Characteristic of briquette from kemiri sunan (*Reutealis trisperma*) shell at several binder ratios

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Abstract. Kemiri Sunan (*Reutealis trisperma*) can be used as raw material of biodiesel. Production of biodiesel from Kemiri Sunan generates shell as waste, that can be utilized as briquette material. During production process, adding binder for briquette is a must in order to create solid and hard shell Kemiri Sunan briquette. This study aims to find out the best ratio of binder (cassava starch) at the production of briquette. Kemiri Sunan was carbonized, ground (mesh 30) and mixed with some binder ratios, then molded. The ratio of binder and Kemiri Sunan shell were 2:100, 4:100, 6:100, 8:100 and 10:100 (w/w). The study showed that binder ratio affected characteristic of Kemiri Sunan briquette. The best ratio was 6:100 with characteristics: moisture content was 5.5%, ash content was 6.6%, fixed carbon was 49.94%, calorific value was 6.372 cal/g and burning time was 101 min.

1. Introduction

Decreasing fossil fuels availability require development of alternative fuels which are more environmentally friendly, including biodiesel. Biodiesel is a fuel made from oil or triglycerides contained in some plants. Among the ingredients that can be extracted for biodiesel fuel is Kemiri Sunan [1]. Kemiri Sunan has high potential to be developed as biodiesel raw material. It can grow easily on marginal land or damaged land, so that it does not use productive land for food [2], with the productivity reaches 12 tons/ha/year [3], it has high oil content of 53.47% [4] and contains toxic α-oleosteric acid components so that it does not compete with oils for food [5].

The process of biodiesel production from Kemiri Sunan through several stages of the process namely shell separation, oil pressing, esterification and transesterification [6]. In these processes, many waste materials are created including shells that generated from kernel separation. This shell can reach 11-16%. Therefore, Kemiri Sunan as a biomass has potential to be adapted as raw material for briquettes [7].
Briquettes are solid fuels derived from residual compressed organic matter [8]. This briquette can replace the use of firewood and reduce the potential of ecology damage. Briquette can be used as fuel for cooking, industrial fuel, and can also be used as electricity generator. The quality of briquette is comparable to the quality of coal and other types of charcoal fuel [9].

Briquette can be made by both carbonizing and non-carbonizing. Briquettes made by carbonizing process create a higher heating value with less smoke than without carbonizing process. Briquettes are made by carbonizing process, size reduction, and then compressed with a certain pressure to get a solid form [10]. In the production of briquette, adding binder is needed to produce consistency and solid form that is not easily damaged during handling or transportation. Commonly used binder material is cassava starch flour [11]. This study aims to find out the concentration of binder that can produce briquettes that meet SNI 01-6235-2000 standard.

2. Methodology

2.1. Materials and Instrument
Kemiri Sunan shell used in this study was collected from waste of biodiesel production using Kemiri Sunan kernel obtained from Garut, West Java. Other materials were cassava starch powder and water. Instruments used for briquette production were carbonizer and hydraulic presser, while instrument for analysis were bomb calorimeter IKA C2000, oven, siever and balance.

2.2. Methods
The method used in this study is descriptive method. The study was conducted in six level of binder ratio 2:100, 4:100, 6:100, 8:100, and 10:100 (w/w). Each treatment was repeated 3 times. The parameter observed were moisture content, ash content, volatile matter, fixed carbon, calorific value and burning time. A one-way ANOVA was conducted in order to test the difference of the parameters in briquettes produced with different binder ratio.

2.3. Bio-briquette process production
Shell of Kemiri Sunan samples were sun dried until its moisture content reach 7% (wb). The dried shell samples were carbonized at temperature of 400-500 °C in biomass carbonizer. Temperature of carbonization process was monitored by thermometer. Carbonized material then immediately removed from the carbonizer to cool it down and prevent the charcoal from being ash. Then they were grinded and sieved (mesh 30). Cassava starch (dilute in water) as the binder were mixed with the grinded Kemiri Sunan shell charcoal in different ratio. Mixture of Kemiri Sunan charcoal shell and cassava starch then placed into tube molder with 2 cm high and 2 cm in diameter. A hydraulic press was used for compacting the solids. The briquettes were sun dried for 3 days, cooled and packed in plastics to prevent water reabsorption.

