การศึกษาสมรรถนะและการปล่อยมลพิษของเครื่องยนต์ดีเซล เมื่อใช้น้ำมันไบโอดีเซลจากไขมันไก่ผสมน้ำมันปาล์มดิบเป็นเชื้อเพลิง

A Study of Performance and Emission Characteristics for Diesel Engine When Using Biodiesel from Chicken Tallow Mixed with Crude Palm Oil

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บทคัดย่อ

งานวิจัยนี้เป็นการนำเสนอการศึกษาสรรถนะของเครื่องยนต์ดีเซลเมื่อใช้เชื้อเพลิงไบโอดีเซลจากไขมันไก่ผสมน้ำมันปาล์มดิบเป็นเชื้อเพลิงโดยทำการทดสอบในเครื่องยนต์ KUBOTA RT 100 ขนาด 1 สูบ ขนาด 599 ซีซี. และทำการเก็บข้อมูลการทดลองเมื่อเครื่องยนต์มีความเร็วรอบตั้งแต่ 800 – 2,400 rpm. (ค่า 800 – 2,400 ± 50 rpm.) โดยทดสอบทั้งด้านสมรรถนะเครื่องยนต์และคุณสมบัติของเชื้อเพลิงผสมระหว่างไบโอดีเซลจากไขมันไก่ผสมน้ำมันปาล์มดิบในอัตราส่วนผสม 100:0, 95:5, 90:10 และ 85:15 โดยปริมาตร เพื่อเปรียบเทียบกับคุณสมบัติของเชื้อเพลิงดีเซลผลการทดลองพบว่าค่าของแรงบิดและกำลังเบรกของเครื่องยนต์ที่ใช้เชื้อเพลิงผสมในอัตราส่วนต่างๆ มีค่าต่ำกว่าเครื่องยนต์ที่ใช้เชื้อเพลิงดีเซล 0.59 – 2.82% และ 0.61 – 3.18% ตามลำดับสอดคล้องกับอัตราการสิ้นเปลืองเชื้อเพลิงจำเพาะก็มีค่าสูงกว่าเครื่องยนต์ที่ใช้เชื้อเพลิงดีเซล 0.78 – 7.35% ในด้านของการปล่อยมลพิษของเครื่องยนต์พบว่าเครื่องยนต์ที่ใช้เชื้อเพลิงผสมมีการปล่อยก๊าซออกไซด์ของไนโตรเจน (NO_x) สูงกว่าเชื้อเพลิงดีเซล 15.09 – 18.72% แต่มีการปล่อยก๊าซคาร์บอนมอนอกไซด์ (CO) และคาร์บอนไดออกไซด์ (CO_2) ต่ำกว่าเชื้อเพลิงดีเซล 17.13 – 33.82% และ 27.58 – 32.18% ตามลำดับ สุดท้ายสรุปได้ว่าเครื่องยนต์ที่ใช้ไบโอดีเซลจากไขมันไก่ผสมน้ำมันปาล์มดิบเป็นเชื้อเพลิงมีสมรรถนะ

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ในเครื่องยนต์ที่ต่ำกว่าเชื้อเพลิงดีเซลแต่การใช้เชื้อเพลิงผสมก็มีข้อดีในเรื่องมีการปล่อยมลพิษในเครื่องยนต์ที่ต่ำกว่าเชื้อเพลิงดีเซล

