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Influence of Coal Dust Waste Addition on the Calorific Value of Biomass Briquettes

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ABSTRACT: *Biomass briquettes represent a renewable energy source with considerable potential to substitute fossil fuels. In this study investigates the influence of coal dust incorporation on the calorific value of biomass briquettes formulated from corn stalks and sawdust. Experimental briquette samples were prepared with coal dust proportions of 0%, 10%, and 20%, and their calorific values were determined using a Bomb Calorimeter. The findings indicate that the addition of coal dust enhances the calorific value of the briquettes, with the maximum value of 4,190 kcal/kg obtained at a composition of 20% coal dust, 40% corn stalks, and 40% sawdust. Furthermore, moisture content and volatile matter were observed to play a significant role in combustion efficiency. Overall, the results underscore the potential of locally available biomass, when combined with coal dust, to serve as an efficient and environmentally sustainable alternative fuel source.*
Keywords: *biomass briquettes, coal dust, corn stalks, sawdust, Bomb Calorimeter, calorific value*

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I. INTRODUCTION

Biomass is an alternative energy source with significant potential in Indonesia. Its quantity is quite abundant, but its use has not been optimally optimized. Indonesia, as an agricultural country, produces a large amount of agricultural waste, which is biomass (Balai, 2014). This agricultural waste, which is biomass, can be used as an abundant alternative energy source. One such agricultural waste is corn stalks and sawdust. According to Statistics Indonesia (BPS) data, in 2023, rice production in Indonesia reached 15.2 million tons. This large production will also generate a large amount of corn stalk waste. This waste can be processed into a synthetic solid fuel with wider use as an alternative fuel, called briquettes.

In Indonesia, the use of agricultural waste for renewable energy has significant potential. With abundant corn production, corn stalks can be widely utilized to meet the energy needs of rural communities (Ahmad et.al, 2019; Handayani et.al, 2020). Technological development for a more effective production process is also expected to improve the quality and productivity of corn stalk briquettes, thereby meeting the need for environmentally friendly alternative energy (Wahyuni et al., 2021). The calorific value of sawdust briquettes ranges from 3900 to 4500 kcal/kg, with teak wood producing the highest calorific value. The carbonization process of sawdust increases the calorific value and reduces smoke emissions during combustion. This makes sawdust briquettes an efficient and environmentally friendly alternative fuel (Rahmawati et al., 2021). Biomass briquettes are an environmentally friendly and sustainable alternative fuel, made from agricultural waste, sawdust, and other organic materials. In recent years, attention to the use of renewable energy has increased along with the need to reduce dependence on fossil fuels and reduce greenhouse gas emissions. Biomass briquettes offer a solution to utilize waste that is usually thrown away, while providing an efficient energy source (Rahmawati et al., 2021).

Coal dust (bottom ash) is a solid waste produced from coal combustion in steam power plants. This waste is in the form of coarse particles that settle at the bottom of the boiler, in contrast to fly ash, which is a fine particle transported with exhaust gases. Bottom ash is generally porous, insoluble in water, and blackish in color. The use of bottom ash as an alternative raw material in the construction materials industry, such as cement, concrete, and lightweight aggregates, has been widely studied (Sujarwo et.al, 2028; Yuliani et.al, 2017. Furthermore, bottom ash also has potential as an energy source due to its still quite significant calorific value. The physical and chemical characteristics of bottom ash depend on the type of coal used and the combustion technology applied. In general, bottom ash contains silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO), and unburned carbon. This carbon content contributes to the calorific value of the bottom ash residue. (Fitriana et.al, 2018; Yuniarti et.al, 2020)

Coal is a very complex mixture of organic chemicals containing carbon, oxygen, and hydrogen in a carbon chain (Arif, 2014). Based on the latest data from the Geological Agency of the Ministry of Energy and Mineral Resources (ESDM), Indonesia's coal reserves reached 26.2 billion tons and there are still recorded coal resources of 124.6 billion tons. According to the American Society for Testing and Materials (ASTM) based on its ranking, coal consists of anthracite, bituminous, sub-bituminous and lignite ranks. Anthracite and bituminous coal are included in the high-rank coal group, while sub-bituminous coal and lignite are included in the low-rank coal group.

According to Kurniawan et.al (2019), the quality of Indonesian coal is generally dominated by low-rank coal (lignite), which accounts for approximately 70% of total resources. However, it has not been widely exploited due to challenges in transportation and utilization. This low-rank coal has a relatively high total water content, resulting in a low calorific value. Therefore, special technology is needed to utilize this low-rank coal so that it can compete with high-rank coal, whose reserves are beginning to dwindle. Furthermore, in addition to its low calorific value, low-rank coal is also brittle. One use for this brittle coal is to make briquettes.

