Enhancing the yield and quality of Kemiri Sunan crude oil by preliminary extraction of feedstock

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Abstract Biodiesel is an alternative fuel produced by chemical reaction between vegetable oil or animal fat with alcohol and catalyst. The preliminary treatment in extraction of biodiesel feedstock is an important process to obtain maximum yield of crude oil. This study aims to find optimal preliminary treatment on extraction of Kemiri Sunan seed in order to produce crude oil with maximum yield and quality. The research investigated the effects of screw press machine rotation and duration of steaming process. Three levels of duration of steaming used were 30, 60 and 90 minutes. Observations of crude oil yield, moisture content, free fatty acid content, kinematic viscosity, density and color were done. The result suggested that the rotation of screw press machine affected the crude oil yield. The duration of steaming process affected the oil yield, free fatty acid content, kinematic viscosity, density and color. The best oil yield result of 70.3% was obtained from the combination of heating duration of 60’ and screw rotation of 25 RPM.

Keywords. Biodiesel; Kemiri Sunan; Screw Pressing Machine, Extraction

1. Introduction

Fuel consumption in Indonesia is increasing year by year, mainly contributed by the transportation sector. In 2000, diesel oil consumption had the largest share (38.7%) followed by kerosene (23.4%), gasoline (23.0%), fuel oil (9.6%), diesel oil (3%), and avtur (2.2%). However in 2014, there was a change in fuel consumption order which became gasoline (45.5%), diesel oil (45.2%), avtur (6.3%), and kerosene and fuel oil each at 1.5%. This change of pattern was due to the high rate of fuel consumption for private vehicles and aircraft. Fuel consumption in the transportation sector has a very high share of 79.7% of the total fuel consumption. [1]
The main fuel used so far in Indonesia is fossil-based fuel, where this fuel is a non-renewable material because it takes a very long time to be formed. Furthermore, fossil-based fuel is also a potential cause of environmental problems, such as global warming. Therefore, the use of plant-based fuel as an alternative can reduce the use of fuels made from fossil.

Biodiesel is a fuel which uses raw materials originally from vegetable oils or animal fats which are reacted with alcohol and catalysts. Biodiesel can be used as an alternative diesel fuel for diesel engines. It has various advantages over petro diesel, both as a mixture with petro-diesel and as pure fuel. The advantages of biodiesel as a fuel, among others, are it is produced from renewable raw materials and can be used on most diesel engines without any modification [2]. Biodiesel is more environmentally friendly because it can decompose in nature, non-toxic, has high efficiency, small exhaust emissions, and low sulfur and aromatic content [3].

Currently, the main biodiesel raw material in Indonesia is made from palm oil. In the economic scale, this plant is the most preferred. This can be seen from the vast area of oil palm plantations in Indonesia which reaches 12.5 million hectares with the production of 35 million tons of CPO [4]. Palm oil is edible source, the use this material for biodiesel will compete with the need for food. Therefore, the development of biodiesel feedstock should be based on non-edible sources. One potential source of vegetable oil for biodiesel feedstock is Kemiri Sunan (Reautealis trisperma). Kemiri Sunan plants can be found in various parts of Indonesia, but the community has not maximally used this plant. The part of Kemiri Sunan plant which is potential as a biodiesel feedstock is its seed. Not only Kemiri Sunan is a non-edible oil material, so it will not compete with the use for food, it also has the highest productivity per hectare among other biodiesel sources [5].

Oil extraction from Kemiri Sunan seeds to obtain crude oil can be done with four basic methods: chemical extraction (using solvents or enzymes), supercritical fluid extraction, steam distillation and mechanical extraction [6]. Mechanical extraction and solvent extraction are the most commonly used methods for commercial oil extraction. Mechanical pressing is used for oil recovery up to 90-95%, solvent extraction is capable of extracting 99% [7]. But solvent extraction method has several disadvantages, such as the equipment required is very expensive, the process is quite dangerous correlating with fire and explosion, and the solvent used requires a specific process before proceeding to the next process [8]. Mechanical extraction is a common method used to extract oil from seeds, because this method is effective for seeds that contain 30-70% oil [9]. Mechanical extraction has several advantages compared to other methods, such as it uses simple equipment, low investment, low operating costs, and the oil does not undergo a solvent separation process [10].

