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Effects of Incomplete Transesterification Reaction of Palm Oil Biodiesel on Fuel Quality and Engine Performance

Watit Pakdee[1], Cattaleeya Pattamaprom[2], Sirichai Phanumnuay[3]

Abstract – *This study investigates how an incomplete tranesterification reaction influences the parameters of quality standards of the produced biodiesel engine performance and exhausts. The parameters evaluated include viscosity, cloud point, acid number and heating value. Biodiesels produced from palm oil were examined in terms of engine performance, where the 3-liter engine with a 4 cylinders 4 strokes, was used. The proportion of methyl ester in biodiesel was varied by adding appropriate amounts of triglyceride. Properties of biodiesel with the methyl ester between 75% and 96.8% by mass were tested against the standard diesel. The engine performance and thermal efficiency when using biodiesels of different qualities were determined under the operating engine speed range between 1,800 and 4,000 rpm. It was found that while the cloud point was raised with methyl ester content the viscosity was decreased. In terms of engine performance, greater proportion of methyl ester provides greater fuel conversion efficiency as well as specific fuel consumption rate. Incomplete conversion of triglyceride to methyl ester, which led to lower methyl ester content, significantly affected the engine performance and emissions. In overall, biodiesel with higher methyl ester content provided better engine performance and exhaust quality.*

***Keywords**: Biodiesel, Palm Oil, Methyl Ester, Triglycerides, Transesterification, Engine Performance, Exhaust Gases*

Nomenclature

$bsfc$	Fuel consumption rate
$\dot{m}_f$	Fuel consumption rate
N	Engine speed
P	Power
Q_{HV}	Heating value
T	Torque
V_d	Displacement volume
η_f	Fuel conversion efficiency

I. Introduction

Biodiesel has become the focus of a large number of studies since it has been proved to be technically sufficient alternative diesel. In addition to its great renewability, biodiesel has many advantages such as good lubricity, reduced emissions [1]-[3]. Biodiesel consists of alkyl monoesters derived from animal fats or vegetable oils or waste cooking oils. A number of previous works investigated vegetable based biodiesel such as sunflower, palm, rapeseed, soybean, jatropha [4]-[8]. Biodiesel produced from vegetable oils is a potential alternative to diesel since their physical and chemical properties are similar to those of standard diesel [9].

Transesterification reaction of triglycerides with methanol has proved to be the most promising process to produce biodiesel [10]-[13].

In this process, fats or oils known as triglycerides are converted into biodiesel in a chemical form of mono-alkyl esters. During the process, fatty acids within triglycerides are reacted with alcohol in the present of catalyst to form the mono-alkyl esters and glycerol.

To determine biodiesel quality, the ASTM task force identified the following as critical items: Complete reaction to the mono alkyl esters, the removal of reactant alcohol and the absence of free fatty acid [14]. While the main component of biodiesel that gives biodiesel similar properties to diesel is esters, the unfavorable components are impurities such as mono-glyceride and triglyceride.

Incomplete conversion of triglyceride to methyl ester led to the presence of triglyceride in biodiesel.

Therefore total ester content can be a measure of the completeness of the transesterification reaction. On the other hand, the unconverted triglycerides in biodiesel have been found to strongly affect the mechanical and chemical properties of biodiesel [15]-[16]. It was reported for instance, the glycerol content in biodiesel is substantially raised with the increased proportion of the raw soybean oil leading to failure to pass the ASTM (American Society for Testing and Materials) D 6751 standard [15]. Accordingly, biodiesel with low quality can significantly affect an engine performance and emissions [17]. In real productions, the cause of incomplete reaction could result from various problems including low quality of raw material used, poor mixing, too low temperature, too short reaction time, or

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inappropriate amount of methanol. Therefore, in the present study, biodiesel from palm oil is produced to investigate the effects of the incompleteness of transesterification reaction not only on the fuel properties but also on engine performance. To best of the authors' knowledge, there has been no complete analysis on the influences of the incomplete reaction on the quality of produced biodiesel engine performance as well as exhaust emissions.

II. Experimental Procedure

In this work we produced biodiesel from palm oil supplied by Prathum Vegetable Oil Co., Ltd. (Thailand).

The biodiesel production was based on the transesterification reaction through our pilot plant (Fig. 1). The transesterification of fresh palm oil was carried out by using the ratio of methanol: oil = 7: 1 by mole.

