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Characterization of Biobriquette from Carbonized Durian Peel Using Coconut Shell as the Binder

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A B S T R A C T

This research aimed to study the characteristics of carbonized durian peel biobriquette using tar as a binder. A 1:10 ratio of binder and carbonized durian peel was used. The 25, 50, and 75% (coded as P1, P2, and P3, respectively) tar were used as a binder alongside tapioca flour to produce a binder with different tar concentrations. The briquette characteristics determined moisture content, ash content, calorific value, density, and water-absorbing capacity. Moisture content ranged from 9.32% to 9,41% for treatments P1 to P3, while the ash content ranged from 12.29% to 13.09%, showing no significant difference among the treatments. Massive difference was observed in calorific value, as P1 gives 5106/35 cal g^{-1} calorific value while P2 and P3 give 9267.56 and 9694.53 cal g^{-1}, respectively. The density observed was relatively low, ranging from 0.5029 g cm-3 to 0.5685 g cm^{-2}. As for water-absorbing capacity, P3 absorbed the least amount of water, 29.43%. From this research, we can conclude that coconut shell tar has the potential to be utilized as a binder in forming biobriquette from carbonized durian peel.

1. INTRODUCTION

1.1. *Research Background*

Energy is one of the most vital entities for humans as a living being. As the human population keeps increasing, energy usage will also increase. Among all available energy resources, fossil fuel is one of the most utilized and the most used. This phenomenon, however, will lead to the decline of fossil fuels due to the increasing usage of energy year by year. Ministry of Energy and Mineral Resources Republic of Indonesia reported that there was a significant increase in energy usage from 2021 to 2022, that is, 265,910,894 BOE in 2021 to 481,161,829 BOE in 2022, marking a huge 81% increase of energy (excluding the biomass resource) usage in one year [1]. The increase in energy needs and the depletion of fossil fuels led us to find and utilize a new energy source that can be used for the long term. One of the most potential renewable energy resources is biomasses.

Biomass can be defined as the waste from organic material that originates from plants. Hence, they are also called green energy resources. Biomass is also considered a carbon-neutral energy resource since it already uses the same amount of carbon dioxide as the carbon it will emit later when exhausted [2]. Biomass is one of the most significant renewable energy resources, providing 55% of renewable energy globally [3]. Biomass could be utilised from a broad spectrum of plant wastes, including crops and trees, agricultural crop wastes, waste from woody and fibrous materials, waste from food and feed industries and other waste from organic materials [4].

These biomasses could be utilized in many forms of energy resources such as biogas, biodiesel, and bioethanol, and one of the forms of biomass utilization is in the form of briquette. Biomass, however, as an organic substance, have several drawbacks in terms of physical and chemical properties. Biomasses from woody, fibrous and herbaceous material have irregular shapes and sizes, making them harder to be handled, transport, and store, which hinders the large-scale utilization of these materials [5]. They also have high moisture content, which not only could decrease the burning efficiency if they were to be turned into a fuel, but they could also facilitate a tremendous microbial activity, leading to the higher rate of microbiologic degradation during storage. This, again, will hinder the large-scale utilization of biomasses [6]. Therefore, the combination of carbonization, densification, and moulding could be used to overcome such limitations in utilising biomass as an energy source. This process, when combined, often called briquetting. From so many agro-wastes, durian is one of the commodities that have the potential to be turned into biobriquette because it yields durian peel as the remaining unused waste

Durian (*Durio zibethinus*) is a local fruit found in Indonesia. Indonesian Central Bureau of Statistics reported that specifically in Lampung Province, Durian has quite high production rate, that is 14.6 ton in 2020 and 20.9 ton in 2021. While the fruit flesh was consumed, the peel was discarded. According to the previous research, durian peel has the highest proportion from a single durian, approximately 69.16 gram from 100 gram of whole durian [7]. The processing of durian peel into biobriquette is possible, giving durian peel more added value as a product. Several research has been accomplished in terms of briquetting durian peel [8]–[10].