The type of machine commonly used in the mechanical press method is the hydraulic press machine and screw press machine / expeller pressing. The hydraulic press machine is classified as a batch mechanical press machine while the press screw is considered as a continuous pressing machine [11]. Several studies have shown that the use of screw press is more efficient than hydraulic press [7,12,13,14]. The use of expeller screw press showed that the optimum yield was obtained at screw speed of 10 rpm [13]. The highest recorded percentage of oil yield was obtained from the combination of screw shafts with diameter of 8 mm, rotational speed at 21 rpm and nozzle size of 6 mm [14].

Several studies have shown that preheating and drying the seeds before extraction can improve the quality and recovery of oil [15,16]. Steaming and microwave heating methods appear to be the most suitable techniques. Both methods highlighted improving oxidative stability, while steaming seemed to cause less formation of free fatty acids than microwave heating [17]. Furthermore, heating can coagulate the protein in the material and reduce the viscosity of the oil, which in turn makes the oil easily released. In addition, heating can cause oil affinity with the material surface to be reduced resulting in maximum oil recovery[18].
Based on the above background, the purpose of this study is to investigate the combination of Kemiri Sunan seed heating duration and the rotation speed of the screw press which results the best oil yield and physicochemical properties of Kemiri Sunan oil to determine the potential of Kemiri Sunan oil as biodiesel feedstock.

2. MATERIALS AND METHODS

Equipment used in this study includes screw press machines with 2 KW power, steamer, oven, scales, filter cloth, filter paper, bottles, furnaces, measuring cups, pycnometers, and viscometers. Kemiri Sunan seeds were obtained from Kemiri Sunan plantations located in the green belt of Gajah Mungkur Dam in Wonogiri and some were also obtained from Kemiri Sunan farmers in Limbangan, Garut, West Java.

Kemiri Sunan seeds were collected by peeling the Kemiri Sunan fruit mechanically using a breaking device. The seeds were broken down to get the kernel. The kernel was then heated in steamer on a variety of heating periods. The temperature set was 100°C, while the variation in heating duration were 30 minutes, 60 minutes and 90 minutes. After steaming, the Kemiri Sunan seeds were measured for their water content. In addition, there were also seeds without any heating treatment prepared as a control. The next stage was extraction with a screw press machine with a rotation variation of 10 RPM, 25 RPM, and 40 RPM. The extraction process was carried out 3 times until there was no more oil coming out. The extracted oil was then filtered using filter paper and the yield was calculated by comparing the amount of oil produced with the raw material processed. The crude oil produced were then analyzed for the physicochemical properties. The properties analyzed were acid numbers, free fatty acids, viscosity, density, water content, and specific gravity.

![Hole cylinder press of a KOMET oil expeller](image-url)
3. Results and Discussion

3.1. Oil Yield

Oil yield is one of the parameters used to determine the amount of oil produced from Kemiri Sunan seeds. The yield was calculated by comparing the amount of oil produced with the amount of raw material of Sunan seeds that were processed.

The test results showed that the oil yield from Kemiri Sunan seeds without heating (control) ranged between 28.2-35.3% with an average value of 32.2% (Figure 3). The lowest yield was generated at 10 RPM. The highest oil yield was obtained in the combination of seed heating duration of 60 minutes and screw rotation speed of 25 RPM, resulting in the value of 70.3%. In general, the yield is higher in seeds that are subjected to heating treatment than those that are not (control). This is due to the heating of the oil-containing material which will clump the protein on the cell wall, so that at the time of pressing it will remain in the cake. Besides, oil in the cake is a mixture of emulsions between oil and protein. Clotting of the protein causes the emulsion to rupture, thus facilitating oil discharge [19].

The results analysis showed that the heating temperature, heating duration, and the interaction of both influenced the yield of Kemiri Sunan. Figure 3 shows that the longer the heating of Kemiri Sunan seeds, the lower the oil yield obtained. This was due to the decrease of water content in the shell and kernel as a result of the increasing temperature and longer heating duration of Kemiri Sunan seeds Therefore, some of the oil was trapped in the shell of the Kemiri Sunan seed [18].

Figure 3 also shows that the percentage of oil yield decreased when the rotation speed was higher (40 RPM). This might happen since the pressure that occured at this speed was too high or above optimal pressure, which might increase heat production as a result of higher friction between the seeds and the screw. Increasing heat to a certain level will reduce seed moisture content. Low moisture content will not be able to help in breaking or cracking of the seed shell, which results in a decreased percentage of oil yield [14]. The decrease of oil yield percentage along with an increase in screw speed rotation is also possible because of reduced residence time. Thus, there is less chance for oil
to flow out of the pressing chamber [20]. Screw rotation speed may also affect oil yield. Slow speed may extend the pressure of the process and result in increasing heat in the machine [21].

