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Combustion Properties of Biochar Briquettes Blend of Goat Manure Charcoal, *Saboak* Shell and Other Biomass

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ABSTRACT: This study aims to determine the quality of combustion properties of biochar briquettes mixed with goat manure charcoal, lontar shell and other biomass. The completely randomized design was applied with 4 different combinations tested, as follows: T1= 50% goat manure charcoal + 40% lontar shell + 10% lontar male fruit; T2= 50% goat manure charcoal + 40% lontar shell + 10% lamtoro twigs; T3= 50% goat manure charcoal + 40% lontar shell + 10% rice husk and T4= 50% goat manure charcoal + 40% lontar shell + 10% corn cob. The variables studied were combustion temperature, combustion rate, combustion resistance, flame color and combustion smoke. The average values obtained consecutively from T_1-T_4 are as follows: combustion temperature 272.9; 231.5; 228.8 and 280.8˚C; combustion rate 2.03; 1.61; 1.67 and 2.03 g/min; combustion resistance 210.0; 205.0; 195.0 and 225.0 min; flame color and combustion smoke 3.70; 3.65; 3.60 and 3.75. The results of variance analysis showed that the treatment had a very significant effect ($P<0.01$) on combustion temperature, but no significant effect ($P>0.05$) on combustion rate, combustion resistance, flame color and combustion smoke. It was concluded that the biochar briquettes produced had good combustion properties with indications of high combustion temperature (253.5°C), slow combustion rate (1.83 g/min), long combustion resistance (208.75 min), bluish red flame colour and no smoke emitted (score 3.68). The best treatment was shown in the mixture of 50% goat dung charcoal + 40% palm shell charcoal +10% corn cob charcoal (T_4).

KEYWORDS: Biochar briquettes, biomass, goat manure, combustion properties, lontar shells

INTRODUCTION

The population of goat in Kupang City in 2022 was 8,768 heads (BPS-NTT, 2022) [1]. A field study reported the fresh faecal production of intensively reared adult Peranakan Ettawa (PE) goats to be around 956.5g/head/day or in the dry state 598.05g/head/day. This potential is quite large with estimated daily feces of 8,386.6g/head/day (Noach and Handayani, 2018) [2] however, not all goats are intensively cultivated.

The existence of intensive livestock businesses is often associated with negative impacts such as ammonia that causes air pollution and unpleasant odours that come from the farm. unprotected environmental sanitation can also cause health problems for both livestock and farmers and other humans. One strategy that can be implemented is to process the waste into products that have added value. In addition to fertilisers, livestock waste in the form of manure/feces can be processed into fuel, namely biogas and biochar briquettes. Goat manure with its solid form is easier to be made into charcoal and then formed into briquettes. however, the disadvantage of this waste is the low carbon content with high volatile materials. The combination of goat manure with other biomasses that have high carbon and low volatiles is expected to produce briquettes with good combustion properties.

When the issue of cheap renewable energy is being discussed, the potential and opportunity to utilise the various kind of biomass through a touch of practical technology is expected to provide important and useful information for humans and the environment. According to Kasmaniar et al (2022) [3] Biomass is the oldest traditional source of energy in Indonesia, and is commonly utilised for to fulfil cooking energy needs in rural areas. Some sectors of agriculture, plantation and agriculture, plantation and forestry sectors use biomass waste to fulfil heat needs during the manufacturing process and some also for energy needs. Despite its huge potential, the utilisation of energy from forest biomass in Indonesia is still very limited. Many previous studies have reported the utilisation of livestock waste (goat manure) mix with other waste as an environmentally friendly alternative fuel including goat manure mixed with lontar shells (Noach et al., 2023; Rosinta et al., 2023) [4] [5], goat manure mixed with lontar male fruit (Amalo et al., 2022) [6] and there are many other waste biomasses that have the potential to be utilised. Biochar briquettes made from biomass will be the hope of the future if supported by comprehensive studies related to its physical and chemical aspects (physicochemical) as an

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environmentally friendly fuel. Scientific studies by combining or mixing several biomass materials to biochar briquettes making need to be the focus because each biomass material has advantages and disadvantages. Despite its physical and chemical aspects, biochar briquettes need to be tested for reliability through the burning process so that specific combustion properties such as combustion temperature, heat of combustion, combustion resistance, flame colour and smoke can be studied. It is realised that there is still limited information on the combustion characteristics of biochar briquettes produced by a mix of various biomass materials sourced from livestock, agricultural and forestry waste. Based on this fact, an experiment has been conducted to assess the combustion of biochar briquettes processed using a blend of goat manure and a variety of other biomasses such as lontar shells, lontar male fruit, rice husks, corn cobs and lamtoro twigs.

