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Original Research Article

The Effect of adding Coconut Shells and Corn Husk to Biobriquettes from Fish Bone Waste

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Abstract
Biomass generates a large amount of waste. One of these is fish bones, corn husks, and coconut shells. Fish bone waste has the potential to be used as biobriquettes because it contains 10.16% carbon. To maximize the potential of fish bone waste, it should be mixed with corn husks and coconut shells. In addition, more calories can be added to the biobriquettes. In the manufacture of biobriquettes, pyrolysis temperature also affects the quality of the resulting biobriquettes. The purpose of this study was to determine the quality of biobriquettes with a mixture of fish bones, corn husks, and coconut shells at 500°C and 350°C. The compositions of the biobriquette materials used in this study were 100% fish bone waste, fish bone:coconut shell waste (50:50), and fish bone waste:corn husk (50:50). The results of the study showed that biobriquettes with a mixture of fish bones and coconut shell 50:50 at a pyrolysis temperature of 350 °C had the best quality according to SNI 01-6235-2000 concerning wood charcoal briquettes. The water content and calorific value were 1.93% and 5,913.6 cal/g, respectively. The addition of coconut shells and corn husks affected the characteristics of biobriquettes made from fish bone waste.

Keywords: Biobriquettes; coconut shells; corn husk; fish bone; pyrolysis

1. Introduction
Alternative energy is a substitute for fossil fuels and can be generated using biomass energy. Biomass energy is a promising alternative because it is renewable and easy to find. Biomass waste has the potential to be developed into alternative energy in the form of briquettes, one of which is fish bone waste. Fish bone waste consists of meat and bone. In this study, only the bones were used as the material for making biobriquette fuel, because based on research fish bone waste has an initial content consisting of 6.32% moisture content, 48.18% volatile matter, 41.67% ash content, and 10.16% carbon content. Apart from fish bone waste, another biomass that can be used as raw material for biobriquette production is corn husk because corn husk has a calorific value of 5,777 cal/g (Za et al., 2021) and a carbon value of 35.3%. In addition to corn husk, coconut shell is also a material for making biobriquettes because coconut shell has a high carbon content of 63.2%, which increases the calorific value. Biobriquettes are produced using a pyrolysis process to produce charcoal.

The quality of biobriquettes is influenced by several factors, such as the temperature during the pyrolysis process and the concentration of the adhesive. In this study using temperatures of 350°C and 500°C, the two temperatures were used as a comparison to determine the effect of temperature increase on briquette quality. According to Ristianingsih et al. (2015), the higher the pyrolysis temperature, the higher the calorific value, which is influenced by the high levels of bound carbon in the briquettes. The greater the carbon content, the better the quality of the briquettes. Increasing adhesive concentration also affects the quality of the biobriquettes. Jannah et al. (2022) stated that variations in adhesive concentration affect the quality of biobriquettes. This can affect the calorific value and combustion rate of the produced biobriquettes. Biobriquettes are products of waste-to-energy conversion. It is a part of refuse-derived fuel (RDF). It is important to reduce waste generation by converting it to energy. Briquettes are biomass fuel substitutes. Energy can be produced from waste to sustain energy (Hafiza et al., 2021).

Based on the above problems, in this study, fish bone waste, coconut shells, and corn husks were processed into biobriquettes. This study aimed to analyze the proximate content, calorific value, and emissions produced to determine the quality of good biobriquettes. The good quality of biobriquettes refers to the SNI 01-6235-2000 standard with 8% moisture content, 15% volatile matter, 8% ash content, and a maximum calorific value of 5000 cal/g.

2. Methods

The research was conducted using several variations of material composition, pyrolysis temperature, and adhesive concentration, as shown in Table 1. The adhesive used in this study is tapioca. For each variation, the proximate content, including the moisture content, ash content, volatile matter, carbon content, and calorific value, was tested. The best biobriquettes will be tested for CO and SO_2 emissions.

