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Drying time and mixture composition effect on biomass of pine cone and palm shell

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ABSTRACT

According to the International Energy Agency (IEA), global energy demand is expected to rise by 45% by 2030, with around 80% still met by fossil fuels. This necessitates urgent development of alternative energy sources, such as biomass, which is renewable and can help reduce organic waste. This study examines the impact of varying drying times and mixture compositions of palm shells and pine fruits on the characteristics of briquettes. These materials were chosen due to their availability and potential to mitigate environmental impacts. The research investigates the moisture content, calorific value, and ash content of the briquettes. Results show all briquette compositions meet the Indonesian National Standard (SNI) No. 1683:2021 for moisture content, though only WP3 fails to meet standards. Ash content for all variations exceeded the SNI threshold (≥ 10%). However, all met the calorific value standard, with WP3 achieving the highest value (6643.18 cal/g). ANOVA analysis indicates both mixture composition and drying time significantly affect moisture and ash content, but only drying time significantly impacts calorific value.

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1. INTRODUCTION

The decline in the availability of fossil energy, especially petroleum, threatens the global energy supply in the future. Fossil energy is predicted to be depleted within the next few decades, making the development of alternative energy crucial. Experts believe that with the current consumption pattern, fossil energy will soon be exhausted. Oil will be depleted in 30 years by 2052, natural gas in 40 years by 2060, and coal in 70 years by 2090. The coal reserves of 900 Billion Tonnes of Oil Equivalent (BTOE) in 2011 are expected to shrink to 400 BTOE by 2055 and may be exhausted by 2086. Meanwhile, other energy reserves such as gas and oil may be exhausted earlier in 2051 and 2061.

Biomass is a renewable energy source derived from organic materials such as plants and industrial waste, including palm shells and pine fruit. Converting biomass into briquettes is an effective solution for utilizing these resources. While coal briquettes are more common, other biomass like palm shells and pine fruit can also

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be processed into briquettes to reduce waste and create sustainable fuel, Parinduri, et. al., 2020. Indonesia has a significant biomass potential, with a total of 306 thousand tons utilized annually, Hantono, 2016. Silitonga and Ibrahim (2020) stated that Indonesia is still vast in biomass potential, thus this research focuses on analyzing the effects of varying mixture compositions and drying times on biomass quality, particularly in terms of moisture content, calorific value, and ash content, to support the development of more sustainable alternative energy.

The production of briquettes using biomass allows for the consideration that the majority of agricultural waste globally can be utilized to make briquettes, given the right raw materials. Briquettes can be made from almost any material as long as they meet the general requirements of being capable of carbonization and having a high calorific value, PT Sinar Mas Agro Resources and Technology tbk. 2022. The quality standards for biomass/biobriquettes refer to Table 1.

Table 1. Quality standard of briquettes, Badan Standarisasi Nasional, 2021.

Parameters	Standard		
	SNI	JIS	BIS
Moisture (%)	≤ 8	6 – 8	3 – 4
Ash (%)	≤ 8	3 – 6	8 – 10
Volatile (%)	≤ 15	15 – 30	16,4
Calorific Value (cal/g)	≥ 5000	5000 – 6000	5870
Fix Carbon (%)	≥ 77	60 – 80	75

The energy potential that can be generated from palm oil by-products through calorific value includes the range of calorific values for each type of palm oil by-product, 20,093 kJ/kg for shells, 19,055 kJ/kg for fibers, 18,795 kJ/kg for empty fruit bunches (EFB), 17,471 kJ/kg for trunks, and 15,719 kJ/kg for fronds. The utilization of shells and fibers to meet energy needs in Palm Oil Mills occurs by using them as boiler fuel to produce steam and electricity, Wijianti, 2017, as an alternative energy source with several advantages. First, this energy source is renewable, ensuring the continuity of production. Second, Indonesia is one of the main producers of palm oil, ensuring the availability of raw materials and the development of the domestic industry, Tjutju, et. al., 2013. The approach to utilizing pine fruit waste is supported by a simple manufacturing process, without the use of hazardous chemicals or high-tech equipment, resulting in a product that is not only easy to apply but also environmentally friendly, Kurniawan and Marsono, 2008.

The production of biomass requires a carbonization stage, which is a process of decomposing materials at high temperatures without direct contact with air, Kuspradini, et. al., 2016. The main components produced during the carbonization process include charcoal, various gases such as CO, CO_2, and acetic acid Hidayati, 2018. According to research done by Moeksin et. al. (2017), the temperature and duration of carbonization will affect the quality of a briquette.

