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The Study of Physicochemical Properties of the Yang – Na (*Dipterocarpus Alatus*) Oil for Use as a High Potentiality Feedstock to Produce Liquid Biofuel in Thailand

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Abstract

In this study, the distilled Yang – Na oil was investigated the physicochemical properties for use as the biofuels substituted petroleum diesel oil. Gas chromatography – mass spectrometry (GC – MS) and Fourier transform infrared spectroscopy (FT–IR) were applied to characterize the chemical composition and to prove the chemical structure of the distilled Yang – Na oil. The results indicated that the distilled Yang – Na oil is a hydrocarbon compound which is a sesquiterpene group. To study the thermal decomposition by the thermogravimetric analysis (TGA) technique revealed that the distilled Yang – Na oil has completely combustion in the rage of ~450 – 500 °C with similar to petroleum diesel oil. Furthermore, the heating values and the fuel properties of the distilled Yang – Na oil also illustrated to meet with the qualifications of liquid bio-auto fuel both the ASTM D6751 and EN 14214 standard. Thus, the distilled Yang – Na oil is one of the attractive choices for development into feedstock as an alternative liquid biofuel in Thailand due to it has a large amount, has high properties suitable, and has high efficiency for using into the diesel engine.

Keywords: Renewable energy; Distilled Yang – Na oil; Physicochemical properties; Characterization

Introduction

Biomass material is one of the renewable energy sources which have a high potential for substituting the energy from the fossil fuel source [1, 2]. Thailand is one of the large agriculture countries and there are several biomass materials sources for produced renewable and clean energy which was covers solid, liquid, and gas energy sources such as biomass charcoal, bioethanol, biodiesel oil, and biogas [3 – 5]. The high potential sources of biomass in Thailand, such as oil palm fruit and other oil crops (together with cassava, cane, scrap leaves, trees, straw, and agricultural wastes like dung), are reachable and low-cost. In this case, they can be used as raw material sources to generate the energy both of industrial scale and community scale for energy self-sufficiency of the country.

Focusing on the liquid biofuel, it is generally known that can replace petroleum oil namely bioethanol and biodiesel [6]. The issue of alternative energy sources to substitute petroleum diesel fuel is a topic that has received a lot of attention in the present because petroleum diesel fuel has a lot of use and it is involved in the industry, agriculture, and transportation [6, 7]. Edible and non-edible oils were utilized for biodiesel production to directly use with diesel engines or blending against petroleum diesel oil [8]. Cassava and cane were used to produce bioethanol applied with gasoline engines by mixing with gasoline oil to derive gasohol (ethanol 10%), E 20 and E 85 (ethanol 20% and 85%, respectively). However, each area has different sources of raw materials and technology for producing liquid fuel energy. Therefore, many studies have emphasized on high potential, available, low – cost, easily – generated (low – technology) and environmentally friendly feedstocks.

In the rural area of Thailand, especially the province in the northeast, such as Ubon Ratchathani, Sakon Nakhon, and Khon Kean, there is a raw material with high potential to utilize for liquid fuel energy, that is Yang – Na oil. Yang – Na (*Dipterocarpus alatus* Roxb. ex. G.Don) is normally known as a large tropical forest tree and widely distributed in Southeast Asia, such as Thailand, Laos, Cambodia and Philippines [9]. Yang – Na is another plant that is able to produce oil (Yang – Na oil). H. Dyrmose et al. [10, 11] studied the oil yields from Yang – Na in Cambodia and they estimated the average oil yield of 27.00 – 32.50 liter per year which collected from 100 Yang - Na trees that were about 50 cm diameter. The traditional method for collected Yang – Na oil is processed by notching trunk to be a large hole and then stimulated with heat urged by fire. This technique was presented in a report by H.T. Luu and F. Pinto [12] and S. Poojeera [13]. In current, Khon Kaen University, Thailand applied a new method to collected Yang – Na by using an electric drill to pierce the trunk with depth 2 of the 3 part of the tree and without heat stimulation [13, 14]. This method can preserve the wood from being damaged by heat.

Thus, the objective of this work was to report the physicochemical properties of the crude Yang – Na oil and the refining Yang – Na oil comparing with petroleum diesel oil and waste cooking oil biodiesel. The data of this research are expected to be very useful for considering the use of Yang – Na oil in terms of renewable energy to substitute petroleum oil for especially in the rural area communities of Thailand.

