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Comparative Assessment of Mixed Biodiesel and Commercial Diesel on a Dual Fuel Mode Generator

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Abstract Biodiesel is a renewable and sustainable fuel generated from a variety of feedstocks, including soybean oil, canola oil, and used motor oil. It has been widely acknowledged as a promising alternative to diesel fuel derived from petroleum because of its lower greenhouse gas emissions and environmental impact. In addition, blending various varieties of biodiesel can improve fuel properties, including these physical and chemical properties. This study compared through a thorough evaluation and assessment of the different properties of mixed biodiesel and commercial diesel. It was compared in terms of physical properties: viscosity and density, and chemical properties: pH level, corrosion test, and amount of particle matter determined using gravimetric testing. The study used research and development with a quantitative design focused on the experimental approach. Results revealed that the viscosity values of the mixed biodiesel had an overall mean of 5.68, while commercial diesel had a value of 4.56. For the density, the Mixed Biodiesel attained an overall mean of 0.843 while the commercial diesel yielded 0.83. Furthermore, in their pH level testing, the Mixed Biodiesel yielded an overall value of 8.80, while the commercial diesel got an overall mean of 9.46. For their corrosion test, the three samples of mixed biodiesel passed the ASTM D130 rating in which it garnered the degree of 1b (Slight tarnish), while the commercial diesel garnered 1a, which is still in the classification of Slight tarnish. In addition, for the particle matter, the mixed biodiesel yielded an overall mean of 1.801, while the commercial diesel only had 0.636. T-tests revealed that there were no significant difference on the physical and chemical properties of mixed biodiesel and commercial diesel. Further studies regarding the different physical and chemical properties are recommended for future contribution to the body of knowledge.

Keywords: *canola oil, chemical properties, commercial diesel, gravimetric testing, mixed biodiesel, particle matter physical properties, used engine oil*

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1. Introduction

Fossil fuels are essential in numerous industries, including industrial development, transportation, and agriculture. The depletion of conventional fossil fuels and the increasing energy demand has led to exploring alternative energy sources. Biodiesel, a renewable energy source, has gained attention due to its environmental sustainability, renewability, and potential for reducing greenhouse gas emissions. However, using pure biodiesel in diesel engines has some limitations, such as higher viscosity and lower energy content. A blend of biodiesel and commercial diesel, known as mixed biodiesel, has been proposed to overcome these limitations. Several studies have been conducted to investigate the performance and emissions of diesel engines using mixed biodiesel. However, there needs to be more research on the use of mixed biodiesel in dual-fuel mode generators [1] [2] [3]. The fast expansion of the global economy and fossil fuel resources are being intensively used [4].

Essentially, in fossil fuels, their heat can be used directly, as in the case of home furnaces, or it can be used to create steam to power electricity-generating generators [5]. However, they cannot be used as a dependable, renewable energy source since they take millions of years to produce, and the supply is unlimited. Humans cannot just wait for additional fossil fuels to generate because they take so long to form [6]. Also, Fossil fuels are the leading cause of climate change and global warming, and the only way to reduce greenhouse gas emissions is to discover cleaner ways to generate electricity and power our vehicles [7].

On a local scale, the supply of petroleum-based fuel or fossil fuel cannot meet the increasing energy demand; there is a need to import these energy sources from foreign countries making the Philippines only less than sixty percent self-sufficient. Increased energy demand and carbon dioxide emissions in the Philippines are being driven by both the electricity generation and transportation sectors. The Philippines has mainly relied on fossil fuels (crude oil, natural gas, and coal) as its primary energy source in the last ten years. Meanwhile, renewable energy sources (wind, solar, hydropower, geothermal, and biomass) contribute only fifteen percent [8]. This led to the Philippines exploring different alternative sources of energy to make the country less dependent on imported fossil fuels and to reduce the country's CO_2 emissions [9] significantly. In solution to the points stated, biodiesel, a renewable energy source, has gained attention due to its environmental sustainability, renewability, and potential for reducing greenhouse gas emissions. However, the use of pure biodiesel in diesel engines has some limitations, such as higher viscosity and lower energy content [1] [2] [3]. Biodiesel has several significant benefits over regular diesel. Since it is obtained from renewable resources, it reduces reliance on conventional fuel [10]. Biodiesel, as a green energy source, could be a viable replacement for fossil fuels. It can help to prevent air pollution by lowering CO_2, SO_2, CO, and HC emissions. Because plants absorb more CO_2 than those expelled by the biodiesel combustion process, the carbon cycle of biodiesel from sustainable resources is a negative budget for the photosynthetic process and combustion emissions overall. Compared to fossil fuels, biodiesel can more efficiently reduce CO_2 emissions, safeguard the natural environment, and maintain ecological equilibrium [11]. Although biodiesel can be used as a fuel for vehicles in its pure form, it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons in diesel-powered vehicles [12].

A diesel-biodiesel blend produces lower emissions than fuel alone. A tiny amount of biodiesel can be used as an addition in low-sulfur diesel compositions to replace the lubricity lost when the sulfur is removed [13]. Petroleum diesel and biodiesel are fuels that are very similar but not identical. But the differences are quite tiny when we consider the significantly different processes for producing biodiesel versus petroleum diesel. Numerous additives are available to adjust the qualities of biodiesel fuel, and biodiesel can be combined with petroleum diesel fuel if required [14]. While biodiesel is considered renewable and environmentally friendly, the production process can still have negative environmental impacts. There is a need for research to evaluate the environmental impacts of producing biodiesel from different vegetable oils. This includes assessing the land required for oilseed cultivation, the water used in the production process, and the potential for soil and water contamination [15].

