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Combustion Performance of Jatropha and UCO Biodiesel Blends Under Varying Equivalence Ratios

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Abstract
This study investigates the combustion characteristics of biodiesel blends derived from Jatropha Methyl Ester (JME) and Used Cooking Oil Methyl Ester (UCOME) under various equivalence ratios (Φ = 0.8, 1.0, 1.1, and 1.2). The biodiesels were produced through a two-step transesterification process, yielding 94.3% for JME and 92.0% for UCOME. Combustion experiments were conducted in a horizontal combustion chamber using a data logger and K-type thermocouples to record wall temperatures. Blends with conventional diesel fuel (CDF) were prepared at 5%, 15%, and 25% biodiesel concentrations. Results showed that wall temperature decreases as the percentage of biodiesel in the blend increases. At stoichiometric conditions (Φ = 1.0), the highest wall temperature was recorded for CDF at 847.03°C, while B25 JME and B25 UCOME recorded the lowest at 782.43°C and 791.09°C, respectively. The percentage reduction in maximum temperature relative to diesel was 7.6% for B25 JME and 6.5% for B25 UCOME. Increasing equivalence ratios led to a rise in wall temperatures across all blends. From Φ = 0.8 to 1.0, temperature increased by up to 10.6% for B15 JME, while from Φ = 1.0 to 1.2, B25 JME saw an increase of 6.6%. The findings confirm that biodiesel blends produce lower combustion temperatures due to reduced energy content and heating values. Nonetheless, all tested biodiesel blends successfully sustained combustion under varying air-fuel ratios, indicating their potential as alternative fuels for low-emission combustion systems.

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1. Introduction

The growing global concern over depleting fossil fuel reserves and rising greenhouse gas emissions has intensified the search for sustainable and environmentally friendly alternative fuels. Biodiesel, a renewable and biodegradable fuel derived from various organic feedstocks, has emerged as a promising substitute for conventional diesel. Among its many benefits, biodiesel can significantly reduce emissions of carbon monoxide (CO), unburned hydrocarbons (HC), and particulate matter (PM) without requiring major modifications to existing diesel engines (Demirbas, 2009; Jalaludin, Kamarulzaman, Sudrajad, Rosdi, & Erdiwansyah, 2025; Muhibbuddin, Muchlis, Syarif, & Jalaludin, 2025; Muhtadin, Rosdi, Faisal, Erdiwansyah, & Mahyudin, 2025). Numerous studies have explored the use of biodiesel from non-edible oils such as Jatropha curcas, which is favored due to its high oil content and ability to grow on marginal land (Abobatta, 2021; Bahagia, Nizar, Yasin, Rosdi, & Faisal, 2025; Khayum, Goyal, & Kamal, 2025; Nizar, Yana, Bahagia, & Yusop, 2025). Similarly, waste-derived biodiesel from Used Cooking Oil (UCO) has gained popularity because of its low cost and dual environmental benefit recycling waste and reducing reliance on virgin feedstocks (Iqbal, Rosdi, Muhtadin, Erdiwansyah, & Faisal, 2025; Mohamed, Betiha, & Negm, 2023; S. M. Rosdi, Ghazali, & Yusop, 2025; Yana, Mufti, Hasiany, Viena, & Mahyudin, 2025). Both sources typically require a two-step transesterification process to effectively reduce free fatty acid (FFA) content and improve conversion efficiency.

Combustion characteristics of biodiesel, particularly wall temperature distribution, ignition behavior, and emission profiles, are critical for evaluating its compatibility in practical combustion systems such as gas turbines and industrial burners (Alenezi et al., 2021; Erdiwansyah et al., 2019; Mamat et al., 2019; S. M. Rosdi, Yasin, Khayum, & Maulana, 2025). Several researchers have observed that biodiesel generally leads to lower combustion temperatures than petroleum diesel due to its lower heating value and oxygenated nature (Gani et al., 2025; Muchlis, Efriyo, Rosdi, & Syarif, 2025; Qi, Chen, Geng, & Bian, 2010; Xiaoxia, Lin, & Salleh, 2025). These thermal differences can significantly impact NOx formation, making biodiesel advantageous in reducing nitrogen-based pollutants. The equivalence ratio (Φ), which denotes the ratio of fuel to air relative to stoichiometric conditions, plays a vital role in determining combustion efficiency and emissions. It has been shown that combustion temperature increases with higher equivalence ratios as a result of richer fuel mixtures and enhanced energy release (Alenezi, Erdiwansyah, Mamat, Norkhizan, & Najafi, 2020; Ghazali, Rosdi, Erdiwansyah, & Mamat, 2025; S. M. M. Rosdi, Erdiwansyah, Ghazali, & Mamat, 2025; Zheng, Wang, Zhao, Wang, & Huang, 2019). However, biodiesel's performance under various equivalence ratios especially wall temperature profiles remains a subject of ongoing investigation.

