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Utilization of Banana Pseudostem Biomass Waste and Coconut Pulp as Briquettes for Alternative Energy Sources

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ABSTRACT

This study aims to utilize banana pseudostem and coconut pulp waste as raw materials for biomass briquettes, evaluate their physical and thermal characteristics, and assess their potential as alternative fuel sources. The research methods included drying, grinding, mixing, molding, and briquette testing. Characterization was conducted through hardness testing using a digital sclerometer, morphological and particle size analysis using a digital microscope, calorific value measurement using a bomb calorimeter, and thermal degradation analysis using Thermogravimetric Analysis (TGA). The hardness test showed that pure banana pseudostem briquettes had the highest compressive strength according to the P3HH standard, while the addition of coconut pulp tended to reduce it. Increasing the proportion of coconut pulp produced larger average particle sizes, affecting briquette porosity. The highest calorific value, 16,829.73 J/g, was obtained from a 50:50 composition, indicating that the oil and lignin content in coconut pulp contributes to combustion energy. TGA analysis revealed that briquettes with higher banana pseudostem content exhibited greater heat resistance, while those with more coconut pulp ignited faster and left less residue. In conclusion, briquettes made from banana pseudostem and coconut pulp can be used as an alternative solid fuel, with compositions adjustable according to the desired energy output and combustion characteristics.

1. INTRODUCTION

Global energy demand is increasing along with population growth and technological developments (Duangkham & Thuadaij, 2023). Dependence on fossil fuels, including LPG, currently widely used for household cooking in Indonesia, presents a number of challenges. In addition to contributing to greenhouse gas emissions that exacerbate climate change, dependence on LPG also contributes significantly to the carbon footprint, as shown by research in Denpasar, where the average household carbon footprint reached 138,037.02 g carbon/month (Wiratama *et al*., 2016). On the other hand, the LPG subsidy burden continues to increase, from IDR 32.8 trillion in 2020 to IDR 67.6 trillion in 2021 (Fauzan, 2025), but its distribution is not entirely on target because around 40% is actually enjoyed more by wealthy households (Muharam *et al*., 2025). This condition shows the need for relocating the negative impacts of LPG to more sustainable, eco-friendly, and locally potential renewable energy sources.

Agricultural countries, such as Indonesia, can capitalize on the booming industry of biomass energy. Biomass energy comes from organic materials, such as cultivated plants, agricultural waste, forestry waste, livestock manure, and even algae (Ahmad *et al*., 2018). One of the most popular types of biomass energy is in the form of briquettes. Biomass briquettes are the most common type of solid fuel to be created and is the direct result from the compression of agricultural biomass and its residues. biomass briquettes are an effective form of energy as it is calorifically valued up to 32.16 MJ/kg, it is the most viable form of energy as it emissions (Asada, 2023).

The natural resources of Bengkulu Province makes developing biomass-based alternative energy projects worthwhile. Banana and coconut production reached 20,735 tons and 7,574 tons, respectively, in 2023 (BPS). Other crops like durian, coffee, and cocoa have also shown high production rates. Unfortunately, agricultural waste like banana pseudostems and coconut pulp are often thrown out, burned, or left to rot, which are all environmentally harmful practices (Adeko *et al*., 2024). The biomass waste materials contain cellulose, lignin, and carbon materials, that, when combusted, also can serve as a natural binder and yield high amounts of energy (Iswara *et al*., 2024).

Much prior work has been done showing that briquettes made of banana pseudostems can burn for a long time (Masthura, 2019) while that made from coconut pulp can give a good heat value (Wijianti *et al*., 2017). But past works concentrated on one biomass. Here, we attempt to blend banana pseudostems with coconut pulp to optimize briquettes for a good trade-off between hardness, morphology, size, combustibility and flame stability. It also helps to contribute to the reduction of reliance on LPG, the diversification of the energy sources of the household, and the agricultural waste processing from a circular economy perspective.

Nonetheless, the heighted levels of smoke coming from the burning of biomass briquettes remains a concern. This leaves the possibility of briquettes going through further development in order to improve the overall quality through torrefaction or pyrolysis processes, resulting in cheap and competitive biomass fuel that is clean and efficient in burning. With that, biomass would yield a sustainable alternative source of energy.

2. MATERIALS AND METHODS

This study utilized an experimental design and data collection methods such as experiments, documentation, and a review of relevant literature. Furthermore, data was analyzed using quantitative methods.

2.1. Research Materials and Tools

The study's primary materials, agricultural waste, consisted of banana pseudostems (Musa paradisiaca L.), rest coconut pulp after coconut milk extraction from the market, and commercial tapioca flour, which acted as glue and together with clean water, served as the solvent.

