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Evaluation of storage stability and corrosiveness properties of biodiesel blends

Fuels - Alternative & New Fuels

Sara Rezaee, Viswa Group

Ganesh Natarajan, Viswa Group
Kalaivani Murugaiah, Viswa Group
Aparna Balachandran, Viswa Group
Ramaratnam Visweswaran, Viswa Group

ABSTRACT

The shipping industry's use of biofuel blends has increased, with approximately 0.7% of the bunker fuel industry utilizing these blends (biodiesel or renewable diesel mixed with residual fuel or distillate) in 2023. One of the potential issues related to biodiesel blends is corrosion and oxidation stability. Biodiesel's water content can increase during storage, worsening its corrosive properties by promoting oxidation and acid formation, which can damage metal components in the fuel system and increase maintenance/replacement requirements.

Organic acids, formed through biodiesel oxidation due to dissolved oxygen during long-term storage, contribute to its corrosivity. Oxidation instability leads to oxidative products such as insoluble, gum, aldehydes, and alcohols, which can cause filter clogging, injector fouling, and deposit formation in the combustion chamber.

In this study, biodiesel blended with distillate fuels underwent accelerated aging following ASTM D4625 methodology (storage at 43°C, open to air, up to twelve weeks). Biodiesel blended with residual fuels was subjected to an in-house accelerated aging method (storage at 60°C, up to twelve weeks). A comprehensive analysis evaluates physicochemical properties, including acid number, sediment content, water, and free fatty acid/glycerin content. Additionally, we studied the impact of water on the storage properties of these biofuel blends.

In addition, this experimental work investigates the corrosiveness of biodiesels in the presence of steel rods at different immersion temperatures. The impact of water at various concentrations was also studied. Oxidation stability and chemical composition of biofuel blends were evaluated to identify any correlations between these parameters and the corrosivity of the fuels.

The investigation will offer valuable insights into the stability, quality, and potential improvements of biodiesel blends with distillate and residual fuels. These findings will aid in informed decision-making regarding fuel formulation, quality control and management practices.

1 INTRODUCTION

Biodiesel is prone to oxidation during prolonged storage, leading to the formation of acids, insoluble particles, and varnish-like substances that can alter its properties. These byproducts may clog fuel lines and filters with accumulated insoluble materials and generate corrosive compounds and deposits that can damage engine components, resulting in operational issues. As oxidation progresses, deposits can accumulate on critical engine parts such as injectors and fuel pump components. In more advanced stages, the chemical structure of the biodiesel breaks down, producing short-chain acids and aldehydes. This process makes the biodiesel more acidic, which promotes corrosion within the fuel system. The acids and deposits formed during oxidation accelerate wear in fuel pumps and injectors, and the presence of water in the fuel further intensifies rust and corrosion, exacerbated by the acids and hydroperoxides generated in the process [1]. Several studies have investigated the storage stability and oxidation behavior of biodiesel over time. Key findings regarding the changes in the stability properties of biodiesel over time from some of these studies are summarized in Table 1. In 2024, the short-term use of biofuels (meeting the specifications of ISO 8217:2024) by the shipping industry yielded positive results. However, it is important to note that most biofuels were used for short periods, and the long-term effects on machinery require further investigation. This study evaluates the storage stability and corrosiveness characteristics of biodiesel blends, addressing potential challenges and providing insights into their safe and effective use in marine applications.

Table 1. Storage stability and performance of biodiesel: a review of recent studies