The amount of KOH catalyst added was 0.49 wt% of the oil using the reaction temperature of about 55 to 60°C and the reaction time of 2 hours.

The reaction mixture was then settled to remove the lower glycerol layer. The biodiesel produced was then neutralized, washed, and dried at temperature slightly above 100 °C to remove excess methanol and water. The successfully produced biodiesel has 96.8 % of methyl ester content which passes the standard value determined by EN 14214. One way to determine the completeness of the transesterification reaction is to measure the ester content in the produced biodiesel. In the present work, our biodiesel produced from palm oil with different proportions of methyl ester were investigated.

Methyl ester contents reflect quality level of biodiesel. Biodiesel with different proportions of methyl ester content were prepared by adding the designated amounts of triglyceride. Properties of all types of biodiesel as well as standard diesel were measured according to EN 14103 standards.

Fig. 1. Pilot plant for biodiesel production

Next, different types of fuel were tested with the direct-injection diesel engine. The engine specifications are shown in Table I. The performance of the diesel engine was measured by the eddy current dynamometer.

Fig. 2 shows the experimental system that includes the dynamometer equipped with the diesel engine.

The engine was then tested under variable loads there by variable speeds. Each test was repeated three times.

The collected data were averaged before being analyzed. The deviation for each test was within 10 %.

The engine performance is analyzed based on a number of parameters [18]. In terms of torque (T), power (P) is computed using:

$$P\,(\mathrm{kW}) = 2 \times \pi \times N \times T \tag{1}$$

where N is the engine speed. To determine how efficiently the engine consumes fuel brake specific fuel consumption ($bsfc$) is examined as is given by:

$$bsfc\left(\mathrm{g\ kW^{-1}hr^{-1}}\right) = \frac{\dot{m}_f}{P} \tag{2}$$

where $\dot{m}_f$ is a fuel consumption rate. One other useful relative engine performance that does not depend on an engine size is the brake mean effective pressure, $bmep$, defined as:

$$bmep = P \times 2 \,/\, V_d \times N\ (\mathrm{kPa}) \tag{3}$$

Further, engine efficiency is considered based on the fuel conversion efficiency (η_f) given by:

$$\eta_f = \frac{P}{\dot{m}_f Q_{HV}} \tag{4}$$

where Q_{HV} is the heating value of fuel.

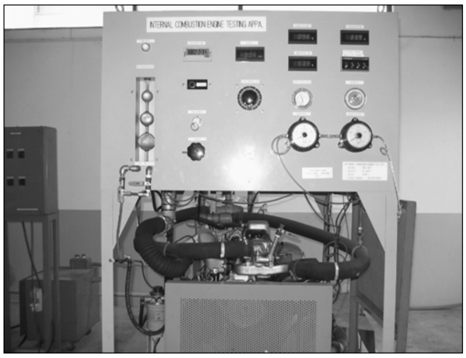

Fig. 2. Engine test system

TABLE I
ENGINE SPECIFICATIONS

Make	Nissan
Model	BD-30
Number of Cylinders	4
Bore × Stroke	96 mm × 102 mm
Displacement	2,953 cc.
Compression Ratio	18.5 :1
Maximum Power	67.1 kW (90 HP)

III. Results and Discussion

Results for the measured properties of different types of fuel are shown in Table II in which the petroleum-based diesel is referred to as a reference, and BM represents biodiesel with various ester contents.

The petroleum-based diesel was acquired from PTT Public Company Ltd. (Thailand). It is found that diesel has lower density than that of biodiesel of every type.

The density increases with an increase in triglyceride content since triglyceride has higher density than methyl ester. Compared among the fuels in term of the difference in heating value, it is observed that heating value of regular diesel is substantially higher than that of biodiesel.

However, the heating values measured of biodiesel for all types are nearly equal. This indicates that methyl ester and glycerides have comparable heating values.

In terms of viscosity, it is evident that viscosity is proportional to triglyceride content. Biodiesel gets more viscous with triglyceride content or, in other words, with higher degree of incompleteness of the reaction. It is known that the cloud point is the temperature at which dissolved solids in oil begin to form and separate from oil. The cloud point is important for determining storage stability. The value of cloud point by diesel is lower than biodiesel. Higher methyl ester content causes higher cloud point value which is not favorable. Therefore unlike the other properties, biodiesel is degraded with larger methyl ester contents in regard to cloud point.

With regard to the differences in acid value, the acid value represents the amount of free fatty acid. The contents of free fatty acids (FFAs) considerably affect transesterification.

