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Physico-chemical Properties of Biocharcoal Briquettes Blend of Goat Manure Charcoal, *Saboak* Shell and Lamtoro Twigs

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ABSTRACT: The study aimed to determine the effect of blend of goat manure charcoal, *saboak* shell and lamtoro twigs on the physical and chemical properties of biocharcoal briquettes. The completely randomised design with 4 treatments and 4 replications was applied in this study. Those treatments were, P_1 = 25% goat manure charcoal + 75% *saboak* shell without lamtoro twigs, P_2 = 25% goat manure charcoal + 50% *saboak* shell + 25% lamtoro twigs, P_3 = 25% goat manure charcoal + 25% *saboak* shell + 50% lamtoro twigs and P_4 = 25% goat manure charcoal without *saboak* shell + 75% lamtoro twigs. The variables studied were: yield, density, moisture content, ash content, calorific value, volatile matter and fixed carbon. Data were analysed according to the analysis of variance procedure. The mean values obtained were: 55.20% yield; 0.56 g/cm3 density; 3.41% moisture content; 14.80% ash content; 5195.05 cal/g calorific value; 25.54% volatile matter; 56.25% fixed carbon. Statistical analysis showed the treatment had a very significant effect ($P<0.01$) on yield, density, moisture content, ash content and fixed carbon, but not significant ($P>0.05$) on calorific value and volatile matter. It can be concluded that blend of goat manure charcoal, saboak shell and lamtoro twigs with an increasing proportion of lamtoro twig as substitute on saboak shell produces biocharcoal briquettes with good moisture, density and calorific value that has fulfilled the requirements standardised in SNI 01-6235-2000, while other physicochemical properties such as fixed carbon, volatile matter ash content not meet these standards.

KEYWORDS: briquettes, physicochemistry, goat manure, lamtoro twigs, *saboak* shells

INTRODUCTION

In addition to producing products that are beneficial to humans, the livestock industry also produces waste that if not managed properly will have a negative impact. Livestock waste includes all residues of livestock activities in the form of solid, liquid and gas waste. The negative impacts of livestock waste include being a source of disease, reducing sanitation and hygiene, causing air pollution and also low economic value. Therefore, it is necessary to process livestock waste to minimise its negative impact while increasing its economic value.

The goat population in East Nusa Tenggara (NTT) Province in the last 3 years has increased from 900 thousand heads in 2020 to around 1 million heads in 2022. The goat population in Kupang City in 2022 was 8,768 heads (BPS, 2022). In intensive goat farming, the average weight of fresh goat manure produced per day is 956.5 g/head and the average dry weight per day is 598.05 g/head (Noach and Handayani, 2018). Based on these data, it can be estimated that the daily goat faeces produced reaches 8,386 kg/day or 251,598 kg/month. This potential has not been optimally utilised as an alternative fuel source. One form of goat manure utilisation is to make briquettes as a solid fuels sourced from biomass.

Processing goat manure into briquettes requires the addition of other biomass because the carbon content is relatively low at 20.76% and the volatile matter contained is quite high at 57.32% (Amalo et al., 2022). Some previous studies have combined goat manure with other biomass such as *lontar* male fruit and *lontar* shell (Amalo et al., 2022; Noach et al., 2023). The addition of other biomass is expected to increase the fixed carbon bound in the briquettes and hence the calorific value.

Lamtoro twigs (*Leucaena leucocephala*) waste from goat feed is goat food waste consisting of lamtoro leaves and twigs. This waste is useless for goats and has low economic value. However, this waste can be optimised as an alternative energy source through composting or burning. According to Nur (2017) the calorific value of lamtoro twigs itself is quite high at 4197 kcal/kg.