Paper title	Biofuel feedstock	Storage time / Temperature	Findings
Long-term storage stability of biodiesel and biodiesel blends [2]	NA	26 weeks at 43°C	A reduction in oxidation stability (from 8.4 hours to 3 hours) was observed over 26 weeks of storage at 43°C.
Storage Stability of Biodiesel [3]	Diesel and Rapeseed oil	6 months at 20°C and 40°C	No significant change in acidity was observed when stored at 20°C, even over extended periods. However, tests at 40°C on samples with humidity over 0.1% showed an increase in free acidity, though it remained within the specified limit.
Biodiesel stability under commercial storage conditions over one year [4]	Rapeseed, Sunflower, Tallow, Used oil	one year at 20°C & 30.1°C	Biodiesel stability is affected by moisture, temperature, and storage material. Glass containers and cooler conditions (20°C) support medium-term stability. Reducing impurities like glycerides and phospholipids during production improves stability.
Stability Studies on Methyl and Ethyl Fatty Acid Esters of Sunflower seed oil [5]	Sunflower seed oil	90 days at 20°C, 30°C, 50°C	Storage of esters in contact with air at a temperature above 30°C, resulted in significant increases in peroxide, ultraviolet absorption, free fatty acid, viscosity and anisidine values. Exclusion of air retarded oxidation at all temperature levels.
Long term storage stability of Jatropha Curcas biodiesel [6]	JCB (Jatropha Curcas biodiesel)	170-200 days at 20°C & 40°C	Fresh JCB was unstable, but adding 200 ppm of Pyrogallol improved stability, keeping it stable for nearly 6 months. Viscosity, peroxide value (PV), and acid value (AV) increased over time but were controlled with the antioxidant.
Storage Stability of Biodiesel and Biodiesel Blends [7]	NA	12 weeks at 43°C	Long-term storage of B100 shows that biodiesel samples without synthetic antioxidants will start to oxidize immediately, regardless of initial induction time. If the induction time is near or below 3 hours, B100 is likely to exceed stability or acid value specifications within 4 months. Even B100 with induction times over 7 hours may fall out of specification for oxidation stability within 4 months, though acidity and deposit formation may not significantly increase.
Long term storage stability of biodiesel: Influence of feedstock, commercial additives and purification step [8]	Soybean, rapeseed, high oleic sunflower and palm methyl ester	6-month period at room temperature and not exposed to day light	Soybean Methyl Ester and Rapeseed Methyl Ester degraded quickly due to high polyunsaturated fats, while Palm Methyl Ester, with low polyunsaturated content, maintained stability (>6 hours induction period) even without antioxidants.
Storage stability of commercially available biodiesels and their blends under different storage conditions [9]	Soybean and Canola oil	12 months at 15°C and 40°C	At 15°C, B100 remained relatively stable throughout the 12-month storage period, with minimal changes in acid value (AV) and induction time (IT). Degradation of unsaturated fatty acid methyl esters was slow, and both canola- and soybean-based biodiesels maintained acceptable stability. However, at 40°C, oxidative degradation was more pronounced, particularly for soybean-based biodiesel due to its higher polyunsaturated FAME

content. Stability lasted for approximately 6 months under these conditions before significant declines in IT and increases in AV were observed.

2 MATERIALS AND METHODS

For the research, biofuel blends in this study were B20 to B35 which were used onboard the ship. The biodiesel component of these blends was primarily sourced from used cooking oils. All biodiesels used in the blends met the EN 14214 or ASTM D6751 specifications.

The storage stability study was conducted at two different temperatures: room temperature and an elevated temperature. At room temperature, the samples were stored in amber glass bottles with tightly sealed caps.

For the elevated temperature test, bio-distillate fuels underwent accelerated aging following the ASTM D4625 procedure. This method involves storing the fuels at 43°C in an open-air environment for up to 12 weeks. It is well-established that this test method simulates oxidation conditions for petroleum diesel, with each week of testing roughly corresponding to one month of real-world storage. However, the correlation between one week of aging at 43°C in the D4625 test and one month of storage at 21°C, which is typically used for petroleum diesel, has not yet been confirmed for biodiesel.

Additionally, bio-residual fuels were subjected to an in-house accelerated aging process, where they were stored at 60°C for up to 12 weeks.

In this study, various characterization techniques were employed to assess the storage stability properties of the biofuel blends. The acidity of the fuel samples, total acid number (TAN), was determined using the ASTM D664 (Procedure B) potentiometric titration method. Oxidation stability was evaluated following the EN 15751 standard method during the induction period. The total sediment existent content (TSE) was measured according to ISO 10307-1, and the water content was determined using ASTM D6304 (Procedure B). The FAME content in bio-residual fuel was measured according to ASTM D7963, while for bio-distillates, it was measured following EN 14078. To evaluate the corrosive properties, a steel corrosion test was conducted in accordance with ASTM D665. The iodine value was tested according to EN14111, and the free fatty acid content was measured as per AOCS Ca 5a-40.

