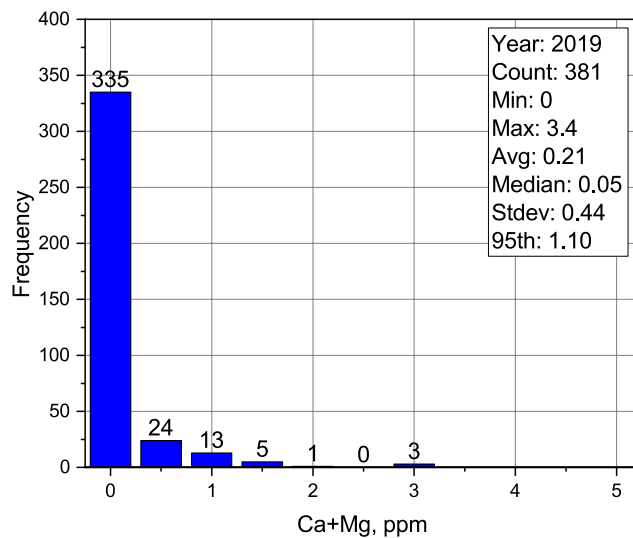


Figure 2. Calcium and magnesium content for biodiesel samples produced January–December 2019

3.3 Phosphorus

Figure 3 illustrates the P content, with an average of 0.46 ppm. The median P content was 0 ppm and the 95th percentile was 3.00 ppm.

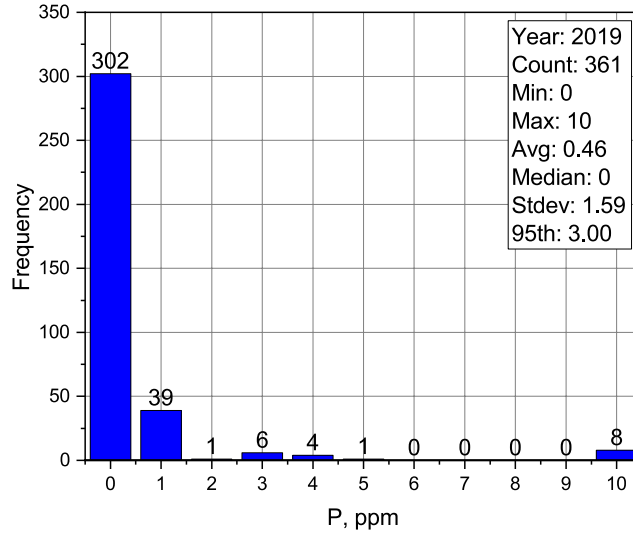


Figure 3. Phosphorus content for biodiesel samples produced January–December 2019

3.4 Alcohol Control and Flash Point

The average flash point of the 2019 biodiesel samples was 152°C, with a median of 157°C. The 5th percentile was 105°C (Figure 4). The average and median methanol content (Figure 5) was 0.072 mass%, the median was 0.070 mass%, and the 95th percentile was 0.14 mass%.

