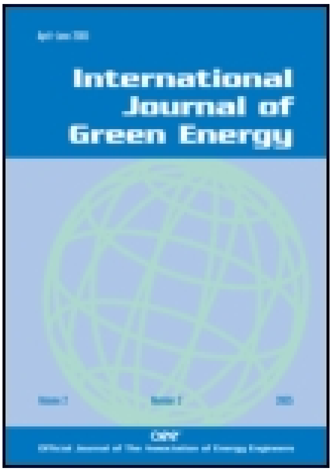

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Does the Maturity of Jatropha Curcas L. Affect the Quality and Quantity of the Yield of Oil for Biodiesel Production?

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DOES THE MATURITY OF *JATROPHA CURCAS* L. AFFECT THE QUALITY AND QUANTITY OF THE YIELD OF OIL FOR BIODIESEL PRODUCTION?

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Biodiesel is a green and popular renewable fuel and unlike mineral diesel, produces fewer toxic emissions. Jatropha curcas* Linn *is a nonedible fruit that commonly used in biodiesel production. This study evaluated the impacts of Jatropha seeds maturity on quantity and quality of yield oil. Production of biodiesel from Jatropha oil and ethanol using natrium hydroxide as the catalyst by transesterification was performed on half-matured (yellow) and matured (black) Jatropha seeds. Experimental investigations have been carried out to examine properties and performance of Jatropha, and different blends of Jatropha oil-diesel (JOD) in comparison to a petroleum-based diesel fuel. Half-matured stage of Jatropha is shown to produces 2.5% less oil than the matured stage. The quality of the maturity stages quantified in terms of mean square error (MSE), and the matured stage showed 13% better performance in contrast to the half-matured stage. Matured stage JOD blends indicate closer performance to petroleum-based diesel and can be used as a biodiesel without engine modification.

Keywords: ***Jatropha; Biodiesel; Maturity; Density; Flash point; Pour point***

INTRODUCTION

Jatropha curcas L. (further Jatropha) commonly known to as “Physic nut,” “Purging nut,” “Habb-El-Meluk,” “Black vomit nut,” “American purging nut,” “Barbados purging nut,” “Big purge nut” is a member of the Euphorbiaceae family which grows in most of the tropical countries (Makkar, Aderibigbe, and Becker 1998). The plant is a shrub or small tree with seeds rich in oil that meet the standard for use as biodiesel (Ouedraogo, Ayers, and Linden 1991; Tiwari et al. 2007), indicating its potential as a renewable energy source. Biodiesel is one of the most popular renewable fuels which can be manufactured from vegetable oils or animal fats through lowering the viscosity by thermal cracking, micro-emulsification, dilution, and transesterification. Catalytic reaction using a transesterification process is the most efficient method for conversion of vegetable oils into low-viscosity biodiesel fuel (Kumar, Ramesh, and Nagalingam 2003; Meher, Vidyasagar, and Naik 2006). The background of using vegetable oil for compression ignition (CI) engine, date backs more than a century ago, when Rudolf Diesel established the principle of

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CI engine by employing peanut oil as fuel. He was the first when suggested that vegetable oils would be the future fuel for diesel engines (Nitske and Wilson 1965).

Due to the toxicity of Jatropha seeds, they are not used by humans. So, oil extraction is justified for its cultivation, mostly due to its high oil content. The oil content is 25–30% in the seed. Some of the chemical elements in the seed, such as cursin, which is poisonous and render the oil not appropriate for human consumption. Oil contents, physical, chemical, and energy values of Jatropha were investigated by numerous researchers (Banerji et al. 1985; Kandpal and Madan 1995; Banerjee, Bhattacharya, and Gupta 2009; Kabir et al. 2009).

