PRODUCTION OF BIODIESEL FROM REFINED PALM KERNEL OIL AS A FUEL AND ITS EFFECTS ON COMPRESSION IGNITION ENGINE PERFORMANCE

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Abstract

This research attempted to study the biodiesel production reaction by transesterification of crude palm kernel oil and refined palm kernel oil. From the experiment found that methyl esters synthesized from crude palm kernel oil were lower than methyl esters synthesized from refined palm kernel oil under the same conditions due to the oil's purity and different acidity. Butanol was used to produce diesohol at a low mixing ratio in this experiment. Physical properties, homogeneity were then tested after six months of storage. Conduct the test by $D90B_u5B5$(RPKO) mixed well without stratification after six months of storage. From the experiment biodiesel produced has a maximum productivity equal to 90.8%. Biodiesel was then used as an ingredient in the $D90B_u5B5$(RPKO). Then testing $D90B_u5B5$(RPKO) for physics properties and performance in the engine. From the experiment found that the $D90B_u5B5$(RPKO) had similar physical properties to diesel fuel except the flash point is lower than high-speed diesel fuel. The result of the performance found that $D90B_u5B5$ had slightly less torque and brake power than standard diesel fuel with a higher fuel consumption rate than diesel fuel

Keywords: Biodiesel, Diesohol, Butanol, Transesterification, Methyl Ester

1. Introduction

Refined palm kernel oil is a vegetable oil with an unstable molecular structure. It cannot be stored for a long time but has an iodine value below 120, so it is a non-drying oil. The iodine value indicates the plant oil's double bond content, indicating the polymerization reaction. Refined palm kernel oil is less polymerized and reacts more slowly than oils with higher iodine values. Direct application of refined palm kernel oil to diesel engines is not workable due to it is a solid oil at room temperature and has high viscosity. Due to its high viscosity, it causes a problem of injecting the oil as a fine mist, impeding the complete combustion of the oil. J. Baumi et al. [1] found that clogging in the fuel line and fuel filter was associated with the saturated fatty acid methyl ester in vegetable oil-based biodiesel. S. Kumar et al. [2] claimed that methanol and ethanol were assessed for their potential in most research studies. M. Wu et al. [3] found that the advantages of these oxygenates are classified into several categories. They are available from sustainable, the cultivation of crops, and atmospheric pollution increased energy security, and the variability of energy sources generate market stability and reduce scarcity risk. G. Knothe et al. [4] found that in the case of ethanol content in diesel: ethanol mixture. Ethanol increases, resulting in incomplete combustion due to lower cetane values and higher CO_2 and CO emissions. Many researchers [5,6] suggested that an abundance of researches have been conducted on the properties of ethanol. Recent research studies on the properties of butanol have shown that it is compatible with diesel fuel. However, the cetane content and flashpoint are higher than ethanol. Butanol is less toxic and corrosive than ethanol. Many studies [7,8] found that due to the presence of oxygen in butanol, the amount of carbon dioxide produced by combustion is reduced when adding butanol to diesel: butanol mixture. S.B. Bankar et al. [9] claimed that the engine will be difficult to start with too much butanol in the diesel mixture because the cetane number of the oil decreases with increasing butanol ratio. E.G. Giakoumis et al. [10] found that recently, researchers have been interested in the simultaneous use of biodiesel, ethanol, and butanol in diesel. Because biodiesel has a high viscosity, lubricity, cetane number and flashpoint than butanol, which can be compensated by using butanol as a fuel ingredient. Mixing biodiesel in diesel fuel can help reduce the amount of carbon monoxide and hydrocarbon in the engine. In this experiment, $D90B_u5B5$(RPKO) was tested in diesel engine

2. Objective

1. To study the production process of biodiesel from Refined Palm Kernel Oil and Crude Palm Kernel Oil by transesterifications method when the reactants were given different oil purity values
2. Study on the homogeneity of fuels when using biodiesel as an emulsifier of Butanol: Diesel fuel to replace the use of additives imported from abroad
3. Comparison of biodiesel produced from Refined Palm Kernel Oil and Crude Palm Kernel Oil when NaOH was used as a catalyst. Study the homogeneity when stored for six months to observe the mixture stratification and chemical properties of $D90B_u5B5$(RPKO). Then take $D90B_u5B5$(RPKO) to test performance and fuel consumption compared with standard diesel