The supplied equipment consisted of the following items: a set of type 12 briquette molds, a sieve, scissors, a digital scale, a Philips HR2115 blender for ingredient crushing, a mixing container, a 250 mL plastic measuring cup, a saucepan, and a stove for the glueing stage. For performing the different characterization tests, the following instruments were also supplied: digital sclerometer for the hardness test, digital microscope for morphology and particle size analysis, bomb calorimeter for measuring the calorific value, and Hitachi STA7300 TG/DTA equipment for thermogravimetric analysis.

2.2. Research Procedure

Briquette production involves six main stages:

1. Drying the materials: banana pseudostems and coconut pulp were sun-dried for 14 days until the moisture content is approximately 10% (Figure 1a, 1c).

Figure 1. Material used to make briquette: Banana pseudostem [dry (a), ground (b)], and Coconut pulp [dry (c), ground (d)]

2. Grinding and sieving: the dry materials were cut, ground, and then sieved to obtain a fine powder (Figure 1b, 1d).
3. Making the adhesive: tapioca flour was mixed with water (1:15) and heated to form a thick gel.
4. Mixing the materials: banana pseudostem powder and coconut pulp were combined with an adhesive at 6% of the total briquette mass, according to the variations in Table 1.

Table 1. Variations in banana pseudostem to coconut pulp ratios to prepare briquette

No	Treatment	Banana Pseudostem (% w/w)	Coconut Pulp (% w/w)
1	B100	100	0
2	B90	90	10
3	B80	80	20
4	B70	70	30
5	B60	60	40
6	B50	50	50

5. Briquette molding: The mixture is poured into a cube-shaped mold with a uniform volume, then pressed using a type 12 briquette mold, as shown in Figure 2a.
6. Re-drying: The molded briquettes were dried in the sun for 5 days to reduce the moisture content until they are ready for testing (Figure 2b). Figure 3 shows the steps for making briquettes from banana pseudostem biomass waste and coconut pulp.

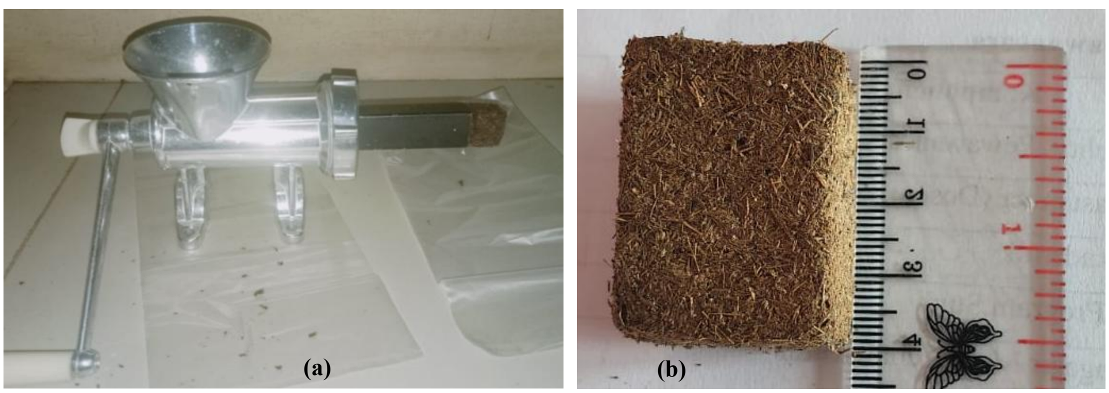

Figure 2. (a) Briquette molding device Type 12, and (b) Briquettes made from banana pseudostem and coconut pulp

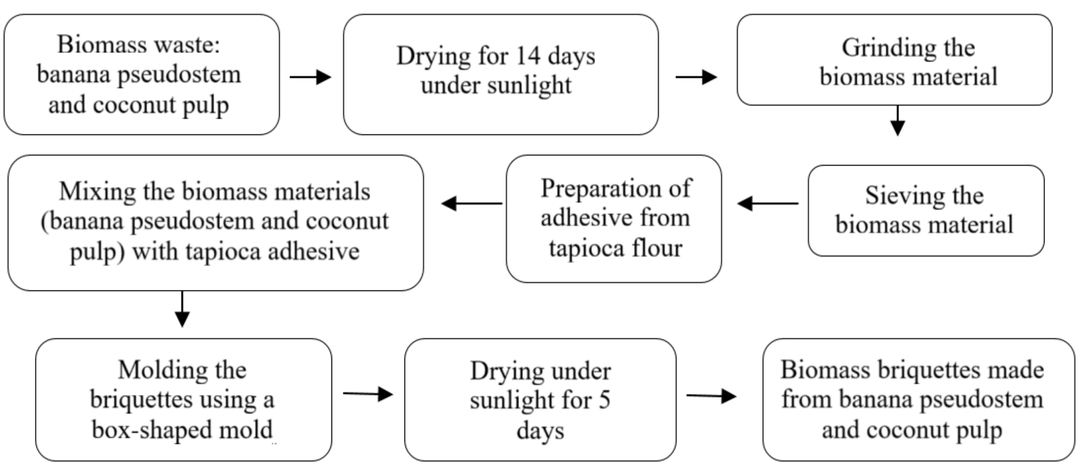

Figure 3. Steps in making biomass briquettes

2.3. Briquette Characterization Test

Briquette characterization was conducted to determine their physical and thermal properties using the following tests:

