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RESEARCH ARTICLE

Manufacture of Biobriquettes from Alaban (Vitex pubescens) Biomass Waste and Rubber Seed Shells using Damar Resin Adhesive

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ABSTRACT

Using biomass as the main ingredient in briquettes is more environmentally friendly because biomass does not contain elements that endanger the health or the environment. This study used experimental research to utilize waste-based charcoal from Alaban wood and rubber seed shells as briquette materials. The raw materials were all ground into powder using a 60-mesh filter. The varied compositions of charcoal from Alaban wood and rubber seed shells were as follows: 100%:0%, 90%:10%, 70%:30%, 50%:50%, 30%:70%, 10%:90%, and 0%:100%. Additionally, 9% resin was added as an adhesive. The briquettes were shaped into 2 x 5 cm cylinders with a printing pressure of 200 kg/cm2 and then dried at room temperature and in the sun for three days. These waste-based briquettes exhibited the following characteristics: an average calorific value of 7645–8731 cal/g, a water content of 2.21-2.72 percent, and an ash content of 5.34–7.86 percent. Furthermore, the quality of briquette combustion was assessed, with an average length of initial ignition time ranging from 3.06 to 4.17 minutes, a burning duration of 92.07–125.27 minutes, and a combustion speed of 0.16-0.22 g/minute. The results indicated that as the percentage composition of Alaban wood charcoal increased, the moisture and ash levels decreased while the calorific value increased. Moreover, regarding the quality of briquette combustion, a higher percentage composition of Alaban wood charcoal led to faster initial ignition times, longer combustion durations, and lower burning speeds. With a calorific value exceeding 5,000 cal/g, these waste-based briquettes meet national standards for commercial briquettes and are expected to serve as an alternative renewable fuel, addressing various environmental challenges.

INTRODUCTION

The rapid growth of the global population has led to an exponential increase in energy consumption. This surge in demand for energy is primarily driven by the extensive use of non-renewable resources such as petroleum, natural gas, and coal. However, the overreliance on these fossil fuels has not only raised concerns about their finite nature but has also resulted in detrimental environmental consequences, including greenhouse gas emissions and climate change (Rismayani and Tayibnapis, 2011).

To combat these challenges, significant efforts are being made to explore and develop renewable and ecologically friendly energy sources. Biomass, which refers to organic matter derived from plants and animals, has emerged as a promising solution to meet our energy needs sustainably. It can exist in various forms, including solid, liquid, and gaseous, and has demonstrated high potential as a renewable energy source (Benti et al., 2021).

Biomass energy harnesses the energy stored in organic materials, such as agricultural residues, forest biomass, energy crops, and organic waste, to produce heat, electricity, and various forms of biofuels. Unlike fossil fuels, biomass is considered a carbon-neutral energy source, as the carbon dioxide released during its combustion is offset by the carbon dioxide absorbed by the plants during their growth. This characteristic makes biomass a viable alternative to mitigate greenhouse gas emissions and combat climate change (Srirangan et al., 2012).

As governments, industries, and communities worldwide recognize the importance of transitioning to sustainable energy sources, biomass and its derivatives such as briquettes have gained significant attention. The development and utilization of these alternative energy sources not only contribute to the diversification of energy portfolios but also foster a cleaner and more sustainable future.

Briquettes are a cost-effective and excellent solution to address the urgent problem of fossil fuel depletion while serving as a renewable energy source. They offer several advantages such as low moisture content, high density, cleanliness, uniformity in size, minimal storage requirements, and portability (Purwanto et al., 2014; Sova et al., 2018). These solid fuels are produced by combining waste materials with adhesive components (Afriani et al., 2017). The utilization of Alaban wood charcoal and rubber seed shells is an effective approach in briquette production.

Alaban wood charcoal exhibits a similar quality to briquette charcoal and does not emit smoke. The abundance of rubber seeds from rubber plants provides a potential biomass source for creating alternative energy briquettes, utilizing the unused rubber seed shells. In July 2016, limited research was conducted on the combination of Alaban wood charcoal, rubber seed shells, damar resin adhesives, and discarded cooking oils to produce briquettes. This type of briquette incorporates resin sap as an adhesive and dye from spent cooking oil, resulting in enhanced calorific value (Julian 2016; Selpiana, Maman, and Ilham 2016). Immersing the briquettes in spent cooking oil further increases their calorific value (Septhiani and Septiani, 2015).

