Characterization Briquettes Coffee Wood Residues and Corncobs as An Alternative Energy Source

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Abstract. The present study conducted a comprehensive evaluation of the feasibility of utilizing Coffee Wood Residues and Corncobs as raw materials for the production of biomass briquettes. In this study, we examined five different compositional combinations of varying proportions of coffee wood and corncob. This notable that the briquette consisted of Coffee Wood Residues exhibited the most gradual combustion rate, at 2.19g/min. The bulk densities of the briquettes that were created exhibited a range of values, specifically falling between 0.72 and 0.90g/cm^3. All types of briquettes exhibiting moisture levels ranging from 4.9% to 5.21%. The fixed carbon content, which varied between 51.83% and 53.57%. The measurements of ash content exhibited variations ranging from 7.37% to 9.92%. These findings not only emphasized the potential of utilizing Coffee Wood Residues and Corncobs as biomass fuel, but also indicated the possibility of improving the quality of briquettes by integrating biomass with higher carbon content.

Keywords: Biomass briquettes, burning rate, bulk density, moisture content, fixed carbon

1 Introduction

The global energy sector is currently at a critical turning point. Due to the escalating expenses and diminishing sources of fossil fuels, countries are driven to reevaluate their energy portfolios as reliance on them becomes more and more unsustainable [1]. Simultaneously, the ecological consequences of using these fossil fuels, including carbon emissions and the destruction of habitats, require a transition towards more environmentally friendly energy alternatives [2]. This transition is particularly crucial in nations such as Indonesia, where ample natural resources may be utilized as alternative sources of renewable energy [3].

Another urgent issue in the 21st century is the increasing energy requirements associated with human activities. Conventional fossil fuels, particularly petroleum, have been the primary source of energy for several decades. Their combustion not only results in the release of greenhouse gases but also contributes to the contamination of air and the damage to the

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ecosystem [4]. Furthermore, the limited availability of these resources gives rise to apprehensions regarding the long-term energy security and stability of economies that rely mainly on them. Given the increasing difficulties we face, it is imperative that we swiftly shift towards cleaner and renewable energy sources in order to meet global energy needs in a sustainable manner.

Renewable energy sources, also known as alternative energies, are obtained from natural resources such as the sun, wind, rivers, geothermal heat, and biomass [5]. Indonesia, with its varied geographical and climatic conditions, possesses a wide range of these renewable resources. Specifically, biomass energy has received considerable interest in recent years due to its dual advantages: converting waste into energy and decreasing reliance on non-renewable fossil fuels. Biomass consists of intricate organic compounds, mostly cellulose, lignin, and a mixture of proteins, lipids, and minerals. It can be obtained from various organic sources, including coffee wood, and corncobs.

Coconut shells have conventionally served as a source of fuel in Indonesia among the several options available for biomass [6]. Recently, improvements have facilitated the transformation of these shells into charcoal briquettes. These briquettes, created by applying appropriate pressure conditions to organic waste, have emerged as a preferable alternative to traditional fossil fuels. In addition to emitting negligible amounts of carbon monoxide (CO), their combustion also presents less health hazards. Their condensed structure enables convenient mobility and retention, hence increasing their appeal as a substitute energy reservoir. Nevertheless, apart from the conventionally employed coconut shells, certain agricultural byproducts such as coffee wood wastes and corncobs are still not fully utilized [7].

Although coffee wood possesses comparable quality to other types of wood, its relatively tiny size has led to its primary utilization as fuel. However, this undervalues the potential it provides. Additionally, there are undiscovered biomass sources such as maize stalks, traditionally utilized as animal feed, and corn straw, which is dried in the sun to provide livestock feed.

Initial investigation into the potential of these remnants has demonstrated encouraging outcomes [8]. Studies have shown that when organic waste is mixed with coconut shells and used as fuel for burning charcoal briquettes, the resulting ash content and concentration of volatile matter can vary. This suggests that the calorific value of the briquettes can be altered depending on the specific combination of materials used.

In addition, regional efforts in areas such as Karo, Sumatera Utara as seen in the **Figure 1**, have begun to investigate the energy capacity of alternative wood byproducts, such as citrus wood. The utilization of techniques such as pyrolysis has had a positive impact on the environment. Initial experiments involving the combination of coconut shell charcoal and citrus wood charcoal have revealed noteworthy implications for enhancing combustion efficiency.