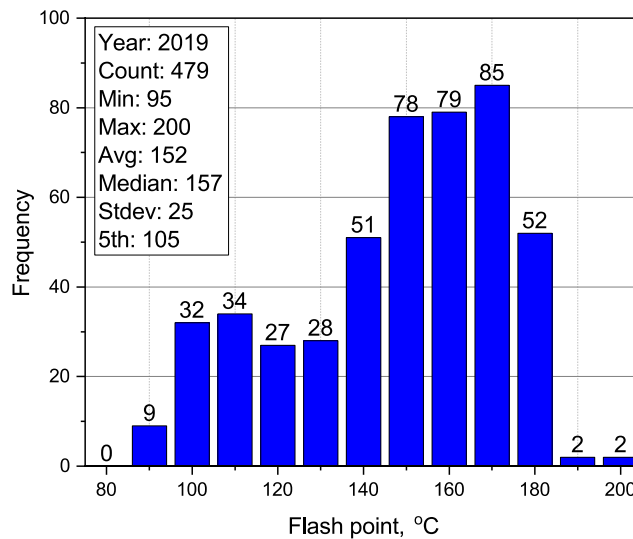


Figure 4. Flash point for biodiesel samples produced January–December 2019

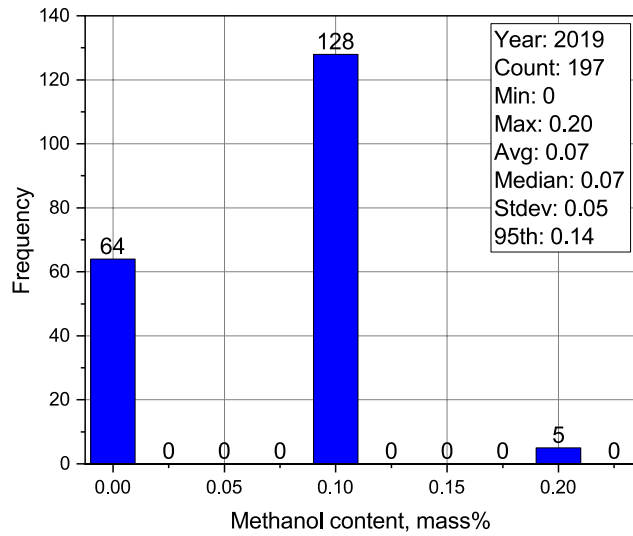


Figure 5. Methanol content for biodiesel samples produced January–December 2019

3.5 Water and Sediment

Figure 6 shows the water and sediment content, with an average of 0.002 vol%. The median was 0 vol% and the 95th percentile was 0.010 vol%. All producers reported samples as clear and bright.

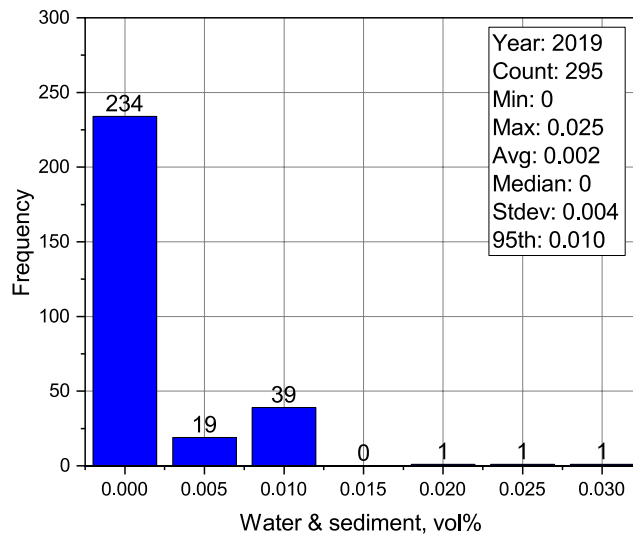


Figure 6. Water and sediment for biodiesel samples produced January–December 2019

3.6 Cloud Point

The average cloud point for the 2019 samples was 0.96°C, with a median of 0°C (Figure 7). The 95th percentile was 10°C. The cloud point is a “report value” and does not have a set minimum.

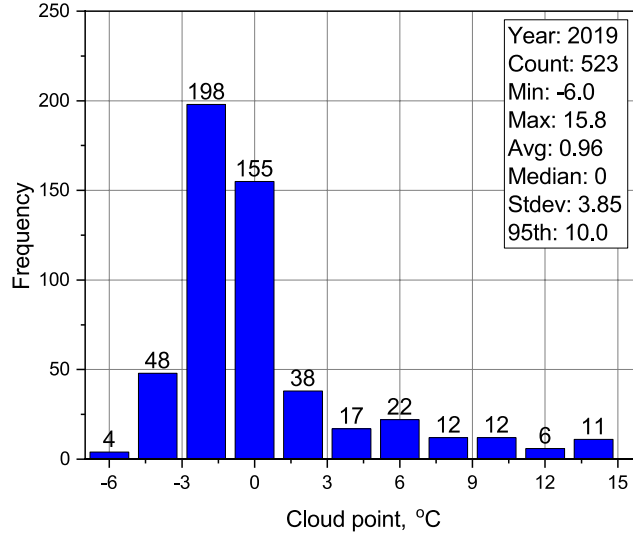


Figure 7. Cloud point for biodiesel samples produced January–December 2019

3.7 Acid Number

Figure 8 illustrates an average acid number of 0.27 milligrams potassium hydroxide per gram (mg KOH/g). The median acid number was also 0.27 mg KOH/g and the 95th percentile was 0.43 mg KOH/g.

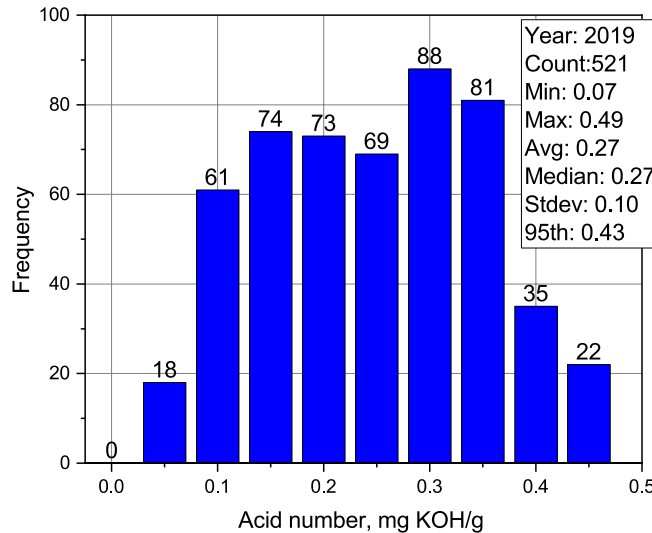


Figure 8. Acid number for biodiesel samples produced January–December 2019

3.8 Free and Total Glycerin

Free glycerin, shown in Figure 9, had an average 0.005 mass%, a median of 0.005 mass%, and a 95th percentile of 0.013 mass%. The total glycerin, shown in Figure 10, had an average 0.094 mass%. The median was 0.101 mass% and the 95th percentile was 0.171 mass%.