Binder is one of the components in briquetting that could affect the properties of briquette that were produced. While the biomass sometimes contain a natural binder, the addition of binder could further improve the characteristic of biobriquette and aids in the processability of the briquette [11]. Many substances could be used as binders in briquetting process. One of them is tar, which is a byproduct from carbonizing biomaterial into a carbonaceous material. Although tar has been stated in some literature to be usable as binder in biobriquette production, the utilization of tar in biobriquette has not been studied yet. Therefore, this research utilized tar from coconut shell pyrolysis process as a binder in biobriquette from carbonized durian peel

1.2. Literature Review

Briquette is defined as the densified fuel. According to the Ministry of Energy and Mineral Resources Republic of Indonesia, briquette is a solid fuel made from carbonized and powdered sub-bituminous coal, lignite, or peat using densification process [1]. Briquetting is the process of forming briquette. Briquette can be formed from either carbonized or un-carbonized material. As stated previously, briquetting of biomass could overcome the limitations in processing, handling, and utilizing biomass as fuel. This could occur due to the combination of carbonization and densification process. Carbonization could solve the high moisture content problem in biomass, leading to the formation of carbonized mass that has low moisture content and high calorific value. Thus, the produced material i.e., the carbonized biomass could be utilized as solid fuel since it can burn and lights on easily, giving the heat energy that can be utilized in many purposes. Densification then solves biomass's problem for having an irregular shape, inconsistent size, and being difficult to handle by applying compression to the biomass. The densified biomaterial, namely biobriquette, is now having a low moisture content, low hydrophilicity, high calorific value with uniform size and dimension which can be handled, packed, transported, and stored more easily than the original biomass itself [5], [6], [11].

Physical characteristics and chemical characteristics are very important for biobriquette. The moisture content needs to be analysed to ensure that the biobriquette produced has low amount of moisture. Moisture content in briquette could affect its performance when it is lit with fire. Ash content also could contribute to the performance of biobriquette. The higher the ash content, the less calorific value it will have. Calorific value is one of the most important characteristic that should be determined when producing biobriquette. The heating value is known as the heating value (HV) or energy value of a briquette. This is the amount of heat released per unit mass of the briquette and is measured using a bomb calorimeter. The calorific value shows the energy contained in the briquettes. This is determined by measuring the heat produced by complete combustion of a certain amount, expressed in calories per gram. This test was carried out to determine the quality standards for briquette fuel power and determine the standard selling value of briquettes . The heating value will be calculated using the fixed carbon content and volatile matter of the briquette. As the heating value increases, more energy is released for work and less fuel is used, resulting in higher thermal efficiency [12].

1.3. Research Objective

This study aims to evaluate the effect of the addition of tar as a binder on carbonized durian peel biobriquette characteristic

2. MATERIALS AND METHODS

2.1. Materials

Materials used in this research are durian peel from local durian seller, tar which was obtained from the pyrolysis of coconut shell, tapioca flour, and tap water.

2.2. Carbonization of Durian Peel

Carbonization process of durian peel was done according to Haryono et al. [13]. Durian peel obtained from the local durian seller was first chopped into smaller sizes before drying. The drying was done under direct sunlight for approximately 12 h. The dried durian peel was then put into a pyrolysis drum and carbonized at 400-450 °C for 4 h. The resulting carbonaceous material was then cooled to ambient temperature before being pulverized and sieved using a 60-mesh screen.

2.3. Biobriquette Production

Biobriquette production was done by mixing carbonized durian peel with varied tar as a binder. Starch (tapioca flour) was also used as a binder. The formulation is presented on Table 1. The addition of binder into carbonized durian peel was added gradually to ensure a proper mixing between binder and the carbonaceous material. After all the binder was added, the mixture is weighed and was fed into the screw press. The resulting extrudate was then cut into a cube shape. The biobriquette was then sun-dried and was stored in a dry, well-ventilated room before characterization.

