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A COMPARATIVE ANALYSIS OF SPRAY COMBUSTION OF KAPOK SEED OIL AND JATROPHA OIL AS AN ALTERNATIVE BIOFUEL

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Abstract

This study is aimed to analyse the comparison of the spray combustion using kapok seed oil and jatropha oil through the combustion length, combustion width and combustion stage by using a video camera with the speed of 420 fps in the spray nozzle tester with a pressure of 2,100 psi. The result of the comparative analysis showed that the spray combustion of kapok seed oil is better than that of jatropha oil; it is found that 1) there is an 11.3 % difference between the maximum spray combustion length of kapok seed oil and jatropha oil, in which the maximum fire ranges of combustion using kapok seed oil and jatropha oil is 136 mm and 121 mm, respectively, 2) there is a 17.95 % difference between the maximum spray width of combustion using kapok seed oil and jatropha oil, in which the maximum fire ranges of combustion using kapok seed oil and jatropha oil are 46 mm and 39 mm, respectively, and 3) the analysis results in the combustion stage shows that there is one combustion stage in the kapok seed oil combustion and four combustion stages in jatropha oil combustion.

Keywords: kapok seed oil, jatropha oil, spray combustion, biofuel

1. Introduction

The diminishing availability of fossil fuels causes highly fluctuative prices and the negative impacts of fossil fuels urges the search of alternative renewable fuels. Research [1] states that biofuel is a fuel that is produced through contemporary

Abbreviations

CS	Combustion Stages
FLSM	Flame Length Spray Maximum
FWSM	Flame width Spray Maximum
JO	Jatropha Oil
KSO	Kapok Seed Oil

biological processes, such as agricultural anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matters. Biofuels can be derived directly from plants, or indirectly from commercial, domestic, and industrial wastes [2]. Non-food raw materials in the production of biofuel or biodiesel are a promising future because they do not compete with food crops and do not increase food prices. Therefore, it is an essential factor to ensure the economic viability of the production of biodiesel [3, 4]. Research [5] has reported that non-food vegetable oils have a lower price than the vegetable oil used as a meal. The development of biodiesel fuel with a derivative approach of vegetable oil has provided an enormous opportunity as an alternative fuel, since the relatively high content of vegetable oils is a major potential that can be used as biofuel based on hydrocarbons. Some biodiesels that have been investigated and discussed are those made of Jatropha, *Pongamia pinnata*, *Calophyllum inophyllum*, *Hevea brasiliensis, Azadirachta indica, Madhuca indica, Sterculia*, etc. [6].

Kapok, or locally known as *kekabu* or cotton, which belongs to the family of Bombaceae, is cultivated in Southeast Asia, Malaysia, Sri Lanka, other parts of Africa, East Asia and tropical America and can grow naturally in the humid and sub-humid tropical America and Africa [7]. Kapok seed occupies about 25-28 % (w/w) of each fruit, seeds contain relatively high crude oil which is about 22-25 % by weight and reported to be almost identical with cottonseed oil. It can be processed to get the oil to manufacture soap and its residue is used as fertilizer or animal feed, and it has a variety of uses in wool production [8]. Physical-chemical properties of biodiesel kapok. Methyl Ester, JO are a popular energy crops in tropical countries. The plant has several uses including energy supply that can be used in crude form as biodiesel. Since the last decade of the last century, methyl ester biodiesel has become more attractive because of its environmental benefits and the fact that it is composed of renewable energy sources [9]. Biodiesel production of a total of 63 seeds of oil can be an alternative biofuel solution in order to reduce fossil fuel use. Biofuel from seed oils are among others jatropha seed, kapok, neem, karanja, rubber seed, mahua, silk cotton tree, etc. [10]. Rapeseed oil methyl ester, the earliest type of biodiesel fuel, is produced commercially [11]. Meanwhile, biodiesel can be a good alternative on the machine marked as single raw material that can run the machine [12]. In recent developments, biodiesel has been more attractive economically and there are opportunities to enhance environmental performance in job creation and rural economic empowerment [13].

2. Literature Review

This section will explain the nature and advantages of using jatropha oil and kapok seeds oil as an alternative to biofuel.