The *saboak* shell (as it is called by the people on the island of Timor for female *lontar* fruit) is the waste of the female fruit of lontar plant. The ripe fruit is used for food and the waste in the form of shells is used as fuel by the community without further processing. *Saboak* shell itself has a carbon content of 22.08%, volatile matter of 71.28% and a calorific value of 4470 kcal/kg (Dae

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Panie et al., 2022). Other research showed that a blend of 25% goat manure and 75% *saboak* shell produced briquettes with the best physical and chemical properties (Rosinta et al., 2023).

Currently, goat manure processing into briquettes by adding *saboak* shell and lamtoro twigs has never been done so that information on its physical and chemical properties is not yet available. Based on this, a study was conducted to determine the effect of different proportions of goat manure charcoal, *saboak* shell and lamtoro twigs on the physical and chemical properties of biocharcoal briquettes.

MATERIALS AND METHODS

Study was conducted in Naimata Village, Maulafa District, Kupang City for 4 months from April to July 2023. This study used three carbonated biomass materials, namely goat manure, *saboak* shell and lamtoro twig charcoal (Table 1), besides tapioca as an adhesive. The equipment used were digital hanging scales of 75 kg capacity with 20 g sensitivity, pyrolysis drum, grinding machine with 20 mesh sieve, digital sitting scales of 5 kg capacity with 1 g sensitivity, briquette mould, 3 tonne hydraulic forge, porcelain cup, analytical balance, furnace, oven, bomb calorimeter and desiccator.

Table 1. Characteristik of goat manure, *saboak* shell and lamtoro twigs

Biomass	Moisture (%)	Ash (%)	Fix Carbon (%)	Volatile matter (%)	Calorific value (cal/g)
Goat manure [1)]	9.38	12.54	20.76	57.32	4070.72
Saboak shell[1)]	1.72	3.36	22.08	71.82	4470.08
Lamtoro twigs [2)]	1.59	5.36	50.71	42.34	6641.20[3)]

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 randomised design with 4 treatments and 4 replicates was applied in this study. Each experimental unit uses 1 kg of biochar powder, with tapioca concentration 10% of the biochar (w/w). Those treatments were:

P_1 = 25% goat manure charcoal + 75% saboak shell charcoal without lamtoro twig charcoal.
P_2 = 25% goat manure charcoal + 50% saboak shell charcoal + 25% lamtoro twig charcoal.
P_3 = 25% goat manure charcoal + 25% saboak shell charcoal + 50% lamtoro twig charcoal.
P_4 = 25% goat manure charcoal + 75% lamtoro twig charcoal, without *saboak* shell charcoal

Variables measured

1. Yield; the yield of briquettes was calculated according to the instructions of Amalo et al. (2022) with the formula:
   Y (%)=(Dry Weight)/(Dough Weight) x 100 % …………………… (1)
2. Density (specific density), expressed as grams/cm3, calculated with the formula used by Noach et al (2023):
   Density (g/cm^3) = m/v ……………………………… (2))
   where, m = mass of briquettes; v = volume of briquettes calculated by the formula: $\pi.r^2.t$
3. Moisture content, expressed as a percent and calculated using ASTM D-3173-03 standard (Elfiano, 2014) with the formula:
   Moisture content (%) = (a-b)/a x 100 ………………………. (3)
   where, a = briquettes mass before heating (grams); b = briquettes mass after heating 107˚C
4. Ash content, expressed as a percent and calculated using ASTM D-3174-04 standard, with the equation:
   Ash content (%) = d/a x 100 ……………………………………. (4)
   where: d = briquettes mass after heating at 950°C (grams); a = briquettes mass before heating (grams)
5. Vollatile Matter; expressed as a percent and calculated with the formula used by Yuliah et al. (2017):
   VM (%) = [$m_3 - m_4 / m_2\ m_1$] x 100 ……………………………………………….. (5)
   where: m_1 = empty bowl, m_2 = empty bowl + sample, m_3 = empty bowl + sample after heating, m_4 = empty bowl + sample after cooling.
6. Calorific Value; expressed in calories/gram and calculated by bomb calorimeter.

