https://doi.org/10.56862/irajtma.v3i1.39

IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)

Vol. 3, No. 1, 2024, pp. 108-118, e-ISSN: 2962-4290

Available online http://e-journals.irapublishing.com/index.php/IRAJTMA/

Scientific Articles

Manufacturing Of Biobriqueetes From A Mixture Of Bottom Ash With Young Coconut Solid Waste Using Molasses Adhesive As An Alternative Fuel

Pembuatan Biobriket dari Campuran *Bottom Ash* dengan Limbah Padat Kelapa Muda Menggunakan Lem Molase sebagai Bahan Bakar Alternatif

Heriansyah Tampubolon[1], Dede Ibrahim Muthawali[2], Zainuddin Ginting[1], Jalaluddin[1], Budhi Santri Kusuma[3]

[1]Department of Chemical Engineering, Universitas Malikussaleh, Aceh, Indonesia

[2]Department of Vocational, Universitas Sumatera Utara, Medan, Indonesia

[3]Department of Industrial Engineering, Universitas Medan Area, Medan, Indonesia

Email: zginting@unimal.ac.id

Diterima: 08-01-2024 **Disetujui: 12-02-2024** **Dipublikasikan: 30-04-2024**

IRAJTMA is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

Abstract

Biobriquettes are solid fuels made from compressed organic residues with adhesives. Bottom ash, a byproduct of boiler combustion at PT Blang Ketumba, and young coconut solid waste both have high calorific value and can be utilized as bio briquettes. This study uses a mixture of young coconut waste and molasses adhesive. The research aims to assess the benefits of these materials in bio briquettes, analyze the composition of bottom ash and young coconut waste, and examine the impact of varying ratios of these materials with molasses adhesive. The biobriquette production process involves mixing bottom ash and coconut waste with 2%, 3%, and 4% molasses adhesive in ratios of 100:0, 75:25, 50:50, 25:75, and 0:100. The resulting biobriquettes are evaluated for moisture, ash content, bulk density, combustion rate, and calorific value. The optimal biobriquette, with 25:75 bottom ash to coconut waste and 4% adhesive, showed 7.6% moisture, 5.9% ash, 14.76% volatiles, 71.74% fixed carbon, 1.74 g/cm³ density, 0.32 cal/sec combustion rate, and 5142 cal/g calorific value, meeting SNI 01-6235-2000 standards.

Keywords: biobriquettes, bottom ash, molasses, organic, and young coconut solid waste.

Abstrak

Biobriket adalah bahan bakar padat yang terbuat dari residu organik yang dikompresi dengan perekat. Bottom ash, produk sampingan dari pembakaran boiler di PT Blang Ketumba, dan limbah kelapa muda padat, keduanya memiliki nilai kalor tinggi dan dapat dimanfaatkan sebagai biobriket. Penelitian ini menggunakan campuran limbah kelapa muda dan perekat molase. Penelitian ini bertujuan untuk menilai manfaat bahan-bahan ini dalam biobriket, menganalisis komposisi bottom ash dan limbah kelapa muda, serta mengkaji pengaruh variasi rasio bahan-bahan ini dengan perekat molase. Proses produksi biobriket melibatkan pencampuran bottom ash dan limbah kelapa dengan perekat molase 2%, 3%, dan 4% dalam rasio 100:0, 75:25, 50:50, 25:75, dan 0:100. Biobriket yang dihasilkan dievaluasi berdasarkan kadar air, kadar abu, densitas bulk, laju pembakaran, dan nilai kalor. Biobriket optimal, dengan rasio 25:75 bottom ash dan limbah kelapa serta 4% perekat, menunjukkan kadar air 7.6%, kadar abu 5.9%, zat volatil 14.76%, karbon tetap 71.74%, densitas 1.74 g/cm³, laju pembakaran 0.32 cal/detik, dan nilai kalor 5142 cal/g, memenuhi standar SNI 01-6235-2000.

Kata kunci: biobriket, abu dasar, molase, organik, dan limbah padat kelapa muda.

1. Introduction

The energy used by society today mostly comes from fossil fuels such as kerosene and gas. The need for energy from fossil fuels is increasing every year, along with increasing human activities. This causes a decrease in the availability of fuel oil, so it is necessary to strive for alternative energy sources that are renewable, environmentally friendly, and can be reached by middle to lower-class people.