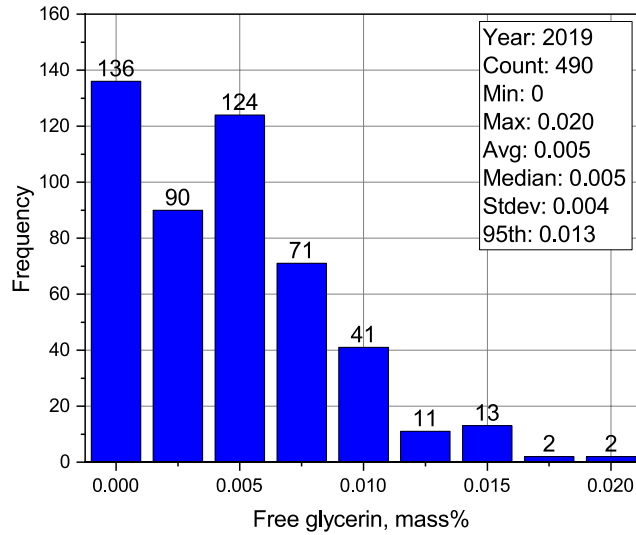


Figure 9. Free glycerin content for biodiesel samples produced January–December 2019

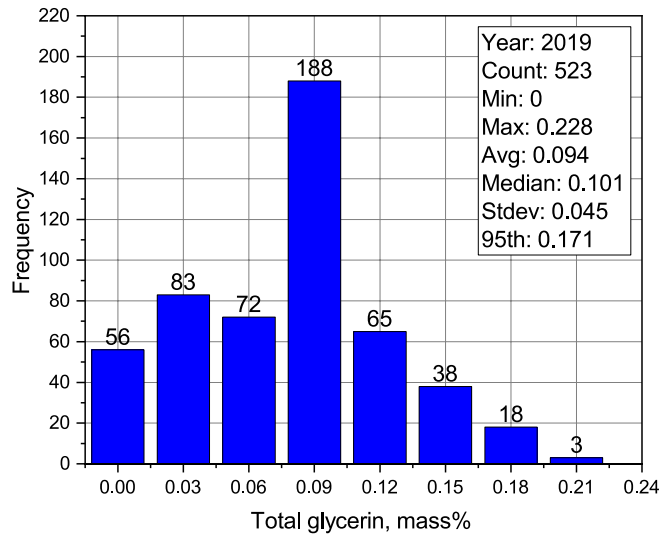


Figure 10. Total glycerin content for biodiesel samples produced January–December 2019

3.9 Monoglycerides

The average monoglyceride content in 2019, illustrated in Figure 11, was 0.269 mass%. The median was 0.309 mass% and the 95th percentile was 0.418 mass%.

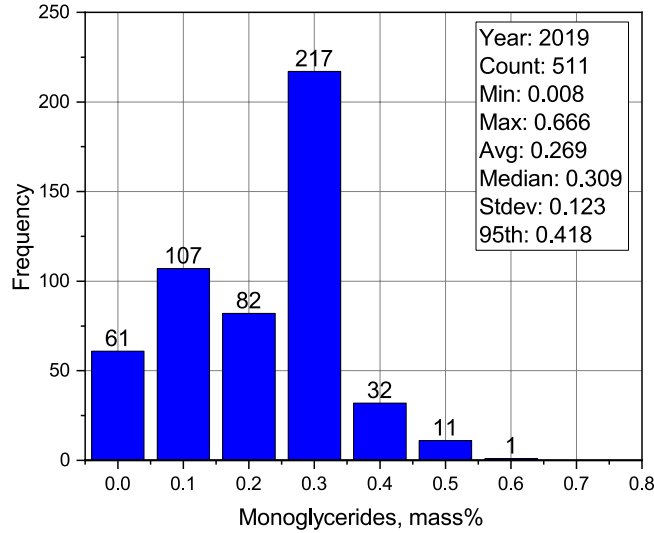


Figure 11. Monoglyceride content for biodiesel samples produced January–December 2019

3.10 Sulfur Content

Sulfur content of the biodiesel samples in 2019 averaged 4.1 ppm, with a median of 2.8 ppm and a 95th percentile of 11.8 ppm (Figure 12).