Blending biodiesel with conventional diesel fuel offers a practical transition strategy, maintaining combustion reliability while leveraging the environmental benefits of biodiesel. Studies such as those by Graboski and McCormick (1998) have demonstrated that blends up to 20–30% biodiesel (B20–B30) perform well in most engines and burners without significant performance penalties. However, the precise effect on combustion chamber temperatures, particularly in lean, stoichiometric, and rich conditions, must be quantified to guide optimal blend usage. In this study, biodiesel derived from Jatropha and UCO was blended with conventional diesel fuel (CDF) in varying proportions (B5, B15, B25) and tested under different equivalence ratios (Φ = 0.8 to 1.2). The objective was to analyze wall temperature profiles in a controlled combustion chamber to assess thermal performance and suitability of these blends for cleaner combustion applications. The results provide critical insights into the relationship between biodiesel concentration, equivalence ratio, and combustion temperature, further supporting the viability of biodiesel as a low-emission alternative fuel.

2. Methodology

Thermocouple and Thermocouple Reader Data Logger

In general, a thermocouple is a sensor designed to measure temperature. It consists of two wire legs made from different metals, joined at one end to form a junction. When the temperature at this junction changes, a voltage is generated, which is then read by a data logger. The data logger converts this voltage into a digital temperature reading. In this experiment, type-K thermocouples were used to measure the wall temperature of the combustion chamber. These thermocouples were installed in eight holes located on the top surface of the chamber. Type-K thermocouples are known for being cost-effective, accurate, reliable, and capable of measuring a wide range of temperatures, from -270°C to 1260°C.

To capture the signals produced by the thermocouples, an additional device, a data logger, was employed. Specifically, the Graphtec GL220 midi logger was used to record the voltage signals and convert them into corresponding temperature values. The specifications for the Graphtec GL220 midi logger are provided in Appendix B2. **Figs 1** and **2** illustrate the type-K thermocouple and the data logger utilized in this experiment.

Fig. 1. Type-K thermocouple

Fig. 1 displays a Type-K thermocouple, which is widely used for temperature measurement in various industrial and research applications. It consists of two dissimilar metal wires, typically chromel and alumel, joined at one end to form a sensing junction. The thermocouple is sheathed with a protective metallic layer to ensure durability and resistance against harsh environments. In this study, the Type-K thermocouple was employed to measure the wall temperature of the combustion chamber, selected for its broad operating temperature range (-270°C to 1260°C), high reliability, and cost-effectiveness.

Fig. 2. Graphtec GL220 Logger

Fig. 2 shows the Graphtec GL220 data logger, an instrument used to record and monitor multiple sensor outputs, including temperature, voltage, and humidity measurements. The device features a high-resolution color display, multiple input channels, and internal memory for long-term data acquisition. In this study, the GL220 logger was utilized to capture the voltage signals generated by the Type-K thermocouples and convert them into digital temperature data. Its portability, high sampling rate, and user-friendly interface made it an ideal choice for monitoring dynamic temperature changes within the combustion chamber during experimental testing.

3. Result & Discussion

Preparation of Biodiesel from Crude Oil

Fig. 3 presents the samples of Jatropha Methyl Ester (JME) and Used Cooking Oil Methyl Ester (UCOME) produced through a two-step transesterification process from their respective crude oils. Visually, both types of biodiesels exhibit a darker coloration compared to conventional diesel fuel, which can be attributed to the inherent color characteristics of the source crude oils. The two-step transesterification process involves an initial acid-catalyzed esterification to reduce the free fatty acid (FFA) content, followed by a base-catalyzed transesterification to convert triglycerides into methyl esters. This method is particularly effective for feedstocks with high FFA levels, such as waste cooking oil and crude jatropha oil, ensuring a higher yield and improved fuel properties.

Physicochemical properties such as viscosity, density, and calorific value of JME and UCOME are influenced by the nature of the feedstock and the reaction conditions. In general, biodiesels derived from waste oils tend to exhibit slightly higher viscosity and lower heating values compared to petroleum-based diesel, factors that must be considered during engine performance and emission evaluations. The darker coloration of JME and UCOME not only reflects the characteristics of the crude feedstocks but also suggests the presence of minor impurities and unsaturated compounds that may remain after the transesterification and purification steps. Although color does not directly affect combustion properties, it can serve as an indicator of biodiesel quality and the effectiveness of the refining process.