2.4. Analytical Methods

Moisture content The moisture content of biobriquette was determined according to SNI 1683:2021. Biobriquette sample was first ground into smaller particle. The ground sample was then weighed precisely (approx. 2 g) into a dish. The sample was then heated using the oven (115 ± 5 °C for 3 h) until constant weight. Moisture content was determined using the following formula:

$$\textbf{Moisture content}\ (\%) = \frac{\boldsymbol{W1}}{\boldsymbol{W2}} \times \mathbf{100}$$

Where *W1* is the weight loss after heating and *W2* is the sample weight

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Table 1. Formulation

Material	Formula 1 (P1)	Formula 2 (P2)	Formula 3 (P3)
Carbonized durian peel (g)	1000	1000	1000
Tapioca flour (g)	75	50	25
Tar (g)	25	50	75
Water (mL)	500	500	500

Ash content was determined according to the same standard reference as moisture content. Approximately 2-3 g of sample was weighed accurately into a dish of known weight. The sample was then carbonized inside an 800 °C furnace for 2 h. Ash content was calculated using the following equation:

$$\textbf{Ash content} = \frac{\boldsymbol{W1}}{\boldsymbol{W2}} \times \mathbf{100}$$

Where *W1* is the weighed of remaining residue on the dish after ashing, and *W2* is the initial sample weight

Calorific value of biobriquette was determined using a bomb calorimeter [8] where approximately 1-2 gram of sample was weighed. The sample was then put into the bomb calorimeter. Oxygen (at 30 atm) was then filled to the bomb vessel until the temperature stabilized. The sample was then further ignited and the calorific value could be measured

Density is defined by the ratio of mass to volume. Density of biobriquette could give us information on how the densification process was done. The density measurement was done according to [11]. Density (ρ) was calculated by dividing the mass of the briquette (g) by its volume (cm^3).

Water absorption capacity test was done according to [14] where the briquette was firstly weighed precisely. The weighed briquette was then immersed in 50 mL of water for 30 minutes. The sample was then taken out from the water and was weighed.

$$\textbf{Water absorption capacity } (\%) = \frac{\boldsymbol{m1}}{\boldsymbol{m2}} \times \mathbf{100}$$

Where m1 is the weight gained after immersion and m2 is the initial sample weight.

2.5. Research design

All treatments (P1, P2, and P3) were done in triplicate. The data obtained from analysis, except calorific value, were analyzed using one-way ANOVA and Tukey test to determine if there were any significant difference between each treatment. The result presented as mean of the data ± standard deviation. Statistics analysis was performed using OriginPro 2023 software.

3. RESULT AND DISCUSSION

3.1. Moisture Content

The water content in the biobriquettes obtained in this research can be seen in Table 2. Based on the ANOVA statistical test with a level of 5%, it can be seen that the water content between treatments is not significantly different ($p > 0.05$). This shows that the treatment using tar as an adhesive does not have a real effect on the water content of the biobriquettes.

Water content is an important parameter in testing the quality of briquettes because this water content parameter will affect the combustion properties of the bio-briquettes produced. This is based on the fact that biomass waste, one of which is durian skin waste, has a relatively high-water content when compared to petroleum raw materials. Higher moisture content and lower energy content of biomass reduce conversion efficiency [6].

The high water content in durian skin has been previously reported [15], [16]. They stated that durian skin has a water content ranging from 80.19 – 84.15% and this can certainly reduce the effectiveness burning if the durian skin is directly processed into briquettes. Therefore, to reduce the water content while increasing the combustion power of the briquettes, the durian skin needs to be processed first, one of which by turning them into carbonaceous material by pyrolysis, specifically carbonization [17].

Table 2. Moisture content of Biobriquette from Carbonized Durian peel

Formula			Moisture
Treatment	Tar (g)	Tapioca (g)	Content (%)
P1	25	75	9.32 ± 0.13^a
P2	50	50	9.32 ± 0.23^a
P3	75	25	9.41 ± 0.13^a

Results are shown in mean ± standard deviation.

