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Effect of Ultrafine Bubble Additives on the Properties of B-35 Diesel Fuel

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ABSTRACT

Improving the quality of B-35 biodiesel fuel is crucial, especially in distillation and flash point parameters that affect performance and safety. The objective of this study was to analyze the effect of oxygen ultrafine bubble application on the fuel characteristics of B-35 including cetane number, viscosity, density, flash point, distillation, and cloud point. Tests were conducted according to ASTM standards: D86 (distillation), D93A (flash point), D613 (cetane number), D445 (viscosity), D4052 (density), and D5773 (cloud point). The treatment was performed by injecting oxygen ultrafine bubble at a rate of 1, 3, and 5 l/min into 1.5 liters of fuel for 10–60 minutes. The results showed the highest distillation temperature of 339.7 °C at 1 l/min and 10 minutes, while the lowest temperature of 330.9 °C was achieved at 5 L/min and 60 minutes (control: 341.6 °C). The highest flash point of 72 °C occurred in the low oxygen injection rate and short duration, while the lowest was 64.5 °C in the high rate and long duration. The treatment increased cetane number from 58.6 to 60.8. The decrease in viscosity and density was insignificant but remained within standard limits. The cloud point decreased from 7.1 °C to 5 °C. UFB oxygen addition shows significant potential in improving the quality and combustion efficiency of B-35 fuel.

1. INTRODUCTION

Biodiesel-based fuel is a promising option to reduce dependence on fossil fuels and lower carbon emissions. The application of biodiesel, however, still faces several technical challenges, including suboptimal combustion efficiency, a tendency for high nitrogen oxide emissions, and chemical instability during long-term storage. Hence, various inventive methods are required to increase biodiesel performance, including ultrafine bubble (UFB) technology. This technology generates tiny gas bubbles that enhance microscopic mixing of air and fuel, thereby accelerate the combustion process and improve the homogeneity of oxygen distribution. Takayama (2018) have shown that UFB application in diesel fuel blends improves engine power and fuel energy efficiency, as well as significantly decreasing destructive emissions.

Senthil *et al.* (2015) stated that efforts to increase combustion efficiency and decrease fuel consumption in engines have motivated different engineering approaches to revise fuel characteristics, in particular for diesel fuel. Additives addition into fuel can reduce fuel viscosity and increase cetane number, which eventually increases fuel stability and improves overall engine performance (Laurinaitis & Mickevičius, 2018). The addition of oxygenated additives in biodiesel improve combustion efficiency due to the presence of extra oxygen that facilitates the combustion process. Overall, using oxygenated additives in diesel fuel enhances the quality of the fuel (in term of Cetane number, fuel viscosity, fuel density, distillation temperature, cloud point, and flash point), and making it more environmentally benign and efficient for diesel engines (Devarajan *et al.*, 2020; Mihaylov *et al.*, 2021).

Recently, the application of UFB technology, which involves the stable dispersion of air or oxygen at a nanometer scale, into a liquid fuel medium become an attractive method (Haq *et al.*, 2024). The existence of UFB in the fuel improves the atomization quality and increase the homogeneity of the fuel-air mixture during the combustion process, which in turn provides to more efficient and cleaner combustion (Markov *et al.*, 2020). UFB technology offers fuel savings without significant modifications to the existing engine system (Soudagar *et al.*, 2018; Takayama, 2018). Integrating UFB technology into diesel fuel formulations is a promising engineering strategy to improve engine performance and thus environmental sustainability (Dou *et al.*, 2017; Ning *et al.*, 2020).

The use of UFB-based additives in biodiesel can optimize combustion and improve engine performance. The existence of microbubbles improves fuel atomization, results in more efficient combustion, increases fuel stability against oxidation, and reduces deposit formation. The addition of UFB also improves fuel viscosity. Additives play a significant role in improving engine performance and reducing emissions in diesel engines. These additives improve the stability of fuel properties and can expand the operational life of diesel engines (Milano *et al.*, 2024). Rashedul *et al.* (2014) and Hamzah *et al.* (2024) compared performance and emission characteristics of a diesel engine fueled by pure diesel and pure biodiesel as well as biodiesel blended with various additives.