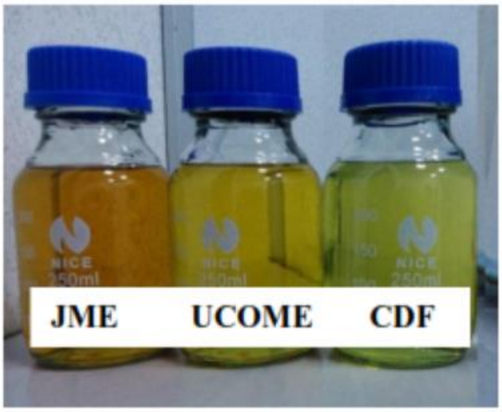


Fig. 3. Sample of JME, UCOME and CDF

JME and UCOME Yield Percentage

Yield or conversion rate is a ratio of quantity product produced to amount provided at first. In Gas Turbine Combustion Research Group laboratory, eight batches of 1200 ml two-step transesterification process were done to produce biodiesel. From the production, for every 9.6 litres of crude oils, the yield percentage of JME is 94.3% whereas UCOME is 92.0%. **Table 1** shows conversion rate and yield for biodiesel production. Considering the best 3 yields from batch 5, batch 6 and batch 7 of jatropha conversion, average yield = (97.1 + 91.3 + 94.6) / 3 = 94.3%. As well as considering the best 3 yields from batch 3, batch 6 and batch 7 of used cooking oil conversion, average yield = (91.7 + 94.2 + 90) / 3 = 92.0%.

Table 1. Yield of jatropha and used cooking oil biodiesels production

No	JME conversion rate	Yield		No	UCOME conversion rate	Yield
1	1010 ml / 1200 ml	84.2%		1	1020 ml / 1200 ml	85.0%
2	1040 ml / 1200 ml	86.7%		2	1055 ml / 1200 ml	87.9%
3	1080 ml / 1200 ml	90.0%		3	1100 ml / 1200 ml	91.7%
4	1070 ml / 1200 ml	89.2%		4	1050 ml / 1200 ml	87.5%
5	1165 ml / 1200 ml	97.1%		5	1070 ml / 1200 ml	89.2%
6	1095 ml / 1200 ml	91.3%		6	1130 ml / 1200 ml	94.2%
7	1135 ml / 1200 ml	94.6%		7	1080 ml / 1200 ml	90.0%
8	1045 ml / 1200 ml	87.1%		8	1070 ml / 1200 ml	89.2%

The conversion rate of biodiesel production depends on several parameters, including the methanol-to-crude oil ratio, catalyst concentration, reaction temperature, and reaction time. Human error during product handling is also considered a contributing factor to the overall conversion efficiency. However, in this study, the primary factor significantly affecting the yield was the formation of soap during the post-treatment process. To minimize soap formation, the unpurified methyl ester must be handled gently and agitated slowly during washing in the separation funnel. As shown in **Table 1**, the yields for Jatropha Methyl Ester (JME) varied from 84.2% to 97.1%, while the yields for Used Cooking Oil Methyl Ester (UCOME) ranged from 85.0% to 94.2%. The relatively higher maximum yield obtained for JME can be attributed to the lower initial free fatty acid (FFA) content in jatropha oil compared to used cooking oil. Higher FFA levels tend to promote soap formation during the transesterification process, which reduces the recovery of pure biodiesel.

Moreover, inconsistencies in yield values among different batches are indicative of slight variations in experimental conditions or handling practices. Minor deviations in methanol dosage, catalyst mixing, or separation efficiency could lead to notable differences in final conversion rates. The observed data highlight the importance of strict control over process parameters and post-reaction handling to achieve consistent and optimal biodiesel yields from various feedstocks. In addition, the data suggest that achieving yields above 90% is feasible for both JME and UCOME under properly optimized conditions. Maintaining minimal agitation during the washing steps, avoiding excessive water contamination, and carefully removing impurities were essential to reduce product loss. Therefore, operational discipline and standardized procedures play a critical role in maximizing biodiesel production efficiency across different raw material sources.

Biodiesel Production Cost

Table 2 shows estimation of biodiesel production cost of 1-litre jatropha and used cooking oil biodiesel. The cost accountable the material utilized in two-step transesterification process within lab scale range. Nevertheless, a correct calculation shall include material, electricity, apparatus, consumable equipment and labour cost. Generally, these costs have minor impact and decline as the production scale range is getting larger. It is stated that 60-75% of biodiesel production cost is from cost of feedstock or crude oil (Canakci et al., 2008; Mata et al., 2010). UCO on the other hand are much cheaper, could be collected national wide at Ringgit Malaysia (RM) 0.50 – 1.00 (Manan, 2015; Harian, 2015). There do not have any standard and specification of UCO as it would be treated as high FFA oil and require a two-step transesterification process to convert it to biodiesel. **Table 2** proved that 83% of jatropha biodiesel production cost covered the crude oil cost, whereas used cooking oil only costs 5.8% of its biodiesel production cost. It is known because of used cooking oil is a used and recycle product, hence the price is cheaper.