คำสำคัญ: ไบโอดีเซลจากไขมันไก่, สมรรถนะเครื่องยนต์ดีเซล, น้ำมันปาล์มดิบ

ABSTRACT

This paper presents a study of performance and emission of diesel engine using biodiesel made from chicken tallow mixed with crude palm oil. This mixed biodiesel was tested in a 598 cc single-cylinder engine of KUBOTA RT100.The engine was run at different engine speeds ranging from 800 to 2,400 rpm (800 to 2,400 ±50 rpm). Its properties of biodiesel fuel and the performance of diesel engine were examined by using the biodiesel fuel made from chicken tallow and crude palm oil in the ratio of 100:0, 95:5, 90:10 and 85:15 by volume, and then compared with the performance of diesel fuel. The results showed that the torque and brake power of the engine using the mixed fuel were 0.59 – 2.82% and 0.61 – 3.18% lower than the engine using diesel fuel, respectively. However, specific fuel consumption of the mixed fuel was 0.78 – 7.35% higher than the engine using diesel fuel. In terms of engine emission, it was found that the engine using the mixed fuel emitted 15.09 – 18.72% more NO_x than diesel fuel, but 17.13 – 33.82% less CO and 27.58 – 32.18% less CO_2. It could be concluded that the engine using the biodiesel made from chicken tallow mixed with crude palm oil had a lower performance than the engine using diesel fuel but the biodiesel has lower emission compared to the standard diesel fuel.

Key words: biodiesel from chicken tallow, performance of diesel engine, crude palm oil

INTRODUCTION

Nowadays, the world begins to find energy from nature in order to fulfill current energy needs. Thailand is one of those countries that have studied and developed renewable energy for use in the country in order to reduce fuel imports. In 2013, a report showed that energy production in the country had increased at 2.6 percent, compared with the same period last year, and in terms of fuels, the production of diesel fuel was higher than other kinds of fuel, that was 44.4% of total instant fuel production (Energy Policy and Planning Office, 2013). The report has motivated many researchers to find renewable diesel fuel in order to improve the transportation in industrial sector and households, in which diesel fuel is the primary fuel used. Therefore, biodiesel is an interesting product as it can be produced from natural raw materials, such as coconut, palm oil, used vegetable oil, animal fat, etc.

Biodiesel is a fuel made from vegetable oil or animal fat through a chemical process transforming its fatty structure to fatty acid esters which have similar properties to diesel fuel (Dorado *et al.*, 2003) and can be an alternative to petroleum diesel used as fuel in diesel engines without causing damage. Chicken tallow is a material that generally exists in markets,about 30,000 ton of chicken fat is annual produced in Thailand from poultry processing industry (Pangui, 2008) and worth for the production of biodiesel fuel because of its advantages: cheap price, rich source of fat, easier to extract than vegetable oil and thus low cost for oil extraction, low free fatty acids which are very suitable for biodiesel production compared with other plants. In terms of application, in spite of the fact that the biodiesel from chicken tallow has a relatively lower production cost than other types of biodiesel, it has not been very popular in use because a chicken gives a small amount of fat.

Thailand is an agricultural country with high agricultural productivity permitting an abundant choice of materials for alternative energy. Among those materials, vegetable oil and animal fat are important and efficient raw materials used in biodiesel supply. An oil crops in Thailand includes oil palm, coconut, soya bean, Jatropha or Physic nut, Castor bean, etc. Crude palm oil (CPO) is one of raw materials that can be used as an alternative fuel in small agricultural engines. Most agriculturists have no knowledge in the field of biodiesel production. In poverty, to substitute fuel, they often heat CPO before use in their agricultural machinery. (Bari *et al.*, 2002) studied the effect of pre-heat palm oil biodiesel blend flowing through the fuel injector. It was found that heating CPO reduced its viscosity, and rising temperature had no impact on engine performance. In order to avoid clogged fuel, CPO should be heated at 60°C. In an analysis of combustion of CPO compared with diesel fuel, it was found that the palm oil biodiesel pre-heated at 60°C gave maximum 6% of pressure with 2.6% of combustion delay. Hitam and Jahis (1995) studied the use of crude palm oil biodiesel blend on Elsbett diesel engine running for a distance of 80,000 km. The average urban fuel consumption was 8 liters per 100 km. and 7 liters per 100 km. for extra urban. No engine problems were found during the test, with smooth running, continuous fuel feed without bubbles. A teardown examination revealed no negative impacts of the CPO on engine parts.