Conversion is complicated if oil contains large amounts of FFAs (>1% w/w) that will form soap with alkaline catalyst [19].

The acid value of our biodiesel is about 0.146 which is lower than the acceptable value in accordance with ASTM standard. It is interesting that different levels of incompleteness have minimal or no effect on the acid value. Furthermore, it should be noted the acid value of our palm oil biodiesel is relatively low compared among different biodiesel originated from different raw materials [20].

In what follow, the results of engine tests are discussed.

Variations of brake torque and brake power with the engine speed ranging from 1,800 to 4,000 rpm are depicted in Figs. 3 and 4 respectively.

For regular diesel, maximum torque of 180 Nm occurs at 2100 rpm while power has a peak value of 63 kW at 3600 rpm. In overall, regular diesel produces higher values of torque and power since regular diesel has higher heating value than that of biodiesel.

Further, torque and power continually drop as proportion of ester is reduced even though the heating values of all types of biodiesel are equally low.

This finding is due mainly to an increase in viscosity with smaller proportion methyl ester that was shown previously in Table II.

Consequently high viscosity leads to poor atomization of the fuel spray and less accurate fuel injection rate.

TABLE II
PROPERTIES OF DIESEL AND BIODIESELS ANALYZED

	ASTM Standard	Diesel	BM96.8	BM90	BM85	BM80	BM75
Ester percentage (%)	EN 14103	-	96.8	90.05	85.3	80.04	75.25
Density at 15°c (kg/m³)	D 1298	845	852	877	879	880	890
Viscosity at 40°c (cSt)	D 445	3.38	4.26	5	5.47	5.83	6.4
Cloud point (°c)	D 2500	1	10.5	8.5	7.3	6.5	5.8
Acid value (mgKOH g^{-1})	D 664	-	0.14	0.146	0.146	0.146	0.146
Heating Value (MJ/kg)	D 1250	46.5	40.24	40.39	40.45	40.49	40.82

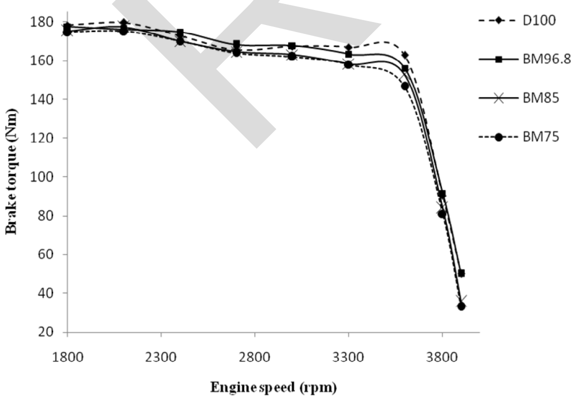

Fig. 3. Variation of brake torque with engine speed

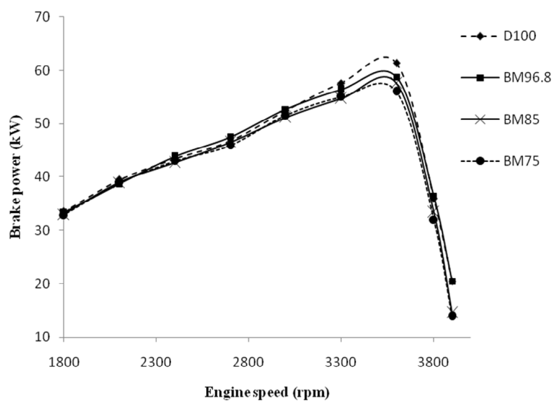

Fig. 4. Variation of brake power with engine speed

Fig. 5 shows how brake specific fuel consumption (*sfc*) changes with engine speed. Diesel has lower specific fuel consumption than the tested biodiesels. This is because diesel has greater heating value in addition to its less viscous than biodiesel.

Under 3300 rpm, *sfc* from diesel is five to ten percent lower than that of biodiesel. The *sfc* increases with increased triglycerides or greater degree of incompleteness. The difference is more pronounced at higher speeds especially at 3900 rpm. Regarding the brake mean effective pressure (*bmep*) shown in Fig. 6, diesel has greater *bmep* than that of biodiesels. The differences of the *bmep* values are clearer at the engine speeds higher than 3000 rpm consistent to power variations previously seen in Fig. 4.

To gain more insight of the effects of triglycerides on engine, the fuel conversion efficiency is computed and shown in Fig. 7.

