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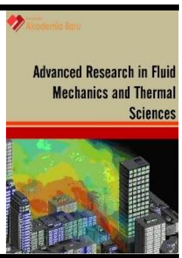

Palm Fatty Acid Distillate (PFAD) as Source of Biofuel: Availability and Suitability Analysis

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Muhammad Hanafi Asril Rajo[1,*], Ahmad Faiz Mat Zin[1], Norzelawati Asmuin[2]

[1] Department of Mechanical Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Malaysia
[2] Department of Energy and Thermofluid, Faculty of Mechanical and Manufacturing, Universiti Tun Hussein Onn Malaysia, Malaysia

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ABSTRACT

Palm oil had been used as fuel in Malaysia with the implementation of petroleum diesel and Palm Methyl Ester (PME) blend at 5% in 2014 and going to 20% blend in 2020. The high cost of the feedstock and the process to convert Free Fatty Acid (FFA) to PME is the major drawback of PME. Alternate feedstock for palm-based biofuel is palm fatty acid distillate (PFAD) obtained from a by-product of crude palm oil (CPO) refining. The present study aims to critically analyze the characteristic of biofuel properties which produced using the blend of PFAD and diesel without any chemical reaction. Five blends of PFAD and diesel blends with 5%, 10%, 15%, 20% and 25% produced in this study. The blending was done using magnetic stirrer and mix continuously for 30 minutes at elevated temperature, 60 °C. The properties of the blends such as density, viscosity, surface tension, pour point and calorific value were determined experimentally. The properties of the blends increase proportionately when PFAD content increases except for calorific value. The calorific value showed a reduction of 3% compared to diesel fuel at 25% blend while the rest showed an insignificant reduction.

Keywords:
Biofuel; free fatty acid; crude palm oil; esterification; feedstock; Palm fatty acid distillate

1. Introduction

Oil palm is one of the cash crops that is widely planted in Malaysia and Indonesia which together account for 84% of palm oil produced in the world. The implementation of palm oil as fuel for transport and industrial used in Malaysia was mandatory in 2014 as B5 which contain blend of 95% petroleum diesel and 5% palm methyl ester and later expanded to B10 which constitute 90% petroleum diesel and 10% palm methyl ester which mandatory for transportation sector on 1 February 2019 [1, 2]. Realizing the impact of biodiesel on palm oil price, Indonesia and later Malaysia

[*] *Corresponding author.*
E-mail address: mhanafi@uthm.edu.my

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government enforce new ruling to implement B20 sold as commercial fuel on September 2018 for Indonesia and year 2020 for Malaysia [3-5].

The palm methyl ester is produced from transesterification and purification of palm oil fatty acid and reacted with alcohol to produce palm methyl ester and glycerol [6]. One of the drawbacks of palm oil biodiesel is the high producing cost of the product due to it is being produced from a high quality of virgin oil with low free fatty acid (FFA) contents namely Refine Bleach and Deodorize Palm Oil (RBDPO) [7, 8]. In order to overcome this limitation, the feedstock of the biodiesel needs to be produced by using cheaper feedstock either from recycled/waste oils, or a by-product of refining vegetable oil that contains high FFA.

The feedstock that can be an alternative in producing the fuel from oil palm is by using palm fatty acid distillate (PFAD). The PFAD is a by-product of crude palm oil (CPO) from refining process. PFAD is inedible and much cheaper as compared to other palm oil product such as Refine, Bleach and Deodorized (RBD) palm olein and RBD palm stearin. From 2009 to 2015, the price trend of PFAD always traded at lower price as compared to RBD palm olein, RBD palm oil and palm stearin [9]. This factor coupled with inedibility and availability of palm oil resourced in Malaysia makes it attractive as alternative feedstock for biofuel usage in Malaysia.

Generally, PFAD contains very high free fatty acid (FFA) that account from 65% until 95% and the remaining is triglyceride [10, 11]. The high contain of FFA requires two step operations that are esterification and transesterification reactions to become methyl ester [12, 13]. Another method to utilize PFAD as a biofuel source is using direct blending with petroleum diesel. This process eliminates the needs of the costly operation of esterification and transesterification.