MATERIALS AND METHODS

Research was taken place at Naimata Village, Maulafa Subdistrict, Kupang City for 4 months from April to July 2023. The biomass materials used consisted of goat manure, *lontar* shells, *lontar* male fruit, lamtoro twigs, rice husks, corn cobs and tapioca as an adhesive. The characteristics of the biomass used in this study based on the results of laboratory testing, presented in Table 1. The equipment used includes pyrolysis drum, grinding machine with 20 mesh size, briquette mould, digital hanging scale of 75kg capacity with 20g sensitivity, digital sitting scale of 5kg capacity with 1g sensitivity, analytical balance and briquettes stove.

Table 1. Characteristics of Biomass Materials Used in Making Biochar Briquettes

Biomass	Moisture (%)	Ash (%)	Volatile Mater (%)	Fixed carbon (%)	Calor value (cal/g)
Goat manure[2]	9.38	12.54	57.32	20.76	4070.72
Lontar shells[1]	1.72	3.36	71.82	22.08	4470.08
Lontar male fruit[2]	10.98	4.67	56.24	28.11	3839.99
Lamtoro twigs[3]	1.56	5.36	42.34	50.74	6640.20
Rice husk[3]	2.39	42.42	21.76	33.43	3167.18
Corn cob [3]	5.7	10.33	17.96	66.01	6204.94

Source: [1)] Rosinta et al. (2023); [2)] Laboratory of Animal Nutrition and Feed of Kupang State Agricultural Polytechnic (2023); [3)] Laboratory of Chem-Mix Pratama (2023).

The completely randomized design (CRD) was applied with four different mixing ratios tested, as follows: T_1= 50% goat manure + 40% *lontar* shell + 10% *lontar* male fruit; T_2= 50% goat manure + 40% *lontar* shell + 10% lamtoro twigs; T_3= 50% of goat manure + 40% *lontar* shell + 10% rice husk; and T_4= 50% of goat manure + 40% *lontar* shell + 10% corn cobs. Each treatment was repeated four times so there are 16 experimental units. Each experimental unit uses 1 kg of biochar powder, with tapioca concentration 10% of the biochar (w/w).

Research Procedure

All biomass were dried under the sunshine to facilitate the carbonisation process. Lontar shells, lontar male fruit, rice husk, lamtoro twigs and corn cob were carbonised using pyrolysis techniques, while goat manure was roasted. The hot charcoal after carbonating process is immediately cooled by sprinkling water and dried. then all biochar materials are finely ground separately to obtain biochar powder of 20 mesh size. The three biochar materials were combined in the proportions according to the specified treatment, with a total mixture of 1000 grams. Tapioca as much as 10% of the charcoal material (w/w) using as adhesive material. The adhesive process by dissolved tapioca in water then heated until it thickens to a clear colour. The adhesive is poured to the mixture of biochar materials and then stirred evenly to form a dough. The dough is put in a cylindrical mould with a height of 12cm diameter of 4cm and then pressed using hydraulics. One press produces four briquettes with a height of 4.0cm. The briquettes obtained were dried until the moisture content reached less than 8% and then used in combustion tests. 12 pieces of briquettes (600 grams) were laid out in a briquette stove furnace and then burned. Observations and measurements of the variables studied were made after 20 minutes the briquettes burned, with time intervals every 20 minutes. The data compilled were tabulated and processed according to the analysis of variance procedure and further tested by Duncan's Multiple Range Test (DMRT) using microsoft excel.

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Table 2 shows the specific physicochemical properties of biochar briquettes mixed with goat manure, lontar shells and several biomasses that have been studied previously by laboratory tested.

Table 2. Physicochemical Properties of the Biochar Briquettes*)

Variable	Treatment				P- value
	T_1	T_2	T_3	T_4	
Rendemen (%)**	56.62±0.83	56.45±2.12	56.00±1.07	56.55±1.64	0.93
Density (g/cm^3)**	0.70±0.02	0.62±0.01	0.68±0.01	0.70±0.02	0.00
Moisture (%)	6.06±0.21	3.55±0.21	5.49±0.60	6.47±0.51	0.00
Ash (%)	20.15±0.37	22.58±0.92	25.84±0.56	20.38±0.22	0.00
Volatile matter (%)	30.56±0.35	27.67±0.39	28.63±0.65	30.50±0.31	0.00
Fixed carbon (%)	43.25±0.48	46.20±0.42	40.04±0.48	42.65±0.49	0.00
Calorific value (cal/g)	4614.00±51.8	4598.24±85.8	4242.14±183.5	4768.29±59.	0.00

Source: *) Laboratory of Animal Nutrition and Feed of Kupang State Agricultural Polytechnic (2023); **) primary data processed.