Conclusively, biomass stands as a promising and renewable energy source, boasting immense potential in its solid, liquid, and gaseous states while remaining regenerable (Rismayani and Tayibnapis, 2011; Alfajriandi et al., 2017). In the context of Indonesia, a country blessed with abundant resources, there lies a remarkable opportunity to foster the development and utilization of alternative energy sources, including the utilization of briquettes. By embracing this path, Indonesia can pave the way towards a sustainable and environmentally friendly energy landscape. .

MATERIALS AND METHODS

This inquiry is an experimental laboratory investigation. The raw materials used to produce briquettes are Alaban wood charcoal sourced from the charcoal business in Guntung Manggis Village, Landasan Ulin Banjarbaru District, South Kalimantan Province. At the same time, rubber seed shell debris is collected from a rubber farmer's garden in Gunung Kupang, district of Cempaka, province of South Kalimantan.

Raw ingredients are dried, ground, and sifted in preparation for the briquette-making process. For example, when making raw material powder from a rubber seed shell, waste shells of rubber seeds are cleaned of debris, sun-dried for three days, and then carbonized at a temperature of 400 C. After carbonization, the charcoal is pulverized and sieved to produce a 60-mesh briquette powder.

According to prior studies, briquettes combine Alaban wood charcoal and rubber seed shells. The raw material is reduced to a powder with a mesh size of 60 and a resin adhesive concentration of 9 percent. The compositional charcoal variance between Alaban wood waste and rubber seed shell is as follows: 100%: 0%; 90%: 10%; 70%: 30%; 50%: 50%; 30%: 70%; 10%: 90%; 100%: 0%. At a pressure of 200 kg/cm2, the mixture is printed in a cylinder of 2 cm by 5 cm. The briquettes are then air-dried and sun-dried for three days at room temperature (Haryanti et al., 2018; Haryanti et al., 2018). In addition, the briquette is submerged for three minutes in used cooking oil for the characteristic and combustion quality tests.

The qualities and characteristics of burning briquettes will be investigated. The water content and ash content are measured according to SNI 06-3730-1995, whereas the calorific value is measured according to ASTM D2015. The calorie bomb method is used to determine the calorific value. Briquette quality standards are based on SNI 01-6235-2000 for the quality of wood briquettes, including water content, ash content of 8%, and a calorific value of 5000 cal/g. The initial ignition time, the duration of the combustion, and the rate of combustion are included in the briquette combustion quality test. SPSS statistical analysis was used to determine differences in composition variations on briquette characteristics and briquette burning quality. After all the tests have been completed, an analysis of the results of the tests is carried out, so that conclusions can then be drawn that can answer the objectives of this study.

RESULTS AND DISCUSSION

The inhabitants of Kalimantan prefer charcoal and smoke created from Alaban wood because they impart a particular flavor and scent to food. In addition, alaban wood (Vitex pubescent) has numerous high shoots and high calorific values, so it has the same potential as biomass energy as Caliandra callothyrsus wood (Alimah, 2020).

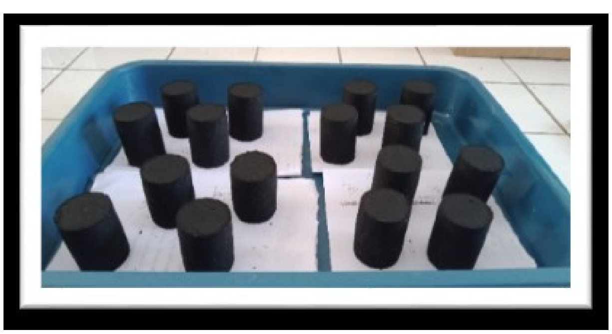

Figure 1: Briquettes consisting the charcoal of Alaban wood and rubber seed shells

In this study, Alabang wood charcoal and rubber seed shells were sourced from local industry and agricultural waste in Banjarbaru, South Kalimantan Province, to produce briquettes. As indicated in Figure 1, the briquettes are printed as a cylinder.