Table 1. Variation of the biobriquettes

No	Material Composition	Pyrolisis Temperature			
		500°C 240 min.		350°C 240 min.	
		Adhesive 10%	Adhesive 7%	Adhesive 10%	Adhesive 7%
1.	100% Fish bone wastes	A1	A2	A7	A8
2.	(50% : 50%) Fish bone wastes : Coconut Shells	A3	A4	A9	A10
3.	(50% : 50%) Fish bone wastes : Corn Husk	A5	A6	A11	A12

2.1. Making the Biobriquettes

Beginning the biobriquet are made with the preparation of material. The organic waste consisted of fish bone waste, coconut shells, and corn. The fish bone waste, coconut shells, and corn husks were washed, cut, and dried in an oven at 105°C (Hayati, 2018) to reduce moisture and ensure an effective pyrolysis process. Subsequently, the organic waste is burned using pyrolysis. The dried fish bone waste, coconut shells, and corn husks were then pyrolyzed at 350°C and 500°C for 240 min. The combustion time was used to ensure that the biomass burned completely. The length of the pyrolysis process can increase the fixed carbon of charcoal, so as to increase the calorific value (Loppies, 2016). The resulting charcoal is used as a material for making the biobriquettes. The pyrolysis reactor used is shown in Figure 1.

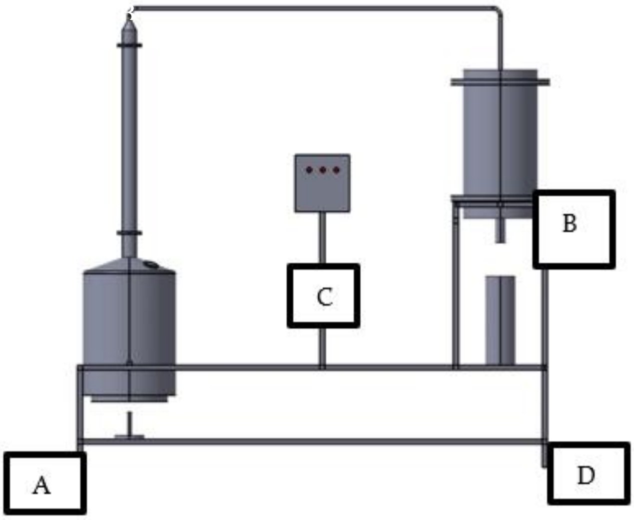

Figure 1. Pyrolisis Reactor

Information:

A = Reactor
B = Condensor
C = Control Panel
D = Liquid Smoke Container

Biomass in the pyrolysis reactor is burned at a predetermined temperature, resulting in charcoal, bio oil, and gas. Bio-oil is produced from condensed pyrolysis gas.

1. Charcoal Pounding
   The charcoal obtained from the pyrolysis process was manually pounded using a pounding tool. This process shapes the charcoal into smaller pieces, making it easier to sift (Haykiri et al., 2013).
2. Sifting
   The sieving process was performed using a 60 mesh sieve (Anggraeni et al., 2021). This process was performed to obtain finer charcoal particles or powder.
3. Mixing the ingredients according to the variation
   Charcoal that has been refined into powder is then mixed with 7% and 10% tapioca starch adhesive according to each variation. Mixing is performed manually, and the mixture is stirred for 5-10 minutes (Djafaar, 2016).
4. Molding and Drying
   The charcoal and adhesive that were mixed were then manually molded using a briquette press to obtain solid and compact biobriquettes. The resulting biobriquettes were then dried in an oven at 102 °C for 3 h. This drying is done to reduce the water content of the biocharcoal briquettes to obtain the best quality briquettes (Djafaar, 2016).

2.2. Proximate Analysis

Proximate analysis was used to determine the chemical composition and energy content, including the moisture content, volatile matter, ash content, and fixed carbon content, as shown in Table 2.

Table 2. Proximate Analysis

Parameters	% Standart	Reference
Moisture Content	≤8%	SNI 06-3730-1995
Ash Content	≤8%	

Parameters	% Standart	Reference
Volatile Matter	≤15%	
Fixed Carbon	≥77%	
Calorific Value	≤5000 cal/g	

2.3. Emission Analysis

Emission tests were conducted to determine the levels of CO and SO2 emissions produced during the burning of biobriquettes. This test was performed on the best biobriquette sample. Sample point according to SNI 19-71172-2005 at least 4 points for a chimney diameter of less than 1 m and maximum 20 points for chimney diameter greater than 4.5 m (Figure 2). where A is the sampling hole, R is the radius chimney, and r is the distance of the crossing point from the center of the chimney.