2. RESEARCH METHODS

This research was conducted using an experimental method, with independent variables being the drying time and the mixture composition of palm shells and pine fruit. The drying times (abbreviated as DT) tested were 1.25 hours, 3 hours, and 4 hours, with mixture composition variations (abbreviated as MC) of 80:20, 50:50, 20:80, and 100:0 for palm shells and pine fruit with tapioca flour binder. The briquette-making process (Figure 1) involved several stages: first, carbonization or burning of palm shells and pine fruit to turn them into charcoal. Next, the carbonized raw materials were ground in the second stage. Subsequently, in the third stage, the sieved briquette powder was mixed with a binder evenly. Then, the briquettes were molded in the fourth stage, and finally, the molded briquettes were dried in the fifth stage to achieve the appropriate moisture content before use. After the drying process, the briquettes were tested for their calorific value using the Bomb Calorimeter method, and for moisture and ash content using the Gravimetric method (ASTM D 3173-03).

Control variables refer to variables that can be regulated and whose values can be kept constant, ensuring that the independent variables are not influenced by other factors outside the scope of the research. The control variables used in this study are shown in Table 2.

This study uses variations in mixture composition and drying time to evaluate their impact on the moisture content, calorific value, and ash content of palm shells and pine fruit. Below is a table showing the independent variables used in this research (refer Table 3).

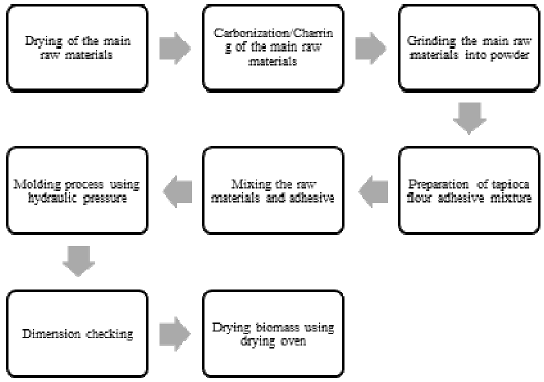

Figure 1. Biomass production process

Table 2. Controlled variables.

Variables	Value
Adhesive Composition	10%
Mesh	≥ 60 *mesh*
Molding Pressure	55 kg/cm
Ukuran Briket	Width: 2cm
	Height: 4cm
Carbonization Temperature	600°C

Table 3. Research variables

Variables	Value	Controlled Variable
Mixture Composition Ratio (MC)	100% of Palm Shell (MC 1)	Drying Time of 3 hours
	80% Palm Shell : 20% Pine Cone (MC 2)	
	50% Palm Shell : 50% Pine Cone (MC 3)	
	20% Palm Shell : 80% Pine Cone (MC 4)	
	100% of Pine Cone (MC 5)	
Drying Time (DT)	1.25 H (DT 1)	Ratio of Palm Shell and Pine Cone (50:50)
	3 H (DT 2)	
	4 H (DT 3)	

3. RESULTS AND DISCUSSION

3.1. Moisture content

Moisture content testing is one of the crucial parameters in determining the quality of briquettes, Purwanto (2011). Data were obtained using the gravimetric testing method, where the drying process was carried out in an oven at 105°C for 3 hours. The tests were conducted three times, and the results are presented in percentages. For the mixture composition variations (MC), the average moisture content obtained was: MC1 at 8.77%, MC2 at 8.64%, MC3 at 8.99%, MC4 at 7.53%, and MC5 at 9.48%. Meanwhile, for the drying time variations (DT) using the same method, the average moisture content obtained was: DT1 at 4.95%, DT2 at 7.79%, and DT3 at 15.46%. For the complete data on the moisture content refer to Tables 4 and 5.

Table 4. Moisture content testing results for mixture composition.

Repetition	Moisture Content (%)				
	MC1	MC2	MC3	MC4	MC5
1	8.61	8.55	9.01	12.09	9.57
2	8.75	8.66	9.09	11.96	9.58
3	8.95	8.71	8.89	11.62	9.30
Average	8.77	8.64	8.99	11,89	9.48

Table 5. Moisture content testing results for drying time.