Briquette characteristics

Briquette water content: The average water content of the briquettes is 2.21–2.72% (Figure 2). Among the different compositions, the briquettes made with 0% Alaban wood charcoal and 100% rubber seed shells have the highest water content, measuring 2.72%. Conversely, the briquettes consisting of 100% Alaban wood charcoal and 0% rubber seed shells exhibit the lowest water content, measuring 2.21%. Notably, the water content of all briquette samples falls below the 8% threshold required by SNI (SNI.01-6235-2000, 2000).

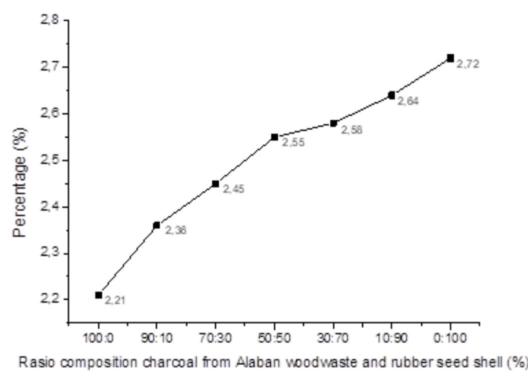

Figure 2: Briquette water content

Briquettes with a high water content will be challenging to ignite. The lower the moisture content, the higher the calorific value of the briquettes (Novrizal et al., 2018). The test results indicate that the compositional modification of Alaban wood charcoal will decrease water content. This is due to the 1.53 percent water content of low Alaban wood charcoal (Haryanti et al., 2018). While the rubber seed shell has a water content of 14.3%, the rubber seed itself has a water content of only 2%. (Selpiana et al., 2016).

Due to the coloring of discarded cooking oil, briquettes contain little water. According to research (Septhiani and Septiani, 2015), a briquette containing a blend of leftover cooking oil has the lowest water content value. The higher the biomass composition employed in water content tests, the greater the water content produced (Slamet and Gunawan, 2015). In previous studies, briquette water content derived from various particle materials and sizes, such as sengon wood sawdust, coconut skin, and water hyacinth in particle size, passed the sieve of 30, 50, and 70 mesh, and the filters of 10, 42, and 60 mesh, with respective values of 10.714%, 9.707%, and 8.949% (Ilminnafik et al., 2015; Sibarani et al., 2016). Therefore, it can be concluded that a combination briquette made from Alaban wood charcoal and a rubber seed shell dyed with used cooking oil has a lower water content than other biomass materials such as Sengon wood sawdust, coconut skin, and water hyacinth, resulting in a more extended expiration period and a faster combustion rate. Based on these test results, an ANOVA was conducted to determine the significance of the raw materials used in this study, using a significance level of 5%.

Table 1: ANOVA test results for water content (*n* = 45)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	0,645a	6	0,107	14,388	0,000
Intercept	126,445	1	126,445	16,934,572	0,000
Composition Variation	0,465	6	0,107	14,388	0,000
Error	0,105	14	0,007		
Total	127,194	21			
Corrected Total	0,749	20			

a. R Squared = 0,860 (Adjusted R Squared = 0,801); Significance α = 5% = 0,05

a. R Squared = 0,860 (Adjusted R Squared = 0,801) Significance α = 5% = 0,05

Hypothesis

0: = 0 (There is no significant difference between the variations in composition and water content)

1 ≠ 0 (There is a significant difference between the variations in composition and water content)

After examining Table 1, the ANOVA test results for water content allow us to make decisions according to the decision rules as follows:

- The treatments significantly differ if the significance value (sig) < α.
- The treatments do not differ significantly if the significance value (sig) > α.

Based on these decision rules, the results indicated by Table 1 show that the significance value (sig) for the variable of variation in composition is 0.000, which is smaller than α (0.05). This means that according to decision rule number 1, the variation in composition shows a significant difference in water content. Since the ANOVA test yielded significant results, a post hoc test was conducted to determine if there were significant differences between variables.