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7. Fixed carbon; the fixed carbon content of the briquettes expressed as a percent and calculated with the formula used by Noach et al (2023):

Fixed carbon (%) = 100% - (% volatile matter + % moisture + % ash)

Research procedure

Goat manure, *saboak* shell and lamtoro twigs were collected and then sun-dried to facilitate the carbonating process. Carbonisation of *saboak* shell and lamtoro twigs by pyrolysis, while the goat manure by roasted on a metal plate heated on a furnace. Those hot charcoal is immediately cooled by sprinkling water and then dried in the sun then all biochar materials are finely ground separately to obtain biochar powder of 20 mesh size. Mixing the three biochar materials following the composition of the specified treatment variety, with a total mixture of 1000 grams. Tapioca as an adhesive material was used as much as 10% of the charcoal material (w/w). Tapioca was dissolved in water then heated until it thickens to a clear colour resembling glue. The adhesive is added 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 were dried and then laboratory tested. The data obtained were tabulated and analysed according to the analysis of variance procedure and further tested by Duncan's Multiple Range Test (DMRT) using SPSS v.29.

RESULTS AND DISCUSSION

Data on the physicochemical properties of biocharcoal briquettes mixed with goat manure, saboak shell and lamtoro twigs obtained in this study are presented in Table 2.

Table 2: Physico-chemical Properties of Biocharcoal Briquettes

Variables	Treatment				P value
	P_1	P_2	P_3	P_4	
Yields (%)	58.75±0.18^c	56.99±1.75^{bc}	54.84±1.70^b	50.21±1.70^a	0.00
Density (g/cm^3)	0.67±0.01^d	0.60±0.04^c	0.52±0.01^b	0.46±0.02^a	0.00
Moisture (%)	4.40±0.58^c	1.16±0.64^a	2.38±0.72^b	5.72±0.43^d	0.00
Ash (%)	17.31±0.50^d	15.42±0.86^c	14.24±0.48^b	12.23±0.22^a	0.00
Calorific value (cal/g)	5047.65±16.71	5190.89±71.13	5367.97±12.81	5173.68±51.12	0.47
Volatile matter (%)	26.09±0.13	25.03±0.74	25.26±0.57	25.78±0.67	0.09
Fixed carbon (%)	52.20±0.34^a	58.40±1.15^c	58.13±0.60^c	56.28±0.74^b	0.00

Note: different superscripts on the same line indicate significantly different ($P<0.05$); P_1=25% goat manure + 75% *saboak* shell without lamtoro twigs; P_2=25% goat manure + 50% *saboak* shell + 25% lamtoro twigs; P_3=25% goat manure + 25% *saboak* shell + 50% lamtoro twigs; P_4=25% goat manure without *saboak* shell + 75% lamtoro twigs.

Yield

The yield of biocharcoal briquettes obtained in this study ranged from 50.21 – 58.75%, with an average of 55.2%. Results of statistical analysis showed that the treatment had a very significant effect ($P<0.01$) on yield. DMRT showed that treatments pairs P_1:P_3, P_1:P_4 , P_2:P_4 and P_3:P_4 were significantly different ($P<0.05$). This means that the blend of goat manure, *saboak* shell and lamtoro twig charcoal with different proportions produces biocharcoal briquettes with different yield.

The data in Table 2 shows a decrease in yield from P_1 to P_4, and indicating that increasing the proportion of lamtoro twig charcoal used in the mixture causes a reduction in the yield of briquettes obtained. It is suspected that this decrease is because lamtoro twig charcoal has a smaller specific gravity and is voluminous than palm shell charcoal, thus the more lamtoro twig charcoal in the mixture, the lighter the briquettes produced. Sudiro and Suroto (2014) stated that the size of the space between the charcoal powder particles that make up the large briquettes causes the briquettes to store more water, but due to the drying process the space filled with water will be filled with air, so that the weight of the briquettes decreases. Komarayati et al. (2011) that the high yield of carbonating results is strongly influenced by the carbonisation process, specific gravity and density and chemical composition of the material.