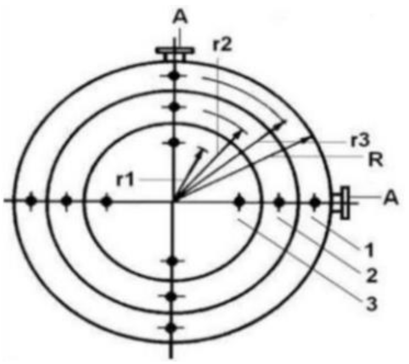

Figure 2. Point Sample of SO2 gas

Figure 2 shows that the point sample consists of test sampling hole (A), radius of the chimney (r), distance of cross point 1 from the center of the chimney (r1), distance of cross point 2 from the center of the chimney (r2), distance of cross point 3 from the center of the chimney (r3), cross point 1 (1), crossing point 2 (2), and crossing point 3 (3). Emission testing refers to the Peraturan Menteri Republik Indonesia No. 41 Tahun 1999 concerning National Ambient Air Quality Standards. The analytical method used for measuring CO emissions in the form of NDIR (non-dispersive infrared) uses the NDIR Analyzer. For SO2 parameters, the pararosanilin analysis method was used, and a spectrophotometer was used. Sulfur dioxide (SO2) gas testing is carried out by adding a solution of pararosanilin and formaldehyde to the dichlorosulfonatomercurate compound, a compound of pararosanilin methyl sulfonate which is purple and measured at a wavelength of 550 nm (SNI 7119-7:2017).

3. Result and Discussion

3.1. Moisture Content

According to SNI 1-6235-2000, the maximum moisture content of briquettes is 8%. Briquettes with such low moisture concentrations are suitable for combustion because excessive energy is required for drying, and a larger moisture content poses a challenge when burning (Yiga et al., 2023). Figure 2 shows that the highest moisture content value was found in variation A9, 50% fish bone waste and 50% coconut shell, with 10% adhesive concentration at 6.01% at 350°C. The lowest moisture content was found in variation A12 (1.33 %) in the composition of 50% fish bone waste and 50% corn husk with 7% adhesive at 350°C. This can be attributed to the higher initial moisture content of the coconut shell, ranging from 11.9% to 32.3% (Nikiema et al., 2022), compared to the corn husk, which has a moisture content of 12.94%. In addition, high adhesive content and low pyrolysis temperature can also reduce the moisture content of the biobriquettes. Adhesive with a concentration of 10% has a high moisture content value because the water contained in the adhesive will be bound to the pores of the charcoal so that it easily absorbs water from the air (Za et al, 2021). Pyrolysis temperature also affects the resulting water content because if the pyrolysis temperature is too low, the water content contained in the briquettes cannot evaporate completely, thereby increasing the water content (Saparudin et al, 2015). In another hand, the more adhesive in the biobriquette make the greather of the amount of water need to changed the adhesive. It caused the moisture content of the the biobriquette which is greater (Pratiwi dan Imam, 2021).