Bottom ash from bio briquettes is a solid fuel that can theoretically be used for small and medium-sized businesses as well as homes. It is an alternative to kerosene. Additionally, bio briquettes are more economically advantageous because of their ease of production, high calorific value, and abundant bottom ash supply in Indonesia, which allows them to rival other fuels. The bottom ash utilized is the leftover combustion from the PKS PT boiler. Blang Ketumba is presently solely disposed of as waste and is not generally used. Even yet, the calorific value of this bottom ash is still somewhat high.

The solid trash from young coconuts is typically just dumped beneath a stand of coconut trees and allowed to dry or rot. Young coconut solid waste has not yet had the opportunity to be fully utilized for profitable endeavors that could raise its market value. Despite their relatively high calorific value, immature coconut shells are composed of 74.3% carbon (carbon), 21.9% oxygen (O2), 0.2% silicon (Si), 1.4% potassium (K), 0.5% sulfur (S), and 1.7% phosphorus (P). These chemical compositions suggest that coconut shells might be utilized as a fuel and a source of activated carbon, which could be combined with other raw materials to create a mixture for bio-briquettes.

Several researchers have conducted research on biobriquettes bottom ash (The Anti-Christ, 2018); (Triantoro., 2019); (Sugeng Slamet., 2018). These bio briquettes are made through the process of authoring or carbonization, mixing with adhesives, printing, and pressing. Bio briquettes from waste Bottom Ash The combustion results in PKS have the advantage of being a prospective waste treatment to increase calorific value density, make it easy to package and distribute, and have a uniform size. Solid fuel from bio briquettes bottom ash is a substitute for the most inexpensive fuel oil, and it uses relatively simple equipment.

Making bio briquettes with a mixture of young coconut solid waste as alternative energy using a carbonization process with adhesives used in this study is molasses, which is based on several considerations, including molasses can also be used as pellet adhesives which in its implementation can increase its calorific value. Making biobriquettes using bottom ash has been done by many previous studies. As in the research of Stevie Erga Anetiesia 2020, Making Bio briquettes from Bottom Ash and Coconut Shell Charcoal as an Alternative Energy Source, the research obtained the results of the best mixture ratio of the research results based on comparisons in accordance with the criteria of SNI 01-6235-2000 concerning Quality Requirements for Wood Charcoal Biobriquettes is 20% bottom ash: 80% coconut shell charcoal with parameters of moisture content 3.45%, ash content 17.32% and calorific value 7945.72 kal/g. The above research has a high calorific value but still has a very high ash content, so this study examines the appropriate mixture with bottom ash.

2. Material and Method

The materials and equipment needed in conducting this research include bottom ash, young coconut solid waste, molasses, authoring tool oven, 80 mesh sieve, watch glass, beaker glass, stirrer, analytical balance stopwatch basin, briquette mold, pounding tool, erlen meyer, and kiln drum.

The four steps of this research are the production of the raw materials, the preparation of the adhesive, the printing of the biobriquettes, and the testing procedure. Different kinds of research were done on the proportion of peat, which is 2%, 3%, and 4%, and the composition of the mixture of bottom ash with young coconut solid waste, which was 75%: 25%, 50%: 50%, 25%: 75%, and 0%: 100%. The testing procedure itself involves bulk density testing to ascertain the bio briquettes compressive strength, combustion rate, and calorific value, in addition to determining the moisture content, ash content, flying compounds, and fixed carbon.

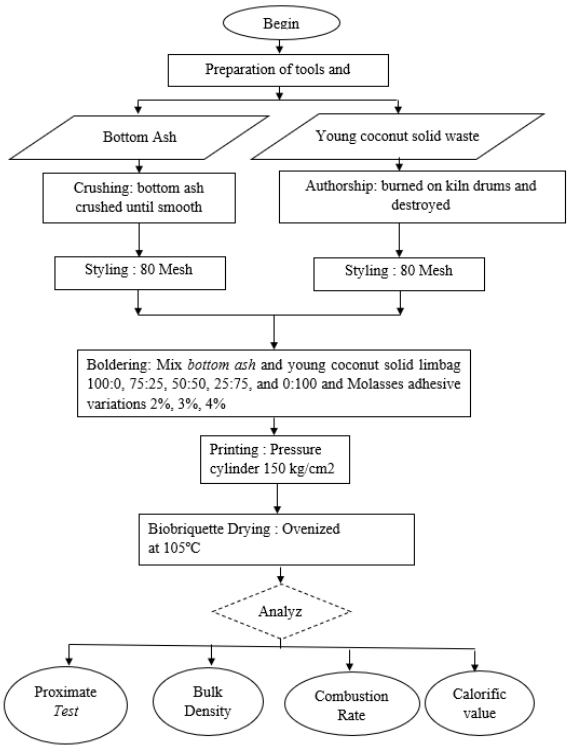

Figure 1. Research flow chart

3. Result and Discussion

3.1. The influence of bio briquette mixtures on water levels

The water rate is the amount of water contained in a material. The water rate is compared to the reverse with the value of the color so that a decrease in the water rate will lead to an increase in the value of the chlor. The water rate affects the fuel so much that in the fuel, the water rate should be as low as the mungin. The results of the water content analysis on bio briquettes mixed with bottom ash and young coconut solid waste are shown in Figure 2.