Table 2: The post hoc test of water content

Composition Variation	N	Subset for alpha = 0,05				
		1	2	3	4	5
100:0	3	2,2067				
90:10	3	2,2700	2,2700			
70:30	3	2,3567	2,3567	2,3567		
50:50	3		2,4533	2,4533	2,4533	
30:70	3			2,5367	2,5367	2,5367
10:90	3				2,6300	2,6300
0:100	3					2,7233
Sig.		0,389	0,198	0,213	0,229	0,184

Based on Table 2, the post hoc test results showed that the variances of the 100:0, 70:30, and 90:10 compositions were in the same subset, namely subset 1. Meanwhile, the variances of the 90:10, 70:30, and 50:50 compositions were in subset 2. The variances of the 70:30, 50:50, and 30:70 compositions were in subset 3, with the 70:30 composition also being in subsets 1, 2, and 3. Additionally, the variances of the 50:50, 30:70, and 10:90 compositions were in subset 4, while those of the 30:70, 10:90, and 0:100 compositions were in subset 5. The variance of the 50:50 composition was in subsets 2, 3, and 4, while the 30:70 composition was in subsets 3, 4, and 5, and the variance of the 10:90 composition was in subsets 4 and 5. Based on this table, the variances of the 0:100 and 100:0 compositions were not in the same subset, and thus the test results differed significantly.

Briquette Ash content: The average amount of ash (5.34–7.86%) was determined (Figure 3). Standard 8% ash is specified by Indonesian Standard SNI No. 01-6235-2000. All briquette samples meet SNI criteria based on the findings of the ash level test. The briquettes with a 100% composition of rubber seed shells have the highest gray content, while those with a 100% composition of alabaster wood have the lowest. The ash content of briquettes is significantly determined by the chemical makeup of the briquettes' raw material (Haryanti et al., 2018). The mix of 100% Alaban wood charcoal is advised to make briquettes more combustible and produce less ash.

Based on Figure 3, the higher the composition of the charcoal shells of rubber seed, the greater the ash content of the briquette. The ash content of Alaban charcoal was 0.36% (Rahmadi, 2018). The ash content in damar resin was 2.24 percent (Wiyono, 1998). In addition, the coloring of used cooking oil somewhat increased its ash content (Efelina et al., 2018). The results of the briquette ash levels are relatively lower than the Irlany research for coconut skin briquettes and water hyacinth, which produced the highest ash content of 21.15% (Iriany et al., 2016), Slamet's research on biomass mixture briquettes (coffee shells, shells, and coconut shell) and coal ash (Slamet and Gunawan, 2015), and Alfajriandi's (Alfajriandi et al., 2017).

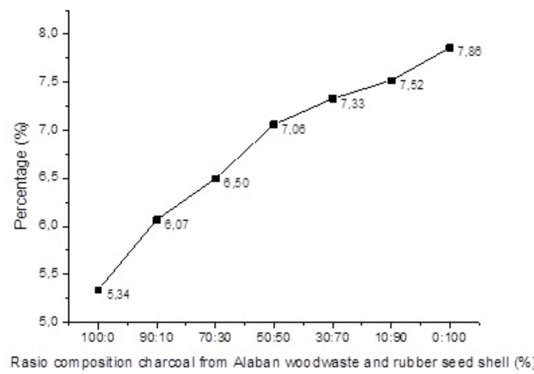

Figure 3: Briquette ash content

Therefore, rubber seed shells and used cooking oil contribute to an increase in the ash level of Alaban wood charcoal briquettes. However, the combined ash content is still lower than other biomass briquette materials. Based on these test results, an ANOVA was conducted to determine the significance of the raw materials used in this study, using a significance level () of 5%.

Table 3: ANOVA test results for ash content

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	14,222a	6	2,370	37,300	0,000
Intercept	974,171	1	974, 171	15329,772	0,000
Composition Variation	14,222	6	2,370	37,300	0,000
Error	0,890	14	0,064		
Total	989,282	21			
Corrected Total	15,112	20			

a. R Squared = 0,941 (Adjusted R Squared = 0,916); Significance α = 5% = 0,05

0: = 0 (There is no significant difference between the variance of compositions and ash content)

1 ≠ 0 (There is a significant difference between the variance of compositions and ash content)

After observing Table 3, the ANOVA test results for ash content can be interpreted based on the decision criteria as follows:

- A *p*-value of less than α indicates a significant treatment difference.
- If the *p*-value is greater than α, it indicates no significant difference in treatments.