2.4. Analysis Procedure
Moisture content, ash content, volatile matter and fixed carbon analysis were determined according to the procedure SNI (Standar Nasional Indonesia) 01-6235-2000, while calorific value were determined using ASTM n:D5885-10a. Burning time is the time needed to burn the briquettes from initial burning to no more flame in minutes.

3. Results and Discussion
Briquettes from Kemiri Sunan shell with cassava starch as binder have different consistency. Control briquettes cannot form solid product, as well as treatment cassava starch and Kemiri Sunan shell
charcoal ratio of 2:100. This was due to absence or small amount of cassava starch as binder, that cannot stick the charcoal together and produce solid briquette. Four briquette samples with ratio of 4:100 6:100, 8:100, and 10:100 were produced using a biomass mold and compressed in compression moulding machine as shown in Figure 1.

![Figure 1. Briquettes produced from different Kemiri Sunan and cassava starch ratio; cassava starch/Kemiri Sunan ratio of 4:100 (a), 6:100 (b), 8:100 (c) and 10:100 (d)]

3.1. Moisture Content

Kemiri Sunan shell briquette has moisture content range from 5.29% to 7.69% as shown in Figure 2. This moisture content meets the SNI 01-6235-2000 which briquette moisture content should less than 8%. Briquette made from Kemiri Sunan charcoal shell and cassava starch ratio of 4:100 had the lowest moisture content of 5.29%, while sample 10:100 with moisture content of 7.69% was the highest value. It was observed that moisture content of control sample and briquette with Kemiri Sunan charcoal shell and cassava starch ratio of 2:100 were similar.

ANOVA analysis showed that moisture content was influenced significantly by binder/Kemiri Sunan ratio (P<0.05). The higher ratio of Kemiri Sunan charcoal shell and cassava starch show higher moisture content. With the same drying time and condition for all treatment, rate of water evaporation in the material would be the same, so the higher binder concentration lead to higher moisture inside the briquettes.
Moisture content affects the quality of briquette produced especially on burning characteristic. It should lower than 8% (SNI 01-6235-2000), to create complete combustion. Low moisture content of briquettes produced high combustion power, while high moisture content will decrease combustion efficiency due to high energy needed to evaporate water [12]. High moisture content also facilitates fungi and others microorganism to grow.

![Figure 2. Moisture content of Kemiri Sunan briquettes.](image)

3.2. Ash content
Ash content in Kemiri Sunan briquette in the range from 4.07% to 6.74%, with the highest value in the control sample and the lowest ash content was in ratio of 2:100 (Figure 3). In compare with SNI standard (≤ 8%), all treatment meets this standard. Ash content shows the amount of residue that correlated with fixed carbon and others combustible component. High ash contain in briquette may cause scale in the burner [13] and decreased briquette quality due to low heating value [14]. Therefore, ash content allowed may not be too large. Percentage of ash in briquette depend on the raw material. Each raw material has certain characteristic due to different component inside. Briquette from mixture of rubber shell and senggani content 4% [15], while *Arundo donax* L mix with coconut coir has average ash content of 5% [16].
3.3. Volatile Matter
Volatile matter is determined by the weight loss that occur when the briquette is heated without air at a temperature 950 °C in a certain heating rate (SNI 01-6235-200). The study showed that volatile matter of Kemiri Sunan charcoal shell were in range between 43.31% to 47.89%, with the highest value at mixture ratio of 2:100 and the lowest volatile matter at 10:100. For ash content, it was observed that there was significant difference in the material ratio. Increasing material ratio lead to decrease volatile matter of briquette produce. Cassava starch as a binder is an organic compound with high carbon content, so that does not evaporate in ashing process. This higher level of binder which means the higher carbon will lower volatile matter content.