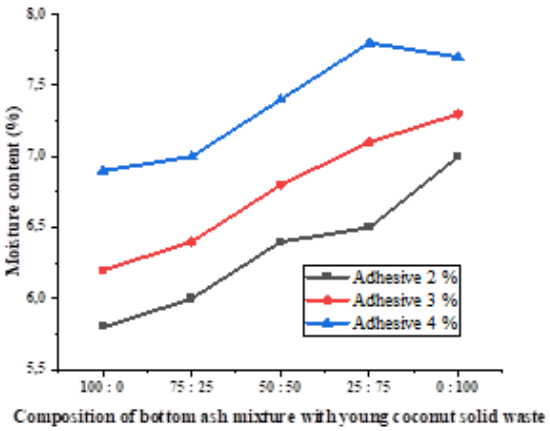

Figure 2. The relationship of the composition of the bio briquette mixture to the water rate

The increase in water content continues to increase as the composition of young coconut solid waste, and the adhesive used are higher. The greater amount of adhesive exerts a huge influence on the moisture content of biobriquettes. According to Winarno (2018), the more adhesive there is, the higher the moisture content. Based on the results of the study, the resulting moisture content value ranged from 5.8% - 7.8%. The results showed that briquettes with a variable mixture of bottom ash with young coconut solid waste met SNI 01-6235-2000 standards, which is a maximum moisture content of 8%.

3.2. The influence of briquette mixtures on ash rates

The amount of parts left unburned after full combustion is ascertained by analyzing the ash content of briquettes. Following total combustion. Combustion equipment might be more difficult to operate and maintain when there is a high ash content. A briquette is considered better if its ash concentration is lower.

After the briquettes are burned, the unburned portions that contain no carbon components have to be identified by measuring the ash content. The amount of ash is similar to the amount of inorganic material found in briquettes. The kind and quality of the material utilized affect the high and low ash content values of bio briquettes, among other things. Minerals include clay, silica, calcium, magnesium oxide, and other elements that makeup ash. The primary component of ash is silica, which negatively affects briquettes' heating value.the briquettes' worth. The large amount of inorganic components in the biomass waste and the high amount of glue used to make the briquettes can both have an impact on the ash content of briquettes. Figure 3 shows the results of the ash content test on briquettes:

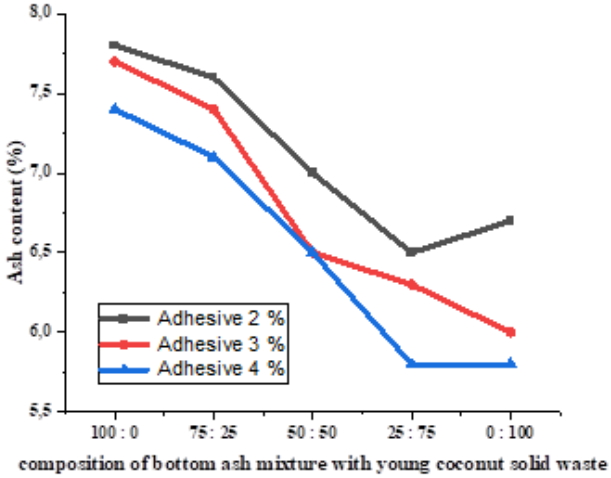

Figure 3. The relationship of the composition of the bio briquette mixture to the ash rate

Figure 3 shows that the higher the adhesive content, the lower the ash content obtained. This is in agreement with, saying that the higher the concentration of tapioca adhesive, the value of ash content will decrease. The picture above also shows the composition of young coconut solid waste; the lower the ash content obtained, this is related to the composition of the constituent raw materials contained in bottom ash and young coconut solid waste where the main constituent component of ash is silica which is found a lot in bottom ash this is also in accordance with research which says The more addition of bottom ash to the briquette mixture, the higher the ash content of briquettes produced. In the results of biobriquette analysis and testing of bottom ash mixture with young coconut solid waste that has been carried out, the highest ash content is obtained in a mixture of 100% bottom ash : 0% Young coconut solid waste with a percent adhesive of 2% with a value of 7.8% while the lowest

ash content is obtained in a mixture of 25% bottom ash: 75% Young coconut solid waste with 4% adhesive percent with a value of 5.8%.