The results showed that acid number of 58.83 was obtained from the seeds without heating treatment and 13.57 from the seeds with treatment. It indicates that the heating temperature and heating duration had an effect on the acid number of Kemiri Sunan seed oil. Higher acid number in seeds without heat treatment is due to higher water content. Seeds that have high water content will produce oil that has a high moisture content and will be easily hydrolyzed [19]. In addition, it was also suspected to be caused by the high activity of enzymes and microorganisms that catalyze the oil hydrolysis process [18].

Furthermore, all enzymes belonging to the lipase group which are able to hydrolyze fat is inactive by heat. Meanwhile, the low acid number resulting from the heating treatment level was predicted to be caused by the low activity of the lipase enzyme in the presence of heating, so that the ability of the enzyme to break down triglycerides into fatty acids and glycerol becomes low. In addition, it may also be caused by the smaller level of water suspended with oil so the hydrolysis process runs slower.

3.2. Acid Number

Acid number is one of the parameters that determine the quality of oil. Measurement of acid number shows how much free fatty acid is contained in oil due to the hydrolysis process. The higher the acid value of oil, the higher the level of damage because the number of triglyceride molecules that are hydrolyzed is also higher. Thus, the quality of the oil will be lower. The hydrolysis process is the opposite of triglyceride synthesis. In hydrolysis reactions, glycerol molecules are also produced in addition to free fatty acids. The formation of free fatty acids in oil can occur due to processing (preparation of materials). The hydrolysis process can take place when the oil is still in seeds, during processing, and storage. Vegetable and animal fats usually contain enzymes that can hydrolyze fat [18].

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3.3. Free Fatty Acids (FFA)
Measurement of free fatty acids aims to determine the level of hydrolytic damage in the oil. Usually the level of free fatty acids are expressed as acid numbers, acid levels, or acid levels. In this study, the level of free fatty acids contained in oil is expressed in percentage obtained from the conversion of acid numbers divided by conversion factors for linoleic fatty acids. That is because the most free fatty acids found in Kemiri Sunan seed oil are linoleic acid [15]. The percentage of FFA obtained from this study was 16.62% for seeds without heat treatment and 0.21% for seeds with heat treatment. Thus the heating treatment significantly decreased the percentage of FFA in oil. This free fatty acid content has a major effect on the process of making biodiesel. FFA content of 3 mg KOH / gr and higher will cause the process of making biodiesel go through the esterification stage. Whereas if it is lower than 3 mg KOH / gr, the process of making biodiesel goes directly to the transesterification process [15].

Table 1 Chemical dan Physical Characteristic of Crude oil Kemiri Sunan

| No  | Properties                  | Original crude oil | Steamed crude oil | Unit     | Method       |
|-----|-----------------------------|--------------------|-------------------|----------|--------------|
|     | Acid Number                 | 58.83              | 13.57             | mg KOH/gr| Volumetri    |
|     | Free Fatty Acid             | 16.62              | 0.21              | %        | Volumetri    |
|     | Water content               | 0.24               | trace             | % Vol    | ASTM D95     |
|     | Specific Gravity            | 0.9289             | 0.9273            | -        | ASTM 1298    |
|     | Density at 15°C             | 0.279              | 0.9273            | gr/ml    | Calculated   |
|     | Kinematic Viscosity at 40°C | 67.26              | 64.73             | mm²/s    | ASTM D 445   |
|     | Color                       | Dark Brown         | Yellow            |          |              |

4. Conclusion
It can be concluded that the combination of Kemiri Sunan seeds heating treatment and rotational speed of screw press produces better oil yield and acid number compared to seeds without any heating treatment. The highest oil yield of 70.3% was obtained in a combination of heating for 60 minutes and screw rotation speed of 25 RPM. Acid Number of 13.57 mg KOH / gr was obtained from seeds with heat treatment and 58.83 mg KOH / gr from seeds without heat treatment. Likewise, free fatty acid level of oil from seeds with heat treatment, with a value of 0.21%, is lower than of seeds without heat treatment. The physical properties such as specific gravity and kinematic viscosity indicated that the results were not too different between those with heat treatment and those without heat treatment. Different physical properties were indicated by the color of oil, which was dark brown for seeds without heat treatment, while seed with heat treatment had yellow color.

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