A total of 33 bio-residual fuels were used in this study. Samples RF1 to RF20 were classified as B24 samples, and RF21 to RF33 are B30 samples. All samples were VLSFOs, except for RF6 and RF31, which were HSFOs. Additionally, 24 bio-distillate fuels were used. Samples DF1 to DF3 were classified as B30, while DF4 to DF24 were classified as B35. All 33 bio-residual fuels (graded as RF20, RF80, and RF180) and 24 bio-distillate fuels (graded as DFA and DFB) complied with the ISO 8217:2024 specifications.

3 RESULTS AND DISCUSSION

3.1 Aging at room temperature

The TSE, water content, and total acid number of bio-residual fuels were measured after storage at room temperature for 12 weeks. The results are summarized in Table 2. The actual FAME content of the samples was measured according to ASTM D7963. Some samples showed FAME content lower than expected, but this was still within the repeatability limits of the test results. Considering that the B100 used for blending had a minimum of 96.5 wt. % FAME and taking into account the repeatability of the test, the measured FAME content remains within an acceptable range.

Table 2. Changes in TAN, TSE, and water content for bio-residual fuels after 12 weeks of storage at room temperature.

ID	FAME, %	TAN Day 1, mg KOH/g	TAN Aged, mg KOH/g	TSE Day 1, wt. %	TSE Aged, wt. %	Water Day 1, ppm	Water Aged, ppm
RF1	22	-	-	0.01	0.08	2500	1848
RF2	22	0.15	0.19	0.01	0.05	500	350
RF3	16	0.77	0.88	0.01	0.10	2000	1588
RF4	21	0.94	1.04	0.02	0.09	2000	1585
RF5	19	-	-	0.01	0.06	2000	1608
RF6	18	0.19	0.19	0.02	0.02	1000	863
RF7	19	0.22	0.18	0.03	0.06	3000	2646

RF8	21	-	-	0.01	0.00	1500	1122
RF9	19	0.48	0.50	0.03	0.10	2000	1924
RF10	19	0.62	0.45	0.02	0.08	1500	808
RF11	17	0.94	0.86	0.01	0.02	1500	945
RF12	22	-	-	0.02	0.01	1500	1127
RF13	21	0.60	0.69	0.01	0.04	1000	833
RF14	23	-	-	0.02	0.01	1500	1007
RF15	23	-	-	0.02	0.04	2000	1920
RF16	19	0.71	0.78	0.01	0.08	4000	3717
RF17	19	-	-	0.03	0.04	2000	1592
RF18	20	0.52	0.59	0.03	0.11	1500	930
RF19	17	-	-	0.01	0.07	2000	1535
RF20	19	-	-	0.04	0.06	9000	8059
RF21	22	0.34	0.30	0.01	0.01	1200	836
RF22	29	-	-	0.02	0.03	790	425
RF23	31	-	-	0.01	0.01	740	999
RF24	26	0.34	0.37	0.01	0.01	1100	886
RF25	25	0.88	1.08	0.02	0.06	2000	2978
RF26	23	0.19	0.22	0.01	0.01	700	829
RF27	28	0.58	0.60	0.01	0.07	2000	1657
RF28	26	0.27	0.29	0.01	0.00	700	627
RF29	17	-	-	0.01	0.00	12100	12800
RF30	21	-	-	0.01	0.00	700	802
RF31	28	0.06	0.11	0.04	0.05	1500	773
RF32	28	0.39	0.45	0.01	0.01	3000	2151
RF33	26	0.45	0.40	-	-	1800	1200

No significant changes were observed in the total acid number and water content of the samples with storage, as the variations remained within the repeatability range of the test results. For most of the bio-residual fuels, there was a reduction in water content, although these results still fall within the repeatability range of the test results.

Regarding sediment content, 12 out of the 32 tested samples showed an increase in sediment values. However, the sediment content remained below or equal to 0.1% (the maximum limit as per ISO 8217) for all samples, with the exception of one sample, where the sediment content exceeded 0.1%. The increase in sediment values may be attributed to the deterioration of the residual fraction in bio-residual fuel blends. According to lab test results for VLSFOs, it has been observed that more than 50% of the samples show a potential for sediment content to increase over time [10].