2.1. Kapok seed oil

The product made of this raw material, when being compared with international biodiesel standards, can be seen as an alternative source for biodiesel [14]. Oleophilic-hydrophobic characteristics of cotton fibres can be ascribed to the surface of the wax [15]. Kapok remains stable after fifteen cycles of reuse with only 30 % of reduction in the absorption capacity [16]. A large part of the plant that produces non-edible oil (non-edible) may be taken into account in the production of biodiesel. Non-edible oils, such as those made of jatropha, microalgae, neem, karanja, rubber seed, mahua, silk cotton tree, etc., are widely available in developing countries and are very economical compared to vegetable oils [17]. The advantage of kapok seed oil is the fact that the physical-chemical properties of kapok seed oil biodiesel produced from this raw material are better compared with the standards of international biodiesel and biodiesel as alternative energy sources for the future [18]. Biodiesel from cotton seed oil has the potential to replace diesel oil to be used as diesel motor fuel. The trial mobilization diesel engine generates power and efficiency not much different from diesel oil, while the emission of CO, HC and NOx is even smaller. The exhaust emission of diesel motor with kapok seed oil biodiesel consists of 0.022 % carbon monoxide, lower than that of diesel oil, which is 0.05133 %; the hydrocarbon emission is 17.467 ppm, lower than that of diesel oil, which is 27.333 ppm; and the nitrogen oxide emission is 3.6 %, lower than those using diesel oil [19].

2.2. Jatropha oil

A comparative study has been conducted on the various methods to improve engine performance using castor oil as the main fuel for compression ignition engines. Crude JO resulted in slightly reduced thermal efficiency. Dilution, micro-emulsification, pyrolysis and transesterification are four techniques that are implemented to solve the problems faced by the viscosity of the fuel that is high [20]. To study the performance and emission characteristics of biofuel comparable with fossil fuels [21]. Seeds of *Jatropha curcas L.* have high oil content and the biodiesel produced has properties similar to petroleum-based diesel [22]. This biodiesel generally causes an increase in emissions of NOx and reduction in HC, CO and PM emissions compared to diesel [23]. It is reported that diesel engines without modifications can be run successfully with a mix of 20% biofuel and 80% diesel without damaging the engine parts [24]. The results of other studies show that the production of biodiesel from *Jatropha curcas* has many social, economic and environmental benefits for the country and can play a big role to solve the energy crisis problem [25]. According to a report presented, it is important to find a profitable source of biodiesel and it should be focused on the raw materials that do not compete with food crops, do not lead to landing clearing and provide a reduction of greenhouse gas [26]. Jatropha oil is more environmentally friendly for engine and it is suitable to be used for machine [27]. Especially for the production of biodiesel, Jatropha can be selected as the plant which does not compete with crops for food, is not consumeable for animals due to its poisonous property, is adaptable in the field, suitable for environmental considerations in reducing pollution, reduces dependency on fossil fuels, provides new business opportunities for farmers to gain more revenue and allows more decentralized fuel production [28].

3. Experimental Procedure

This research used material KSO and JO in the spray at the pressure of 2,100 psi by using a nozzle tester, on the back of the nozzle in the long tide gauges are used to compare the length and width of flame. The results of the oil spray in turn by lighter the end of the nozzle so that the oil burned in the free air space, and then the flame is recorded at a speed of 420 fps from the side. Video recordings are processed using software solver video footage into a picture frame, this method is also developed [29]. The tool used for spray combustion in this study using a nozzle tester. Furthermore, combining images obtained at the time and chose according to the image change for 3 seconds. The measurements of the length and width of the flame bursts of kapok seed oil and jatropha oil are measured through the frame of the drawing using a measuring device by comparing the measurement of the length and width of the flame on the frame results. Determination of the analysis of the combustion stage can be seen from the frame character of the image of the flame. The shape of the flame frame will be oval in the early stages. The next stage, the shape of the fire image frame will move forward and at a certain stage the fire image will go back and forth to some stage.

The flame burning combustion method is an acceptable and efficient standard method for fuels, since this method is the development of some previous research results. The method used to compare combustion results on the KSO and JO in a given time by breaking the video into an image and performing the width measurement that has been developed [30], the method of calculating the length and width of the combustion spray on KSO and JO using the method used [31], and combustion methods to compare KSO and JO refer to the results of the study [32]. Research [33] also uses a shooting method using a flame-shaped pattern that is used to determine the speed of the extension of the flame.

4. Results and Discussion

This section describes the composition of fatty acids found in KSO and JO in the results of research and comparison of results of the analysis of the spray combustion using KSO and JO (length, width and stage).

4.1. Composition of KSO and JO

The data of kapok seed oil and jatropha oil compositions obtained from the laboratory test are shown in Table 1.