Table 2. Biodiesel production cost (material) per litre in Ringgit Malaysia (RM)

Material	Quantity	Cost for JME (RM)	Cost for UCOME (RM)
Crude Oil	1 litre	80.00	1.00
Methanol, MeOH	750 ml	8.70	8.70
Acid Sulfuric, H_2SO_4	15 ml	0.23	0.23
Potassium Hydroxide, KOH	9.1 g	0.50	0.50
Distilled Water	7.5 litre	6.82	6.82
Total material cost (RM)		**96.25**	**17.25**

Table 2 summarizes the material costs associated with the production of biodiesel per litre for Jatropha Methyl Ester (JME) and Used Cooking Oil Methyl Ester (UCOME), expressed in Malaysian Ringgit (RM). It can be observed that the major contributor to the total production cost is the crude oil feedstock. For JME, the crude jatropha oil accounts for RM80.00 per litre, representing over 83% of the total material cost. In contrast, the crude used cooking oil for UCOME production costs only RM1.00 per litre, significantly reducing the overall production cost. The cost breakdown further reveals that the expenses for methanol, sulfuric acid, potassium hydroxide, and distilled water are relatively similar

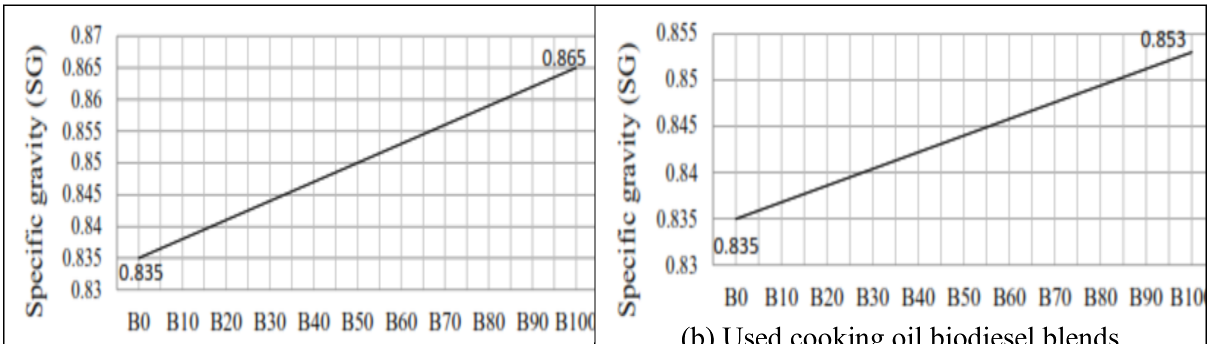
between the two biodiesel types. These chemicals are essential for the two-step transesterification process and contribute marginally to the final cost structure compared to the crude oil itself. As a result, the total material cost for JME production reaches RM96.25 per litre, whereas UCOME production only incurs RM17.25 per litre, highlighting the economic advantage of using waste cooking oil as a feedstock. This significant cost disparity emphasizes the economic feasibility of UCOME as a competitive alternative fuel, especially in markets where low-cost feedstocks are readily available. Furthermore, optimizing the production process to minimize chemical usage and improve conversion efficiency can further reduce the cost of biodiesel production. Consequently, the choice of feedstock plays a critical role not only in determining the quality of the final biodiesel product but also in influencing the overall production economics.

Blending Test Fuels

Blending process to produce jatropha and used cooking oil biodiesel blends were carried at Gas Turbine Combustion Research Group laboratory. Blending machine or mixer was used to blend CDF with biodiesel according to amount and composition required as presented in Table 3.1. Figure 4.2 shows the sample of test fuels. **Fig. 4** shows graph of specific gravity plotted to estimate the blends homogenously during blending process.

Fig. 4. Sample of test fuels

Fig. 4 shows the prepared samples of test fuels used in this study, including conventional diesel fuel (CDF), biodiesel blends with Jatropha Methyl Ester (B5 JME, B15 JME, B25 JME), pure Jatropha biodiesel (B100 JME), biodiesel blends with Used Cooking Oil Methyl Ester (B5 UCOME, B15 UCOME, B25 UCOME), and pure UCOME (B100 UCOME). The blends were formulated by mixing biodiesel with diesel at volumetric percentages of 5%, 15%, and 25% to evaluate the effect of increasing biodiesel content on fuel properties and combustion characteristics. Visually, it can be observed that the color of the fuel samples becomes slightly darker with higher biodiesel content, especially for B100 JME and B100 UCOME. This darker coloration is associated with the intrinsic properties of the biodiesel, derived from the crude feedstock, and does not significantly impact the combustion behavior. However, changes in physical properties such as density and viscosity are expected with increasing biodiesel concentrations, which may influence engine performance and emission profiles. The preparation of these test fuels was conducted under controlled conditions to ensure homogeneity and consistency across all samples. Proper mixing was essential to avoid phase separation, especially at higher biodiesel concentrations. These fuel samples were later subjected to a series of physicochemical property measurements and engine testing to assess the suitability and performance of JME and UCOME blends as alternative fuels for diesel engines.



