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Effect of Volume and Time Process With Hydrogen Adding on Viscosity of Yang Oil

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Abstract

The purpose of this research was to investigate the viscosity in Yang oil which results from hydrogen adding. In the experiment of this research, the volume of oil at 200, 800, and 1400 mL was added to a 2000 mL-sized bottle. The samples of Yang oils were added hydrogen at 1 bar and were stood for 6, 15, and 24 h for 30 ºC. Finally, the viscosity of the treated oils was measured in accordance with ASTM D445. The results showed that the average viscosity of the oil before the hydrogen adding was 4.81 cSt. When treated, the average viscosities on each amount of oils were 4.93, 4.71, and 4.50 cSt, respectively. In addition, the average viscosities on each time were 4.69, 4.73, and 4.72 cSt, respectively. After being treated, the viscosity of the Yang oil was decreased with proper ratio of hydrogen to oil. In contrast, the viscosity was increase because the Yang oil was polymerizations. If the ratio of hydrogen to oil is high, the oil has a higher viscosity.

Keywords: Yang-Na; Yang oil; Viscosity; Hydrogen

Introduction

Energy is a key fundamental factor in living and national development. In the current situation, the demand for energy tends to increase causing more crises in terms of energy sources [1]. There were researched and developed energy from various sources such as solar energy, wind energy, water energy, and energy from biomass [2]. Part of the research and development of fuel is the invention of fuel that can replace diesel. Diesel is an important fuel source for the industry, transportation, and agriculture. Plants oils are used to improve a substitute diesel, which is called "biodiesel", such as castor palm, coconut, and jatropha [3]. Thus, more than 95% of biodiesels are produced from edible oils. If edible oils are produced a fuel in great demand, it will affect a food security of people. Hence, there was research and developing additional fuel source materials that will not affect human food sources [4]. From the local wisdom, the *Dipterocarpus alatus*

(*D. alatus*) resin is used to make a fire for cooking stoves and making torches for use at night. Therefore, there is a study and development to use *D. alatus* resin to be able to be used as fuel [5 – 7].

D. alatus (in the common name "Yang") is a large perennial plant that belongs to the *DIPTEROCARPACEAE* family and found in tropical forests and can occur in almost all areas of Thailand [7, 8]. The Yang oil is extracted from *D. alatus* trees through a process called tapping. The Yang oil is collected by slicing or partially cutting a groove in the bark of the tree using a knife or an ax and peeling the bark or even partially cutting deep into the trunk to make an excavated hole on a tree. The size of the hole is about $15 \times 20 \times 15$ cm^3 and the hole is heated by a fire to stimulate the flow of the resin [5]. The oil that has a turbid, greenish-brown liquid (Fig. 1(a)) flows out and is trapped in an excavated hole. The new method that has been developed is to drill holes into the trunk of the tree in an oblique manner so that the oil flows out and then use a container. In which the obtained oil has physical characteristics divided into two parts. The upper part is a clear liquid with a brownish-orange color and the lower part is creamy sludge (Fig. 1(b)). This method allows the Yang oil have better physical characteristics and does not affect the growth of the plants which will be a dependable and sustainable use of natural energy sources [5]. In the use of Yang oil to be used as biofuel, the preliminary studies had been conducted to develop the production process of biofuel from resin to had efficiency and quality in many ways and found that the distillation method is an appropriate method for the production of biofuels from Yang oil. [5] The distilled oil has a clear yellow color (Fig. 1(c)).