Based on the above decision criteria, the results shown in Table 3 indicate that the *p*-value for the composition variance is 0.000, which is smaller than α (0.05). Therefore, according to decision criterion number 1, the variance of compositions shows a significant difference in ash content. After obtaining significant results from the ANOVA test, a post hoc test is conducted to determine if one variable has a significant difference from another variable.

Table 4: The post hoc test of ash content

Composition Variation	N	Subset for alpha = 0,05				
		1	2	3	4	5
100:0	3	5,3400				
90:10	3		6,0700			
70:30	3		6,5000	6,5000		
50:50	3			7,0600	7,0600	
30:70	3				7,3267	7,3267
10:90	3				7,5200	7,5200
0:100	3					7,8600
Sig.		1,000	0,408	0,163	0,337	0,200

Based on Table 4, the post hoc test results reveal that the composition variations of 90:10 and 70:30 belong to the same subset, subset 2. The composition variations of 70:30 and 50:50 are in subset 3, while the composition variation of 70:30 is in subsets 2 and 3. The composition variations of 50:50, 30:70, and 10:90 are in subset 4, and the composition variations of 30:70, 10:90, and 0:100 are in subset 5. The composition variation of 50:50 is in subsets 3 and 4, and the composition variations of 30:70 and 10:90 are in subsets 4 and 5. Based on the table, it can be concluded that the composition variations of 0 and 100 do not belong to the same subset, indicating significant differences in the test results for the composition variations of 0:100 and 100:0.

Briquette Calorific Value: The calorific value is the most crucial factor in determining the quality of briquettes. A higher calorific value indicates that briquettes are of higher quality. The higher the calorific value, the more heat the briquettes produce. The calorific value of the briquette conforms to ASTM D5142-02 based on Figure 4. The average calorific value produced by the briquettes is 7645–8731 cal/g. The most significant calorific value of the briquette is 8431 cal/g for a 100% Alaban wood charcoal composition. The lowest caloric density is 7645 calories per gram for a rubber seed shell-only composition. According to SNI No. 01-6235-2000, the briquettes must have a calorific value of at least 5,000 cal/g, and all samples of the produced briquettes meet these standards.

The calorific value is associated with the moisture and ash content of the briquettes. Because briquette ignition will be easy if the moisture level is low, the heat content will be high (Novrizal et al., 2018). The calorific value of Alaban wood charcoal is 6673.15% (Haryanti et al., 2018). Its calorific value can be increased by using resin sap as an adhesive and dipping it in cooking oil (Efelina et al., 2018). Using resin adhesives on briquettes resulted in a higher calorific value than tapioca adhesives (Firdaus and Nurdin, 2019).

The results of the briquette calorific value are more significant than the calorific value of briquettes made from coconut shells and coal bottom ash, 5102.90 cal/g (Iriany et al., 2016); briquettes made from banana leaves, 4,646 cal/g (Alfajriandi et al., 2017); and briquettes made from rubber seed shells and coal ash, 3597.59 cal/g-45 (Haryanti et al., 2018).

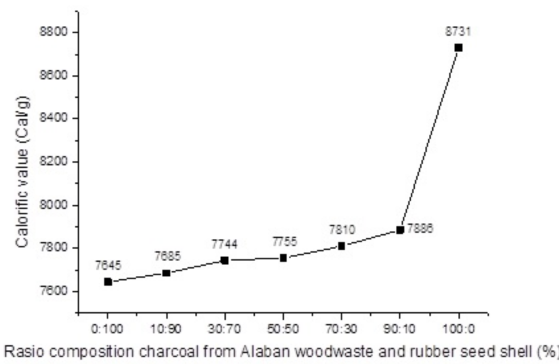

Figure 4: Briquette Calorific value

The results from Figure 4 indicate that briquettes made from Alaban wood charcoal without adding rubber seed shells had the highest levels of ash and water content and calorific value. Although the composition of these briquettes contains ash and water, they still meet national criteria despite their lower quality. Based on these test results, an ANOVA test was conducted to determine the significance of the raw materials used in this study, using a significance level of 5%.