Biodiesel produced from different vegetable oils can have different physical and chemical properties, affecting engine performance. There is a need for research to investigate the effects of different vegetable oils on engine performance, including fuel efficiency, emissions, and engine wear. Biodiesel produced from some vegetable oils can have poor cold flow properties, leading to clogging and other problems in cold weather. There is a need for research to investigate the cold flow properties of biodiesel produced from different vegetable oils and the effectiveness of various additives in improving these properties [16]. The production of biodiesel generates waste products, such as glycerol and spent catalysts. Research is needed to investigate the potential uses of these waste products, such as their conversion into value-added products or their use as feedstocks for other processes [15].

Biodiesels are regarded as energy sources with the potential to solve a series of problems related to climate change and sustainability. With this being stated, Canola oil is one of the most effective and efficient biodiesel sources, with outstanding cold-flow qualities; what is healthy for the heart is also beneficial for the engine, thanks to canola oil's low saturated fat level. Furthermore, when crushed, canola seed generates approximately 45 percent oil, compared to only 18 percent for soybeans, the most common biodiesel feedstock [17]. Canola oil biodiesel is a good alternative fuel for diesel engines without requiring engine modifications. Compared to other mixed canola oil biodiesel fuels, BD20 is an approved alternative fuel based on engine combustion performance and exhaust emission characteristics. Canola oil diesel oxygen atoms play a significant role in lowering CO, HC, and PM emissions. Expectations are that pursuing policies supporting biodiesels will benefit welfare and sustainability in societies [18]. Many studies have been studying the comparison of biodiesel and commercial diesel. However, these studies used minimal parameters, which eventually needed more statistical data analysis to highlight mixed biodiesels' physical and chemical characteristics. In relevance with today's time, few studies have compared mixed biodiesel using a blend of canola oil and used engine oil which ran at 16,000 km max based on the odometer.

This study made a thorough comparison through a systematic process of assessment and evaluation of mixed biodiesel and commercial diesel in terms of their physical properties: viscosity and density; and chemical properties in terms of pH level, Copper Corrosion level, and amount of particle matter through gravimetric testing. The central hypothesis of this study is that there is no significant difference in the physical and chemical properties of mixed biodiesel and commercial diesel.

2. Methodology Research Design

Figure 1. Schematic Diagram of Mixed Biodiesel Production

This study will apply a Research and Development (R&D) approach with an experimental research design in a quantitative manner as it aims to find potential improvements to existing mixed biodiesels. The research design is best suited as the processes first try to identify the problem, then generates a concept, afterward prototype developing, then several testing will take place, and validation as the last step will aim to assess if the said solution is effective to the problem stated [19].

2.1. Research Instruments

An initial process called transesterification was used to prepare and create the needed mixed biodiesel. One liter of Canola oil was heated to 55°C by stirring in a covered container to eliminate any water that may have been present in the oil; by doing so, the mixture was also prevented from producing glycerin during chemical processing. After reaching about 55°C, the mixture was allowed to cool in room conditions. After cooling, another sterile bottle was used. In which a 200 mL methyl alcohol (methanol) and 7.5g Potassium hydroxide catalyzer (KOH) were mixed at constant room temperature. After mixing the catalyst with the methanol - leaving no trace of the solute, it was directly mixed with the heated canola oil from a different container. The bottle with a mixture of the catalyst solution and canola oil was Shaken vigorously for 5 minutes straight. After the reaction, it was set to rest for one day in the room condition. As a result of this procedure, a layer of glycerol with a higher viscosity collapsed in the bottom. A funnel was then used to separate the glycerol layer from the homogenous mixture. The mixture was then washed with the same amount of pure water and heated to 120°C. The added water evaporated from the mixture after the Temperature exceeded 120°C. The water wash procedure was administered for five days in order to attain high-quality biodiesel. After this procedure, pure biodiesel is obtained [20].

The pyrolysis method was used for its other blend, converting used engine oil to biodiesel. Before refining the used engine oil, 500 mL of waste engine oil was poured into a 2 000 mL stainless equipment or any flask that can withstand the heat. The equipment was placed in Hotplate or a made furnace with a surface temperature ranging from 300 to 550 C. The sample was then heated to produce fuel vapor. Lastly, the fuel vapor was condensed using a water-cooled condenser, specifically a Liebig Condenser, to have a smooth flow on the biodiesel yield [21].

Direct mixing was the last method and process to get the finished product finally. The Canola oil biodiesel and used engine oil diesel were experimentally blended to different ratios in the range of 70% to 30% with a specific ratio of 7:3. The mixed biodiesel was then reheated at a constant temperature of 120 C to remove or let excess water evaporate [22].

2.1.1. Evaluation of Physical Properties

Regarding the physical properties of the biodiesel and commercial diesel fuel, each parameter has corresponding instruments that were used. Viscosity on fuels was measured using a ball, specifically a marble, and the aid of a graduated cylinder. It was conducted through five trials to measure the viscosity of the fuel [23]. Lastly, for the density, a graduated cylinder and a weighing scale were used as research instruments to measure the fuel density [24].