Twenty-four bio-distillate fuels (DF1 to DF24) were tested after 12 weeks of storage at room temperature for TSE, TAN, and water content. No changes in these values were observed over time. The results are not included in the paper to maintain a focus on the essential details and maintain simplicity.

3.2 Aging at elevated temperature

3.2.1 Water – Acid Number – Sediment

No clear increase in the measured water content was observed for bio-residual fuels after aging at 60°C for 12 weeks (referring to Table 3). In fact, most of the tested samples showed a decrease in water content, which can be explained by the fact that the samples were open and aged at elevated temperatures, allowing for the possibility of water evaporation over time.

Table 3. Changes in TAN, TSE, and water content for bio-residual fuels after 12 weeks of storage at 60°C.

ID	TAN Day 1, mg KOH/g	TAN Aged, mg KOH/g	TSE Day 1, wt. %	TSE Aged, wt. %	Water Day 1, ppm	Water Aged, ppm
RF1	1.13	1.15	0.08	0.09	1348	186
RF2	0.19	0.29	0.05	0.015	350	158
RF3	0.88	1.07	0.10	0.06	1188	253
RF4	1.04	1.22	0.09	0.06	1285	223
RF5	0.16	0.07	0.06	0.13	1308	171
RF6	0.19	0.17	0.02	0.05	863	256
RF7	0.18	0.38	0.06	0.12	1646	202
RF8	0.43	0.91	0.01	0.27	1122	249
RF9	0.50	0.54	0.10	0.10	924	176
RF10	0.45	0.55	0.08	0.08	808	189
RF11	0.86	1.01	0.02	0.06	945	226
RF12	0.70	0.87	0.01	0.10	1027	273
RF13	0.69	0.86	0.04	0.06	833	193
RF14	1.03	1.12	0.01	0.06	1007	236
RF15	1.05	1.09	0.04	0.07	920	235
RF16	0.78	0.93	0.08	0.08	2717	180
RF17	0.22	0.38	0.04	0.15	1192	250
RF18	0.59	0.65	0.11	0.09	930	215
RF21	0.12	0.35	0.01	0.08	836	290
RF22	0.24	0.48	0.03	0.42	425	253
RF23	0.12	0.42	0.01	0.02	999	301
RF24	0.37	0.77	0.00	0.02	386	210
RF25	1.08	2.53	0.06	0.165	2978	858
RF26	0.22	0.61	0.01	0.07	329	186
RF27	0.60	0.78	0.07	0.07	1657	213
RF31	0.11	0.32	0.05	0.58	773	283
RF32	0.45	0.68	0.01	0.07	2151	224

During 12 weeks of storage at 60°C, the sediment content of 48% of the tested bio-residual fuels increased. This rise in sediment content is mainly linked to the residual fractions, which are more paraffinic and prone to degradation over time. An increasing trend in the acid number of bio-residual fuels was observed after 12 weeks of aging. For some samples, the increase in acid number was within the test's repeatability range. However, for about 40% of the samples, there was a noticeable rise in acid number (over a 50% increase), although the results remained within the acceptable limits set by ISO 8217. An increase in acid number can indicate degradation over time due to oxidation [1]. The results for bio-distillate fuels are presented in Table 4. Samples DF1 to DF3 were classified as B30, while DF4 to DF24 were classified as B35.

The sediment content of the samples remained unchanged after 12 weeks of storage at 43°C. Since the sediment content for all samples, both before and after aging was 0.01%, the results are not included in the table. Most of the tested samples exhibited a reduction in water content, likely due to exposure to air and aging at elevated temperatures, which may have led to water evaporation.

Most blends showed an increase in acid number after 12 weeks of storage, yet they remained within the specified total acid number limit for distillate fuel. The increase in acid number can be due to the oxidation reaction and changes in the chemical structure of biodiesel compounds. The most significant increase was observed in the DF22 sample. Further analysis of this sample revealed that the oxidation stability of this sample has reduced from 10.8 hrs to 3.6 hrs. A significant increase in the acid number and a reduction in oxidation stability indicate FAME degradation and the formation of compounds such as acids, aldehydes, ketones, and peroxides in the sample.

Table 4. Changes in TAN and water content for bio-distillate fuels after 12 weeks of storage at 43°C.

