Assessment of BQ-9000 Biodiesel Properties for 2022

Robert L. McCormick

National Renewable Energy Laboratory

Produced under direction of Clean Fuels Alliance America by the National Renewable Energy Laboratory (NREL) under Cooperative Research and Development Agreement CRC-15-593.

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The author extends special thanks to Ms. Teresa Alleman of Holly Energy Partners, Mr. Steve Howell of MARC-IV Consulting, Mr. Scott Fenwick of Clean Fuels Alliance America, and Dr. Richard Nelson of Enersol Resources for technical support.

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

Acknowledgments

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List of Acronyms

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

Executive Summary

This is the sixth in a series of reports documenting the quality of biodiesel from U.S.- and Canadian-based producers that participate in the BQ-9000 program, the biodiesel industry's voluntary quality assurance program. Participants agreed to provide monthly data on critical quality parameters for calendar year 2022. The quality data were provided to a team of experts, who removed any identifying company information and provided anonymized data to the National Renewable Energy Laboratory (NREL) for statistical analysis. The critical quality parameters analyzed are listed in Table ES-1 along with descriptive statistics for the 2022 data set.

Table ES-1. BQ-9000 Critical Parameter Summary, Calendar Year 2022

BQ-9000 Parameter	# of Values Reported	Minimum	Maximum	Average	Median	Standard Deviation	95th Percentile
Na+K, ppm	426	0	4.2	0.528	0.210	0.713	2.0
Ca+Mg, ppm	429	0	4.4	0.226	0.043	0.545	1.83
P, ppm	430	0	2.0	0.190	0.001	0.328	0.86
Flash point, °C	453	93	196	150	155	24.5	105 [a]
Alcohol control, mass %	299	0	0.24	0.054	0.058	0.0	0.143
Water and sediment, vol %	308	0	0.05	0.003	0.00	0.007	0.011
Cloud point, °C	483	−6	15.5	1.00	0.00	3.821	8.69
Acid number, mg KOH/g	483	0.046	0.479	0.266	0.269	0.093	0.420
Free glycerin, mass %	465	0	0.110	0.005	0.004	0.006	0.013
Total glycerin, mass %	471	0.007	0.330	0.089	0.100	0.045	0.159
Monoglycerides, mass %	483	0	0.598	0.254	0.290	0.132	0.419
Sulfur, ppm	465	0	14.8	3.975	2.45	4.00	12.42
Oxidation stability, h	482	3.1	24	9.13	8.70	2.72	5.3 [a]
CSFT,[b] s	483	49	293	106	101	27.9	157

[a] Data for 5th percentile

[b] Cold soak filterability test.

Table of Contents

List of Figures

List of Tables

1 Introduction

This is the sixth in a series of reports that documents the quality of biodiesel produced in the United States and Canada. Previously, the National Renewable Energy Laboratory (NREL) and Clean Fuels Alliance America (formerly the National Biodiesel Board [NBB]) collected and analyzed monthly quality data from BQ-9000[1] producers for the years 2017 to 2021 (Alleman 2020a, 2020b, 2020c, 2021, 2022). Producers were asked to voluntarily submit monthly fuel quality parameter data for analysis and inclusion in the report.

The purpose of this report is to document critical fuel quality parameters for biodiesel for calendar year 2022. These quality parameters are:

- 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 (CSFT).

2 Methods

Mr. Steve Howell (MARC-IV Consulting), Mr. Scott Fenwick (Clean Fuels Alliance America), and Dr. Richard Nelson (Enersol Resources) contacted all BQ-9000 producers to request submission of monthly quality data for calendar year 2022. Upon receipt of the data, all company identifying information was removed. NREL only received numeric data for each parameter with no identifying company information.

Each company provided data "as is." Due to the variety of ways companies collect and store these data, two types of data were received. In the first type, the submitted data included actual values that were used in the analysis. For our analysis, we calculated average, median, minimum, maximum, and either the 5th or 95th percentile for the data. For specification parameters in ASTM International's (ASTM's) B100 specification, ASTM D6751-23, that have a minimum requirement like oxidation stability or flash point, we present a 5th percentile, where only 5% of the data are below the calculated value. All other parameters include a 95th percentile, where 95% of the data are below the calculated value.

In the second data type, the data were reported as "greater than" or "less than" a value. These data were not included in the statistical analysis in the body of this report because the actual

[1] More detail on the BQ-9000 program is available at www.bq-9000.org.

values are unknown. In an effort to capture this information, those data have been summarized in the appendix. For those data, any values reported as “greater” or “less” than were assigned that value prior to providing the data to NREL. For example, if a flash point was reported as >150°C, the analysis in the appendix assumes the value was 150°C. No statistics were calculated for these data.

3 Results

The significance of the parameters included here are discussed in ASTM International specification D6751-23, *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels* (ASTM 2023). All the data presented in both the body and appendix are shown without limits. Under the BQ-9000 program, producers must follow specific procedures to resolve out-of-specification parameters. Any information on how a producer chose to resolve these issues is beyond the scope of this report. The binning for each parameter was selected for ease of presentation only.

3.1 Sodium and Potassium

Figure 1 illustrates the sodium and potassium content of biodiesel produced in 2022. The average Na+K was 0.53 parts per million (ppm), with a median of 0.21 ppm and a 95th percentile of 2.0 ppm (Figure 1), meaning that 95% of reported values are below 2.0 ppm.

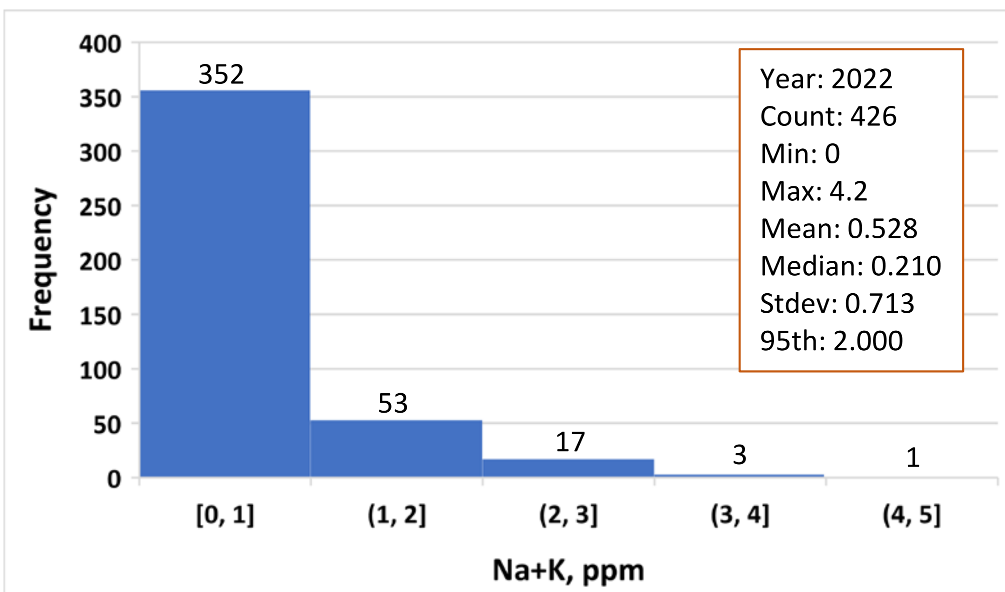

Figure 1. Sodium and potassium content of biodiesel

3.2 Calcium and Magnesium

The Ca+Mg data are shown in Figure 2, with an average of 0.23 ppm, a median of 0.04 ppm, and a 95th percentile of 1.83 ppm.