3. Methodology

3.1 Biodiesel production process (Biodiesel from Refined Palm Kernel Oil)

1. One thousand milliliters of biodiesel from RPKO were poured into beaker one, then the oil was stirred and heated by setting the stirring speed at 1500 rev/min and the temperature at 60°C. Seven grammes of NaOH (0.7%NaOH(wt/vol)) and methanol: RPKO at a ratio of 1:3 were put into a second beaker, stirred and heated to dissolve the NaOH flakes. Then the mixture from the second beaker was poured into the beaker one, stir for 60 minutes and then the stirrer was turned off. The glycerol was separated, and the methyl ester was washed with warm water at 40°C. Rinsed until the pH of the water was seven. Then the experiment was carried out under the following conditions:
2. Change the volumetric ratio of methanol: RPKO at 1:2 and 1:4
3. Change the reaction time from 60 minutes to 30 minutes
4. Change percent by mass 0.6%NaOH(wt/vol) and 0.8%NaOH(wt/vol)

3.2 Biodiesel production process (Biodiesel from Crude Palm Kernel Oil)

1. One thousand milliliters of biodiesel from CPKO was poured into a beaker, then stirred and heated by setting the stirring speed at 1500 rev/min and the temperature at 60°C. Eight grammes of NaOH (0.8%NaOH(wt/vol)) and methanol: CPKO at a ratio of 1:3 were put into a second beaker, then stir and heat to dissolve the NaOH flakes. The mixture from the second beaker was poured into the first beaker, stirred for 60 minutes, and then the stirrer turned off. The glycerol was separated, and the methyl ester was washed with warm water at 40°C. Then rinse until the pH of the water was seven. Then the experiment was carried out under the following conditions:
2. Change the volumetric ratio of methanol: CPKO at 1:2 and 1:4
3. Change the reaction time from 60 minutes to 30 minutes
4. Change percent by mass 0.7% NaOH(wt/vol) and 0.9% NaOH(wt/vol)

3.3 Diesohol production process

1. Testing homogenous and emulsification stability by mixing diesel at low mixing. To do this, the ratio of Diesel: Butanol: Biodiesel (RPKO) at 90:5:5 (volume) mixed using butanol with a purity of 99.4%. Then, adding biodiesel blend by increasing the mixing ratio at all times with 5% by volume of a mixing ratio ranging from 5%-15% by volume of mixed oil. The test oil was stirred at room temperature of 25°C and 35°C, 30 min and then stored for six months to observe the mixture stratification
2. Take 1 to test the homogeneity
3. Take $D90B_u5B5$(RPKO) to test physical properties
4. Then take $D90B_u5B5$(RPKO) to test performance and fuel consumption compared with standard diesel

4. Equipment

1. RET BASIC SAFETY CONTROL IKAMAG
2. A set of equipment used in the production of biodiesel
3. Refined Palm Kernel Oil
4. Crude Palm Kernel Oil
5. Industrial grade methanol, purity is not less than 99.5%
6. n-Butanol 99.4% AR.Grade
7. Industrial grade sodium hydroxide, the purity value is not less than 90%
8. Sodium sulfate

HONMAR Diesel Engine Specification

Model	: DH850
Horsepower	: 6.7HP/ 3600 rpm
Engine type	: Single-cylinder
Cooling system	: Direct injection
Combustion system	: 78 x 62
Displacement volume	: 296 cc
Capacity	: 3.5 liters