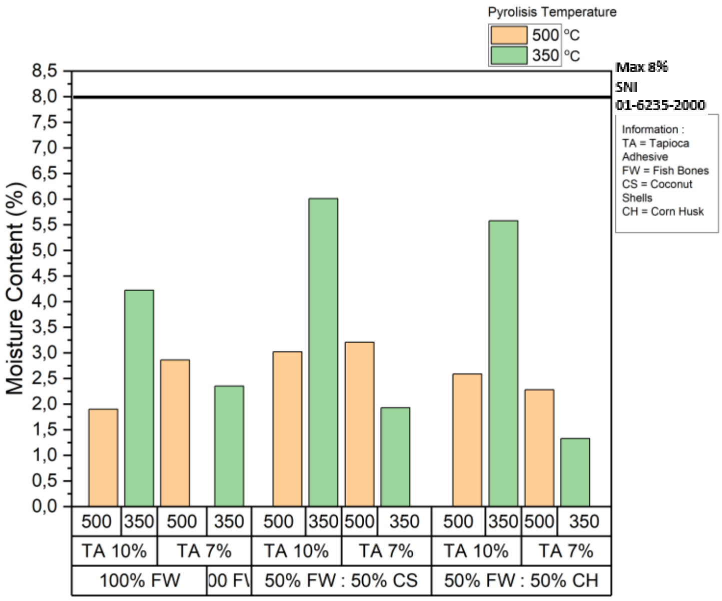

Figure 2. Moisture content

3.2. Ash Content

The lowest ash content test results were seen in variation A10 with 50% fish bone waste and 50% coconut shell, 7% adhesive at 350°C of 10.34%, while the highest ash content was 18.37% in variation A5 50% fish bone waste and 50% corn husk at 10% adhesive concentration and 500°C temperature. High ash content can be determined based on the initial ash content contained in the biobriquette composition. Corn husk has a high initial ash content of 10.99% compared to the coconut shell ash content of 3.54%, so the ash content will decrease with the addition of coconut shell. Increasing temperature and adhesive concentration can also increase ash content. The increase in temperature and time during pyrolysis can make the carbon particles that burn into ash also increase so that the resulting ash content becomes greater (Purwanto and Sofyan, 2014). Meanwhile, an increase in adhesive concentration causes an increase in ash content because adhesives contain organic matter that produces high ash during combustion (Hasan et al, 2017). As shown in Figure 3, the ash content of biobriquettes is more than 8%, which is above the standard value.

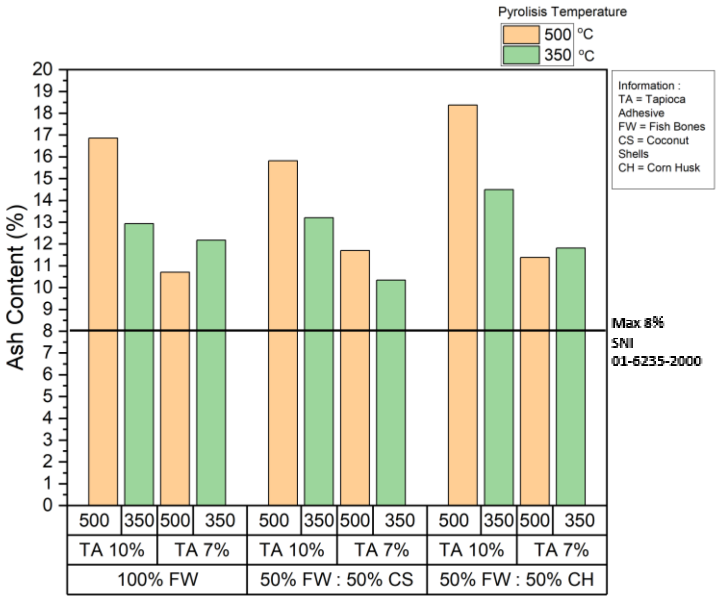

Figure 3. Ash content

3.3. Volatile Matter

The amount of volatile matter can be used to measure the amount of smoke produced during combustion. The greater the volatile matter value, the greater the amount of smoke (Djaafar, 2017). The test results of the lowest volatile matter content of 41.764% were found in the composition of 50% fish bone waste and 50% coconut shell with 7% adhesive at 500°C. The highest volatile matter content was found in the composition of 50% fish bone waste and 50% corn husk with 10% adhesive at 350°C of 62.178%. Fish bone waste has a high initial volatile matter content of 48.17%. The high test of volatile matter content in the composition of fish bone waste and corn husk is due to the higher initial volatile value of corn husk in the study, 53.69%, compared to the initial coconut shell volatile matter of 3.23%. Briquettes with the highest volatile matter content were made by adding corn husk and tapioca adhesive to the briquettes. This is because the added adhesive can increase the volatile content (Iskandar et al., 2019). In addition, the low pyrolysis temperature used can increase the volatile matter content of the produced biobriquettes (Iriany, 2016). From Figure 4, it can be seen that the briquettes exceed 15% and don't meet SNI 01-6235-2000.