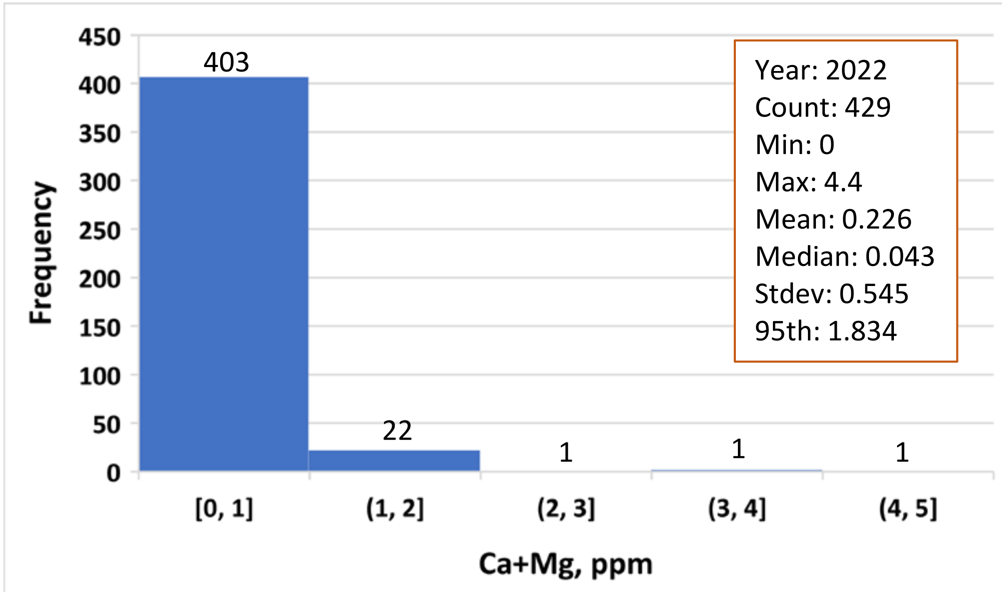

Figure 2. Calcium and magnesium content of biodiesel produced

3.3 Phosphorus

The average phosphorus content was 0.19 ppm (Figure 3). The median value was 0.001 ppm and the 95th percentile was 0.86 ppm.

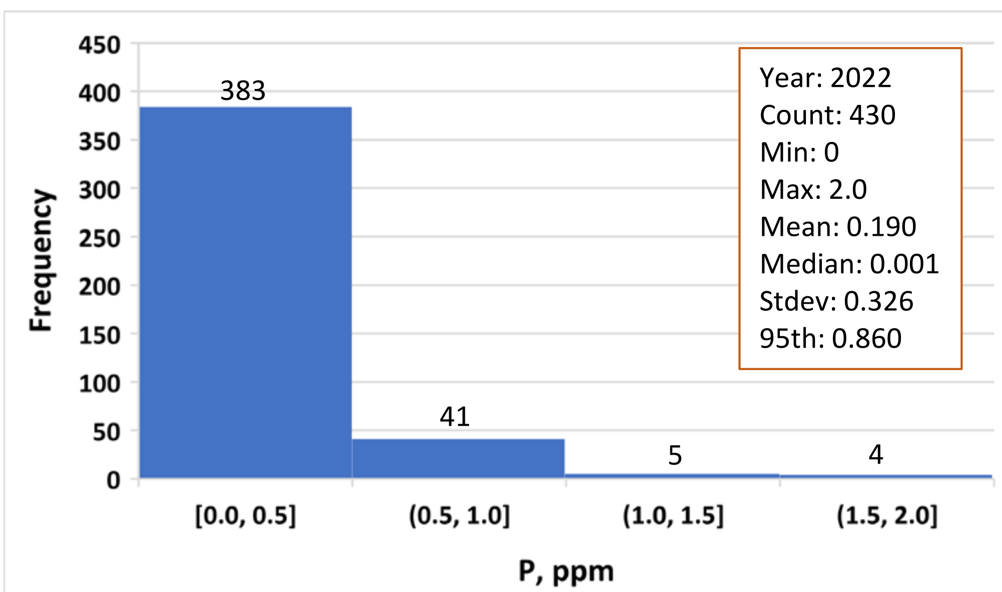

Figure 3. Phosphorus content of biodiesel

3.4 Flash Point and Alcohol Control

Figure 4 shows the flash point analysis. Biodiesel produced in 2022 had an average of 150°C, a median flash point of 155°C, and a 5th percentile of 105°C, meaning that 95% of values were above this level. The average alcohol content was 0.05 mass %, with a median of 0.06 mass %, and the 95th percentile was 0.14 mass % (Figure 5).

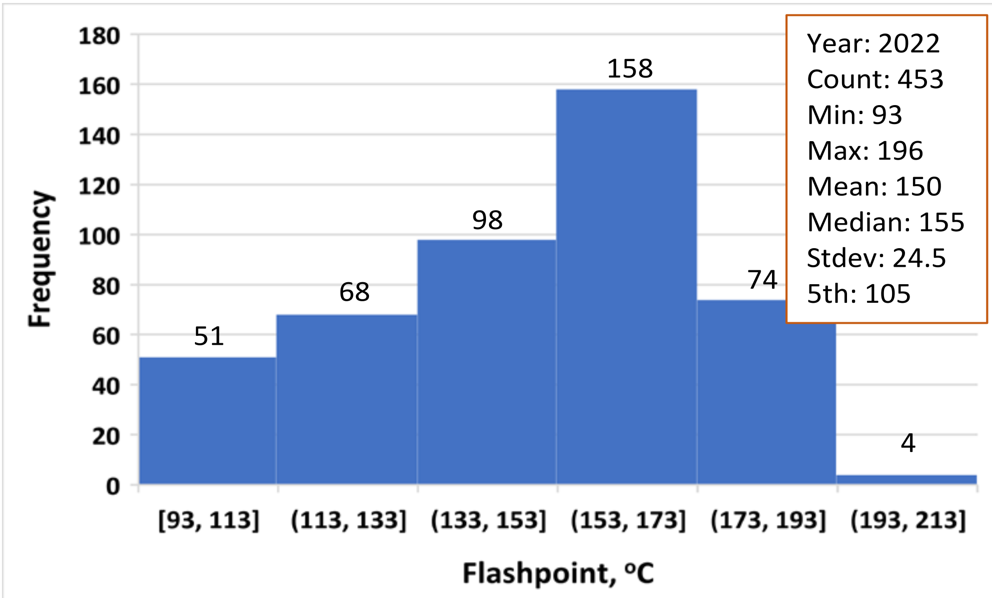

Figure 4. Flash point for biodiesel

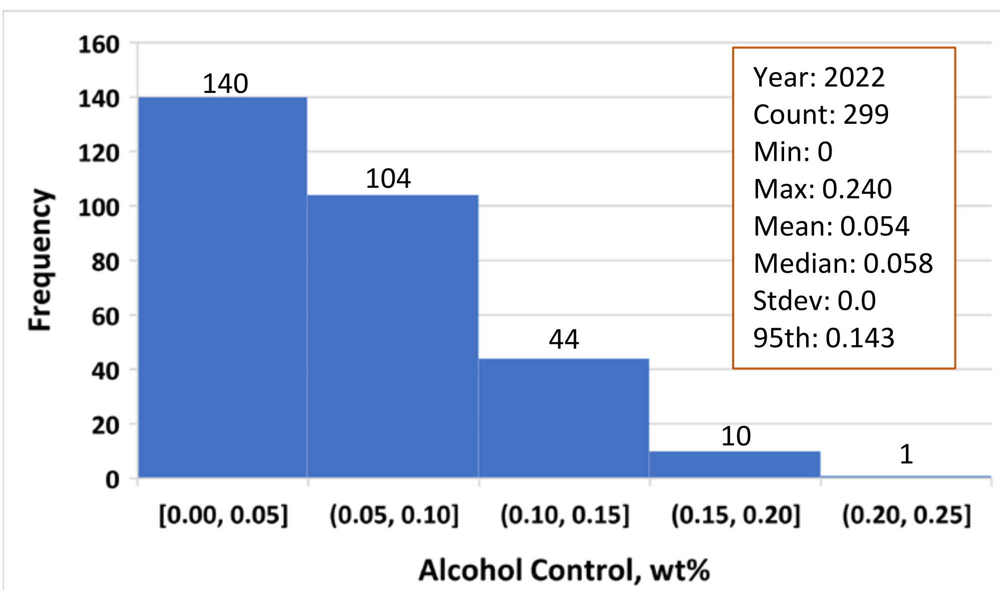

Figure 5. Alcohol content for biodiesel

3.5 Water and Sediment

The results from the water and sediment analysis are shown in Figure 6. The average was 0.003 vol %, the median was 0.000 vol %, and the 95th percentile was 0.011 vol %.