Table 5: ANOVA test results for calorific value

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2569141,207a	6	428190201	2492928,812	0,000
Intercept	1308337681,784	1	1308337681784	7617158668,550	0,000
Composition Variation	2569141,207	6	42,190,201	2492928,812	0,000
Error	2,405	14	0,172		
Total	1310906825,395	21			
Corrected Total	2569143,611	20			

a. R Squared = 1,000 (Adjusted R Squared = 1,000); Significance α = 5% = 0,05

Hypothesis Testing **0: = 0** (There is no significant difference between composition variations and calorific value) **1: ≠ 0** (There is a significant difference between composition variations and calorific value)
After examining Table 5 and conducting an ANOVA test, a decision can be made based on the decision rules as follows:

- If the *p*-value < α, it indicates a significant difference in treatments.
- If the *p*-value > α, it indicates no significant difference in treatments.

Based on the two decision rules above, the results shown in Table 5 indicate that the *p*-value for the composition variation variable is 0.000, which is smaller than α (0.05). According to decision rule number 1, the composition variation shows a significant difference in calorific value. Therefore, after obtaining significant results from the ANOVA test, a post hoc test is conducted to determine if one variable differs significantly from others.

Table 6: The post hoc test of calorific values

Composition Variation	N	Subset for alpha = 0,05				
		1	2	3	4	5
100:0	3	5,3400				
90:10	3		6,0700			
70:30	3		6,5000	6,5000		
50:50	3			7,0600	7,0600	
30:70	3				7,3267	7,3267
10:90	3				7,5200	7,5200
0:100	3					7,8600
Sig.		1,000	0,408	0,163	0,337	0,200

Based on Table 6, the post hoc test results reveal that all composition variations do not belong to the same subset. From this, it can be concluded that there are significant differences in the test results among all composition variations, including 100:0, 90:10, 70:30, 50:50, 30:70, 10:90, and 0:100.

Quality of burning briquettes

Testing the quality of burning briquettes is to determine the time required for the briquettes to ignite and be ready for use and the durability of the briquettes' heat release. The variables measured consist of the initial ignition time, the combustion duration, and the combustion speed, as indicated in Table 2.

The quality of burning briquettes with an average initial ignition time of (3.06 to 4.17) minutes (Figure 5), burning duration of (92.07 to 125.27) minutes (Figure 6), and combustion speed of (0.16-0.22) g/minute (Figure 7) The flame features of briquettes with high combustion quality are flammability, a prolonged combustion period, and a low combustion rate.