Based on the research results, the water content of durian skin briquettes treated with a combination of tar and tapioca as adhesive had a water content ranging between 9.32% - 9.41%, whereas the water content of the briquettes obtained in this study was higher when compared with water content standards listed in SNI 01-6235-2000. However, the results obtained still meet the standards issued by the Minister of Energy and Mineral Resources No. 47 of 2006, which limits the maximum water content of carbonated bio briquettes to a maximum of 15%. The water content of the biobriquettes in this study contradicts with the results from several studies that have been carried out on durian skin charcoal briquettes. Wirabuana & Alwi reported that durian skin charcoal briquettes with starch adhesive had a water content of 5.85% [18]. Sitti Rahmawati et al. also said in their research that briquettes made from carbonated durian skin waste with sago starch adhesive had a low water content of 3.6% [10]. However, the results of the water content of biobriquettes in this study are in line with the results reported by Merry M. Mitan et al., who stated that durian skin biobriquettes with starch adhesive had a water content of > 10% [9]. The high-water content in durian peel biobriquettes can be caused by the storage of the biobriquettes and the water-absorbing nature of the biobriquettes produced in this research.

3.2. Ash Content

The ash content in biobriquettes obtained in this study can be seen in Table 3. Based on the ANOVA statistical test with a level of

5%, it can be seen that the ash content between treatments is not significantly different ($p > 0.05$). This shows that the treatment using tar as an adhesive does not have a real effect on the ash content of biobriquettes.

Based on Table 3, it can be seen that the ash content of biobriquettes (wet basis) obtained in this study is in the range of 12.29 – 13.09%, which is higher than the ash content required in SNI 01-6235-2000 but still complies with the bio briquette ash content standards set by the Minister of Energy and Mineral Resources Regulation No. 47 of 2006 which requires a maximum ash content for biobriquettes of 10-18% (dry basis). The high ash content in durian skin charcoal biobriquettes is contrary to several similar studies, but is in line with the results obtained in research conducted by Nuriana et al. who reported that the ash content of durian skin charcoal biobriquettes had an ash content of 18.18 % [19]. Apart from that, Efelina et al. also reported that the ash content of durian peel biobriquettes with tapioca adhesive was 12.32% [20].

Table 3 Ash content of carbonized durian peel briquette using various amount of tar as binder

Formula			Ash Content	Ash content
Treatment	Tar (g)	Tapioca (g)	(wet basis)) (%)	(dry basis) (%)
P1	25	75	12.96 ± 0.79[a]	14.27 ± 0.88[a]
P2	50	50	13.09 ± 0.29[a]	14.29 ± 0.55[a]
P3	75	25	12.29 ± 0.25[a]	13.60 ± 0.24[a]

Results are shown in mean ± standard deviation

Ash is a residue from combustion that does not evaporate after burning at high temperatures. Ash content has an inverse relationship with heating value, where the higher the ash content value, the lower the heating value of a biobriquette sample, which makes it more difficult for the biobriquette to burn [11]. Based on Table 3, it can be seen that the ratio of tar and tapioca use does not have a significant effect on the ash content of the biobriquettes produced. This shows that the use of tar in durian peel biobriquettes does not make a significant difference in the ash content of durian peel biobriquettes and shows the potential for using tar as an adhesive for biobriquettes. The ash content results obtained are in line with the results of previous research on the ash content of tar from coconut shell pyrolysis conducted by Hasanah et al. [21]. The researcher reported that the tar obtained from the pyrolysis of coconut shells had an ash content of 0.46%, so when applied as an adhesive to briquettes, the use of tar would not have a significant effect on the ash content of the briquettes produced [21].

3.3. Calorific Value

The calorific value of the durian peel charcoal biobriquettes which were given tar as an adhesive can be seen in Table 4. Based on Table 4, it can be seen that there is a difference in the calorific value between the treatments and a quite large difference can be seen between the calorific value of the sample using the 25 g tar with two other samples with higher amount of tar as an adhesive.