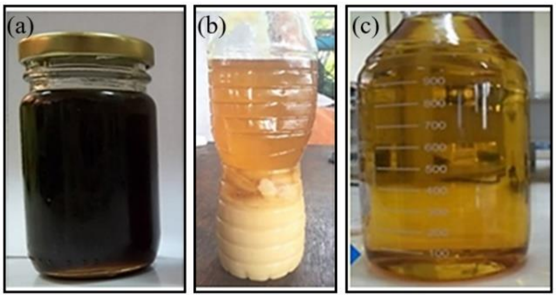

Fig. 1 Physical characteristics of Yang oil (a) Yang oil burned, (b) Yang oil drilled, and (c) Yang oil distilled**.**

A study of the compound in the Yang oil found that the major component is 2 types of *Sesquiterpene*. There were 15 carbon atoms and 24 hydrogen atoms called *alpha-Gurjunene and beta-Gurjunene* (Fig. 2). There were 4 types of secondary compounds that were short-chain hydrocarbon substances group; *short chain hydrocarbon, sterols, terpenes, and terpenoids* [9]. In addition, the oil was subjected to quality analysis results as announced by the department of the energy business, Thailand as shown in Table 1.

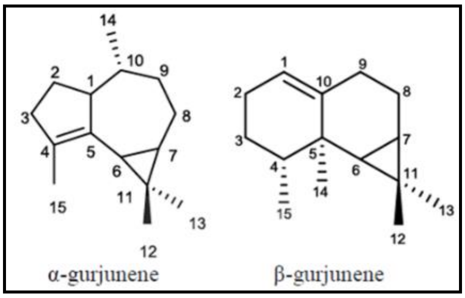

Fig. 2 Molecular structure of Yang oil.

Table 1 Properties of Yang oil.

Property	**Test method**	**Standard Value***	**Yang oil**
Heating Value, kJ kg^{-1}	ASTM D240	-	4.51×10^4
Specific Gravity@ 60F, kg m^{-3}	ASTM D1298	0. 81 – 0.87	0.92
Cetane Index	ASTM D976	>50	27
Viscosity@ 40 ºC, cSt	ASTM D445	1.80 – 4.10	4.70
Pour Point, ºC	ASTM D97	< 10	< –39
Sulfur content, %wt	ASTM D2622	$< 0.05 \times 10^{-1}$	0.00
Copper Strip Corrosion	ASTM D130	< No.1	No.1
Oxidation stability, g m^{-3}	ASTM D2274	< 25	25
Carbon Residue, %wt	ASTM D189	< 0.05	0.00
Water, %wt	EN ISO 12937	< 300	270
Ash %wt	ASTM D482	< 0.01	0.00
Flash Point, ºC	ASTM D93	>52	104
Distillation, ºC	ASTM D86	< 357	257
Polycyclic Aromatic Hydrocarbons, %wt	ASTM D2425	< 11	1
Color	–	Yellow	Yellow
Intensity	ASTM D1500	< 4.00	1.50

* Announced by the department of energy business, Thailand.

From Table 1, it was found that some requirements were still not in accordance with the announcement of the Department of Energy Business such as viscosity. In order to use the Yang oil to work with the engine be used as B100, the Yang oil must be studied to improve the quality with other processes [5].

Previous research had used hydrogen to improve the structure of oil with double bonds in the structure, such as palm oil [10] cotton seed oil [11] sunflower seed oil [12, 13] kapok seed oil [14] Pyrolysis oil from biomass [15, 16]. The work had studied the factors; temperature (25 – 149 ºC), gas pressure (0 – 80 bar), time (6 – 12 h), and catalysts (Platinum, Palladium, Nickel). Narumon's research on the molecular structure of Yang oil shows that the oil molecules had 15 carbon atoms and only 24 atoms of hydrogen, which had double bonds (Fig. 3) therefore keeping the oil in an unstable state [9, 10 – 16]. The researcher was interested in research and development to improve the quality of Yang oil using hydrogen as another method. The introduction of hydrogen inevitably changes the molecular structure of the oil which can change the properties of oil in both positive and negative directions [12 – 15]. Therefore, having to study the condition factors to be suitable so that the Yang oil was stable. It also has improved properties from the reaction. Initially, the researcher has studied the effect of hydrogen on the fuel properties of Yang oil with considering the results of the kinematic viscosity of the Yang oil.