This occurs because ash is the residue of burning that no longer contains carbon components or calorific value. The ash content number represents the amount of mineral substances that remain at the end of the combustion process and are not lost throughout the combustion process. According to Sudarmaji et al. (2017), the ash content is affected by the type of material, the method of ashing, and the duration and temperature employed for drying. According to the study's findings, the resulting moisture content value ranged from 7.8% to 5.8%. Briquettes with temperature and time variables satisfied SNI 01-6235-2000 criteria, with a maximum ash content of 8%, according to the results.

3.3. Effect of bio briquette mixture on flying substances

The flying substance in the charcoal briquette is a compound – a compound other than water, ash, and carbon made up of hydrocarbons, methane, and carbon monoxide. The high level of flying matter in the charcoal briquette will create more smoke at the time the briquette is lit. The results of the analysis of flying substance levels in bio briquettes mixed with bottom ash with young coconut solid waste are shown in Figure 3.

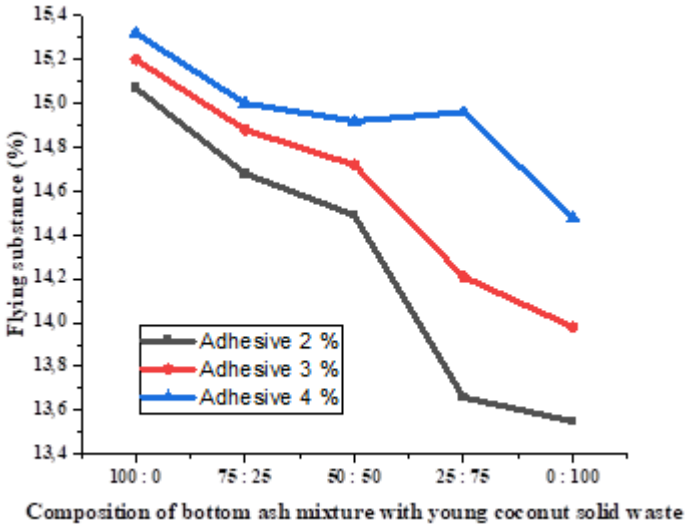

Figure 4. Relationship of bio briquette mixture composition to substances fly

Figure 4 shows that the higher the adhesive content, the higher the flying substance content obtained; this is in accordance with the theory that the more adhesive concentration, the higher the value of the flying substance contained in the biobriquette because the more adhesive conversion will make the biobriquette more moist and increase the flying substance level as well. This is in accordance with research that the adhesive composition will affect the percentage of flying substance content in biobriquettes. The more adhesive composition is used, the more the content of flying substances will increase. The picture above also shows the greater composition of young coconut solid waste; the value of flying substances obtained is related to the composition of constituent raw materials contained in bottom ash and young coconut solid waste, where the main constituent component of flying substances is an active substance that accelerates the combustion process. The flying substance consists of flammable gases such as hydrogen (H), carbon monoxide (CO), and methane (CH_4), which are found in a lot of bottom ash. This is in accordance with research (Hendra and Darmawan, 2020) that determines the size of flying substances by the type of material used. The higher the calorific value of the raw materials used, the lower the value of flying substances. It was said that the

high and low results obtained were caused by sufficient raw materials containing high levels of flying substances.

In the results of biobriquette analysis and testing of the bottom ash mixture with young coconut solid waste that has been carried out, the highest levels of flying substances were obtained in a mixture of 100% bottom ash: 0% Young coconut solid waste with a percent adhesive of 4% with a value of 15.32% while the lowest levels of flying substances were obtained in a mixture of 0% bottom ash: 100% Young coconut solid waste with 2% adhesive with a value of 13.55%. The results of the analysis of flying substance levels in bio briquettes mixed with bottom ash with young coconut solid waste have been given variations in composition, and also, the number of adhesives range from 13.55% - to 15.32%. The results showed that biobriquettes met SNI 01-6235-2000 standards, namely a maximum of 15% flying substance levels.