It is interesting to point out from the results that biodiesel of all types has greater fuel conversion efficiency than that of regular diesel.

Although biodiesel has lower heating value, it converts available chemical energy from fuel into usable work more efficiently than regular diesel does.

Additionally, biodiesel with higher ester content has better conversion efficiency than biodiesel with lower ester content.

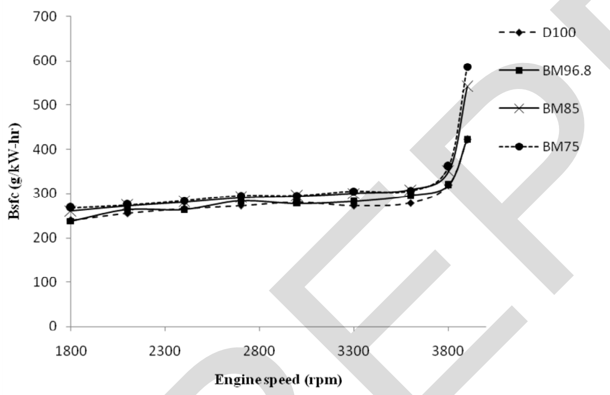

Fig. 5. Variation of brake specific fuel consumption with engine speed

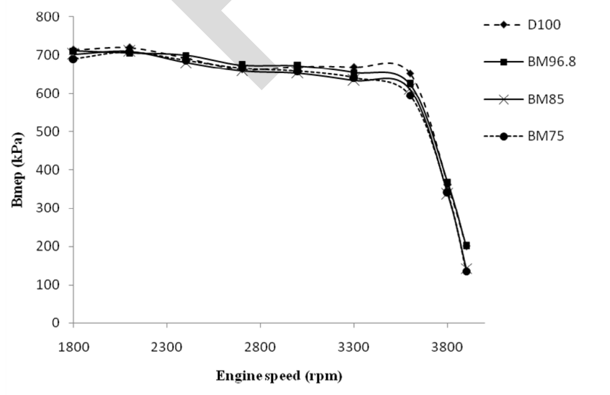

Fig. 6. Variation of brake mean effective pressure with engine speed

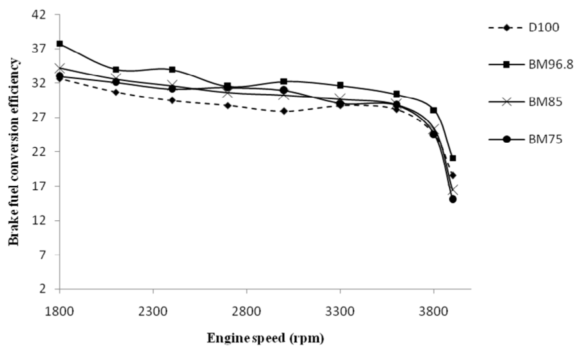

Fig. 7. Variation of brake fuel conversion efficiency with engine speed

In the following section, emission data obtained by using the test 350 gas analyzer, Germany, are analyzed.

The emission tests are carried out at 3600 rpm at which the brake power is maximized. The engine load was ranged from 0 kg to 30 kg. The exhaust emissions examined include carbon dioxide (CO_2) carbon monoxide (CO) and nitrogen oxides (NO_x).

Carbon dioxide (CO_2)

Based on the results depicted in Fig. 8, it is obvious that the amount of CO_2 increases with the given load since the engine needs higher rate of fuel injection at higher load. This causes higher rate of combustion resulting in greater CO_2 production rate. It can be seen that all types of biodiesel produce less amount of CO_2 than regular diesel for the entire range of loads due to the existence of oxygen content in biodiesels. Moreover, it is found that CO_2 is reduced with the content of triglycerides.

This is attributed to greater fraction of oxygen content in the fuel with high amount of triglycerides resulting in lesser degree of combustion.

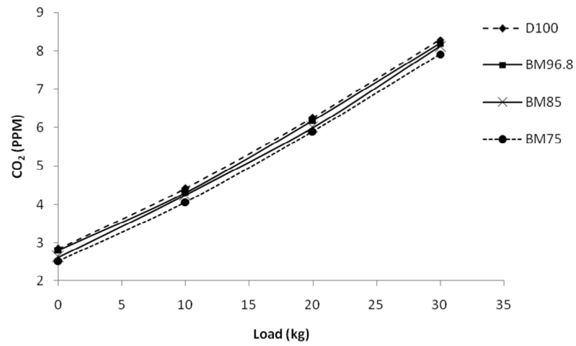

Fig. 8. Percentage by volume of CO_2 that is varied with engine load for different types of fuel

Carbon monoxide (CO)

The measured data of CO is graphically presented in Fig. 9. CO is formed due to incomplete combustion in which O_2 is insufficient. In addition, too short residence time for combustion may cause CO formation as well.

