



# Assessment of BQ-9000 Biodiesel Properties for 2020

Teresa L. Alleman

National Renewable Energy Laboratory

*Produced under direction of National Biodiesel Board by the National Renewable Energy Laboratory (NREL) under Cooperative Research and Development Agreement CRD-15-593.*

**NREL is a national laboratory of the U.S. Department of Energy  
Office of Energy Efficiency & Renewable Energy  
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at [www.nrel.gov/publications](http://www.nrel.gov/publications).

Contract No. DE-AC36-08GO28308

**Strategic Partnership Project Report  
NREL/TP-5400-79815  
May 2021**



# Assessment of BQ-9000 Biodiesel Properties for 2020

Teresa L. Alleman

National Renewable Energy Laboratory

## Suggested Citation

Alleman, Teresa L. 2021. *Assessment of BQ-9000 Biodiesel Properties for 2020*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-79815.

<https://www.nrel.gov/docs/fy21osti/79815.pdf>.

**NREL is a national laboratory of the U.S. Department of Energy  
Office of Energy Efficiency & Renewable Energy  
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at [www.nrel.gov/publications](http://www.nrel.gov/publications).

Contract No. DE-AC36-08GO28308

**Strategic Partnership Project Report**  
NREL/TP-5400-79815  
May 2021

National Renewable Energy Laboratory  
15013 Denver West Parkway  
Golden, CO 80401  
303-275-3000 • [www.nrel.gov](http://www.nrel.gov)

## NOTICE

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support for the work was also provided by the National Biodiesel Board under Cooperative Research and Development Agreement CRD-15-593. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at [www.nrel.gov/publications](http://www.nrel.gov/publications).

U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via [www.OSTI.gov](http://www.OSTI.gov).

*Cover Photos by Dennis Schroeder: (clockwise, left to right) NREL 51934, NREL 45897, NREL 42160, NREL 45891, NREL 48097, NREL 46526.*

NREL prints on paper that contains recycled content.

## Acknowledgments

Funding for this work was provided by the National Biodiesel Board under Cooperative Research and Development Agreement CRD-15-593. The author thanks Mr. Steve Howell of M4 Consulting, Mr. Scott Fenwick of the National Biodiesel Board, and Dr. Richard Nelson of Enersol Resources for their technical support.

## List of Acronyms

ASTM	ASTM International
CSFT	cold soak filterability test
NREL	National Renewable Energy Laboratory

## Executive Summary

Biodiesel producers in the United States and Canada can voluntarily participate in the industry's BQ-9000 quality assurance program. This is the fourth in a series of reports documenting biodiesel quality from participating producers for calendar year 2020. Participants in the BQ-9000 program were requested to voluntarily provide data to a third-party team. This team anonymized and randomized the data prior to providing to the National Renewable Energy Laboratory for analysis and reporting. The data was not weighted for production volumes from the participating companies. The critical quality parameters analyzed are listed below, and the statistical analysis for these parameters is presented in Table ES-1:

- Sodium and potassium (Na+K)
- Calcium and magnesium (Ca+Mg)
- Phosphorus (P)
- Flash point and alcohol control
- Water and sediment
- Cloud point
- Acid number
- Free and total glycerin
- Monoglycerides
- Sulfur
- Oxidation stability
- Cold soak filterability test.

**Table ES-1. BQ-9000 Critical Parameter Summary Table, Calendar Year 2020**

<b>BQ-9000 Parameter</b>	<b># of Values Reported</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Average</b>	<b>Median</b>	<b>Standard Deviation</b>	<b>95<sup>th</sup> Percentile</b>
Na+K, ppm	392	0	6	0.576	0.200	0.898	2.500
Ca+Mg, ppm	389	0	3	0.125	0.037	0.261	0.500
P, ppm	363	0	2	0.097	0.000	0.248	0.496
Flash Point, °C	445	94	204	153	158	24	107 <sup>a</sup>
Alcohol Control, mass%	312	0.000	0.200	0.045	0.030	0.050	0.131
Water and Sediment, vol%	263	0.000	0.040	0.001	0.000	0.004	0.010
Cloud Point, °C	485	-4.9	15.8	0.75	0.00	3.71	9.0
Acid Number, mg KOH/g	486	0.060	0.500	0.259	0.270	0.109	0.450
Free Glycerin, mass%	457	0.000	0.020	0.006	0.005	0.004	0.013
Total Glycerin, mass%	485	0.000	0.194	0.089	0.098	0.043	0.157
Monoglycerides, mass%	484	0.000	0.593	0.262	0.295	0.124	0.412
Sulfur, ppm	481	0	23	3.5	1.8	4.1	12.7
Oxidation Stability, hr.	485	4	29	9.4	8.6	3.3	5.5 <sup>a</sup>
Cold Soak Filterability Test, sec	497	65	330	99	92	28	150

<sup>a</sup> Data for 5<sup>th</sup> percentile

# Table of Contents

<b>1</b>	<b>Introduction</b> .....	<b>1</b>
<b>2</b>	<b>Methods</b> .....	<b>1</b>
<b>3</b>	<b>Results</b> .....	<b>2</b>
	3.1 Sodium and Potassium .....	2
	3.2 Calcium and Magnesium.....	3
	3.3 Phosphorus .....	3
	3.4 Alcohol Control and Flash Point.....	4
	3.5 Water and Sediment .....	5
	3.6 Cloud Point.....	5
	3.7 Acid Number .....	6
	3.8 Free and Total Glycerin.....	6
	3.9 Monoglycerides.....	7
	3.10 Sulfur Content .....	8
	3.11 Oxidation Stability .....	8
	3.12 Cold Soak Filterability Test .....	9
<b>4</b>	<b>Summary</b> .....	<b>9</b>
	<b>References</b> .....	<b>11</b>
	<b>Appendix</b> .....	<b>12</b>