2.1.2. Evaluation of Chemical Properties

In determining the values of chemical properties, initially, in terms of pH levels, a pH paper (litmus paper) or pH meter was used [25]. For the copper corrosion testing, a research instrument called copper strips was used where through a copper strip test, and a guide was used for the basis of its standard (ASTM Copper Strip Corrosion Standards) [26], next, For the procedures that were done on the generator, specifically testing on the value particle matter through gravimetric testing, which was tested in the Land Transportation Office where the said opacimeter is available [22].

2.2. Statistical Treatment of Data

The data results that will be collected from the assessment of both physical and chemical properties of the mixed biodiesel and commercial diesel will be analyzed through mean, standard deviation, and independent samples T-tests, which will compare the quality of both fuels.

2.3. Data Gathering Procedures

Physical Properties

In gathering data needed for viscosity, a 250 mL graduated cylinder was used as a container of the mixed biodiesel, and marble was used to determine its viscosity. A timer or stopwatch helped identify the time the ball reached the end of the graduated cylinder. The total grams of the biodiesel was measured on a weighing scale, and the liquid length from 250 mL to the bottom of the graduated cylinder was measured in centimeters. This test was done for three trials at a minimum. A typical marble has a 2.7 g/cm^3 density [23]. Where its equation is as follows:

$$v = \frac{\left(2\left(density\ of\ \ marble - density\ of\ \ diesel\right)gr^2\right)}{\left(9vt\right)}$$

Note: g = acceleration due to gravity, r = radius of the cylinder, v = volume of the marble, and

t = time for the marble to travel

The density of the mixed biodiesel was determined using a 250 mL graduated cylinder and also through the aid of a digital weighing scale. In which density (p) is defined as the ratio of an object's mass to its volume. The equation is as follows:

$$p = \frac{M}{V}$$

Note: M represents the Mass, and V represents the Volume

Chemical Properties

In gathering needed pH levels, a pH paper or pH meter was used and will be dipped in the final mixed biodiesel for three trials at a minimum and five trials at a maximum [25].

For Copper corrosion testing, three copper trips were used that were dipped for three trials for three hours on the said mixed biodiesel and commercial diesel with separate containers. A standard or guide was followed (ASTM Copper Strip Corrosion Standards) to conclude the said testing [26].

In continuation, for the testing of the amount of particle matter, gravimetric testing will be carried out – where the said mixed biodiesel and commercial diesel, together with the dual fuel mode generator, was brought to the Land Transportation Office for its gravimetric testing [22].

3. Results and Discussion

Physical Properties Analysis

Table 1. Mean and Standard Deviation data for the Viscosity test of mixed biodiesel and commercial diesel after five trials

Variable	Seconds	Grams	Viscosity (*Centipoise*) at 40°C in 250 mL
	Mean and SD	Mean and SD	Mean and SD
Mixed Biodiesel	0.38 ± 0.04	210.67 ± 0.47	5.68 ± 0.73
Commercial Diesel	0.47 ± 0.05	207.33 ± 0.47	4.56 ± 0.49
Overall Mean and Standard Deviation	0.43 ± 0.05	209 ± 1.67	5.121 ± 0.79

The viscosity test results for the two fuel variables, blended biodiesel, and commercial diesel, are summarized in Table 1. As shown in Table 1, the differences between values are relatively minor and readily identifiable. The centipoise viscosity values have mean values ranging between 4 and 5, which are optimally close to one another.

Using Table 1 as the primary basis for the data results, it is clear that the values for the five trials preceding the mean and standard deviation are comparable. In 2020, according to ASTM International, the range of acceptable diesel viscosity at 40°C varied but is typically between 1.9 and 6 centipoises. Nevertheless, the precise viscosity requirement may vary based on the application and national or regional specifications. Additionally, the viscosity requirement varies based on the required specifications of the testing machine. Based on the provided data results, it can be inferred that the average viscosity values met the criteria for an acceptable viscosity value.

As to analyzing the given results in Table 1, At 40°C in a 250 mL cylinder, the mixed biodiesel has a higher viscosity than the commercial diesel. This may be due to the difference in chemical composition between the two fuels, with biodiesel typically comprising longer chain fatty acid methyl esters, which can result in a greater viscosity than conventional petroleum diesel. However, it is essential to note that viscosity can also be influenced by factors such as Temperature and pressure – which is not just through the fatty components [27]. Concerning the seconds or time for the ball to flow, it has a significantly fast time to reach – with a decimal value of around 0.40 to 0.50 seconds, and it can reach the bottom of the cylinder. Concerning this idea, Diesel fuel viscosity should not be excessive, which can lead to engine and fuel system problems. If the viscosity of the fuel is too high, it can cause problems with fuel injection and atomization, leading to incomplete combustion and diminished engine performance [28]. In addition, high viscosity can lead to fuel filter clogging, decreased fuel flow, and increased wear and strain on fuel injectors, which can cause engine damage [29].

To support the prior statements, Diesel viscosity must be properly maintained for effective fuel combustion and optimal engine performance. If diesel fuel is too viscous, it can result in several issues, including difficulty in the fuel flow, insufficient fuel atomization, incomplete combustion, and increased exhaust emissions [30]. On the other hand, if the diesel fuel is too dilute, engine elements may experience increased wear and strain, leading to a possible engine failure [31].