Repetition	Moisture Content (%)		
	DT1	DT2	DT3
1	4.85	7.93	15.29
2	5.02	7.95	15.94
3	4.99	7.48	15.15
Average	4.95	7.79	15.46

3.2. Ash content

Ash content testing is an important indicator in assessing biomass quality. In this study, ash content testing for mixture composition variations (MC) and drying time variations (DT) was conducted using the gravimetric method. Samples were placed in a furnace and heated at 600°C. The results are presented as percentages, with each test conducted three times. The average ash content for mixture composition variations (MC) was: MC1 at 29.41%, MC2 at 35.69%, MC3 at 37.00%, MC4 at 37.42%, and MC5 at 37.42%. For drying time variations (DT), the average ash content obtained was: DT1 at 39.58%, DT2 at 36.51%, and DT3 at 29.36%. For complete data on ash content for mixture composition variations (MC) and drying time variations (DT), refer to Tables 6 and 7 as follows.

Table 6. Ash content testing result for mixture composition

Repetition	Ash Content (%)				
	MC1	MC2	MC3	MC4	MC5
1	28.81	35.94	36.82	37.73	37.98
2	29.68	35.57	37.31	37.55	37.23
3	29.74	35.57	36.87	36.99	37.05
Average	29.41	35.69	37.00	37.42	37.42

Table 7. Ash content testing result for drying time

Repetition	Ash Content (%)		
	DT1	DT2	DT3
1	39.60	36.39	29.79
2	39.25	36.44	29.17
3	39.89	36.71	29.11
Average	39.58	36.51	29.36

3.3. Calorific value

Knowing the calorific value of biomass is crucial as it indicates the amount of energy produced during the combustion process, Nurhaji et. al. (2020). In this study, calorific value testing was conducted using an IKA C2000 bomb calorimeter, following the ASTM D5865/D5865M – 19 standard procedures. Based on the test results, the average calorific values for mixture composition variations (MC) were as follows: MC1 at 6579.41 cal/g, MC2 at 6489.04 cal/g, MC3 at 6539.44 cal/g, MC4 at 6399.24 cal/g, and MC5 at 6346.13 cal/g. Meanwhile, for drying time variations (DT), the average calorific values obtained were: DT1 at 6154.66 cal/g, DT2 at 6528.45 cal/g, and DT3 at 6643.18 cal/g. For the complete data on calorific values for mixture composition variations (MC) and drying time variations (DT), refer to Tables 8 and 9 as follows.

Table 8. Calorific value testing result for mixture composition

Repetition	Calorific Value (cal/g)				
	MC1	MC2	MC3	MC4	MC5
1	6559.90	6396.29	6526.94	6399.16	6043.04
2	6575.67	6573.04	6506.16	6350.43	6468.66
3	6602.66	6497.80	6585.22	6448.12	6526.70
Average	6579.41	6489.04	6539.44	6399.24	6346.13

Table 9. Calorific value testing result for drying Time

Repetition	Calorific Value (cal/gr)		
	DT1	DT2	DT3
1	6157.92	6553.93	6635.38
2	6163.66	6556.56	6646.60
3	6142.40	6474.87	6647.56
Average	6154.66	6528.45	6643.18

3.4. Variable relationship analysis

Based on the testing, the moisture content of biomass in the mixture compositions (MC 1 to MC 5) ranged between 7% and 9%, with the lowest moisture content in MC 4 (7.53%) and the highest in MC 5 (9.48%). The higher moisture content in MC 5 is due to the increased proportion of pine fruit, which reduces the calorific value because energy is used to evaporate the water before generating heat (Siagian and Ginting, 2013). In the drying time variations (DT), DT1 had the lowest moisture content (4.95%) and DT3 the highest (15.46%), with a tendency for moisture content to decrease with longer drying times (Siagian and Ginting, 2013). However, increased moisture content can occur due to the carbon's moisture-absorbing properties or suboptimal drying (Yuriandala, 2020).

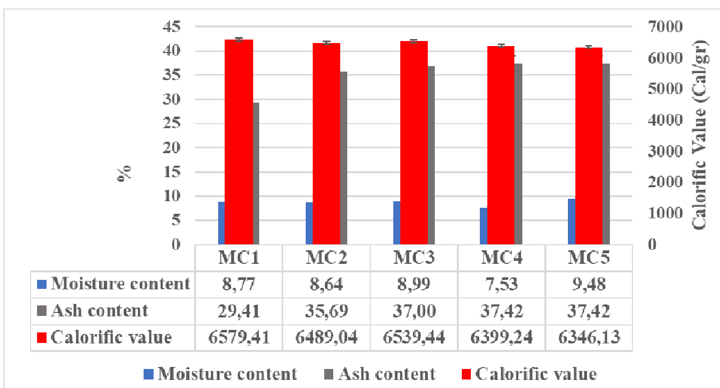

Figure 2. Effect of mixture composition to moisture, ash content, and calorific value.