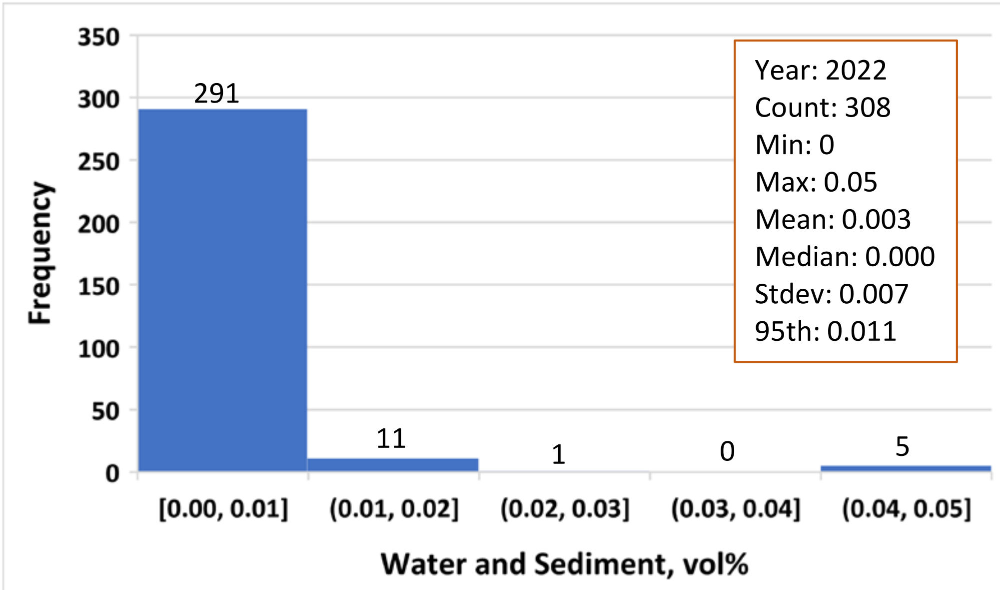

Figure 6. Water and sediment content for biodiesel

3.6 Cloud Point

The cloud point average was 1.0°C, with a median of 0.0°C and a 95th percentile of 8.7°C (Figure 7).

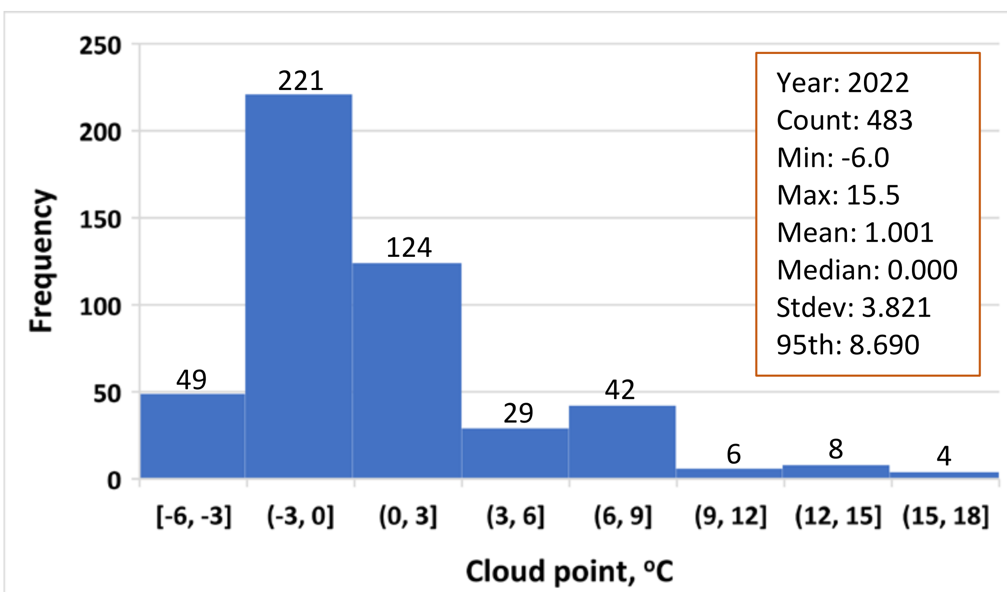

Figure 7. Cloud point results for biodiesel

3.7 Acid Number

Biodiesel in 2022 had average and median acid number results of 0.27 mg KOH/g each, and the 95th percentile was 0.42 mg KOH/g (Figure 8).

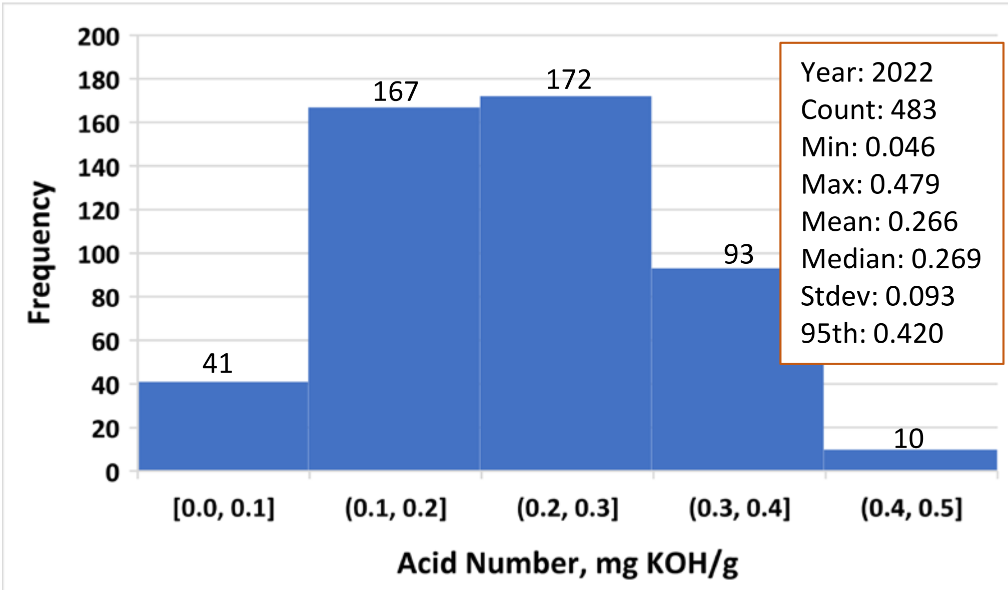

Figure 8. Acid number results for biodiesel

3.8 Free and Total Glycerin

Figure 9 shows the average free glycerin of 0.005 mass %, median of 0.004 mass %, and 95th percentile of 0.013 mass %. The total glycerin data are shown in Figure 10. The average was 0.089 mass %, the median was 0.100 mass %, and the 95th percentile was 0.159 mass %.