Jatropha oil can be burnt in its neat form or it can be mixed with diesel fuel in any concentration, such as 6% (B6), 8% (B8), and 10% (B10) (Abugre and Quashie-Sam 2010). Biodiesel is produced by alkaline catalyzed transesterification of oil in methanol. Frequently used alkalis are KOH, NaOH or their corresponding solid or liquid alkoxides (Murugesan et al. 2009). Partial replacing of diesel in CI engines is believed to reduce the economic and environment effects. In some countries, new regulations imposed on using at least 5% biodiesel in diesel consumption (Montes et al. 2011). Numerous studies have shown that biodiesel blends actually increase the diesel engine performance (Bojan, Chelladurai, and Durairaj 2001; Pramanik 2003; Forson, Oduro, and Hammond-Donkoh 2004; Rao et al. 2009; Bassyouni et al. 2012; Singh et al. 2013).

Oil extraction at a suitable maturation stage is one of the important economic factors for biofuel production. In plant species such as Jatropha, the amount and quality of extracted oil, depends on the volume and quality of their seeds. Jatropha has indeterminate fruiting periods (Silip et al. 2010), and therefore, determination of the stage of maximum yield oil is essential. In an experiment conducted on four colors of Jatropha seeds, the best maturity color for oil yield production was dark yellow, mainly because it produced the highest oil yield (Batin 2011). Anandalakshmi (2009) recommended harvesting yellow fruits for maximum oil yield. In another study (Silva et al. 2012), the oil content of different stages of maturity shows that the seeds from green fruits had less oil compared to the seeds from other fruit categories, which had similar levels of oil. However, uncertainty existed to choose the best maturity stage in the literature. Moreover, performance parameters needed to assess the quality of the yield oil from the maturity stages of Jatropha seeds. Realizing this fact, this study aims to: (1) determine the fruit color of Jatropha that yields the highest oil content; and (2) assess the performance of JOD blend at various concentrations in terms of some physical properties. This paper is the first part of a research project conducted for characterization of *Jatropha curcas* L. as a biodiesel blend in Malaysia.

The rest of the paper is organized as follows. Methodology section provides the material and methods of the conducted experiments, such as seed sample selection and oil extraction, transesterification process, blended biodiesel preparation, and properties determination. The results of Jatropha yield oil and performance of Jatropha oil as a biodiesel, and performance of JOD blend are introduced and briefly discussed. Then, the results obtained in the matured and half-matured JOD blends are compared with petroleum-based diesel and pure Jatropha oil. Finally, the results will be summed up in the conclusion section.

METHODOLOGY

The present investigation is an attempt to test the maturity of *Jatropha curcas* seeds in yielding oil for biodiesel production. Consequently, the properties and performance of Jatropha and different blends of JOD in comparison to a petroleum-based diesel fuel have been investigated. In this study, the oil is produced by mechanically pressing Jatropha

Figure 1 Two stages of Jatropha seeds maturity assessed for yield/quality of oil in this study (color figure available online).

raw seeds. Then, to lower its viscosity, the extracted oil was synthesized using natrium hydroxide powder instead of liquid catalysts in the transesterification process and the characteristics of the Jatropha oil as biodiesel were investigated. Later, the biodiesel was separated into five samples each from different stages and blended with conventional diesel fuel. In order to determine the oil quality, some physical properties, which are density, pour point and flash point, were determined on the blended samples. Same tests were conducted for pure Jatropha oil and the mineral diesel. Generally, the laboratory work of this study could be divided into five parts, which is selection and preparation of raw material, oil press, transesterification process, blending samples, and properties or quality determination. Figure 1 shows yellow and dark colors of Jatropha seeds which were used for determination of yield/quality of oil in this study.

The physical properties such as density, flash point, and pour point were measured for Jatropha oil and blended JOD. For density determination, a glass hydrometer has been used. The values of API gravity for each JOD blended samples and pure Jatropha oil were determined as per ASTM D1298-85. The pour point and flash point for each blended sample and Jatropha oil was measured according to ASTM D97-87 and ASTM D3828-87, respectively. The same characteristics study was also carried out for the conventional diesel fuel for obtaining the base line data for analysis.