Indonesia have implemented B35, a mixture of 35% biodiesel and 65% diesel fuel. The correct viscosity of B35 is important to improve fuel atomization such that combustion can occur more optimally, while maintaining the fuel ability to protect injection components so that the engine continues to work reliably (Sánchez-Rodríguez *et al.*, 2025). The addition of UFB oxygen into B35 fuel is expected to improve fuel quality. The primary focus of this study is to observe changes in the physicochemical characteristics of the fuel due to UFB oxygen addition. This method is expected to improve combustion efficiency, reduce exhaust emissions, reduce fuel consumption, and ultimately supporting the transition to more sustainable energy and providing added value for the industrial and corporate sectors. Scientifically, the results of this study have the potential to broaden academic discourse, enrich reference sources on UFB in the context of biodiesel, and open new directions for research exploration in the field of renewable energy.

2. RESEARCH MATERIAL AND METHODS

2.1. Materials and Experimental Design

The main material used in this experiment was biodiesel fuel B-35 with a CN value 48 (B-35 CN48) obtained from a gas station in Bogor. In addition, oxygen with purity of 95% was purchased from local gas supplier. This experiment was designed to evaluate the effect of UFB oxygen injection rate and injection duration on the fuel properties of B35-CN48. Injection rate varied from 1, 3, and 5 L/min, while injection duration varied from 10 min to 60 min (increment of 10 min). Each treatment was performed in triplicates to obtain reliable average values.

In this study, oxygen was injected into B35-CN48 in form of UFB (Figure 1). The injection process utilized a special nozzle capable to form bubbles sizing of approximately 200 nm, and was supported by an oxygen generator with a flow capacity 1–5 L/min. The bubbles characteristics were analyzed using a Dynamic Light Scattering (Malvern) instrument. Based on the measurement results, it was revealed that UFB oxygen increased the bubble intensity to 11.5%, higher than that of control fuel (without oxygen injection), which only reached 4.9%.

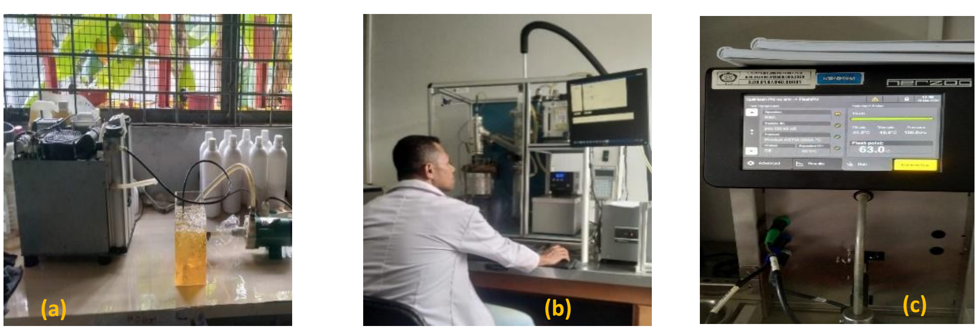

Figure 1. (a) Oxygen UFB injection into biodiesel fuel B-35 CN48, (b) Distillation temperature measurement, (c) Flash point test

2.2. Measurement and Methods

Important physicochemical properties of the fuel were analyzed, including cetane number, viscosity, density, distillation temperature, flash point, and cloud point. Analysis was carried out in triplicates and the average values were used for discussion. In this study, standard methods from the ASTM were used to analyze the properties of B-35 CN48, including D4052, D613, D445, D86, D5773, and D93. The density of biodiesel fuel was determined according to ASTM D4052 standard approach. This technique commonly provides consistent and reliable results (Abdurrojaq *et al.*, 2021). The cetane number of biodiesel fuel was determined based on ASTM D613 test method using a CFR engine that compares the test fuel to a reference fuel. According to Garcia *et al.* (2022), this method is widely used to assess fuel quality, study the effects of additives, and design better fuel formulations.

The ASTM D445 method was referred to measure the viscosity of biodiesel fuel (Sentanuhady *et al.*, 2020). Whereas, with a distillation temperature range ranging from 180 °C to 360 °C, the distillation temperature was analyzed based on the ASTM D86 standard, and cloud point was determined based on ASTM D5773 method. Flash point of biodiesel fuel was determined according to the ASTM D93 standard, which has been proven effective and accurate. According to Amalluddin *et al*. (2024), this method has reliable predictive capabilities with a low error rate.