## List of Figures

Figure 1. Sodium and potassium content for biodiesel produced in calendar year 2020.....	2
Figure 2. Calcium and magnesium content for biodiesel produced in calendar year 2020 .....	3
Figure 3. Phosphorus content for biodiesel produced in calendar year 2020 .....	3
Figure 4. Flash point for biodiesel produced in calendar year 2020.....	4
Figure 5. Alcohol content for biodiesel produced in calendar year 2020 .....	4
Figure 6. Water and sediment content for biodiesel produced in calendar year 2020 .....	5
Figure 7. Cloud point results for biodiesel produced in calendar year 2020 .....	5
Figure 8. Acid number results for biodiesel produced in calendar year 2020 .....	6
Figure 9. Free glycerin results for biodiesel produced in calendar year 2020 .....	6
Figure 10. Total glycerin results for biodiesel produced in calendar year 2020.....	7
Figure 11. Monoglyceride results for biodiesel produced in calendar year 2020 .....	7
Figure 12. Sulfur results for biodiesel produced in calendar year 2020 .....	8
Figure 13. Oxidation stability results for biodiesel produced in calendar year 2020.....	8
Figure 14. CSFT results for biodiesel produced in calendar year 2020.....	9
Figure A-1. All data analysis of sodium and potassium content for biodiesel samples produced in calendar year 2020.....	12
Figure A-2. All data analysis of calcium and magnesium content for biodiesel samples produced in calendar year 2020 .....	12
Figure A-3. All data analysis of phosphorus content for biodiesel samples produced in calendar year 2020 .....	13
Figure A-4. All data analysis of flash point for biodiesel samples produced in calendar year 2020.....	13
Figure A-5. All data analysis of alcohol control for biodiesel samples produced in calendar year 2020...	14
Figure A-6. All data analysis of water and sediment content for biodiesel samples in calendar year 2020	14
Figure A-7. All data analysis of cloud point for biodiesel samples produced in calendar year 2020.....	15
Figure A-8. All data analysis of acid number for biodiesel samples produced in calendar year 2020.....	15
Figure A-9. All data analysis of free glycerin content for biodiesel samples in calendar year 2020.....	16
Figure A-10. All data analysis of total glycerin content for biodiesel samples in calendar year 2020.....	16
Figure A-11. All data analysis of monoglyceride content for biodiesel samples produced in calendar year 2020.....	17
Figure A-12. All data analysis of sulfur content for biodiesel samples produced in calendar year 2020...	17
Figure A-13. All data analysis of oxidation stability for biodiesel samples produced in calendar year 2020 .....	18
Figure A-14. All data analysis of CSFT for biodiesel samples produced in calendar year 2020 .....	18

## List of Tables

Table ES-1. BQ-9000 Critical Parameter Summary Table, Calendar Year 2020.....	vi
Table 1. Summary of BQ-9000 Critical Quality Parameters for Calendar Year 2020 .....	10

# 1 Introduction

The National Renewable Energy Laboratory (NREL), in collaboration with the National Biodiesel Board, has reported on the quality of biodiesel produced in the United States and Canada in calendar year 2020. This is the fourth annual report in the series (Alleman 2020a; 2020b; 2020c). As in previous years, producers were asked to voluntarily submit monthly quality data for analysis.

The data analyzed included critical biodiesel fuel quality parameters: sodium and potassium (Na+K); calcium and magnesium (Ca+Mg); phosphorus (P); flash point and alcohol control; water and sediment; cloud point; acid number; free and total glycerin; monoglycerides; sulfur; oxidation stability; and cold soak filterability test (CSFT). For calendar year 2020, the data set contained 6,024 unique data points. A more detailed description of the BQ-9000 program can be found in the 2017 report (Alleman 2020a) and on the BQ-9000 website at [www.bq-9000.org](http://www.bq-9000.org).

## 2 Methods

To ensure company confidentiality, the raw data were submitted by each producer to the team of Mr. Steve Howell from M4 Consulting, Mr. Scott Fenwick from the National Biodiesel Board, and Dr. Richard Nelson of Enersol Resources. This team contacted the BQ-9000 producers and requested a voluntary submission of quality data for calendar year 2020. The team served as a firewall between the companies and NREL by anonymizing and randomizing the data. NREL only received numerical values<sup>1</sup> for each parameter analyzed and no other information about the company or plant location.

The data presented in this report represent the “clean” data set provided to NREL. As with previous years, participating producers were asked to provide data “as-is.” This resulted in two types of data in the submission. In the first type, the producer reported an actual value, and this was included in the analysis. In the second type, the producer reported data that were “greater than” or “less than.” These data were omitted from the analysis in the body of the report, as the true value of the parameter was not known. For more detailed discussion of the theory behind this handling, refer to Alleman (2020a). Any data reported as “greater than” or “less than” are included in the Appendix using the assumption that the value is the true value. For example, if free glycerin was reported as <0.0005 mass%, this data point was omitted from the body of the report but included in the Appendix as 0.0005 mass%. No statistical analysis is provided on the data in the Appendix.

Our statistical analysis included calculation of the average and median, the minimum and maximum, the number of data points for each parameter, and either the 5<sup>th</sup> or 95<sup>th</sup> percentile. For parameters that include a minimum in ASTM International’s (ASTM’s) D6751 specification (ASTM 2020), the data include the 5<sup>th</sup> percentile, or the level at which only 5% of the data are below the value reported. The flash point and oxidation stability are reported with 5<sup>th</sup> percentiles.

---

<sup>1</sup> Data provided was not production volume weighted for this analysis

All the other parameters are reported with 95<sup>th</sup> percentiles, where 95% of the data are below the value reported.

### 3 Results

ASTM D6751-20a, *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels* (ASTM 2020) includes parameter limits and discussion of the significance for biodiesel quality. The data are presented here without limits, as the BQ-9000 program includes a resolution requirement if a particular batch did not meet the specification limits. NREL did not receive any information on the resolution if a parameter was out of specification, and no pass/fail information is discussed. The data for each parameter was statistically binned for graphing purposes.