Table 1 shows that the value of fatty acid composition for kapok seeds in oleic compounds is 53.10% w/w, linoleic is 3.16% w/w, and palmitic is 20.56% w/w. The linoleic contained in the KSO tested is 3.16% w/w, whereas the linoleic contained in the JO tested is 37.75% w/w. There was a difference of 34.59% w/w. This was expected to lead to a difference in the resulted spray flame of KSO and JO. This finding is in line with the results of [29, 24, 34] which states that the content of palmitic fatty acids in kapok seeds is 2.46-23.20% w/w. The fatty acid composition for jatropha oil in Table 1 shows the oleic compound of 45.27% w/w, linoleic of 37.75% w/w, and palmitic of 14.94% w/w. The results of this study are in line with the findings of [35,36] which states that fatty acid content in jatropha oil for linoleic compounds is 35.11-53.76% w/w.

Table 1. The composition of Kapok Seeds Oil and Jatropha Oil

No.	Fatty Acid	Kapok seed oil (% w/w)	Jatropha oil (% w/w)
1	**oleic**	53.10	45.27
2	**linoleic**	3.16	37.75
3	**palmitic**	20.56	14.94
4	**palmitoleic**	-	0.84
5	**lauric**	1.14	0.62
6	**myristic**	0.79	0.34
7	**caprylic**	0.11	0.08
8	**capric**	0.19	0.08
9	**stearic**	4.19	0.11
10	**linolenic**	1.15	0.20

4.2. The comparative analysis of the spray combustion using KSO and JO in the combustion length, width and stage

The analysis results that in KSO combustion on Fig. 1. Figure 1 shows the analysis results that in KSO combustion, there is one CS. It can be seen in the figure that the movement of the flames gradually advanced from below upward, and the initially small fire enlarged until it shrinks and discharged.

Figure 2 shows the relationship between the length of time of the combustion and KSO flame spray, the method of the combustion measurement is performed by examining the results of breaking video into images and measurement of width has been developed in [35]. The length of fire in the picture is extended to a maximum of 182.81 cm at 3 s. The width of KSO flame spray is small at the beginning but it expands and reaches a maximum width of 48.75 cm at 1.75 s, and then it shrinks back until it is out. This shows relatively stable and regular KSO flame spray.

Figure 3 shows the analysis of the CS. This method is developed in [29, 32, 34] by analysing changes in flame. One regular movement of flame expanding from small to big and then shrinking again makes one CS. The combustion using JO has four CS, which can be seen in the figure. In the first stage (i) the image shows the movement of the flame that gradually advances from below upwards. In the beginning, the flame is small, then it enlarges until it is tapered and discharged. In stage two (ii) at the beginning of the fire retreats enlarged image from the bottom and then presents the enlarged until then it shrinks and the fire flames are discharged. In the third phase (iii) at the beginning the fire retreats, it enlarges image from the bottom and then moves the enlarged until then it shrinks and the fire flames are discharged. Finally in step four (iv) at the beginning the fire retreats, it enlarges image from the bottom and then moves the enlarged until then it shrinks and the fire flames are discharged.

Figure 4 shows the relationship between the length of time of the combustion and the length of flame spray in the combustion using JO. The method of the combustion measurement is breaking video into images, and the width measurement has been developed in [30]. Figure 4 shows that the length of the fire continued to rise from the beginning until it reaches a maximum length of 177 cm at 1.5 s, then decreases at 1.75 s and 2 s, rises back at 2.25 s, drops again at

2.5 s and 2.27 s, and finally increases at 3 s. As for the width of JO flame spray, it expands from the start until reaching the maximum width of 46.80 cm at 1.5 s, then shrinks until it is out. This shows that JO flame spray is irregular and unstable. Meanwhile, Fig. 5 shows the comparison of length (a) and width (b) of spray flame of KSO and JO.

Fig. 1. Stages of flame spray on KSO.