Adding coal dust to biomass as a raw material for briquettes can increase the energy efficiency of the resulting product. According to research by Santoso et al. (2019), mixing coal dust and biomass at a certain ratio can produce briquettes with a higher calorific value. Furthermore, the study found that this blended briquette has more stable combustion characteristics, potentially reducing production costs compared to using pure biomass.

Corn stalks are an abundant agricultural waste with high potential as an alternative fuel. Corn stalk waste, typically left to rot or burned directly, can be converted into biomass briquettes (Donal, 2004). Corn stalk briquettes have sufficient calorific value to meet various energy needs, particularly in rural areas with limited access to fossil fuels. Utilizing corn stalks as briquettes helps reduce pollution and provides added economic value for farmers (Wahyuni et al., 2021; Wahyudi et.al, 2022).

However, the ratio of coal dust to biomass requires careful consideration. If the amount of coal dust is too high, it will result in increased emissions of harmful gases, such as carbon monoxide and sulfur dioxide (Kurniawan et al., 2018; Hakim &Nurhasanah, 2020). Therefore, this mixture ratio needs to be adjusted to achieve optimal energy efficiency while maintaining low emissions. Sawdust briquettes offer many benefits, including the use of renewable energy, pollution reduction, and the high economic value of typically unused wood waste Kusuma et.a;;, 20. These briquettes also reduce dependence on fossil fuels, especially in rural areas or small-scale industries. The main challenges in utilizing sawdust briquettes are the carbonization process, which requires special technology and additional costs, as well as limited access to adhesives in some areas (Nugroho and Susanto, 2022; Kusuma et.all, 2019).

Therefore, it is necessary to develop briquette production as an effort to utilize corn stalk waste. Furthermore, there are several advantages to processing fuel into briquettes. First, the method of making briquettes is relatively easy, inexpensive, and does not take a long time. Second, the heat generated from burning briquettes is comparable to fossil fuels. Furthermore, briquettes have good ember distribution capabilities, are not easily extinguished, and do not require additional energy for stable combustion. To achieve this, research is being conducted to produce high-quality, environmentally friendly briquettes with high economic value. The utilization of corn stalks and sawdust into briquettes is expected to reduce environmental pollution, provide an alternative renewable fuel source, and benefit the community.

II. MATERIAL AND METHODS

This stage aims to ensure that all necessary equipment and materials are available, in good condition, and ready for use according to the planned procedures. Good preparation can improve accuracy, efficiency, and safety in the testing process. The purpose of this grinding is to refine and standardize the size of the raw material, thus facilitating subsequent processes, such as compaction in briquette making. Finely ground material also has a larger surface area, which is important for improving the properties of natural adhesives or the addition of external adhesives used in the briquette forming process.

Figure 1. Drying of biomass briquettes at 0%, 10% and 20%

Data collection in biomass sample testing is an important step in obtaining quantitative and qualitative information about the biomass being tested. Biomass includes organic material derived from living organisms, such as plants, animals, and microorganisms. This testing is often conducted to evaluate energy potential, physicochemical properties, calorific value, or other aspects relevant to the research objectives. In this test, the finished sample will be sent to the testing institution PT Surveyor Carbon Consulting Indonesia (SCCI) by PT PLN UPK. TAMBORA. The sample is tested using a bomb calorimeter.

III. RESULTS

After testing on biomass briquettes, test data was obtained from biomass briquettes with variations in coal dust composition of 0%, 10% and 20%.

Table 1 Calorific Value

Composition	Composition (% w)			Calorific value (kcal/kg)
	Coal dust	Corn stalks	Sawdust	
A	0	50	50	3604
B	10	45	45	4167
C	20	40	40	4190

The calorific value test was conducted at PT Surveyor Carbon Consulting Indonesia using a Bomb Calorimeter. This calorific value determination was to determine the intensity of the combustion heat value that the briquettes could produce. The calorific value is a quality parameter with variations in the mixture of coal dust, corn stalks and sawdust of 0%:50%:50%, 10%:45%:45% and 20%:40%:40%. This test was conducted with the ASTM D5865/D5865M-19 testing standard.