Variables Studied

1. *Combustion heat*, is defined as the heat generated from the combustion process of biocharcoal briquettes. The measurement of combustion heat is carried out in a span of 20 minutes using an infrared thermometer during the combustion process and is expressed in degree of Celcius/°C (Dae Panie et al., 2023) [7].
2. *Combustion rate*, is the speed of the mass of biochar briquettes burning in unity of time and is expressed in g/minute. the combustion rate can be calculated according to the instructions of Aljarwi et al. (2020) [8]:
   Burning rate = t/m
   Description:
   m = mass of burnt briquettes (initial briquette mass - residual briquette mass (grams)
   t = burning time (minutes)
3. *Burn resistance*, is the length of time required in the combustion process of biochar briquettes. Measurement of burn resistance is carried out using a stopwatch and is expressed in minutes referring to the procedure of Taklal et al. (2022) [9].
4. *Flame colour and smoke emitted*, is the flame colour produced by burning briquettes and smoke condition that arises during combustion. Observations of colour and smoke were made by panelists based on the indicators as presented in Table 2.

Table 3. Scoring List of Colour and Combustion Smoke

Score	Flame colour	Smoke
1	Yellow	a little bit of smoke
2	Reddish-yellow	a little bit of smoke
3	Red	not emitting smoke
4	Bluish-red	not emitting smoke
5	Blue	not emitting smoke

Source: Dae Panie (2023) [7]

RESULTS AND DISCUSSION

Data on the combustion properties of biochar briquettes blend of goat manure charcoal, *lontar shell*, *lontar* male fruit, rice husk, corn cob and lamtoro twigs obtained in this study are presented in Table 3.

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Tabel 4. Combustion Properties of Biochar Briquettes Blend of Goat Manure Charcoal and Other Biomasses

Variables	Treatment				P-value
	T_1	T_2	T_3	T_4	
Combustion temperature (°C)	272.9±25.73[b]	231.5±24.65[a]	228.8±17.45[a]	280.8±14.07[b]	0.006
Combustion rate (g/minute)	2.03±0.03[a]	1.61±0.6[a]	1.67±0.65[a]	2.03±0.02[a]	0.417
Combustion resistance (minute)	210.0±11.55[a]	205.0±10.00[a]	195.0±19.15[a]	225.0±19.15[a]	0.101
Flame colour	3.70±0.12[a]	3.65±0.19[a]	3.60±0.00[a]	3.75±0.10[a]	0.382
Smoke emitted	3.70±0.12[a]	3.65±0.19[a]	3.60±0.00[a]	3.75±0.10[a]	0.382

Note: different superscripts on the same line indicate significantly different (P<0.05). T_1= 50% goat manure charcoal + 40% *lontar* shells + 10% *lontar* male fruit, T_2= 50% goat manure charcoal + 40% *lontar* shells + 10% lamtoro twigs; T_3= 50% ,goat manure charcoal + 40% *lontar* shells + 10% rice husk; T_4= 50% goat manure charcoal + 40% *lontar* shells + 10% corn cob.

Combustion Temperature

Table 4 shows that the average combustion heat of briquettes ranged from 228.8-280.8 °C with average 253.5 °C. Statistical analysis showed that the treatment had a significant effect (P<0.05) on combustion heat. The use of different biomass materials in a mixture of goat manure and palm shells produces briquettes with different combustion heat. The results of the Duncan test showed that the pair of treatments T_1:T_2, T_1:T_3, T_2:T_4 and T_3:T_4 is different, while T_1:T_4 and T_2:T_3 not different. Table 3 showed that the use of *lontar* male fruit and corn cobs separately at 10% each in a mixture of goat manure and *lontar* shells produced biochar briquettes with a higher heat of combustion (272.9 and 280.8°C) than lamtoro twigs and rice husks (231.5 and 228.8°C). This is because the briquettes produced in the T_1 and T_4 treatments have a greater calorific value than the other two treatments (Table 2). Yuli et al. (2015) [10] stated that calorific value greatly affects the high and low combustion heat, where the higher the calorific value, the more the combustion heat increases.

Overall, the average briquette combustion temperature obtained from this study is lower than previous studies, as reported by Hero et al (2024) [11] that ranged from 307.8-357.7 ^{0}C for briquettes of goat manure, *lontar* shells and corn cobs, Dae Panie et al. (2022) [7] of 264.60^{0}C on the briquette mixture of goat manure charcoal and saboak shell and Dhawi (2017) [12] of 261.27^{0}C in the briquette mixture of goat manure charcoal and hazelnut shell charcoal.

Combustion Rate

Table 4 shows that the average combustion rate ranged from 1.61-2.03 g/minute with average 1.83 g/minute. Statistical analysis showed that the treatment had no significant effect (P>0.05) on the combustion rate. This means that the use of 10% other biomass such as lontar male fruit, rise husk, lamtoro twigs and corn cob charcoal in a mixture of goat manure charcoal and saboak shell, produced biochar briquettes with similar combustion rates. One of the factors that affect the burning rate is the density of the briquette itself. The tendency of the same briquette burning rate in this study is due to all biomass mixture treatments producing briquettes with uniform density (Table 2). Hendra (2007) [13] states that briquettes with low density will produce the burning rate faster than briquettes that have high density.

