Effect of Particle Size Variation on Coconut Waste Briquettes Quality

Hasnatun Nabilah[a,*], Nurchayati[a], Ida Bagus Alit[a]
[a]Mechanical Engineering Department, Engineering Faculty, University of Mataram
Jl. Majapahit no. 62, Mataram, NTB, 83125, Indonesia.
*E-mail: hasnabilabahri@gmail.com

Abstract

Coconut is one of the largest agricultural commodities in Indonesia. Various traditional Indonesian dishes use coconut milk as a key ingredient. In recent years, coconut oil has also been produced at a large scale by the community. The process of making coconut milk begins with grating the coconut meat, followed by extraction. Grating methods include traditional hand graters, mechanical graters, and blenders, every methode is resulting in different particle sizes of coconut waste. Coconut waste can be further utilized as an alternative fuel source in the form of briquettes. This study aims to determine the quality of coconut waste briquettes based on particle size, using mesh sizes of 20, 40, and 60. The quality tests performed include moisture content (using a moisture analyzer), ash content (using a furnace), mechanical strength (drop test from 180 cm), and calorific value (using a bomb calorimeter). The results show that all coconut waste briquettes meet the requirements of the SNI 01-6235-2000 standard. Moisture and ash content increased with finer mesh sizes. The highest calorific value was found in the 20-mesh briquettes (5611 cal/g), while the lowest was observed in the 60-mesh briquettes (5325 cal/g), indicating that smaller particle sizes result in lower energy content. For the drop test, the mass loss results for mesh sizes 20, 40, and 60 were 0.148%, 0.092%, and 0.049%, respectively.

Keyword: coconut waste; briquette; particle size; quality of briquette

Abstrak

Kelapa merupakan salah satu komoditas pertanian terbesar di Indonesia. Berbagai hidangan tradisional Indonesia menggunakan santan kelapa sebagai bahan utama. Dalam beberapa tahun terakhir, minyak kelapa juga telah diproduksi secara luas oleh masyarakat. Proses pembuatan santan diawali dengan kegiatan pemarutan daging kelapa, diikuti dengan tahap ekstraksi. Metode pemarutan yang digunakan meliputi parutan manual tradisional, parutan mekanis, dan blender, di mana setiap metode menghasilkan ukuran partikel ampas kelapa yang berbeda. Ampas kelapa tersebut selanjutnya dapat dimanfaatkan sebagai sumber bahan bakar alternatif dalam bentuk briket. Penelitian ini bertujuan untuk mengetahui kualitas briket ampas kelapa berdasarkan variasi ukuran partikel, dengan menggunakan ukuran ayakan (mesh) 20, 40, dan 60. Uji kualitas yang dilakukan meliputi kadar air (menggunakan *moisture analyzer*), kadar abu (menggunakan tungku pembakaran/furnace), kekuatan mekanik (uji jatuh dari ketinggian 180 cm), serta nilai kalor (menggunakan *bomb calorimeter*). Hasil penelitian menunjukkan bahwa seluruh briket ampas kelapa memenuhi persyaratan standar SNI 01-6235-2000. Kadar air dan kadar abu meningkat seiring dengan semakin halusnya ukuran partikel (mesh). Nilai kalor tertinggi diperoleh pada briket dengan ukuran 20 mesh yaitu sebesar 5611 kal/g, sedangkan nilai kalor terendah ditemukan pada briket berukuran 60 mesh sebesar 5325 kal/g. Hal ini menunjukkan bahwa semakin kecil ukuran partikel, maka kandungan energi yang dihasilkan semakin rendah. Pada uji jatuh, persentase kehilangan massa masing-masing untuk ukuran mesh 20, 40, dan 60 adalah sebesar 0,148%, 0,092%, dan 0,049%.