#### 3.1 Sodium and Potassium

The average sodium and potassium was 0.576 parts per million (ppm) and the median was 0.200 ppm for 2020 (Figure 1). The 95<sup>th</sup> percentile was 2.5 ppm.

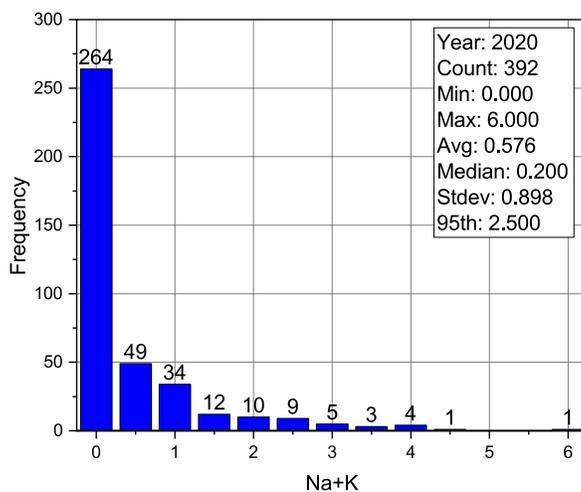


Figure 1. Sodium and potassium content for biodiesel produced in calendar year 2020

### 3.2 Calcium and Magnesium

Figure 2 illustrates the results for calcium and magnesium. The average calcium and magnesium was 0.125 ppm with a median of 0.037 ppm and a 95<sup>th</sup> percentile of 0.500 ppm.

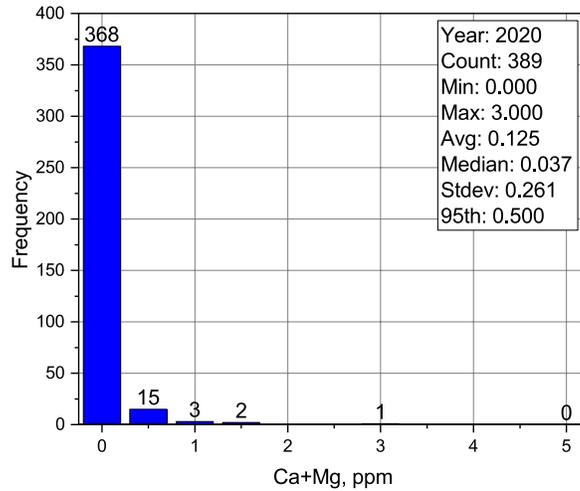


Figure 2. Calcium and magnesium content for biodiesel produced in calendar year 2020

### 3.3 Phosphorus

The phosphorus content averaged 0.079 ppm, with a median value of 0.000 ppm (Figure 3). The 95<sup>th</sup> percentile was 0.496 ppm.

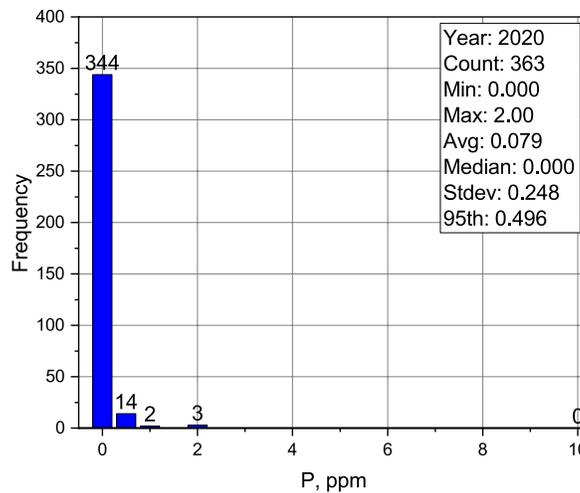


Figure 3. Phosphorus content for biodiesel produced in calendar year 2020

### 3.4 Alcohol Control and Flash Point

The flash point for biodiesel produced in 2020 is shown in Figure 4, with an average of 153°C and a median of 158°C. The 5<sup>th</sup> percentile was 107°C. The average alcohol content was reported as 0.045 mass%, with a median of 0.030 mass% and a 95<sup>th</sup> percentile of 0.131 mass% (Figure 5).

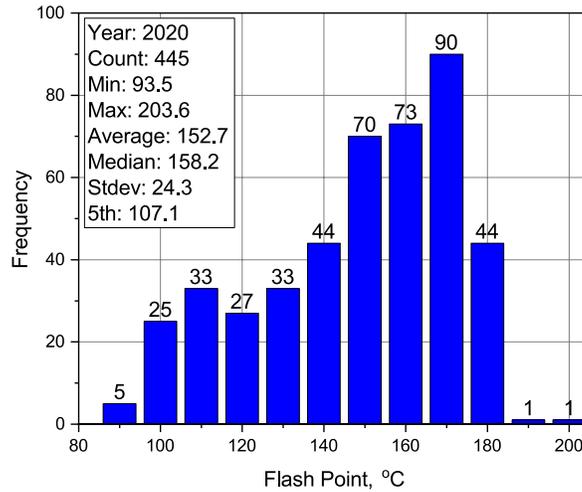


Figure 4. Flash point for biodiesel produced in calendar year 2020

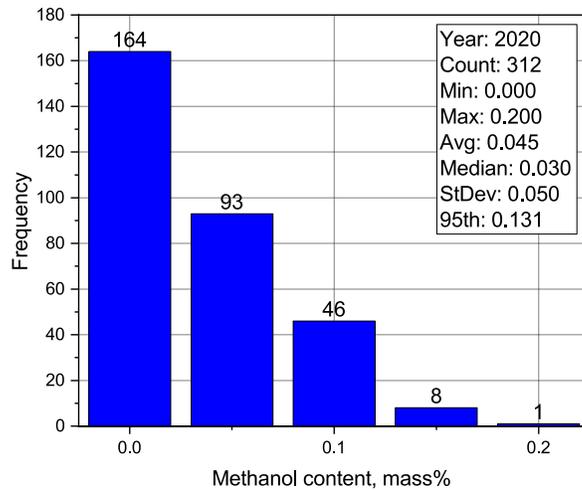


Figure 5. Alcohol content for biodiesel produced in calendar year 2020

### 3.5 Water and Sediment

The average water and sediment, shown in Figure 6, was 0.001 vol%. The median and 95<sup>th</sup> percentile were 0.000 vol% and 0.010 vol%, respectively.