In order to optimize engine performance and reduce hazardous emissions, diesel fuel must maintain an appropriate viscosity level. Washing biodiesel with water can help preserve its viscosity by removing impurities and contaminants that could cause an increase in viscosity. Mixing biodiesel with water and agitating the concoction to remove any water-soluble impurities from the biodiesel. These contaminants can include detergents, glycerol, and other substances that can increase viscosity. By eliminating these impurities, biodiesel can maintain its desirable viscosity and avoid any detrimental effects on engine performance. Whichrinsing biodiesel with water significantly reduced its viscosity. The study found that unwashed biodiesel had a viscosity of 6.14 centipoises, while water-washed biodiesel had a viscosity of 5.12 centipoises. Due to eliminating impurities that can contribute to increased viscosity, viscosity decreased. [32].

Table 2. Mean and Standard Deviation data for the Density Test of mixed biodiesel and commercial diesel after three trials

Variable	Grams	Milliliters	Density (g/ml) at 15°C
	Mean and SD	Mean and SD	Mean and SD
Mixed Biodiesel	210.67 ± 0.47	250 ± 0	0.843 ± 0.002
Commercial Diesel	207.33 ± 0.47	250 ± 0	0.83 ± 0.002
Overall Mean and Standard Deviation	209 ± 1.67	250 ± 0	0.84 ± 0.01

Table 2 provides a direct summary of the density test data for the two variables of fuels, specifically mixed biodiesel and commercial diesel. As shown in Table 2, there is little change or difference in their mean and standard deviation values, leaving the aggregate section with a value of 0.84 ± 0.01.

Based on the data presented in Table 2, it can be inferred that the values are constant and highly the same due to their small to nonexistent differences. The standard value for diesel density is 0.82 to 0.88 at a temperature range of 15°C to 15.6°C. It was assumed that the density values would be in this range. Mixed Biodiesel and Commercial Diesel were also anticipated to have little to no distinct masses due to their substantially different compositions, feedstocks, and processing levels [39].

By analyzing the results from the data in Table 2, it appears that the density of mixed biodiesel is slightly higher than that of commercial diesel, as the mean density of mixed biodiesel is 0.843, while the mean density of commercial diesel is 0.83. Additionally, both samples have relatively low standard deviations, with the density of mixed biodiesel having a Standard Deviation of 0.002 and commercial diesel having a Standard Deviation of 0.002. These results may be helpful for researchers or professionals working in biofuels or energy production. Biodiesel has a marginally greater density than conventional diesel fuels. Biodiesel is typically denser than petroleum diesel, although the difference is relatively small [40]. In addition, the milliliters maintained the same amount as a 250 mL graduated cylinder was used to aid in measuring its density. This instance could mean that there is no significant difference in the values as both variables failed to reject the null hypothesis because they are equally or ideally dense based on the standards [41].

Biodiesel would have a relative increase in density value due to its chemical composition. This is mainly because Biodiesel consists of fatty acid methyl esters (FAMEs), which have greater molecular weights and densities than the hydrocarbons found in conventional diesel fuels [42]. In addition, where the values concerning the density can fluctuate due to its given impurities. These impurities can be water and other residual glycerin, increasing biodiesel's density [43]. Essentially, concerning emission testing in the later part, biodiesel contains more oxygen than conventional diesel fuels, contributing to its greater density. Oxygen ions in FAME molecules increase the biodiesel's total mass [44]. In addition, Temperature affects the biodiesel density. As Temperature increases, biodiesel density decreases, and as Temperature decreases, biodiesel density increases. 15°C (59°F) is the optimal Temperature for measuring the density of biodiesel because it is an industry-standard reference temperature. 15°C is an industry-standard reference temperature for determining the density of biodiesel. This reference temperature enables consistency and comparability of results across laboratories and suppliers of fuel. However, it is essential to note that biodiesel's density can vary with Temperature, and the actual density of a quantity of biodiesel may need to be adjusted for the operating Temperature [45] [46].

Table 3. T - test for the significance of the difference between the Viscosity of mixed biodiesel and commercial diesel after five trials

Variable	Mean	SD	95% Confidence Interval	P value
Mixed Biodiesel	5.68	± 0.73	± 0.61	0.230680
Commercial Diesel	4.56	± 0.49	± 0.91	

Significant at <0.05

Table 3 presents the T-test of the viscosity testing of the mixed biodiesel and commercial diesel. The mean and standard deviation values are the same value from the table above about the mean and standard deviation for their viscosity levels. It can be observed that the mixed biodiesel yielded a value of ± 0.61 in its confidence interval, while the commercial biodiesel yielded a much higher amount of ± 0.91. Despite the different values on the confidence intervals, it yielded a p-value of 0.231 which exceeded the level of significance.

In reference to Table 3, it can be seen that there is no significant difference since the p-value exceeded the level of significance, which is 0.05. In their confidence intervals, if the mean viscosity of biodiesel is 5.68 and we have a 95% confidence interval of ±0.61, it means that it is with 95% confidence that the true viscosity of the population of biodiesel samples lies within the range of 5.07 to 6.29. This can be explained in several implications: Initially, it may indicate that the blended fuel could be used in diesel engines without significant modifications. Second, it may imply that the blended fuel may have similar flow properties to diesel fuel, which is essential for appropriate fuel atomization and combustion within the engine. Blended biodiesel-diesel fuels may offer some environmental advantages over traditional diesel fuel, such as reduced emissions of particulate matter and greenhouse gases. Additionally, the use of biodiesel, which is typically derived from renewable sources, may contribute to sustainability objectives by reducing reliance on fossil fuels. Blended biodiesel-diesel fuels may offer some environmental advantages over traditional diesel fuel, such as reduced particulate matter emissions and greenhouse gases. Additionally, biodiesel, typically derived from renewable sources, may contribute to sustainability objectives by reducing reliance on fossil fuels. Thus, based on these generalizations, it can be said that both mixed biodiesel and commercial diesel passed the standard values for the viscosity of a diesel, which implies that it failed to reject the null hypothesis.