Seed Sample Selection and Oil Extraction

The Jatropha seeds were taken from two stages of maturity; half-matured was taken from the yellow colored fruit while the matured was taken from the black colored fruit. Prior to compression process, the seeds were heated in the oven at temperature of 60°C for 48 hours in order to remove the moisture content. The oil was extracted from the Jatropha seeds using compression machine (Figure 2). A 5.0 kg of Jatropha seeds from half-matured stage was gradually passed through the funnel of the compression machine. The oil that has been extracted was collected into a beaker. The whole process was then repeated in order to extract the oil from the matured stage seeds, as shown in Figure 3. The crude oils were then allowed to settle for one day in order to separate the oil from the precipitate through filtering the oil using filter paper. The crude oils from the two stages were weighted to obtain the yield of the biodiesel from respective stages.

Transesterification Process

The oil warmed up to 60ºC in a 500 ml beaker in order to increase the reaction rate. Then, transfer the sodium ethoxide solution to a 500 ml beaker with the magnetic stirrer. The beaker was covered with an aluminum foil to protect the oil mixture against burning and the stirred turn up and continued for about 30 minutes. The mixture then transferred into a separator funnel and allowed to settle for 12–24 hours. After settling, darker colored glycerol byproduct will be at the bottom with a clear line of separation from the pale liquid

Figure 2 Compression machine for extracting oil from Jatropha seeds (color figure available online).

Figure 3 Collected oil of Jatropha seeds after compression (color figure available online).

above, which is the biodiesel as shown in Figure 4. In order to make sure the oil certainly separated from the glycerol, the contents spin for 15 minutes in the centrifuge machine. The centrifuge was kept spinning until the layer completely separated. The biodiesel varies somewhat in color according to the oil used but usually is pale and yellowish.

Blended Biodiesel Preparation and Properties Determination

The blended JOD used in the study is shown in Table 1. To prepare 1 liter of B6, 940 ml of conventional diesel which is 94% of total volume is mixed with 60 ml (6%) of Jatropha oil. After the correct composition is determined, the mixture then shacked violently for 2–3 minutes until the mixture is homogeneous. In addition to JOD blends, density, pour and flash points of pure Jatropha oil and a conventional diesel were determined too.

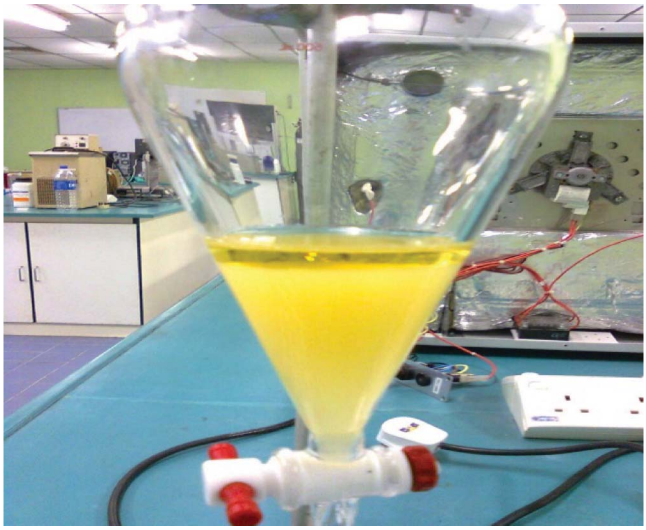

Figure 4 Separation process in the separator funnel (color figure available online).

Table 1 Composition of JOD Blends

Sample No.	Diesel content (%)	Biodiesel content (%)
B6	94	6
B7	93	7
B8	92	8
B9	91	9
B10	90	10

The density for each biodiesel blended sample, pure Jatropha oil and conventional diesel used was measured as per ASTM D1298-85 standard procedure. The pour point was determined accordance to ASTM D97-87 standard procedure, and the flash point was determined as per ASTM D3828-87 standard procedure.

RESULTS AND DISCUSSION

Different blends of JOD (6%, 7%, 8%, 9%, and 10%, v/v), were prepared in this study. The physical properties of the blends against pure Jatropha oil and mineral diesel presented as follows.