This study intends to further investigate the properties of briquettes made from coffee wood wastes and corncobs, building upon their original success and potential. By conducting a thorough investigation, our objective is to determine the most advantageous combination of these waste materials to achieve the highest possible energy content, in accordance with the Indonesian National Standards (SNI). This research aims to contribute to Indonesia's pursuit of a sustainable energy future by harnessing the untapped energy potential of these ignored wastes.

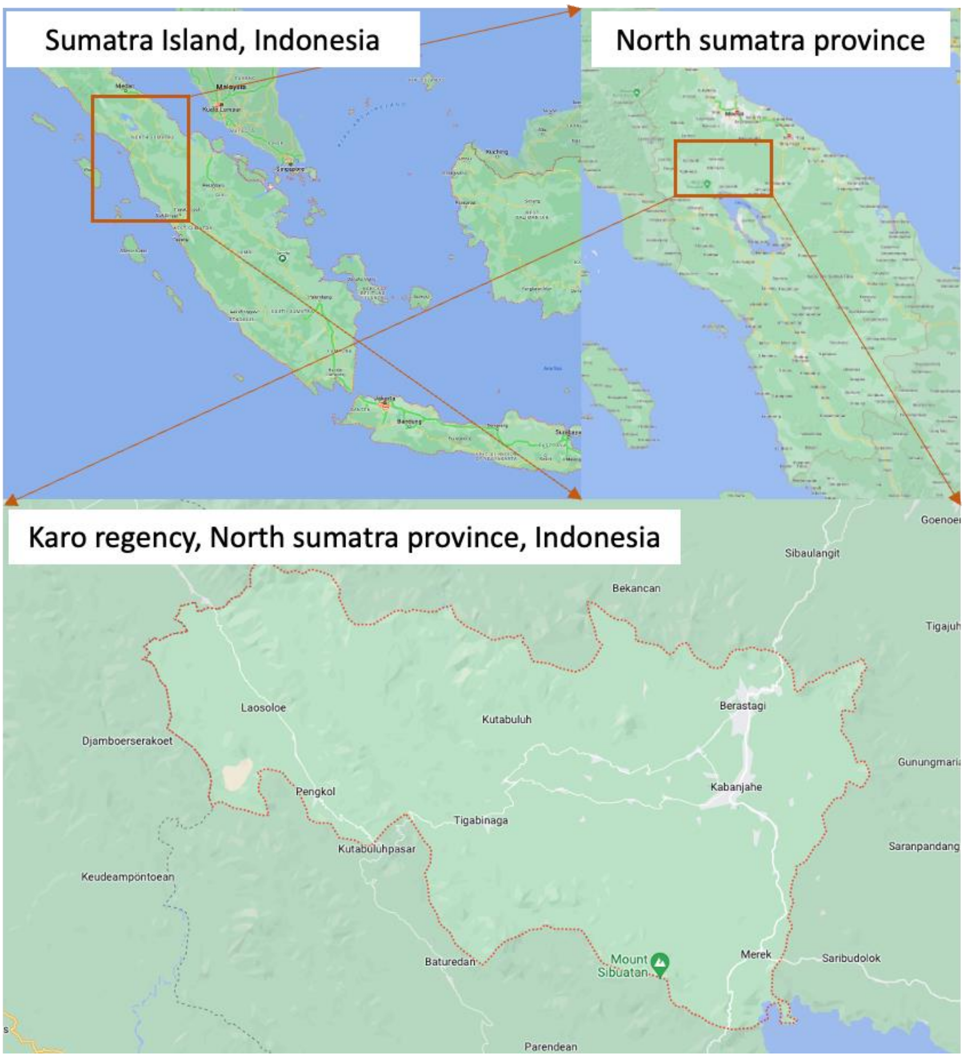

Fig. 1. Location of the study area in Karo regency, North sumatra province, Indonesia

2 Previous study related to briquettes in Indonesia

The extensive research has been conducted on briquettes in Indonesia, and has lasted for more than ten years, highlights the country's dedication to utilizing renewable energy sources. Commencing with the most ancient, by [9] conducted a comparative evaluation of coconut shell briquettes in relation to coal, straw, and sugarcane pulp. The high calorific value of coconut shell briquette, despite its low moisture and volatile matter concentration, makes it an appealing alternative fuel for the culinary industry. Nevertheless, while comparing it to sugarcane pulp, straw, and coal, it became clear that blending was necessary because of its relatively lower fixed carbon content, with the goal of reducing pollution. In [10], the study investigated the combined effects of coconut shell charcoal and organic waste. The cylindrical briquettes exhibited notable characteristics, such as low moisture content and exceptional compressive strength. Subsequently, [11] explored the combination of coffee husks and sawdust. The briquettes achieved ideal calorific values and notable compressive strength, among other measures, when the concentration of coffee husk reached 30%.