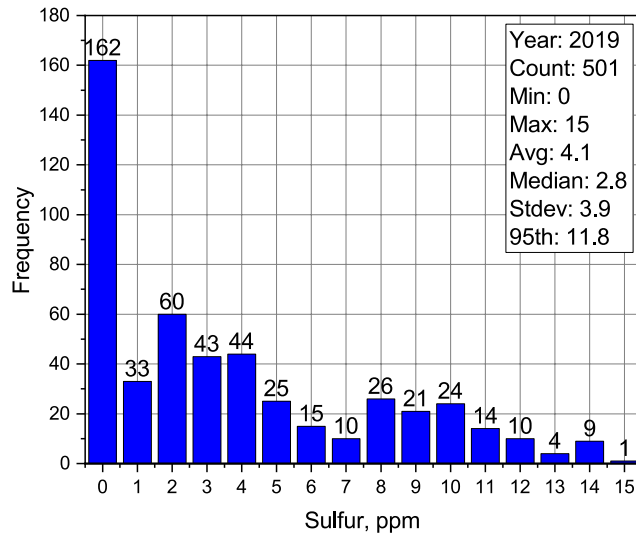


Figure 12. Sulfur content biodiesel samples produced January–December 2019

3.11 Oxidation Stability

The average oxidation stability of biodiesel samples in 2019 was 9.1 hours (Figure 13). The median was 8.5 hours and the 5th percentile was 5.3 hours.

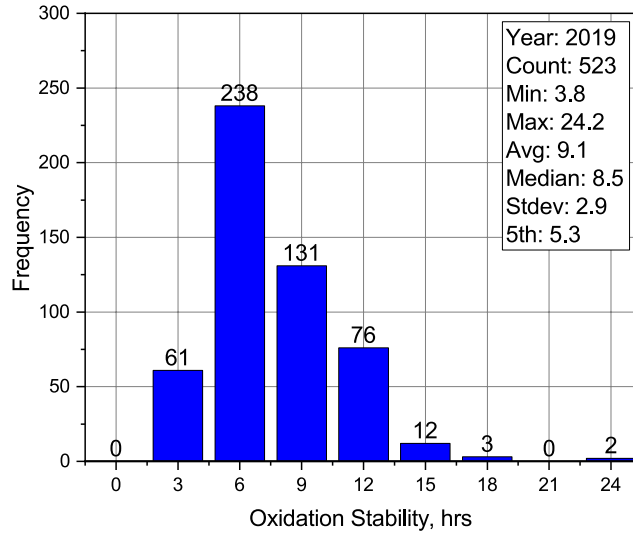


Figure 13. Oxidation stability for biodiesel samples produced January–December 2019

3.12 Cold Soak Filterability Test

Figure 14 shows the CSFT results from biodiesel produced in 2019. The average was 101 seconds, the median was 95 seconds, and the 95th percentile was 153 seconds.

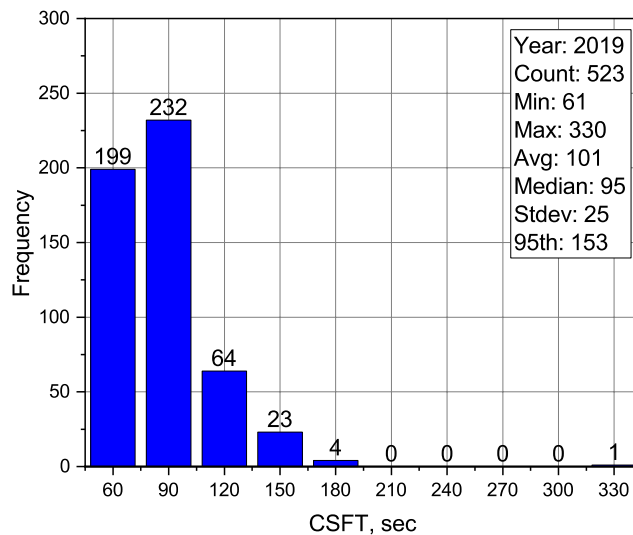


Figure 14. CSFT for biodiesel samples produced January–December 2019

4 Summary

Using industry-provided data, we analyzed monthly quality parameters of biodiesel produced and sold in the United States in calendar year 2019. The data were collected by a third-party team and anonymized and randomized prior to providing to NREL. All study participants provided data voluntarily and no identifying information on participants is available.

Similar to our previous reports (Alleman 2020a and 2020b), the analysis includes parameters critical to biodiesel quality and summarized in Table 1. The analysis shows biodiesel routinely met and exceeded the property limitations set forth in ASTM D6751 for biodiesel quality.