(a) Jatropha biodiesel blends

(b) Used cooking oil biodiesel blends

Fig. 5. Specific gravity versus biodiesel blends

Fig. 5 illustrates the variation of specific gravity (SG) with different biodiesel blend ratios for both Jatropha biodiesel (Figure 5a) and Used Cooking Oil biodiesel (Figure 5b). For both fuel types, an increasing trend in specific gravity is clearly observed as the biodiesel content rises from B0 (pure diesel) to B100 (pure biodiesel). The specific gravity of pure diesel (B0) was measured at 0.835, while B100 JME and B100 UCOME recorded specific gravities of 0.865 and 0.853, respectively. The increase in specific gravity with higher biodiesel blending can be attributed to the intrinsic properties of biodiesel, which generally possesses a higher density than conventional diesel fuel. Jatropha biodiesel showed a slightly higher specific gravity compared to UCOME across all blend ratios, likely due to the molecular structure and composition differences between the two biodiesel types. This characteristic is important, as it may affect fuel atomization, spray characteristics, and consequently, engine performance and emissions. Overall, the linear relationship observed between specific gravity and biodiesel content suggests predictable and consistent behavior of biodiesel-diesel blends. This consistency is critical for engine calibration and fuel injection systems, as variations in fuel properties can influence combustion efficiency. Thus, understanding specific gravity trends provides valuable insights for optimizing biodiesel usage in existing diesel engines without major modifications.

Density

The density property test was conducted using a Pycnometer followed the ASTM D941 measuring standard. The biodiesel blends have different weight, therefore change in densities. Table 4.3 shows densities of the test fuels. From the table, the density of CDF is the lowest among all other fuels. B100 biodiesels show highest value among their blends, 868.0 kg/m 3 for B100 JME and 858.7 kg/m 3 for B100 UCOME. As the percentage of biodiesel increases in a blend, the density of that fuel rises too.

Table 3 Density of fuels

Fuel	**Density (kg/m^3)**
CDF	830.1
B5 JME	833.8
B15 JME	837.4
B25 JME	841.0
B100 JME	868.0
B5 UCOME	827.4
B15 UCOME	830.5
B25 UCOME	833.5
B100 UCOME	858.7

Table 3 presents the measured densities of the test fuels, including conventional diesel fuel (CDF), various blends of Jatropha Methyl Ester (JME), and Used Cooking Oil Methyl Ester (UCOME). The density of CDF was recorded at 830.1 kg/m³, while the densities of biodiesel blends increased progressively with higher biodiesel content. For B100 JME and B100 UCOME, the densities were measured at 868.0 kg/m³ and 858.7 kg/m³, respectively, indicating the inherently higher density characteristics of pure biodiesel compared to petroleum diesel. A detailed comparison reveals that JME blends exhibit higher density values compared to UCOME blends at corresponding blend ratios. This can be attributed to the different feedstock properties and molecular structures of the two biodiesels. The increase in density with biodiesel addition is significant, as higher density fuels can impact the fuel injection process, potentially leading to larger fuel droplet sizes, altered spray patterns, and variations in combustion characteristics. The observed trend is consistent with findings reported in previous biodiesel studies, which indicate that biodiesel typically possesses greater density due to its higher molecular weight esters. While a moderate increase in fuel density can enhance combustion efficiency through better air–fuel mixing, excessive density changes may affect atomization and lead to increased particulate emissions. Therefore, understanding and managing density variations is crucial for ensuring optimal engine performance when operating with biodiesel blends.

Surface Tension

The surface tension property test was conducted using an auto Kruss K20 tensiometer which conforms to the ASTM D971 measuring standard. Surface tension of test fuel was measured thrice to get the accurate value. Table 4.6 shows the surface tension of the fuels tested in this study. CDF has the lowest surface tension which is 29.5 mN/m to compare to other fuels tested. As increasing of percentage of biodiesel in a blend, surface tension for that fuel is also increase. It follows the trend of density where biodiesel is heavier compared to CDF. Thus surface tension of biodiesel is larger than CDF.

Table 4. Surface tension of fuels

Fuel	Average Surface Tension (mN/m)
CDF	29.5
B5 JME	29.7
B15 JME	29.9
B25 JME	30.1
B100 JME	31.6
B5 UCOME	29.7
B15 UCOME	29.9
B25 UCOME	30.0
B100 UCOME	32.1

Table 4 shows the average surface tension values for CDF, JME blends, and UCOME blends. The surface tension of conventional diesel fuel (CDF) was measured at 29.5 mN/m. As the biodiesel content in the fuel blends increased, a gradual rise in surface tension was observed. The highest surface tension values were recorded for pure biodiesel samples, with B100 JME at 31.6 mN/m and B100 UCOME at 32.1 mN/m, indicating that biodiesel possesses inherently higher surface tension compared to petroleum diesel. The increase in surface tension with higher biodiesel concentration is attributed to the molecular structure of biodiesel, which contains longer and more complex hydrocarbon chains with polar groups, leading to stronger intermolecular interactions. JME and UCOME blends showed relatively similar trends in surface tension increments, although UCOME exhibited slightly higher values at B100

compared to JME. This slight variation could be linked to differences in fatty acid composition between jatropha oil and used cooking oil. Surface tension plays a critical role in the atomization process during fuel injection. Fuels with higher surface tension tend to form larger droplets, which may reduce the spray quality and influence the combustion process. Therefore, understanding surface tension behavior is essential when evaluating biodiesel blends for diesel engine applications, as it directly impacts spray characteristics, ignition quality, and overall engine efficiency.