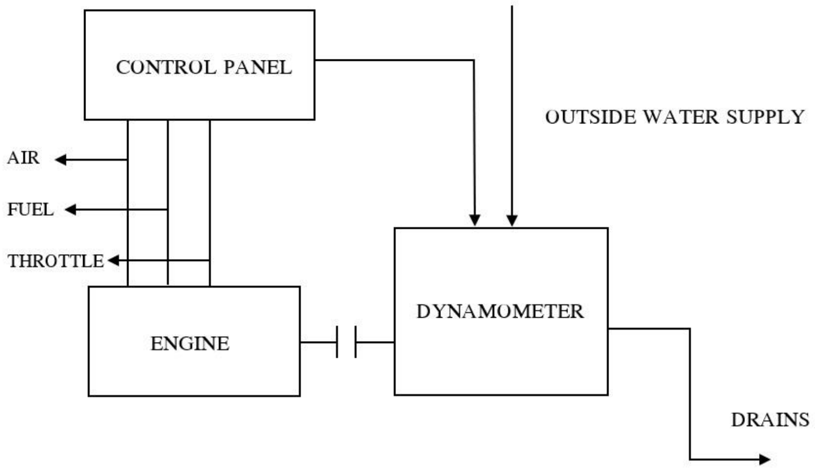

Figure 1 Installation of the engine

5. Results

Table 1 Volumetric ratio of methanol to refined palm kernel oil, 0.7%NaOH(wt/vol), at 60°C for 60 min

(Methanol : RPKO) (by volume)	Yield (%)
1:2	-
1:3	90.8
1:4	72

The results showed that biodiesel production from RPKO was significantly higher than biodiesel from crude palm kernel oil; the difference was equal to 5%. From Table 1, the test results when changing the volumetric ratio of methanol to RPKO at 1:2, 1:3 and 1:4 at 60 min showed that the volumetric ratio of methanol: RPKO gave percentage equal to 90.8%

Table 2 Change in proportional time at a volumetric ratio of methanol to refined palm kernel oil, 0.7%NaOH(wt/vol), at 30 minutes and 60 mintutes

Time (min)	Oil (cc)	Biodiesel (cc)	Yield (%)
30	250	177.5	87
60	250	185	90.08

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Table 3 Percentage change by NaOH catalyst mass proportional of methanol to refined palm kernel oil 1:3, 60°C, for 60 minutes

%NaOH(wt/vol)	Oil (cc)	Biodiesel (cc)	Yield (%)
0.6	250	194	77.6
0.7	250	227	90.8
0.8	250	202	80.8

From Table 2 and Table 3, the reaction of the volumetric ratio of methanol to refined palm kernel oil, 0.7%NaOH(wt/vol), at 60°C, reaction time of 60 min was more complete than at 30 min with a difference in production percentage of 3.08%. Therefore, best biodiesel production from refined palm kernel oil was 60 minutes due to the significant percentage difference; the percentage by catalyst mass per oil volume 0.7%NaOH(wt/vol) was the percentage by volume of the product obtained with the highest oil consumption of 90.8% when compared to the percentage by catalyst masses of 0.6 and 0.8%NaOH(wt/vol)

Table 4 Number of biodiesel rinsing times with distilled water, by volume methanol to refined palm kernel oil 1:3, reaction temperature 60°C, for 60 min. Biodiesel washing: distilled water at a ratio of 1:3, reaction temperature 40°C, Na_2SO_4 45% by weight of biodiesel. The time required for rinsing 30 minutes

%NaOH(wt/vol)	Time	Yield (%)
0.7	3	90.8

From Table 4, the percentage ratio by the catalyst mass to the oil volume 0.7%NaOH(wt/vol) can totally remove soap and methanol catalyst from the oil. Water must rinse three times to neutralize the biodiesel

Table 5 Homogeneity test results of low mixing proportion fuels. (percent by volume) using biodiesel from refined palm kernel oil and butanol as a mixture at room temperatures of 25°C and 35°C using butanol with a purity of 99.4%

Diesel	Butanol	Biodiesel (RPKO)	Stability Observation (25°C)	Stability Observation (35°C)
90	5	5	clear and not separated	clear and not separated
85	5	10	clear and not separated	clear and not separated
80	5	15	clear and not separated	clear and not separated

From Table 5, fuel produced were homogeneous and non-stratified when stored for six months

Table 6 Volumetric ratio of methanol to crude palm kernel oil, 0.8%NaOH(wt/vol), at 60°C, for 60 min

(Methanol : CPKO) (by volume)	Yield (%)
1:2	-
1:3	77.2
1:4	70

Table 7 Change in proportional time at a volumetric ratio of methanol to crude palm kernel oil, 0.8%NaOH(wt/vol), at 30 minutes and 60 minutes