The lowest ash content was found in MC 1 (29.41%) and the highest in MC 4 and MC 5 (37.42%), more than 20% ash significantly influenced by the use of non-combustible tapioca flour adhesive which resemble the research conducted by Retnawati, et. al. in 2023. In the drying time variations, the highest ash content was in DT 1 (39.58%) and the lowest in DT 3 (29.36%), where longer drying times reduced ash content, Utomo (2013). Impurities in the raw materials also increased ash content, Alfernando, et. al. (2023).

The highest calorific value was recorded in MC 1 (6579.41 cal/g) and the lowest in MC 5 (6346.13 cal/g), with the addition of palm shells increasing the calorific value through the torrefaction process that enhances carbon content [18]. In the drying time variations, DT 3 had the highest calorific value (6643.18 cal/g), while DT 1 had the lowest (6154.66 cal/g), with longer drying times increasing calorific value due to reduced moisture content (Radyantho, 2023). The test results are shown in Figure 2 and Figure 3.

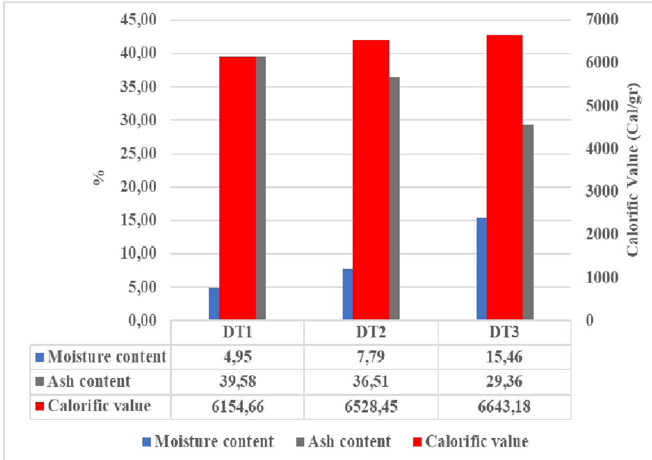

Figure 3. Effect of drying time to moisture, ash content, and calorific value.

3.5. Statistic hypothesis analysis

The ANOVA test results for ash content in mixture composition variations, as shown in Table 10, indicate an F value of 224.10 and a P-value of 0.00000000010. The very small P-value (below 0.05) indicates statistically significant results, thus rejecting the null hypothesis (H_0). This signifies that the mixture composition variations have a significant impact on the ash content of the briquettes. In the ANOVA test for drying time variations (Table 10), an F value of 903.82 and a P-value of 0.0000000362 indicate that drying time also has a significant impact on ash content, indicating significant differences in ash content among the various drying time variations. The ANOVA test results for calorific value in mixture composition variations showed no significant differences between the tested compositions. The F value was 1.71 and the P-value was 0.223, which is well above the 0.05 threshold, indicating that mixture composition variations do not significantly affect the calorific value. Therefore, the null hypothesis (H_0) is not rejected. Conversely, the ANOVA test results for drying time variations showed highly significant differences in calorific value, with an F value of 252.94 and a P-value of 0.0000016105. This indicates that drying time significantly affects the calorific value of the briquettes, thus rejecting the null hypothesis (H_0). The ANOVA test results data for mixture composition and drying time on calorific value can be seen in Tables 10.

Table 10. ANOVA Testing Result

ANOVA	F Value	P Value
Mixture Composition on Moisture Content	208.08	0.0000000014
Drying Time on Moisture Content	1036.56	0.0000000240
Mixture Composition on Ash Content	224.1	0.0000000010
Drying Time on Ash Content	903.82	0.0000000362
Mixture Composition on Calorific Value	1.71	0.223
Drying Time on Calorific Value	252.94	0.0000016105

4. CONCLUSION

From the results of the experiments that have been carried out, several findings have been obtained. ANOVA analysis showed that both composition variation and drying time significantly affected ash content. The calorific value test showed that MC 1 had the highest value at 6579.41 cal/g, making it the most efficient in energy production, while MC 5 had the lowest value at 6346.13 cal/g. All variations met the SNI standards for second-grade quality (6000–6500 cal/g). In the drying time variation, DT 3 had the highest calorific value at 6643.18 cal/g, while DT 1 had the lowest at 6154.66 cal/g, all meeting the SNI standards. Based on ANOVA, composition variation did not significantly affect the calorific value, while drying time variation had a significant impact.

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