Table 1 shows the effect of coal dust addition on the calorific value of a biomass mixture consisting of corn stalks and sawdust. At the initial composition without coal dust (0%), a mixture of corn stalks and sawdust at 50% each produced a calorific value of 3604 kcal/kg. When coal dust was added at 10%, the proportion of corn stalks and sawdust was reduced to 45% each, and the calorific value increased significantly to 4167 kcal/kg. The addition of coal dust up to 20% with 40% each of corn stalks and sawdust produced the highest calorific value of 4190 kcal/kg. This indicates that the gradual addition of coal dust can increase the calorific value of the biomass mixture.

Table 2 Water content

Composition	Composition (% w)			Water contents (%)
	Coal dust	Corn stalks	Sawdust	
A	0	50	50	12,73
B	10	45	45	11,84
C	20	40	40	15,69

This test was conducted using the ASTM D3302/D3302M-19 standard testing method. The calorific value test was conducted at PT Surveyor Carbon Consulting Indonesia using several methods, namely air-received (AR), air-dried basis (ADB), dry basis (DB), and dry ahs free (DAF) using the ASTM D5865 testing standard. The value to be analyzed is the calorific value using the AR method because it is the most commonly used method and the only one that has a water content value on the laboratory results sheet issued by PT Surveyor Carbon Consulting Indonesia.

Table 2 illustrates the effect of varying coal dust composition on the moisture content in a biomass mixture consisting of corn stalks and sawdust. At the initial composition without coal dust (0%), with 50% corn stalks and sawdust each, the moisture content was recorded at 12.73%. When coal dust was added at 10%, the proportion of corn stalks and sawdust was reduced to 45%, and the moisture content decreased to 11.84%. However, when the coal dust content was increased to 20%, with 40% corn stalks and sawdust each, the moisture content actually increased significantly to 15.69%. This indicates that the addition of coal dust can affect the moisture content of the mixture, with a non-linear effect.

The determination of this calorific value is to determine the intensity of the combustion heat value that can be produced by biomass briquettes. The calorific value is a quality parameter of biomass briquettes. The composition of the briquette significantly influences the calorific value; this is influenced by the water content and compounds in it. The more coal dust added, the lower the calorific value obtained.

The data above can be seen that the lowest calorific value obtained in this test was 3604 kcal/kg in specimen 1 with a composition of 0:50:50 and the highest calorific value was in specimen 3 with a calorific value of 4190 kcal/kg with a composition of 20:40:40. This indicates that the calorific value decreased from specimen 1 to specimen 2 and experienced a significant decrease in specimen 3. From the data obtained, a graph of the relationship between calorific value and composition can be made, such as the graph

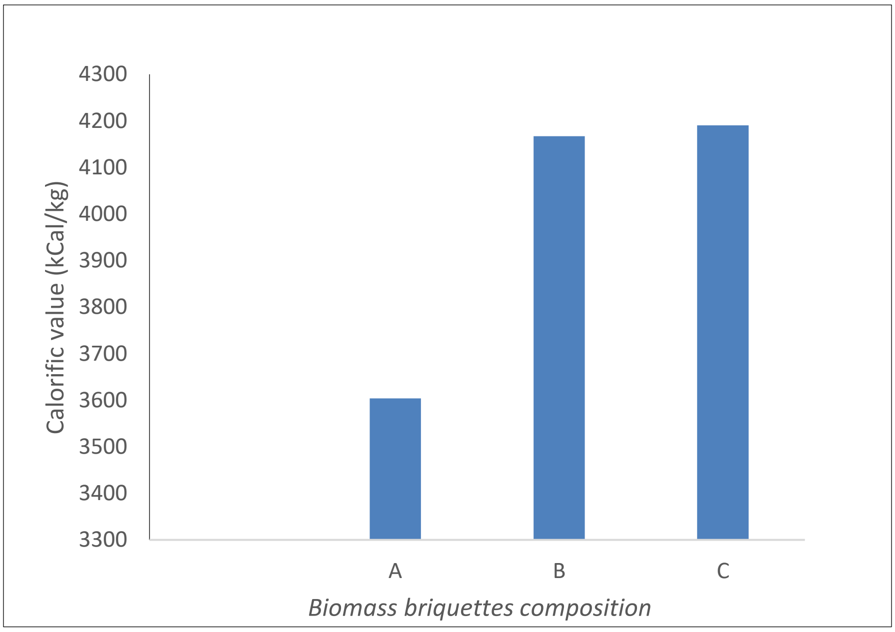

Figure 1 Relationship Between Calorific Value and Composition

The calorific value test uses the AR received (AR) method with a bomb calorimeter, the purpose of which is to determine the amount of briquette energy and to determine the extent of the calorific value produced by the briquette which is a mixture of coal dust, corn stalks and sawdust.