In 2015, [12] conducted a study on the factors that determine the quality of coffee pulp-based briquettes, utilizing PT Santos Jaya Abadi as a specific example. The study emphasized the crucial significance of density, mix ratios, and furnace type in determining the quality of briquettes. By [13] conducted an analysis on briquettes made from a combination of organic waste charcoal and coconut shell charcoal. The ash content and volatile matter concentrations exhibited notable changes, depending on the mixing ratios. An unusual finding was made regarding the low ash concentration while combining 200 g of organic waste charcoal with 800 g of coconut shell charcoal. By [14] on briquettes made from coffee husks and coconut shells. While the moisture and ash content indicators did not meet international and SNI criteria, the calorific value metrics exceeded SNI norms. [15] investigated the characteristics of coconut shell briquettes in accordance with SNI standards. Although the carbon content deviated from the norm, the majority of indicators, such as moisture, ash, calorific value, and volatile compounds, met the required norms.

By [16] study focused on briquettes made from sugarcane pulp and rice husk. The variation with a mass ratio of 3:2 of sugarcane pulp to rice husk has proven to be preferable since it meets the strict standards for moisture and calorific content. By [17] highlighted the significant impact of mixing orange wood charcoal with coconut shell charcoal on the length of combustion. Out all the versions that were evaluated, the blend that contained coconut shell had the longest burn period, which emphasized its superiority. These studies reflected Indonesia's changing story of using agricultural by-products to produce briquettes. This combines the need for energy with ecological responsibility.

3 Material and method

3.1 Briquette preparation

Raw material. Approximately 40-50 kg of coffee wood and corn cobs were obtained from community agricultural waste in Karo Regency, North Sumatra, Indonesia. The detail of raw materials for this study can be seen in **Figure 2** below. There were five different mixtures tested in this study which have different ratio between coffee wood and corn cob. The mixtures were composed of different ratios of coffee wood and corncob. Mixture A contained 100% coffee wood, mixture B contained 70% coffee wood and 30% corncob, mixture C contained 50% coffee wood and 50% corncob, mixture D contained 30% coffee wood and 70% corncob, and combination E contained 100% corncob.

Preparation Process. The precise manufacturing of briquettes derived from coffee wood wastes and corncobs proceeded with a required pre-treatment phase. The coffee wood and corncobs residues received careful sifting and size reduction. Once the materials were made uniform in size and quality, they were laid out to dry in the sun, being exposed to the surrounding temperature of 32–34°C for a period of 4 days.

After the drying phase, the raw materials were introduced into the carbonization process. The participants underwent the traditional drum technique for carbonization, a required and gradual pyrolysis procedure, carried out at an ideal temperature of 400°C. Following the modified cylindrical carbonized design described in previous studies [18], a low-oxygen environment was created. Upon the ignition of carbonization, the lid of the container was deliberately left partially open for the first 15 minutes, allowing the volatile vapors to be safely discharged. Afterwards, the lid was tightly closed to prevent any air from leaking. The carbonization durations were selected based on the material type. Coffee wood residues were carbonized for a fixed length of 2 hours, while corncobs required approximately 3 hours. The resulting totally carbonized material was then introduced into the crushing stage. In order to produce an optimal mixture consistency and compactness, the carbonized output was carefully crushed until it reached a particle size below 300 microns (50 mesh). Subsequently, the important next stage was the process of blending, in which the crushed carbonized substance was combined with a binding agent. The product was subjected to a rigorous mixing process for 20 minutes using a motor-driven mixer, assuring uniformity. The recommended ratio, as suggested by [19], was adhered to: 10% of the binder-water mixture and 90% of the raw components. Due to its impressive physicochemical properties, widespread availability, and cost-effectiveness, tapioca/cassava starch was chosen as the preferred binder [20].

