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Droplet combustion behavior of crude palm oil-carbon nanoparticles blends

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Abstract. Research on the combustion behavior of a mixture of palm oil and carbon nanoparticles has been carried out. The burning phenomenon is observed through oil droplets that are ignited at the thermocouple junction, and the evolution of the droplets is recorded with a high-speed camera. The results indicate that the addition of carbon nanoparticles increases the molecular density of the fuel. This has the potential to produce effective collisions that weaken the strength of carbon chain bonds and increase the reactivity of fuel molecules. The increased motion of fuel molecules makes it easy for molecules to absorb heat and burn. This analysis was proven because the results showed that the addition of carbon nanoparticles succeeded in increasing the temperature and burning rate.

Keywords: single droplet, crude palm oil, carbon nano particle, combustion characteristics

1. Introduction

Crude vegetable palm oil (CPO) is one of the natural resources that can be used as an alternative fuel [1,2]. However, the presence of OH molecules in the carbon triglyceride chain has the potential to inhibit fuel combustion performance. Furthermore, the physical properties of CPO fuels have high density and viscosity. This makes the fuel difficult to burn at low temperatures [3] so that it has the potential to reduce fuel performance [4-6]. However, these factors makes the atomization process more difficult because it produces large droplets, making fuel difficult to evaporate. A low evaporation rate makes it difficult for fuel to react with air, resulting in incomplete combustion. This can cause carbon crust on fuel components and lines such as injectors, piston rings, valves, and fuel filters. On the other hand, application-based studies have not revealed much fundamental scientific information. Therefore the researchers used the suspended single droplet method to simplify the observation method [7-12]. Unfortunately, not much scientific information can be revealed about the combustion performance of CPO. Therefore, further research into the combustion process of CPO is crucial so that it can produce fuels with good performance. Therefore, to improve fuel performance, some researchers use nanoparticles as a homogeneous catalyst mixed with crude palm oil. A homogeneous catalyst are

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used because they can expand the contact area of the reaction with carbon chains of crude vegetable oil triglycerides [7,13,14]. This has the potential to increase the dynamics of atoms and fuel molecules thereby increasing the frequency of collisions between molecules and the reactivity of fuel molecules increases [15]. Moreover, the addition of carbon nanoparticles has been shown to accelerate the combustion rate, shorten ignition delay, and decreased burnout times [16-18]. Unfortunately, scientific information about the effects of CNP on crude vegetable oils such as CPO has not been revealed. Therefore, this study aims to reveal scientific information about the effect of adding carbon nanoparticles to the combustion of CPO.

2. Fuel preparations and experimental setup

Fuel mixture is obtained by mixing carbon nanoparticles with CPO manually with a composition of 100 ml mixed with two variations of the number of carbon nanoparticles 1 ppm and 5 ppm. Carbon fibre made of the coal of coconut shell [19] made of The process of collecting data is done by observing the characteristics of fuel combustion. Fuel droplets are ignited with electric coil heaters at a 0.1 mm diameter thermocouple junction. Observation data taken by high- speed camera at a frame 120 fps to allow in determining the height and width of the flame, the temperature of the combustion, and the burning rate of the fuel droplets when ignite. The research scheme can be seen in Figure 1.