Time (min)	Oil (cc)	Biodiesel (cc)	Yield (%)
30	250	177.5	74
60	250	185	77.2

Table 8 Percentage change by NaOH catalyst mass proportional to methanol to crude palm kernel oil 1:3, at 60°C, for 60 minutes

%NaOH(wt/vol)	Oil (cc)	Biodiesel (cc)	Yield (%)
0.7	250	184	73.6
0.8	250	193	77.2
0.9	250	178	71.2

From Table 6 to Table 8, as a result, the ratio by volume of methanol to crude palm kernel oil at 1:3 was the highest product percentage, 77.2%, when using sodium hydroxide base as a catalyst. The reaction of the volumetric ratio of methanol to crude palm kernel oil, 0.8%NaOH(wt/vol), at 60°C, reaction time of 60 min was more complete than at 30 min with the difference in production percentage of 3.2%. Therefore, biodiesel production from crude palm kernel oil was 60 minutes due to the significant percentage difference. Moreover, a percentage by catalyst mass per oil volume 0.8%NaOH(wt/vol) was the percentage by volume of the product obtained with the highest oil consumption of 77.2% when compared with the percentage by catalyst masses of 0.7 and 0.9%NaOH(wt/vol)

Table 9 The number of biodiesel rinsing times with distilled water, by volume methanol to crude palm kernel oil 1:3, reaction temperature 60°C, time 60 min. Biodiesel washing: distilled water at a ratio of 1:3, reaction temperature 40°C, Na_2SO_4 45% by weight of biodiesel. The time required for rinsing 30 minutes

%NaOH(wt/vol)	Time	Yield (%)
0.8	3	77.2

From Table 9, the percentage ratio by the catalyst mass to the oil volume 0.8%NaOH(wt/vol) can totally remove soap and methanol catalyst from oil. Water must rinse three times to neutralize the biodiesel

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Table 10 Properties of Fuel

Test Description	Test Method	High Speed Diesel	$D90B_u5B5$
	Visual Inspection	**Bright and Clear**	**Bright and Clear**
Color	ASTM D1500	Max 4.0	L1.0
Cetane Index	ASTM D976	Min 50	55.8
Distillation, C	ASTM D86		
Initial Boiling Point		-	113.4
90%vol. Recovered		Max 357	345.5
Flashpoint	ASTM D93	Min 52	42.0
Pour Point, °C	ASTM D97	Max 10	3.0
Viscosity at 40 C, cSt	ASTM D445	1.8 - 4.1	2.7
Total Contamination, mg/kg	EN 12662	Max 24.0	2.9
Micro Carbon Residue (MCR), %mass	ASTM D4530	Max 0.3	<0.01
Ash, %wt	ASTM D482	Max 0.010	<0.001
Total Sulfur Content, mg/kg	ASTM D5453	Max 50	37.2
Water and Sediment, %Vol.	ASTM D2709	Max 0.05	<0.01
Corrosion	ASTM D130	No.1 max	No.1