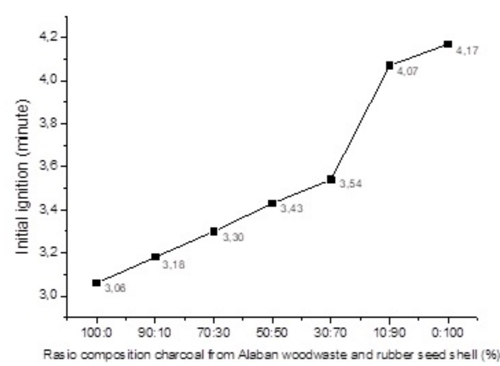

Figure 5: Initial ignition time

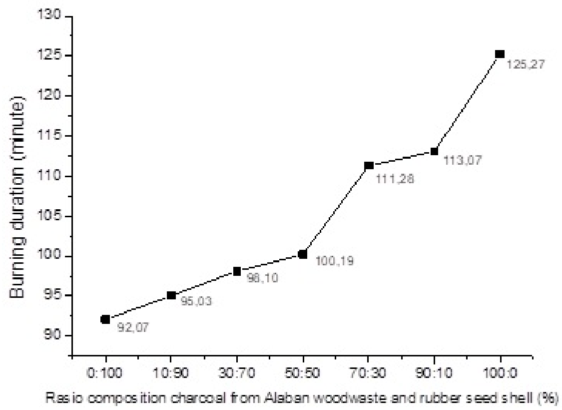

Figure 6: Burning duration

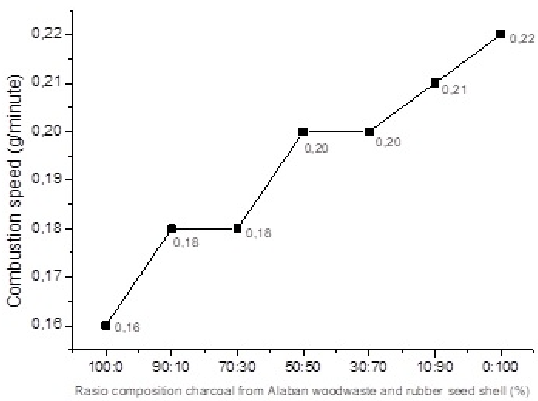

Figure 7: Combustion speed

Briquettes are expected to be easily ignited as fuel and create coal rapidly. As can be observed, briquettes composed of 100 percent rubber seed shells have the longest igniting duration at 4.17 minutes.

The briquette with a composition of 100 percent Alaban wood charcoal is produced the quickest, at 3.06 minutes. In the study by Haryanti et al. (2019), briquettes made with coal base ash and Alaban wood charcoal had an initial ignition time of 1.32 to 2.22 minutes, then 1.32 to 1.52 minutes with coal fly ash material and Alaban wood charcoal, and 10.35 to 12.21 minutes with rubber seed shells and coal base ash. Compared to this study, the initial ignition of briquettes is typically quick because of the dyeing of briquettes in spent cooking oil, which ignites the flame.

The particle size influences the igniting time of briquettes. When the particle size decreases, the briquettes' ignition takes longer. It is considered that when particle size decreases, briquettes grow denser and more compact. This state makes it more difficult to ignite the briquettes. The larger particle size will result in greater porosity, where the pores will make oxygen circulation simpler and quicker to initiate. A comparison of avocado seed briquettes with an early ignition time in Malik's research (Malik et al., 2017).

In addition, the duration of briquette combustion is analyzed and shown in Table 2. As seen, a briquette composed of 100% Alaban wood charcoal has a longer combustion period (125.27 minutes) because it contains more materials to burn. The duration of burning briquettes is reduced to 92.07 minutes when they are composed of 100% rubber seed shells. Radam et al. (2017) stated that alaban wood charcoal had a 70-minute burning time. The amount of water in a substance affects the time or length of combustion.

In the generated briquettes, the greater the content of rubber seed shell, the shorter the burning, and vice versa, the greater the composition of Alaban wood charcoal, the longer the burning. This briquette has a longer burning time than briquettes (Ajiboye et al., 2016) made from a blend of sawdust and charcoal with particle sizes of 70, 40, 30, 20, and 18 mesh, with the longest burning time of 31 minutes. This study demonstrated that burning a briquette made from 100% Alaban wood charcoal takes longer than one manufactured from 100% rubber seed shells. A briquette that has a long burning period is a quality briquette. The longer the duration of the flame, the fewer briquettes will be used as fuel.

The material's structure, the bonded material's carbon content, and the material's hardness level all affect the combustion rate of briquettes (Jamilatun, 2008). The shorter the briquette spins, the faster the combustion rate. The briquette with a 100 percent Alaban wood charcoal composition has the highest combustion rate, 0.16 g/minute. The briquette with a 100% rubber seed shell composition is the longest. Based on these results, it is evident that increasing the amount of rubber seed shells will increase the combustion rate. As the composition of Alaban charcoal increases, the difficulty of outside air entering the briquettes increases, leading the briquettes to burn for longer. The longer the briquettes are burned, the lower the combustion rate.

The compatibility of research results with briquette quality standards and the determination of the highest quality briquettes

SNI No. 01 - 6235 - 2000 is used to determine briquette specifications. Table 3 presents briquettes with varying compositions of Alaban wood and rubber seed shells compared to the standard. Based on Table 7, the briquettes produced in this study conform to the quality standards of commercial briquettes in Indonesia, the United Kingdom, and the United States, having a high calorific value and low levels of ash and water.

