

# Renewable Fuel Innovation: Sustainable Briquettes from Cardava Banana Peels (*Musa balbisiana*) and Onion Skins (*Allium cepa* L.)

Irish Nicole Alejandro<sup>1</sup>, Dr. Lizamyl Robles Laping<sup>2</sup>

<sup>1</sup>Department of Sanitary Engineering, Western Mindanao State University, Zamboanga City, Philippines-7000

<sup>2</sup>College of Engineering and Technology, Western Mindanao State University, Zamboanga City, Philippines-7000

Email address: xt202000366@wmsu.edu.ph, lizamyl.laping@wmsu.edu.ph

**Abstract**— This study explores the use of cardava banana peels and onion skins in producing sustainable briquettes, focusing on their physical and mechanical properties. Three mixtures were evaluated based on weight, height, density, moisture content, water boiling time, ash content, burn rate, and shatter resistance, with briquettes produced through grinding, mixing, compaction, and drying. In terms of density, all three mixtures had relatively similar densities, with Mixture 2 having the highest density at 0.526 g/cm<sup>3</sup> and Mixture 3 the lowest at 0.447 g/cm<sup>3</sup>. Mixture 2 also recorded the lowest moisture content at 2.905%, suggesting better combustion characteristics, while Mixture 3 had the highest at 4.878%. The water boiling test showed similar boiling times for all three mixtures: Mixture 1 at 11.762 minutes, Mixture 2 at 12.565 minutes, and Mixture 3 at 11.547 minutes. Burn rate tests revealed that Mixture 3 burned the slowest at 82.62 minutes, suggesting potential for longer fuel use. Although ash content was relatively high for all samples, with Mixture 1 at 40.727%, Mixture 2 at 39.222%, and Mixture 3 at 44.296%. Shatter resistance was consistently high, with Mixture 2 achieving the highest value at 92.486% demonstrating strong mechanical durability. Mixture 2 was the optimal formulation, balancing high density, low moisture, and durability. Future studies should explore the use of natural binders, improved mold design, and pressure control. Furthermore, the study should be conducted in controlled environments with consistent and complete raw material collection to ensure reliability. Additionally, the potential of hybrid mixtures combining different biomass materials should be investigated.

**Keywords**— Briquettes, Cardava banana peels, Onion skins, Solid waste management, Biomass, Manual briquetting compactor, Renewable energy.

## I. INTRODUCTION

The growing interest in briquettes stems from their potential to address several pressing challenges, including waste management, energy scarcity, and environmental sustainability. By converting organic waste into briquettes, communities can significantly reduce the amount of materials sent to landfills, thereby minimizing pollution and greenhouse gas emissions. In addition to their environmental benefits, briquettes offer practical advantages for households and industries. They burn more efficiently than raw biomass, providing a cleaner and more consistent source of heat. This efficiency contributes to better air quality and reduces the health risks associated with smoke and emissions from conventional fuels. Converting these abundant and otherwise

discarded materials into valuable products not only addresses the pressing issue of waste disposal but also paves the way for sustainable solutions in energy production and environmental conservation. This kind of energy source is an environmentally friendly substitute for fossil fuels such as coal, natural gas, and petroleum

The Philippines' agriculture industry produces a lot of inorganic and organic trash. The Philippines generates approximately 35 million tons of agricultural waste each year, indicating that the country's agricultural waste management needs to be improved, as well as increased awareness among farmers and local government units about proper waste disposal and utilization. Incomplete combustion during biomass disposal can lead to elevated indoor levels of harmful pollutants, such as particulate matter and carbon monoxide, posing health risks. Inefficient use or disposal of biomass waste can further aggravate pollution, contributing to public health deterioration and environmental degradation. One potential solution is converting these waste materials into energy-efficient briquettes through densification (Velusamy et al., 2021).

Utilizing onion and banana peels as feedstock for fuel is a significant step toward developing sustainable and renewable sources. Banana, one of the most widely produced crops globally generates significant waste in the form of peels, with approximately 1.67 metric tons of banana peel waste produced annually in the Philippines (Torres & Aberilla, 2024). Onions, like many other biomass by-products are valuable for their potential applications, including bioenergy generation, which contributes to renewable energy production (Patel et al., 2021). Disposing of onion peels in landfills is not only costly but also environmentally harmful. As it leads to the release of greenhouse gases such as CO<sub>2</sub> and methane (CH<sub>4</sub>) (Zhang et al. 2019).

This study investigates the physical properties and combustion efficiency of briquettes made from banana peels and onion skins, explicitly contrasting them with other peels that have been studied. By addressing these gaps, the research seeks to contribute to the development of sustainable energy solutions. Thus, this study propounds a novel approach to the utilization of banana and onion peels for energy production and to establish a framework for sustainable biomass

utilization, offering practical implications for waste management and renewable energy development.