Kata kunci: ampas kelapa, briket, ukuran partikel, kualitas briket

1. Introduction

Coconut is one of Indonesia's most important agricultural commodities, with a plantation area of approximately 3,728,600 hectares, producing an estimated 18.3 million tons annually [1]. Coconut milk is commonly used in many Indonesian dishes such as *rendang*, *gulai*, *soto*, and *kolak* during Ramadan. In Lombok, during the traditional celebration called *Begawe*, coconut milk is a critical ingredient in large-portion cooking. According to Saiful [2], a local chef in a *Begawe* event, each celebration typically requires 300 to 350 coconuts, generating significant amounts of coconut waste. Moreover, various local MSMEs (micro, small, and medium enterprises) such as food vendors and coconut oil producers also generate coconut waste on a daily basis [3].

Studies have shown that coconut waste has great potential as a raw material for briquettes. A briquette is a solid fuel made by compressing biomass and a binder. Briquettes are a cost-effective alternative fuel source that can be mass-produced using relatively simple technology [4]. Findings by Wahab (2010), as cited in Chusniyah et al. [5], which indicate that coconut waste converted into biomass briquettes possesses a calorific value of 7245.992 cal/g. This value exceeds the minimum calorific value of 5000 cal/g required by the Indonesian National Standard (SNI) 01-6235-2000 for high-quality briquettes. Furthermore, Chusniyah et al. [5] investigated the moisture and ash content of coconut waste charcoal briquettes using 60 mesh-sized charcoal powder. Their study revealed that the optimal moisture content was achieved in sample number 3, which contained 25 g of coconut waste charcoal, 35 g of binder, and 50 ml of water, resulting in a moisture content of 4.459%. This value falls well within the maximum moisture content limit of 8% stipulated by SNI 01-6235-2000, indicating that the coconut waste charcoal briquettes meet the established quality standards.

Yogi [6] conducted a study investigating the effect of particle size variation on the calorific value characteristics of briquettes made from coconut shell. The study utilized particle sizes of 20, 40, and 60 mesh. The findings revealed that the highest calorific value, 6704.69 cal/g, was obtained from the sample with a particle size of 60 mesh. In addition to its influence on calorific value, particle size was also found to affect the moisture and ash content of the briquettes. Supporting this, Huda et al. [7] examined the impact of particle sizes specifically 12 and 24 mesh on briquettes with a binder concentration of 20%. The results demonstrated that the 24 mesh particle size yielded superior performance compared to 12 mesh, with a recorded moisture content of 6.9% and an ash content of 5.06%.

One important factor affecting briquette quality is the particle size of the raw material. Uniform particle size simplifies the molding process. Smaller particles generally result in stronger briquettes with slower burn rates, while larger particles burn faster but may reduce structural integrity [8]. Excessively large particles can weaken the bonds between components, producing brittle briquettes, whereas finer particles create more compact and durable briquettes. With today's diverse grating methods including blenders, machines, and traditional hand grater, resulting particle size of coconut waste varies widely. Therefore, it is essential to understand the effect of particle size on the quality of briquettes made from coconut waste.

2. Material and Method

This study involves two types of variables: Independent variables and dependent variables. The independent variable refers to the factor that can be modified, which in this case is the particle size. The particle sizes of the coconut waste used in this study were 20, 40, and 60 mesh. The dependent variable refers to the outcomes measured as a result of changes in the independent variable, which in this case is the quality of the briquettes. The quality parameters of the briquettes to be tested include moisture content, ash content, and calorific value. To determine the moisture content, the briquettes were analyzed using a moisture analyzer. The ash content was obtained by placing the briquettes in a furnace at 750°C for 1 hour, after complete incineration, the initial mass of the briquettes was compared with the mass of the resulting ash. Meanwhile, the calorific value was measured using a bomb calorimeter. The quality standards of briquettes in Indonesia are regulated under SNI 01-6235-2000.