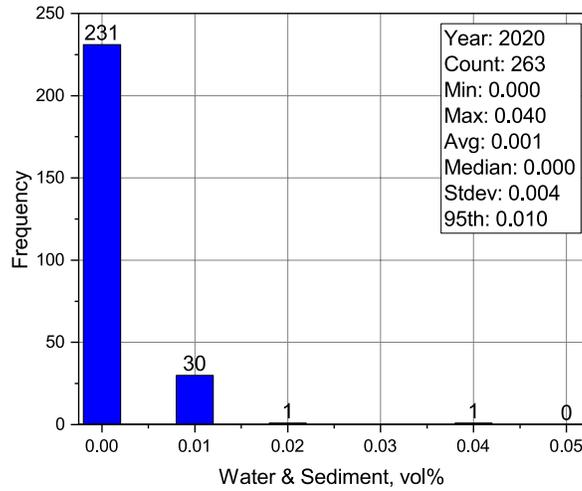


Figure 6. Water and sediment content for biodiesel produced in calendar year 2020

### 3.6 Cloud Point

The average cloud point was 0.75°C for biodiesel produced in 2020 (Figure 7). The median cloud point was 0°C and the 95<sup>th</sup> percentile was 9°C.

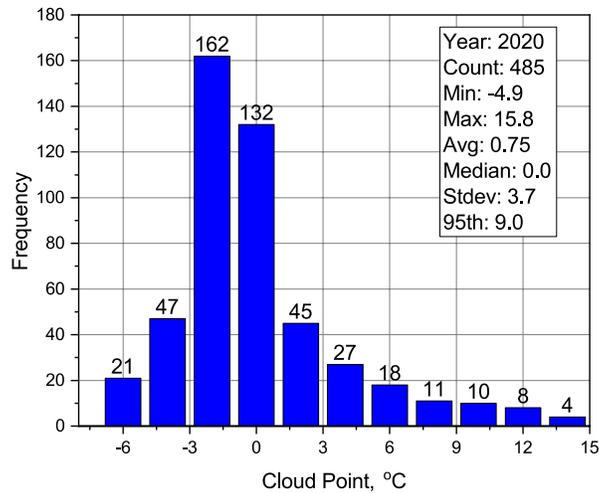


Figure 7. Cloud point results for biodiesel produced in calendar year 2020

### 3.7 Acid Number

The acid value, shown in Figure 8, averaged 0.259 milligrams potassium hydroxide per gram (mg KOH/g) and had a median value of 0.270 mg KOH/g. The 95<sup>th</sup> percentile was 0.450 mg KOH/g.

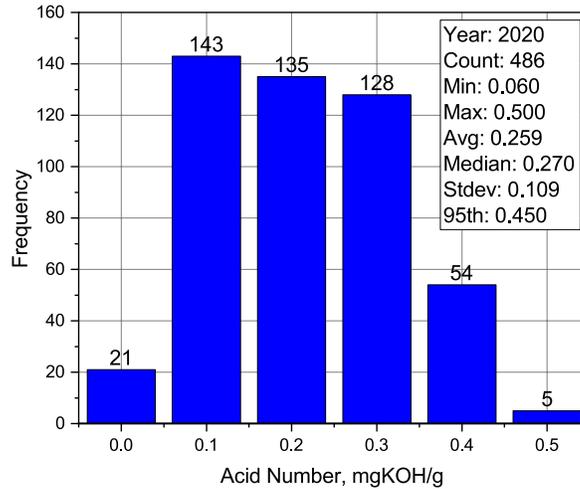


Figure 8. Acid number results for biodiesel produced in calendar year 2020

### 3.8 Free and Total Glycerin

Figures 9 and 10 show the free and total glycerin results, respectively. As shown in Figure 9, the average free glycerin was 0.006 mass%, the median was 0.005 mass%, and the 95<sup>th</sup> percentile was 0.013 mass%. Figure 10 shows the average total glycerin of 0.089 mass%, the median of 0.098 mass%, and the 95<sup>th</sup> percentile of 0.157 mass%.