As a result of its lower carbon content and other factors, such as its ability to reduce particulate matter and sulfur emissions, biodiesel is generally deemed to have lower emissions. At the same time, this is due to its viscosity as a result of the water cleansing process, which gave it nearly identical characteristics to commercial diesels [47]. Biodiesel mixtures in diesel engines could result in enhanced engine performance, such as increased thermal efficacy of the brakes and decreased smoke emissions [48].

The density of biodiesel is crucial because it influences the fuel's energy content and combustion efficacy. Biodiesel's energy content is directly proportional to its density, and fuels with a higher density can provide more energy per unit volume. In addition, the biodiesel's density can influence the blend's overall density and viscosity, which may affect its flow properties and combustion efficiency. Denser biodiesel typically results in more complete combustion and fewer emissions.

Table 4. T-Test for the significance of the difference between the density of mixed biodiesel and commercial diesel after three trials

Variable	Mean	SD	95% Confidence Interval	P value
Mixed Biodiesel	0.843	± 0.002	± 0.0057	0.500000
Commercial Diesel	0.83	± 0.002	± 0.0057	

Significant at <0.05

Table 4 displays the T-test for determining whether a significant difference exists between mixed biodiesel and commercial diesel density values. The mean and Standard deviation values are the same as those mentioned in Table 2. In addition, confidence intervals are of the same value of ± 0.0057 on both variables. Lastly, it has a P value of

0.500000, greater than the significance threshold of 0.05, as shown in Table 4.

Inferring to the results given in Table 4, it can be directly assumed that there is no significant difference between the density values of mixed biodiesel and commercial diesel, even though there was a slight increase in the values. The 0.50 P-value indicates that there is insufficient evidence to reject the null hypothesis. This indicates that at the 0.05 level of statistical significance, the difference in densities between biodiesel and diesel is not statistically significant.

In analyzing the given results, there is no significant difference in the density values in using the t-test in interpreting the data given. It indicates that the density measurements of the two fuels are comparable, and no statistical evidence suggests that they differ substantially. This information could be beneficial for various applications, such as determining the appropriate fuel for a particular engine or assessing the quality of various fuel samples [49]. Nevertheless, if based on the initial values of their densities, it only had a difference of 1 decimal point in the hundredths place, leaving it with no significant difference on the t-test table. This would also mean that if the mean density of biodiesel is 0.84 and the 95% confidence interval is 0.0057, it is 95% certain that the proper density of the population of biodiesel samples lies between 0.8343 and 0.8457. This contributes to the body of knowledge that it failed to reject the null hypothesis.

It is believed that there is no significant difference in their density values. This is since there are several reasons to consider. One could be that both fuels have similar molecular structures and compositions, resulting in similar densities. Another reason is that both fuels' production processes may involve similar reactions and feedstocks, which could also contribute to similar densities. The testing methods used to determine the densities may also play a role in the results obtained [50].

Additionally, the mixed biodiesel had undergone different processing before it was completely made as a biodiesel. One chemical procedure that affected its density value would be the 1-week water wash to attain almost the same quality as a commercial diesel in terms of viscosity and density. Water washing is a common technique for reducing diesel fuel viscosity and other properties relating to its density. The process involves combining water with diesel and then allowing the mixture to settle so that the diesel's water and impurities can be removed. Eliminating water-soluble impurities can reduce diesel's viscosity and improve its density, making it more fluid and more straightforward to use [51].

Chemical Properties Analysis

Table 5. Mean and Standard Deviation data for the pH level of mixed biodiesel and commercial diesel after five trials

Variable	Temperature	pH levels at 25°C to 30°C
	Mean and SD	Mean and SD
Mixed Biodiesel	28 ± 0	8.80 ± 0.69
Commercial Diesel	27.44 ± 0.29	9.46 ± 0.77
Overall Mean and Standard Deviation	27.72 ± 0.28	9.13 ± 0.46

Table 5 summarizes the results of pH testing with a pH meter on mixed biodiesel and commercial diesel after five trials. The temperature values for both variables decreased significantly, with only the decimal values differing. On the other hand, as shown in Table 5, the mean and standard deviation of the pH levels of the two variables at room temperature ranging from 25°C to 30°C showed a relatively modest increase in values.

Based on Table 5, the pH levels of the mixed biodiesel and commercial diesel were independent. The values on the mean and standard deviation of the two values are normally distributed. The values ranging from 8 to 9 are on the slightly alkaline pH level, far from progression decay and rusting. While there is no standard pH value for biodiesel, most sources indicate that it should fall between 6 and 9. Values outside this range may indicate the presence of impurities or other factors that degrade the fuel's quality. Biodiesel production and use must maintain appropriate pH levels to ensure optimal performance and reduce the risk of corrosion and other issues. It can be inferred that both the mixed biodiesel and commercial diesel have no distant values relating to their pH levels. Both variables equally belong to the slightly alkaline levels [52].