Table 1. BQ-9000 Critical Parameter Summary Table, Calendar Year 2019

BQ-9000 Parameter	Minimum	Maximum	Average	Median	95th Percentile
Na+K, ppm	0	5	0.588	0.260	2.423
Ca+Mg, ppm	0	3.397	0.206	0.047	1.069
P, ppm	0	10	0.465	0	3.000
Flash Point, °C	95	200	152	157	105 ^a
Alcohol Control, mass%	0	0.200	0.072	0.070	0.140
Water and Sediment, vol%	0	0.025	0.002	0	0.010
Cloud Point, °C	-6.0	15.8	0.956	0	10
Acid Number, mg KOH/g	0.070	0.490	0.266	0.270	0.431
Free Glycerin, mass%	0	0.020	0.005	0.005	0.013
Total Glycerin, mass%	0	0.228	0.094	0.101	0.171
Monoglycerides, mass%	0.008	0.666	0.269	0.309	0.418
Sulfur, ppm	0	15	4.081	2.800	11.800
Oxidation Stability, hr.	3.800	24.200	9.107	8.446	5.3 ^a
Cold Soak Filterability Test, sec	61	330	101	95	153

a: Data is for 5th percentile

References

Alleman, T.L. 2020a. *Assessment of BQ-9000 Biodiesel Properties for 2017*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-75795.

Alleman, T.L. 2020b. *Assessment of BQ-9000 Biodiesel Properties for 2018*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-75796.

ASTM International. 2020. *ASTM D6751, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels*. West Conshohocken, PA: ASTM International.
<http://doi.org/10.1520/D6751-20>.

Appendix

The figures included in the Appendix are for informational purposes only and include all data voluntarily submitted by producers participating in the BQ-9000 program in 2019. The data shown here assumes that any data point reported as “greater than” or “less than” was simply the value reported. For example, a reported Na+K of <1 ppm was assumed to be 1 ppm for this analysis. No statistics have been calculated on the data set due to this unique method of data handling.

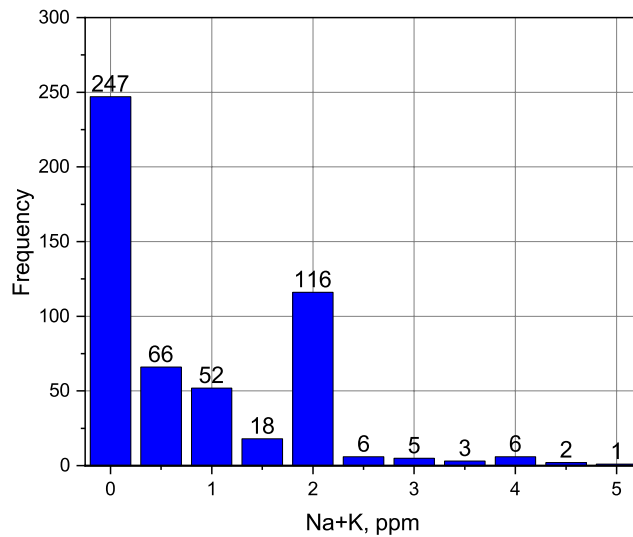


Figure A-1. All data analysis of sodium and potassium content for neat (100% by volume) biodiesel (B100) samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

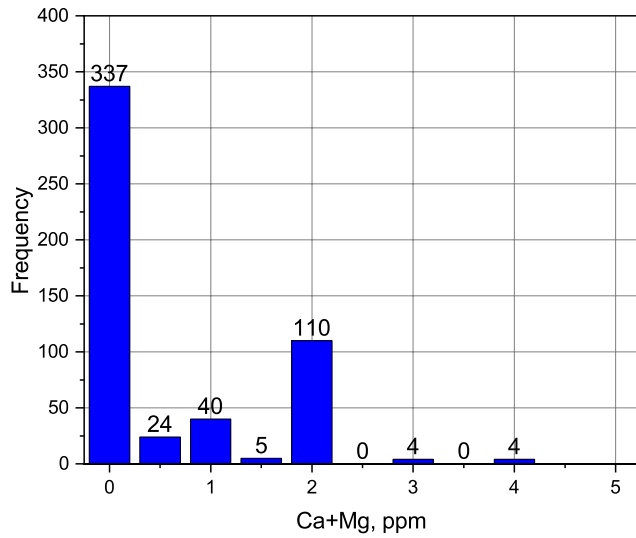


Figure A-2. All data analysis of calcium and magnesium content for B100 samples produced January–December 2019

Data reported as "greater than X" or "less than X" are assumed to have a value of X