3. RESULTS AND DISCUSSION

Testing of B-35 CN48 UFB diesel fuel is presented in Figure 1. Table 1 show the results of B35 diesel fuel with a cetane number of 48 enriched with UFB. The data are average of three tests conducted for each treatment. Fuel properties of B-35 CN48 UFB is discussed in the following section.

Table 1. Test results of B-35 CN48 diesel fuel with UFB

No	Physicochemical Properties Ultrafine Bubble Fuel B-35 CN48 1.5 Liters								Control	Min	Max
	Parameter	Oxygen (L/min)	Bubbling Time (min)								
			10	20	30	40	50	60			
1	Cetane Number	1	58.6	58.8	59.1	59.3	59.6	59.9	57.2	49	
		3	58.8	59.1	59.3	59.5	59.7	60			
		5	59.5	59.8	60.1	60.3	60.6	60.8			
2	Viscosity (mm^2/s)	1	3.19	3.18	3.16	3.15	3.14	3.13	Control	Min	Max
		3	3.17	3.16	3.15	3.14	3.13	3.12	3.2	2	5
		5	3.16	3.14	3.13	3.12	3.11	3.1			
3	Density (kg/m^3)	1	833.6	833.54	833.5	833.43	833.38	833.32	Control	Min	Max
		3	833.5	833.46	833.42	833.38	833.33	833.26	840	815	880
		5	833.4	833.38	833.33	833.3	833.25	833.2			
4	Distillation (°C)	1	339.9	338.5	337.4	336.3	335.2	333.8	Control	Min	Max
		3	338.8	337.6	336.4	335	333.8	332.4	341.6		370
		5	337.4	336	334.9	333.5	332.3	330.9			
5	Flash point (°C)	1	72	71.1	70.1	69.3	68.3	67.4	Control	Min	Max
		3	71	70.2	69.2	68.2	67.3	66.6	73	52	
		5	69	68.1	67.1	66.3	65.4	64.5			
6	Cloud point (°C)	1	7.1	6.9	6.7	6.5	6.3	6.1	Control	Min	Max
		3	6.9	6.7	6.5	6.3	6	5.7	8		18
		5	5.9	5.7	5.6	5.4	5.2	5			

3.1. Cetane Number of B-35 CN48 UFB

Etane number indicates how quickly the fuel can self-ignite in an engine. The graph in Figure 2 shows the B-35 fuel with oxygen injection through UFB technology at various flow rates of 1, 3, and 5 L/min for 60 min can gradually increase the cetane number. The higher the cetane number, the shorter the ignition delay, resulting in a more efficient combustion process. Overall, there is a tendency for the cetane number to increase along with the increase in the process duration and the given oxygen flow rate. At a flow rate of 1 L/min, the cetane number value rises from 58.6 to

59.8; while at 3 L/min there is an increase from 58.8 to 60.0; and the highest rate, namely 5 L/min, results in a jump in value from 59.5 to 60.8. These findings indicate that increasing oxygen flow in the UFB system improves the combustion properties of diesel fuel, as reflected in the increase in the cetane number value. The findings in this study are in line with previous studies that examined the effect of nano-additives in diesel-biodiesel fuel blends, with the finding that the use of nano-additives in diesel and biodiesel fuel blends overall made a beneficial contribution to fuel stability, engine performance, and the resulting emission patterns (Baskar & Senthilkumar, 2016).

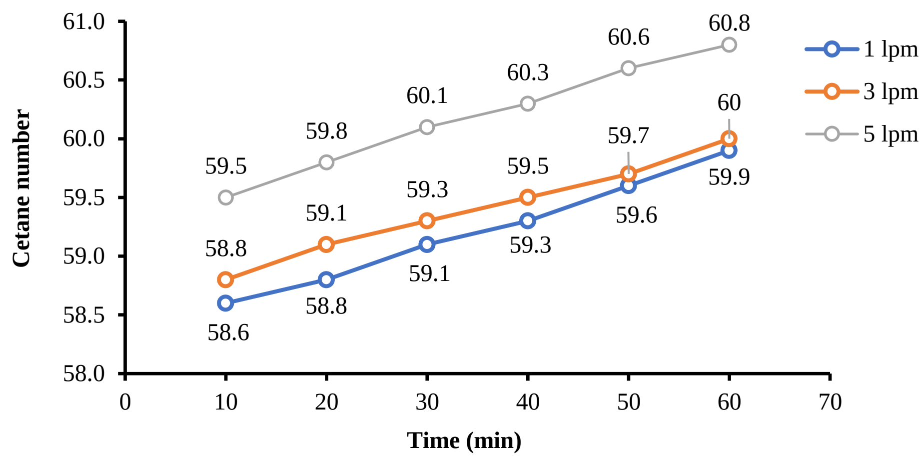

Figure 2. Effect of oxygen flowrate and bubbling time on the cetane number of B-35 CN48