Materials and Methods

The Materials Preparation

In this research, the Yang – Na trees used in the study are in the area of the Khon Kaen University and Sakon Nakhon Rajabhat University. The crude Yang – Na oil was obtained by an electric drill of trunk Yang – Na trees with the depth of 2 of the 3 parts and collected with the container without burning the tree as shown in Fig. 1 [13]. The refining Yang – Na oil was obtained from Khon Kaen University by simple distillation around 280 °C as depicted in Fig. 2 [14]. The biodiesel product was obtained from waste cooking oil as raw material by using a prototype solar reactor following the report of S. Inthachai, and W. Roschat, [15]. Petroleum diesel oil was purchased from the general gas station in Sakon Nakhon province.

Fig. 1 The process of collecting Yang – Na oil by using an electric drill to pierce the trunk of Yang – Na.

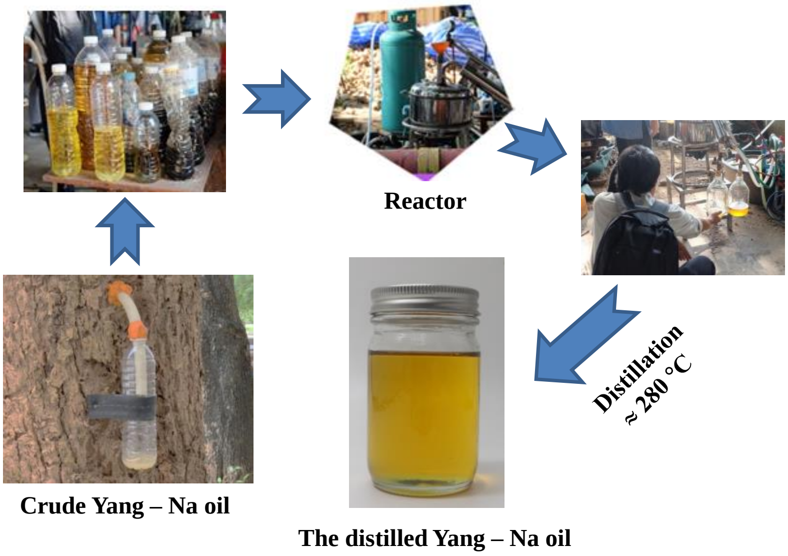

Fig. 2 The process for distillation of the crude Yang – Na oil by using the distilled reactor.

The Materials Characterization

Gas chromatography – mass spectrometry (GC – MS) on a CP-3800 Varian was employed to analyze the chemical composition of the distilled Yang – Na oil which analyzed by Laboratory Service Unit (LSU), Suranaree University of Technology, Thailand. Thermogravimetric analysis (TG) was carried out on a Rigaku TGDTA 8120 thermal analyzer under air flow condition with a temperature ramp rate of 10 °C min^{-1} to determine the thermal decomposition of the crude Yang – Na oil and the distilled Yang – Na oil. Perkin-Elmer Spectrum Two FT – IR was applied for the characterization of the various functional groups in the chemical compound of distilled Yang – Na oil. In this study, the heating value of all liquid fuel was performed by using Automatic Bomb Calorimeter LECO AC – 350. The fuel properties following the ASTM D6751 and EN14214 standard of the distilled Yang – Na oil compared with waste cooking oil biodiesel and petroleum diesel oil were tested by the Materials for Energy Research unit, the National Science and Technology Development Agency, Thailand.

Results and Discussion

Characterization of the Distilled Yang – Na Oil

Gas chromatography – mass spectrometry (GC – MS) was used to analyze the chemical composition of the distilled Yang – Na oil as shown GC – MS mass spectrum in Fig. 3. The GC – MS mass spectrum result indicated that the chemical composition of the distilled Yang – Na oil consists of the α – Gurjunene as a major component (60.70 wt%), β – Gurjunene (22.30 wt%), and the minor product namely Allo – aromadendrene (4.60 wt%), γ – Gurjunene (4.40 wt%) and other compounds (8 wt%), respectively. Additionally, the chemical structure of distilled Yang – Na oil was also depicted in Fig. 4. This result indicates that the major chemical composition of the distilled Yang – Na oil was the sesquiterpene group as a hydrocarbon compound. These data were compared with the reference standard compounds against the databases and also accorded with the report by S. Poojeera et al., [13] and C. Suiuay et al., [14].