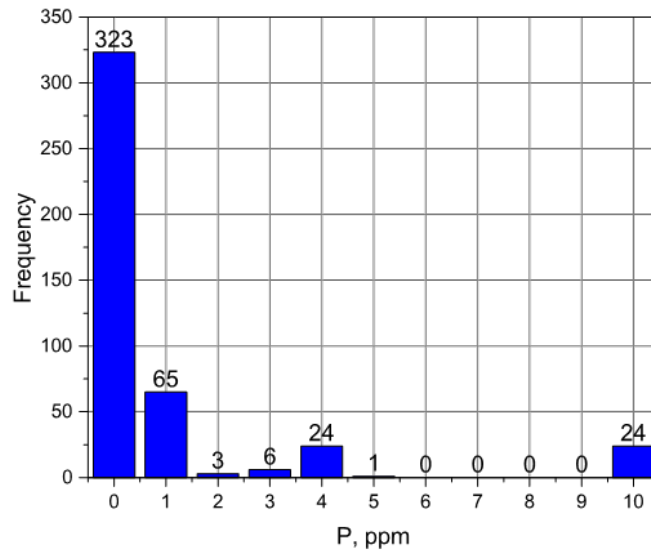


Figure A-3. All data analysis of phosphorus content for B100 samples produced January–December 2019

Data reported as "greater than X" or "less than X" are assumed to have a value of X

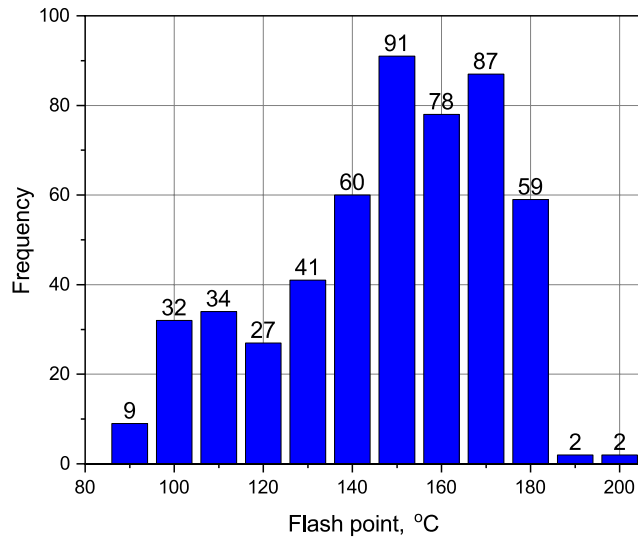


Figure A-4. All data analysis of flash point for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

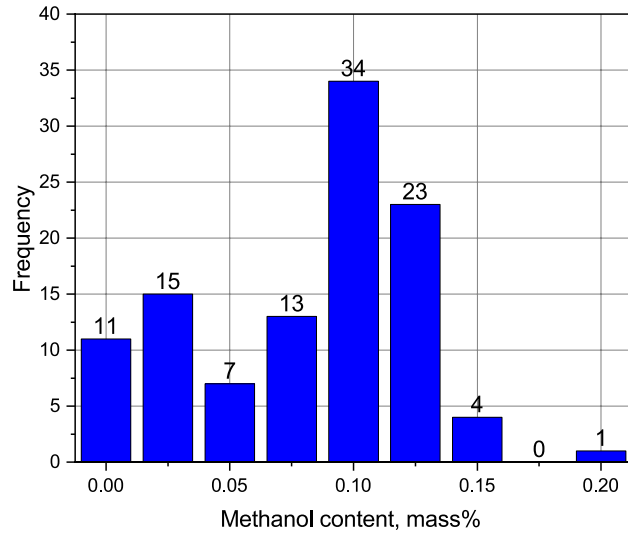


Figure A-5. All data analysis of alcohol control for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

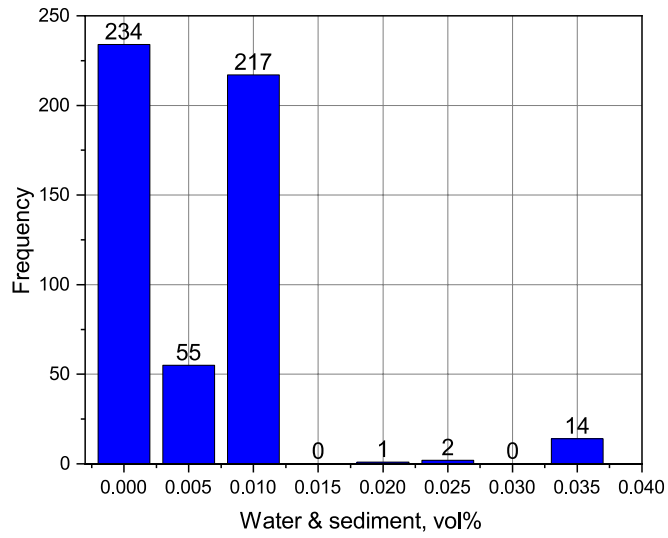


Figure A-6. All data analysis of water and sediment for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