The tools and materials used in the production of coconut waste briquettes, included: dried coconut waste, tapioca flour, water, a gas stove, a pot and a spoon, digital scale with an accuracy 0,01g, vernier caliper with an accuracy 0,02 mm, a simple hydraulic briquette mold, and an oven. The briquette binder was prepared by mixing tapioca flour and water in a ratio of 1:2.6, followed by boiling the mixture. The hydraulic mold used in this study was not equipped with a pressure gauge, and therefore, the exact applied pressure was not measured. The briquette mixture was made by combining dried coconut waste and binder in ratio of 80:20, with 10 grams of mixture used per mold. The drying process was carried out after the briquettes were left at room temperature overnight, followed by oven drying at 50°C for 5 hours.

2.1 Particle size

The coconut waste particles used in this study were sized at 20, 40, and 60 mesh. The term "mesh" denotes the number of sieve openings per linier inch, for instance, a 20-mesh sieve contains 20 openings per inch. A increase in mesh number corresponds to a greater density of openings, thereby permitting the passege of finer particles. Each mesh specification is associated with a distinct aperture diameter, which subsequently determines the particle size distribution. The aperture dimensions for several commonly utilized mesh classifications are presented in Table 1. below:

Table 1. Mesh size [9]

Mesh Number	Aperture diameter (mm)
4	4.750
6	3.350
8	2.360
10	2.000
12	1.680
16	1.180
20	0.850
30	0.600
40	0.425
50	0.300
60	0.250
80	0.180

Variations in particle size influence the compression, combustion rate, and durability of the resulting briquettes. Smaller particle sizes lead to briquettes with reduced pore sizes, resulting in higher compressive strength but slower combustion rates. Conversely, larger particle sizes increase the combustion rate but reduce the compressive strength of the briquettes [8].

In this study, to obtain coconut waste particles of 20, 40, and 60 mesh sizes, several sieve levels were used sequentially, namely sieve numbers 16, 20, 30, 40, and 60. The selection of sieve sizes was determined based on the sieves available in the laboratory. The coconut waste selected for each mesh size consisted of particles retained on the corresponding sieve. For instance, to obtain 20-mesh particles, only the coconut waste retained on sieve number 20 was used, meaning that particles larger or smaller than the 20-mesh specification were excluded. According to Table 1. the particle size for 20 mesh ranges from 0.850 mm to <1.180 mm. Particles of 40 mesh have a size range of 0.425 mm to <0.600 mm, as sieve number 30 was positioned above mesh 40. Meanwhile, 60-mesh particles range from 0.250 mm to <0.425 mm.

2.2 Quality of briquettes

The quality of briquettes in Indonesia is regulated by the national standard SNI 01-6235-2000. Briquette quality is a critical factor that determines their effectiveness and efficiency as an alternative energy source. The quality standards for briquettes in Indonesia, based on SNI, are shown in **Table 2.**:

Table 2. Quality standards of briquettes [10]

No	Parameter	SNI 01-6235-2000	unit
1	Moisture content	≤ 8	%
2	Ash content	≤ 8	%
3	Fix carbon	≥ 7	%
4	Calorific value	≥ 5000	cal/g
5	Drop test	≤ 1	%

One of the key factors in improving briquette quality is the drying process. Drying is typically carried out either under direct sunlight or using an oven at specific temperatures and durations. In the present study, the drying process was conducted in an oven at a constant temperature of 50°C for a duration of 5 hours [11]. After the briquettes were confirmed to be dry, they were subjected to several tests. The following evaluations were conducted:

2.2.1 Moisture content

Moisture content plays a significant role in determining the quality of briquette products. The presence of moisture in briquettes is a critical factor, as it affects smoke production, ignition performance, and shelf life [12]. Moisture content testing was conducted using a laboratory instrument known as a moisture analyzer. This device operates based on the thermogravimetric method, in which the reduction in sample weight occurs due to heating by a halogen lamp. The heating process causes continuous weight loss in the sample, which ceases once a constant weight is achieved [13]. The heating takes place at a predetermined temperature over a specific period, during which the instrument continuously monitors the sample's weight. The process automatically stops when the sample's weight stabilizes.