Analysis of B-35 CN48 fuel applied with UFB oxygen (Figure 3) shows increased cetane number associated with higher dissolved oxygen levels. The presence of UFB oxygen promotes mild reactions with unsaturated molecules, producing more flammable compounds. In addition, more uniform fuel distribution and the potential for generating active radicals also expedite the ignition process. The increase of cetane number implies improvement of combustion quality. Results of our study support to (Ghany *et al.*, 2024) who found improvement in combustion efficiency, increase in power, and reducing emissions during observing the effects of oxygen-enriched dual diesel fuels.

Our research shows the critical role of cetane number and additive use in optimizing combustion and diesel engine performance. Fuel with a high cetane number accelerates combustion and reduces fuel consumption, while additives such as cetane improvers help to increase engine efficiency and power. Alias *et al.* (2021) and Takayama (2018) reported the synergy between fuel quality and proper additives that significantly improve diesel engine performance and reliability. The cetane number is the primary indicator of diesel fuel quality that greatly influences rapid combustion of B-35 CN48 biodiesel fuel. The high cetane number ensure complete combustion of fuel, thereby reducing emissions and improving engine performance (Hasan & Rahman, 2017).

3.2. Viscosity of B-35 CN48 UFB

Figure 3 shows the effect of treatment on the viscosity of biodiesel B-35 CN48. The graph reveals a tendency for the viscosity of B-35 CN48 fuel to decrease after being treated with UFB oxygen. As the bubbling time increases, this viscosity decrease consistently at different oxygen injection rates (1 to 5 L/min). At a rate of 1 L/min, the viscosity decreased from 3.19 mm^2/s to 3.13 mm^2/s when the bubbling time increase from 10–60 min. The decrease in fuel viscosity is more intensive at higher injection rates. At flow rate 3 L/min and 5 L/min the fuel viscosity decrease from 3.17 mm^2/s to 3.12 mm^2/s and from 3.16 mm^2/s to 3.10 mm^2/s, respectively. The initial viscosity value of control B35 fuel is 3.20 mm^2/s. It is clear that the UFB oxygen addition effectively reduce fuel viscosity. This effect leads to the possibility of changes in the molecular structure of the fuel due to the ultrafine gas diffusion process, which encourages smoother flow and a more uniform fuel mixture. The higher the gas flow rate, the greater the impact of viscosity reduction achieved, but in this study, it is still within the minimum threshold value. Soudagar *et al.* (2018) and Yamamoto *et al.* (2022) stated that UFB technology can reduce fuel viscosity by increasing oxygen solubility.

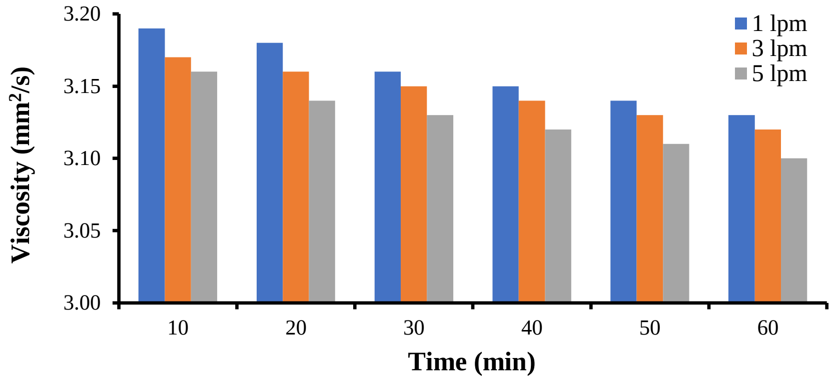

Figure 3. Effect of oxygen flowrate and bubbling time on the viscosity of B-35 CN48