As gleaned in Table 5, it can be analyzed that there is a difference in the pH values of Mixed biodiesel and commercial diesel as the Temperature varies. Also, the pH is affected by Temperature; the pH value of biodiesel or diesel may change if the Temperature is increased by 1 degree Celsius. However, the magnitude of the difference would depend on the chemical composition of the specific biodiesel or diesel being considered. However, pH levels can be affected by Temperature but not by itself. Several factors, including the solution's nature and the temperature change spectrum, will influence the change. Generally, a one °C change is unlikely to result in a significant change in pH, particularly for solutions with pH values close to neutral. It is crucial to note that the effect of Temperature on pH is not universal and that Temperature can have a significant impact on pH in specific solutions [53].

In addition, biodiesel and diesel have different pH levels due to their distinct chemical constituents. Biodiesel, which is derived from renewable resources like vegetable oils and animal lipids, contains free fatty acids (FFAs) that can alter its pH level. Diesel fuel, which is derived from crude oil, contains no FFAs and has a neutral pH [54]. This would mean that pH levels are not affected by Temperature alone but also by its composition, chemical procedures, and another type of feedstock used. Fatty acid methyl esters (FAMEs) are created by converting triglycerides to fatty acid methyl esters (FFAs) during biodiesel production. Some FFAs may persist in the biodiesel after the conversion procedure. The type of feedstock used in biodiesel synthesis can also influence its pH level. For instance, biodiesel derived from animal lipids is typically more acidic than vegetable oils. Diesel fuel, on the other hand, is primarily composed of hydrocarbons, which have no appreciable effect on pH value. Consequently, diesel fuel pH is typically neutral. Overall, the difference in pH levels between biodiesel and diesel is attributable to their respective chemical compositions and production processes [55].

Table 6. T-test for the significance of the difference between the pH level of mixed biodiesel and commercial diesel after five trials

Variable	Mean	SD	95% Confidence Interval	P value
Mixed Biodiesel	8.80	± 0.69	± 0.860	0.417010
Commercial Diesel	9.46	± 0.77	± 0.963	

Significant at <0.05

The results of the T - test to determine the significance of the difference between the pH values of mixed biodiesel and commercial diesel are presented in Table 6. With the 95% Confidence intervals, mixed biodiesel garnered a value of ± 0.860. However, for the commercial diesel, it yielded a much higher value of ± 0.963. Consider not that the result would be significant at 0.05, but based on the P value presented in Table 6, which is 0.417010, the result lapses to its significance level.

As can be inferred in Table 6, there is no significant difference between the pH values of the mixed biodiesel and commercial diesel, even though there was a slight increase in its raw value. The results of the T - test to determine the significance of the difference between the pH values of mixed biodiesel and commercial diesel are presented in Table 6. This is undoubtedly concerning its confidence values. The mean pH level of biodiesel is 8.80, and the 95% confidence interval is 0.860; it can be 95% certain that the accurate pH level of the population of biodiesel samples lies between 7.94 and 9.66. Also, with a 95% confidence interval of 0.963 and a mean pH of 9.46 for commercial diesel fuel, it is with 95% confidence that the true pH level of the population of commercial diesel samples lies between 8.497 and 10.423.

In analyzing the given data results of the T-test, there is no significant difference in their pH levels. This would mean that they are compatible with one another – having the same characteristics. Similar pH variations in biodiesel and diesel can be used for quality control. For instance, if the pH of diesel is known to fall within a specific range, and the pH of biodiesel falls within the same range, this indicates that biodiesel quality is comparable to diesel [56]. In addition, biodiesel and diesel with similar pH levels may be more compatible. This compatibility is essential when coupling biodiesel and diesel to ensure the mixture is stable and performs well in engines [57]. On both ends, with the statements given, this would entail that it is proven that the pH levels of the biodiesel and diesel are closely related if the processes are done gradually and successfully. The biodiesel quality was immersed just like the evident quality of the diesel. Again, there is no significant difference in the values since the p-value lapsed the significance threshold, which is 0.05. It can be said that it failed to reject the null hypothesis because the mean pH values can be claimed with 95% confidence.

Copper corrosion is an essential biodiesel parameter because it indicates the fuel's potential to corrode fuel system components, especially those made of copper or copper alloys. As a polar solvent, biodiesel can cause copper to oxidize and form copper compounds, damaging fuel system components, decreasing engine performance, and increasing maintenance costs. It can also accelerate the deterioration of engine components, resulting in increased maintenance costs and outages. Biodiesel can alter the blend's resistance to copper corrosion, affecting its compatibility with fuel system components.

Table 7. ASTM Copper Corrosion Test Guide

Classification	Designation	Description
Freshly polished strip	--------	--------
1	slight tarnish	a. light orange, almost the same as a freshly polished strip b. dark orange
2	moderate tarnish	a. claret red b. lavender c. multicolored with lavender blue or silver, or both overlaid on claret red d. silvery e. brassy or gold
3	dark tarnish	a. magenta overcast on the brassy strip multicolored with red and green showing, but with no gray
4	corrosion	a. transparent black, dark gray, or brown with peacock green barely showing b. graphite black or lusterless black c. glossy or jet black

Table 7 shows the copper corrosion test standards that will guide in determining the level of corrosion of the mixed biodiesel and commercial diesel. A freshly polished strip is the pretest result of the copper strip. While on the other classifications, 1 to 4 is the posttests after the said testing, which can be ranked into different levels depending on their descriptions.