Materials and Methods

The first, the conditions of the determined study factors were the amount of Yang oil (200, 800, and 1400 mL), the setting time (6, 15 and 24 h) after added hydrogen at 1 bar, and the temperature was controlled at 30 ºC. After the amount of distilled Yang oil was measured, it was contained in a 2000 mL-sized reaction bottle (Fig. 3). Then, the air inside the bottle was pulled out with a vacuum until the dial of the pressure gauge and vacuum gauge showed the pressure at -1 bar for 10 min. After that, the hydrogen was filled inside the bottle until the dial of the pressure and vacuum gauge showed the pressure inside the bottle as 1 bar. Next, the bottle was placed in a water bath with temperature control for a specified time (perform all conditions experiments 3 times). When completion of the specified time, the processed oil was taken to measure the kinematic viscosity of oil in accordance with ASTM D445 [17] with the viscosity measuring instrument (Fig. 4(a)). For viscosity measurement, the sample oil was placed in a small glass tube of 20 mL and then soaked in the test oil for 1 h so that the oil temperature was 40 ºC according to the testing standards. After that, the oil in the measuring tube was sucked up by a vacuum suction vacuum which had the edge on the oil above the starting line and let the oil inside the measuring tube flow down. To record the time, time was started when the top edge of the oil was at the starting line and was stopped when that edge comes down to the end line (Fig. 4(b)).

Fig. 3 A 2000 mL-sized reaction bottle contained Yang oil.

The measurement of viscosity was carried out 3 times for each sample and then multiply the average time by the constant value of the small hole glass tube to calculate the viscosity of the oil sample by using the Eq. (1);

$$\mu = C \times t \tag{1}$$

Where μ is viscosity (cSt), C is Glass tube constant, and t is the time of flow through the measurement line (sec.)

When the experiment was complete, take the viscosity obtained from all 3 experiments to calculation the average value. Finally, the effect of hydrogen on the Yang oil viscosity was analyzed from the results both before and after treatment.

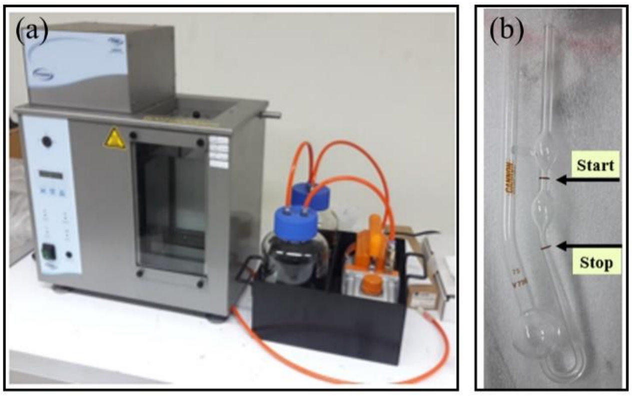

Fig. 4 Viscosity measurement (ASTM D445) apparatus (a) Measuring instrument (b) Tube No.75.

Results and Discussion

The result of observing the physical characteristics and measuring the specific gravity of the Yang oil that has been tested. The oil has the same characteristics and value. After that, the oils in the bottles were used to measure the change in viscosity when the oils were hydrogenated. The viscosity of the distilled Yang oil before the treatment was 4.81 cSt with the recorded time of the Yang oil that was tested. As shown in Table 2.

Table 2 Average time of flow through the measurement line.

Volume of oil (mL)	**Time of placement (h)**	**1st test (sec)**	**2nd test (sec)**	**3th test (sec)**
200	6	675.75	677.04	676.32
	15	683.28	683.55	682.52
	24	680.91	680.43	680.78
800	6	646.37	646.51	645.89
	15	652.27	652.80	652.72
	24	650.21	650.79	650.78
1400	6	616.94	616.73	615.13
	15	623.12	623.05	622.76
	24	620.35	620.64	620.21

Next, the average time is multiplied by 72.53×10^{-4} cSt sec^{-1}. which is the constant value of small glass tube number 75. The average viscosity of Yang oil through experiment and the percentage of the change of viscosity which was different from the viscosity of the Yang oil before the experiment was shown in Table 3 and the comparison results are shown in the chart as shown in Fig. 5.