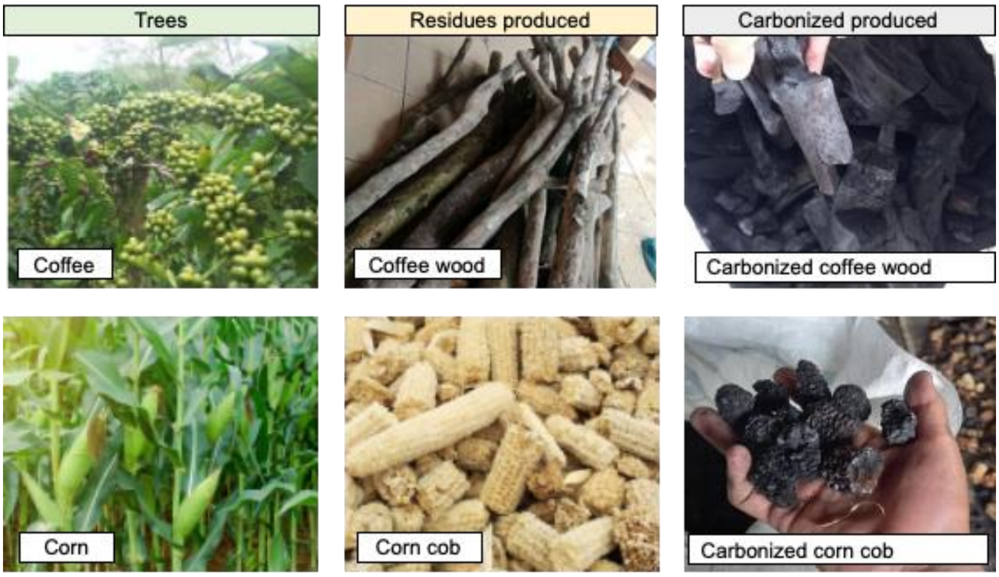

Fig. 2. Agriculture residues used for the briquette (coffee and corn) in Karo Regency, North Sumatra Indonesia

After the mixing process, a press machine operating at 150 psi (kg/cm) is used to produced charcoal briquettes, creating a cylinder that measures 3.5 cm in diameter and 6 cm in height. After being shaped, the briquettes were set on a tray and allowed to dry out in the sun for three days at the surrounding temperature of 32-34 °C, in order to achieve a dried state. Extracting any remaining moisture was a necessary step in order to make the briquettes perfect for burning. The process of creating briquettes was conducted at the Briquette House located at Jl. Kanal

Raya, Marindal Satu, Kec. Medan Amplas, Deli Serdang Regency. **Figure 3** showed the coffee wood residue and corncob briquetting process in this study adopted from [21].

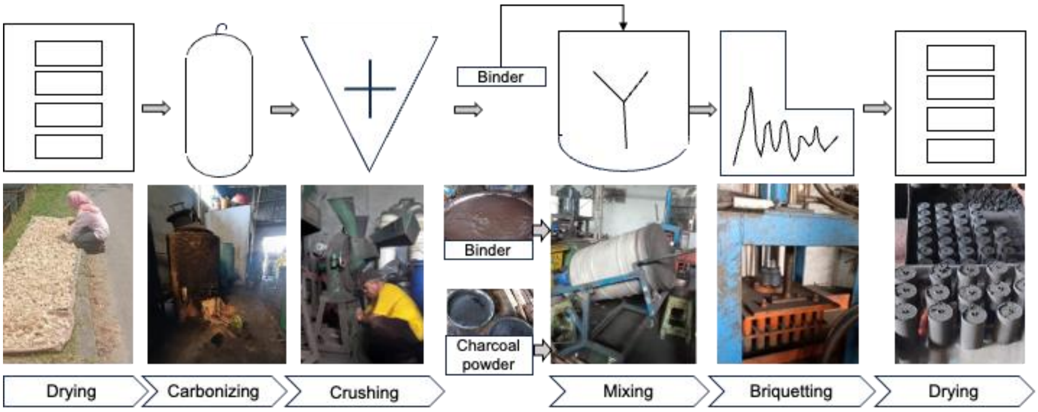

Fig. 3. Briquetting process of coffee wood and corn cob conducted at the Briquette House, North Sumatra, Indonesia

3.2 Determination of physical and combustion characteristics

A comprehensive assessment of the physical and combustion parameters of briquettes is crucial to guarantee their dependability and performance as an alternative fuel source. In the current study, the first step analysis was conducted in the laboratory of PPKS (Palm Oil Research Center), to determine the water content, ash content, and carbon content. The tests evaluated the essential elements of the briquettes, which can greatly be affected to the combustion characteristics.