ID	FAME, %	TAN Day 1, mg KOH/g	TAN Aged, mg KOH/g	Water Day 1, ppm	Water Aged, ppm
DF1	35	0.23	0.35	503	127
DF2	31	0.17	0.25	325	21
DF3	37	0.16	0.32	383	94
DF4	31	0.29	0.38	298	64
DF5	35	0.23	0.31	325	80
DF6	36	0.01	0.05	400	84
DF7	36	0.03	0.07	273	109
DF8	29	0.13	0.19	238	51
DF9	40	0.11	0.17	303	92
DF10	38	0.08	0.14	444	125
DF11	21	0.27	0.41	208	57
DF12	37	0.17	0.30	393	123
DF13	36	0.14	0.21	327	77
DF14	35	0.21	0.36	310	128
DF15	23	0.15	0.21	205	66
DF16	36	0.16	0.23	356	101
DF17	34	0.13	0.21	324	79
DF18	35	0.06	0.12	289	70
DF19	36	0.09	0.16	341	71
DF20	29	0.04	0.13	239	54
DF21	39	0.05	0.13	309	79
DF22	33	0.14	1.10	397	281
DF23	35	0.14	0.29	344	185
DF24	36	0.10	0.19	340	105

3.2.2 Oxidation stability

The oxidation stability test measures the extent of oxidation damage in the fuel, which is a critical property affecting both the immediate and long-term performance of the engine. Oxidation and polymerization reactions often result in the formation of high molecular weight insoluble sediments and gums [1]. The oxidation stability of biodiesel is influenced by the fatty acid composition, particularly the degree of unsaturation. Impurities such as metals, free fatty acids (FFAs), additives, and antioxidants also significantly impact its stability [1].

Six bio-distillate fuels (B35) were tested for oxidation stability on day 1 and after 12 weeks of aging at 43°C. The results indicated that if the initial oxidation stability exceeds 20 hours, it is expected to remain above 20 hours after 12 weeks of storage at 43°C. For the three samples with oxidation stability between 10 and 20 hours, a reduction in stability of more than 30% was observed. The oxidation stability of two samples remained within the ISO 8217:2024 acceptable limit of 8 hours, while the stability of one sample decreased to 3.6 hours, falling below the acceptable limit. This suggests that, for these biofuel blends (B35), the B100 sample used for blending with the distillate likely had an oxidation stability lower than 8 hours. For sample DF22, a significant increase in acid number and a decrease in oxidation stability were noted, which could be attributed to the sample's initially low oxidation stability and the use of different types of antioxidants.

Table 5. Oxidation stability and TAN of six bio-distillates before and after aging at 43°C for 12 weeks

ID	Oxidation Stability, Day 1 hrs	Oxidation Stability, 12 weeks hrs	Acid number, Day 1 mg KOH/g	Acid Number, 12 weeks mg KOH/g
DF5	>20.0	>20.0	0.23	0.31
DF11	>20.0	>20.0	0.27	0.41
DF16	>20.0	>20.0	0.16	0.23
DF12	17.2	12.4	0.17	0.30
DF14	16.7	11.3	0.21	0.36
DF22	10.8	3.6	0.14	1.10

3.2.3 Corrosivity properties

The acid number indicates the level of acidity in biodiesel or blends under test conditions. However, it cannot predict their corrosiveness in real-world use, as oxidation products and organic acids vary in their ability to cause corrosion. There is no direct correlation between the acid number and the likelihood of metal corrosion [11].

The corrosive properties of biodiesels were assessed using the steel corrosion test outlined in ASTM D665. This test measures the susceptibility of carbon steel to corrosion when exposed to biofuel blends. It is an accelerated test designed to evaluate the corrosive nature of oils under harsh conditions, including exposure to 10% water at 60°C. However, it is important to note that these test conditions may not fully replicate onboard environments, as the water concentration (10% v/v), temperature, and material conditions may differ from real-world conditions. Several biofuel blends (DMA B35, shown in Figure 1; RF1, shown in Figure 3; RF2, shown in Figure 4; RF25, shown in Figure 2) used onboard the vessels were tested according to ASTM D665. The results indicated slight to moderate rusting on the steel rods. However, the vessels operated without any reported issues. Since the fuel consumption period for these blends was under 60 days, further investigation is needed to assess the long-term effects of biofuel blends in real-world conditions. All fuels met the ISO 8217:2024 specifications. Figure 1 provides examples of the tested samples.