Table 3 Average viscosity of hydrogenated Yang oil.

time (h)	Volume (mL)	Viscosity of oil (cSt)		
		Experiment value	Predicted value	Abs. Error (%)
6	200	4.91 ± 0.005	4.91	0.03
	800	4.69 ± 0.002	4.67	0.49
	1400	4.47 ± 0.007	4.43	1.00
15	200	4.95 ± 0.004	4.94	0.17
	800	4.73 ± 0.002	4.70	0.63
	1400	4.52 ± 0.001	4.46	1.14
24	200	4.94 ±0.002	4.97	0.61
	800	4.72 ± 0.002	4.73	0.18
	1400	4.50 ± 0.002	4.49	0.30

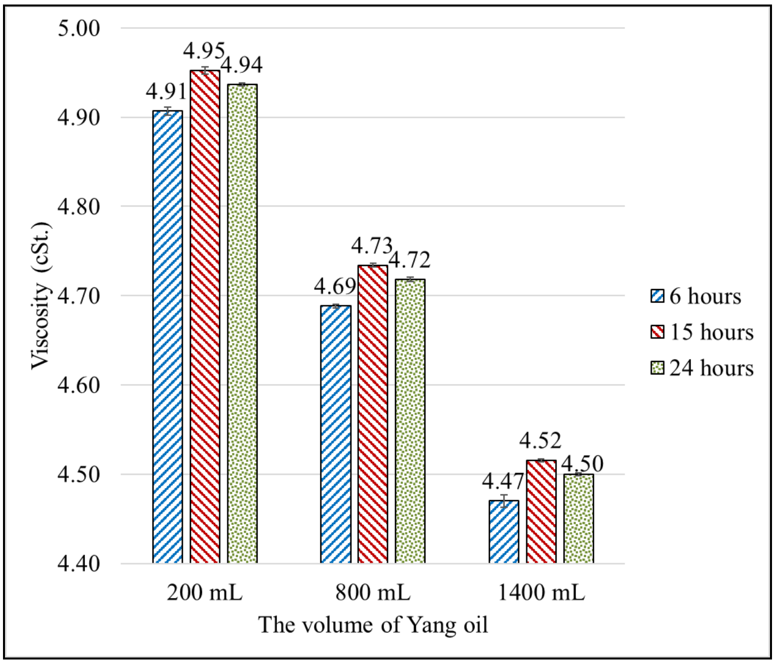

Fig. 5 The viscosity of the Yang oil that has been tested at 1 bar of hydrogen pressure and 30 ºC.

From the results, the average viscosity of Yang oil was determined at the oil content in the same test bottle at different times. it was shown that 200 mL of Yang oil at 6, 15, and 24 h were 4.91, 4.95, and 4.94 cSt., respectively, 800 mL of Yang oil at 6, 15, and 24 h were 4.69, 4.73 and 4.72 cSt., respectively, and 1400 mL of Yang oil at 6, 15 and 24 h were 4.47, 4.52, and 4.50 cSt., respectively. The average viscosity of Yang oil at different times, the viscosity was not that much different that values in the range between 4.69 – 4.73 cSt.

When the viscosity of the oil was determined at the oil content in the test bottle differently at the same time, it was found that at 6 h of 200, 800, and 1400 mL of Yang oil, the average viscosity was 4.91, 4.69, and 4.47 cSt., respectively. For 15 h of 200, 800, and 1400 mL of Yang oil, the average viscosity was 4.95, 4.73 and 4.52 cSt., respectively. For 24 h of 200, 800, and 1400 mL of Yang oil, the average viscosity was 4.94, 4.72, and 4.50 cSt., respectively. The average viscosity value of different levels of Yang oil, the viscosity was different. In the range between 4.50 – 4.93 cSt.