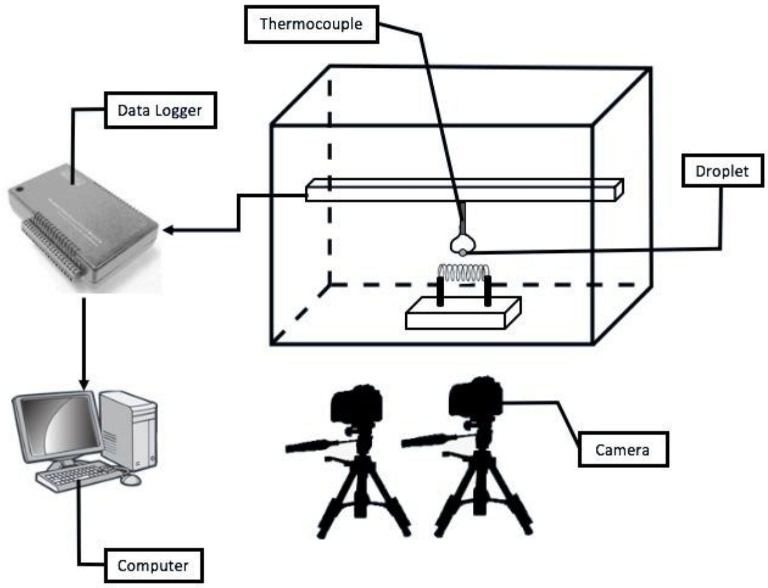

Figure 1. Experimental apparatus

3. Result and discussion

Figure 2 shows the evolution of droplet temperatures with and without carbon nanoparticles. From the observations, it can be seen that all three droplet fuels have almost the same trend, in which it is seen that all three droplet fuels have a heating time which ranges from 2 seconds. However, in a row it seems that the fastest time at the start of ignition is as follows, CPO1 turns on at 2.4 s at 281.76 ºC, followed by CPO at 2.5 s with an ignition temperature of around 365. 71 ºC. Whereas the CPO5 has the longest ignition time, where it occurs around the 2.6 seconds with the ignition temperature around 340.56 °C. After the droplet turns on, it is accompanied by a surge in energy which is marked by an increase in the temperature of the droplet. This shows that the droplet entered the second phase of the ignition stage.

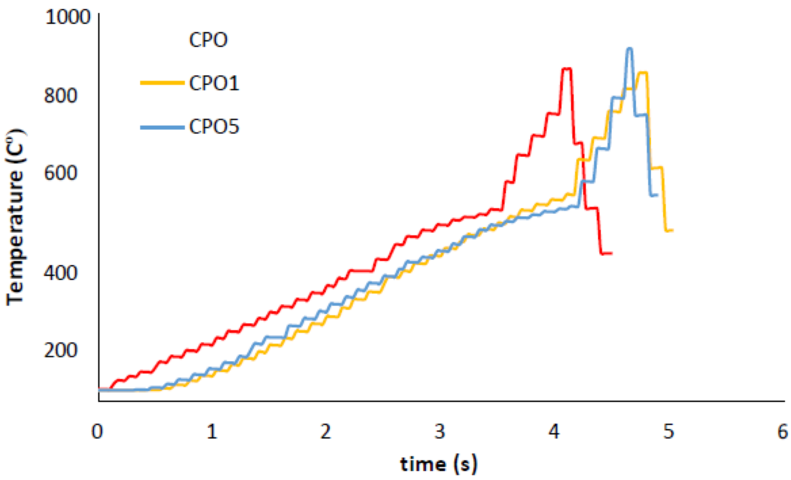

Figure 2. Temperature evolution of CPO droplets with and without carbon nano-particles

From Figure 2 it can also be seen that around 3.4 seconds to 4.2 seconds, all three droplets enter the second phase which indicates that glycerol is burning, and respectively the temperature reached in this second phase by CPO1 of 567.08 °C is achieved around seconds to 4.2s, after that followed by CPO5 of 502 °C about seconds to 4.2 s. While the lowest temperature is achieved by pure CPO of 494.27 °C at 3.5 s seconds. Moreover, the observations also showed that the highest temperature was achieved by CPO5 fuel at 908 °C at 4.6s seconds, after that CPO was 856 ºC reached around 4s seconds, and the lowest temperature was owned by CPO1 fuel at 847 °C at 4.6 seconds. These results indicate that CPO1 has the best performance. This is clarified from the fastest ignition which indicates that the CPO1 fuel can absorb heat faster. This phenomenon indicates that the addition of carbon nanoparticles of 1 ppm can increase fuel reactivity caused by increased density between fuel molecules. This has the potential to increase collisions between atoms and fuel molecules so that the fuel burns easily. On the other hand, CPO5 has the longest heating time. This phenomenon shows that the presence of carbon nanoparticles as a catalyst does not always have a positive impact because the amount of carbon nanoparticles that is too much has the potential to produce densities between molecules so that the molecules are difficult to move. This is very possible because from Figure 2 it appears that in the 0 to 3 seconds the CPO5 has the longest heating time with the lowest temperature. This analysis is following the results of our previous research [20,21]. These results indicate that the addition of CPO5 has not been able to increase the reactivity of fuel molecules, even inhibiting the rate of absorption and release of heat. Moreover, the addition of 5 ppm carbon nanoparticles has the potential to increase the mass of fuel molecules so that the bonding force between carbon chains increases. This is what makes the fuel take longer to ignite. On the other hand, although pure CPO fuel has a higher ignition temperature than CPO1, it is achieved with a longer time. This phenomenon shows that the effective contact distance between fuel molecules has not yet been reached so that the fuel molecules are less reactive. From Figure 3 it can be seen that shortly after the droplet caught flame there was an increase in the flame height of the three fuels with and without carbon nanoparticles. The start of the combustion of the three fuel droplets occurs at the same second, which is around 0.01 s when the droplet is at its saturation point and an exothermic reaction begins with the appearance of a flame. Consequently, the highest flame dimension was achieved by CPO5 around 1.96 mm, after that CPO, and the lowest was CPO1 which was around 1.03 mm