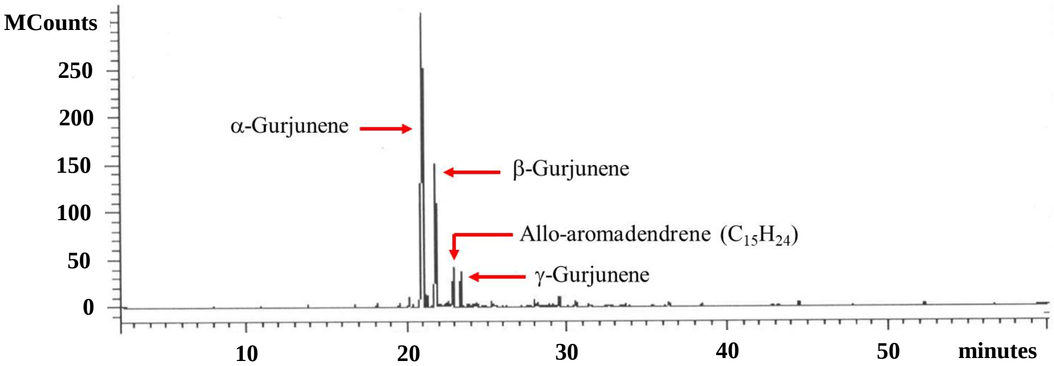

Fig. 3 GC – MS mass spectrum of the distilled Yang – Na oil.

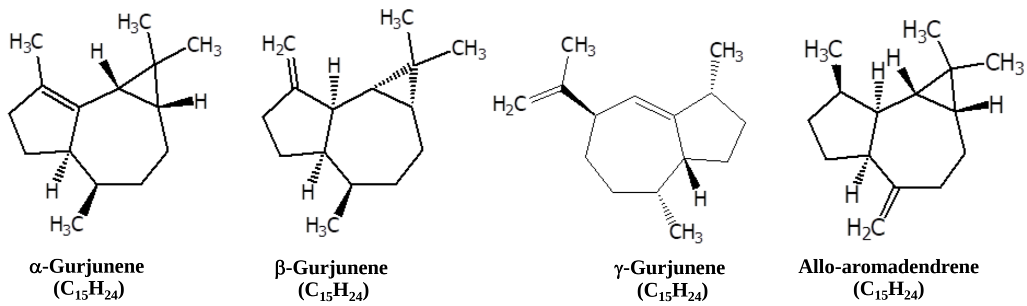

Fig. 4 The chemical structure of distilled Yang – Na oil.

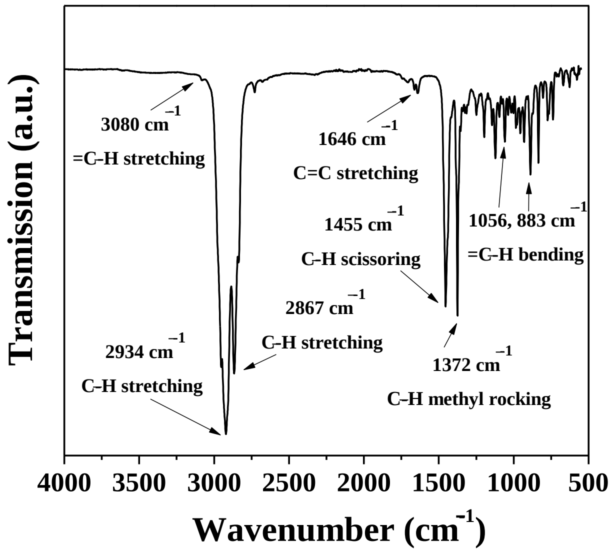

Fig. 5 FT–IR spectrum of distilled Yang – Na oil.

Fourier transform infrared spectroscopy (FT–IR) was applied to determine the various functional groups in the chemical compound of distilled Yang – Na oil and the FT–IR spectrum were shown in Fig. 5. The result found that the spectrum of distilled Yang – Na oil comprised only the hydrocarbon group because a strong peak stretching of the carbonyl group (C=O) in the range of 1650 – 1820 cm^{-1} disappeared. Furthermore, the hydroxyl group (O – H) stretching which was the strong and broad peak at 3200 – 3600 cm^{-1} was not found in this FT–IR spectrum. Not only the carbonyl and hydroxyl group that did not show in the FT–IR spectrum, in this case, but also included C–O functional group which would be stretching as a strong peak in the range of 1000 – 1300 cm^{-1}.