Yield of Jatropha Oil

The result for yield (mixture of oil and its fats) from each maturity stage is shown in Table 2. From Table 2, it can be seen that both stages are capable of producing Jatropha oil. However, the amount of oil acquired is different. For 5.0 kg raw Jatropha seeds of respective maturity, the matured stage seeds produced more than the half-matured stages seeds. From the result obtained, the main factor that can affect the amount of oil produce is the seeds moisture content. If the seeds are too dry, it will decreased the moisture content

Table 2 Oil Yield for Two Stages of Jatropha Maturity

Maturity stage of raw seed	Raw seeds used (kg)	Extracted oil (ml)	Oil produced per kg (ml/kg)	Yield (%)
Half-matured	5.0	1100	220.0	25.65
Matured	5.0	1200	240.0	28.03

in the seeds. As a result, the oil in the seeds will also decrease where it will result in low amount of oil that can be generated. Therefore, period where the seeds were heated for 48 hours might be too long where it affects the amount of oil produced.

Performance of Jatropha Oil as a Biodiesel

The physical properties of Jatropha oil are considered as the major factors that will determine its viability as biodiesel. The extracted oil needs to fulfill the standard requirement for biodiesel which must be accordance to ASTM D6751. As shown in Table 3, both stages of Jatropha oil had favorable properties as biodiesel. As for the half-matured stage, the average density is 0.8576 kg/l which is slightly below the standard density for biodiesel. The pour point was 12°C which is below the maximum requirement. The flash point gave the average value of 225°C, which is above the minimum value. The results from the matured stage do not show much different as the half-matured stage. The average density is 0.8563 kg/l which is also slightly below the half-matured stage and the standard density requirement for biodiesel. The pour point was also 12°C which is below the maximum requirement. The flash point gave the average value of 220°C, which is above the minimum value.

From the results showed above, the properties for Jatropha oil of both stages of maturity are complying with the standard requirement of biodiesel. Although the results for density are slightly below from the requirement, it is still acceptable because the value is considerably near the standard value. Therefore, from these results, it shows that the Jatropha oil from both stages of maturity can be produced as a good quality biodiesel that can be used in CI diesel.

Performance of Jatropha/Diesel Blend

Density of JOD Blends

Density defined in a qualitative manner as the measure of the relative heaviness of objects with constant volume. The densities of different JOD blends are increased with

Table 3 Properties of Jatropha Oil and Its Biodiesel (B100) According to ASTM 6751 and Petrol Diesel ASTM D975

Properties	ASTM D975 diesel limits	ASTM D6751 Biodiesel (B100) limits	Biodiesel from half-matured seeds	Biodiesel from matured seeds
Density (kg/l)	0.85	0.86–0.90	0.8576	0.8563
Pour point (C)	−35 to –15*	−15 to 10	12	12
Flash point (C)	60–80	130 minutes	225	220

*12–15 based on MS123:1993, Malaysian Standard for Diesel Fuel.

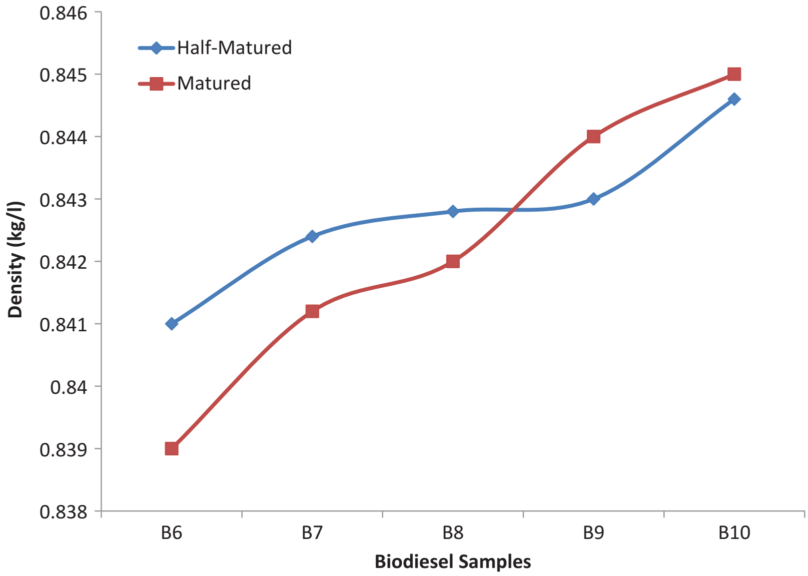

Figure 5 Density of various JOD blends (color figure available online).