2.2.2 Ash content

Ash is an iorganic residue derived from the combustion of organic matter. It consists of various micronutrients (such as Zn, Cu, and Fe) and macronutrients (such as Mg, Ca, and K) [14]. The main ash components in biomass include calcium, potassium, magnesium, and silica, all of which can influence the calorific value of the material [15]. Ash content analysis was carried out by incinerating the briquettes at high temperatures using a laboratory furnace (muffle furnace). The samples were placed in the furnace and heated at 750°C for 1 hour. The briquettes were weighed before and after incineration to determine the ash content. According to [16], the percentage of ash content in the briquettes was calculated based on the ASTM D-3174-04 standard using the following equation 1:

$$\text{Ash content (\%)} = \frac{B}{A} \times 100\% \quad (1)$$

Where A is initial mass (g), B is ash mass (g). Subsquently, the ash mass of the briquette can be determined using equation 2 as follows:

$$B = m_{ca} - m_c \quad (2)$$

m_{ca} is the mass of the cruible containing ash (g) and m_c is the mass of empty cruible (g).

2.2.3 Calorific value

The calorific value refers to the maximum amount of heat energy released or produced by a fuel during complete combustion per unit mass or volume [17]. It is typically expressed in units of calories (cal) or joules (J). A higher calorific value indicates that a fuel can release more energy during combustion. The calorific value of a fuel can be determined using an instrument known as a bomb calorimeter. This method typically yields two types of values: the Higher Heating

Value (HHV), which includes the latent heat of vaporization of water, and the Lower Heating Value (LHV), which excludes it.

3. Result and Discussion

The results of the coconut waste briquette tests are presented as follows:

3.1 Moisture content

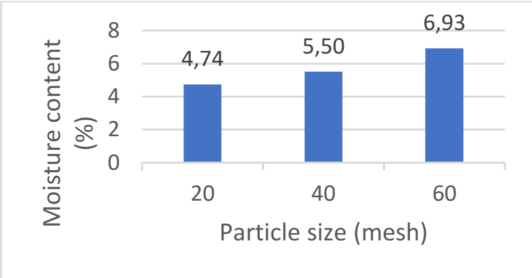

Figure 1. Moisture content of three particle size variations.

Based on Figure 1, the highest moisture content was observed in briquettes made with 60 mesh particle size, reaching 6.39%, while the lowest moisture content was recorded in those made with 20 mesh particles, at 4.74%. Larger particle sizes make it more difficult for the coconut waste to bind effectively with the adhesive. After the molding process, the briquettes tend to expand, often resulting in cracks. However, in comparison to the briquette quality standard SNI 01-6235-2000, all coconut waste briquettes tested in this study still meet the standard, as their moisture content remains below the maximum threshold of 8%. The moisture content results are presented in decimal form, as the analysis was conducted using a moisture analyzer, which directly displays the measurement with two decimal places

According to Chusniyah et al. [5], coconut waste charcoal briquettes made using 60 mesh particle size yielded a moisture content ranging between 4.5–5.8%. When compared to non-carbonized biomass briquettes made from coconut waste with the same particle size, the moisture content in non-carbonized briquettes is generally higher. This is because biomass is a raw material that has not undergone carbonization, and still contains cellulose, which is hygroscopic and thus readily absorbs moisture.