1. Briquette Hardness Test

The hardness test was conducted using a digital sclerometer to measure the briquette's compressive strength to the point of shattering. Given that there is no Indonesian National Standard (SNI) specifically specifying the hardness limit for biomass briquettes, the test results in this study were compared with the briquette quality standard issued by the Forest Products Research and Development Center (P3HH), Bogor (Sudrajat, 1982), which stipulates a minimum compressive strength of >12 kg/cm².

2. Morphology and Particle Size Test

The morphology and particle size distribution were observed using a digital microscope. Measurements were taken at 50 sample points for each variant to assess interparticle bonding and porosity levels. The results were compared with the solid biomass quality standard SNI 9032:2021 (Wood Chips).

3. Calorific Value Test

The calorific value was measured using a bomb calorimeter using the ASTM D5865-13 method, then the results were compared with the solid biomass quality standard SNI 9032:2021 (Wood Chips).

4. Thermogravimetric Analysis (TGA)

TGA analysis was performed using a Hitachi STA7300 TG/DTA instrument at a temperature of 32–950°C with a heating rate of 10°C/minute and 25 mL/minute of N_2 gas. Data were analyzed using Pyris Software and presented as a graph of residual mass versus temperature (Zulkifli & Raudah, 2016).

2.4. Data Analysis

Data were analyzed quantitatively. The hardness value was compared with the standard issued by the Center for Forest Products Research and Development (P3HH), Bogor (Sudrajat, 1982), while the morphology and particle size were analyzed from digital microscope images with 50 measurement points for each variant referring to SNI 9032:2021 (Wood chips). The calorific value was calculated using the ASTM D5865-13 method and classified based on the quality category in SNI 9032:2021. TGA analysis was used to determine the initial temperature of degradation, peak temperature, mass loss rate, and final residue in four variations of briquette composition.

3. RESULTS AND DISCUSSION

The briquettes used in this study were produced through a combination of biomass of banana pseudostem wastes and coconut pulp due to its low cost and availability. More so, these materials have a great potential to be alternative energy sources. The pictures of briquettes can be seen in figure 1b. The briquettes were then subjected to a series of tests to determine their quality and ability to carry loads and withstand pressure during transportation, storage, and usage. Table 2 summarizes physical characteristics of briquette made of banana pseudostem and coconut pulp at different ratios.

Table 2. Characteristic of briquette made of banana pseudostem and coconut pulp at different ratios

No	Treatment (ratio)	Hardness (kg/cm²)*	Sum of Particle Size (mm)†	Particle Size (mm)	Calorific Value (J/g)
1	B100 (100:0)	15.25	64.4	1.29	11,984.08
2	B90 (90:10)	6.24	65.1	1.30	13,046.16
3	B80 (80:20)	5.08	66.4	1.33	13,859.58
4	B70 (70:30)	4.15	68.0	1.36	15,627.99
5	B60 (60:40)	3.97	68.9	1.38	15,671.74
6	B50 (50:50)	3.61	69.2	1.41	16,829.73

Note: *) According to Forest Product Research and Development Center (P3HH), Bogor, briquette quality standard for hardness is > 12 kg/cm².
†) Sum of 50 points

3.1. Briquette Hardness Test

The purpose of hardness test is to make sure that the structure of the briquettes are enough to withstand the crushing and cracking that may happen and therefore, preserving their burning efficiency and their burning quality (Ajimotokan *et al*, 2019). In this study, a digital sclerometer was used in testing the briquettes to assess how much load the briquettes are able to bear and the point at which the briquettes strength is at its maximum. This maximum point is reached when the briquettes can no longer bear the load (Lase *et al*, 2023). Table 2 shows the data of the hardness test conducted on the briquettes made of banana pseudostem and coconut pulp.

The data presented in Table 2 indicates that the highest values of the hardness of the briquettes produced was when 100 percent of the composition is the banana pseudostem fibrous material (15.25 kg/cm^2) whereas the lowest value was when the composition had 50 percent banana pseudostem and 50 percent coconut pulp (3.61 kg/cm^2). The variation in the recorded hardness of the produced briquettes indicates that the composition of the raw materials has a distinct effect on the mechanical properties of the produced briquettes.