Based on figure 1 above, the relationship between briquette composition variations and calorific value was obtained. The highest calorific value was 4190 kcal/kg in specimen 3, with a composition of 20:40:40 (20% coal dust, 40% corn stalks, and 40% sawdust). The lowest calorific value was 3604 kcal/kg in specimen 1, with a composition of 0:50:50 (0% coal dust, 50% corn stalks, and 50% sawdust). Specimen 2, with a composition of 10:45:45 (45% coal dust, corn stalks, and sawdust), obtained a calorific value of 4167 kcal/kg.

Calorific value is a very important property of biomass briquettes, as it determines their suitability for use as fuel. Based on the calorific value graph above, the most optimal calorific value is obtained in specimen 3 with a composition of 20:40:40, where 20% coal dust, 40% corn stalks, and 40% sawdust have a calorific value of 4190 kcal/kg. So, it can be said that in specimen 3, the composition variation of the 20:40:40 mixture has a large calorific value because it has a mass percentage of 20% coal dust, which can be said that the more or higher the percentage of coal dust, the higher the calorific value.

The addition of coal bottom ash to biomass briquettes can increase the calorific value due to the mineral oxide content that acts as a catalyst in the combustion process. Compounds such as CaO, Fe_2O_3, and SiO_2 contained in bottom ash can accelerate the oxidation reaction of carbon and volatile biomass, so that stored chemical energy can be released more optimally (Setiawan et.al,2019). Furthermore, bottom ash also functions as a heat absorber that helps distribute energy evenly within the briquettes, resulting in more stable and efficient combustion. This effect increases the energy produced per unit mass of the briquettes, reflected in a higher calorific value.On the other hand, the addition of bottom ash also affects the physical properties of the briquettes, particularly their density and structural compactness. The presence of mineral particles makes the briquettes denser, and the contact between biomass particles is tighter, improving heat transfer and oxygen diffusion. This reduces energy loss due to incomplete combustion and increases energy conversion efficiency. However, it should be noted that the increase in calorific value only occurs at optimal bottom ash levels; if too much is added, the ash content will dominate and actually reduce combustion quality because the energy released is reduced compared to the total mass of the briquettes.

Moisture content is one of the parameters that can be used to determine briquette quality because it affects the ignition of the briquettes and the calorific value of biomass briquettes. Each fuel contains moisture content that will affect the combustion process. Table 4.7 and Figure 4.2 show the moisture content in biomass briquettes.