The use of a direct blend of palm oil product already been done by number of researchers. The blends of Refine, Bleach and Deodorized Palm Olein (RBDPO) with petroleum diesel gave a performance on par with petroleum diesel in term of spray and combustion characteristics especially at lower blend (10% blend) [14] while the emission of NOx and CO reduce when the content of palm oil increased in the blend [15]. Eiadtrong *et al.,* [16] study whether un-preheated blends of palm fatty acid distillate (PFAD) with commercial high-speed diesel (CHSD) without adding any solvent to improve cold flow property could be used as a diesel substitute. The study found that the 10% blends (PFAD 10 wt.%) are recommended to use as a simple cost-effective diesel substitute. Chongkhong *et al.,* [12, 13] developed the continuous esterification of palm fatty acid distillate (PFAD) using an economical process using a continuous stirred tank reactor (CSTR). The components and properties of fatty acid methyl ester (FAME) could meet the standard requirements for biodiesel fuel. Cho *et al.,* [17] investigated the single step method for non-catalytic esterification of palm fatty acid distillate (PFAD), which is readily applicable to actual production of biodiesel.

2. Availability of PFAD as Biofuel

In order for a vegetable oil suitable to become feedstock for biofuel, the concern regarding availability of the said oil must be address. Figure 1 shows the production and average monthly stock of PFAD at palm oil refinery for seven years from year of 2012 to 2017. It can be seen that the amount of PFAD produced by refinery in Malaysia is in the range of 659 to 766 kilotons annually for the six consecutive years which average production stood at 683 kilotons. The monthly average stock of PFAD at palm oil refinery varies from the lowest 47 kilotons to the highest at 66 kilotons while average for seven years is 58 kilotons. In a percentage perspective, in average 8.5% of PFAD produced by refinery in Malaysia remain untraded.

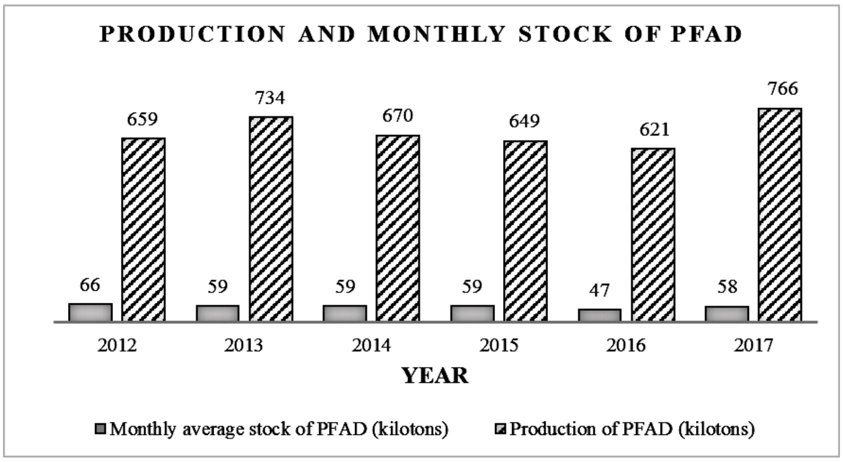

Fig. 1. Production and monthly average stock of PFAD [18]

Table 1 shows the annual consumption of diesel fuel in Malaysia from year 2012 to 2017 and simulated data for implementation of PFAD as biofuel in Malaysia. The average annual consumption of diesel fuel in six years is 9.6 mtoe (million tonnes of oil equivalent). If the government of Malaysia enforces the usage of PFAD in diesel fuel at 2%, as much as 191 ktoe (kilo tonnes of oil equivalent) PFAD will be required annually to be blended with diesel fuel. The number increase to 383ktoe, 575ktoe, 766ktoe, 959ktoe for 4%, 6%, 8% and 10% blend respectively.

At 2% PFAD in diesel fuel, it will consume 28% of PFAD from total average production in Malaysia for the year of 2012-2017. If the mandate goes to 8% PFAD, the amount of PFAD required to fulfil the demand of average diesel fuel consumption is 766ktoe while the average production of PFAD only 683ktons, thus creating shortage of PFAD. This show that the amount of PFAD produce in Malaysia suffice up to 6% blend of PFAD to diesel fuel. The addition of PFAD in diesel fuel will increase demand of PFAD thus eliminate the stock of PFAD in refinery. The increase in demand will increase the price of PFAD, bring additional profit to the downstream palm oil player.