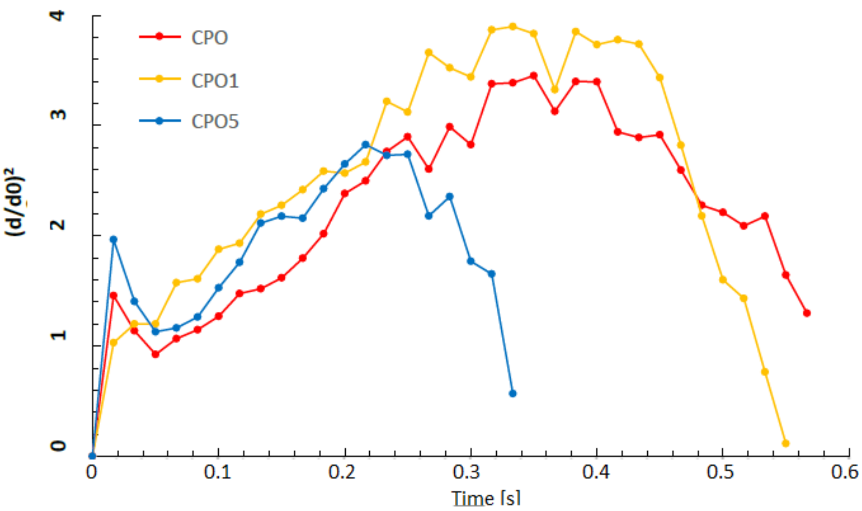

Figure 3. Flame height evolution of CPO droplets with and without carbon nanoparticles

This phenomenon shows that at the start of combustion of CPO5 has the fastest rate of heat release and has the best power, after that followed by CPO and the most recent is CPO1. Furthermore, observations showed that around seconds to 0.05 s there was an increase in the flame height of the three droplet fuels which showed that the fatty acid compounds were burning. Consequently, the highest flame height dimension was achieved by CPO1 which was around 1.2 mm, after that CPO5 was 1,129 mm, while the shortest flame dimension was achieved by CPO which was around 0.925 mm.

From these results, it can be seen that there has been a change in the flame height achievement by the three fuels. From the observations, it can be seen that if previously the highest flame dimension was achieved by CPO5, then in the second stage of burning droplets, CPO1 had the highest flame dimension. Also, the peak height of the flame from the three fuel droplets was reached at different times. From the results of the measurement of flame height, it can be seen that the highest peak of flame owned by CPO1 is 3,898 mm at 0.33 s, followed by CPO 3.45 mm which is reached in seconds to 0.35, while the last is CPO5 which is around 2,827 mm at seconds to 0.21 s.

This phenomenon shows that heat absorption, heat release, and combustion performance of CPO fuel droplets are not affected by the addition of carbon nanoparticles. But more influenced by the ability of the reactivity of the carbon chain. The factor is very important because the ability of the carbon chain to move is greatly influenced by the space of the carbon chain. The easier the carbon chain moves, the contact and collision between fuel molecules are easily achieved. On the other hand, Figure 4 shows a different phenomenon. It appears that the increase in flame width for CPO and CPO5 fuels occurs at the same time which is around 0.016 s, but both have different flame widths. The width of the CPO flame that occurred at the start of combustion was greater than CPO5, which was around 1,236 mm, while the CPO5 was 1,192 mm. This phenomenon shows that CPO has more power than CPO5. This is very possible because when CPO receives heat, the carbon chain relaxes, so it has the potential to reduce the viscosity so that the fuel is more flammable. On the other hand, the presence of 5 ppm carbon nanoparticles in CPO5 makes the molecular density increase. This has the potential to increase the density of the fuel and make the molecules do not have enough space to move so that the geometry of carbon chains is difficult to bloom and more rigid. On the other hand, when the droplet starts to ignite, the result shows that the width of the CPO1 flame is around 1,042 mm, which occur at a longer time, which is around 0.033 s. However, these results do not immediately show that CPO1 has a less good performance compared to CPO and CPO5. This analysis is very possible because when viewed from the flame height data, CPO1 has a flame height greater than CPO and CPO5. The height of the flame indicates that the fuel is volatile and easy to ignite. However, this phenomenon shows that the power of CPO1 is greater than CPO and CPO5. Moreover, from Figure 4 it can be seen that the maximum flame width produced by the three fuels occurs at different times and sizes. Consequently, the largest flame width was owned by CPO around 2,102 mm which occurred around seconds to 0.283 s, after that CPO1 of 1,819 mm occurred around seconds to 0.416 s, while the last was CPO5 of 1,475 mm which occurred around seconds to 0.266 s.