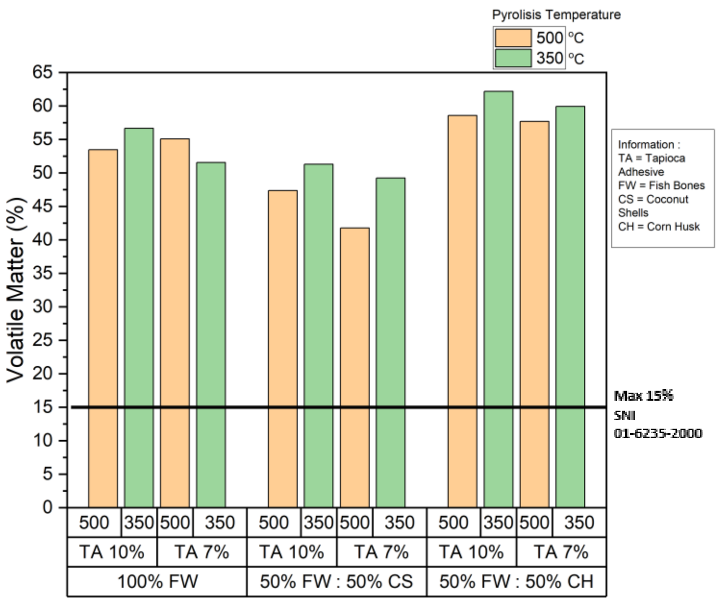

Figure 4. Volatile matter

3.4. Fixed Carbon

Carbon content is influenced by volatile materials. The more volatile the components, the lower the carbon content. As seen in Figure 5, the carbon content of biobriquettes is more than 77%, which is not in accordance with SNI 01-6235-2000. The figure shows that variation A7 with 50% fish bone waste and 50% corn husk, 7% adhesive at 500˚C has the highest carbon content of 46.85%. Meanwhile, the lowest carbon content in the A2 variation of 24.62% was found in the variation of 100% fish bone waste, 10% adhesive at 350°C. This could be due to the higher initial corn husk content compared to coconut shell. In addition, it can also be caused by the high pyrolysis temperature. The increase in carbon content can be caused by the increase in pyrolysis temperature, when burning, which causes the compounds that make up the biobriquette material to decompose due to high temperatures, so that the remaining content in the biobriquette material is carbon (Alam, 2022). Meanwhile, according to Pane et al. (2015), the addition of adhesive decreases the carbon content, and the higher the adhesive and water content, the lower the carbon content. This is because briquettes that use materials with high additives increase the ash and volatile contents of a briquette.

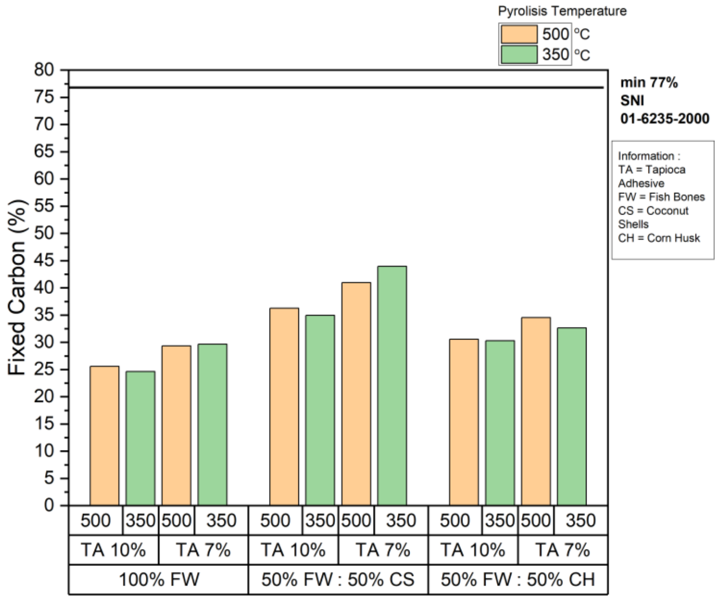

Figure 5. Fixed Carbon

3.5. Calorific Value

The most important parameter that determines the quality of biobriquettes is the calorific value. The higher the calorific value indicates the better quality of the briquettes produced (Ristianingsih et al., 2015). The highest calorific value of the briquettes was 5,913.6 cal/g, found in the A10 variation with a temperature of 350°C, a composition of 50% fish bone waste and 50% coconut shell with 7% adhesive content. This is similar to the results of Ridhuan et al. (2020), where the high calorie value of the biobriquettes was determined by the coconut shell content. Meanwhile, the lowest calorific value was found in the A1 variation with a composition of 100% fish bone waste and 10% adhesive at a temperature of 500°C. The results of this study show that the highest calorific value was achieved with the addition of coconut shells compared to corn husks, as shown in Figure 6. Increasing the percentage of adhesive and pyrolysis temperature can also increase the calorific value of the biobriquettes (Jannah et al., 2022). The caloric value of the biobriquettes depend on moisture content in material of the biobriquettes (Hakika et al, 2023).