Figure 1. Steel rods with different DMA B35 blends showing different degrees of rust despite being the same grade: a. TAN = 0.13, b. TAN = 0.14, and c. TAN = 0.06 mg KOH/g fuel, tested according to ASTM D665. a. No discoloration or rust, b. Slight rusting, and c. Moderate rusting.

One key conclusion from this study is that there was no direct correlation between the acid number and rust formation on the rods. For instance, three samples shown in Figure 1 have low and approximately similar acid numbers while the degree of corrosion is different.

To investigate the cause of rust corrosion, we analyzed the oxidation stability, iodine value, and free fatty acid content of the samples. The results, as shown in Table 6, were very similar, and we were unable to differentiate the samples based on these parameters. The potential cause of corrosion may still lie in the chemical composition of the samples. For example, the amount of glycerides present in the samples could influence rust formation. Additionally, the type of antioxidant used in the biodiesel may play a role. There are two primary types of antioxidants: polar and non-polar. If a sample contains a non-polar antioxidant, it may better resist oxidation in the presence of high water content. Therefore, it is possible that sample a contains a non-polar antioxidant, while the other two samples contain polar antioxidants. Christensen et al. demonstrated that fuels treated with polar antioxidants and exposed to water or high humidity experienced decreased stability due to the extraction of the polar antioxidants into the water layer. In contrast, fuels treated with non-polar antioxidants exhibited better long-term stability under the same conditions [12].

Table 6. Chemical and oxidation stability properties

Sample ID	Free Fatty Acids, oleic acid, %	Iodine Value, g Iodine per 100 g	Oxidation Stability, Hours
DMA 35 a	0.4	37.5	25
DMA 35 b	0.5	24.1	26
DMA 35 c	0.5	40.1	24

As discussed earlier, various factors can influence the corrosive nature of biodiesels, including their chemical composition, presence of glycerides, metals, free fatty acids, oxidation stability, and the types of antioxidants used. Figure 2 presents the relationship between oxidation stability and the corrosive properties of biodiesel. DF25 exhibited an oxidation stability greater than 20 hrs while DF26 had oxidation stability equal to 6.5 hrs, clearly can be seen that the degree of rust formation on the rods for sample DF26 is higher than DF25. Lower oxidation stability means the fuel is more likely to react with oxygen, forming acidic and corrosive byproducts. These byproducts can cause rust to form on metal rods by promoting corrosion when they come into contact with the metal.

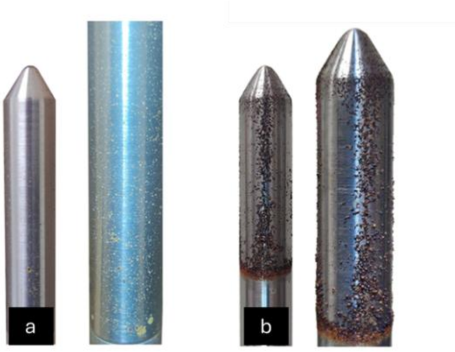

Figure 2. Steel rods showing the effect of oxidation stability. The testing was according to ASTM D 665 for: a. DF25 with TAN = 0.01 mg KOH/g and oxidation stability > 20 hrs showing slight rusting, b. DF26 with TAN = 0.01 mg KOH/g and oxidation stability = 6.5 hrs showing moderate to heavy rusting.

In addition to the composition and chemical properties of biodiesel, the presence of water and temperature can significantly influence its corrosive properties. To assess the impact of temperature on the corrosiveness of bio-residual fuels, sample RF1 (grade B30) was tested at 40°C and 60°C. The test results (refer to Figure 3) indicated slight variations in corrosion severity between the rods tested at 40°C and 60°C. At 60°C, minor rust formation was observed on the rods, which was not present at 40°C. This suggests that the higher temperature accelerates oxidation, leading to rust formation.