3.4. The influence of bio briquette mixes on fixed carbon

Carbon content is the amount of pure carbon contained in charcoal. The higher temperature in the carbonization process greatly affects the quality of charcoal, including carbon content. The higher the fixed carbon level, the lower the evaporation level. The results of the analysis of fixed carbon levels in bio briquettes mixed with bottom ash with young coconut solid waste are shown in Figure 5.

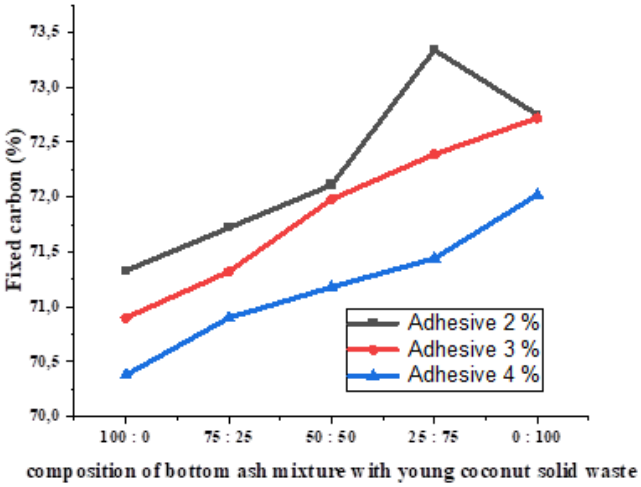

Figure 5. The relationship of bio briquette mixed composition to fixed carbon

Figure 5 shows that the higher the adhesive content, the lower the level of flying substances obtained because the moister the biobriquette will make, the fixed carbon content contained will also decrease; this is in agreement with research conducted by, showing that the higher the use of the amount of adhesive, the biobriquette making tends to be more moist so that there is a decrease in fixed carbon levels. The picture above also shows the composition of young coconut solid waste; the higher the fixed carbon value obtained, the more related to the content of water content, ash, and flying substances between each component of bottom ash and young coconut solid waste; this is also in accordance with research Fixed carbon produced from coconut shell bio briquettes is greater than that in bottom ash, This is because the value of fixed carbon in coconut shells is quite high.

In the results of bio briquette analysis and testing of bottom ash mixture with young coconut solid waste that has been carried out, the lowest flying substance content is obtained in a mixture of 100% bottom ash : 0% Young coconut solid waste with a percent adhesive of 4% with a value of 70.38% while the highest fixed carbon content is obtained in a mixture of 25%

bottom ash: 75% Young coconut solid waste with 2% adhesive percent with a value of 73.34%. The results of the analysis of fixed carbon levels in bio briquettes mixed with bottom ash with young coconut solid waste ranged from 70.38% - 73.34%. When compared with SNI 01-6235-2000 concerning bio briquettes, it meets a maximum bound carbon parameter of 77%.

3.5. Effect of briquette mixture on bulk density

Density is the ratio of weight to volume of biobriquettes. The density is influenced by the size and degree of homogeneity of the charcoal biobriquettes made. The results of bulk density analysis on bottom ash mixed biobriquettes with young coconut solid waste are shown in Figure 6.