3.3. Density of B-35 CN48 UFB

The effect of treatment on the density changes of B-35 CN48 fuel are presented in Figure 4. Density is important parameter in assessing fuel quality because it influences flow characteristics during the fuel injection process, combustion efficiency, and overall diesel engine performance (Pham *et al.*, 2018). Increasing injection flowrate of UFB oxygen from 1 to 5 L/min resulted in the decrease of fuel density. Similarly, increasing bubbling duration from 10 to 60 min also decline the density of B-35 CN48 biodiesel fuel. With a flow of 1 l/minute, the density value initially of 833.60 kg/m^3 decreased to 833.32 kg/m^3 after 60 min, lower than the untreated fuel of 840 kg/m^3. A similar trend was also observed at flow rate of 3 and 5 L/min, with the lowest values reaching 833.26 kg/m^3 and 833.20 kg/m^3, respectively. The fuel density, however, was still higher than the minimum threshold value of 815 kg/m^3. This finding indicates that the greater the flow rate and duration of oxygen contact through UFB, the greater the potential for changes in the physical characteristics of the fuel, especially in terms of decreasing density. This decrease is closely

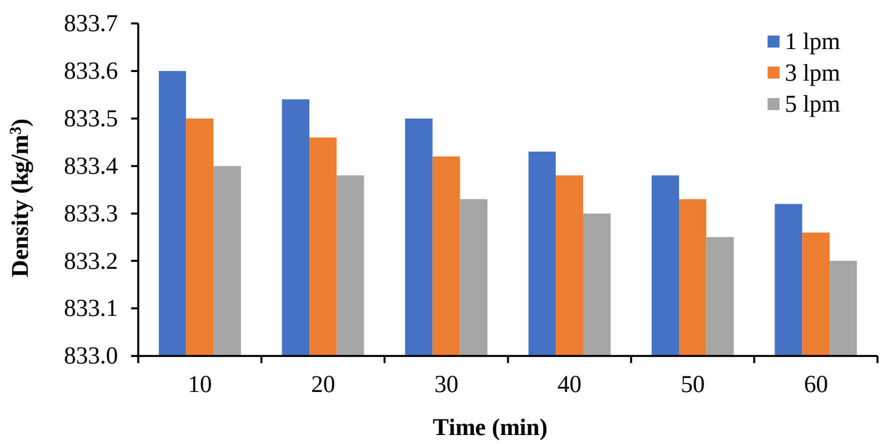

Figure 4. Effect of oxygen flowrate and bubbling time on the density of B-35 CN48

related to the interaction between dissolved oxygen and unsaturated elements in the fuel, which triggers a mild reaction and produces a new compound structure that tends to be lighter and more easily evaporated. Furthermore, the instability of intermolecular bonds caused by oxygen in nano sizes also influences the decrease in overall density. The findings in this study are similar to those of previous researchers who observed the effect of oxygen nano-additives in diesel-biodiesel fuel blends, finding that oxygen additives mixed with biodiesel reduced viscosity, density, and flash point (Soudagar *et al.*, 2018).

3.4. Distillation of B-35 CN48 UFB

Distillation temperature curve describes the level of fuel volatility, which plays an important role in engine performance. Distillation contributes to improve fuel stability and quality by eliminating volatile components and heavy residues. The distillation process for diesel fuel utilizes the differences in boiling points between hydrocarbon compounds to obtain fractions that meet quality specifications. Initial and final boiling points are used as primary indicators in assessing the quality of the final product (Shuai *et al.*, 2013; Chybowski, 2022). The distillation temperature of diesel fuel affects engine performance, vibration levels, and exhaust emissions. Fuels with low distillation temperatures tend to evaporate more easily, thus promoting efficient combustion, resulting in better engine performance and reduced vibration due to stable combustion. Conversely, fuels with high distillation temperatures have a slower evaporation rate, risking incomplete combustion, decreased performance, and increased engine vibration (Zheng *et al.*, 2017). Fuels with a high distillation point tend to cause incomplete combustion and increase particulate emissions. Diesel fuel with a narrower distillation range usually provides more optimal combustion results and reduces the emission levels (Fernández-Feal *et al*., 2017). According to Zheng *et al.* (2017), increasing injection pressure can improve atomization and air mixing, thus promoting better combustion efficiency.