Stoichiometric Condition

For stoichiometric condition, at equivalent ratio 1.0, it is known as a complete combustion where ratio of fuel with air required in combustion are just enough for both excess completely leaving no oxygen left in the air. **Fig. 6** shows the wall temperatures for CDF, B5 JME, B15 JME, B25 JME, B5 UCOME, B15 UCOME and B25 UCOME blends versus station for 1.0 equivalence ratio. The pattern of wall temperature profile for stoichiometric condition in **Fig. 7** is almost matching to the fuel lean conditions in **Fig. 6** and **7**. The highest logged wall temperature was CDF with 847.03°C, followed by B5 JME, B15 JME, B5 UCOME, B15 UCOME, B25 UCOME and B25 JME blends with 839.3 °C, 830.70 °C 810.50 °C, 797.80 °C, 791.09 °C and 782.43 °C correspondingly. Another way of seeing this is that as the amount of biodiesel increases in a fuel blends, the wall temperature during combustion decreases. Like previous lean conditions, the wall temperature rose up until it reaches the third quarter region of the combustion chamber, at Station 6, which was 600 mm away from the burner, then the wall temperature started to reduce slightly till the end of the combustion chamber. This complied with all test fuels which maximum temperature stated above detected at Station 6. **Fig. 7** presents percentage of reduction of highest temperature of test fuels relative to diesel fuel highest temperature at equivalent ratio Φ 1.0. From the chart, B25 JME shows largest reduction followed by B25 UCOME, B15 UCOME, B5 UCOME, B15 JME and B5 JME with percentage of reduction 7.6, 6.5, 5.8, 4.3, 2 and 1 respectively. It is suggested that as the percentage of biodiesel in a fuel increase, it will consequently decrease the energy content and heating value of the fuel. Thus, generating lesser wall temperature during combustion. Again, the change in energy content and heating value of test fuels resulted in to the wall temperature differences among all the fuels.

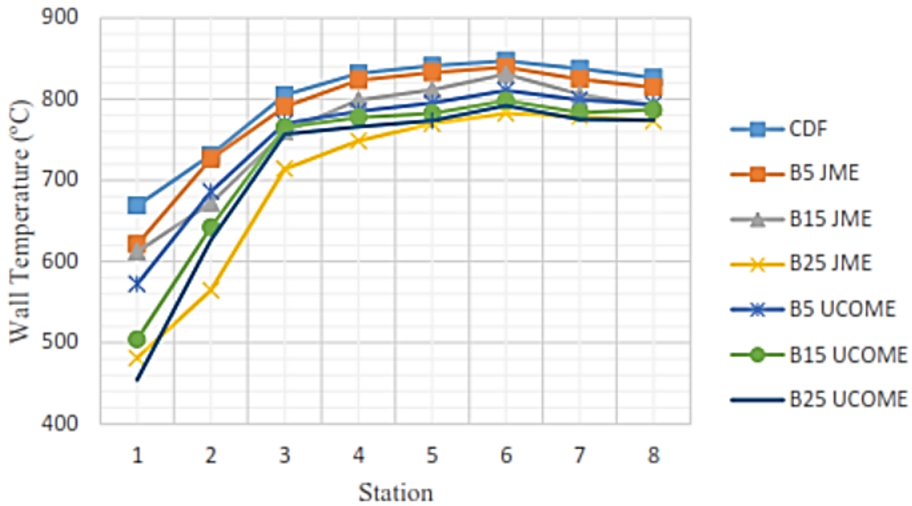


Fig. 6. Wall Temperature for Equivalent Ratio, Φ = 1.0

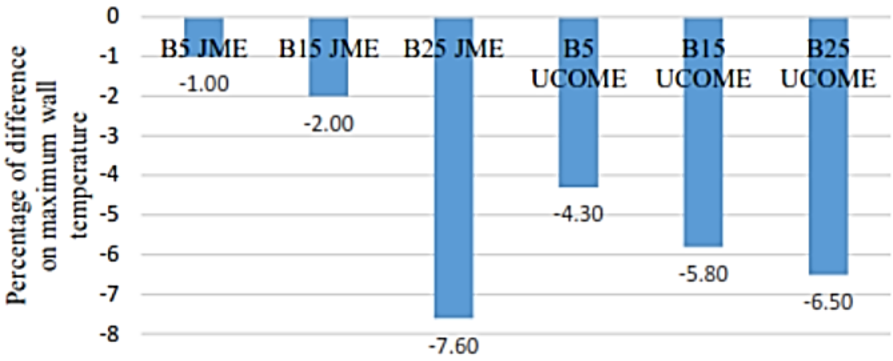


Fig. 7. Percentage of maximum temperature of test fuels relative to highest temperature of diesel fuel for Equivalent Ratio, Φ = 1.0