Table 1
Annual Consumption of Diesel Fuel (toe) and simulated implementation of PFAD as Biofuel [19]

Year	2012	2013	2014	2015	2016	2017	Avg
Diesel	9,410,000	9,568,000	10,161,000	9,377,000	9,254,000	9,747,000	9,586,167
2% PFAD	188,200	191,360	203,220	187,540	185,080	194,940	191,723
4% PFAD	376,400	382,720	406,440	375,080	370,160	389,880	383,447
6% PFAD	564,600	574,080	609,660	562,620	555,240	584,820	575,170
8% PFAD	752,800	765,440	812,880	750,160	740,320	779,760	766,893
10% PFAD	941,000	956,800	1,016,100	937,700	925,400	974,700	958,617

3. Material and Methods

3.1 Biofuel Preparation

The sample of PFAD was obtained from PGEO Sdn. Bhd, a subsidiary of Wilmar International. The quantity of each element in the PFAD-diesel blend depends on its mixing ratio, for instance, if B5, then it contains 95% of diesel fuel and 5% PFAD. The blending detail for other PFAD blends is shown in Table 2. Total one litre of PFAD-diesel blend was produced according to the designated blending ratio. The blending was done using magnetic stirrer at an elevated temperature 60°C and was stirred for 30 minutes in a one-litre glass beaker to allow the mixture to become homogenous.

Table 2
Composition of PFAD and Diesel for Each Blend

Blends	PFAD (l)	Diesel (L)	Total (l)
B0	0.00	1.00	1.00
B5	0.05	0.95	1.00
B10	0.1	0.9	1.00
B15	0.15	0.85	1.00
B20	0.2	0.8	1.00
B25	0.25	0.75	1.00
B100	1.00	0.00	1.00

The colour of the blend becomes darker as the percentage of PFAD added into the blend increased as shown in Figure 2. Due to its high melting points, PFAD remains in the solid form at room temperature.

Fig. 2. Biofuel from Mixing of PFAD and Diesel

3.2 Physico-Chemical Properties of PFAD-Diesel Blend

In order to obtain physicochemical properties for PFAD-diesel Blend, several tests series were conducted according to international standard procedures. The physicochemical properties of the PFAD blend being tested include density, specific gravity, kinematic viscosity, surface tension and calorific value. Type of properties and measuring equipment used were listed as in Table 3 with their respective standard specification.

Table 3
Measuring standard and equipment for characterization of PFAD properties

Properties	Standard	Measuring Equipment
Density (g/cm3)	ASTM D941	A&D N92 balance and Pycnometer
Kinematic viscosity @ 40°C, cst	ASTM D445-94	Anton Paar stabinger viscometer SVM3000
Surface Tension (mN/m)	ASTM D971	Kruss K20Tensiometer
Calorific Value (kJ/kg)	ASTM D240	IKA C2000Bomb Calorimeter
Pour Point, °C	ASTM D97-93	

4. Result and Discussion

The physicochemical properties of PFAD blend were experimentally determined in this study. Figure 3 shows the density for each blend of PFAD-diesel. It showed that the density increases when the PFAD content in the blend is increased. This indicates that the higher density of PFAD contributes greatly towards the density of the blend. High in atomic mass means that the arrangement of the atoms of PFAD-Diesel blend is much closely-packed as the amount of PFAD in the blend keep increasing thus resulted in an increase in density of the blend.

Figure 4 shows the kinematic viscosity of PFAD based biofuel. From the figure, the kinematic viscosity of PFAD-Diesel blend is marginally increased from B5 and B10. The graph showed a tremendous increment starting from B10 until B25. This shows that the shear resistance in PFAD-Diesel blend keeps increasing as the PFAD content in the blend increases. The PFAD contributes significantly towards the inter-molecular friction that is exerted whenever the layers of the PFAD-blend attempt to slide to each other.