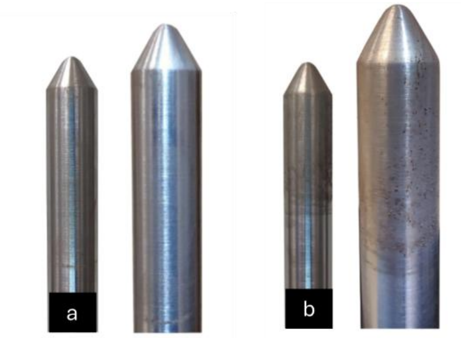

Figure 3. Steel corrosion test showing the effect of temperature. For RF1, according to the modified ASTM D665, at two different temperatures: a. 40°C showing no corrosion, and b. 60°C showing mild corrosion.

To examine the impact of water concentration, RF2 was tested at varying levels of water content (10 % to 0.5%). As shown in Figure 4, no rust formation was observed on the rods at 2% water concentration. However, rust formation occurred at 5% and 10% concentrations. This highlights the critical importance of preventing external water contamination in tanks.

Figure 4. Steel corrosion test showing the effect at different water concentrations for RF2 according to the modified ASTM D665. Rust formation is present at 5% and 10% water concentrations.

In addition to bio-distillate fuels, a B100 sample with an initial oxidation stability of 6 hours was tested for steel corrosion both before and after aging for 12 weeks at 43°C. The results (Figure 5) clearly indicate that the B100 sample underwent oxidation, as significant rust formation was observed on the rods after 12 weeks of aging. After aging, the oxidation stability of the B100 sample was reduced to 2.5 hours. This decrease indicates that biodiesels are susceptible to thermal stress, leading to oxidation and the formation of byproducts, which contributed to rust formation on the steel rods during testing.

Figure 5. Steel corrosion test showing the effect of aging on corrosion. This test was performed according to ASTM D665 for a. B100 unaged showing no corrosion & b. B100 aged at 43°C for 12 weeks showing significant corrosion.

4 CONCLUSIONS

Storage stability was evaluated for 33 bio-residual fuels. No significant changes were observed in the total acid number and water content of the samples, as the variations remained within the repeatability range of the test results when stored at room temperature after 12 weeks. Regarding sediment content, 12 out of the 33 samples showed an increase, though the sediment content remained below the ISO 8217 maximum limit of 0.1% for all but one sample, where it exceeded this threshold. The increase in sediment values may be attributed to the deterioration of the residual fraction in bio-residual fuel blends.

For the 24 bio-distillate fuels tested, no changes were observed in sediment content, TAN, or water content after 12 weeks of storage at room temperature.

When bio-residual fuels were aged at 60°C for 12 weeks, no clear increase in water content was observed. However, 48% of the samples showed an increase in sediment values, and more than 50% exhibited an increase in acid number, though all results remained within ISO 8217's acceptable limits.

For bio-distillate fuels aged at 43°C for 12 weeks, no changes were seen in water content or sediment values. While most bio-distillate blends showed an increase in acid number, they remained within acceptable limits. However, the DF22 sample experienced a significant drop in oxidation stability, decreasing from 10.8 to 3.6 hours, suggesting greater susceptibility to oxidation.

Regarding the oxidation stability of B35 bio-distillate samples, blends with initial oxidation stability over 20 hours maintained stability above 20 hours after 12 weeks. For samples with initial oxidation stability between 10 and 20 hours, a reduction of greater than 30% was observed. One sample's oxidation stability fell below the acceptable limit, indicating that the B100 used for blending likely had lower stability.

Overall, for both bio-distillate and bio-residual fuels, no significant changes in water content were observed after 12 weeks of storage at room temperature, 43°C for bio-distillate, and 60°C for bio-residual fuels. However, changes in acidity, oxidation stability, and sediment were observed in most samples. The acid values remained within the ISO 8217 limit. These findings suggest that if the fuels are to be stored for longer than 12 weeks, it would be beneficial to reassess key properties such as acidity, oxidation stability, and sediment levels. In terms of the corrosive properties of steel material, as determined by ASTM D665, no correlation was found between the acid number and rust formation on the steel rods. However, a relationship was observed between the chemical composition of biodiesel, oxidation stability, temperature, and water content with rust formation. Higher temperatures and increased water content can accelerate corrosion, which depends on the chemical composition and the type of antioxidant additives in the biodiesel. Corrosion may occur at different temperatures or water content levels, depending on these factors.

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