Figure 5 presents the effect of UFB oxygen addition on the distillation temperature of B-35 CN48 biodiesel fuel. The results show that an increase in the oxygen injection rate generally reduces the distillation temperature. At an injection rate of 1 L/min, the distillation temperature was 339.9 °C with a injection time of 10 min, and 333.8 °C at injection time 60 min. At a rate of 3 L/min, the temperature ranged from 338.8 °C at 10 min to 332.4 °C at 60 min injection time. The distillation temperature decreased to 337.4 °C at the highest injection rate of 5 L/min for 10 min injection time, and decline further to 330.9 °C at 60 min injection time. For comparison, the distillation temperature of the control biodiesel sample (without UFB oxygen) was 341.6 °C, still lower than the maximum permitted of 370 °C.

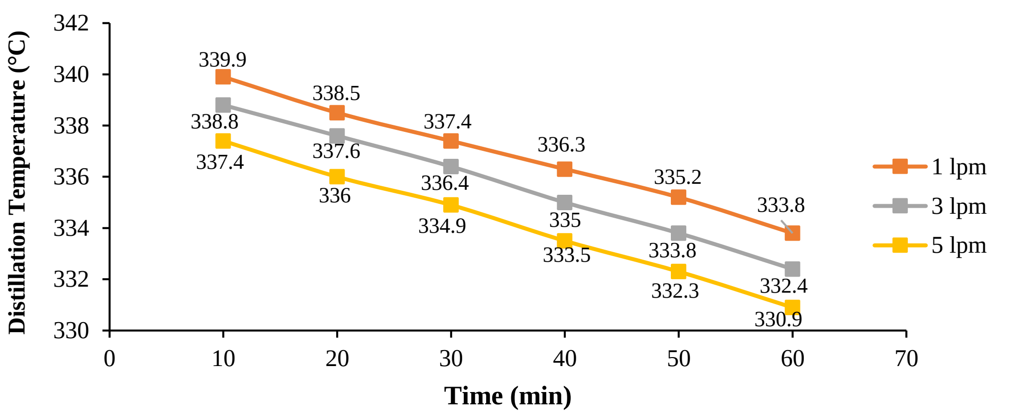

Figure 5. Effect of oxygen injection flowrate and bubbling time on the distillation temperature of B-35 CN48

Results in Figure 6 indicate that the bubbling duration and oxygen flow rate can accelerate the evaporation of the B-35 CN48 diesel fuel fraction, resulting in a lower distillation temperature than that of control fuel, but still below the maximum standard limit. The findings of this study are consistent with previous research that examined the density, viscosity, and distillation temperature of diesel fuel blends combined with oxygenated components at various temperature levels. For example, Osman & Stefaniu (2023) reported the distillation temperature of blend fuels is lower than that of diesel fuel without oxygenated additives, which may potentially affect the evaporation and combustion mechanisms.

The phenomenon of decreasing distillation temperature in Figure 5 for B-35 CN48 biodiesel fuel that undergoes UFB oxygen injection with varying flow rates and bubbling durations can be caused by mild oxidation reaction. This reaction changes the heavier hydrocarbon compounds into lighter and more volatile fractions, causing a decrease in the average boiling point of the fuel. In turn, the distillation temperature at 90% volume is lower than that of the fuel without oxygen injection treatment. In addition, the higher the oxygen injection flowrate and bubbling duration, the more intense the oxidation reaction occurs, the more noticeable changes in fuel composition, which causes a significant decrease in the distillation temperature. Thus, UFB oxygen injection contributes to increase the volatility of B-35 CN48 fuel by reducing the proportion of heavy components, which ultimately lowers the distillation temperature of the fuel in accordance with the increase in the oxygen injection rate and duration. The findings of this study align with previous research that examined the influence of distillation characteristics and aromatic content on the performance of gasoline compression ignition. For example, (Chuahy *et al.*, 2021) showed that fuels with lighter fractions have lower boiling points and tend to be more volatile and spread more quickly, thereby enhancing the homogeneity of the air-fuel mixture. Vellaiyan (2020) also observed improvements in combustion characteristics, performance, and emissions of diesel engines fueled with biodiesel by using water emulsions and nano-additives. Their findings indicate that nano-additives in the fuel can enhance fuel atomization, accelerate combustion, and promote faster oxidation reactions.