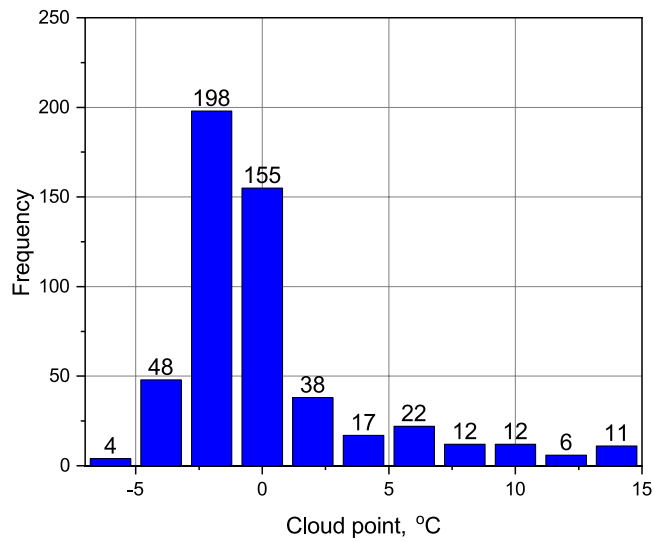


Figure A-7. All data analysis of cloud point for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

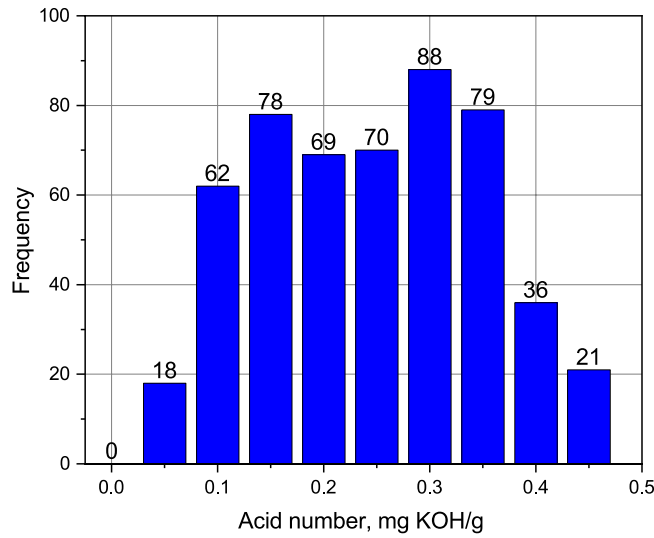


Figure A-8. All data analysis of acid number for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

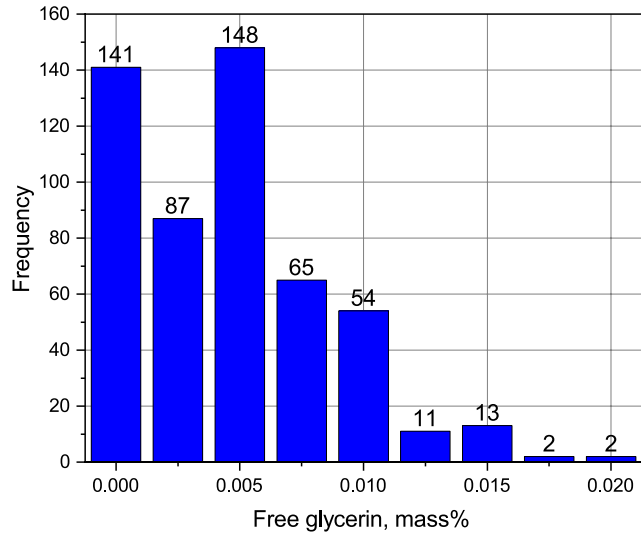


Figure A-9. All data analysis of free glycerin content for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

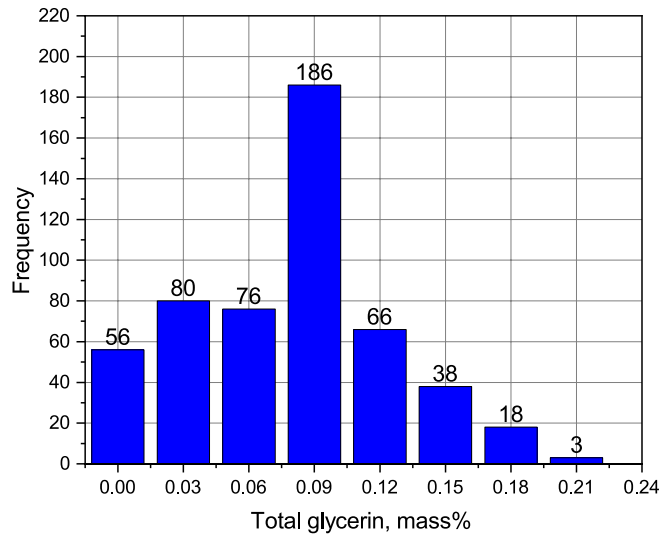


Figure A-10. All data analysis of total glycerin content for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