## II. METHODOLOGY

### A. Collection of Raw Materials

The banana peels used in the study were collected from local banana cue stands located in Brgy Sta. Maria and Calarian. The peels, which are often discarded after use, serve as an abundant raw material for briquette production. Given the large volume of banana cues sold in the area, this waste material is a valuable resource that would otherwise contribute to environmental waste. Similarly, onion skins were sourced from vendors at the Magay Public Market, where they are typically discarded as waste after the onions are peeled for sale. The onion skins, often seen as an inconvenient by-product, accumulate in large quantities during peak market days.

### B. Preparation of Raw Materials

The raw materials were thoroughly cleaned to remove any dirt or contaminants, ensuring that only pure biomass was used in the subsequent processes. The cleaned banana peels and onion skins were dried to reduce their moisture content through oven drying for about two (2) hours at a temperature of 100 °C to fasten the drying phase. After the drying process, the materials were transferred into an aluminum tray. Once the raw materials were thoroughly dried, they were ground into smaller pieces through a two in one blender to facilitate better compression during briquette formation. The materials are further processed into fine particles or powder for about 30 minutes. The processed banana peel and onion skin particles were mixed in a stainless mixing bowl with three varying mixture proportions (60:40, 80:20, and 50:50). Two hundred fifty (250) mL were then added into the mixture and gradually, the materials were thoroughly mixed by using a scooper. Another two hundred fifty (250) mL water was added for homogenizing the mixture.

### C. Briquette Formation

The production process involves the use of a manual compactor capable of producing six briquettes per batch. Once the mixture was prepared, it was fed into the chambers of the briquette mold which compresses the raw materials into compact cylindrical-shaped briquettes. To maintain uniformity in size and density across all samples, a careful and precise filling method was employed. The mixture is compacted by closing the lid and pushing down the lever. The compression process forces the particles to bind together, forming solid fuel unit. After the densification, the briquettes were ejected from the compactor by opening the lid and pushing down the lever downwards. This simplified process allows for efficient manual operation while ensuring the effective compression of the briquette mixture into solid, well-formed units.

### D. Drying of Formed Briquettes

After the briquettes were formed, they were left to dry further in a controlled environment. By shielding the briquettes from environmental elements such as rain, wind,

dust, and insects, the risk of contamination, uneven drying, and structural degradation is significantly reduced. This controlled isolation ensures that the briquettes retain their physical integrity and do not absorb excess moisture or debris, which could compromise their combustibility and storage stability. The drying process took seven days and the dried briquettes were subjected to testing. Proper drying ensures that the briquettes are stable and durable, improving their combustion efficiency (Hassan et al., 2018).

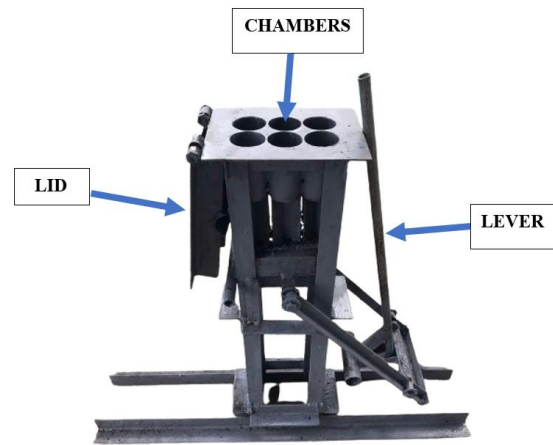


Figure 1. The briquette mold from the study of Tarroza (2024) utilized during the experimental process

### E. Testing of Briquettes

A series of tests on the three mixture proportions of the produced briquettes to assess their physical and mechanical properties was performed. The various testing methods were employed to evaluate the quality and performance of the briquettes produced from banana peels and onion skins.

#### Physical Properties

##### Density

The first step is obtaining the mass of the briquette. The briquette was carefully placed onto the weighing scale and reading the weight displayed. Thereafter, the volume of the briquette was obtained. The specific procedure for this is based on the cylindrical shape of the briquette. Once the mass and volume are known, the density was then calculated using the formula (ASTM 6347/ASTM 6347M-05):

$$\rho = \frac{m (g)}{v (cm^3)} \tag{1}$$

##### Moisture Content

For half an hour, the briquettes were heated up at 110 °C for about 30 minutes inside an oven. The same digital weighing scale was used for the briquettes and was reweighed the final weight represents the weight of the briquettes following oven drying to eliminate any traces of moisture. The water content if the briquette was calculated using the formula from the ASTM D3173-11:

$$\text{Moisture Content} = \frac{\text{Dried weight} - \text{Oven dried weight}}{\text{Dried weight (grams)}} \times 100\% \tag{2}$$

##### Boiling Time

The water boiling test was performed by using four (4) samples of the produced briquettes and were placed in a charcoal stove to boil 350 mL of water in an aluminum pot and the time it takes for each sample per mixture to boil the water with the aid of a stop watch (Davies et al., 2013).