In this research, the performance and emission of diesel engine using biodiesel fuel made from chicken tallow mixed with crude palm oil were studied. The biodiesel fuel properties of the mixed fuel were tested in a diesel engine that did not have any customization. In this test, the biodiesel from chicken tallow mixed with crude palm oil in three different ratios was used, and the experimental results were compared with the use of biodiesel and diesel fuel in order to determine the impact on the engine and the exhaust pollution emission, and, based on the data obtained, make a decision on the future use

of the mixed fuel in diesel engines.

METHODS

1. Biodiesel from Chicken tallow

For this research, chicken fat was collected from Sakon Nakhon's areas. Methanol with purity of 98.9% and potassium hydroxide (KOH) concentration of 95% were used as the main raw materials to produce biodiesel by the process of Transesterification. Firstly, the chicken tallow was dry rendered at the temperature of 100°C. Before the dry rendering, it looked stiff and lump. But after this process, it gave brownish-clear oil which was then left to cool down to the temperature of 60°C. When the desired temperature was attained, the oil was blended with the mixture of methanol (250 cc. per 1 liter of chicken tallow) and potassium hydroxide (15 g. per 1 liter of chicken tallow) (Pangui, 2008). These three components were stirred until homogeneous. This procedure is called "Transesterification", of which the stirring step must be done in taking into account the time and temperature of reaction. After this step, the stirred compound was exposed to the sun for about 8 hours to get a distinct separation of the biodiesel and glycerol. Next, the glycerol was separated from the biodiesel which was then washed with clean water in order to remove the residual chemicals of the reaction. In this step, 250 cc. of clean water was used for 1L of biodiesel, and the wash was done in 3-4 repetitions. The biodiesel after wash was turbid because of the water remained from the washing process. It was then dehydrated by boiling at 100-110°C until becoming clear yellow. The biodiesel obtained was filtered to remove the precipitates. Then the biodiesel made from chicken tallow was ready to be used.

2. Crude palm oil (CPO)

Crude palm oil (CPO) used in the test was extracted from palm fruit. Degumming process was carried out on the CPO to separate the gums (Oumsapsin, 2012) using phosphoric acid (H_3PO_4) mixed with pure water. In this study, 1 liter of palm oil reacted with 10 ml. of pure water mixed with 1 ml. of phosphoric acid. The temperature of the crude palm oil for the reaction was at 80°C. The mixture was then filtered before being used in the test.

3. Properties of biodiesel made from chicken tallow mixed with crude palm oil

In this study, the biodiesel made from chicken tallow was mixed with crude palm oil (CPO) in 4 ratios: 100:0, 95:5, 90:10, and 85:15 and used to test the engine performance, compared with diesel fuel. But before being tested in the engine, the mixed biodiesel had to be tested for its properties of fuel as shown in Table 1.

EXPERIMENTALSETUP

In this study, the tests of performance and emission of diesel engine were carried out on a 1-cylinder, 598 cc. water cooled engine of KUBOTA RT100 which had not been customized. The dynamometer used in the test to measure the torque of the engine was a water

brake dynamometer of Gimatic dynamometer CTS-400, as showed in Figure 1 and 2. Before each test, the engine was warmed up for about 10 minutes. Then, the torque was measured following the engine speed intended. In these tests, the speeds were set at 800, 1,000, 1,300, 1,600, 1,900, and 2,400 rpm. While measuring the torque, the rate of specific fuel consumption was measured by introducing a self-invented equipment, a kind of 1,000 ml. glass tube, connected to the engine's fuel filter. The fuel consumption at each speed was measured per minute. Furthermore, in the aspect of the engine effect on environmental pollution, an exhaust measuring tool of KANE auto 5-1 was applied at all speeds set simultaneously with the measurement of the fuel consumption rate. The brake power and specific fuel consumption of engine were calculated by the equation 1 and 2, respectively.

$$P_b \text{ (kW)} = 2\varpi NT / 60x1000 \quad (1)$$

$$\text{BSFC (kg/kw.hr)} = m_c/P_b \quad (2)$$

P_b, N and T are brake power, engine speed (rpm) and torque (N.m), respectively. BSFC and m_c are specific fuel consumption and rate of fuel consumption during the given period of time.