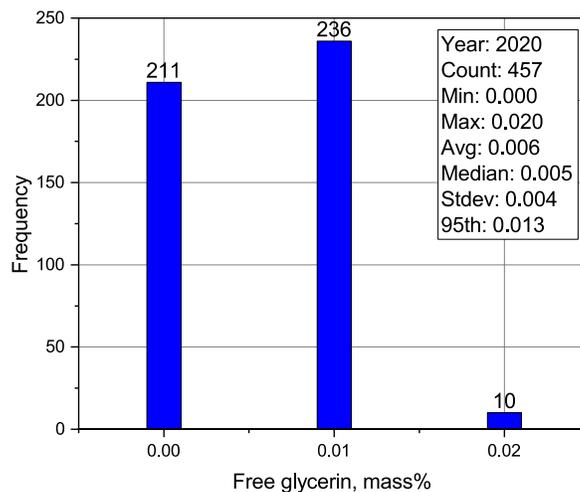


Figure 9. Free glycerin results for biodiesel produced in calendar year 2020

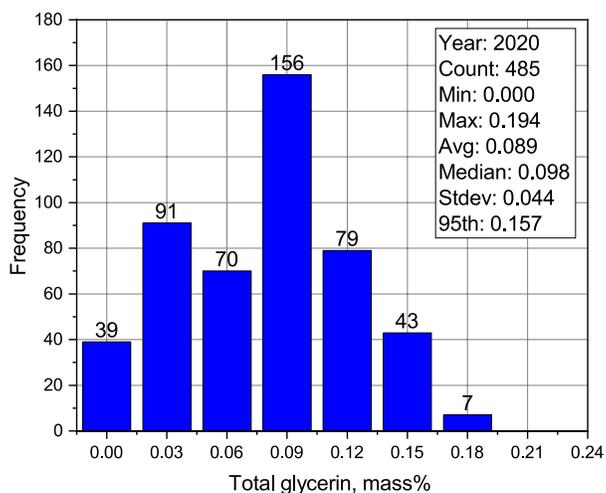


Figure 10. Total glycerin results for biodiesel produced in calendar year 2020

### 3.9 Monoglycerides

The average monoglyceride content was 0.262 mass%; the median value was 0.295 mass% and the 95<sup>th</sup> percentile was 0.412 mass% (Figure 11).

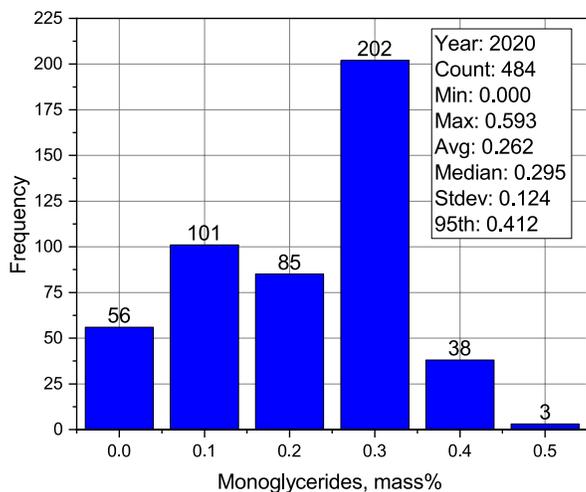


Figure 11. Monoglyceride results for biodiesel produced in calendar year 2020

### 3.10 Sulfur Content

Figure 12 illustrates the sulfur content of biodiesel samples produced in 2020. The average value was 3.5 ppm, the median was 1.8 ppm, and the 95<sup>th</sup> percentile was 12.7 ppm.

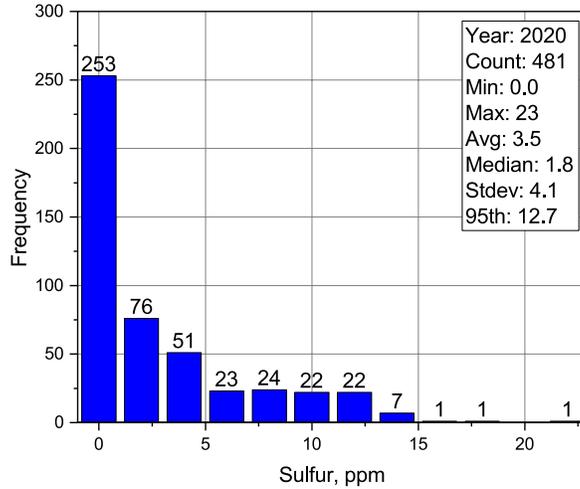


Figure 12. Sulfur results for biodiesel produced in calendar year 2020

### 3.11 Oxidation Stability

Figure 13 shows the average oxidation stability of the biodiesel samples produced in 2020 to be 9.4 hours. The median result is 8.6 hours and the 5<sup>th</sup> percentile is 5.5 hours.

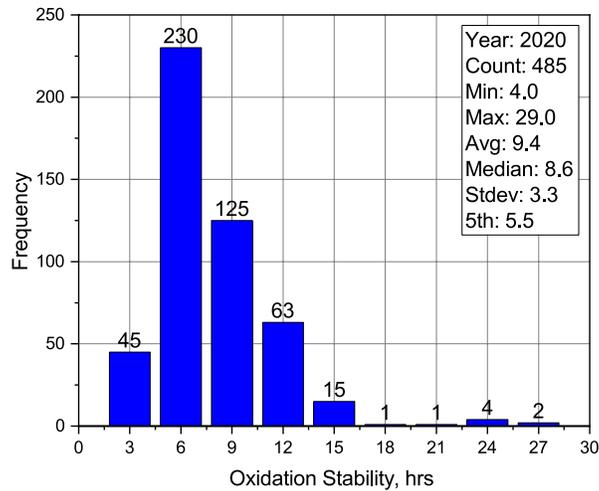


Figure 13. Oxidation stability results for biodiesel produced in calendar year 2020

### 3.12 Cold Soak Filterability Test

CSFT results are presented in Figure 14. The average CSFT was 99 seconds, the median was 92 seconds, and the 95<sup>th</sup> percentile was 150 seconds.

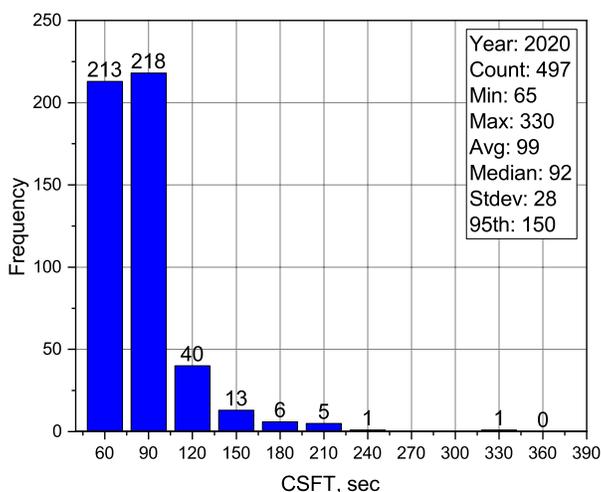


Figure 14. CSFT results for biodiesel produced in calendar year 2020

## 4 Summary

As the fourth in a series of reports, we analyzed voluntarily provided data on critical biodiesel quality parameters (see also Alleman 2020a; 2020b; and 2020c) for calendar year 2020. BQ-9000 producers were asked to voluntarily provide results of monthly quality analyses for inclusion in this report. The data were submitted to a third-party team that anonymized and randomized the data before providing the data set to NREL for analysis. The data was not production volume weighted. Additionally, the data was statistically binned for graphing.