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The yield obtained in this study was higher than the results of previous studi that reported by Rosinta et al. (2023) of 52.69% on biocharcoal briquettes blend of goat manure charcoal and *saboak* shell and Amalo et al. (2022) of 52.75% on briquettes blend of goat manure and *lontar* male fruit.

Density

The density of biocharcoal briquettes ranged from 0.46 - 0.67 g/cm3 with an average of 0.56%. The results of statistical analysis showed that the treatment had a very significant effect (P<0.01) on the density. DMRT showed all treatment pairs are significant difference (P<0.05). This means that the blend of the three materials (goat manure, *saboak* shell and lamtoro twig charcoal) with varying proportions produces briquettes with different densities

The higher the proportion of lamtoro twig charcoal used, the lower the density. This is thought to be because the density value of lamtoro twigs is lower than the density value of saboak shell so that the weight of the briquettes decreases with increasing proportions of lamtoro twig charcoal, in accordance with Hendra (2007) who states that raw materials that have high density will produce charcoal briquettes with high density. Chavan et al. (2015) stated that the specific gravity of lamtoro wood was 0.65 g/cm^3, meanwhile, according to Kumar (2018) the specific gravity of saboak shell was 0.84 g/cm^3.

The low density can also be influenced by the homogeneity of the ingredients that make up the briquettes. Wood with high specific gravity produces heavier charcoal powder than wood with low specific gravity, causing the volume (amount) of charcoal powder when weighed with the same weight to be smaller (less) than charcoal powder from wood with low specific gravity. Charcoal powder is larger (much) and the volume of charcoal briquettes becomes larger, thus reducing the density (Alpian et al., 2020). The large amount of charcoal powder causes the percentage of 10% tapioca adhesive material to be unevenly mixed when it is printed, as a result the adhesion between particles is also lacking so that the briquettes produced are less compact. The addition of adhesive causes the density of the briquette to increase because when given the pressure of briquetting the adhesive will occupy the empty spaces between the particles (Arifah, 2017).

From this study obtained biocharcoal briquettes with densities almost the same as previous reports of 0.5 g/cm^3 (Amalo, 2022) and 0.62 g/cm^3 (Noach 2023) and have met the minimum requirement of 0.44 g/cm^3 SNI 01-6235-2000 for biocharcoal briquettes.

Moisture

The moisture of biocharcoal briquettes in this study ranged from 1.16-5.72%, with an average of 3.4%. The results of statistical analysis showed that the treatment had a very significant effect (P<0.01) on the moisture. DMRT showed all treatment pairs are significant difference (P<0.05). This means that the blend of the three materials (goat manure, saboak shell and lamtoro twig charcoal) with varying proportions produces briquettes with different moisture.

High moisture content will reduce the calorific value and combustion rate because the heat provided is used first to evaporate the water contained in the briquette (Maryono et al., 2013). The moisture content of briquettes is influenced by the moisture content of the raw materials, the drying process, the environment and weather, the use of adhesives, handling and storage. The high moisture content in P4 is thought to be due to the less than optimal drying process which results in a lot of water contained in the briquettes. Storage methods can also affect moisture content because briquettes have hygroscopic properties so that if left in the open air, the briquettes will absorb water from the air (Nurmalasari and Afifa, 2017).

Table 2 shows that the moisture content of the briquettes varies, but overall it meets the requirements set by SNI 01-6235-2000, which is a maximum of 8%. The moisture content obtained from this study is lower than the previous study (Rosinta et al., 2023) of 4.52%. in biocharcoal briquettes blend of goat manure and *saboak* shell.