The burning rate obtained in this study is still slower than the results of previous research by Hero et al (2024) [11] 2.15-2.57 g/minute on briquettes of mix goat manure, *lontar* shells and corn cobs, Dae Panie et al. (2022) [7] of 2.28 g/minute on briquettes of goat manure charcoal and saboak shell but faster than reported by Nahas et al. (2019) [14] with a burning rate of 0.29 g/minutes on a mixture of cow dung and tapioca flour.

Combustion Resistance

Table 4 shows that the combustion resistance ranges from 195.0-225.0 minutes with average 208.75 minutes. Statistical analysis showed that the treatment had no significant effect (P>0.05) on the combustion rate. This means that the use of 10% other biomass such as *lontar* male fruit, rise husk, lamtoro twigs and corn cob charcoal in a mixture of goat manure charcoal and *lontar* shell, produced biochar briquettes with similar burn resistance. Two variables that play an important role in determining the combustion resistance of briquettes are density and combustion rate. According to Satmoko et al. (2013) [15] the higher the density, the higher the resistance. Similar to Hendra (2007) [13], which states that raw materials that have a high density will produce charcoal briquettes

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with a high density so as to produce a long enough combustion resistance. In this study, although the density is different (Table 2), but the combustion rate (Table 4) is the same and thus the combustion resistance of the biochar briquettes is tended to be the same. The combustion resistance obtained in this study is longer than the results of previous research by Dae Panie et al. (2022) [7] of 175.00 minutes on a mixture of goat manure charcoal and saboak shell, but almost the same as the results of the research reported by Hero et al (2024) [11], with a combustion resistance of 185 - 220 minutes on briquettes of goat manure mixture of palm shell and corn cob.

Flame Colour

Table 4 shows that the score of flame colour ranges from 3.60 – 3.75 with average score 3.68. The results of variance analysis showed that the treatment had no significant effect (P>0.05) on the colour of burning briquettes. This means that the mixture of goat manure charcoal, *lontar* shell and combinated to 10% of other biomass such as *lontar* male fruit, rise husk, lamtoro twigs and corn cob produces biochar briquettes with the same flame colour. Based on the table scoring (Table 4) the range of scores indicates that the flame colour of burning briquettes in this study is between the red (score 3) to bluish red (score 4). Overall, the colour of the flame produced by the burnt briquettes is an attractive red-bluish or near-blue colour. This result is better that previous studies that reported by Hero et al (2024) [11] on a mixture of goat manure charcoal, saboak shell and corn cobs with flame colour red (score 3.2) and by Dae Pannie et al. (2022) [7] of 2.75 on a mixture of goat manure charcoal and saboak shell.

Smoke Emitted

Table 4 shows that the smoke emitted score ranges from 3.60 – 3.75 with average score 3.68. The results of variance analysis showed that the treatment had no significant effect (P>0.05) on smoke emitted of the briquettes. This means that the mixture of goat manure charcoal, lontar shell and combinated to 10% of other biomass such as lontar male fruit, rise husk, lamtoro twigs and corn cob produces biochar briquettes with the same smoke emitted. Based on the table scoring (Table 3) score 3 to 5 indicating not emitting smoke. Thus, the smoke assessment score on burning briquettes in this study, which ranged from 3.60 to 3.75, explained that the biochar briquettes of goat manure mixture of *lontar* shells and other biomass varieties did not emitting smoke.

The presence or absence of smoke from burning charcoal briquettes is determined by the moisture content of the briquettes, the type of adhesive proportion used and the pyrolysis process. The absence of smoke generated from burning briquettes in all treatments is due to the low water content of briquettes 3.55 - 6.47 (fulfil the Indonesian National Standard of 8%). according to Riseanggara (2008) cited by Susilawati et al. (2022) [16] Smoke aroused during burning is also influenced by water content, the higher the water content contained, the more smoke is produced during combustion. according to Saleh (2013) [17] the use of tapioca adhesive produces relatively little smoke compared to other adhesives. The incomplete charring process also affects the presence of smoke because there are still remnants of raw materials.

CONCLUSION

It was concluded that the biochar briquettes produced had good combustion properties with indications of high combustion temperature (253.5°C), slow combustion rate (1.83 g/min), long combustion resistance (208.75 min), bluish red flame colour and no smoke emitted (score 3.68). The best treatment was shown in the mixture of 50% goat dung charcoal + 40% palm shell charcoal +10% corn cob charcoal (T_4)

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