The banana pseudostem, along with having a massive matrix structure, with a relatively low density has been reported to have high levels of lignin and hemicellulose (Mitchell *et al*., 2020). These are natural binders that strengthen the interparticle bonds formed during the briquettes forming and pressing processes. The greater the content in the composition of the briquettes is, the denser and stronger the final structure of the briquettes will be. On the other hand, coconut pulp is reported to have a low content of lignin, and a relatively high content of oil (Hasanudin and Lahay, 2012). The oil in the composition of the briquettes serve as a lubricant and thus reduces adhesion of the particles in the briquettes formed. Therefore, the mixture of coconut pulp in the briquettes formed will yield a lower value of hardness.

For this study, the accepted standard of measurement in hardiness is P3HH and more than 12 kg/cm^2 when squeezing, as the SNI (Standar Nasional Indonesia Keyboard) does not yet have provision provided for the hardiness specification for the briquettes. In this standard, only the briquettes who have 100% banana pseudostem (15.25 kg/cm^2) is the only one who met the standard, whereas of all the blends which contain coconut pulp equally fell below the standard. Pure banana pseudostem's harder than the other biobriquettes that has coconut shells, corncobs and cow dung which only have 9.32 kg/cm^2 (Kalsum *et al*, 2021) and it's slightly better than briquettes made of meranti sawdust which only has 13.07 kg/cm^2 (Alpian *et al*, 2024) This indicates the strong competition of banana pseudostem to be utilized as a viable raw material for it's superior mechanical character.

This study's novelty stems from the fact that the addition of coconut pulp low hardness due to its low lignin and high oil content, thus underscoring the opposing functions of these materials in determining the mechanical properties of the briquettes. To remedy the hardness problem of the briquettes made from banana pseudostem and coconut pulp in future work, the authors suggested the use of natural or synthetic binders, the adjustment of the pressing pressure and temperature, and the addition of other lignocellulosic biomass materials with higher lignin content. The obtained briquettes are expected to be more mechanically durable and harness the oil-rich energy of coconut pulp.

3.2. Morphology Test and Briquette Particle Size Analysis

This experiments intent was to study the structure and physical attributes of the briquettes made from the biomass waste of banana pseudostem and coconut pulp. The morphology test measures the surface structure and the shape of the particles of the briquettes. This can help to evaluate the homogeneity and particle arrangement, and identify the pore, which affect the burn and density. In addition, this study can help identify the degree of bonding between the particles, which determines the strength of the briquettes. On the other hand, the objective of the particle size analysis is to find out the distribution of size of the raw materials and the briquettes produced, since this can affect the briquettes density, the efficiency of the combustion, and the duration of which the briquettes burn (Alfajriandi *et al*., 2017). The test was done using a digital microscope of approximately 60x magnification which helped to clearly visualize the particle structure of the sample type and to examine the surface of the briquettes. The morphology of the banana pseudostem and coconut pulp particles is shown in Figure 4 where it can be observed that the particles of the banana pseudostem are flat, and those of the coconut pulp have a rounded morphology. The average particle size for 50 point measurements taken for each sample of briquettes made from banana pseudostem and coconut pulp biomass is reported in Table 2.