Our analysis examined critical quality metrics for biodiesel produced in the United States and Canada in calendar year 2020. The results of the analysis are summarized in Table 1.

**Table 1. Summary of BQ-9000 Critical Quality Parameters for Calendar Year 2020**

<b>BQ-9000 Parameter</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Average</b>	<b>Median</b>	<b>95<sup>th</sup> Percentile</b>
Na+K, ppm	0	6	0.576	0.200	2.500
Ca+Mg, ppm	0	3	0.125	0.037	0.500
P, ppm	0	2	0.097	0.000	0.496
Flash Point, °C	94	204	153	158	107 <sup>a</sup>
Alcohol Control, mass%	0.000	0.200	0.045	0.030	0.131
Water and Sediment, vol%	0.000	0.040	0.001	0.000	0.010
Cloud Point, °C	-4.9	15.8	0.75	0.00	9.0
Acid Number, mg KOH/g	0.060	0.500	0.259	0.270	0.450
Free Glycerin, mass%	0.000	0.020	0.006	0.005	0.013
Total Glycerin, mass%	0.000	0.194	0.089	0.098	0.157
Monoglycerides, mass%	0.000	0.593	0.262	0.295	0.412
Sulfur, ppm	0	23	3.5	1.8	12.7
Oxidation Stability, hr.	4	29	9.4	8.6	5.5 <sup>a</sup>
Cold Soak Filterability Test, sec	65	330	99	92	150

<sup>a</sup> Data for 5<sup>th</sup> percentile

## References

Alleman, T.L. 2020a. *Assessment of BQ-9000 Biodiesel Properties for 2017*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-75795.  
<https://www.nrel.gov/docs/fy20osti/75795.pdf>.

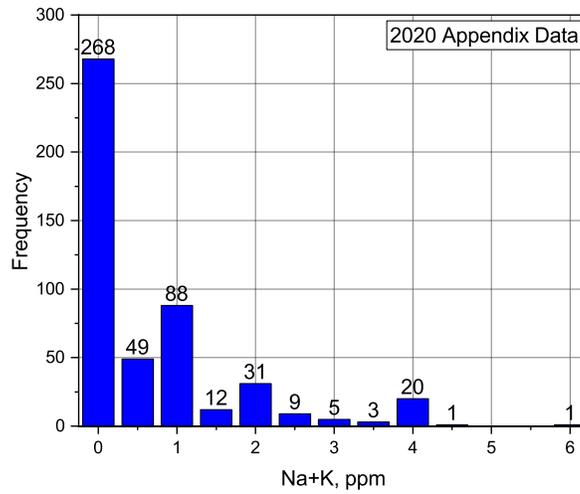
Alleman, T.L. 2020b. *Assessment of BQ-9000 Biodiesel Properties for 2018*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-75796.  
<https://www.nrel.gov/docs/fy20osti/75796.pdf>.

Alleman, T.L. 2020c. *Assessment of BQ-9000 Biodiesel Properties for 2019*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-76840.  
<https://www.nrel.gov/docs/fy20osti/76840.pdf>.

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

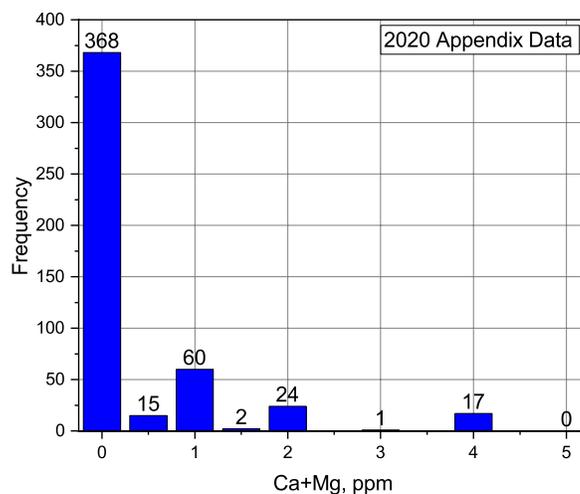
## Appendix

The figures presented in the Appendix include “all data” voluntarily submitted by producers in 2020. In this data representation, any data submitted as “greater than” or “less than” were assumed to be the value reported. Thus, a value reported as “<10 ppm phosphorus” was assumed to be 10 ppm phosphorus and used for statistical binning purposes. Due to this unique manner of handling the data, no statistical analysis (such as mean, minimum, maximum) is presented for the data in the Appendix.



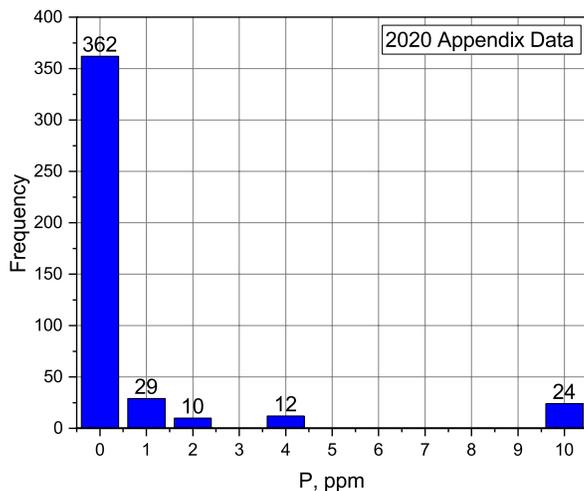
**Figure A-1. All data analysis of sodium and potassium content for biodiesel samples produced in calendar year 2020**