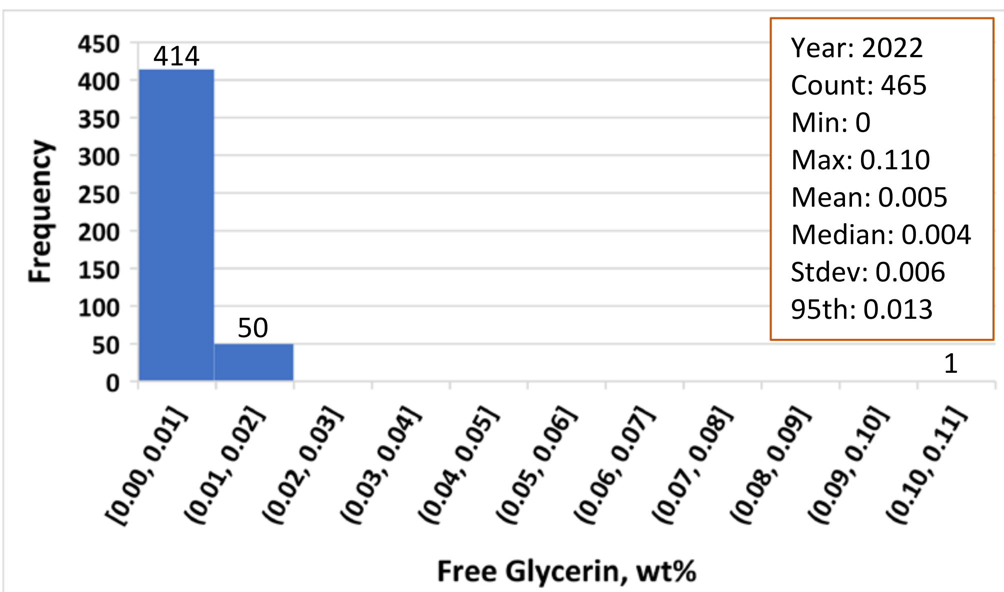

Figure 9. Free glycerin content of biodiesel

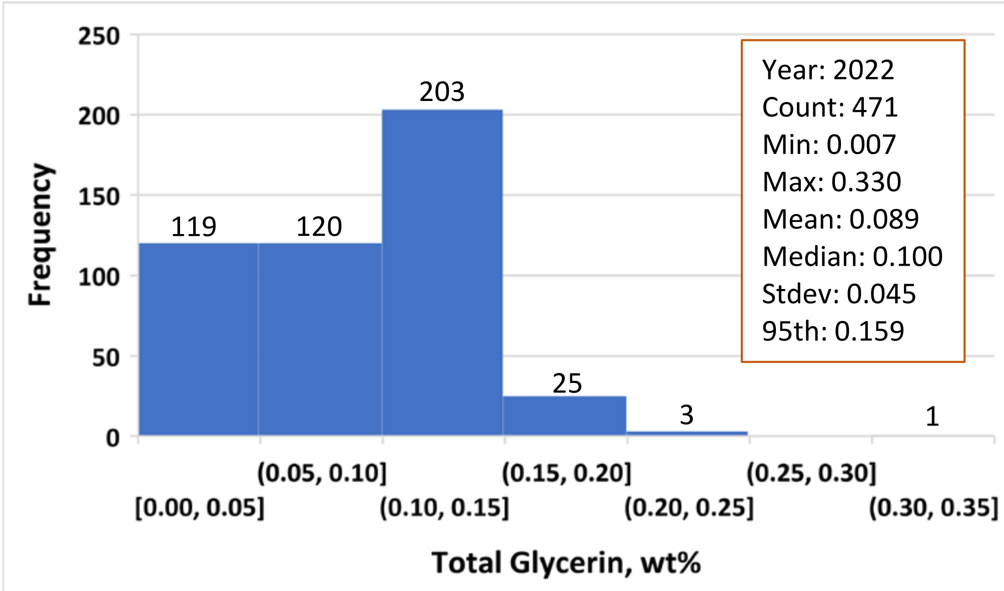

Figure 10. Total glycerin content of biodiesel

3.9 Monoglycerides

Figure 11 shows the distribution of monoglycerides from biodiesel produced in calendar year 2022. The average monoglyceride content was 0.254 mass %, the median was 0.290 mass %, and the 95th percentile was 0.419 mass %.

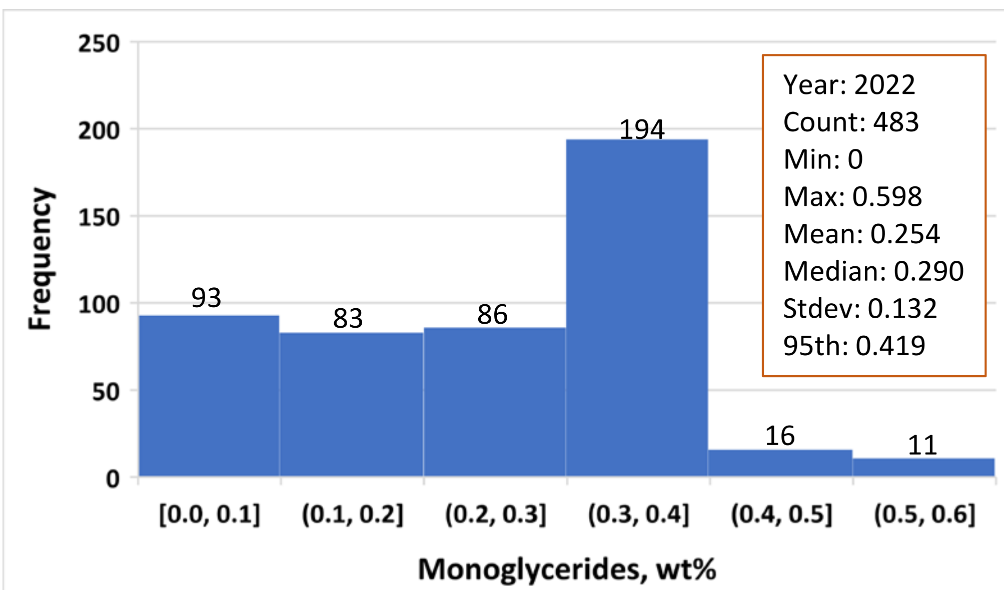

Figure 11. Monoglyceride content of biodiesel

3.10 Sulfur Content

The average sulfur content of biodiesel produced in 2022 was 4 ppm, with a median value of 2.5 ppm and a 95th percentile of 12.4 ppm (Figure 12).

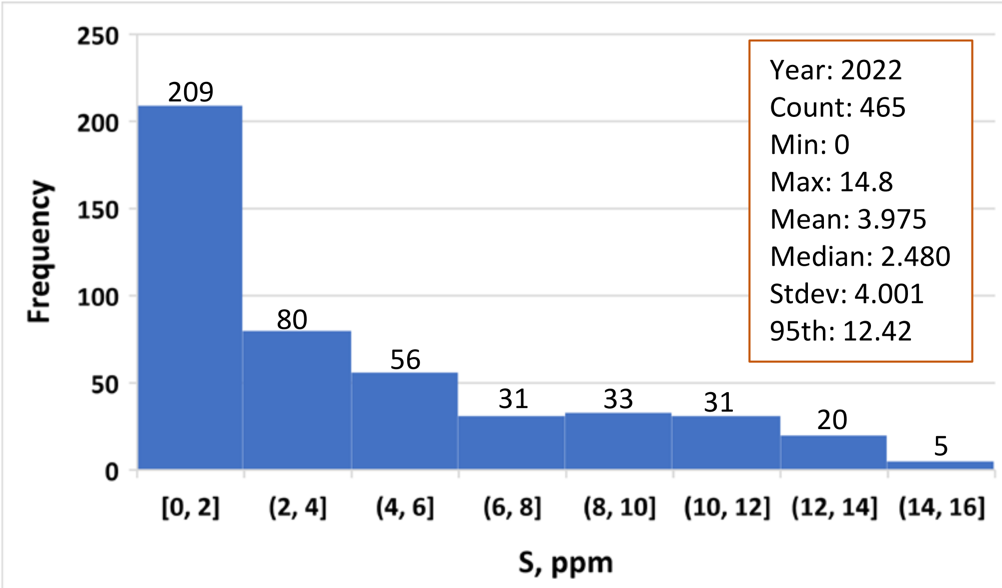

Figure 12. Sulfur content of biodiesel

3.11 Oxidation Stability

The average oxidation stability, shown in Figure 13, was 9.1 hours with a median of 8.7 hours. The 5th percentile for these samples was 5.3 hours.