Table 1 Properties of fuel

Properties of fuel	Diesel (D)	Ratio of biodiesel from chicken tallow : CPO (by volume)			
		CP 100:0	CP 95:5	CP 90:10	CP 85:15
Heating value (kJ/kg)[a]	40,000	36,710	35,860	35,670	35,050
Viscosity at 40°C (cSt)[b]	4	4.6	4.9	4.97	5.1
Flash point (°C)[b]	80	87.66	88.66	89.33	90.66
Pour point (°C)[b]	87	94.66	94.66	96.33	97.66
PH-value (pH)[b]	5.5	6	6	6	6

[a] Properties were tested at the department of automotive engineering, faculty of engineering, Phanomwancollege of technology, Thailand.

[b] Properties were examined at the department of mechanical engineering, faculty of industry and technology, Rajamangala university of technology Isan Sakon-Nakhon campus, Thailand.

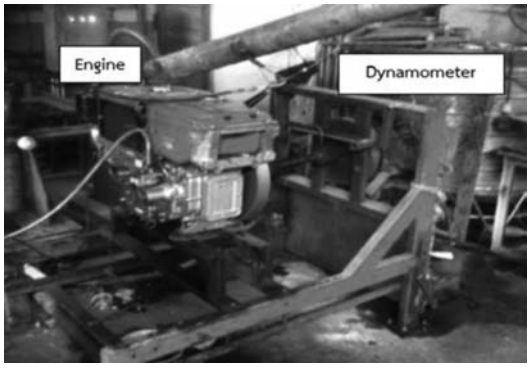

Figure 1 The experimental setup

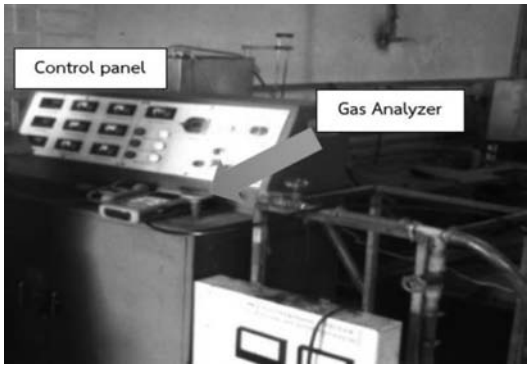

Figure 2 Control panel and exhaust gas analyzer

RESULTS ANDDISCUSSION

1. Performance of diesel engine

From Figure 3 and 4, it is seen that the biodiesel fuel mixed with CPO in different proportions gives a 0.59 – 2.82% lower torque than diesel fuel, and likewise for brake power which is 0.61 – 3.18% lower than diesel fuelwhich is consistent with experiments of Gürü *et al.* (2010). Thus, the performance of the biodiesel is quite lower than diesel fuel. This is because the heating value of the mixed fuel is less than diesel fuel. However, the test results give the conclusion that the biodiesel made from chicken tallow mixed at any proportions with CPO can be used for diesel engines.