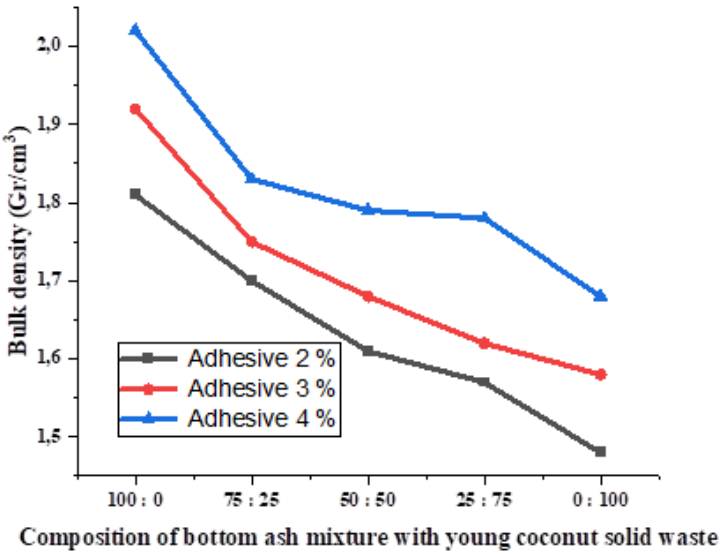

Figure 6. Composition relationship of bio briquette mixture to bulk density

Figure 6 shows that the higher the adhesive content, the higher the bulk density obtained; this is due to the concentration of adhesive, which has gluing and hard properties that can affect adhesion to biobriquettes. This is also in agreement with research, saying that the higher the adhesive presentation, the lower the value of bio briquettes because increasing the adhesive content will increase adhesion and bonding between molecules that make up bio briquettes. The picture above also shows the more composition of the bottom ash, the higher the bulk density value obtained; this is related to the content of the bottom ash because it has pozzolanic properties that allow bio briquettes to be denser and harder, and also the historic character of bottom ash which has fine particles so that it has higher adhesion than young coconut solid waste which has larger particles. According to (Idzni & Sukandar, 2016), the compressive strength in bottom ash briquettes is greater than in coconut shells because bottom ash particles have a smaller surface area. This is seen based on the particle size of the bottom ash, which is finer, so the particles are denser than coconut shells.

In the results of bio briquette analysis and testing of bottom ash mixture with young coconut solid waste that has been carried out, high bulk density levels are obtained in a mixture of 100% bottom ash: 0% Young coconut solid waste with 4% adhesive percent with a value of 2.02 gr/cm^3 while low bulk density levels are obtained in a mixture of 0% bottom ash: 100% Young coconut solid waste with 2% adhesive percent, with a value of 1.48 gr/cm^3. Based on the results of the study, the results of the analysis of bulk density levels in bio briquettes mixed with bottom ash mixture with young coconut solid waste ranged from 1.48 gr/cm^3 to 2.02 Gr/cm^3 Each treatment has met the quality standards set by Japan (1-2 g/cm^3), America (1 g/cm^3), England (0.85 g/cm^3) and SNI standards (0.46 g/cm^3). It is suspected that there is an

uneven compressive strength given so that there are denser particles in each biobriquette. In addition, differences in the composition of raw materials and adhesives affect the weight and volume of bio briquettes, increasing the density of bio briquettes because the bond between materials is better and combustion is longer.

3.6. The influence of bio briquette mixtures on combustion speed

Testing for the combustion rate is carried out to determine the combustion rate of briquettes, starting from the combustion rate until the briquettes run out into ash during the combustion process. Combustion rate testing is carried out 1 time simultaneously. The experimental results for this combustion rate are a faster briquette flame time, higher temperature, and shorter ignition. According to Rahmadani, solid briquettes will be difficult to burn because there is no air cavity for oxygen that helps ignite the fire. The rate of combustion is also influenced by the calorific value and moisture content in briquettes. Briquettes that have a high calorific value and low moisture content will produce a high combustion rate. The reduction in weight per unit minute during combustion is referred to as combustion speed. The faster the combustion, the quicker the briquette will ignite. The combustion speed is calculated by dividing the dry weight of the briquettes by the time it takes for the briquettes to burn out into ashes.

The results of the combustion rate analysis on bio briquettes mixed with bottom ash with young coconut solid waste are shown in Figure 7.

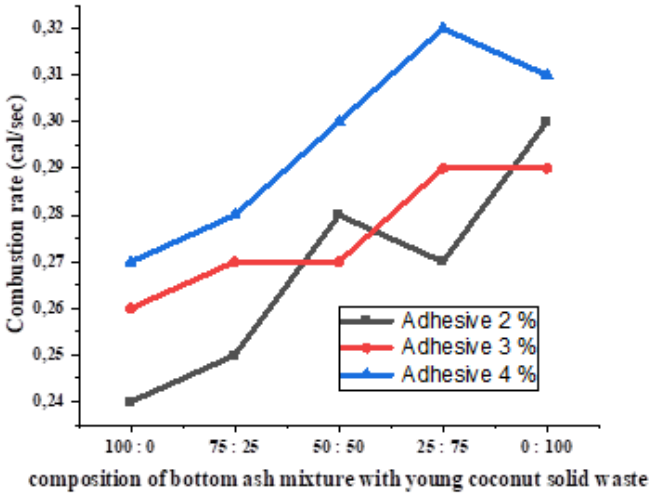

Figure 7. Relationship of biobriquette composition to combustion rate

Figure 7 shows the greater the number of briquette assemblers, the longer the burning time because the more adhesive composition, the moisture content will also be higher, will slow down the combustion rate and prolong the burning rate of bio briquettes and with more adhesive, it can also cause bio briquettes to become denser and oxygen is not easily trapped inside, causing the bio briquettes to take longer in the combustion process. This is the same as research (5) says: the higher the percentage of adhesive, the lower the burning rate of the bio briquettes, due to the higher adhesive that can cause briquettes to become solid, complicating the burning process.