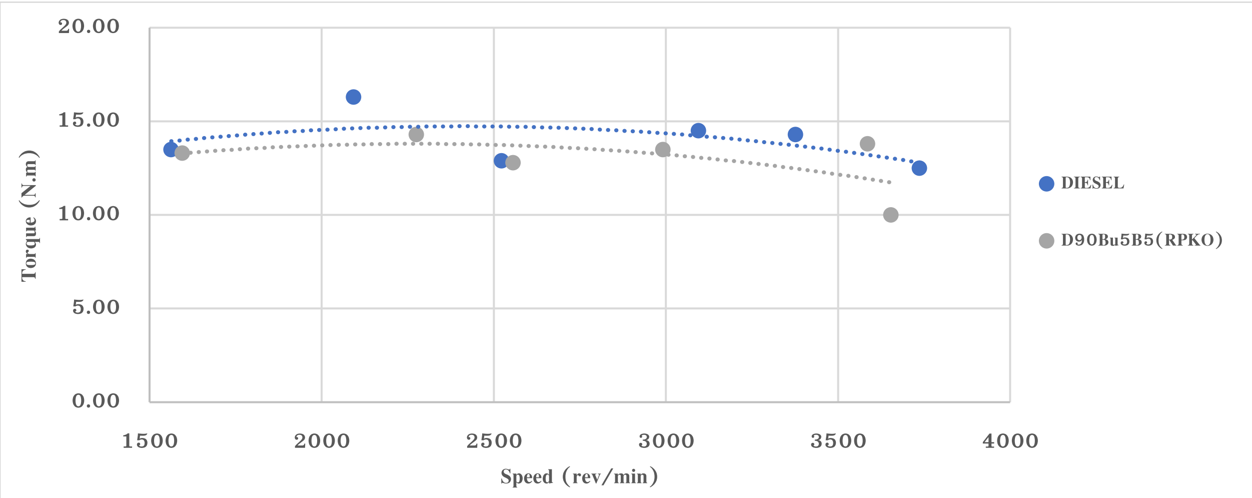

Figure 2 Relationship between torque and engine speed when using $D90B_u5B5$ (RPKO)

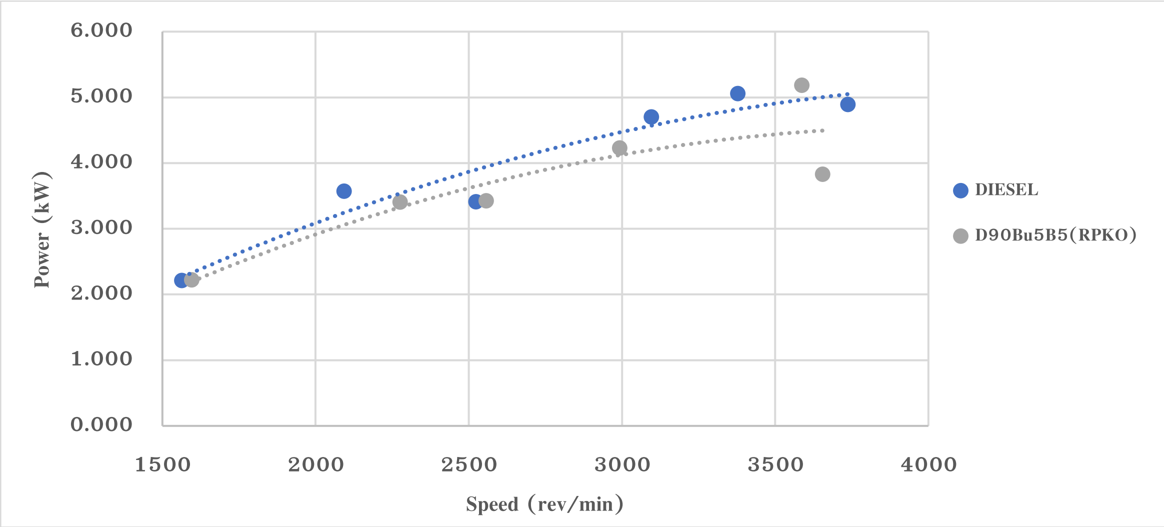

Figure 3 Relationship between power and engine speed when using D90B$_u$5B5 (RPKO)