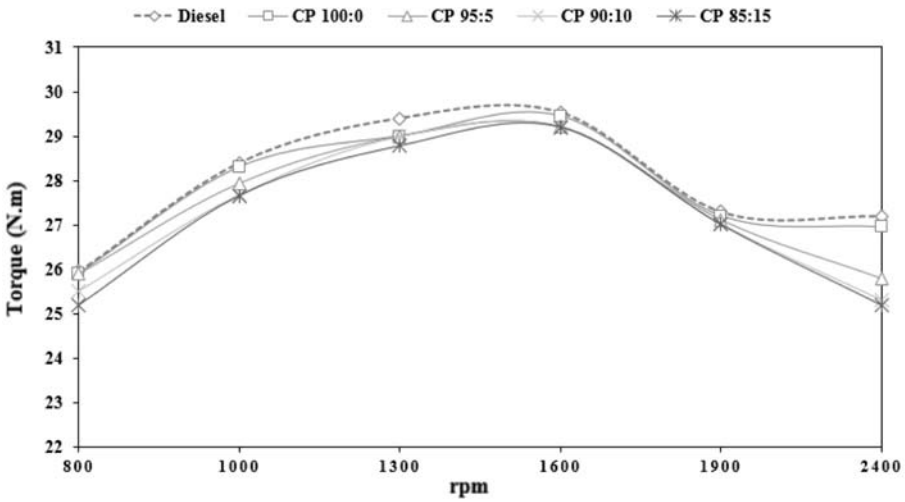

Figure 3 Variation of torque with rpm.

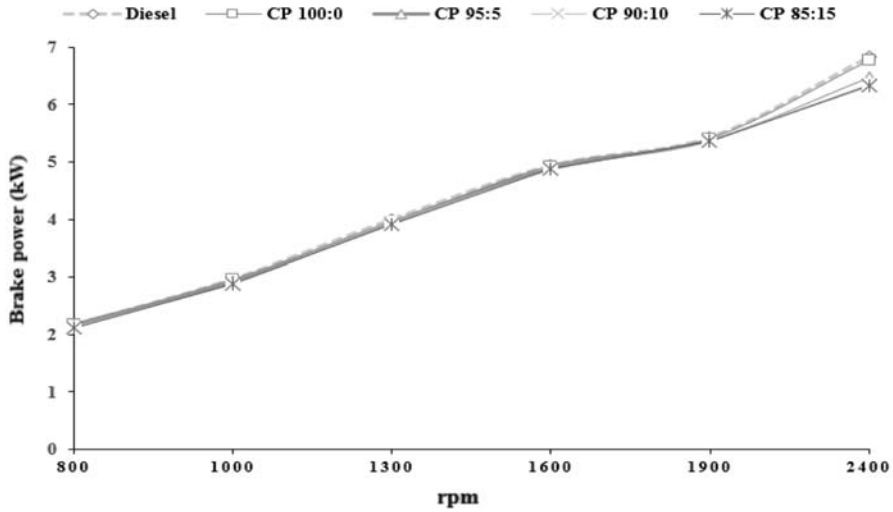

Figure 4 Variation of brake power with rpm.

From Figure 5, the results on the rate of specific fuel consumption of the diesel engine using mixed fuel show that its fuel consumption rate is about 0.78 – 7.35% higher than diesel fuel, and suggests that the fuel consumption rate of the biodiesel made from chicken tallow mixed with CPO is quite high. But empirically to a speed is 800 to 1,300 rpm, the specific fuel consumption is high than a speed is 1,600 rpm which is consistent with experiments of Öner and Altun (2009). This means that the mixed fuel with low heating value and high viscosity has impact on the performance of the engine and its fuel consumption rate as well.

2. Emission of diesel engines

The results of a test, in Figure 6, to find nitrogen oxides show that the engine using the biodiesel made from chicken tallow mixed with