Previous research by Yogi [6] and Sabindo et al. [18] also reported that larger particle sizes tend to produce briquettes with higher moisture content. In larger particles, the surface area is smaller, which slows down water evaporation during drying [19]. On the other hand, briquettes made from finer particles typically have lower moisture content due to their smaller pore sizes and better compaction properties [20]. Interestingly, the findings of this study deviate from this general trend. As shown in Figure 1, briquettes made with smaller particle sizes actually exhibited higher moisture content. This discrepancy may be attributed to differences in the structural form between biomass coconut waste briquettes and charcoal briquettes. The appearance of the coconut waste briquettes can be observed in figure 2 below:

(a) (b) (c)

Figure 2. Cococnut pulp briquettes, (a) mesh 20, (b) mesh 40, (c) mesh 60

Figure 2. shows that larger particle sizes tend to produce more and larger cracks in the briquettes. These cracks suggest weaker interparticle bonding, indicating suboptimal compaction. The presence of such cracks facilitates the escape of moisture, which may explain why briquettes made from larger particles recorded lower moisture content compared to those with smaller particles.

3.2 Ash content

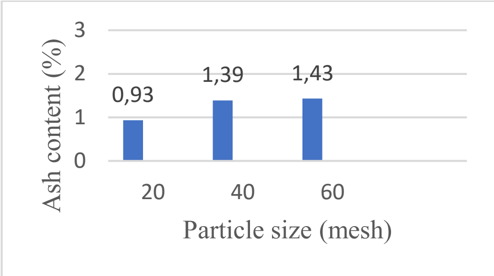

Figure 3. Ash content of three particle size variations.

Figure 3. the ash content decreases with increasing particle size. This trend aligns with the pattern observed in moisture content. The highest ash content was recorded in briquettes made from 60 mesh particles, reaching 1.43%. The results of the ash content tests indicate that all samples comply with the quality standard for briquettes (SNI 01-6235-2000), which specifies a maximum ash content of 8%. The ash content results are presented in decimal form with two decimal places to highlight the differences among the variations. If the values were rounded to whole numbers, they would all appear identical at 1%

The primary purpose of ash content testing in this study is to determine the proportion of non-combustible material within the briquettes. This finding is consistent with studies conducted by Kalsum et al. [19] and Aliah et al. [21], which reported that ash content tends to increase as particle size decreases. Smaller particles result in higher ash content, while larger particles yield lower ash content. This phenomenon occurs because briquettes made with finer particles have a smoother and denser surface, which may hinder complete combustion [21].

Ash is the residue left after combustion and typically consists of non-combustible minerals such as silica, calcium, magnesium, and potassium. These minerals are not always evenly distributed in raw biomass. When the biomass is ground into finer particles, the mineral content becomes more uniformly dispersed throughout the material. As a result, finer particles may retain more minerals than larger particles, leading to higher ash content in briquettes made from smaller-sized particles.

3.3 Calorific value

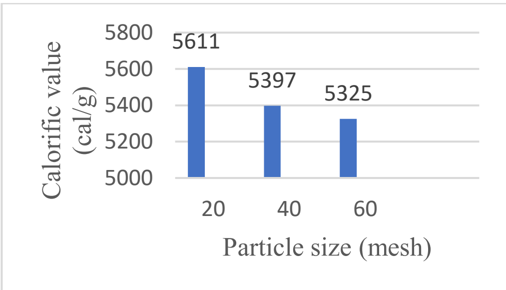

Figure 4. Calorific value of particle size variations.

Based on the data presented in Figure 4, the highest calorific value was obtained from briquettes made using 20-mesh particle size, which reached 5611 cal/g. The figure also shows a decreasing trend in calorific value as the particle size becomes finer. According to the test results, all briquettes met the calorific value requirements set by the SNI 01-6235-2000 standard, which stipulates a minimum of 5000 cal/g. Although this study utilized different raw materials, earlier studies conducted by Huda et al. [7], Ibrahim et al. [22], and Sabindo et al. [18] suggest that calorific value tends to decrease with increasing particle size, due to the higher moisture content associated with larger particles. However, the current findings present a contrasting trend, where briquettes made with finer particles demonstrated lower calorific values.