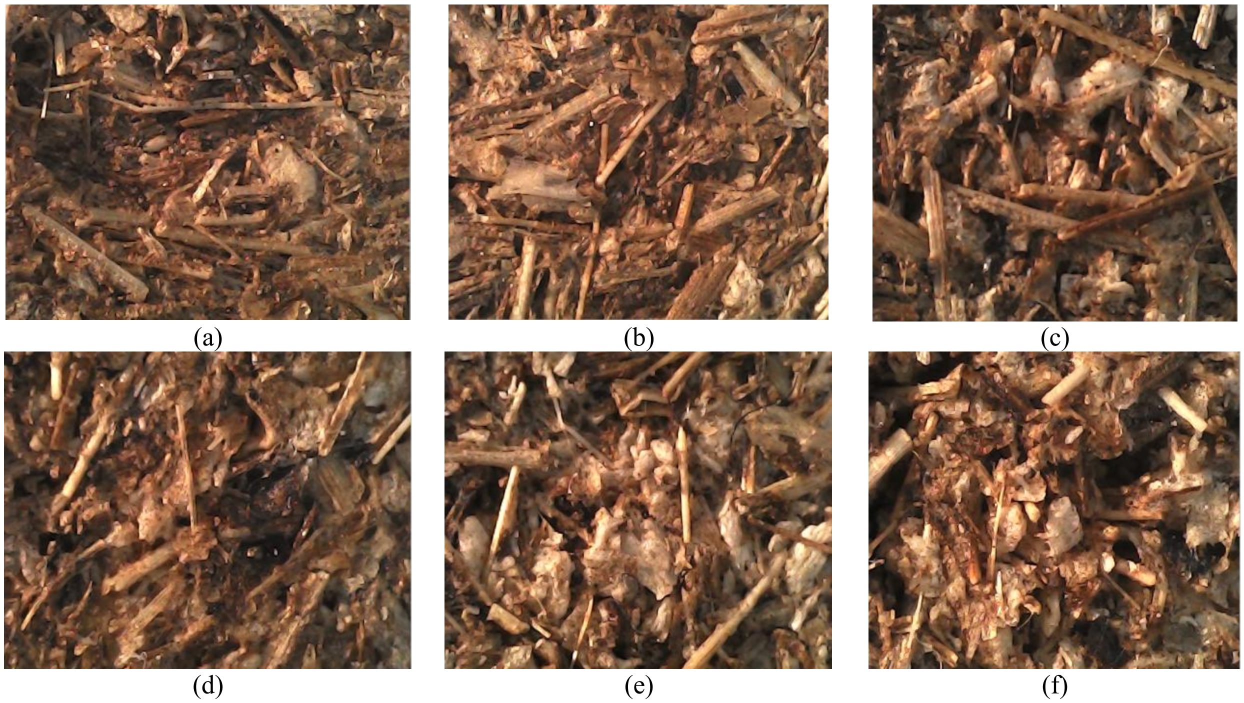

Figure 4. Microscopic test result of briquette sample: (a) Sample 1 B100 (100% banana pseudostem) (b) Sample 2 B90 (90% banana pseudostem : 10% coconut pulp) (c) Sample 3 B80 (80% banana pseudostem : 20% coconut pulp) (d) Sample 4 B70 (70% banana pseudostem : 30% coconut pulp) (e) Sample 5 B60 (60% banana pseudostem : 40% coconut pulp) (f) Sample 6 B50 (50% banana pseudostem : 50% coconut pulp).

From the data shown in Table 2, it can be seen that the average particle size increases with increasing coconut pulp proportion in the briquette mixture. The average particle size of the 100% banana pseudostem sample was 1.29 mm. In comparison, the average particle size of 50% banana pseudostem: 50% coconut pulp sample was 1.41 mm. This suggests that the coconut pulp has larger particles than banana pseudostem, and therefore, a greater proportion of it leads to briquettes with a greater average particle size.

The size of the particles plays a significant role in the briquettes porosity and mechanical properties. Smaller particles are more likely to lower the air voids within particles and increase the binding and adhesion, thus resulting in a lower porosity and increased mechanical properties of the briquettes (Wijayanti, 2009). On the other hand, larger particles of a given mass will increase the voids within a sample, and therefore reducing the overall mechanical properties of the briquettes. This confirms what was reported by Alfajriandi *et al.* (2017) that high particle size results in a less compacted structure of the briquettes, leading to high porosity, poor compressive strength and combustion efficiency.

The particle size of the briquettes produced in this study (1.29–1.41 mm) is much smaller than the maximum limit of <16 mm for the Circulating Fluidized Bed (CFB) and stoker genre in the standard (SNI 9032:2021, particle size quality specification table). This is in stark contrast to the SNI 9032:2021 standard for wood chips as energy feedstock where the particle size was much larger. This suggests that the biomass particles in this study might be much finer in contrast to other studies. From the perspective of briquetting, a particle size smaller than the wood chip standard would be advantageous as it would lead to better uniformly distributed briquettes, compacting to a higher density. The only downside would be the need for better adhesive to withstand the compacting of particles.

Consequently, this study provides a new insight that the particle size of briquettes made from banana pseudostems and coconut pulp is not only above the required mechanical strength but is also of a finer microparticle scale than the wood chip standard in SNI 9032:2021. This also suggests that the briquettes may have better mechanical properties in terms of densification and reduced combustion.

3.3. Calorific Value Analysis of Briquettes

Using a bomb calorimeter, the gross energy of the briquettes consisting of both banana pseudostem and the coconut pulp mixture was evaluated, and the briquettes' calorific value was determined. Calorific value, as defined by Aljarwi et al. (2020), is the total amount of heat that is released as energy through the complete combustion of a fuel (or a mixture) and is measured in relation to the mass or volume of that particular fuel (or mixture).

2 presents the results of the calorific value assessment of the briquettes made of the banana pseudostem and the blended mass of banana pseudostem and coconut pulp.