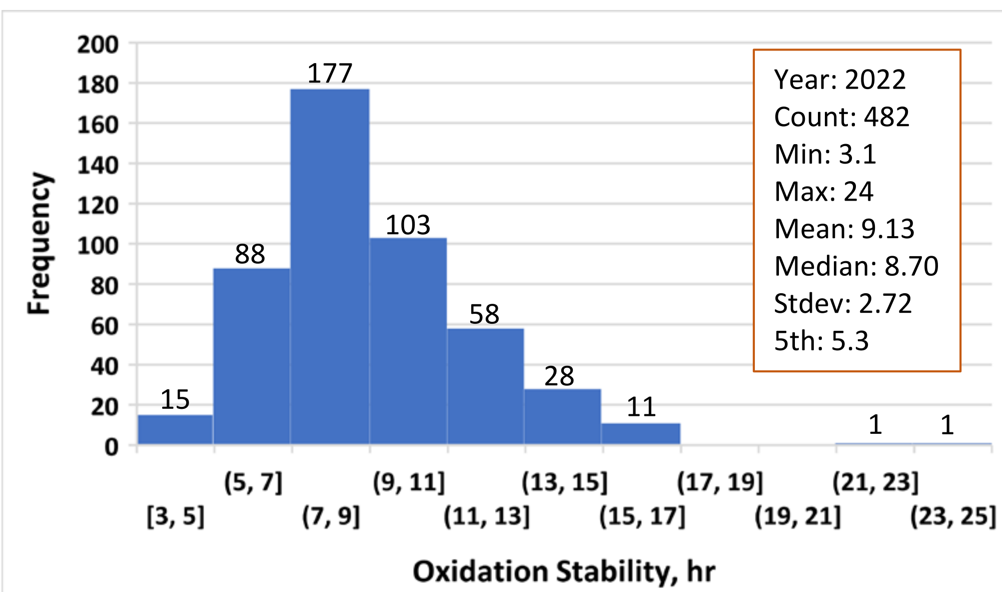

Figure 13. Oxidation stability results for biodiesel

3.12 Cold Soak Filterability Test

Biodiesel produced in 2022 had an average CSFT result of 106 seconds, a median of 101 seconds, and a 95th percentile of 157 seconds.

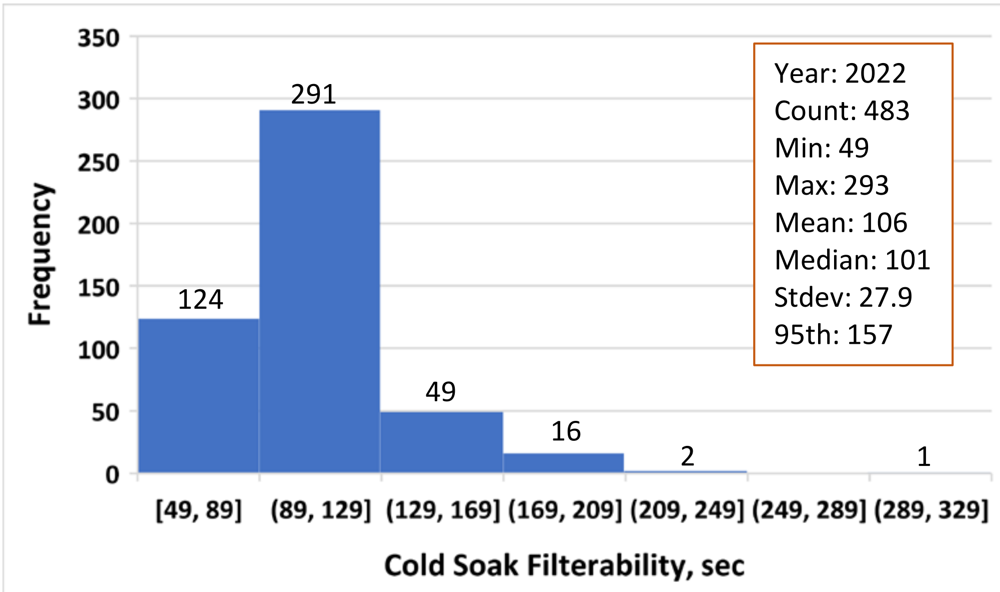

Figure 14. CSFT results for biodiesel

4 Summary

We analyzed monthly quality data voluntarily provided by BQ-9000 biodiesel producers in the United States and Canada for calendar year 2022. This is the sixth in a series of reports on the subject. Monthly quality data were submitted to a third-party team that removed any identifying company information before providing it to NREL. Our statistical results are summarized in Table 1. The data were not weighted for production volume, and binning was selected for ease of data presentation.

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[a] Data for 5th percentile.

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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

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ASTM International (ASTM). 2023. *ASTM D6751-23, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.* West Conshohocken, PA: ASTM International. http://doi.org/10.1520/D6751-23

Appendix

Data presented in this appendix represent "all data" voluntarily supplied for analysis. For these figures, any data that included "greater than" or "less than" were assumed to be equal to the value reported. As an example, Na+K data reported as <5 ppm were included as 5 ppm in this appendix. The purpose of including the data here is to best capture the data on biodiesel quality in calendar year 2022. Due to the nonstandard treatment of the data, no statistical analysis of appendix data was performed.

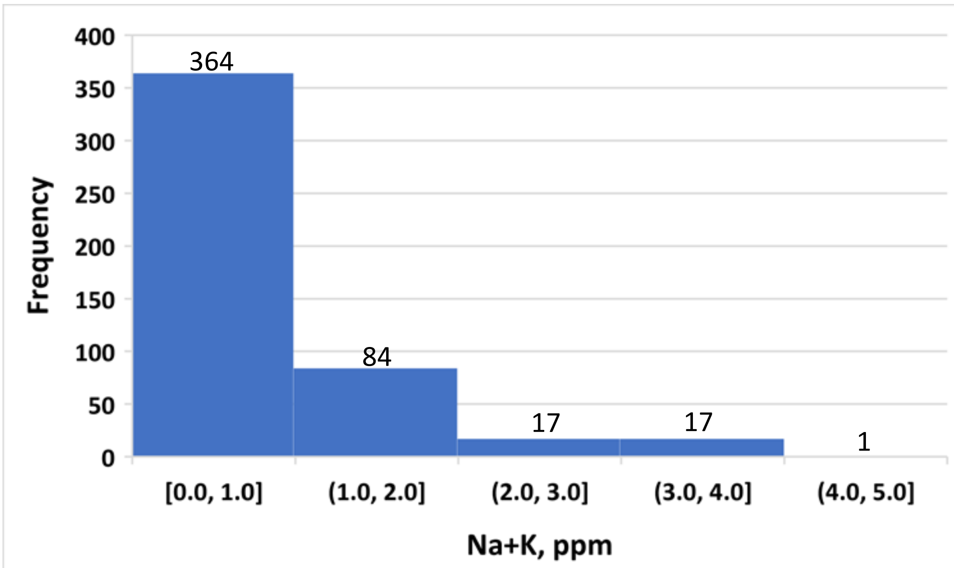

Figure A-1. All data analysis of sodium and potassium content of biodiesel.