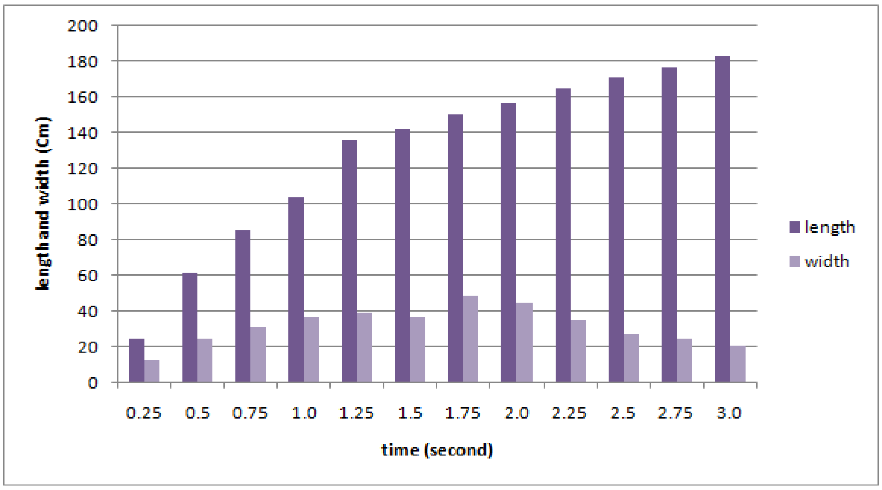

Fig. 2. The length and width of the flame spray of KSO.

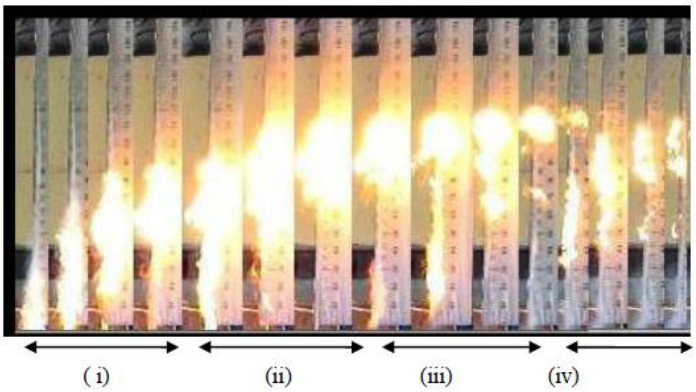

Fig. 3. Stages of JO flame spray.

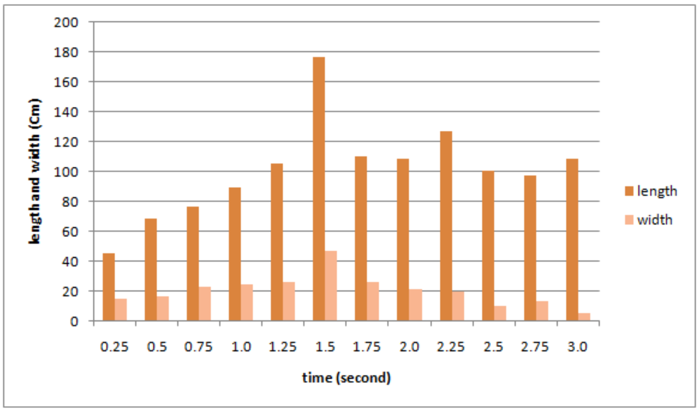

Fig. 4. The length and width of the JO flame spray.

Figure 5 shows KSO and JO flame length and width spray. There are different characteristic of combustion that is in Fig. 5 (a) flame length of spray KSO is longer than flame length of spray JO. Figure 5(b) shows that the Flame width spray KSO is wider than the Flame width spray JO. This can occur by looking at the components of the KSO and JO compositions shown in Table 1. The composition of kapok seeds oil and jatropha oil, with the amount of fatty acid palmitic KSO 20.56 % while the fatty acid palmitic JO 14.94 % and the amount of fatty acid oleic KSO 53.10 % while fatty acid oleic JO 45.27 %.

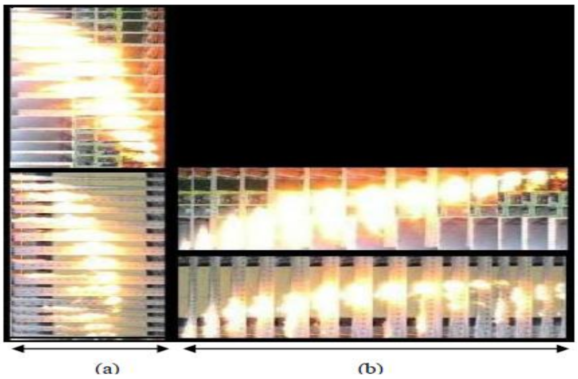

Fig. 5. Comparison of (a) length and (b) width of flame spray of KSO and JO.