Figure 2. Post copper corrosion test images of copper strips (Heated from Mixed Biodiesel at 120°C for 3 hours ± 5 minutes)

Figure 2 shows the post-copper corrosion test of copper strips which were heated at a surface temperature of 120°C for 3 hours ± 5 minutes, which was done through three trials. Noticeable changes in its appearance can be seen in the figure. In this case, it may indicate that the environment is relatively benign and not particularly corrosive. However, it is essential to note that the degree of corrosion can vary based on variables such as the duration of the test, the type of environment, and the state of the copper sample. Nonetheless, this test is subjective to the tester's eyes, as it relies on the appearance based on the provided standard chart.

Figure 3. Post copper corrosion test images of copper strips (Heated from Commercial Diesel at 120°C for 3 hours ± 5 minutes)

Figure 3 shows the post-copper corrosion test of copper strips heated from a commercial diesel at a surface temperature of 120°C for 3 hours ± 5 minutes. Slight changes in its appearance can be noticed after three trials that were conducted. The degree of tarnishing observed in a copper corrosion test must be interpreted in conjunction with other variables in order to comprehend the potential corrosiveness of the environment being tested thoroughly. Different variables, such as time or duration and Temperature, require careful consideration.

Table 8. Corrosion classification and test results for copper strips heated from mixed biodiesel and commercial at 120°C for 3 hours ± 5 minutes

Sample	ASTM D130 rating	Result
First Copper Strip tested with the mixed biodiesel (Heated for 3 hours ± 5 minutes at 120C)	1b (Slight Tarnish)	Pass
The second Copper Strip was tested with the mixed biodiesel (Heated for 3 hours ± 5 minutes at 120C)	1b (Slight Tarnish)	Pass
Third Copper Strip tested with the mixed biodiesel (Heated for 3 hours ± 5 minutes at 120C)	1b (Slight Tarnish)	Pass
First Copper Strip tested with the Commercial Diesel (Heated for 3 hours ± 5 minutes at 120C)	1a (Slight Tarnish)	Pass
Second Copper Strip tested with the Commercial Diesel (Heated for 3 hours ± 5 minutes at 120C)	1a (Slight Tarnish)	Pass
Second Copper Strip tested with the Commercial Diesel (Heated for 3 hours ± 5 minutes at 120C)	1a (Slight Tarnish)	Pass
Third Copper Strip tested with the Commercial Diesel (Heated for 3 hours ± 5 minutes at 120C)	1a (Slight Tarnish)	Pass

Table 8 summarizes the corrosion test of copper strips that were heated from the mixed biodiesel and commercial diesel for a surface temperature of 120°C for 3 hours ± 5 minutes. Three samples of copper strips were used for the mixed biodiesel, while there were also three samples of copper strips used for testing the commercial diesel. Based on its results on the ASTM D130 rating, the mixed biodiesel yielded the same result of 1b (Slight tarnish), which has a remark of passed. On the other hand, the commercial diesel yielded a different result of 1a (Slight tarnish) but was also in the same classification, which is 1. Still, it had a passed remark in the end.

In analyzing Table 8, it can be confident that three copper corrosion tests were conducted on a fuel blend composed of biodiesel and commercial diesel. Multiple tests may be conducted to ensure the accuracy and dependability of the results by accounting for any variations or fluctuations in the test conditions or the fuel sample itself. The biodiesel and diesel fuel mixtures had a copper corrosion rating of "1a" or "1b," indicating only minor tarnish on the copper strips and a minimal risk of corrosion to copper or copper alloy fuel system components. This would eventually mean that there would be a relatively minimal risk of corrosion to the engine [58]. The level of this degree is a typical value since this is the typical degree of commercial diesel. In congruence with this study, due to the presence of sulfur compounds in both biodiesel and diesel, the findings of copper corrosion tests on the two fuels are often quite comparable to one another. The sulfur level of the fuel and its chemical form are the primary factors determining the degree to which copper will corrode. With this, it can be certain that both variables are viable in getting minimal corrosion to the engine [59].

Gravimetric testing is essential for measuring diesel engine particulate matter (PM) emissions. PM is a significant pollutant that can have adverse health effects on humans and contributes to environmental problems such as climate change and air quality. The mass of PM emitted by a diesel engine can be precisely determined through gravimetric testing. This is significant because PM emissions vary significantly based on engine load, fuel type, and operating conditions. Understanding the actual level of emissions and determining the efficacy of emission control technologies requires precise measurement.

Table 9. Mean and Standard deviation of Gravimetric testing of mixed biodiesel and commercial diesel with a tube temperature of 75°C

Variable	k (m^{-1})
	Mean and SD
Mixed Biodiesel	1.801 ± 1.4
Commercial Diesel	0.636 ± 0.64
Overall Mean and Standard Deviation	1.22 ± 0.82

Table 9 summarizes the mean and standard deviation of both mixed biodiesel and commercial diesel in gravimetric testing. The mixed biodiesel resulted in a mean and standard deviation value of 1.801 ± 1.4 in k (m-1), while the commercial diesel had a 0.636 ± 0.64. The overall value of mixed biodiesel resulted in a 1.22 ± 0.82.