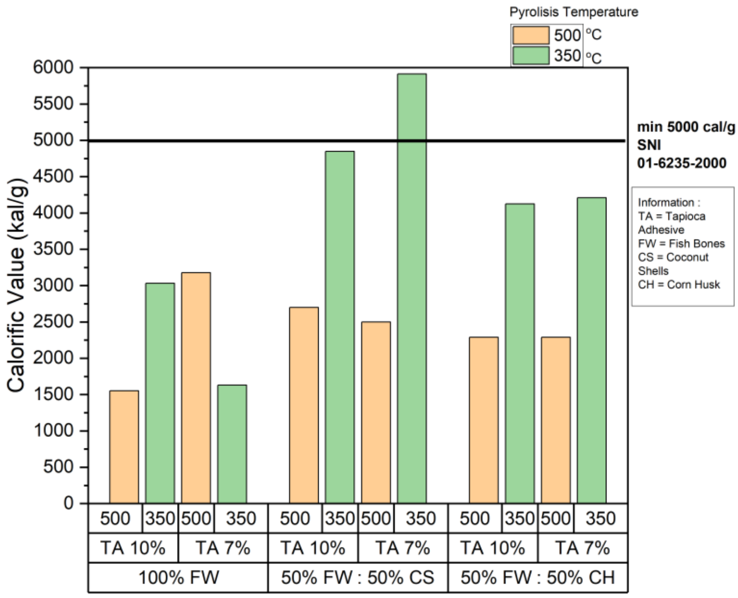

Figure 6. Calorific Value

3.6. MANOVA Statistical Analysis

The research data in the form of moisture content, volatile matter content, ash content, carbon content, and calorific value of biobriquettes were then subjected to statistical testing using Multivarist Analysis of Variance (MANOVA). Hypothesis in the research was the effect of temperature, composition and adhesive have effect to biobriquettes quality. variation MANOVA test results can be seen in Table 2.

Table 2. The Result of MANOVA Test

Independent Variable	F	Probability (Sig.)	Hypothesis	Information
		Composition		
Moisture Content	11,998	0.009	H1 accepted	Effected
Volatile Matter	7,898	0.023		
Ash Content	9,968	0.013		
Fixed Carbon	0,336	0.048		
Calorific Value	2,842	0.030		
		Temperature		
Moisture Content	11,535	0.009		Effected
Volatile Matter	10,029	0.013	H1 accepted	
Ash Content	9,533	0.015		
Fixed Carbon	0.539	0.044		
Calorific Value	0.067	0.038		
		Adhesive		

Independent Variable	F	Probability (Sig.)	Hypothesis	Information
Moisture Content	6,141	0.038	H1 accepted	Effected
Volatile Matter	0.374	0.049		
Ash Content	0.113	0.045		
Fixed Carbon	21,844	0.002		
Calorific Value	0.003	0.049		
Composition, Temperature, and Adhesive				
Moisture Content	9,091	0.017	H1 accepted	Effected
Volatile Matter	4,153	0.036		
Ash Content	12,277	0.008		
Fixed Carbon	0.022	0.026		
Calorific Value	0.020	0.028		

The MANOVA test data in Table 2 obtained a value not exceeding 0.05. The test data can be stated that the H1 hypothesis was accepted if the P-value <0.05. Table 2 shows that for variations in composition, temperature, and adhesive which the results state that the hypothesis. H1 was accepted, so it can be concluded that variations in composition, temperature, and adhesive in biobriquettes have a significant effect on moisture content, volatile matter content, ash content, carbon content, and calorific value. The composition of the raw material, combustion temperature in the pyrolysis process, and adhesive of the briquettes affected the briquette quality.

3.7. Best Biobriquettes

The best briquettes were determined using a scoring method based on the criteria according to SNI 01-6235-2000, which include moisture content, volatile matter, ash content, carbon content, and calorific value. A scoring system was used to assign a value to each variation according to the individual characteristics of the briquettes. The scoring system uses numbers 1 and 0 (Saputri, 2021). Parameters that meet the quality criteria use the number 1, and parameters that do not meet the quality criteria use the number 0. Table 3 shows the results of the scoring assessment.