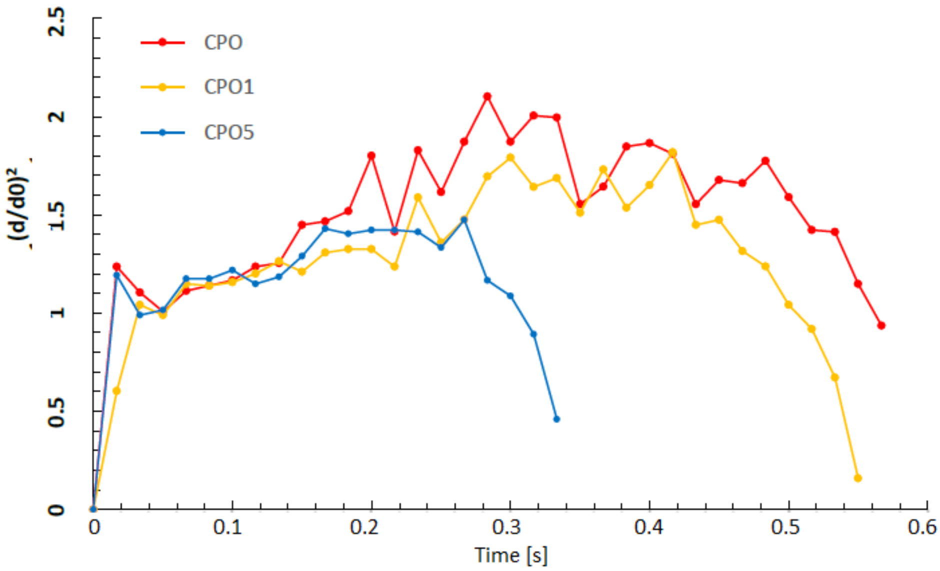

Figure 4. Flame width evolution of CPO droplets with and without carbon nanoparticles

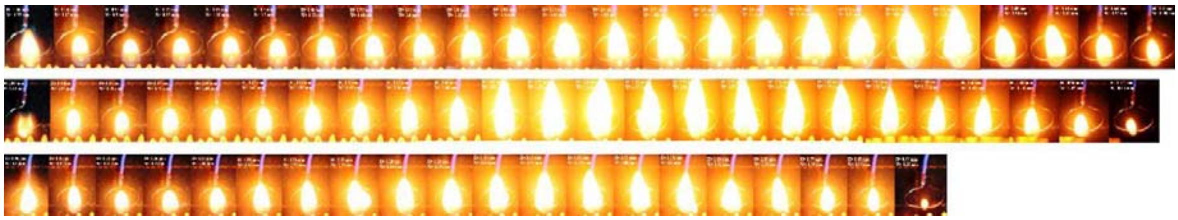

Figure 5. Flame evolution of CPO droplets. Top (CPO), middle (CPO1), and bottom (CPO5).

Figure 5 shows the flame evolution of all three droplet fuels. It appears that CPO has a longer burning lifetime than CPO1 and CPO5. This shows that the burning rate of CPO is slower than CPO1 and CPO5. Besides that, it also shows that the burning life of CPO5 is the shortest. However, this phenomenon does not mean that the CPO5 burning rate is faster than CPO and CPO1. This happens because the presence of nanoparticles in the fuel is a barrier to fuel performance. The nanoparticles in CPO5 are more heat absorbers so that flame droplets die faster. This is because the addition of nanoparticles increases the density between carbon chain molecules so that the density of the fuel increases Figure 5 shows the fire evolution of all three droplet fuels. It appears that CPO has a longer burning lifetime than CPO1 and CPO5. This phenomenon indicates that the burning rate of CPO is slower than CPO1 and CPO5, and the burning life of CPO5 is the shortest. However, this phenomenon does not mean that the CPO5 burning rate is faster than CPO and CPO1. This is due to the presence of nanoparticles in the fuel is a barrier to fuel performance. The nanoparticles in CPO5 are more heat absorbers so that flame droplets are easy to extinction. This is due to the addition of nanoparticles increases the distances between carbon chain molecules of triglyceride so that the density of the fuel increases.

4. Conclusion

Experiments on the combustion of CPO fuels with and without carbon nanoparticles have been carried out under normal pressure and room temperature. Important findings obtained from this study include:

- The presence of carbon nanoparticles makes the distance between fuel molecules closer so that the potential for collisions increases and the fuel is flammable.
- The addition of 1 ppm nanoparticles to CPO success improves fuel performance as evidenced by the higher and more volatile form of CPO1 flame from CPO and CPO5 fuels. The flame spike shape of the CPO1 indicates that a micro explosion has the potential to increase the burning rate.
- For CPO5, the addition of nanoparticles of 5 ppm is proven to have an adverse effect, which indicates that the density increases and reduced fuel performance.

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