As what can be inferred based on Table 9, the mixed biodiesel with a mean of 1.801 k (m^{-1}) demonstrates that the sampled air has a comparatively high attenuation coefficient, which suggests that there are a significant number of light-scattering or light-absorbing particles in the air while commercial diesel had Gravimetric testing yielding a value of 0.63 k (m^{-1}) indicates that the sampled air contains a significant amount of particulate matter [60]. It can be confident that the values concerning the particulate matter of the mixed diesel are higher than the commercial diesel. The number of gas concentrations is relatively different based on the values presented in the table.

Table 10. T-test for the gravimetric testing k (m^{-1}) values of both mixed biodiesel and commercial diesel

Variable	Mean	SD	95% Confidence Interval	P value
Mixed Biodiesel	1.801	± 1.4	± 3.44	0.175439
Commercial Diesel	0.636	± 0.64	± 1.59	

Significant at <0.05

Considering the t-test result of gravimetric testing. Table 10 summarizes the t-test result of k (m-1). The mixed biodiesel presented a mean value of 1.801 with ± 1.4 standard deviations, while the commercial diesel had a mean value of 0.636 with a ± 0.64 standard deviation. Mixed biodiesel with a 95% confidence interval resulted in a ±3.44 while commercial diesel had ±1.59. Lastly, it has a P value of 0.175439, which is greater than the significance of 0.05, as shown in Table 10.

In analyzing the table, A higher mean value for the mixed biodiesel sample (1,801) than for the commercial diesel sample (0.636) suggests that the mixed biodiesel may produce higher particulate matter emissions. The standard deviation values indicate that the data for the mixed biodiesel sample (1.4) may be more dispersed around the mean than the data for the commercial diesel sample (0.64), indicating greater variability in the particulate matter emissions from the mixed biodiesel.

In the context of a comparison of particulate matter emissions between mixed biodiesel and commercial diesel, a 95% confidence interval of 3.44 for mixed biodiesel and 1.59 for commercial diesel would typically indicate that the true population means value for particulate matter emissions from mixed biodiesel is likely to fall within the range of (3.44 +/- margin of error) with a 95% chance. With 95% probability, the true population mean value for particulate matter emissions from commercial diesel will lie within the range of (1.59 +/- margin of error). The larger confidence interval for mixed biodiesel (3.44), compared to commercial diesel (1.59), suggests that the estimate for mixed biodiesel is less precise, indicating that the data are more variable and the margin of error is greater.

In terms of comparing the two fuels, the fact that the confidence interval for mixed biodiesel does not overlap the confidence interval for commercial diesel indicates that there is a statistically significant difference between the mean values of the two groups. In this instance, there is a 95% probability that mixed biodiesel produces higher particulate matter emissions than conventional diesel. The emission for the biodiesel and commercial diesel. Results have shown that biodiesel had a significant amount than the diesel itself due to different chemical processes [61].

4. Conclusion

Based on the given data results in the aforementioned tables, the comparison of the given values showed an almost identical value as it yielded a degree that only differed primarily in decimal places. Results have revealed that the values concerning the physical properties of the mixed biodiesel and commercial diesel have shown no significant difference, specifically in their viscosity and density values. T–tests with 95% confidence intervals have shown that despite the tiny fluctuations in the values, there were no significant differences with 95% confidence.

On the other hand, their chemical properties, specifically their pH levels and corrosion testing. Still, both mixed biodiesel and commercial diesel did not have a wide range of their values as it still showed no significant difference on the T-test with 95% confidence intervals. Concerning the corrosion testing, both of the coppers had a slight tarnish but with a different degree: 1a and 1b. However, both passed the appearance testing based on the ASTM copper corrosion testing method D130.

Lastly, the gravimetric testing on the particle matter was done through three trials to garner its average that the mean must not exceed a value of 2. Though there was an increase in values concerning the testing of the mixed biodiesel and commercial diesel on their particle matter, through the t-test method with 95% confidence intervals, it was still concluded that both had no significant differences concerning the values on their particle matter emitted in the environment.

With this, it can be said that both are almost the same in terms of their physical and chemical properties, as several t-tests have shown no significant differences in their values. Thus, results have shown that it had failed to reject the null hypothesis in which there are no significant differences in their values. Therefore, mixed biodiesel is a viable alternative to commercial diesel as they have almost the same properties and characteristics.

5. Recommendations

In reference to the concluded statements above regarding the comparison of mixed biodiesel and commercial diesel in terms of their physical and chemical properties, these are the following recommendations of the study: In testing the viscosity of biodiesels and commercials diesel, a viscometer would highly be required or a pre-requisite instrument to be used to provide an accurate and precise value. For its density test, it is recommended that the fuels must be stabilized at 15C when measuring their density since this is its standard value. However, it can be done once, as there is a tendency for the fuel to condensate and lose an amount when it is done for several trials.

In terms of pH level testing, it is efficient to test it using a pH meter at room temperature for it to have accurate results. Concerning corrosion testing, it is reliable if there is an expert who can assist in determining the appearance of the coppers, as the test is based on a subjective view.

For the testing on particle matter, it is recommended that an expert in the field of gravimetric testing would be present to explain the values presented on the opacimeter. It is also recommended that other researchers can include the comparison of odor on both fuels, as this can be influential also in gravimetric testing. Lastly, testing of cetane number on its chemical properties is also recommended because this would test the ignition delay properties. However, though ignition delay can be determined by gravimetric testing, it is applicable to test its cetane number to provide accurate data.

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