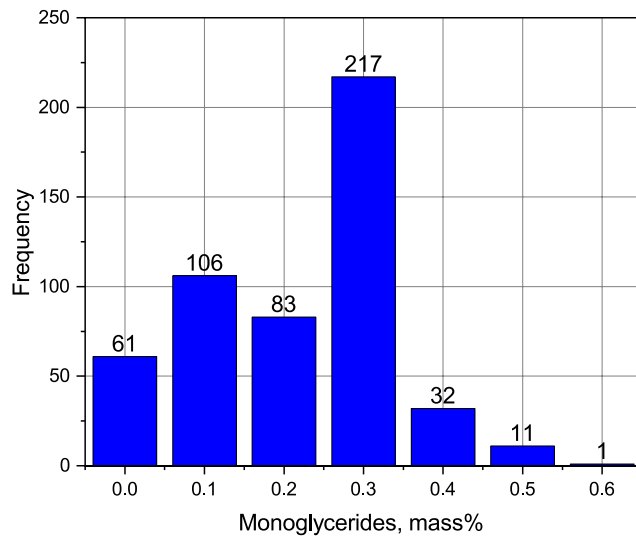


Figure A-11. All data analysis of monoglyceride content for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X

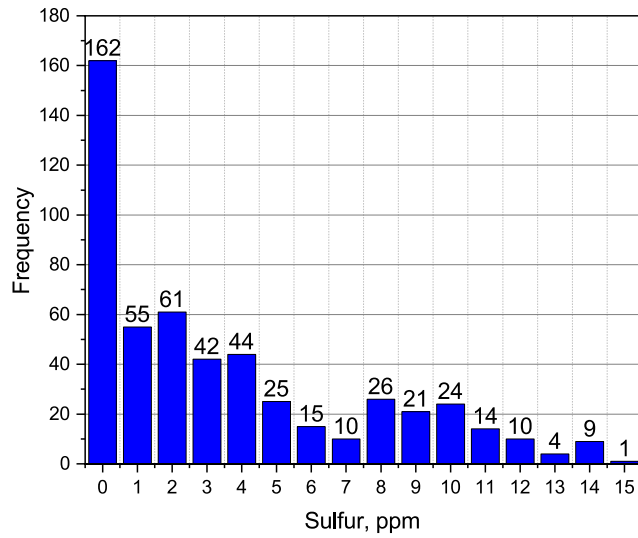


Figure A-12. All data analysis of sulfur content for B100 samples produced January–December 2019

Data reported as "greater than X" or "less than X" are assumed to have a value of X

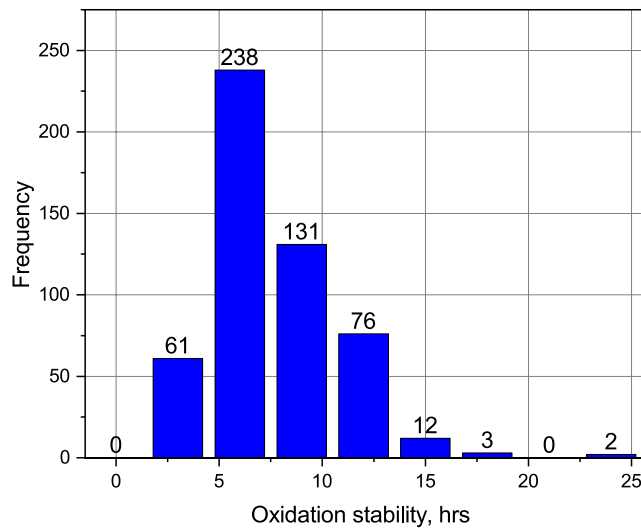


Figure A-13. All data analysis of oxidation stability for B100 samples produced January–December 2019

Data reported as "greater than X" or "less than X" are assumed to have a value of X

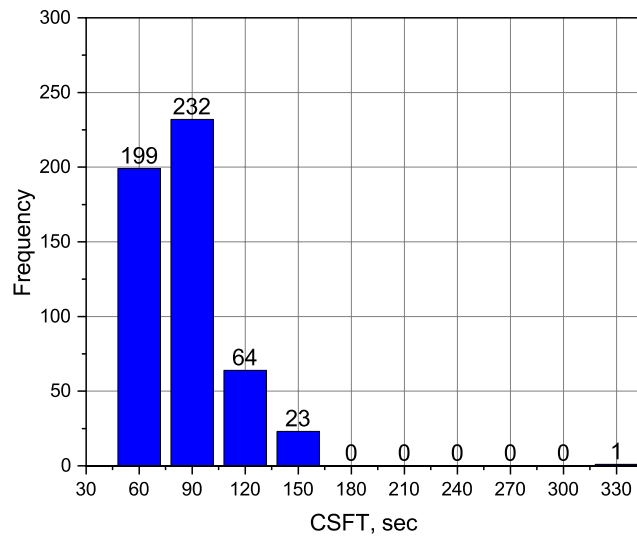


Figure A-14. All data analysis of CSFT for B100 samples produced January–December 2019

Data reported as “greater than X” or “less than X” are assumed to have a value of X