Fuel Rich Condition

Fuel rich condition means more fuel was supplied in combustion compared to air provided. Equivalence ratios 1.1 and 1.2 indicate fuel mixture are in rich condition. **Figs** 8 and **9** show the wall temperatures for CDF, B5 JME, B15 JME, B25 JME, B5 UCOME, B15 UCOME and B25 UCOME blends against station of thermocouple distance from the burner for 1.1 and 1.2 equivalence ratios correspondingly. The maximum wall temperature logged for equivalence ratio 1.1 was from CDF with 879.20°C, followed by B5 JME, B15 JME, B25 JME, B5 UCOME, B15 UCOME and B25 UCOME blends with wall temperatures of 852.17°C, 842.67°C, 813.33°C, 813.07°C, 769.00°C and 801.03°C individually. Likewise, for equivalence ratio 1.2, the wall temperature for CDF was the highest recorded among all test fuels followed by B5 JME, B5 UCOME, B15 JME, B25 JME, B15 UCOME and B25 UCOME blends with the values of 902.57°C, 860.8°C, 852.00°C, 846.00°C, 833.97°C, 819.90°C and 811.20°C respectively. Alike to the fuel lean and stoichiometric condition, the wall temperature continues to escalate until it reached the third quarter region of the combustion chamber, at Station 6, 600 mm away from the burner, which was where the highest wall temperature for all test fuel were recorded. This point is the location where air and fuel are homogeneously combusted thus produced higher temperature. Then, from that point on, the wall temperature was slightly lower till the end of the combustion chamber.

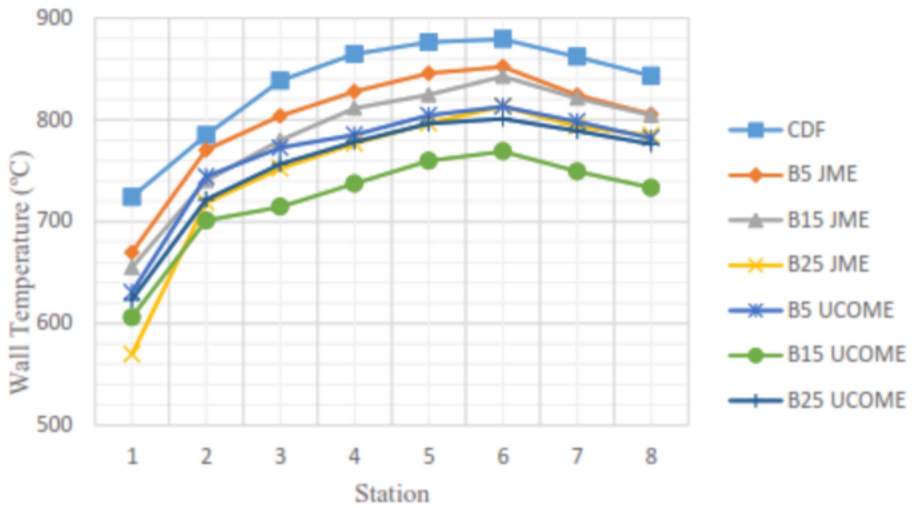


Fig. 8. Wall Temperature for Equivalent Ratio, Φ = 1.1

From **Figs 4**, **6** and **9**, a graph was tabulated to study relationship between maximum wall temperature and rise of equivalent ratio considered lean, stoichiometric and rich condition as presented in Fig. 10. These results validated to a report said temperature increase as the equivalent ratio increases (Hosseini et al., 2010). The increments of wall temperature for CDF, B5 JME, B15 JME, B25 JME, B5 UCOME, B15 UCOME and B25 UCOME from equivalent ratio 0.8 to 1.0 are approximately 8.0%, 5.9%, 10.6%, 7.0%, 4.5%, 3.7% and 6.5% respectively. And from equivalent ratio 1.0 to 1.2 are approximately 6.6%, 2.6%, 1.8%, 6.6%, 5.1%, 2.8% and 2.4% correspondingly. It is observed that increasing of equivalent ration, average wall temperature for each test fuels was inclined. Larger amount of heat will be released through combustion as more excess fuel are burned.