Several factors influence the calorific value of biomass briquettes. Firstly, moisture content plays a significant role; higher moisture levels typically reduce the calorific value. This discrepancy is attributed to the fact that the raw materials in this study were not carbonized, resulting in an increase in moisture content as the particle size decreased. Compared at the same particle size, the moisture content of non-carbonized biomass briquettes is higer than charcoal briquettes. When the moisture level is high, a portion of the combustion energy is used to evaporate the water content before combustion can fully proceed, thereby reducing the net energy output. Secondly, ash content also affects calorific value. High ash content indicates the presence of more non-combustible materials, which do not contribute to heat generation during combustion. Therefore, briquettes with lower ash content, such as those made with larger particle sizes, tend to produce higher calorific values. Following the preceding explanation, the values obtained from the test are summarized in the table 3. below:

Table 3. Summarize of the values coconut waste briquette quality

Parameters	SNI 01-6235-2000	20	40	60
Moisture content (%)	≤ 8	4.74	5.50	6.39
Ash content (%)	≤ 8	0.93	1.39	1.43
Calorific value (cal/g)	5000	5611	5397	5325

4. Conclusion

Based on the experimental results, coconut waste biomass briquettes were found to meet the quality standards outlined in SNI 01-6235-2000. Briquettes produced with larger particle sizes exhibit weaker bonding between particles, leading to the formation of cracks. The findings indicate that as the particle size decreases, both the moisture content and ash content tend to increase. In terms of calorific value, larger particle sizes yielded higher energy output. This is attributed to the lower moisture content present in larger particles compared to finer ones.

Acknowlwdments

The author would like to express gratitude to all parties who have provided support, both moral and material, which made the completion of this research possible. Special thanks are extended to the advisors and all staff of the Department of Mechanical Engineering at University of Mataram for their guidance and the facilities provided during the research process.