3.5. Cloud Point of B-35 CN48 UFB

Visual cloud in the fuel is an indicator for cloud point temperature at which paraffin crystals begin to form in the fuel. Cloud point temperature is essential for evaluating the flow properties and fuel performance (Bantchev *et al.*, 2024). The cloud point is an essential parameter in assessing the flow characteristics of B-35 CN48 biodiesel fuel, which consists of a mixture of diesel fuell and biodiesel. According to Pradana *et al.* (2024), the cloud point value also affects fuel and engine performance reliability. Figure 6 portrays effect of treatment on the cloud point of B-35 CN48 biodiesel fuel. The graph shows that increasing oxygen injection flow rate and bubbling durations decrease the cloud point of the fuel. At an oxygen injection rate of 1 L/min, for example, the cloud point value declines from approximately 7 °C to 6 °C, while at a rate of 5 L/min the cloud point decrease from 5.9 °C to 5 °C. Results of this study indicate that increasing oxygen injection flowrate accelerate changes in fuel characteristics, especially in reducing the cloud point temperature. In other words, the oxygen injection treatment can improve the fuel adaptability to lower ambient temperatures. In addition, the findings in this study is in accordance with (Takayama, 2018) who observed the addition of ultrafine bubble hydroxyl radicals (•OH) to fuel, and found that injecting ultrafine bubbles into fuel can reduce fuel consumption by up to 20%.

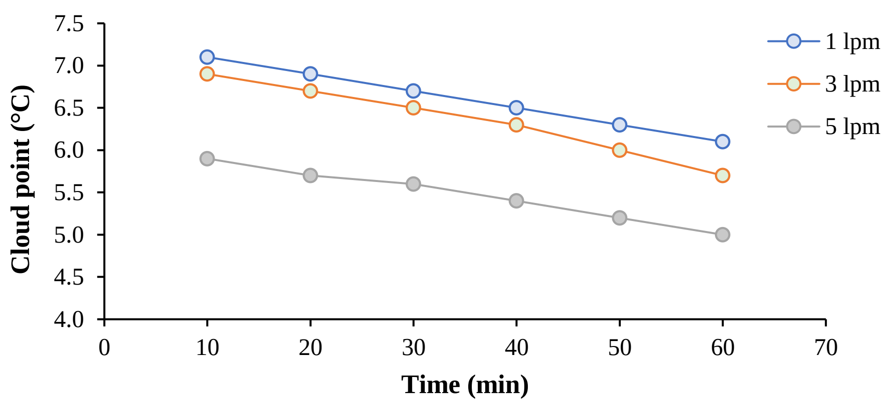

Figure 6. Effect of oxygen injection flowrate and bubbling time on the cloud point of B35 CN48

3.6. Flash Point of B-35 CN48 UFB

Flash point value closely relates to the physical properties of the fuel and the combustion process and can be used for fuel quality control strategy in the industrial sector. Higher oxygen levels have been shown to significantly lower the spontaneous ignition point of fuel while increasing the effectiveness of combustion process (Ghany *et al.*, 2024). Figure 7 presented the effect of combination treatment of oxygen injection rate and bubbling time on the flash point of B-35 CN48. It is revealed that increasing oxygen injection flow resulted in the decrease of flash point. Similarly, increasing injection duration from 10 to 60 min also caused the decrease in flash point of the fuel. The reference value without treatment (control) is 73 °C, while the minimum threshold for safety is set at 52 °C. The results show that increasing the rate and duration of oxygen injection tends to decrease the flash point value. At oxygen injection of 1

L/min, the flash point decreased from 72 °C at 10 min to 67.4 °C at 60 min, while at an oxygen injection rate of 3 L/min, there was a decrease in the flash point from 71 °C at a bubbling time of 10 min to 66.6 °C at 60 min. Similarly, at 5 L/min oxygen injection rate, the decrease was recorded from 69 °C at bubbling time 10 min to 64.5 °C at time 60 min. Although the flash point value decreased, all of them in each treatment were still above the minimum threshold, so B-35 CN48 fuel remained in the safe category for use. This findings align with previous researchers who observed the impact of oxygen-additive fuel on diesel engines, reporting that adding oxygen to diesel fuel can increase thermal efficiency and combustion quality (Kashyap *et al*., 2022). Our findings also in agreement with Imdadul *et al.* (2015) where additives addition into a mixture of biodiesel and diesel can accelerate the combustion, reduce ignition delay, and increase thermal efficiency and engine performance. Similarly, Semorile *et al.* (2023) showed that adding short-chain oxygenated compounds (such as hydroxyl groups) lowers the flash point value, providing advantages in terms of safety, storage, handling, and quality of fuels.