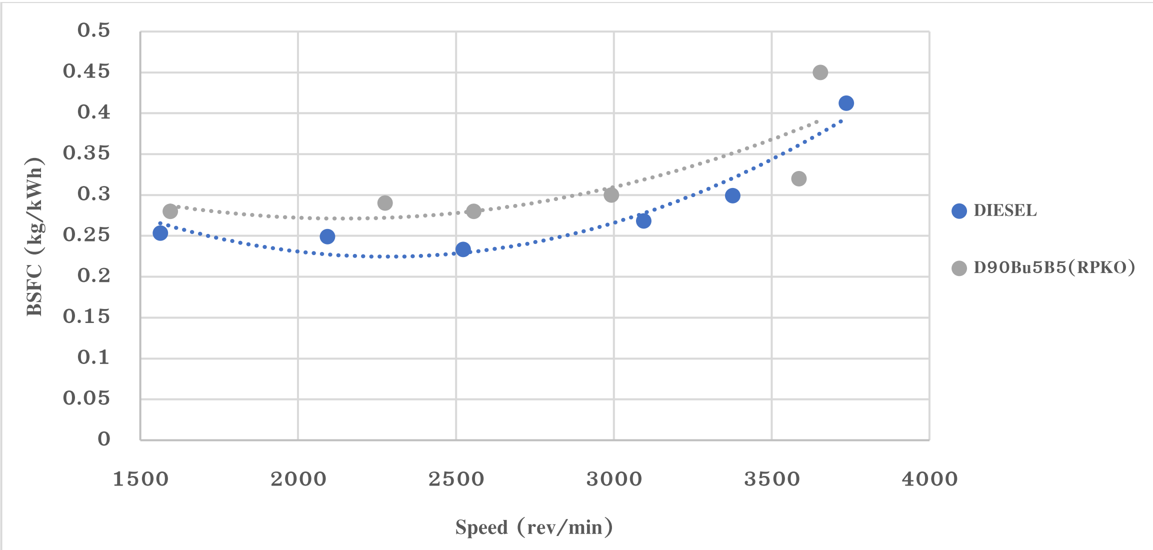

Figure 4 Relationship between BSFC and engine speed when using D90B$_u$5B5 (RPKO)

From Figure 2 to Figure 4, the results found that D90B$_u$5B5 from refined palm kernel oil gave torque and braking power similar to diesel fuel. The benefit of using butanol and biodiesel blends in diesel fuel is that because butanol is blended in the oil, the oil's viscosity will be reduced to compensate for biodiesel. The experiment mixed the proportions of butanol and biodiesel at the same ratio to study the behavior of the oil when used in diesel engines. It is influenced by the density of the fuel properties, which directly affects the engine's performance characteristics. The oil test results showed that low blending ratio diesohol D90B$_u$5B5 from refined palm kernel oil had slightly less torque and brake power than standard diesel fuel with a higher fuel consumption rate than diesel fuel. The main benefit of using biodiesel in diesohol because biodiesel has a high viscosity which compensates for the low viscosity of butanol-diesel blends. A low blending ratio of diesohol, D90B$_u$5B5 from refined palm kernel oil had slightly less torque and brake power than standard diesel fuel

5. Conclusion

From the experiment, when considering the cost of the oil used as raw material, it was found that biodiesel production from RPKO has a simple production process. Thus, it is an oil crop that has potential as a raw material source for industrial biodiesel production because it requires only a cheap plant that is easily available within Thailand

Base is chosen as a catalyst because it is a highly economical technology as it is a chemical process that uses catalyst conditions to produce at low temperature and pressure and has a shorter reaction time than using acid as a catalyst. Summary of factors affecting the production process are reaction temperature, oil and alcohol ratio, type and concentration of catalyst, and reactant purity

In the experiment, the investigators considered choosing biodiesel produced from RPKO for engine testing because RPKO biodiesel had lower polyunsaturated fatty acid content and higher productivity compared to biodiesel made from CPKO. In addition, production control at 60°C for a short time increases biodiesel oxidation stability, making the fuel produced stable and non-stratified

The pour point of the D90B$_u$5B5 from RPKO has a pour point temperature of 3°C, so it can be used in a temperature range of not less than 3°C. This will cause the oil to become waxy, which will cause clogged problems in the oil duct and fuel filter. The produced diesohol has a discharge point that does not exceed the high-speed diesel standards set by the Department of Energy Business

Biodiesel and butanol have lower calorific values than standard diesel. Therefore, when mixing biodiesel and butanol in an increased proportion of the mixture, the calorific value of the fuel is reduced

The increased mixing ratio of butanol will cause a lower flash point of the fuel produced. However, when butanol is added to an increased mixing ratio, the resulting fuel has a lower flashpoint

From the experiment, diesohol produced from RPKO has a flashpoint of 42°C, which is lower than the standard for high-speed diesel fuel. Separate storage areas are required and safety management in oil transportation

According to the results of the experiments standard corrosion test ASTM D130, diesohol can be used in engines without causing the effects of oil corrosion on the metal parts of the engine and does not affect the operation of the engine.

The D90B$_u$5B5(RPKO) had similar trends in torque and braking power at a low speed diesel engine and high speed diesel engine with standard diesel fuel

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