Ash content

The average ash content of biochar briquettes in this study ranged from 12.23-17.31%, with an average of 14.8%. Statistical analysis showed that the treatments had a very significant effect (P<0.01) on the ash content. DMRT showed that all treatment pairs are significant difference (P<0.05) and it means that the blend of the three materials (goat manure, saboak shell and lamtoro twig charcoal) with varying proportions produces briquettes with different ash content. The data in Table 2 shows a decrease in ash content from P_1 to P_4, and indicating that increasing the proportion of lamtoro twig charcoal used in the mixture causes a reduction in the ash content of briquettes obtained.

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Ash content in briquettes can also be affected by the carbonating process. In conventional carbonating processes tend to produce high ash content. This is because the material burned in conventional charring has a tendency to interact with air in the environment so that the biomass is decomposed into ash (Rahmadani et al., 2017). The ash content of the briquettes obtained in this study is lower than the results of previous studies that have been reported by Rosinta et al. (2023) of 29.61%. The ash content from this study has not fulfilled SNI 01-6235-2000, which is a maximum of 8%.

Calorific value

The average calorific value of biocharcoal briquettes in this study ranged from 5047.65 to 5367.97 cal/g, with an average of 5195.05 cal/g. The results of statistical analysis showed that the treatment had no significant effect ($P>0.05$) on the calorific value of the biocharcoal briquettes produced. The mixture of charcoal from the three biomass materials with different proportions did not cause significant changes in the calorific value of the briquettes produced. Despite this result, the average calorific value obtained shows an increasing trend with increasing proportion of lamtoro twig charcoal until 50%. This is thought to be influenced by fixed carbon content of lamtoro twigs that higher than *saboak* shells. According to Siahaan et al. (2013) that high fixed carbon content will produce higher calorific value.

Table 2 shows that the lowest briquette calorific value at P_1 (25% goat manure + 75% *saboak* shell, without lamtoro twigs) was 5047.65 cal/g, the highest in P3 (25% goat dung, 25% saboak shell and 50% lamtoro twigs) at 5367.97 cal/g. Overall the calorific value obtained in this study is higher than previously reported (Rosinta et al., 2023) on briquettes of a mixture of goat manure charcoal and *saboak* shells of 3874.93 kal/g and these results have met the Indonesian National Standard (SNI 01-6235-2000) of 5000 cal/g.

Volatile matter

The average volatile matter content of biocharcoal briquettes in this study ranged from 25.78-26.09% with an average of 25.54%. The results of statistical analysis showed that the treatment had no significant effect ($P>0.05$) on the volatile matter content of the biocharcoal briquettes produced. This means that different mixtures of goat manure charcoal, *saboak* shell and lamtoro twigs produce briquettes with volatile matter levels that tend to be the same.

The volatile matter content obtained from this study is not different from the results of research by Noach et al. (2023) on briquettes a mixture of goat manure and *lontar* shell, which is 25.04% and has not met the Indonesian national standard (SNI 01-6235-2000), which is a maximum of 15%. The high volatile matter obtained in this study is thought to be due to the suboptimal carbonisation process and should be studied more specifically. According to Rahmadani et al. (2017 the higher the temperature and time of carbonisation, the more volatile matter content is wasted so that the resulting volatile matter content is low. The same thing was also stated by Maryono et al. (2013) that the high and low levels of volatile matter are influenced by the temperature and length of carbonisation process.

Fixed Carbon

The average fixed carbon content of biocharcoal briquettes produced in this study ranged from 52.21-58.39% with an average of 56,25%. The results of statistical analysis showed that the treatment of adding lamtoro twig charcoal had a very significant effect ($P<0.01$) on the fixed carbon content of the briquettes. DMRT showed the treatment pairs P_1:P_4, P_1:P_3, P_1:P_2; P_4:P_3 and P_4:P_2 were significantly different ($P<0.05$). This means that the blend of the three materials (goat manure, saboak shell and lamtoro twig charcoal) with varying proportions produces briquettes with different fixed carbon content.