From Fig. 9, CO is reducing when load increases from 0 kg to 20 kg since temperature in the combustion chamber increases. However, CO becomes increased when the load increases further from 20 kg to 30 kg since fuel is used more with higher load.

Oxygen becomes highly insufficient for complete combustion resulting in greater CO production towards the largest tested loads. Further, as expected, biodiesel generates less CO than regular diesel since biodiesel composes of some fraction of oxygen. When compared among biodiesels, CO is found reduced with greater ester content. This finding indicates better completion of combustion in the case that the transesterification is more completed.

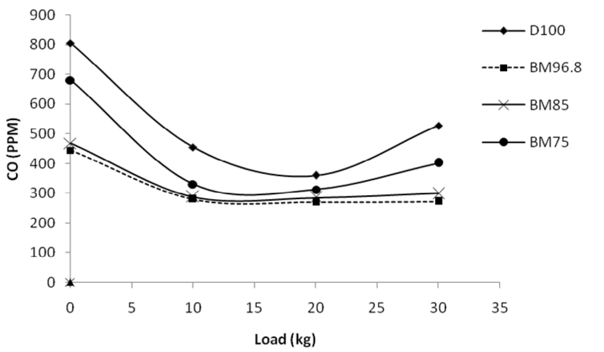

Fig. 9. Average values of CO percentage for all varied loads for different types of fuel

Nitrogen oxides (NO_x)

The resulting data are depicted in Fig. 10 that shows how the NO_x concentrations change under various loads. It can be easily seen that NO_x increases with the applied load. This result is due to higher temperature in combustion chamber at higher load. No_x emission is generated during combustion process when nitrogen and oxygen are present at elevated temperatures. It can be observed that biodiesel produces more NO_x than regular diesel since in case of combustion in biodiesel, extra amount of oxygen reacts with nitrogen leading to NO_x formation. When compared among biodiesel, greater methyl ester percentage leads to greater NO_x level.

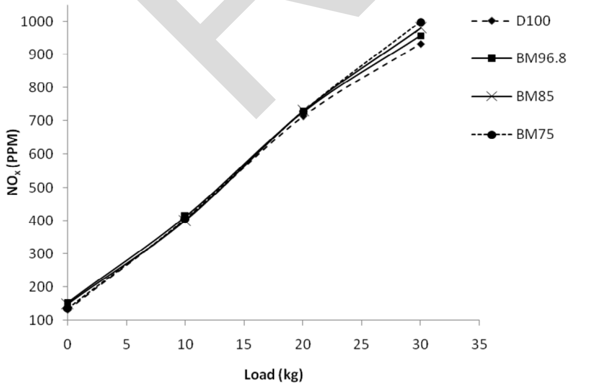

Fig. 10. NO_x concentration that is varied with engine load for different types of fuel

This result suggests that the incomplete transesterification process enhances production rate of NO_x. The difference prevails at higher load as the chamber temperature is high. This indicates that the effect of temperature is more important factor than the effect due to the difference in the amount of oxygen.

IV. Conclusion

Biodiesel originated from palm oil was systematically produced via a transesterification process. During the process, palm oil was converted into methyl ester.

Chemical and mechanical properties of biodiesel with various methyl ester percentages were examined.

Additionally these different types of fuel were tested to determine the engine performance as well as the quality of exhaust gas. While variations with methyl ester content of heating value and acid value are slight, it is obvious that the cloud point is raised and viscosity is decreased when the amount of ester increases. With higher proportion of methyl ester, greater torque and power are delivered.

Additionally, biodiesel with higher ester content has better conversion efficiency as it converts fuel energy into output work more efficiently than biodiesel with lower ester content. The incomplete transesterification process enhances production rate of NO_x. Furthermore, greater CO_2 and less CO produced with increased ester content suggest more complete combustion from the supplied fuel. Methyl ester content essentially reflects quality of biodiesel. On the other hand, unconverted triglycerides due to incomplete transesterification reaction considerably degraded biodiesel properties especially viscosity, which in turn negatively affected the engine performance and the quality of the exhaust.