The picture above also shows the more composition of young coconut solid waste, the higher the combustion rate value obtained; this is related to the oxygen concentration content, gas temperature, and Reynold number between each component of bottom ash and young coconut solid waste, where young coconut solid waste contains oxygen concentration, gas temperature, Reynolds number higher than bottom ash. This is also in accordance with Borman

and Ragland's (2018) research in Rahman (2019), indicating that the rate of burning of charcoal is affected by oxygen concentration, gas temperature, Reynolds number, size, and porosity of charcoal, while wood charcoal has a high porosity.

In the results of biobriquette analysis and testing of bottom ash mixture with young coconut solid waste that has been carried out, the lowest burning rate is obtained in a mixture of 100% bottom ash: 0% Young coconut solid waste with a percent adhesive of 2% with a value of 0.24 cal/sec while the highest fixed carbon content is obtained in a mixture of 25% bottom ash: 75% Young coconut solid waste with 4% adhesive percent, namely with a value of 0.32 cal/sec. Based on the results of the analysis of the combustion rate in bio briquettes, a mixture of bottom ash with young coconut solid waste ranges from 0.24 – 0.32 cal/sec. The graph shows that the higher the composition of young coconut solid waste, the higher the combustion rate.

3.7. The effect of bottom ash mixture with young coconut solid waste on calorific value

The quality of the bio briquettes that are generated is mostly determined by their calorific value. The calorific value indicates the quality of the bio briquettes that are generated. To calculate the amount of combustion heat that briquettes as fuel can create, one must know the calorific value. This is because, according to Purnama et al. (2022) in (Ristianingsih et al., 2020), the carbon content bonded to charcoal briquettes affects the high and low calorific value of charcoal briquettes. This is because the combustion process requires carbon, which will combine with oxygen to produce heat.

As stated in (Iskandar et al., 2019) by Rahman (2011). The quantity of heat generated per unit weight during combustion from a single, sufficiently combustible material is known as the calorific value. The calorific value is the primary factor used to assess the quality of briquette fuel. The heat produced when a certain amount of fuel units (mass) burns, producing ash, CO2 gas, SO2, nitrogen, and water as byproducts; water that evaporates is not included in the calorific value calculation. Better fuel quality is indicated by more heat. When the amount of carbon bound to the biobriquettes is high, the biobriquettes' calorific value will also be high. The results of the calorific value analysis on bio briquettes mixed with bottom ash with young coconut solid waste are in Figure 8.

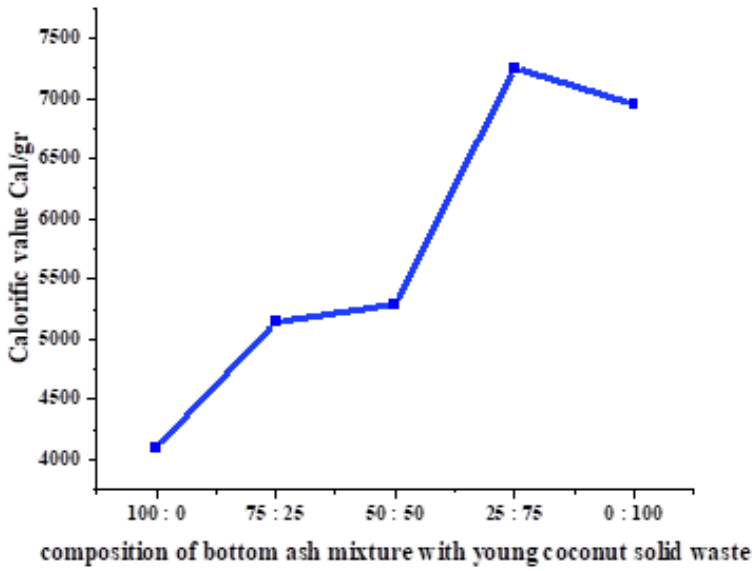

Figure 8. The relationship of bio briquette composition to calorific value

Figure 8 shows that the higher the composition of young coconut solid waste, the higher the calorific value obtained. Judging from the water content and ash content, the higher the bio briquette ash content will reduce the calorific value of the bio briquettes produced. This is in line with (Sabindo et al., 2020). The higher the calorific value, the better the quality of bio briquettes, so the amount of bio briquettes used for combustion becomes less.