Table 2 shows that the highest fixed carbon content of the briquettes, was found in P_2 (25% goat manure, 50% *saboak* shell and 25% lamtoro twigs) dan P_3 (25% goat manure, 25% saboak shell and 50% lamtoro twigs) are 58.4% and 58,13%, respectively, followed by P_4 (25% goat manure and 75% lamtoro twigs without *saboak* shell) is 56.28 and the lowest in P_1 (25% goat manure and 75% *saboak* shell) is 52.21%.

The presence of fixed carbon can determine the calorific value of the briquette, the higher the fixed carbon, the higher the calorific value. Fixed carbon is the fraction of carbon (C) bound in charcoal other than water, volatile matter and ash content. The higher the water, ash and volatile matter content, the lower the fixed carbon content. Rindayatno and Lewar (2017) descibe that the high and low value of charcoal fixed carbon content is influenced by the specific gravity of the raw materials used, the carbonisation process and volatile substances. High specific gravity of raw materials will produce high fixed carbon. Low volatile substances will increase the fixed carbon.

Overall, the fixed carbon content obtained from this study is higher than previous reported by Noach et al. (2023) on briquettes of goat manure and *lontar* shell mixtures, of 40.84%. Result of this study also does not meet the Indonesian National Standard (SNI 01-6235-2000), which is at least 78.35%.

CONCLUSION

It can be concluded that blend of goat manure charcoal, *saboak* shell and lamtoro twigs with an increasing proportion of lamtoro twig as substitute on *saboak* shell produces biocharcoal briquettes with good moisture, density and calorific value that has fulfilled the requirements standardised in SNI 01-6235-2000, while other physicochemical properties such as fixed carbon, volatile matter ash content not meet these standards. The best physicochemical properties of the biocharcoal briquettes were found at blend of 25% goat manure charcoal, 25% *saboak* shells and 50% lamtoro twigs.