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

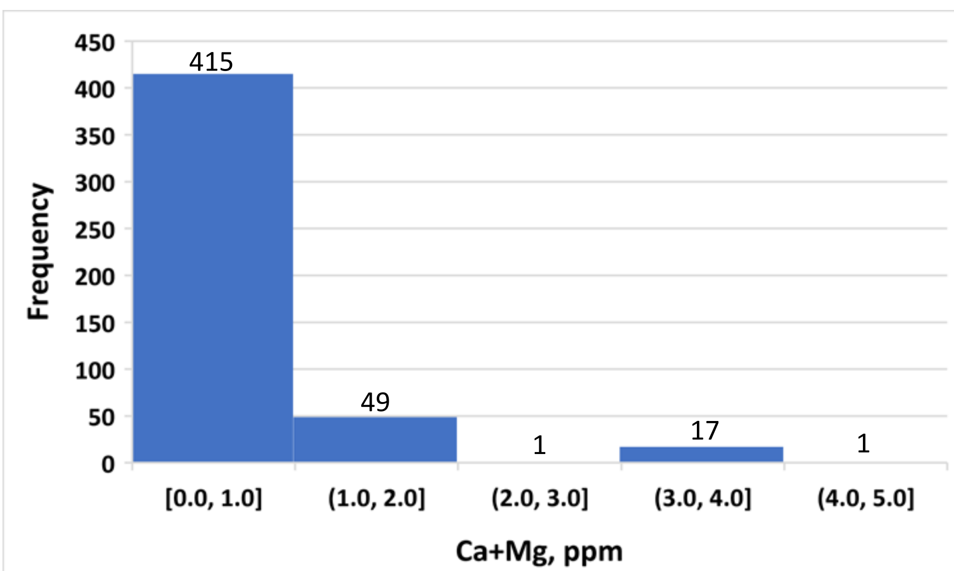

Figure A-2. All data analysis of calcium and magnesium content of biodiesel.

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

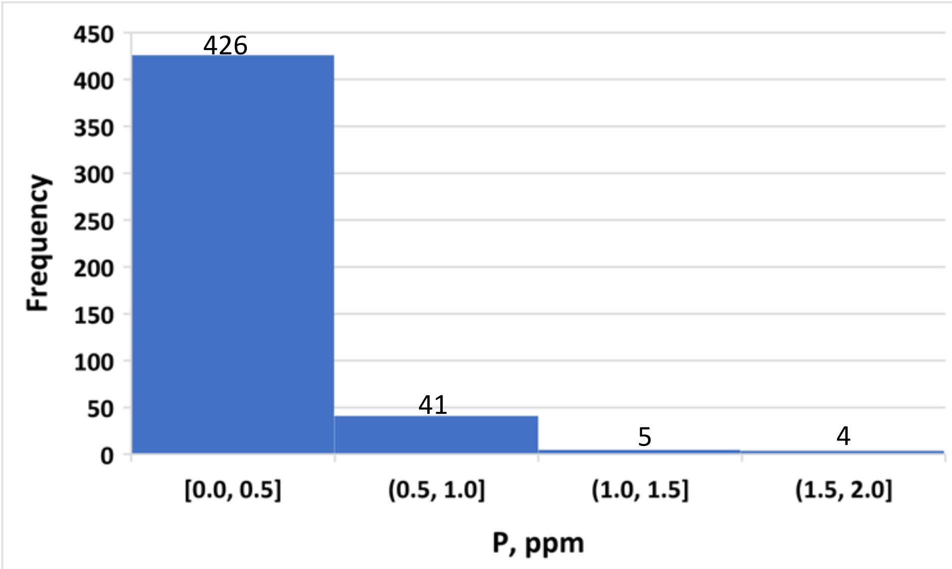

Figure A-3. All data analysis of phosphorus content of biodiesel.

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

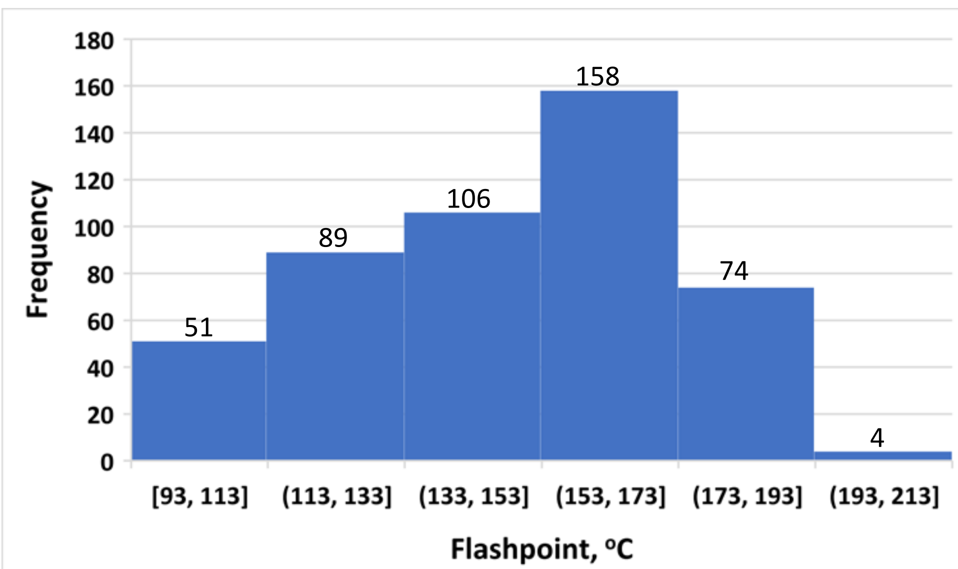

Figure A-4. All data analysis of flash point of biodiesel.

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

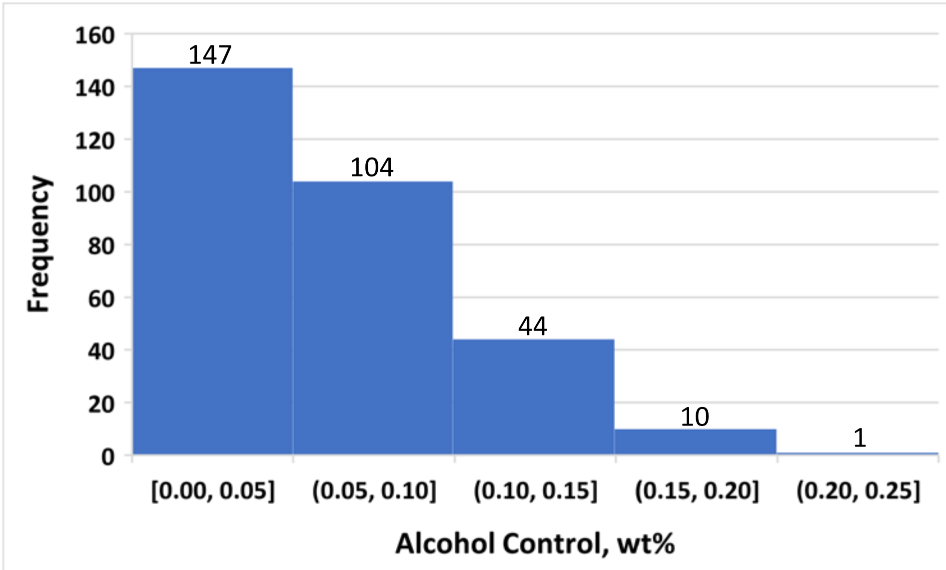

Figure A-5. All data analysis of alcohol control of biodiesel.

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

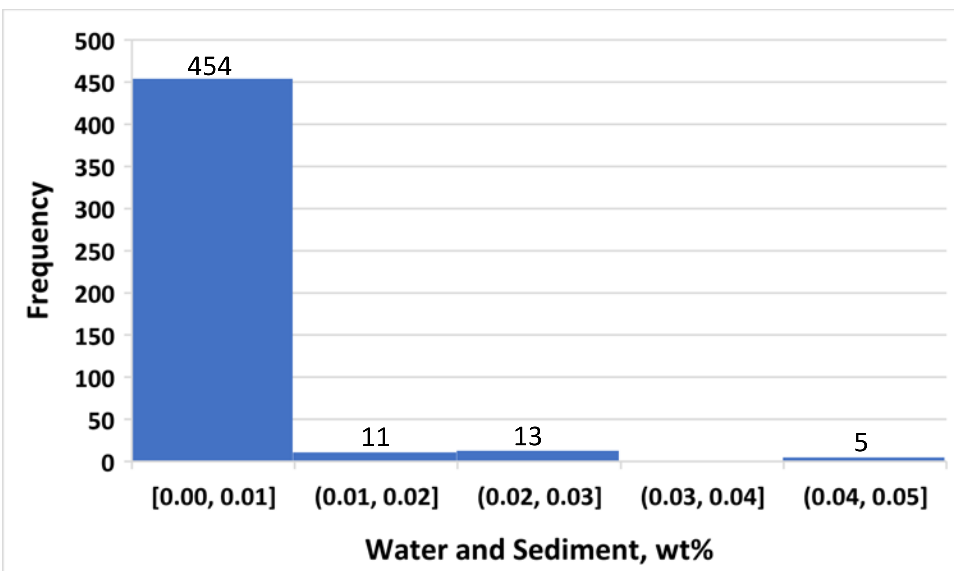

Figure A-6. All data analysis of water and sediment content of biodiesel.