Table 4. Calorific value of carbonized durian peel biobriquette using various amount of tar as an adhesive

Formula			Calorific value
Treatment	Tar (g)	Tapioca (g)	(cal g^{-1})
P1	25	75	5106.35
P2	50	50	9267.56
P3	75	25	9694.53

Based on Table 4, it is known that durian skin charcoal biobriquettes with 25 g tar and 75 g tapioca (P1) as the adhesive has a calorific value of 5106.35 cal g^{-1} while for durian skin charcoal biobriquettes P2 and P3 have a calorific value of 9267.56 cal g^{-1} and 9694.53 cal g^{-1}, respectively. The calorific value of durian peel charcoal biobriquettes increases as the amount of tar used increases. The results obtained are in line with research conducted by Hasanah et al. (2012) who examined the characteristics of tar resulting from coconut shell pyrolysis. The researcher reported that coconut shell tar has a high calorific value, ranging from 6,210 kcal/kg – 10,304 kcal/kg [21]. Through the results of this research, it is proven that the high calorific value of tar can cause the biobriquettes glued together by the tar to have a high calorific value.

Coconut shells consist mostly of lignin, then cellulose and hemicellulose. Pyrolysis breaks down these compounds. Hemicellulose will decompose at a temperature of 200-260 °C, cellulose at a temperature of 240-350 °C, and lignin at a temperature of 280-500 °C. Heavy tar mostly contains oxygenate and phenolic compounds with phenol as the highest component. These phenolics compound have relatively high calorific values. This is largely due to lignin decomposition. Heavy tar is an organic fraction that cannot be dissolved in water, which is mostly a product of heavy lignin pyrolysis reactions [21].

Durian skin charcoal briquettes using tar from the pyrolysis of coconut shells in this study have a high calorific value, so it can be said that durian skin and tar from pyrolysis of coconut shells have increased potential to be used as raw materials and adhesives in making biobriquettes. When compared with the calorific value of durian peel biobriquettes reported by Nuriana et al. (2014), the calorific value of biobriquettes obtained in this study tends to be higher. This difference could occur due to differences in the adhesive used, where Nuriana et al. used corn starch as the adhesive. Apart from that, the calorific value of durian biobriquettes with tar adhesive produced in this research was also recorded to be higher when compared to the biobriquettes produced in the research of Haryati et al. who reported that durian peel charcoal biobriquettes with tapioca as adhesive had a calorific value of 6157 cal g^{-1} for torrefaction treatment at a temperature of 350 °C [8]. Calorific value is an important parameter in biobriquettes because it represents the energy content of the fuel. A higher heating value indicates a higher energy content, which is important for efficient and effective combustion. This characteristic is important in determining the quality and performance of biobriquettes as a fuel source [22].

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3.4. Biobriquette Density

Density is an important parameter for the development of biobriquette products. The density of biobriquettes from each treatment in this study can be seen in Table 5. Based on Table 5, it can be seen that the average density of treatments P1, P2, and P3 is 0.5029, 0.5529, and 0.5685 g cm^{-3} respectively. The Tukey test results stated that each treatment's density was not significantly different, but in terms of value, the higher the amount of tar used, the higher the density value of the briquettes produced. The density values produced in this research tend to be lower when compared to research which also carried out biobriquettes from durian skin charcoal. Nuriani et al. (2014) reported that the density of durian peel charcoal briquettes produced in their research was 0.99 g $mL^{-1.}$

Briquette densification is a material compaction process that is applied and used to convert biomass into a higher density, uniform shape, low water content, and increased energy content. This densification, besides improving biomass's characteristics as fuel, can also increase efficiency in handling and transportation of biomass [23]. In addition, according to Gilvari et al., in general, densification has the function of increasing kamba density, increasing ease of handling in transportation, reducing dirt in the form of dust in the air, and reducing work costs [14]. Densification can also facilitate direct combustion. Density is directly influenced by the pressing parameters carried out during the biomass densification process into briquettes. The low density of the biobriquettes obtained in this study could occur because the printing and binding process was carried out using a manual press, which according to Tandiono & Sri Endah, pressing using a manual press produces biobriquettes with a lower density when compared to briquettes. produced using press technology using a machine [24].