Table 3. Scoring best biobriquettes

Characteristic	Unit	Variation											
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
Moisture Content	%	1.90 (1)	2.35 (1)	3.02 (1)	3.21 (1)	2.59 (1)	2.28 (1)	4.22 (1)	2.86 (1)	6.01 (1)	1.93 (1)	5.58 (1)	1.33 (1)
Volatile Matter	%	53.4 (0)	51.5 (0)	49.2 (0)	47.3 (0)	51.2 (0)	41.7 (0)	57.7 (0)	56.6 (0)	62.1 (0)	55.0 (0)	59.9 (0)	58.5 (0)
Ash Content	%	16.8 (0)	12.1 (0)	15.8 (0)	11.6 (0)	18.3 (0)	11.3 (0)	12.9 (0)	10.7 (0)	13.2 (0)	10.3 (0)	14.4 (0)	11.1 (0)

Characteristic	Unit	Variation											
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
Fixed Carbon	%	29.6 (0)	36.2 (0)	34.9 (0)	40.9 (0)	30.3 (0)	46.8 (0)	29.3 (0)	32.6 (0)	24.6 (0)	34.5 (0)	25.5 (0)	30.5 (0)
Calorific Value	Cal/g	1550.5 (0)	1629.8 (0)	2698.9 (0)	2497.8 (0)	2289.0 (0)	2289.2 (0)	3030.2 (0)	3178.1 (0)	4846.2 (0)	5913.6 (1)	4122.8 (0)	4209.4 (0)
Score		1	1	1	1	1	1	1	1	1	2	1	1

Table 3 shows that the best briquettes were obtained in variation A12 with 50% fish bone waste and 50% coconut shell using 7% adhesive variation at 350 °C, which met two briquette standards, namely moisture content and calorific value. This was caused by the temperature suitable for the combustion of fish bone waste and coconut shells. Arafah and Soni, 2021 showed that the composition of raw materials of the biobriquettes affects the quality of the biobriquettes. The raw material characteristics of the biobriquettes produced good-quality biobriquettes. Hakika et al. (2023) stated that a higher coconut shell content produces more calories and good-quality biobriquettes. This is the same with the result of this study

3.8. Emission

Fuel combustion in the form of biobriquettes produces gas emissions that must be known for emission testing. The parameters tested are CO and SO_2. The emission test aims to measure the value of emissions produced when burning biobriquettes. Table 4 shows the results of the biobriquette emission test.

Table 4. Emission of best biobriquettes

No.	Parameters	Results (mg/Nm³)	Standars (mg/Nm³)
1.	CO	2,099.9	726
2.	SO_2	0	800

Table 4 shows that the CO emission test results are above the quality standard values. Peraturan Gubernur Jawa Timur No. 10 Tahun 2009 states that the quality standard for the CO parameter is 726 mg/Nm³ . CO emission measurements were conducted to determine the amount of CO generated by burning biobriquettes. Biobriquettes have chemical compounds consisting of C, H, O, N, and Sulfur (Ekayuliana, 2020). Coconut shell has a high C and O content of 58.07% and 35.65%. Carbon, nitrogen, and sulfur in fuel mix with oxygen in the air to form carbon monoxide and other gases (Qistina, 2016). Table 4 shows that the SO_2 measurement results are below the quality standard value of 800 mg/Nm3 in accordance with Peraturan Menteri Energi dan Sumber Daya Mineral Tahun 2006.. High and low levels of SO_2 can be caused by the sulfur content in the raw materials used to make biobriquettes (Setiani et al., 2019). The sulfur content in fish bone waste is 0.91% (Reza et al., 2022) and in coconut shells is 0.5% (Tamado et al., 2013). The low sulfur content of biobriquettes can reduce SO_2 emissions. Mahidin et al, 2016 showed that reduction of sulfur content in the biobriquettes can removal SO_2 emission. This is because the sulfur content in the biobriquettes is lower cause SO_2 lower.

4. Conclusions

The results of testing biobriquettes showed that the best biobriquettes with a calorific value and moisture content that meet SNI 01-6235-2000 are in the variation of 50% fish bone waste and 50% coconut shell with 7% tapioca adhesive at 350°C of 1.93% and a calorific value of 5,913.6 cal/g. Emission testing resulted in a CO parameter of 2,099 mg/Nm³ and 0 mg/Nm³ for the SO2 parameter. The variation and temperature of the pyrolysis affected the characteristics of the biobriquettes. One of the steps that can be tried to improve the quality of biobriquettes on parameters that have not been met is to rearrange the percentage composition of the mixture of raw materials, such as the composition of coconut shell, which is more than the composition of fish bone waste. In addtion, futhermore research fish bone waste is not suitable treatment waste to energy.

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