Sample B100, which consists entirely of banana pseudostem, yields the lowest calorific value at 11,984.08 J/g, while sample B50, which consists of equal proportions of banana pseudostem and coconut pulp, yields the highest calorific value of 16,829.73 J/g. The increased heating value associated with the addition of coconut pulp indicates that coconut pulp positively impacts the potential of the briquette to produce heat. The oil or fat content present in the coconut pulp also positively influences the calorific value. According to (Angelia, 2016), fat is an organic substance that has high calorific content and, upon combustion, is able to produce higher energy in the form of heat compared to the energy contained in fiber or cellulose. Additionally, as (Anuchi *et al*., 2022) mentions, coconut pulp also has lignin, which is a complex organic substance that forms the cell walls of some plants and is also responsible for the increased calorific value. Consequently, it can be shown that coconut pulp is a beneficial material to use in the production of briquettes of higher energy value.

Comparing this study's results with SNI 9032:2021 (Utility 12,600 J/g, Standard 14,600 J/g, Premium 17,300 J/g), it is found that the highest calorific value has exceeded both the Utility and Standard and is nearing Premium. Thus, the briquette formulation of 50% banana pseudostem and 50% coconut pulp briquette formulation has the prospect of being upgraded to the Premium category with some optimizations and is determined to be compliant with national standards for biomass fuel. This is applicable for instance, to better the optimization through higher density and lower moisture content.

These findings parallels Masthura (2019) study outcomes on the calorific value, which showed that the briquettes made from banana pseudostem and tapioca adhesive were about 3,494.5 cal/g or around ±14,620 J/g. Hence, the briquette formulation of the banana pseudostem and coconut pulp mixture in this study was comparatively better than the banana pseudostem alone. In addition, in the study done by Pramuda & Siregar (2024) the biobriquettes produced from coconut shells and the other materials had a calorific value of 5383.84 cal/g, which equals to about ±22,540 J/g, and was compliant to the SNI, this indicated a higher energy value of coconut shells. Even though the briquettes produced in this study, were comparable to the banana briquettes, the level of quality was in some aspects below that of the coconut shells, thus there was a need to improve on the formulation or the production process to get a better quality briquette. The study showed that banana pseudostems and coconut pulp where used together in creating briquettes that have energy quality, which fulfills the requirement of the national standards. This sows the possibility of using agricultural waste in creating an environment friendly alternative energy source from locally available biomass.

3.4. Thermogravimetric Analysis (TGA)

In order to investigate how the weight of samples changed when subjected to a constant heating rate, TGA (Thermogravimetric Analysis) was conducted to analyze the thermal degradation. During this process, mass may be lost by the sample due to evaporation and decomposition, or mass may be gained due to reactions with the gas that the sample will be exposed to (Caroko *et al*., 2015). TGA was conducted in this study, however, on only four of the six variations of the briquette which are 100% banana pseudostems, 80% banana pseudostems: 20% coconut pulp, 70% banana pseudostems: 30% coconut pulp, and 50% banana pseudostems: 50% coconut pulp. Applying a purposive sampling process, these samples were selected to reflect the particular traits under study.

A broad range of compositions and corresponding thermal biomass characteristics are represented by these four selected samples. According to the Threshold Effect, this selection is explained by the thermal properties equally significantly changing up to a threshold, and beyond that threshold, the properties will remain stable (Mukherjee *et al*., 2004). Because of this, the study was limited to the primary trend in thermal property variation that was due to the difference in raw composition of the material, and the smaller variation in composition was disregarded.

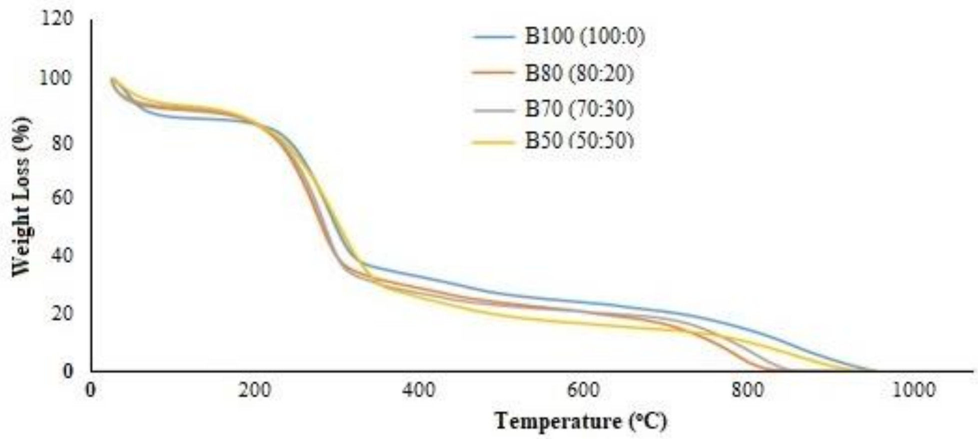

Figure 5. Thermogravimetric curves of banana pseudostem and coconut pulp briquette samples

Figure 5 shows the results of the quantitative analysis by thermogravimetry concerning the briquettes containing 100% banana pseudostem, 80% banana pseudostem: 20% coconut pulp, 70% banana pseudostem: 30% coconut pulp, and 50% banana pseudostem: 50% coconut pulp.