As shown in Fig. 5, the hydrocarbon compound peak of the distilled Yang – Na oil consist of a strong C–H stretching in $-CH_2-$ and $-CH_3$ functional group at 2934 and 2867 cm^{-1}, respectively. The C–H scissoring vibration of $-CH_3$ and $-CH_2-$ groups met at a wavenumber of 1455 cm^{-1} and C–H methyl groups ($-CH_3$) showed rocking vibration peak at 1372 cm^{-1}. Additionally, the FT–IR spectrum were also illustrated weak peak of C=C alkene group stretching vibration at 1646 cm^{-1}. While =C–H stretching and bending vibration were observed at 3080 cm^{-1}, 1056 cm^{-1}, and 883 cm^{-1}, respectively. These results confirm that the distilled Yang – Na oil was the hydrocarbon compound as a sesquiterpene group and accorded to the data of GC – MS.

Thermal Decomposition of the Distilled Yang – Na Oil

Thermal decomposition of fuels is one of the important factors in terms of combustion in engines and pollution resulting from incomplete combustion. Several research reports have found that the temperature in a cylinder of the engine is around 800 °C occurred from the process to compress air without the fuel inside the cylinder [16 – 18]. In this work, the thermogravimetric analysis (TGA) technique was applied to test the thermal decomposition of both the crude Yang – Na oil (raw material) and the distilled Yang – Na oil which the results were shown in Fig. 5 (a) and (b). The thermogravimetric curve of the crude Yang – Na oil as the raw material (Fig. 5 (a)) has shown the decomposition consist of 3 phases namely the range of room temperature to ~250 °C, ~250 – 450 °C, and completely decomposed at ~450 – 500 °C, respectively. This result can be explained that the crude Yang – Na oil is not purity due to it may be contaminated with some substances such as moisture, triglyceride, fat or gum resin, and other organic compounds [13, 14].

On the other hand, distilled Yang – Na oil showed weight loss significantly at ~200 °C which has a mass loss of over 90% and completely decomposed at ~500 °C. This result confirms that the distilled Yang – Na oil is a green liquid fuel because the combustion within the engine is completely as less than 800 °C. Furthermore, the comparison of combustion temperature between the distilled Yang – Na oil of this work against petroleum diesel fuel from several reports, the result showed that there were similarities approximately 200 – 300 °C [19, 20]. For this reason, the use of the distilled Yang – Na oil as renewable fuel with diesel engines especially the low–speed diesel engines (agricultural engines) is possible in terms of using only the distilled Yang – Na oil or blending with diesel oil.

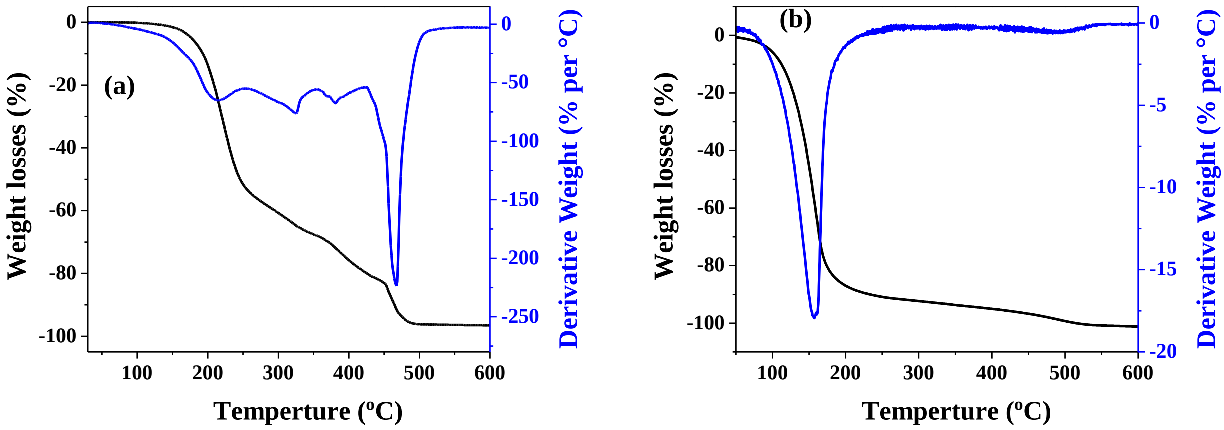

Fig. 6 The thermogravimetric curve of (a) Yang – Na oil as raw material and (b) the distilled Yang – Na oil.