Following the laboratory testing, the combustion rate test is performed. The aim is to determine the duration of the flame produced by the briquette when used as a fuel source. In order to guarantee the accuracy of this evaluation, the mass of the charred briquette is measured. This combustion test is performed three times, ensuring data consistency and accuracy. The combustion rate is calculated by dividing the mass of the burnt briquette by the duration of burning. The precise quantity of briquette consumed during the process is determined by subtracting the residual briquette mass from its initial mass. After that, the density is done to measure the mass density of the briquette charcoal. It is important as the compactness of a briquette is closely correlated with its combustion efficiency. Similar to the preceding test, this experiment is also conducted three times in order to assure the accuracy. The mass density is calculated by dividing the briquette's mass by its volume.

Finally, a practical boiling test is conducted to compare the efficiency of the briquettes with that of traditional fuels. This experiment involves measuring and comparing the duration required to boil 250 ml of water using five briquettes and comparing it with the duration required using LPG gas. In order to guarantee the ability to replicate and achieve accuracy, this boiling experiment is performed three times.

4 Result and discussion

The Table 1 and **Figure 4** showed the characteristic of coffee wood and corn cob studied in North Sumatra provinces including combustion rate, bulk density, moisture content, ash content, fixed carbon content, and time used to boil water compared to LPG. The detail of each content is discussed in the following chapter.

Table 1. Result of bulk density and combustion characteristics for coffee wood and corn cob in North Sumatra Province, Indonesia

Variation	CW (kg)	CC (kg)	CR (g/min)	BD (g/cm^3)	MC (%)	AC (%)	FC (%)	Water boiling		
								This study		LPG (min)
								n	time (min)	
A	10	0	2.17	0.53	5.18	9.92	51.83	5	38.67	3
B	7	3	2.56	0.50	5.11	8.76	52.12	7	51.33	3
C	5	5	2.94	0.48	4.94	7.85	53.08	7	77.67	3
D	3	7	3.21	0.42	4.91	7.52	53.37	7	91.33	3
E	0	10	3.72	0.41	4.90	7.37	53.58	9	111.67	3

CW: Coffee wood; CC: Corn cob; CR: Combustion rate; BD: Bulk density; MC: Moisture content; AC: Ash content; FC: Fixed carbon; LPG: Liquified petroleum gas used commonly by the citizens in the study area

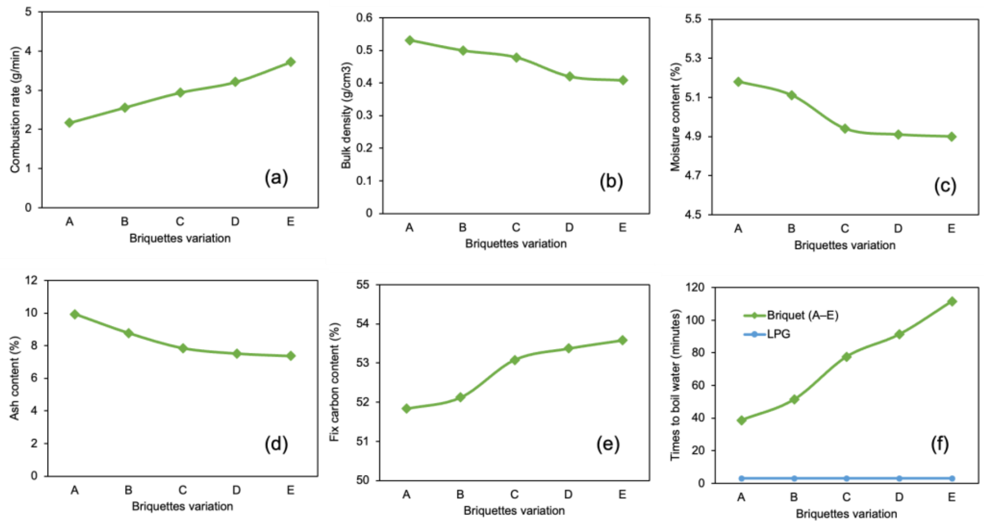

Fig. 4. Result of (a) combustion rate (b) bulk density (c) moisture content (d) ash content (e) fixed carbon content (f) times to boil water for coffee wood and corn cob in North Sumatra Province, Indonesia