From the thermogravimetric analysis (TG) depicted in Figure 5, evidence suggests three stages in the thermal degradation of the biomass. From the start point (26–200°C) there are losses in moisture and volatile compounds in the mass of 15.07–15.68% of the total initial weight. There was mass loss, but the samples with more coconut pulp tended to moist capture the more dominant losses of weight and appear to be more moisture stable than the banana pseudostem samples less. The second stage (200–500°C) was said to be the primary decomposition of hemicellulose, cellulose and lignin with mass losses in the samples cumulating to 58.37–61.58% of the total initial weight. The samples with more coconut pulp exhibited more intense degradation in the banana pseudostem sustained a more gradual decomposition. This suggests that the biomass with more pseudostems has more higher thermal resistance. The last stage (>500°C) is described to be the advanced carbonization step, coupled with the losses of mass in excess of 19.03–26.06%, here the material remaining is in the order of 0.002–0.325% of the original mass and with the pseudostem biomass leaving more material remaining. This is consistent with the account of therefore more attributed to their higher lignin and mineral content. This is in accord to the findings of Nyakoojo et al. (2024); that biomass with higher cellulose content decomposes with far more intensity, and the lignin counteracts that total thermal resistance. Results for DTG analysis, as depicted in Figure 6, focus on the study's briquettes and the varied proportions of 100% banana pseudostem, 80% banana pseudostem : 20% coconut pulp, 70% banana pseudostem : 30% coconut pulp, and 50% banana pseudostem : 50% coconut pulp.

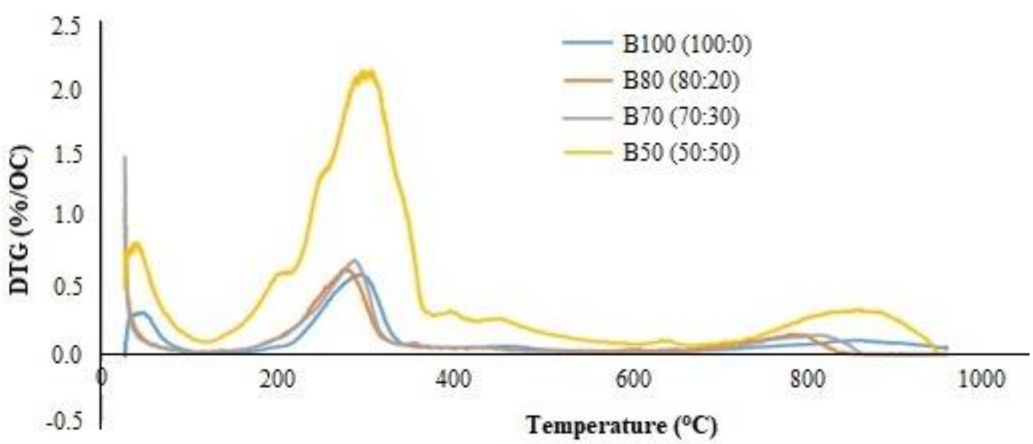

Figure 6. DTG curves of banana pseudostem and coconut pulp briquette samples.

DTG curves reveal the banana stalks and the coconut pulp's comparative water and volatile release rates. Below 200°C, banana stalks release water and volatiles at a faster rate than the coconut pulp, while in the 200 and 400°C range, coconut pulp suffers intense volatile constituents and peaks, in hemicellulose and cellulose decomposition, as banana stalks degrade at a more gradual rate than coconut pulp. Above 400°C, banana stalks further degrade at a more gradual rate than the coconut pulp, which once more exhibits a more dominant peak, characterizing a more dominant carbonization.

Results of the TG and the DTG analyses indicate the influence of the briquette's composition, and consequently the thermal degradation characteristics. Residue level, rate of energy production, and decomposition, above 200°C are rapid in briquettes with a higher coconut pulp content, while the opposite is true for brickets with a higher banana stalk content, which further supports the slower rate of combustion. The relationship of these results to the level of volatile content in the briquettes is correct as high levels of banana peels and other constituents. Mibulo *et al*. (2023) focused on the constituents of the briquette to determine the rate of volatile release during the severe degradation phase rather than the early phase. The degradation rate of the coconut material at high temperature and the 90% mass loss at 450°C are the highlights of the work of Sari & Yulis (2023) as the materials also indicate the rapid degradation of the coconut fiber briquettes.