References

[1] Kambey, E., Tooy, D., Rumambi, D., 2023, "Uji Kualitas Briket Sabut Kelapa Sebagai Sumber Energi Bioamassa Alternatif," *Cocos*, 15: 1–8.
[2] Saiful, "Wawancara Pribadi," Narmada, Jan. 02, 2025.
[3] Mulyawati, S., Febrilia, B.R.A., 2023, "Analisis Pendapatan Dan Kelayakan Usaha Minyak Kelapa (Minyak Jeleng) Oleh Kwt Nine Seru Di Desa Lantan Batukliang Utara Kabupaten Lombok Tengah," *Jurnal Agribisnis Unisi*, 12: 92–100.
[4] Suhartoyo., Sriyanto., 2017, "*Efectivitas Briket Biomassa*," Prosiding SNATIF ke-4 Tahun 2017, Badan Penerbit Universitas Muria Kudus, 623–627.
[5] Chusniyah, D.A., Pratiwi, R., Benyamin., Suliestyah., Abidin, M.Z., Sugiarti, L., 2021, "Laporan Penelitian Unggulan Studi Pemanfaatan Limbah Ampas Kelapa Menjadi Briket Sebagai Sumber Energi Alternatif dalam Skala Rumah Tangga", *Laporan*, Universitas Trisakti.
[6] Yogi, A.S., 2023, "Pengaruh Variasi Ukuran Partikel pada Karakteristik Briket Berbahan Tempurung Kelapaterhadap Nilai Kalor," *Skripsi*, Universitas Islam Riau.
[7] Huda, A.A., Muliatiningsih, M., Karyanik, K., Fathoni, A., Hakim, A., 2023, "Effect of Adhesive Concentration and Particle Size on the Quality of Hazelnut Shell Briquettes with Glutinous Rice Adhesive," *Jurnal Agrotek Ummat*, 10: 304-313.
[8] Priyanto, A., Sudarno., 2018, "*Pembakaran pada Briket Kayu Sengon*," Seminar Nasional Sains dan Teknologi Terapan VI, 541–555.
[9] Das, B., 1988, "*Mekanika Tanah (Prinsip-prinsip Rekayasa Geoteknis)* 1st ed," Erlangga, Surabaya.
[10] Ariski, M.A., Mikhratunnisa., 2023, "Uji Karakteristik Briket Berbahan Baku Tempurung Kelapa dengan Perekat Tepung Kanji Berdasarkan Dimensi dan Berat," *JAPPRI: Jurnal Argoteknologi Pertanian & Publikasi Riset Ilmiah*, 5: 1–16.
[11] Syamsiro, M., Saptoadi, H., 2007, "*Pembakaran Briket Biomassa Cangkang Kakao : Pengaruh Temperatur Udara Preheat*," Seminar Nasional Teknologi 2007 (SNT 2007), 1–10.
[12] Chusniyah, D.A., Pratiwi, R., Benyamin, B., Suliestyah., 2022, "Uji Kualitas Briket Berbahan Arang Ampas Kelapa Berdasarkan Nilai Kadar Air," *Jurnal Abdi Masyarakat Indonesia (JAMIN)*, 7: 14–23.
[13] Sembiring, P., Lestari, L., 2022, "Formulasi Dan Uji Ektivitas Antibakteri Sediaan Lotion Ekstrak Etanol Daun Sawao Terhadap Bakteri Stapylococcuc Aureus Dan Escherchia Coli," *Jurnal Farmasi dan Herbal*, 4: 20–28.
[14] Kukuruzovic, J., Martin, A., Kricka, T., Martin, B., Brandic, I., Antonovic, A., 2023, "The Effects of Demineralization on Reducing Ash Content in Corn and Soy Biomass with the Goal of Increasing Biofuel Quality," *Energies (Basel)*, 16: 967.
[15] Iskandar, N., Nugroho, S., Feliyana, M.F., 2019. "Uji Kualitas Produk Briket Arang Tempurung Kelapa Berdasarkan Standar Mutu SNI," *Momentum*, 15: 103–108.
[16] Elfiano, E., Subekti, P., Sadil, A., 2014, "Analisa Proksimat dan Nilai Kalor pada Briket Bioarang Limbah Ampas Tebu dan Arang Kayu," *Jurnal APTEK*, 6: 57–64.
[17] Aljarwi, M.A., Pangga, D., Ahzan, S., 2020, "Uji Laju Pembakaran dan Nilai Kalor Briket Wafer Sekam Padi dengan Variasi Tekanan," *Jurnal Hasil Kajian, Inovasi, dan Aplikasi Pendidikan Fisika*, 6: 200–206.

[18] Sabindo, L.O., Kadir., Hasbi, M., 2020, "Pengaruh Variasi Ukuran Mesh Terhadap Nilai Kalor Briket Arang Tempurung Kelapa," *ETHALPY: Jurnal Ilmiah Mahasiswa Teknik Mesin*, 5: 01–08.
[19] Kalsum, U., Atikah., Ibrahim, A., 2023, "Pengaruh Ukuran Partikel dan Komposisi terhadap Kualitas Briket dari Campuran Batubara dan Cangkang Sawit," *Jurnal Teknik Patra Akademik*, 14: 136–146.
[20] Abineno, J.C., Dethan, J.J.S., Bunga, F.J.H., Bunga, E.Z.H., 2025, "Characterization and performance analysis of Kesambi branch biomass briquettes: A study on particle size effects," *Journal of Ecological Engineering*, 26: 213–222.
[21] Aliah, H., Winarti, I., Iman, R.N., Setiawan, A., Safarina, R., Sawitri, A., 2023, "Influence of Sieve Size on Calorific Value and Proximate Properties of Bio-Briquette Composites," *Journal of Ecological Engineering*, 24: 25–34.
[22] Ibrahim, J.U., Usman, D.D., Jauro, Y.U., Mazza, M., Jahun, B.G., 2025, "Effects of Particle Sizes and on Combustion Characteristics of Briquettes Produced from Sugar Cane Biomass," *UNIABUJA Journal of Engineering and Technology*, 2: 41–47.