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



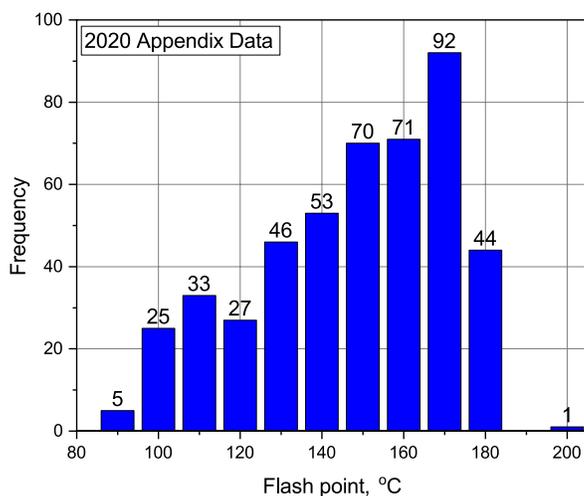
**Figure A-2. All data analysis of calcium and magnesium content for biodiesel samples produced in calendar year 2020**

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



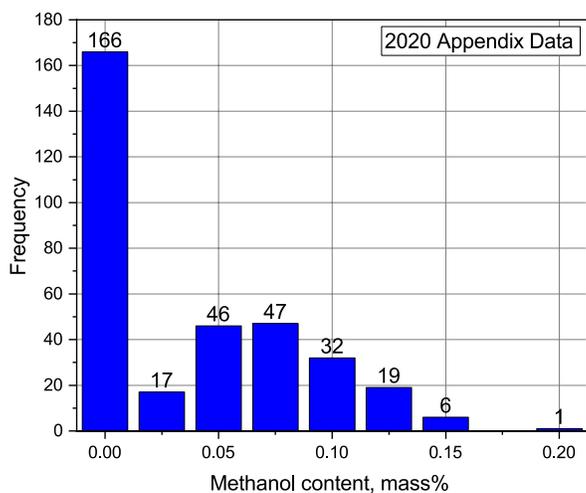
**Figure A-3. All data analysis of phosphorus content for biodiesel samples produced in calendar year 2020**

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



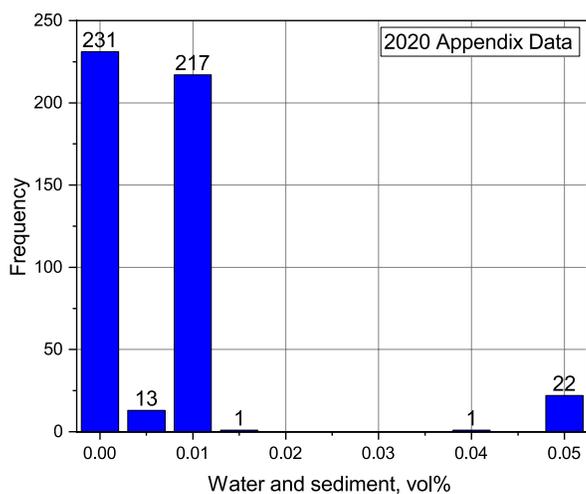
**Figure A-4. All data analysis of flash point for biodiesel samples produced in calendar year 2020**

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



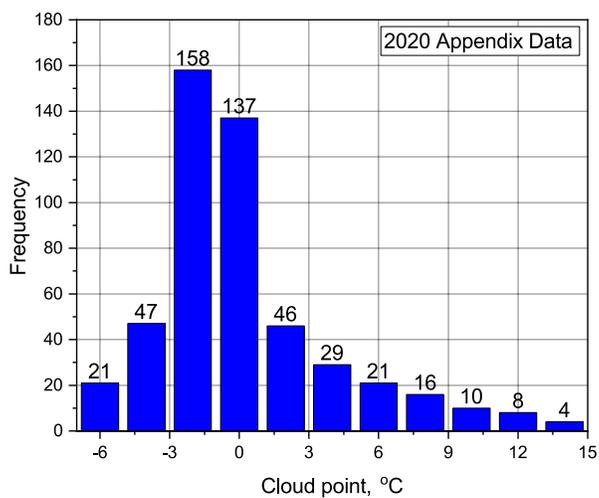
**Figure A-5. All data analysis of alcohol control for biodiesel samples produced in calendar year 2020**

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



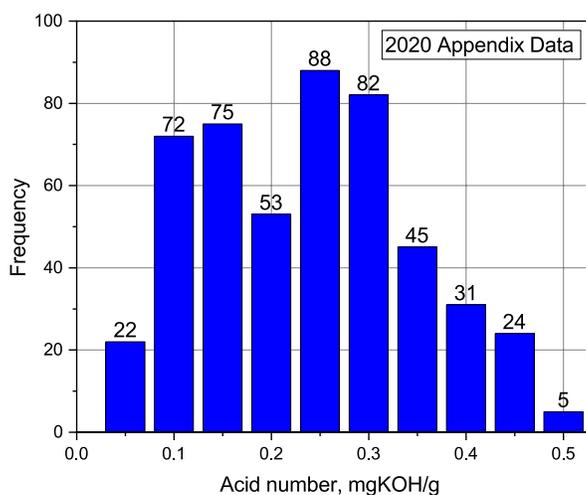
**Figure A-6. All data analysis of water and sediment content for biodiesel samples in calendar year 2020**

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



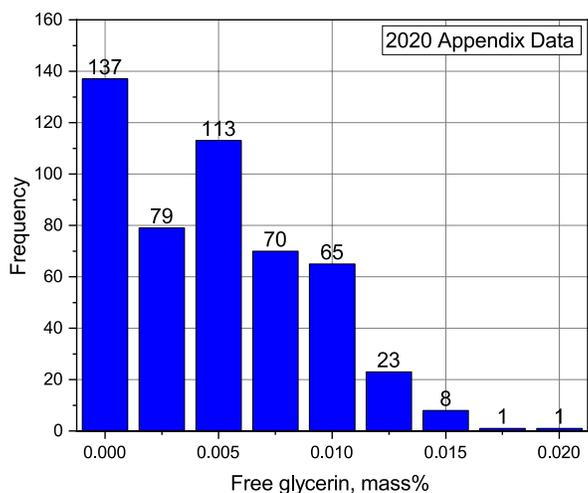
**Figure A-7. All data analysis of cloud point for biodiesel samples produced in calendar year 2020**