increase in blend percentage and some variation existed in density from each stage of maturity, as shown in Figure 5. The density of the conventional diesel is 0.837 kg/l. The half-matured blend has slightly higher density compare to the matured blend at B6, B7, and B8. Then the trend changed, where at B9 and B10, the density of the matured blend is higher than the half-matured blend. In general, the values of density from matured stage were a little higher than the density for conventional diesel. This means that the matured JOD blends are suitable to be used as the alternative fuels in CI diesel engine since their density satisfied the standard density of a conventional diesel fuel. Although, as shown in Table 3, the attained density from Jatropha oil is located in the range of the ASTM-D6751, and the matured blended JOD brings about a slight change in density and it has almost similar density, less than 1%, as that of mineral diesel, and the high density can be reduced by heating of fuel.

Pour Point of JOD Blends

When petroleum products are cooled, a point is reached when some of the constituents begin to solidify, and if cooling continues, eventually the oil will not flow. The pour point is the lowest temperature at which it will pour or flow under prescribed conditions. It is also as the indication of the lowest temperature at which oil is readily pumpable. As shown in Figure 6, it can be noticed that the pour point from the two stages are almost the same for B6, B7, B8, and B10. The pour point of the pure diesel is 12°C. When it was blend with various percentage of biodiesel, the pour point obtained is the same for both maturity stages blend except for the B9. The pour point for B9 using the half-matured blend is slightly higher compared to the matured blend that is 9°C and 8°C, respectively. Hence, generally, it can be said that the pour point of various JOD blends from both stages is lower than the conventional diesel pour point. This result verified that the biodiesel is a good choice as the alternative fuel since the oils temperature is much lower than the

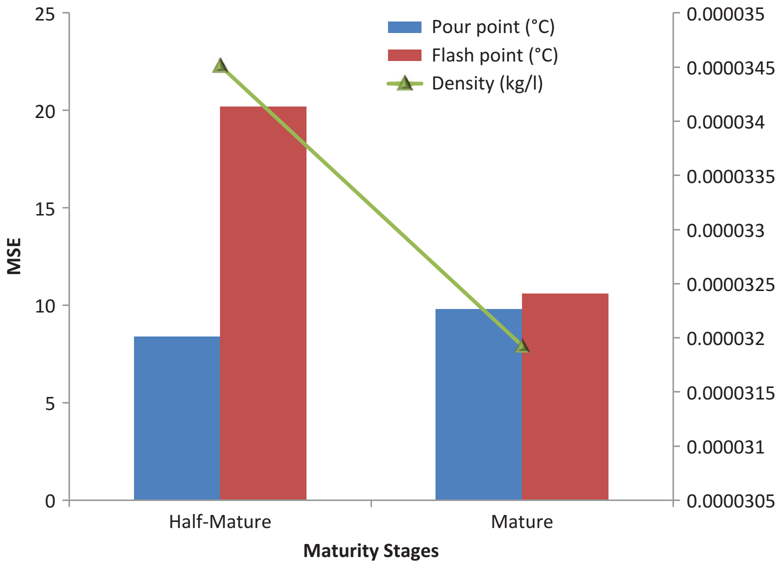

Figure 6 MSEs of the physical properties of JOD blends of two stages of Jatropha maturity versus petroleum-based diesel (color figure available online).

lowest anticipated diesel temperature. As a result, although it should be tailored for the specific climate needs, the oils will not be able to solidify quickly in the engine during low temperature condition.