This means that the type of composition of the briquettes should also be aligned on the basis of energy needs and the combustion duration that one wants to achieve. As per DTA analysis done on the briquettes that is composed of 100% banana pseudostem, 80% banana pseudostem: 20% coconut pulp, 70% banana pseudostem: 30% coconut pulp, and 50% banana pseudostem: 50% coconut pulp is presented in Figure 7.

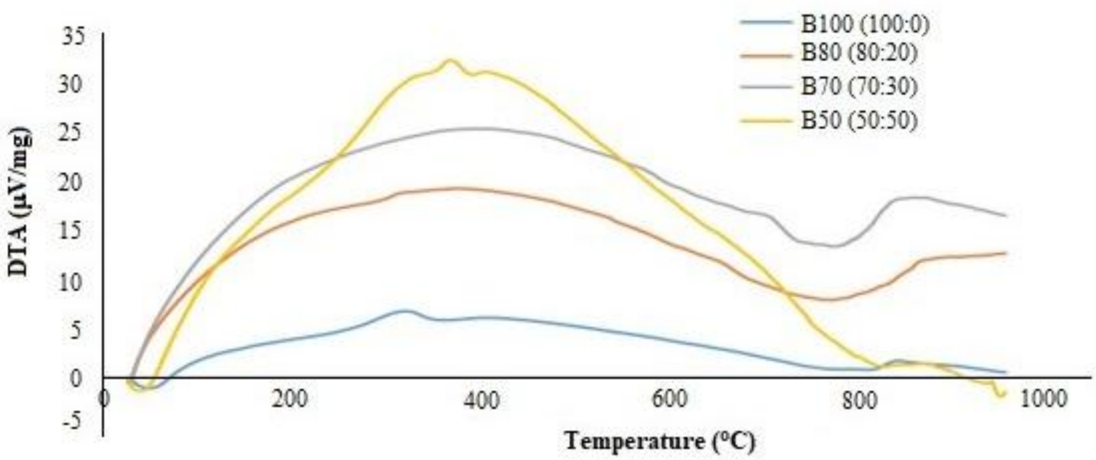

Figure 7. DTA curves of banana pseudostem and coconut pulp briquette samples

Differential thermal analysis (DTA) was performed to obtain the thermal behavior of heating the briquette samples of banana pseudostem and coconut pulp. The thermal behavior of the briquettes is presented in three stages in Figure 5. The first stage is a low-temperature stage (<200 °C) which has a dip in heat flow and is considered an endothermic peak. This is due to the samples dehydrating and releasing volatile matter as the samples that contained banana pseudostem appeared to gradually dry compared to the ones that contained coconut pulp. In the second stage, which is (200–500 °C), the heat flow registers an exothermic peak which is due to the degradation of hemicellulose, cellulose and lignin. In this stage, the sample containing coconut pulp is higher and sharper, while the one containing banana pseudostem has a lower peak that is broader indicating that the degradation is slow and graduated. In the last stage, which is higher than (>500 °C), is where the carbonization process accelerates. The sample that contained coconut pulp has a rapid decrease in the exothermic (in a negative direction) while the one that contained pseudostem released energy at a consistent rate which indicates that more carbon was left after the process.

These findings confirm Chua et al. (2024), who, while studying banana peels, identified three major phases of decomposition and noted the presence of high volatility and significant amounts of char. This establishes banana biomass as decomposing, within the literature, at low rates, resulting in high carbon retention. This indicates that the composition of a briquette affects its burning properties. Samples containing coconut pulp are known to undergo more rapid and exothermic decompositions, which can improve burning efficiency but result in lower amounts of carbonized residuals. More pseudostems in the sample result in slower combustion and longer burn times which are desirable in some end use applications.

4. CONCLUSION

The raw material that you use will determine the briquette's durability, shape, heat retention, and thermal stability. Increasing the banana pseudostems lead to increased durability, whereas increased coconut pulp deteriorates durability because of the oil content which makes it brittle and deters adhesion. Increasing the coconut pulp results in increased porosity which means that the briquettes will burn faster, but the briquettes will also be less dense. More coconut pulp will increase the briquette's total heat value. The TGA analysis shows that thermal degradation happens in three stages and the briquettes without oils (banana pseudostems) have better thermal resistance while coconut pulp briquettes tend to be more flammable, degrade faster, and have less remaining substances. The briquettes should be designed for the combustion needs. The use of banana pseudostems and coconut pulp wastes allows the briquettes to be an environmentally friendly alternative energy source for homes and small industries while also supports the management of agricultural waste on the local level.

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