In the results of biobriquette analysis and testing of a mixture of bottom ash with young coconut solid waste that has been carried out, the lowest calorific value is obtained in a mixture of 100% bottom ash: 0% Young coconut solid waste with a value of 4101.81 cal / g while the highest calorific value is obtained in a mixture of 25% bottom ash: 75% Coconut solid waste with a value of 7255.73 cal/g. Based on the results of the calorific value analysis on biobriquettes mixed with bottom ash with young coconut solid waste ranging from 4101.81 – 7255.73 cal/g. The increase in calorific value that occurs shows that young coconut solid waste has a higher calorific value than bottom ash; according to (Sudarsi, 2018), Bio charcoal has a calorific value of more than 6000 cal/g. The obtained calorific value parameter is at least 5000 cal/gram when compared to SNI 01-6235-2000. Since the calorific value of the bio briquettes made from a bottom ash combination and young coconut solid waste exceeds the minimal level, it satisfies SNI requirements. A fuel's calorific value indicates its quality; the higher, the better.

4. Conclusion and Suggestions

From the results of the study, it can be concluded that the manufacture of biobriquettes obtained the highest calorific value test, which was 7255.73 cal/gr, found in a mixture of 25%: 75%. The results of all tests of bio charcoal briquettes meet SNI 01-6235-2000 standards, and the best bio briquettes are found in a mixture of 25% bottom ash and 75% young coconut solid waste with 4% adhesive.

Based on the research that has been carried out for further bio briquette manufacturing research, when using waste from palm oil mills, it is expected to use waste other than bottom ash like Fiber, empty palm shells, and bunches, due to the use of boiler ash (bottom ash) less effective in making bio briquettes.

Bibliography

Anggoro, D. D., M. H. D. Wibawa, dan M. Z. Fathoni. 2018. "Making Charcoal Briquettes From a Mixture of Coconut Shell and Sengon Wood Sawdust." *Technical* 38(2): 76. https://doi.org/10.14710/teknik.v38i2.13985.

Arifin, Z., dan W. Nuriana. 2019. "The Calorific Value of Sengon Wood Waste Briquettes with Cornstarch Adhesive Is Higher than Tapioca, Sago and Cassava Flour." *Journal of Technology Pillars: Scientific Journal of Engineering Sciences* 3(2): 37–41. https://doi.org/10.33319/piltek.v3i2.18.

Haliza, H. N., dan H. Saroso. 2023. "Making Bio-briquettes from Coconut Husk and Teak Sawdust Using Tapioca Flour Adhesive." *DISTILLATE: Journal of Separation Technology* 8(1): 238–244. https://doi.org/10.33795/distilat.v8i1.308.

Kapita, H., S. Idrus, dan F. Fanumbi. 2021. "Utilization of Coconut Biomass Waste and Corn Cobs for the Manufacture of Briquettes." *Journal of SILITEK Engineering* 1(01): 9–16. https://doi.org/10.51135/jts.v1i01.2.

Kusmartono, B., A. Situmorang, dan M. Yuniwati. 2021. "Making Briquettes from Coconut Shells (Cocos nucifera) and Wheat Flour." *Journal of Technology* 14(2): 142–149. https://doi.org/10.34151/jurtek.v14i2.3770.

Mangin, L., dan C. B. Nugroho. 2015. "The Effect of the Drying Temperature of Sawdust Briquettes and Starch on the Pressure Strength." *Journal of Integration* 7(1): 31–35.

Patabang, D. 2013. "Thermal Characteristics of Meranti Wood Sawn Powder." *Mechanical Journal* 4(2): 410–415.

Saleh, A., L. Novianty, S. Murni, dan A. Nurrahma. 2017. "Quality Analysis of Wood Sawdust Briquettes with the Addition of Coconut Shells as an Alternative Fuel." *Al-Chemistry* 5(1): 21–30. https://doi.org/10.24252/al-kimia.v5i1.2845.

Setyawan, B., dan R. Ulfa. 2019. "Quality Analysis of Charcoal Briquettes from Biomass Waste Mixture of Coffee Skin and Coconut Shell with Tapioca Flour Adhesive." *Edubiotics: Journal of Educational, Biological and Applied* 4(02): 110–120. https://doi.org/10.33503/ebio.v4i02.508.

Triantoro, A., A. Mustofa, dan A. W. Saputri. 2021. "The Study of the Utilization of a Mixture of Coal Bottom Ash with Sawdust and Coconut Shell Charcoal as Biobriquettes Is Reviewed from Quality Parameters." *Journal of GEOSAPTA* 7(1): 65. https://doi.org/10.20527/jg.v7i1.10235.