Flash Point of JOD Blends

The flash point is the lowest temperature at which it can form an ignitable mixture in air. At this temperature, the vapor may cease to burn when the source of ignition is removed. The flash points of different blends of JOD are increased with increase in JOD percentage as shown in Figure 7. Also, it is observed that the flash point of half-matured blend is higher than the matured blend. The flash point of the pure diesel is 76°C. As seen from the figure, the flash point of the half-matured blend increased steadily from B6 to B9. The highest point reach is at 82°C where it met the same highest point of flash point from the matured blend. Meanwhile, as for the matured blend, the flash point also increased upon the percentage of biodiesel blend except for B8 that is 76°C. Overall, the flash point of JOD blends is higher than the flash point of conventional diesel. This scenario showed that the blended biodiesel produced higher volatility and as the temperature increases, the vapor pressure will increase where the concentration of evaporated flammable liquid in the air will also increase. Diesel fuel is designed for the use in a CI engine, thus, it is required to have a high flash point, less combustible, and a low auto ignition temperature. Therefore, the blended biodiesel from Jatropha oil offer a suitable high flash point that fulfills the standard requirement of diesel, and it can be used as a fuel without any fire accidents. Flash point of JOD blends decreases in contrast to Jatropha oil, which shows that its volatile characteristics had improved and it is also safe to handle.

Presented results in Figure 8 show the MSEs of two stages of Jatropha maturity in terms of density, pour point and flash point. The results show that matured

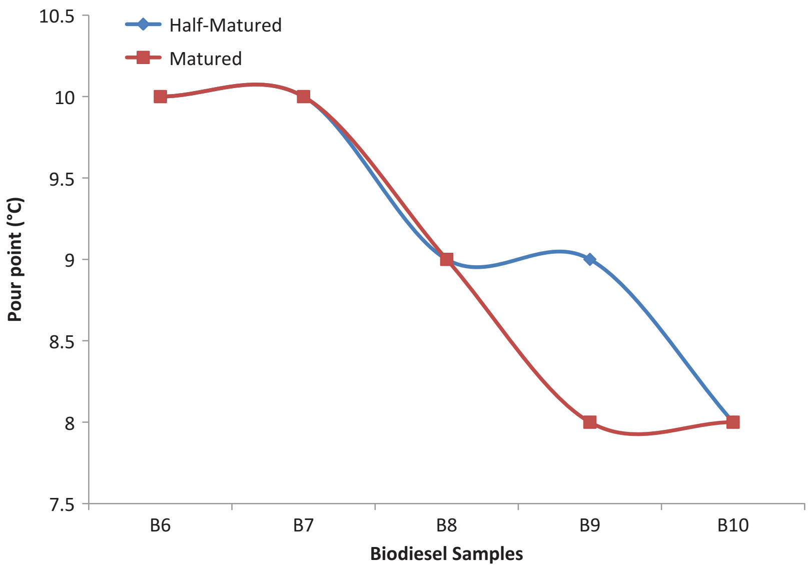

Figure 7 Pour point of various JOD blends (color figure available online).

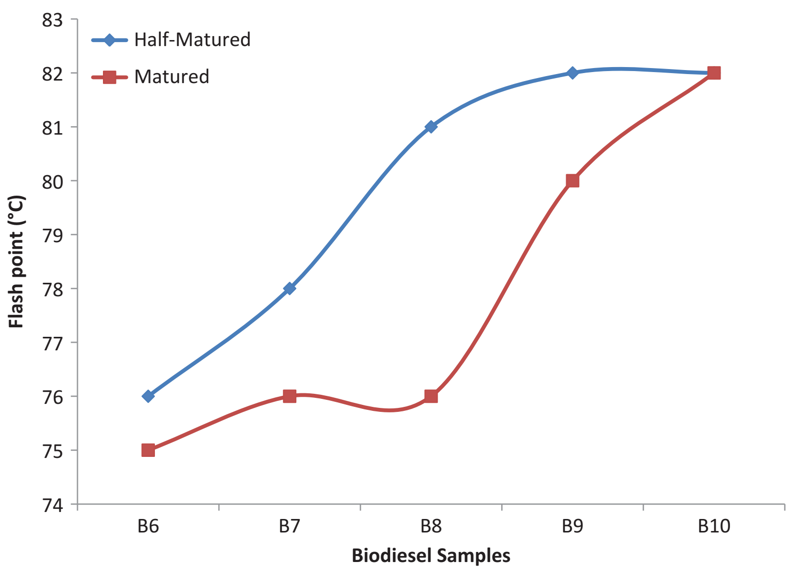

Figure 8 Flash point of various JOD blends (color figure available online).