Volatile matter is substances that evaporate as a result of compound decomposition of material other than water [14]. This matter depends on material composition and the condition of carbonization especially its temperature. Different raw material will produce different ash content. SNI 01-6235-2000 is a briquette quality standard for wood charcoal with a maximum volatile matter of 15%, while briquette from a mixture of Arundo donax L and coconut coir has an average volatile matter of 83.87% [16]. Volatile matter content will affect the heating value, ease of ignition and smoke production during briquette burning. High content of volatile matter implies the lower carbon content that lead to lowering heating value [13]. Therefore, briquette from Kemiri Sunan would have higher heating value in comparison with wood charcoal briquette as well as mixture of Arundo donax L and coconut coir.
3.4  Fixed carbon

Fixed carbon represents the percentage of carbon contained in briquette. It was found that fixed carbon in Kemiri Sunan briquette between 48.11% and 50.59%, with ratio of 10:100 has highest value and control as the lowest one (Figure 5). The higher ratio of cassava starch gave higher value of fixed carbon. Thus, is in line with research by Zuairu and Ghan [17] on the production of briquette from agro-waste with carbonization process. It was obtained from the study that Anova analysis show there was significant difference in ratio treatment. The more cassava starches the more fixed carbon value. Cassava starch is an organic compound, so the higher binder ratio increases the fixed carbon in the briquette. The higher fixed carbon value indicates the lower ash content (Figure 2) and volatile matter (Figure 4).

The number of fixed carbon depends on the type of material. Different raw materials will produce different composition. The level of fixed carbon in Kemiri Sunan briquette produce from this study is lower than wood (77% as SNI standard) but greater than the mixture of Arunda donax L and coconut coir (11.33%) [16].
3.5. *Calorific value*

Calorific value determines the quality of briquette, the greater calorific value, the better quality [14]. It was found that calorific value of Kemiri Sunan briquette in the range of 6.18 kcal/g and 6.68 kcal/g, with the highest is from ratio of 2:100 as shown in Figure 6. Anova analysis found there was a significant difference in the treatment (P<0.05). The calorific value is influenced by several factors including moisture content, ash content, volatile matter and fixed carbon content. The lower ash content and volatile matter, the greater heating value by briquette and the higher fixed carbon will increase calorific value [18]. However, on contrary the study showed that the higher binder the lower heating value. This likely due to an increase in moisture content (Figure 2).

The heating value is strongly influenced by the type of material. Different raw materials will produce different heating values. SNI 01-6235-2000 is a briquette quality standard derived from wood charcoal with a minimum calorific value of 5000 cal/g, for briquettes from solid waste tannery ranging between 18.63 and 24.1 MJ/kg [18], while briquettes from water hyacinth (*Eichhornia crassipes*) between 13.4-16.6 MJ/kg [19]. The calorific value of the Sunan Kemiri shell briquette is lower than 7500, 7400, 7300 cal/g obtained from Teak, Acacia and Trembesi, respectively [20] but is above 5000 cal/g from wood charcoal briquettes (SNI 01-6235- 2000) and 5950 cal/g from sengon and 6260 cal/g from coconut shell [20].

*Figure 5. Fixed carbon of Kemiri Sunan briquettes.*
3.6. Burning time

Burning time was determined by first ignites until briquette goes out. It was observed that burning time of Kemiri Sunan briquette range from 98 min to 108 min. The smallest burning time is at 4:100 while the biggest is at 10:100 ratio. Anova analysis show there was no significant difference in the material ratio (P>0.05).

Burning rate is influenced by material structure, fixed carbon value, and material hardness [21]. If the volatile compound is high, briquette will burn easily with high rate of combustion. Burning time of Kemiri Sunan shell briquette is longer than 18.65-26.07 min resulting from groundnut shell briquette [22]. Burning time is an important quality parameter of briquette as fuel because it determines the qualities of briquette. The longer briquette burns the better its quality [23].
4. Conclusions
Kemiri Sunan shell can be used as raw material for briquette. Briquette with Kemiri Sunan charcoal shell with cassava starch ratio 4:100, 6:100, 8:100 and 10:100 can create solid briquettes, while control and 2:100 can not produce firm material. Moisture content, ash content, volatile matter and calorific value are influenced by Kemiri Sunan charcoal shell with cassava starch ratio, while fixed carbon and burning time are not. Moisture content 95.29-7.68%, ash content (4.07-6.74%) and calorific value (6.180-6.668 cal/g) meet the requirement of SNI 01-6235-2000. In contrast to wood charcoal briquettes as reference for SNI 01-6235-2000, Kemiri Sunan briquettes have higher volatile matter value of 43.31-47.81% and lower fixed carbon of 48.11-50.49%.

Acknowledgments
Authors would like to show their appreciation to the research fund provided by Universitas Padjadjaran for its Academic Leadership Grant Program with Prof. M.A.M. Kramadibrata as the leader.

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