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



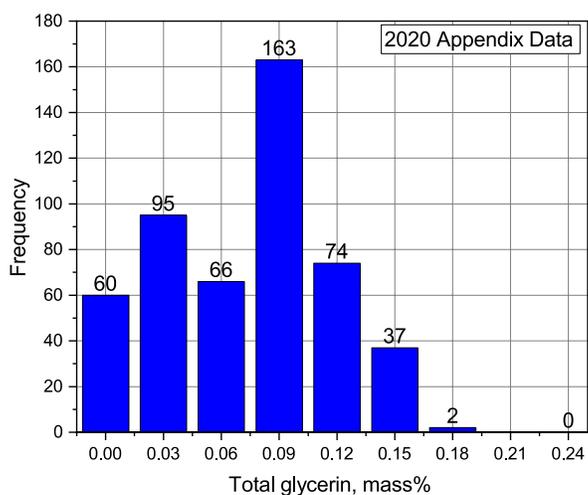
**Figure A-8. All data analysis of acid number for biodiesel samples produced in calendar year 2020**

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



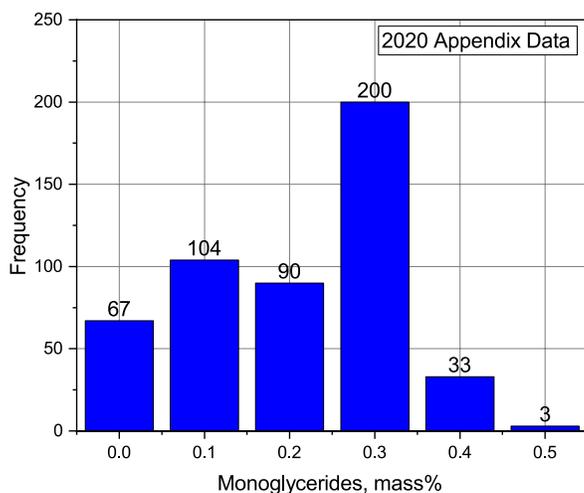
**Figure A-9. All data analysis of free glycerin content for biodiesel samples in calendar year 2020**

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



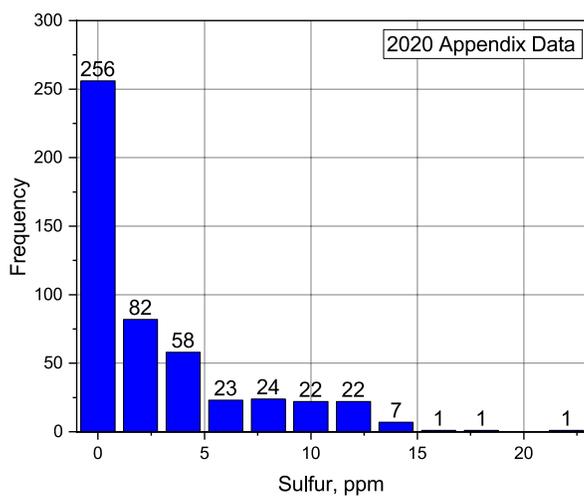
**Figure A-10. All data analysis of total glycerin content for biodiesel samples in calendar year 2020**

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



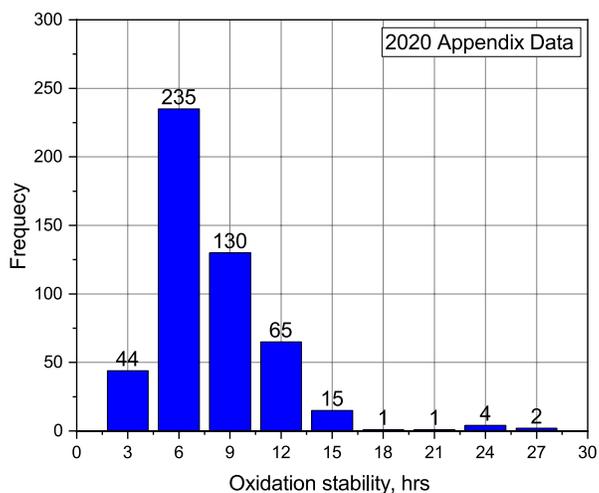
**Figure A-11. All data analysis of monoglyceride content for biodiesel samples produced in calendar year 2020**

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



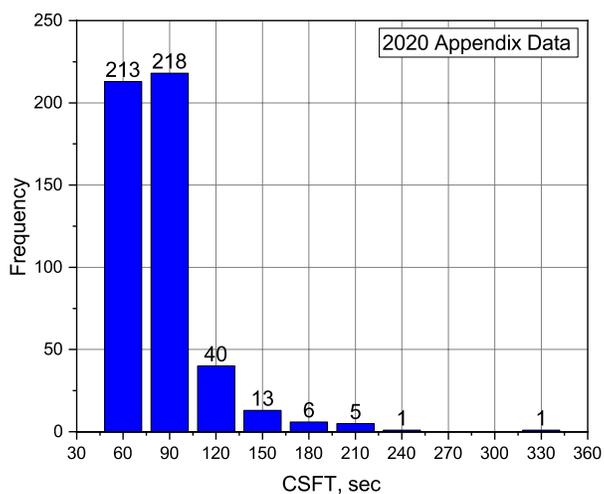
**Figure A-12. All data analysis of sulfur content for biodiesel samples produced in calendar year 2020**

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



**Figure A-13. All data analysis of oxidation stability for biodiesel samples produced in calendar year 2020**

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



**Figure A-14. All data analysis of CSFT for biodiesel samples produced in calendar year 2020**

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