Jatropha has closer performance to mineral diesel than half-matured stage. As illustrated in Figures 9–11, the performance of matured JOD improved the fuel properties and indicates that the measured physical properties are within the range specified by ASTM 6751, not only for biofuel but also for diesel too. In Figures 9–11, the dashed line show the minimum standard limit for biofuel and the solid line represents the minimum standard limit for diesel fuel. The comparison of these properties with petroleum-based diesel shows that the matured JOD blend has relatively closer fuel property values to

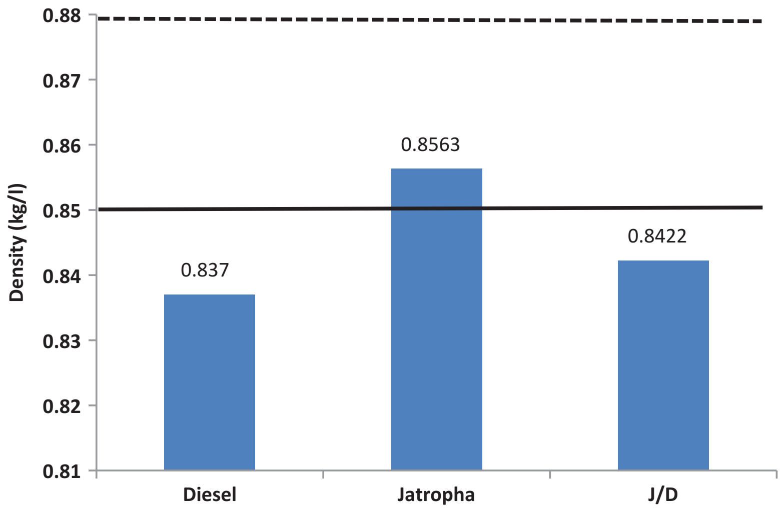

Figure 9 Density comparison among diesel, Jatropha, and matured JOD. Dashed line is the limit of biofuel as per ASTM 6751 and solid line represents the limit of diesel as per ASTM D975 (color figure available online).

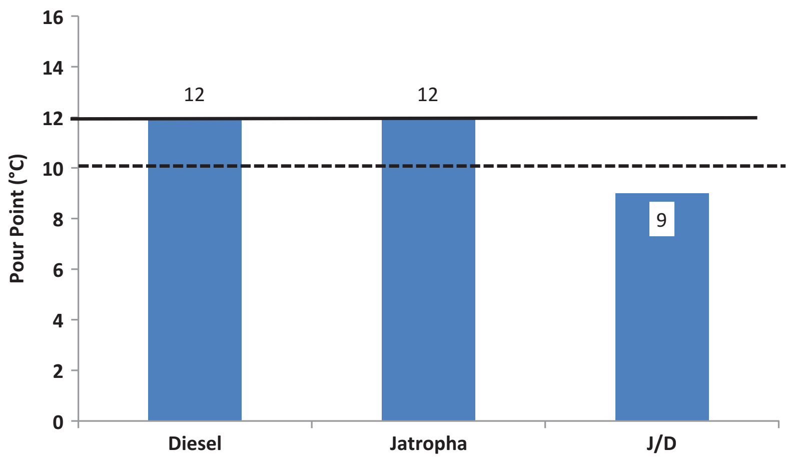

Figure 10 Pour point comparison among diesel, Jatropha, and matured JOD. Dashed line is the limit of biofuel as per ASTM 6751 and solid line represents the limit of diesel as per Malaysian Standard for Diesel Fuel (MS123, 1993) (color figure available online).