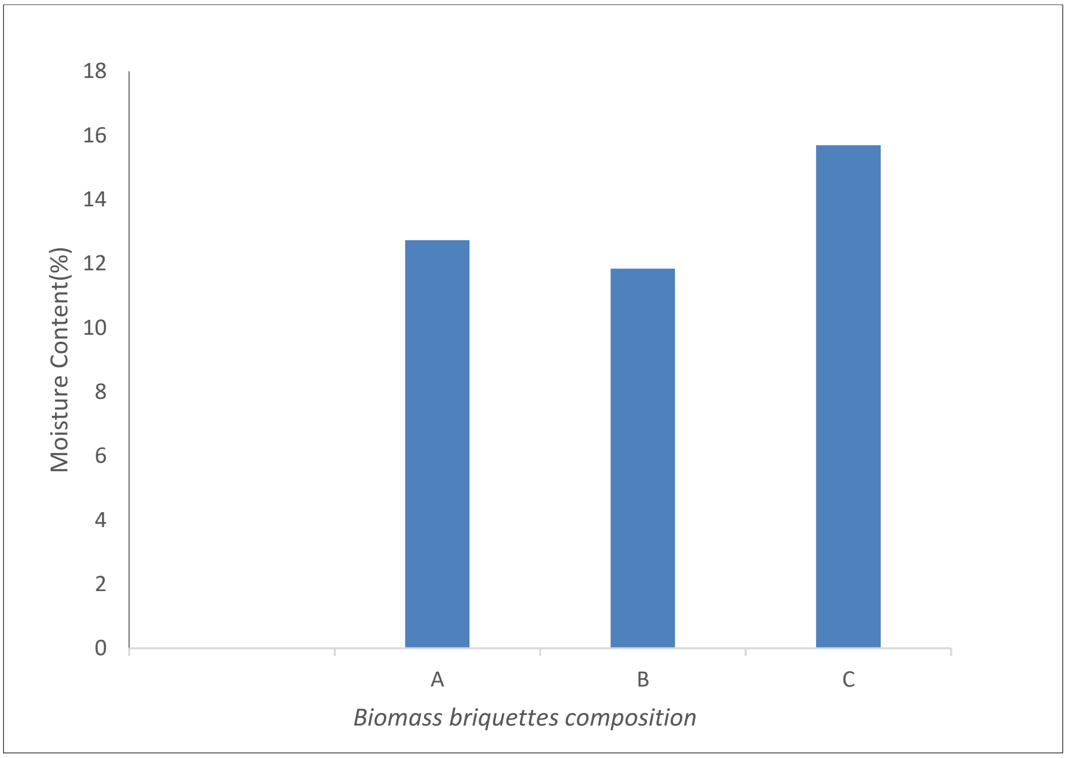

Figure 2 Moisture Content

Based on figure.2, it can be seen that specimen C has the highest moisture content at 15.69%, while specimen B has the lowest moisture content at 11.84%. Therefore, it can be concluded that the composition does not affect the moisture content in biomass briquette production.

Figure 2 shows the moisture content (%) of three biomass briquette compositions labeled A, B, and C. Composition A has a moisture content of approximately 14%, composition B is slightly lower at approximately 13%, while composition C has the highest moisture content at approximately 16%. These differences in moisture content reflect variations in the briquette raw material formulation, which can affect physical properties and combustion performance. In general, lower moisture content, such as in composition B, tends to be more advantageous for combustion because it generates heat more efficiently and reduces energy wasted on water evaporation. Conversely, high moisture content, such as in composition C, can reduce the effective calorific value and slow the combustion process. Therefore, controlling moisture content is a crucial aspect in optimizing the quality of biomass briquettes.

The moisture content of biomass briquettes is crucial because it affects their calorific value, combustion stability, and shelf life. The higher the moisture content, the more energy is wasted evaporating the water before combustion. This lowers the briquettes' effective calorific value, resulting in a weaker flame and increased smoke production. Conversely, a low moisture content allows energy to be directly used for fuel oxidation, increasing combustion efficiency.

The differences in moisture content in biomass briquette compositions A, B, and C can be scientifically explained by the hygroscopic properties and pore structure of each component. Sawdust and corn stalks have a relatively high capacity to absorb and retain water due to the polar structure of cellulose and hemicellulose, which readily bind with water molecules. When the proportions of these ingredients change, the mixture's total water absorption capacity also changes. In composition C, the highest moisture content (around 16%) is likely due to the dominance of more hygroscopic ingredients or to mixing and storage conditions that allow more moisture to be absorbed.

Furthermore, the addition of coal dust in compositions B and C also plays a significant role. Coal dust is hydrophobic, meaning it doesn't readily absorb water. Therefore, in composition B (with 10% coal dust), the moisture content decreases to around 13%. However, in composition C (with 20% coal dust), the moisture content actually increases. This can occur if the coal dust particle distribution is uneven or if the mixing process causes agglomerations that trap moisture. Other factors such as ambient humidity, drying techniques, and storage time can also affect the final moisture content of the briquettes. Overall, moisture content is influenced by a complex interaction between the material composition, the physical and chemical properties of the material, and the production process conditions.