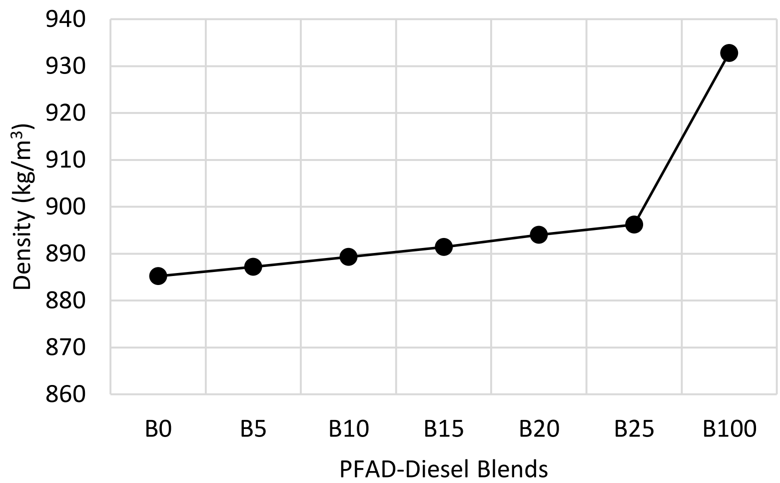

Fig. 3. Density of PFAD-Diesel Blends

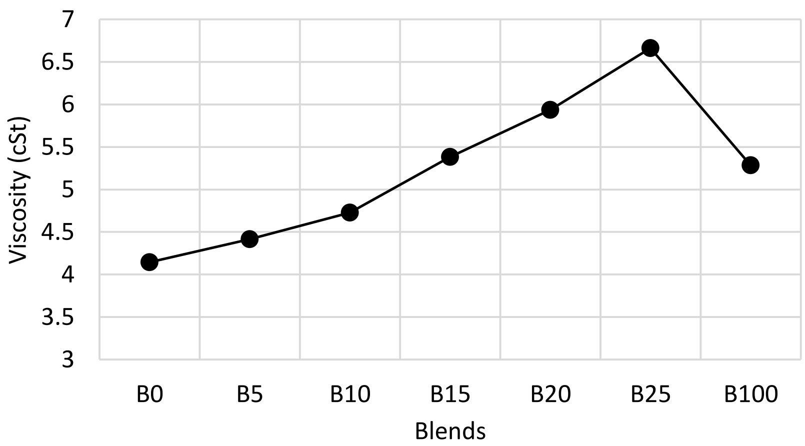

Fig. 4. Kinematics Viscosity of PFAD-Diesel Blend

The surface tension test was conducted for PFAD-Diesel blend to identify its surface property that resists any external force. This property depends on the molecule cohesive nature. Therefore, after conducting the test, the surface tension recorded data are tabulated and shown in Figure 5.

Figure 5 clearly shows that the surface tension of PFAD-Diesel blend increases as the PFAD content in the blend is increased. There is a significant increment in surface tension value from B0 to B5, and from B5 until B20, the value increases steadily. This shows that the intermolecular force of PFAD-Diesel blend is increasing as the PFAD content increases. Large intermolecular force contributes towards the bonding strength between molecules at the liquid surface.

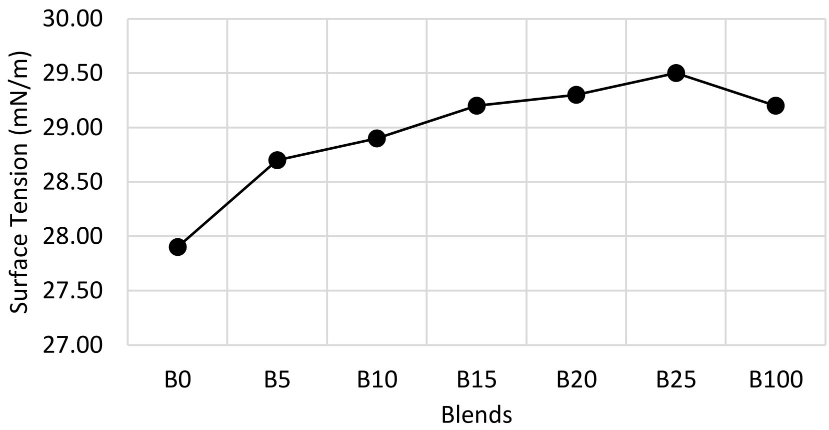

Fig. 5. Surface Tension of PFAD-Diesel Blend

Figure 6 shows the pour point of PFAD-Diesel blend. Pour point is a property in which represents the lowest temperature at which oil is capable to flow under gravity pull. It can be shown that diesel fuel can still flow at sub-zero temperature. The increase of PFAD content in the blend reduces the capability of the biofuel blend to flow at low temperature. The lowest temperature for the blend to flow under gravity is 24℃ for B20 and B25.