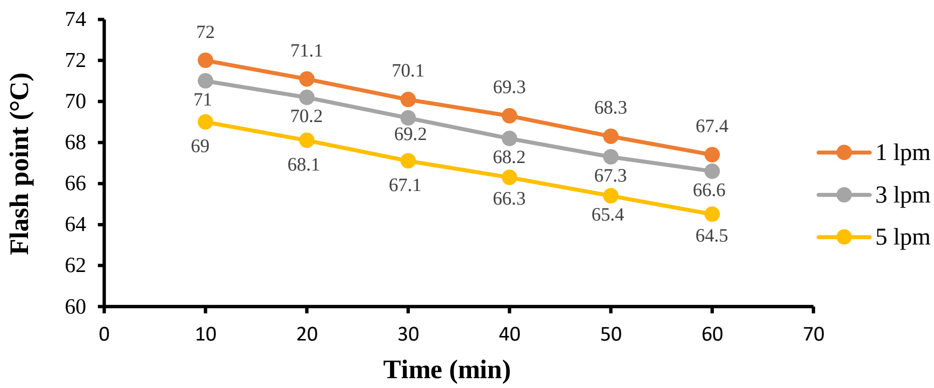

Figure 7. Effect of oxygen flowrate and bubbling time on the flash point temperature of B-35 CN48

Figure 7 shows the phenomenon of analysis of the decrease in flash point value in B-35 CN48 diesel fuel after being injected with oxygen in the form of ultrafine bubbles with various flow rates and durations caused by the increase in the concentration of dissolved oxygen in the fuel, this increase in oxygen causes changes in the physical and chemical properties of the fuel, especially increasing volatility and facilitating the formation of vapor at lower temperatures. The results of this study are similar to those of previous scientists who observed the impact of oxygen levels in fuel on diesel engine combustion, indicating that increasing oxygen content can improve combustion quality (Song *et al.*, 2016).

This observation shows that dissolved oxygen in B-35 CN48 diesel fuel can accelerate the mild oxidation reaction to hydrocarbon compounds, resulting in more volatile products, which contributes to a decrease in the flash point of the fuel. However, the recorded flash point is still above the minimum safety limit determined, so the fuel remains safe and suitable for use. The results of this finding align with previous researchers who observed the flash point predictions of petroleum, who reported that chemical structure, such as the length of the carbon chain and the presence of functional groups, significantly affect the flash point value (Alqaheem & Riazi, 2017). Other researchers also observed flash point measurements and predictions of biofuels and biofuel mixtures with aromatic liquids, finding that the transformation of aromatic compounds, such as toluene or xylene, can lower the flash point of the fuel (Fu, 2019).

4. CONCLUSION

The results of this study can be seen in the characteristics of the physicochemical properties of cetane number, viscosity, density, distillation, cloud point, and flash point of B-35 CN48 treated with ultrafine bubble oxygen:

1. The oxygen-based ultrafine bubble injection in the B-35 CN48 increased the cetane number from 58.6 to 60.8, indicating higher combustion efficiency. Viscosity decreased from 3.19 to 3.11 mm²/s, and density slightly

declined from 833.6 to 833.2 kg/m^3, but was still within standards. The decrease of cloud point from 7.1 °C to 5.1 °C suggested improvement of fuel performance at low-temperature.

2. Along with the increase of oxygen injection rate and duration in form ultrafine bubbles, the distillation temperature of B-35 CN48 decreased from 341.6 °C to 330.9 °C, reflecting increasing fractionation efficiency and potential improvement in combustion quality. The highest distillation temperature was 339.7 °C recorded at an oxygen injection rate of 1 L/min for 10 min, still lower than the limit of 370 °C.
3. Rate and duration of oxygen injection decrease the flash point temperature of B-35 CN48 from the reference value of 73 °C, but remained above the safe limit of 52 °C. This implies a potential for increased combustion efficiency.

Our research confirmed the improvement of physicochemical properties of B-35 that ultimately supporting more efficient fuel and reliable combustion in engines. Further research, however, is required to evaluate the impact of ultrafine oxygen bubbles on the engine performance and fuel stability during storage.

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