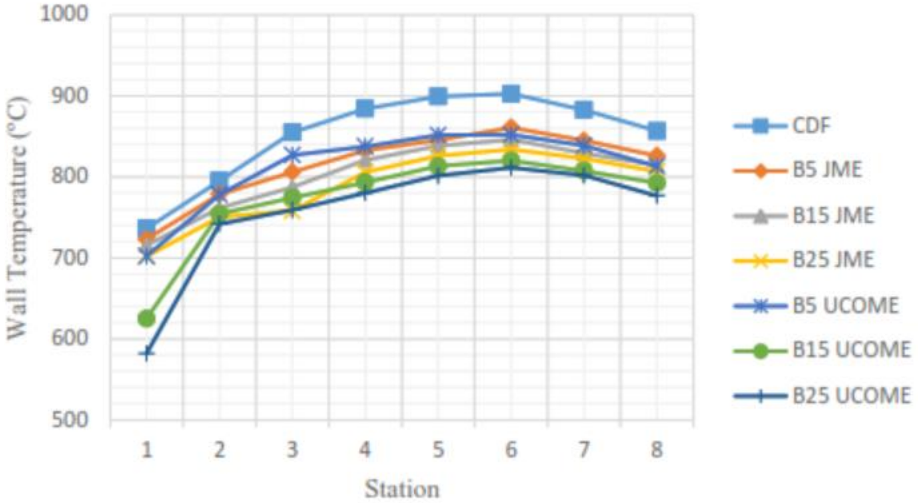


Fig. 9. Wall Temperature for Equivalent Ratio, Φ = 1.2

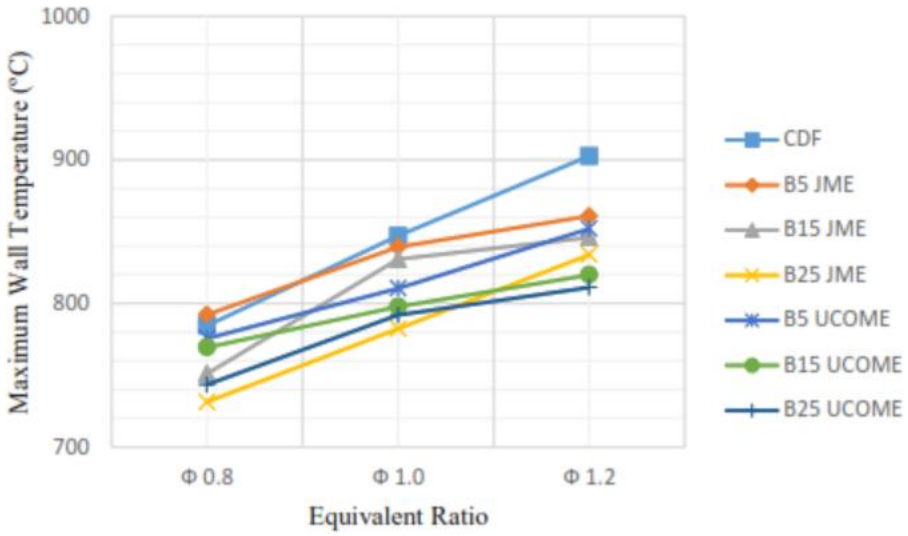


Fig. 10. Maximum wall temperature of test fuels versus equivalent ratio.

In conclusion, based on **Figs 4** to **10**, it was observed that the wall temperature is inversely proportional to biodiesel percentage in a fuel. B25 JME and B25 UCOME blends with the lowest energy content and heating value among their blends, generated the lowest wall temperatures in all lean-stoichiometric-rich conditions. It is validated to a report stated the temperature increases as the increasing of percentage of biodiesel in a blend (Sawarimuthu et al., 2008). On the other hand, CDF has the highest calorific value compared to other test fuels, hence, higher energy content and heating value, produced the highest wall temperatures among all of the fuels in each condition. From these figures too, it is noticeable that the wall temperature was proportional to the equivalence ratios itself. With the increase of equivalence ratio, the wall temperatures for each test fuel increases significantly. This is simply being explained by the excessive presence of fuel through combustion in higher equivalent ratio. Finally, graphs presented shows that all test fuels were able to combust in all equivalent ratios.

4. Conclusion

This study concludes that biodiesel blends from Jatropha Methyl Ester (JME) and Used Cooking Oil Methyl Ester (UCOME) are viable alternative fuels with measurable effects on combustion temperature. The production yields achieved were 94.3% for JME and 92.0% for UCOME using a two-step transesterification method. Combustion experiments demonstrated that as the biodiesel percentage in the blend increases, the wall temperature decreases due to the lower energy content and heating value of biodiesel compared to conventional diesel fuel (CDF). At stoichiometric conditions ($\Phi = 1.0$), the maximum wall temperature for CDF was 847.03°C, while B25 JME and B25 UCOME recorded significantly lower temperatures at 782.43°C and 791.09°C, representing a temperature reduction of 7.6% and 6.5%, respectively. Under fuel-rich conditions ($\Phi = 1.2$), CDF reached a peak temperature of 902.57°C, whereas B25 JME and B25 UCOME registered 833.97°C and 811.20°C. Furthermore, the study confirmed that combustion temperatures increase with rising equivalence ratios across all fuel types, with B15 JME showing the highest temperature increase (10.6%) from $\Phi = 0.8$ to $\Phi = 1.0$. Despite the reduction in peak temperature, all biodiesel blends maintained stable combustion throughout the tests. These results highlight the potential of JME and UCOME biodiesel as sustainable fuels that offer reduced thermal output, which could be advantageous in minimizing NOx emissions in practical combustion systems.

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