Table 5. Density of carbonized durian peel biobriquette using various amount of tar as an adhesive

	Formula		Density
Treatment	Tar (g)	Tapioca (g)	(g cm^{-3})
P1	25	75	0.5029 ± 0.06[a]
P2	50	50	0.5529 ± 0.05[a]
P3	75	25	0.5685 ± 0.08[a]

Results are shown by mean ± standard deviation

3.5. Water-absorbing capacity

One of the disadvantages of using biomass waste as a fuel source is that it tends to have a high water content, which causes low calorific value and difficulty in burning due to its use as fuel. Therefore, to utilize biomass as fuel, it is necessary to modify the treatment of biomass, one of which is the process of torrefaction and carbonization of biomass so that it produces a solid with a high density and does not easily absorb water. Therefore, one parameter that is also important to analyze is the water absorption capacity of biobriquettes or hydrophilicity. The water absorption capacity of durian charcoal peel biobriquettes can be seen in Table 6 and Figure 1.

Table 6. Water-absorbing capacity of carbonized durian peel biobriquette using various amount of tar as an adhesive

	Formula		Water-absorbing capacity
Treatment	Tar (g)	Tapioca (g)	(%)
P1	25	75	121.49 ± 24.14[a]
P2	50	50	100.19 ± 26.14[a]
P3	75	25	29.43 ± 8.62[b]

Results are shown by mean ± standard deviation

Table 6 shows that the water absorption capacity in treatments P1 and P2 is 121.49% and 100.19%, while the water absorption capacity in treatment P3 is 29.43%. Furthermore, based on the results of Tukey's further tests, the water absorption capacity of the P3 treatment was significantly different from the other two samples. Meanwhile, treatments P1 and P2 had water absorption capacities that were not very different between treatments. Based on these results, it can be seen that the use of tar can reduce the water absorption capacity of the biobriquettes produced.

Adhesives in briquettes can be classified into two types, namely organic and inorganic. Organic bonds can be further divided into two types, namely hydrophobic adhesives (asphalt, tar and petroleum residues) and hydrophilic adhesives (biomass and starch). Organic adhesives have good adhesion but have poor thermal stability. Tar is an adhesive that is included in the type of organic adhesive with hydrophobic properties so that its use as an adhesive in biobriquettes can increase the hydrophobicity of the briquettes produced [25]. The hydrophobic nature of tar is caused by the non-polar nature of the tar. Tonpakdee et al reported in their research that tar can be dissolved in large quantities in biodiesel produced from rapeseed oil where in the rapeseed methyl ester, there is oleic acid, which is the primary fatty acid. Oleic acid has non-polar properties which, according to the test results in this research, can dissolve large amounts of tar compared to pure oils derived from palm oil, sunflowers, rice bran and refined palm oil, which are ingredients -This material has more polar groups than non-polar so the tar cannot dissolve in large quantities. The polarity of tar is different from that of water. Tar is a compound with a low polarity level while water is a polar compound. The difference in polarity of tar and water can explain why the use of more significant amounts of tar in briquettes causes an increase in the hydrophobicity of the briquettes obtained [26]

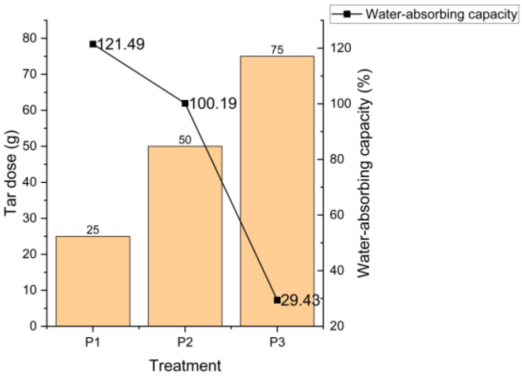

Fig. 1 Graphic presentation of the water-absorbing capacity of each treatment

4. CONCLUSION

Based on the findings of the study, the incorporation of tar as a binding agent in the production of carbonized durian peel biobriquettes did not yield statistically significant variations in terms of moisture content, ash content, and density. However, it did lead to an increase in the calorific value of the biobriquettes, while simultaneously reducing their water-absorbing capacity. Hence, tar can be employed as a binding agent for biobriquettes derived from carbonized durian peel.

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