4.1 Combustion rate

The combustion rate refers to the speed at which a fuel is burned up during the process of combustion. The rate of combustion is a crucial determinant of the efficiency of a combustion system. An increased combustion rate will lead to a greater amount of heat generated per unit of time. According to the data in Table 1, Variation A, which is made entirely of coffee wood, has a combustion rate of 2.17 g/min. Consequently, a total of 2.17 grammes of briquettes are combusted per minute. Variation B, including 70% coffee wood and 30% corncob, Variation C, comprising 50% coffee wood and 50% corncob, and Variation D, comprising 30% coffee wood and 70% corncob, exhibited combustion rates of 2.56 g/minute, 2.94 g/minute, and 3.21 g/min correspondingly. The combustion rate of Variation E, including solely of corncob, was 3.72 g/min, indicating that 3.72 grammes of corncob briquettes were consumed per minute. The study findings indicate that corn cob briquettes have the highest combustion rate value. The reason for this might be due to corn cobs possess a fiber content of 28.89%, whilst coffee wood has a fiber level of 17.2%. According to [18] the combustible nature of fibers causes briquettes with a higher fiber content to burn more quickly.

The combustion rate denotes the velocity at which the briquette undergoes combustion. According to [19], a higher combustion rate resulted in a faster consumption of the briquette. The research findings indicate that coffee wood briquettes exhibited a slower burnout rate in comparison to corn cob briquettes and mixed briquettes, while demonstrating a higher combustion rate [22].

4.2 Bulk density

When the densities of these briquettes are compared, it can be seen that Variation A, which is made entirely of coffee wood, has the highest density at 0.53 g/cm3, according to the results shown in Table 1. Then Variation B, which has a density of 0.50 g/cm3 and is made up of 70% coffee wood and 30% corncob. Densities of 0.48 g/cm3 and 0.42 g/cm3, respectively, were found in Variations C, which contained 50% coffee wood and 50% corncob, and D, which contained 30% coffee wood and 70% corncob. At 0.41 g/cm3, Variation E, which was composed entirely of corncob, had the lowest density. In general, the density of charcoal made from biomass derived from agricultural waste ranges from 0.41 to 0.53 g/cm3. The bulk density findings for corncob and coffee wood in all of their variations fall within this recommended range. Longer burning times are associated with higher density briquettes and shorter burning times with lower density briquettes. Due to a lack of combustion components, the combustion process takes longer as the air spaces between briquette particles get smaller as density rises [23].

4.3 Moisture content

Based on these findings, it is evident that charcoal briquettes produced from Variation A, which only utilized coffee wood, had a higher water content (5.18%) compared to the other samples. The presence of excess fat and collagen substances in the skin may be the cause. Variation B is composed of 70% coffee wood and 30% corncob, Variation C is composed of 50% coffee wood and 50% corncob, and Variation D is composed of 30% coffee wood and 70% corncob. These variations had moisture content of 5.11%, 4.94%, and 4.91%, respectively. Variation E, which exclusively consisted of corncob, had a moisture content of 4.90%. Interestingly, all varieties of briquettes exhibited adherence to the SNI 1683:2021 standard, which aligns with the literature's suggestion of maintaining a moisture level of ≤8% for high-quality briquettes derived from agricultural waste. These values indicate the favorable characteristics of the briquette in terms of its ability to be stored and its potential to burn. The findings are supported by [24], [25] who said that a decrease in moisture content corresponds to an increase in calorific value. Briquette moisture content refers to the proportion of water within the briquettes, measured as a percentage of the briquettes' total weight. The moisture level of briquettes is a crucial determinant of their quality and function.

4.4 Ash content

Based on the data presented in Table 1, a comparison of the ash level of the briquettes reveals that Variation A, which comprised entirely of coffee wood, had the highest ash content at 9.92%. Variation B, which consisted of 70% coffee wood and 30% corncob, had an ash value of 8.76%. Variation C comprised a composition of 50% coffee wood and 50% corncob, whereas variation D comprised a composition of 30% coffee wood and 70% corncob. The ash concentration of variation C was measured at 7.85%, while variation D had an ash value of 7.52%. Variation E consisted 100% of corncob had the lowest ash content 7,37%. Based on the results, it can be observed that the ash content values of all variations comply with the SNI 1683:2021 standard, which is ≤4%. The ash content of briquettes refers to the quantity of inorganic residue that remains once the briquettes have undergone combustion. The percentage is calculated based on the total weight of the briquettes. The ash concentration of briquettes plays a crucial role in defining their quality and function. Briquettes that have a high ash content will result in a greater amount of ash being generated during combustion. Ash residue has the potential to obstruct the flow of air in chimneys and fireplaces, as well as hinder the effectiveness of combustion systems. Briquettes possessing a diminished ash content will yield a less amount of residue upon combustion, hence enhancing their efficiency [26].