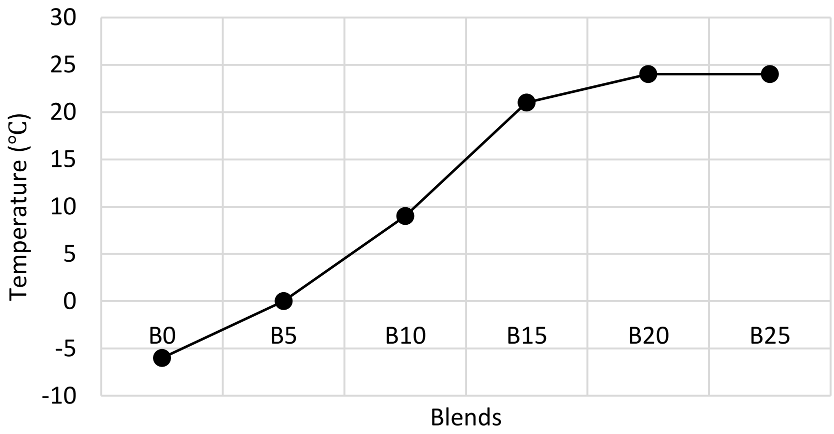

Fig. 6. Pour Point of PFAD-Diesel Blend

Figure 7 shows the calorific value (CV) of PFAD and Diesel blend. Calorific value is the amount of energy produced by the complete combustion of a material or fuel. From the figure, it shows that Diesel fuel has the highest calorific value that is 45.25 MJ/kg and PFAD is the lowest at 38.90 MJ/kg. The decrease in calorific value as shown in Figure 7 resulted from the increment amount of PFAD in the blend. At 25% blending ratio, the calorific value was reduced around 3% as compared to diesel fuel while for the rest of the blending ratio recorded an insignificant reduction in CV as compared to diesel fuel.

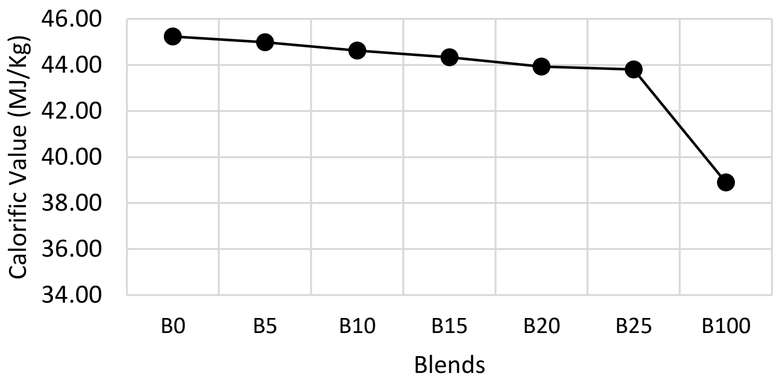

Fig. 7. Calorific Value of PFAD-Diesel Blend

5. Conclusions

This study shows that in average, about 8.5% of PFAD produce by palm oil refinery remain untraded (as stock) from the year 2012 to 2017. This stock of PFAD could potentially been used as biofuel. The blending of 5% PFAD in diesel fuel will consume 480 ktoe of PFAD which represent is sufficient to accommodate the demand of average diesel fuel consumption from year 2012 to 2017. The present work characterized five blends of petroleum diesel and PFAD starting with 5% PFAD, followed by 10%, 15%, 20% and lastly 25%. The rest constituent in the blend is diesel. Physical and chemical properties of the blends were determined experimentally. The properties are density, kinematics viscosity, surface tension, pour point and calorific value. The result showed that the increase in PFAD content in the blend increase the density, kinematics viscosity and surface tension while the ability of the blend to flow at colder temperature decrease significantly as the content of PFAD increase. On the other hand, since PFAD has a lower calorific value as compared to diesel, the PFAD-Diesel blend showed maximum 3% decrease in calorific value at 25% blending ratio while for the rest of the blending ratio recorded insignificant reduction (around 1%) in calorific value as compared to diesel fuel

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