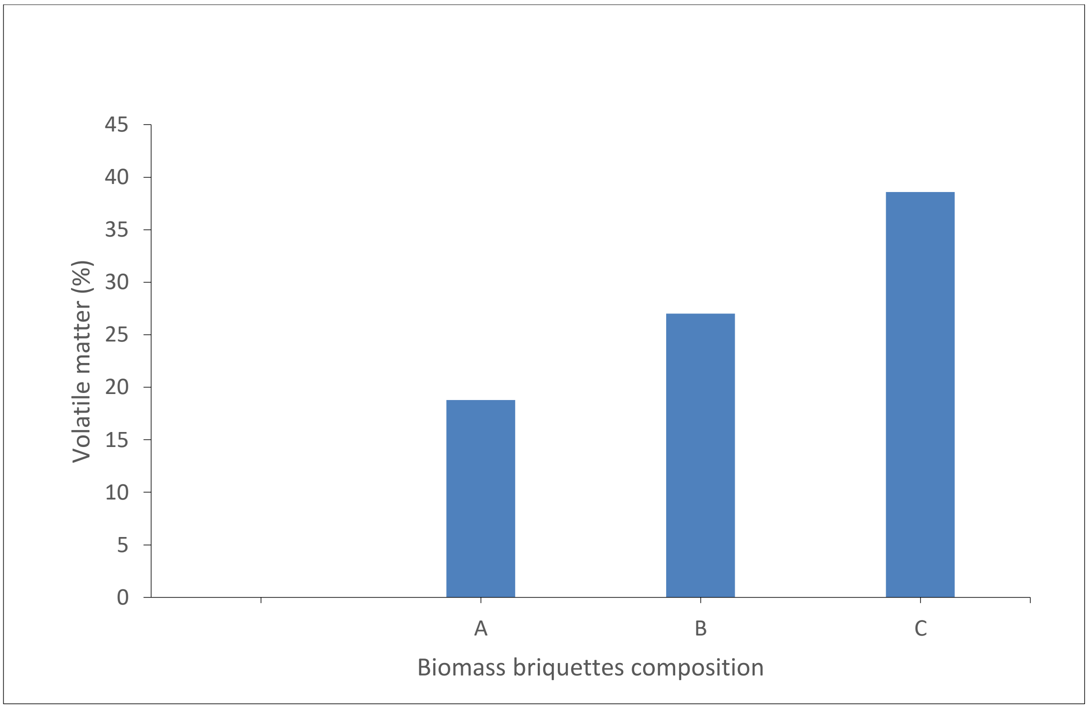

Figure 3Volatile matter

Volatile matter is a volatile substance contained in bagasse charcoal briquettes, from table 4.8 can be seen and observed the effect of composition on the volatile matter content of biomass briquettes. Based on the data above it can be seen that the volatile matter value has increased from specimen 1 which has a composition of 0:50:50, 0% coal dust, 50% corn stalks and 50% sawdust with a volatile matter value of 18.80% to specimen 2 which has a composition of 10:45:45, 10% coal dust, 45% corn stalks and 45% sawdust with a volatile matter value of 27.01%. in specimen 3 which has a composition of 20:40:40, 20% coal dust, 40% corn stalks and 40% sawdust with a volatile matter value of 38.58%. This shows that the addition of coal dust will add to the volatile matter value.

Volatile matter in biomass is the fraction of organic components that can decompose and evaporate when heated, typically hydrocarbon gases, tar, and oxygen compounds. The volatile content significantly determines combustion characteristics: the higher the volatile content, the faster the flame will form, but it also has the potential to result in incomplete combustion if there is no catalyst or medium to stabilize the reaction. When bottom ash is added to biomass briquettes, the oxide minerals in it act as catalysts, aiding the oxidation of these volatile compounds. As a result, more volatile substances that would normally escape as unburned gas can be converted into heat energy. In other words, bottom ash increases the efficiency of volatile matter utilization, thereby increasing the effective calorific value of the briquettes. However, if the bottom ash content is too high, the ash content will decrease the active fuel fraction and actually reduce the volatiles' contribution to the total energy.

Scientifically, the increase in volatile matter levels in biomass briquettes supplemented with bottom ash can be explained by the interaction of the oxide minerals contained in the ash. Bottom ash contains compounds such as CaO, Fe_2O_3, and SiO_2, which act as catalysts for the biomass pyrolysis process. The presence of these minerals accelerates the decomposition of complex organic components into volatile fractions (hydrocarbon gases, tar, and oxygen compounds), thereby increasing the measurable amount of volatile matter. In other words, bottom ash acts as a catalyst, promoting the release of more volatile matter during the initial heating stage.

Furthermore, bottom ash also affects the physical structure of the briquettes. Mineral particles mixed with the biomass can increase microporosity and improve heat transfer within the briquettes. This intensifies the devolatilization process, resulting in a higher fraction of volatile matter released during proximate analysis. However, it should be noted that this increase does not necessarily mean that the biomass produces more energy from volatiles alone; rather, it results from the catalytic effect and changes in physical properties resulting from the addition of bottom ash. If the bottom ash content is too high, the ash content will dominate and reduce the net energy contribution even though the measured volatile matter value increases.

IV. DISCUSSION AND CONCLUSION

From the research that has been conducted, several conclusions have been obtained. The following are some of the conclusions obtained from this study: Biomass briquettes have a high calorific value of 4190 calory/gram with a composition of 20:40:40, 20% coal dust, 40% corn stalks and 40% sawdust, so they can be used as an alternative fuel. The water content in biomass briquettes is related to the calorific value that will be produced. In testing this briquette, it shows that the volatile matter value is affected by the composition of coal dust.

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