that of diesel and biodiesel standard. Low pour point biofuel is achieved in this study and located within the range specified by ASTM D6751. On the other hand, as can be seen from Table 3, the limit for pour point in ASTM D975 for diesel fuels is –35 to–15, but the obtained value for JOD blends up to 10% is 9. Although, this could be attributed to low methanol level in the biodiesel, utilization of JOD blends up to 10% is feasible in tropical countries. In Figure 10, instead of illustrating –15, which is the pour point maximum limit according to ASTM D975 for diesel fuel, the value of 12 which is the maximum limit according to Malaysian Standard for Diesel Fuel (MS123, 1993) is used. According to MS123, matured JOD blends found to outperform mineral diesel in terms of pour point; because this critical parameter was decreased about

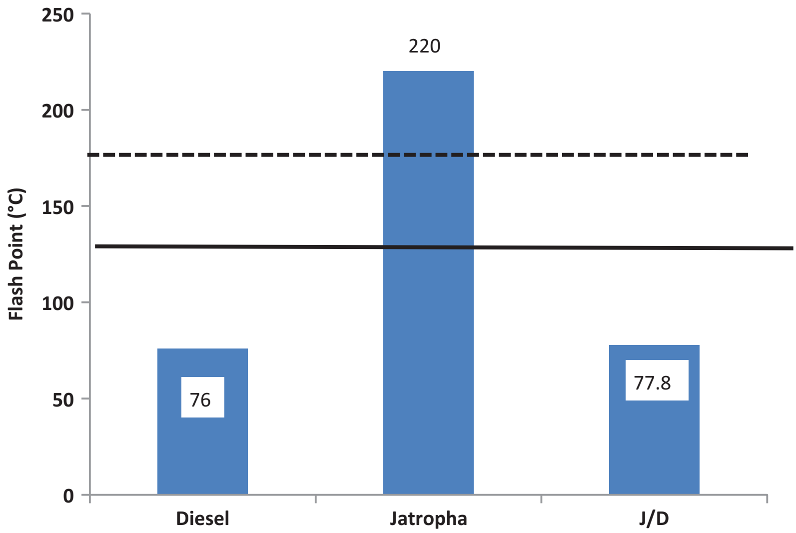

Figure 11 Flash point comparison among diesel, Jatropha, and matured JOD. Dashed line is the limit of biofuel as per ASTM 6751 and solid line represents the limit of diesel as per ASTM D975 (color figure available online).

25% (from 9 to 12°C) to fulfill even lower temperature conditions in tropical countries. It should be noted that the specification of matured JOD blends are not suitable as diesel fuel in cold climate conditions and it should be tailored for the specific climate needs.

The flash point value obtained by matured JOD blend is slightly and pure Jatropha is significantly more than petroleum-based diesel (Figure 11). So, JOD and Jatropha oil are safer than mineral diesel to handle and store.

CONCLUSION

Proper selection of Jatropha seeds maturity based on color must be ascertained not only to produce higher quantity but also to ensure the highest level of quality of biofuel. In this study, the potential of Jatropha for maximum oil yield is investigated by selecting the best fruit maturity that could give the most oil yields. The results of this study revealed that the amount of oil produced from the half-matured Jatropha seeds is about 2.5% less than the matured stage. Statistical analysis showed that the quality of the blended biodiesel using half-matured stage of Jatropha oil is about 13% differs from the matured stage. The performance for different matured JOD blends was found to be very close to diesel. The pour point for JOD blends was found to be lower, and density and flash point slightly higher than diesel. The overall results of Jatropha blends showed performance characteristics close to diesel. So, a diesel engine can perform satisfactorily on biodiesel blends without any engine modifications. Ten percent JOD blend was found to be the optimum concentration, which slightly improved some of the physical properties of the diesel fuel. Using biodiesel also eliminates the durability problems associated with the vegetable oil thus making it a safe and suitable fuel for long-term usage in CI engine. Such knowledge would provide valuable source for a deeper understanding of the role played by the maturity in the production of biofuels from Jatropha seed.

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