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

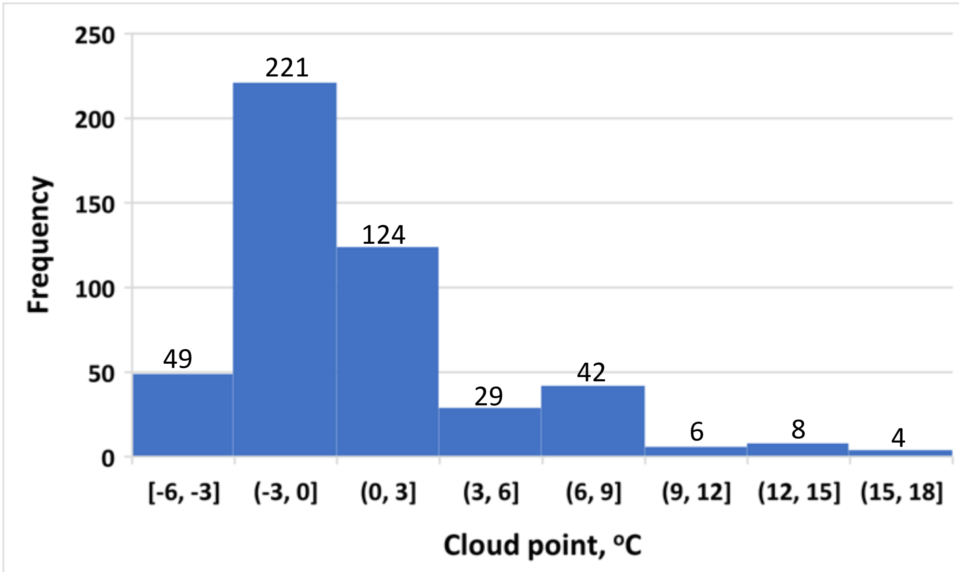

Figure A-7. All data analysis of cloud point of biodiesel.

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

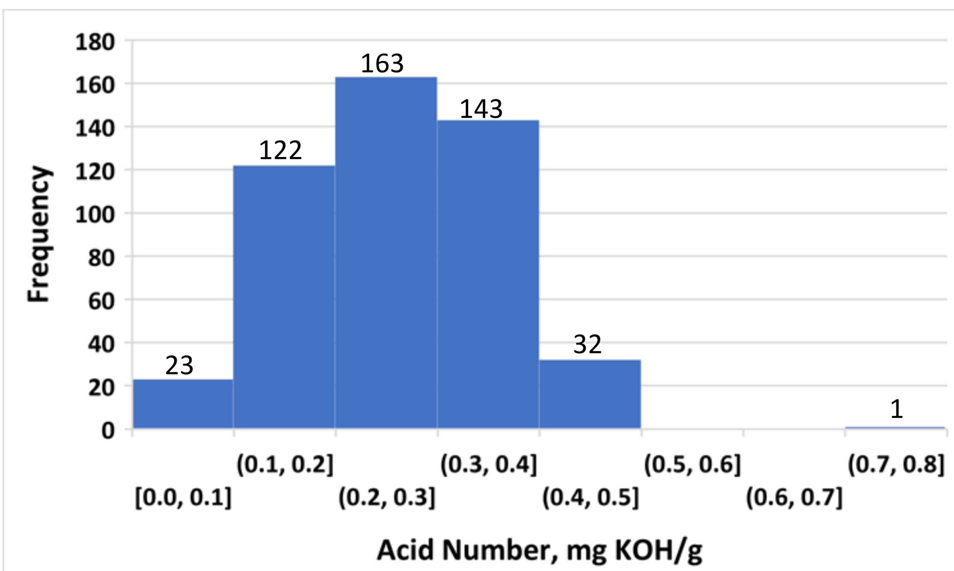

Figure A-8. All data analysis of acid number of biodiesel.

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

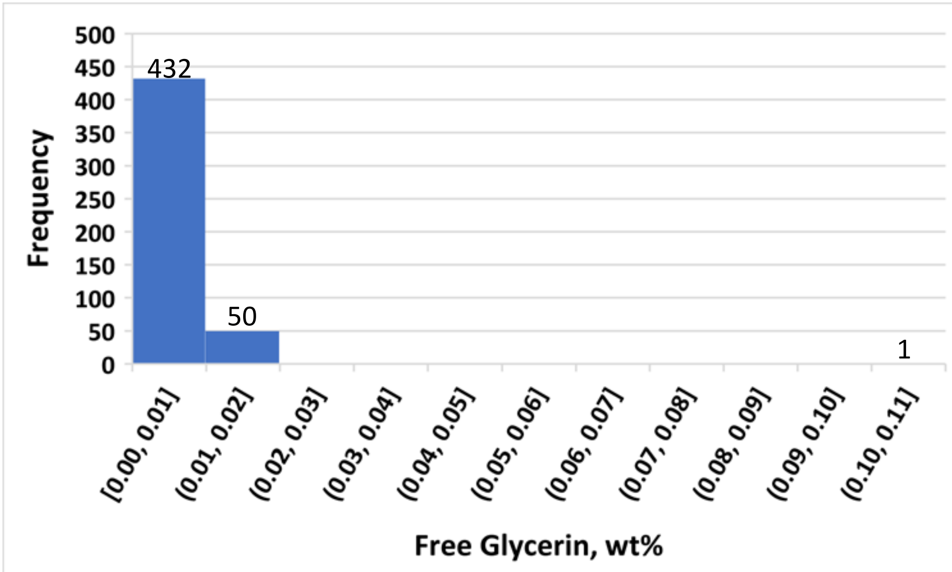

Figure A-9. All data analysis of free glycerin content of biodiesel.

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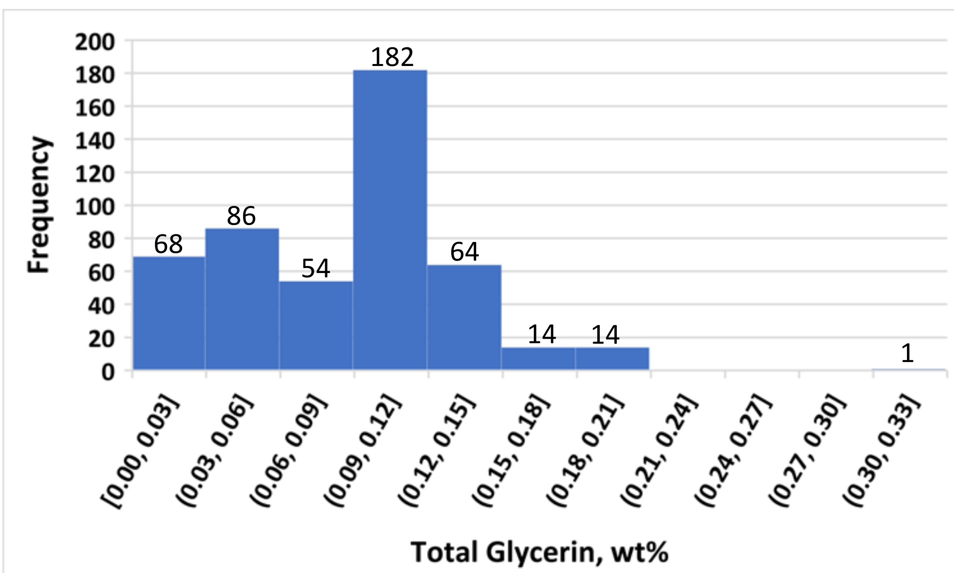

Figure A-10. All data analysis of total glycerin content of biodiesel.