Table 7: Comparison of research results according to briquette quality standards

Properties	Standard				
	Jepang	Inggris	USA	SNI	Research result
Water content (%)	6-8	3-4	6	8	2,21-2,72
Ash content (%)	3-6	8-10	18	8	5,34-7,86
Calorific value (cal/g)	6000-7000	7300	6500	5000	7645-8731

Table 8: Selected composition assessment

No	Rasio Alaban wood waste: Rubber seed shell	Quality category	Value	Information	Score
1	90:10	Water content (%)	2,36	-	4
		Ash content (%)	6,07	-	
		Calorific value (Cal/g)	7884	+	
		Initial ignition (minute)	3,18	+	
		Burning duration (minute)	113,07	+	
		Combustion speed (g/minute)	0,18	+	
2	70:30	Water content (%)	2,45	-	4
		Ash content (%)	6,50	-	
		Calorific value (Cal/g)	7810	+	
		Initial ignition (minute)	3,30	+	
		Burning duration (minute)	111,28	+	
		Combustion speed (g/minute)	0,18	+	
3	50:50	Water content (%)	2,55	-	4
		Ash content (%)	7,06	-	
		Calorific value (Cal/g)	7755	+	
		Initial ignition (minute)	3,43	+	
		Burning duration (minute)	100,19	+	
		Combustion speed (g/minute)	0,20	+	
4	30:70	Water content (%)	2,58	-	4
		Ash content (%)	7,33	-	
		Calorific value (Cal/g)	7744	+	
		Initial ignition (minute)	3,54	+	
		Burning duration (minute)	98,1	+	
		Combustion speed (g/minute)	0,20	+	
5	10:90	Water content (%)	2,64	-	4
		Ash content (%)	7,52	-	
		Calorific value (Cal/g)	7685	+	
		Initial ignition (minute)	4,07	+	
		Burning duration (minute)	95,03	+	
		Combustion speed (g/minute)	0,21	+	

Decision making

Based on the testing of briquette characteristics and combustion quality, as shown in Figures 2–7, and the analysis presented in Tables 1–6, it has been determined that the best composition in this study is 90% Alaban wood charcoal and 10% rubber seed shells. This composition exhibits the lowest water content, highest calorific value, quick ignition, and extended duration, as indicated by positive values in the post hoc test for this percentage. This decision is made by weighing the obtained values against the predetermined quality standards. If the quality exceeds the standard, it is marked as positive (+); conversely, if the test value falls below the standard, it is marked as negative (-). Finally, the selection of the preferred composition is determined by summing the number of positive values obtained from all tested parameters (Table 8). In the case of equal final scores, the selection is based on the highest scoring value (Table 10).

Table 9: Classification of Alaban wood charcoal briquettes and rubber seedshells

Category	Quality	Calorific value	Water content	Ash content	Initial ignition	Burning duration	Combustion speed
1	Low	7645 - 8007	2.56 - 2.72	7.03 - 7.86	3.81 - 4.17	92.07 - 103.13	0.21 - 0.22
2	Currently	8008 - 8369	2.39 - 2.55	6.19 - 7.02	3.44 - 3.8	103.14 - 114.20	0.19 - 0.20
3	High	8370 - 8731	2.21 - 2.38	5.34 - 6.18	3.06 - 3.43	114.21 -125.27	0.16 - 0.18

Table 10: The results of scoring the quality of the Alaban wood charcoal briquette and the rubber seed shell

Rasio Alaban wood waste: Rubber seed shell	Quality category						Score
	Calorific Value	Water Content	Ash Content	Initial Ignition	Burning Duration	Combustion Speed	
90:10	1	3	3	3	2	3	15
70:30	1	2	2	3	2	3	13
50:50	1	2	1	3	1	2	10
30:70	1	1	1	2	1	2	8
10:90	1	1	1	1	1	1	6

CONCLUSION

The characteristics and quality of combustion of biomass-based briquettes made from Alaban (Vitex pubescent) wood waste and rubber seed shells are studied based on variations in the material mixture's composition. The composition of the material influences the characteristics and quality of burning briquettes. The greater the characteristics of the briquette obtained, the greater the composition of Alaban wood charcoal briquettes, with a lower water and ash content and a higher calorific value. The higher the composition of Alaban wood charcoal, the faster the initial ignition time, the speed of briquette combustion, and the combustion duration. The recommended composition is 90% alabaster wood charcoal and 10% rubber seed shells because briquettes are produced with the lowest ash content and the highest calorific value following SNI provisions. The suitability of the research results with the quality standards of the briquettes demonstrates that briquettes made from Alaban charcoal waste and rubber seed shells can be used as commercial briquettes in Indonesia.

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