Figure 5 shown that when the amount of hydrogen per oil content was higher, the resulting in higher viscosity values and the oil has a higher chance of polymerization which was consistent with the research of T. Hudayaa et al. [14], and Z. H. Spangler [15]. Moreover, the same time and the amount of Yang oil in the bottle increased causing the viscosity of the Yang oil to decreased. While the same amount but spend more time, the viscosity of the Yang oil was not very different which was consistent with the research of Z.M. Zarins et al. [11], H. Topallar et al. [12], and T. Hudayaa et al. [14]. For the difference in viscosity of Yang oil significantly, the reaction may be required to added time or used a catalyst. From the experimental results, it was able to find the relationship between viscosity, the volume of Yang oil, and time process as in the Eq. (2) ;

$$\mu = (-0.01\times T^2 + 0.64\times T - 0.04\times Q + 495.04)\times 10^{-2} \quad (2)$$

where μ is viscosity (cSt), T is time (6 – 24 h), and Q is volume of Yang oil 200 – 1400 mL.

In order to check the reliability of the derived kinematic viscosity model, Table 3 provides both the experimental and predicted from eq. (2) values. For all examined cases, a practically negligible error of less than 1.20% was established, proving the predictive capability of the model. Fig. 6 expands on the results of Table 3 illustrating the correlation of the predicted viscosity with the experimental results. An R-square value of 0.99 was determined which is believed to be quite satisfactory.

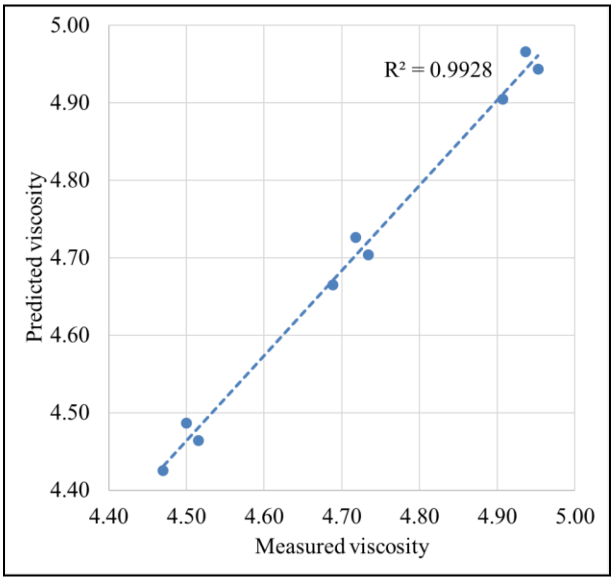

Fig. 6 Predictive capability of the developed model for kinematic viscosity.

Conclusion

From the experimental results, it can be concluded that hydrogen affects the viscosity of the distilled Yang oil. The ratio of the amount of hydrogen to the Yang oil had affected the viscosity, both positively and negatively. In a positive way, the viscosity of the Yang oil was reduced. In a negative way, the viscosity of the Yang oil was increased. By the time that the bottle was installed, it does not significantly affect the viscosity of the Yang oil. If the improving quality of the Yang oil process had a suitable proportion between hydrogen and Yang oil, the process will result in a better quality of the viscosity of the Yang oil. In the next step, the study of the ratio of hydrogen to the amount of distilled Yang oil must be studied. The viscosity of the Yang oil must be produced according to the standard of the Department of Energy Business announcement. The study of the duration of the bottle setting increased while also studying other factors such as the pressure of hydrogen and the temperature during the experiment in the form of adding hydrogen to the Yang oil distillation and using catalysts in the process. Including, the effect of hydrogen on the specifications of other oil quality requirements to be used as information in the development and design of the process to improve the quality of Yang oil. The Yang oil can be used as fuel directly to the engine. The counties have a domestic energy reserve resources and a reduce energy. In addition, it also helps citizen who realize about benefits of the conservation of natural resources and the Yang tree. Aside from the use of Yang wood alone, but the benefits were increased by being a fuel source. Farmers can produce and use in the agricultural which will lead to energy self-reliance that is available in their communities.

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