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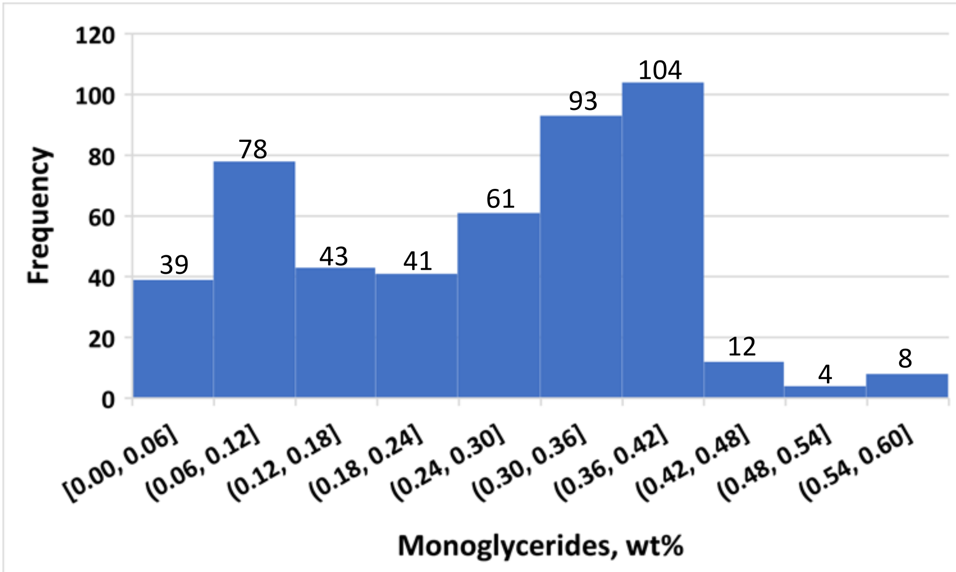

Figure A-11. All data analysis of monoglyceride content of biodiesel.

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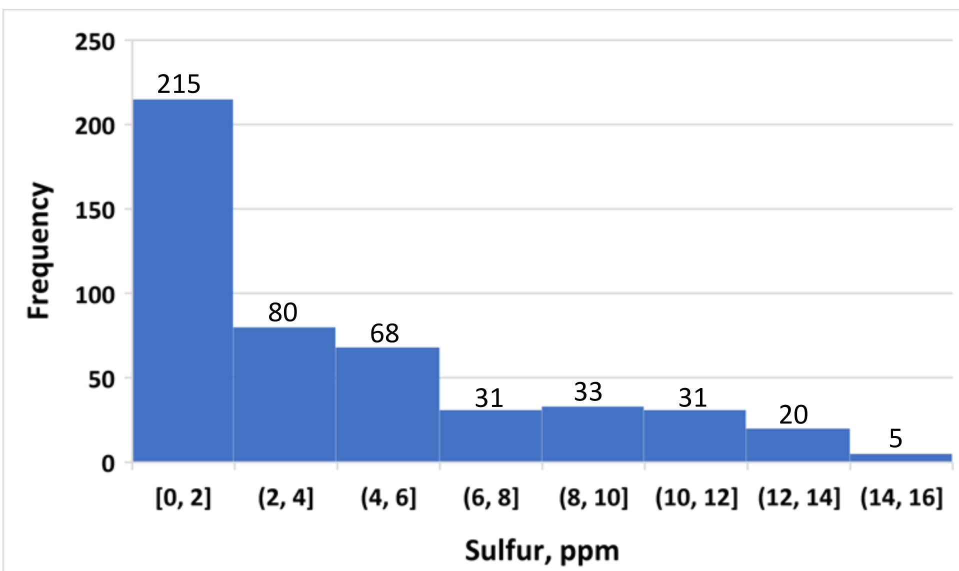

Figure A-12. All data analysis of sulfur content of biodiesel.

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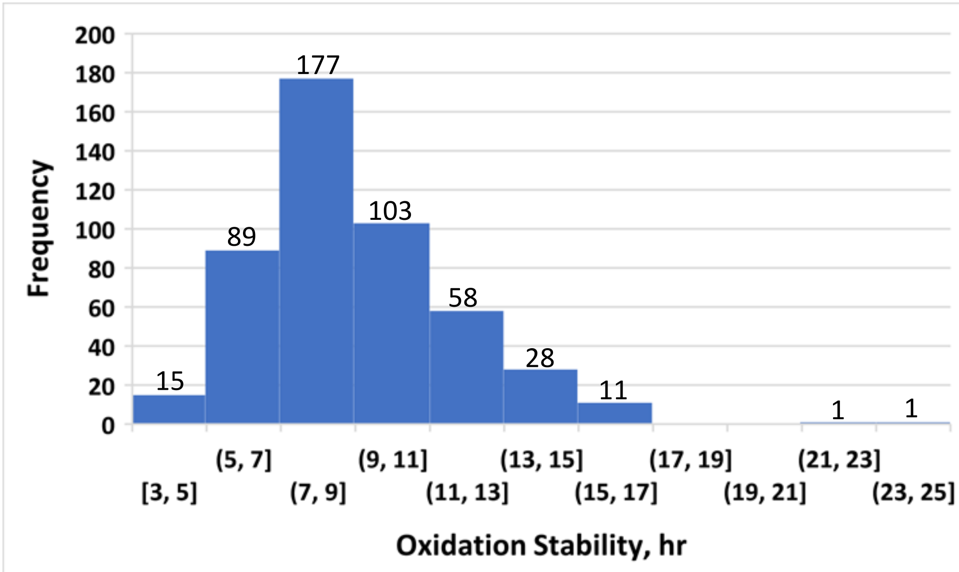

Figure A-13. All data analysis of oxidation stability of biodiesel.

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

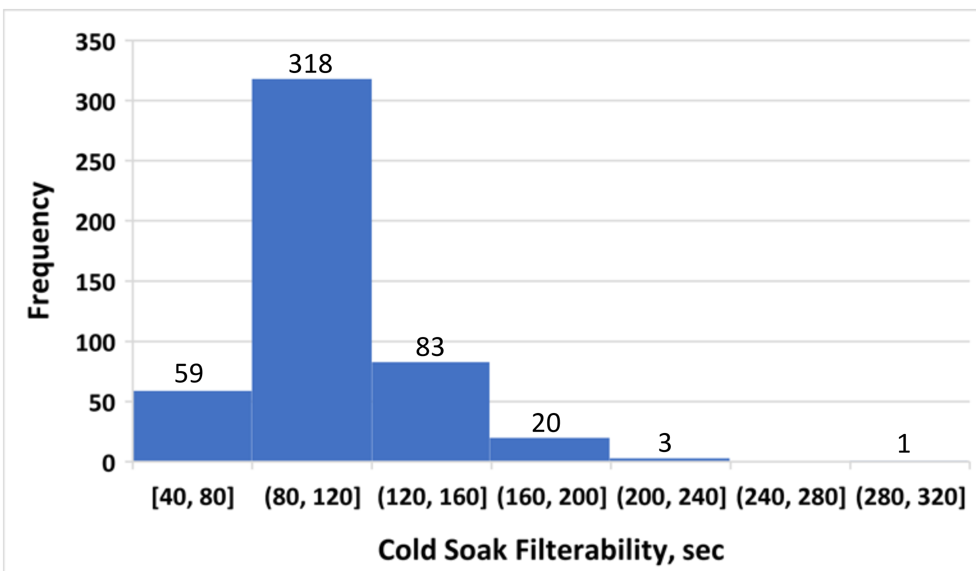

Figure A-14. All data analysis of CSFT of biodiesel.

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