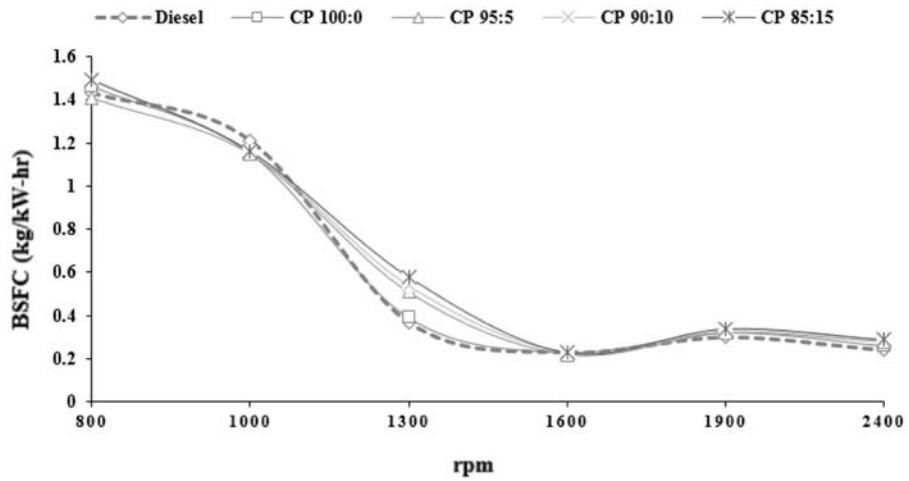

Figure 5 Variation of specific fuel consumption with rpm.

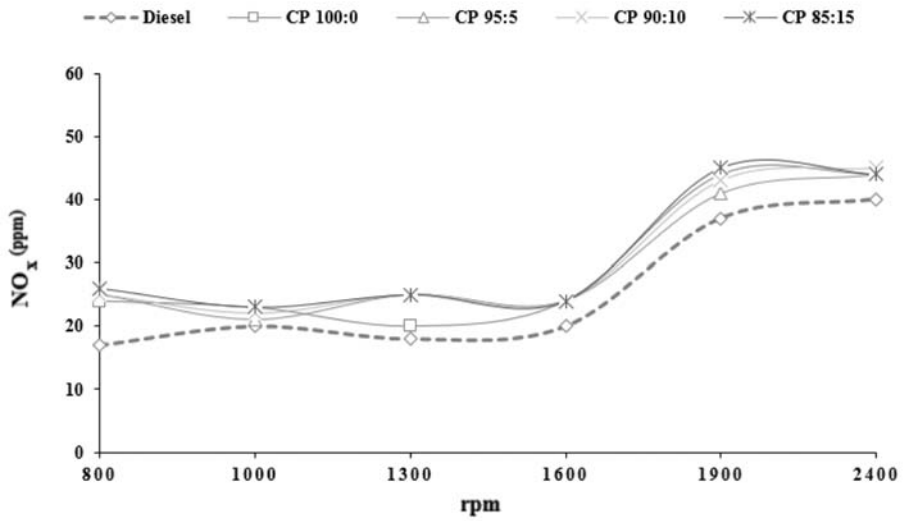

Figure 6 Variation of NO_x with rpm.

CPO gives an approximately 15.09 – 18.72% higher value of nitrogen oxides than diesel fuel. The nitrogen oxides are the result of an excess of oxygen in the mixed biodiesel. This results in air pollution of nitrogen oxides causing breathing difficulty, dizziness and headache in human in case of exposure to a high amount of the gas, and a danger to life in case of a consistent and intense exposure.

Figure 7 and 8 show the results of a test of carbon monoxide and carbon dioxide which indicate that the engine using the biodiesel made from chicken tallow mixed with CPO gives approximately 17.13 – 33.82% lower carbon monoxide and about 27.58 – 32.18% lower carbon dioxide than diesel fuel. This suggests that the mixed fuel contains higher amount of oxygen than diesel fuel. A test of the value of nitrogen oxides indicates that biodiesel contains a high amount of oxygen. This results in a low emission of carbon dioxide and carbon monoxide because the oxygen enhances the engine combustion.

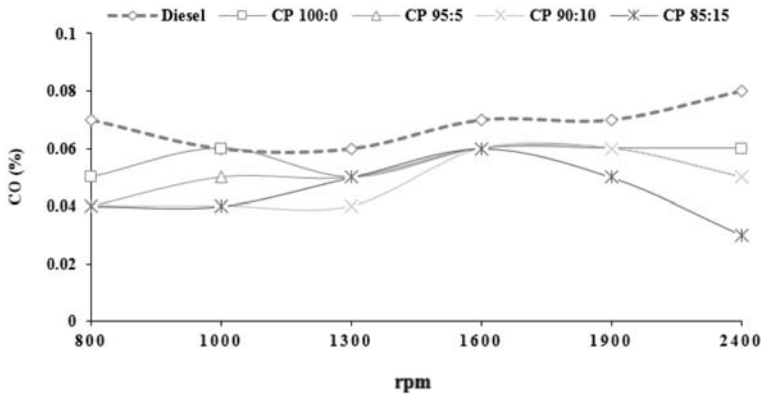

Figure 7 Variation of CO with rpm.