4.5 Fixed carbon

The carbon content value is determined by the presence of carbon within the material. The carbon content refers to the quantity of carbon that remains in the briquette once the volatile components, ash content, and moisture have been eliminated. Bound carbon content refers to the overall quantity of carbon present in the briquette. The presence of bound carbon in briquettes directly affects their quality. Specifically, a higher bound carbon content leads to a higher quality briquette. This is because the combustion reaction between carbon and oxygen results in a higher calorific value for the briquette [14]. According to the provided graph, the average carbon content measurement for coffee wood briquettes is 51.83%, for maize cob briquettes it is 53.58%, and for mixed briquettes it is 53.08%. Based on the aforementioned results, it is evident that these values have not yet reached the minimum national quality level for briquettes, which is equal to or more than 79.

4.6 Time to boil water compared to LPG

In assessing the practical effectiveness of various briquette types compared to LPG, a key factor to consider is the duration required to boil a set amount of water (250 ml). LPG, a common fuel used by the citizens of Karo Regency, consistently heated water to its boiling point in a rapid 3 minutes, demonstrating its exceptional energy efficiency. The coffee wood briquette, specifically labeled as variation A, had a notable disparity in efficiency when compared to LPG, since it required 38.67 minutes. Despite the fact that variation A is composed entirely of coffee wood, its extended boiling time suggests certain constraints on its energy production. Introducing corn cob to the mix, as seen in variation B, which has 70% coffee wood and 30% corn cob, further extended the boiling time to 51.33 minutes. The gradual rise implies that the composition of the maize cob may be causing a decline in efficiency. The trend becomes more prominent in variation C, which is a mixture of coffee wood and corn cob in equal proportions. Variation C recorded a boiling duration of 77.67 minutes. Variation D, which consists mainly of corn cob (70%), had a recorded time of 91.33 minutes, following the established trend. Ultimately, variation E, which consists of pure corn cob briquettes, had the longest boiling period of 111.67 minutes. This confirms the fact that higher corn cob content leads to longer boiling times. The insights obtained from the data are crucial. Their emphasis is the necessity of improving the composition of the briquette in order to achieve a harmonious combination of sustainable production and functional efficiency. Although utilizing agricultural waste such as coffee wood and corn cob is praiseworthy from an environmental standpoint, there is a noticeable compromise in terms of boiling efficiency, particularly when compared to conventional fuels like LPG. Further investigation could focus on optimizing these briquettes to increase their energy efficiency while maintaining their environmentally favorable characteristics.

5 Conclusion

The global transition towards sustainable energy solutions has stimulated the investigation of organic waste as a reliable biomass fuel source. The goal of our study is to utilize Coffee Wood Residues and Corncobs as raw materials for biomass briquettes. Our study examined five different compositional mixes and highlighted the flexibility of blending these organic elements in varied ratios to achieve different combustion and density characteristics. Notably, briquettes made solely from Coffee Wood residues exhibited a significantly higher combustion rate. With a measured value of 2.17 g/min, it demonstrated its potential as a highly efficient fuel source. Moreover, the measured bulk densities of the resulting briquettes fell within the range of 0.41 to 0.53 g/cm3, indicating the consistent quality of these biomass resources. It is noteworthy that all varieties of briquettes complied with the specifications specified in SNI 1683:2021, notably in terms of moisture levels. However, a slight deviation in the fixed carbon content from the expected standards suggested an opportunity for optimization. This is further supported by the observed range of ash content, which varies from 7.37% to 9.92%. Our research highlights the considerable potential of coffee wood residues and corncobs as biomass fuel sources. However, it also suggests the necessity for additional improvements, possibly by including biomass materials with greater carbon content. This work represented a significant advancement in the pursuit of sustainable, efficient, and economically viable energy sources within the biomass sector.

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