Acknowledgements

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References

[1] E. S. Murillo, J. L. Miguez, J. Porteiro, E. Granada, J. C. Moran, Performance and exhaust emissions in the use of biodiesel in outboard diesel engines, *Fuel*, Vol. 86, pp. 1765 – 1771, 2007.

[2] C. Y. Lin, H. A. Lin, Diesel engine performance and emission characteristics of biodiesel produced by the peroxidation process, *Fuel*, Vol. 85, pp. 298-305, 2006.

[3] A. M. Liaquat, H.H. Masjuki, M. A. Kalam, M. Varman, M. A. Hazrat, Experimental Analysis on Engine Performance and Emission Characteristics using Biodiesel obtained from Non-edible Oil, (2012) *International Review of Mechanical Engineering (IREME)*, 6 (3), pp. 659-665.

[4] C. L. Peterson, Vegetable oil as a diesel fuel: status and research priorities, *Transactions of ASAE*, Vol. 29, pp. 1413 – 1422, 1986.

[5] M. Ziejewski, H. Goettler, G. L. Pratt, Comparative analysis of the long-term performance of a diesel engine on vegetable oil based alternative fuels, Warrendale, PA, USA, *SAE*, 1986, Paper 860301.

[6] M. S. Graboski, R. L. McCormick, Combustion of fat and

vegetable oil derived fuels in diesel engines, *Progress in Energy and Combustion Science*, Vol. 24, pp. 125 – 164, 1998.

[7] D. Vashist, A. Mukhtar, Energetic and Economic Feasibility Associated with the Production, Processing and Conversion of Jatropha Oil to a Substitute Diesel Fuel in India, (2009) *International Review of Mechanical Engineering (IREME)*, 3 (4), pp. 503-509.

[8] M. A. A. Hasagaya, M. N. M. Jaafar, M. S. A. Ishak, Investigation of Oil Burner Combustion Performance when utilizing Palm Biodiesel Blends, (2011) *International Review of Mechanical Engineering (IREME)*, 5 (3), pp. 548-552.

[9] C. Kaplan, R. Ridvan, A. Surmen, Performance Characteristics of Sunflower Methyl Esters as Biodiesel, *Energy Sources*, *Part A*, Vol. 28, pp. 751 –755, 2006.

[10] S. Gryglewicz, Rapeseed oil methyl esters preparation using heterogeneous catalysts. *Bioresources and Technology*, Vol. 70, pp. 249 – 253, 1999.

[11] A. Demirbas, S. Karslioglu, Biodiesel Production Facilities from Vegetable Oils and Animal Fats, *Energy Sources*, *Part A*, Vol. 29, pp. 133 –141, 2007.

[12] Z. Utlu, S. K. Mevlut, The effect of biodiesel fuel obtained from waste frying oil on direct injection diesel engine performance and exhaust emissions, *Renewable Energy*, Vol. 33, pp. 1936 – 1941, 2008.

[13] Obed M. Ali, Rizalman Mamat, Che Ku M. Faizal, Palm Biodiesel Production, Properties and Fuel Additives, (2012) *International Review of Mechanical Engineering (IREME)*, 6 (7), pp. 1573-1580.

[14] Independent Bussiness Feasibility Group LLC, *The biodiesel plant development handbook – executive summary*. IBFG, 2002.

[15] S. Fernando, P. Karra, R. Hernandez, S. K. Jha, Effect of incompletely converted soybean oil on biodiesel quality, *Energy*, Vol. 32, pp. 844 – 851, 2007.

[16] A. Srivastava, P. Ram, Triglycerides-based diesel fuels, *Renewable and Sustainable Energy Review*, Vol. 4, pp. 111 – 133, 2000.

[17] C. Pattamaprom, W. Pakdee, S. Ngamjaroen, Storage degradation of palm-derived biodiesel: Its effects on chemical properties and engine performance, *Renewable Energy*, Vol. 37, pp. 412 – 418, 2012.

[18] J. B. Heywood, *Internal Combustion Engine Fundamentals*, 4th edition, McGraw-Hill, 1998).

[19] P. K. Sahoo, L. M. Das, M. K. G. Badu, S. N. Naik, Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine, *Fuel*, Vol. 86, pp. 448 – 454, 2007.

[20] G. Knothe, Some aspects of biodiesel oxidative stability, *Fuel Processing and Technology*, Vol. 88, pp. 669– 677, 2007.

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