Biodiesel or biofuel with unsaturated fatty acid composition will facilitate combustion [37]. The palmitic unsaturated fatty acid and oleic KSO are larger than the palmitic and oleic fatty acid KSO so that the Flame length spray KSO is longer than the Flame length spray JO as well as the Flame width spray KSO wider than the JO flame width spray.

The evaporation rate of different types of biofuel fuels is due to the different components of the biofuel composite [38]. In biofuel the combustion properties may vary depending on the composition and a multi-component evaporation method of biofuel combustion [39] is required. Direct use of vegetable oil in fuel engines does not burn entirely [40].

Figure 6 shows the range of KSO flame spray is longer and more stable movement when compared to flame spray JO this may occur due to the composition of unsaturated fatty acids in KSO more so as to affect the result of KSO injection pressure resulting in KSO flame spray range longer. The maximum length range of KSO obtained is 182.81 cm and the maximum length range of JO (below) obtained was 1,77 cm.

The properties and the kinematic viscosity produced by biofuel show that the properties are influenced by the length of the chain and the degree of carbon saturation [41]. Injection pressure on different viscosities will result in different spray qualities, which may affect the length of the spray range in the combustion process [42].

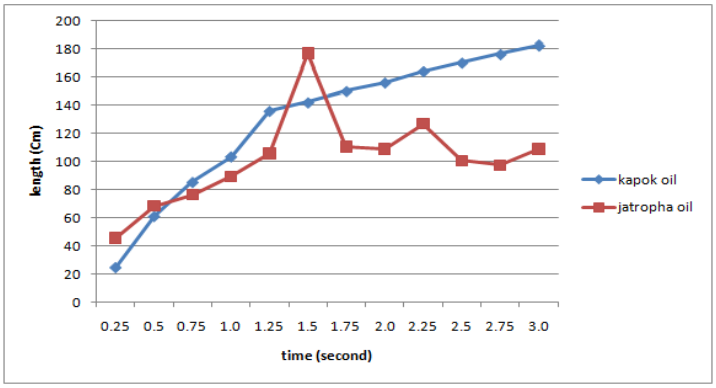

Fig. 6. Comparison of KSO and JO flame spray lengths.

Figure 7 shows that the maximum width range of KSO flame spray (top) obtained is 48.75 cm, while the maximum width of JO flame spray (below) obtained is 46.80 cm. Viscosity is another physical characteristic that can affect spray pattern [43]. The spray forming angle decreases and the biofuel spray results are narrower, this is due to the higher biofuel viscosity [31], if the comparison of KSO and JO flame spray widths shows that the KSO flame spray widths are wider than JO flame spray widths. This is in accordance with the composition of unsaturated fatty acids in KSO more when compared with the composition of unsaturated fatty acids in JO.

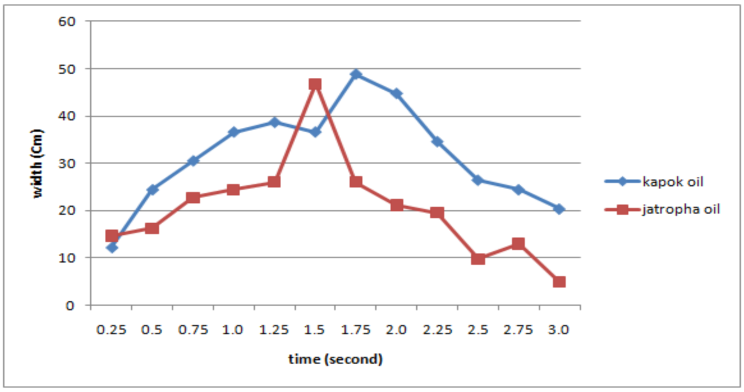

Fig. 7. Comparison of KSO and JO flame spray widths.

5. Conclusions

A comparative analysis of spray combustion shows that at the of 2,100 psi and video camera speed of 420 fps, there is a 3.18 % difference in FLSM between KSO and JO, where the maximum flame spray length of KSO is 182.81 cm and the maximum flame spray length of JO is 177 cm. At the pressure of 2,100 psi and video camera speed of 420 fps, there is a 4 % difference in the FWSM between KSO and JO, where the maximum spray flame width of KSO is 48.75 cm and the maximum spray flame width of JO is 46.80 cm. At the pressure of 2,100 psi and video camera speed of 420 fps, there is one combustion stage in KSO combustion and there are four combustion stages in JO combustion. The resulted combustion of biofuel KSO is better than that of JO.

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