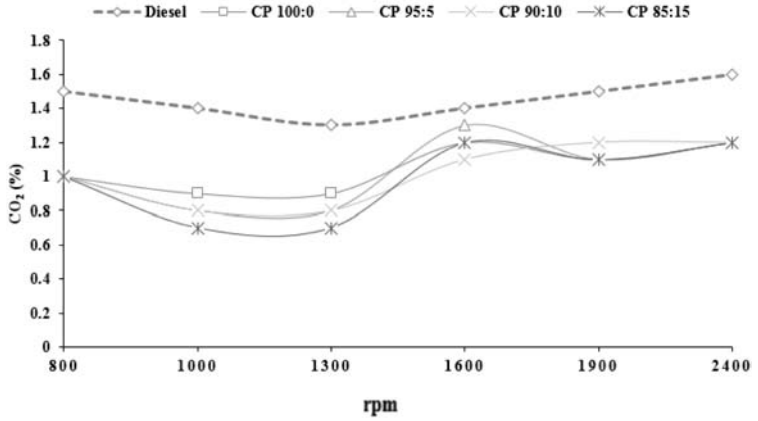

Figure 8 Variation of CO_2 with rpm.

CONCLUSIONS

This research aims to study the performance of diesel engines using the biodiesel made from chicken tallow mixed with crude palm oil. Before being tested in the engine, the mixed biodiesel was examined for the properties of fuel. This showed that the mixed biodiesel fuel had a lower heating value and higher viscosity than diesel fuel. The tests on the performance of the engine indicated that the engines using the fuel mixed in different proportions had an approximately 0.59 – 2.82% lower torque and 0.61 – 3.18% lower brake power than the engine using diesel fuel, while their specific fuel consumption rate was approximately 0.78 – 7.35% higher. From the tests, it was found that the approximate mixing proportion to diesel fuel is CP 95:5, biodiesel ratio CP 95:5 due to its performance were as good as diesel fuel by torque, brake power and specific fuel consumption difference of diesel fuel at the percentage 1.67%, 2.05% and 1.56% respectively, and it can be concluded that a too low heating value of fuel impacted on engine performance whereas a too high viscosity of fuel could cause engine performance as well, which is consistent with experiments of Bari *et al.* (2002).

The tests on exhaust emission revealed that the fuel mixed in different proportions gave a 15.09 – 18.72% higher amount of nitrogen oxides, a 17.13 – 33.82% lower amount of carbon monoxide and a 27.58 - 32.18% lower quantity of carbon dioxide than diesel fuelwhich is consistent with experiments of Sakkampang *et al.* (2013). Biodiesel ratio CP 95:5 due to its exhaust emission were as good as diesel fuel by NO_x, CO and CO_2 consumption difference of diesel fuel at the percentage 15.46%, 24.38% and 28.75% respectively. It can be concluded in terms of exhaust emission that the biodiesel made from chicken tallow mixed with crude palm oil is a fuel that contains a high quantity of oxygen and it causes decreaseemission. It is good for the current world environment.

In terms of used biodiesel from chicken tallow mixed with crude palm oil in engine can be used biodiesel in diesel engine is all ratios. But if you use biodiesel from lard by without mixing diesel fuel the value is a viscosity of fuel is too high to make consequences of engine in long term. Therefore, the researchers recommend to used biodiesel from chicken tallow mixed with crude palm oil in the ratio of CP 95:5 because a performance and fuel consumption of engine with used biodiesel from lard is similar to diesel fuel.

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