REFFERENCES

1. Badan Pusat Statistik. 2022. *Populasi Ternak Kambing Provinsi NTT*. https://ntt.bps.go.id/indicator/24/55/1/populasi-ternak-kecil-menurut-kabupaten-kota.html. [diakses 26 September 2023].
2. Noach, YR., and HT. Handayani. 2018. Model peningkatan produksi susu dan kinerja produksi anak kambing perah peranakan Etawah (PE) melalui suplementasi pakan lokal dan zn biokompleks. *Laporan Penelitian DRPM.* Universitas Nusa Cendana. Kupang
3. Amalo, HMA., TO. Dami Dato., G. Maranatha, and YR. Noach. 2022. Karakteristik fisiko-kimia briket bioarang campuran arang kotoran kambing dan mayang *saboak*. *Journal of Animal Science*. *7(4):* 65-67.
4. Noach, YR., R. Rosinta., US. Rosnah., TO. Dami Dato, G. Maranatha, SMC. Noach, and YL. Henuk. 2023. The influence of different ratio of goat dung and lontar shells (*Borassus flabellifer* Linn) charcoal on the biochar briquettes properties. *IJCSRR. 6(7):* 75.
5. Nur, AB. 2017. Uji Kelayakan Potongan Lamtoro Sebagai Bahan Bakar Tungku Biomassa UB Tipe Granular. *Disertasi.* Program Pascasarjana, Universitas Brawijaya, Malang.
6. Dae Panie, WLD., US. Rosnah, and TO. Dami Dato. 2022. Kualitas bakar briket bioarang campuran arang kotoran kambing dan arang tempurung *Saboak*. *Jurnal Peternakan Lahan Kering*. *4(4):* 2435-2443.
7. Rosinta, R., YR. Noach, and US. Rosnah. 2023. Karakteristik fisiko-kimia briket bioarang campuran arang kotoran kambing dan tempurung *saboak*. *Jurnal Peternakan Lahan Kering*. *5(2):* 300-309.
8. Elfiano, E., P. Subekti and A. Sadil, 2014, Analisa proksimat dan nilai kalor pada briket bioarang limbah ampas tebu dan arang kayu, Jurnal Aptek Vol. 6 No. 1 Januari 2014, pp 57-64
9. Yuliah, Y., S. Suryaningsih and K. Ulfi, 2017. Penentuan Kadar Air Hilang dan Volatile Matter Pada Bio-Briket dari Campuran Arang Sekam Padi dan Batok Kelapa. *Jurnal Ilmu dan Inovasi Fisika* Vol. 01, No. 01 (2017) 51 – 57.
10. Sudiro, SS. 2014. Pengaruh komposisi dan ukuran serbuk briket yang terbuat dari batubara dan jerami padi terhadap karakteristik pembakaran. *Politeknik Indonusa, Surakarta*. *2(02).*
11. Komarayati, S., G. Gusmailina, and G. Pari. 2011. Produksi cuka kayu hasil modifikasi tungku arang terpadu. *Jurnal Penelitian Hasil Hutan. 29(3):* 234-247.
12. Hendra, D. 2007. Pembuatan briket arang dari campuran kayu, bambu, sabut kelapa dan tempurung kelapa sebagai sumber energi alternatif. *Jurnal Penelitian Hasil Hutan*. *25(3):* 242-255.
13. Chavan, SB., AR. Uthappa., A. Keerthika., KT. Parthiban., S. Vennila., P. Kumar, and KB. Sridhar. 2015. Suitability of *Leucaena leucocephala* Lam. de Wit as a source of pulp and fuelwood in India. *Journal of Tree Sciences*. *34(1):* 30-38.
14. Kumar, KR. 2018. Studies on the properties of sustainable light weight pervious concrete using palmyra palm shells. *International Journal of Civil Engineering and Technology. 9(4):* 752-760.
15. Alpian, A., R. Panjaitan., A. Jaya., Y. Yanciluk., WS. Supriyati, and EU. Antang. 2020. Sifat fisika mekanika briket arang dengan komposisi jenis kayu gerunggang (*Cratoxylon arborescens*) dan kayu tumih (*Combretocarpus rotundatus*). *Daun: Jurnal Ilmiah Pertanian dan Kehutanan*. *7(1):* 1-10.
16. Arifah, R. 2017. Keberadaan karbon terikat dalam briket arang dipengaruhi oleh kadar abu dan kadar zat yang menguap. *Wahana Inovasi*. *6*(2): 365-377.

17. Maryono., Sudding, and Rahmawati. 2013. Pembuatan dan analisis mutu briket arang tempurung kelapa ditinjau dari kadar kanji. *Jurnal Chemica*. *14(1):* 74-83.
18. Nurmalasari, N., and N. Afiah. 2017. Briket kulit batang sagu (*Metroxylon sagu*) menggunakan perekat tapioka dan ekstrak daun kapuk (*Ceiba pentandra*). *Dinamika*. *8(1):* 1-10.
19. Rahmadani, R., F. Hamzah, dan F.H. Hamzah. 2017. Pembuatan briket arang daun kelapa sawit *(Elaeis guineensis* Jacq.*)* dengan perekat pati sagu *(Metroxylon sago* Rott*.). Disertasi*. Program Pascasarjana, Universitas Riau, Pekanbaru.
20. Siahaan, S., M. Hutapea and R. Hasibuan. 2013. Penentuan kondisi optimum suhu dan waktu karbonisasi pada pembuatan arang dari arang sekam padi. *Jurnal Teknik Kimia*. *2(1):* 26-30.
21. Rindayatno, R., and D.O. Lewar. 2017. Kualitas briket arang berdasarkan komposisi campuran arang kayu ulin (*Eusideroxylon zwageri* Teijsm dan Binn) dan kayu sengon (*Paraserianthes falcataria*). *ULIN, Jurnal Hutan Tropis*. *1(1): 39-48*