The Heating Value of the Distilled Yang – Na Oil

The heating value of liquid fuel is the amount of heat released during its combustion in the engine. In this case, the bomb calorimeter was used to analyze the heating value or heat of combustion of the distilled Yang – Na oil comparing with waste cooking oil biodiesel, palm oil biodiesel, and petroleum diesel oil. As shown in Fig. 6, the heating value of petroleum diesel oil showed a higher value than biodiesel oil produced from waste cooking oil and palm oil, and the distilled Yang – Na oil. The results of this study were similar to the reports of Keera et al. [8], Poojeera et al. [13] and Roschat et al. [19]. However, when considering the distilled Yang – Na oil, it was found that the heating value was higher than biodiesel oil and closer to diesel oil. This may be the chemical structure of the distilled Yang – Na oil is a hydrocarbon compound similar to diesel oil. For this reason, the efficiency of to use the distilled Yang – Na oil with the engine was similar to petroleum diesel oil and they can be effectively used as a high potential alternative and renewable energy for the people in rural areas especially in the northeast of Thailand which has a large amount of raw materials.

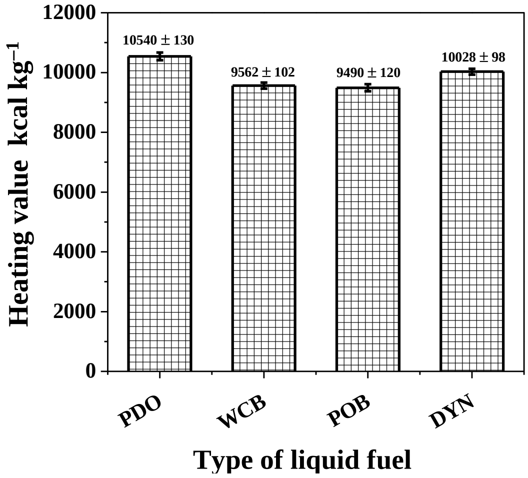

Fig. 7 Comparison of the heating value of liquid fuel; PDO = petroleum diesel oil, WCB = waste cooking oil biodiesel, POD = palm oil biodiesel, and DYN = distilled Yang – Na oil.

Table 1 Physicochemical properties of the distilled Yang – Na oil, waste cooking oil biodiesel, and petroleum diesel oil.

Properties	Waste cooking oil biodiesel	Distilled Yang – Na oil	Petroleum diesel oil
Kinematic viscosity at 40 °C (cSt)	4.53	4.12	2.50
Density at 15 °C (kg m^{-3})	880	923	835
Cloud point (°C)	6	<–10	–4
Pour point (°C)	–1	<–10	–4
Oxidation stability (h)	12.80	13.50	>18
Total acid number (mg KOH g^{-1} oil)	0.28	0.12	0.02
Flash point (°C)	187	122	90
Water content (wt%)	0.02	0.01	<0.01
Copper strip corrosion (number)	1a	1a	1a

The Fuel Properties of the Distilled Yang – Na Oil

The physical and chemical characteristics of the distilled Yang – Na oil compared with waste cooking oil biodiesel and petroleum diesel oil were presented in Table 1 as followed with ASTM D6751 and EN 14214 which was the qualification standard for biodiesel oil (biodiesel oil 100% (b 100), without any blending) [21 − 23]. The data showed that the fuel properties of kinematic viscosity as a major property involved the resistance of oil to flow and directly affected to spraying oil in the engine was in compliance with the required standard for liquid fuel. Additionally, other properties namely cloud point, pour point, oxidation stability, total acid number, flash point, water content, and copper strip corrosion were within the range of liquid fuel standard both of ASTM and EN standard for bio-auto fuel and similar with waste cooking oil biodiesel and petroleum diesel oil. However, it was found that the density of the distilled Yang – Na oil was still higher than the standard criteria (860 − 900 kg m^{-3}). This problem can be solved by mixing the distilled Yang – Na oil with petroleum diesel oil or biodiesel oil in order that the density met the liquid fuel standards. Consequently, the information about the liquid fuel characteristics of the distilled Yang – Na oil represented the efficiency and potential to be used as a substitute for petroleum diesel oil which was the one choice for developing renewable and clean energy of Thailand to move forward.

Conclusion

In summary, the research on the use of distilled Yang – Na oil as alternative energy can be concluded that the chemical composition of the distilled Yang – Na oil was the hydrocarbon compound that consists of the α – Gurjunene and γ – Gurjunene as a major component. Furthermore, the fuel properties of the distilled Yang – Na oil were also within the recommended standards for bio-auto fuel both ASTM and EN standard. Therefore, it is highly possible to use the distilled Yang – Na oil with agricultural engines to replace diesel fuel due to both the results of decomposition and the heating value of them was similarly against petroleum diesel oil. For all these reasons, the oil from the Yang – Na trees is one of the attractive alternatives raw materials because they are highly efficient and have extremely the potential to be used for liquid fuel source of Thailand.

Acknowledgements

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