**Ash Content**

The ASTM D3174-8943 testing technique was used to determine the ash content. Ash from the experiment were obtained and weighed using a digital weighing scale. The total ash content is calculated by dividing the weight of the ash by the weight of the original sample, multiplying by 100%.

$$\text{Ash content} = \frac{\text{Ash (grams)}}{\text{Original weight of sample (grams)}} \times 100\% \quad (3)$$

**Mechanical Properties**

**Burn Rate**

The entire time it takes for the briquette to burn was measured using a timer or stopwatch. The process should be observed closely, ensuring that the briquette is fully consumed by the flame, leaving only ash. The total time from ignition to complete combustion is recorded (Galadima et al., 2024).

**Shatter Resistance Index**

In assessing the shatter resistance index of the briquettes, a drop height of 1.8 meters will be utilized, with each sample being dropped twice. A drop test was used to examine the briquette durability. The durability is calculated using this equation where in the mass of the briquette after drop test divided by the mass of briquette before drop test multiplied by 100% is the shatter resistance index (Kuranc et al., 2020).

$$\text{Durability} = \frac{\text{Mass of briquette after drop test}}{\text{Mass of briquette before drop test}} \times 100\% \quad (4)$$

**F. Data Analysis and Interpretation**

The obtained results of the three mixture proportions (60:40, 80:20, and 50:50) are the basis for the data analysis and interpretation. The results were analyzed through the representation of tables and graphs that evaluate the key parameters to assess the viability and capacity of onion peels and banana peels as raw materials for briquette production as an alternative fuel source. For data analysis, ten (10) trials were done for each parameter for testing to ensure the accuracy of the result. Before applying parametric or non-parametric statistical methods for significance testing at p = 0.05, data was checked for normality using the Shapiro-Wilk Test and for homogeneity with Levene’s Test. For normal and homogeneous variance data, one-way ANOVA was used otherwise Kruskal-Wallis. A public domain online statistics tool like the Statistics Kingdom website and Statistics Calculator also helped with the analysis. A 5% significance level was used in the statistical analysis

**III. RESULT AND DISCUSSION**

The briquette made in this study contained banana peels and onion skins as its primary components. The two raw materials with differing characteristics were combined to create a balanced briquette with desirable properties. Physical and mechanical properties 53 can be determined through testing.



Figure 2. Sample briquettes of the three (3) mixture proportions

Results show that based on the physical and mechanical analysis, Mixture 2 which contains 80% powdered banana peels and 20% powdered onion skins appears to be the optimal mixture overall due to its combination of lower moisture content and higher shatter resistance.

TABLE 1. Ranking of Briquettes Based on Parameters

| Parameters           | Mixture 1  | Mixture 2   | Mixture 3   |
|----------------------|------------|-------------|-------------|
| Density              | 2          | 3           | 1           |
| Moisture Content     | 2          | 3           | 1           |
| Boiling Time         | 1          | 3           | 2           |
| Ash Content          | 2          | 3           | 1           |
| Burn Rate            | 1          | 2           | 3           |
| Shatter Resistance   | 1          | 3           | 2           |
| <b>Total Average</b> | <b>1.5</b> | <b>2.83</b> | <b>1.67</b> |

Note: 1 = Least desirable performance  
 2 = Moderate performance  
 3 = Most desirable performance

The ranking presented in Table 1 provides a comprehensive evaluation of the overall performance of the briquettes formulated from varying proportions of banana peels and onion skins. The assessment was based on six key parameters: density, moisture content, boiling time, ash content, burn rate, and shatter resistance. Each mixture was rated using a scale in which 1 indicates the least desirable performance, 2 represents moderate performance, and 3 reflects the most desirable performance. Based on the computed average scores, Mixture 2 emerged as the most effective formulation with the highest average rank of 2.83, demonstrating superior performance across key parameters. This indicates that Mixture 2 achieved the most balanced and optimal combination of properties suitable for fuel application. Mixture 3 followed with an average score of 1.67, performing well in terms of moisture content and ash content, which are essential for clean and efficient combustion. Meanwhile, Mixture 1 recorded the lowest average score of 1.5, suggesting relatively less favorable performance overall.

In contrast, Mixture 1, with an average score of 1.5, recorded the lowest overall performance. Although it achieved moderate results in density, moisture content, and ash content, it performed poorly in critical areas such as boiling time, burn rate, and shatter resistance. This suggests limitations in both fuel efficiency and mechanical integrity, making it the least desirable option for practical use. Mixture 3 obtained a slightly higher average score of 1.67, performing well in burn rate and moderately in shatter resistance and boiling time.

However, it was significantly hindered by poor density, high moisture content, and high ash content.

TABLE 2. Tabulated Data for Comparison Between a Commercial Wood Charcoal and a Banana Peel and Onion Skin Briquette

| Parameters                   | Mixture 1 | Mixture 2 | Mixture 3 | Commercial Wood Charcoal |
|------------------------------|-----------|-----------|-----------|--------------------------|
| Density (g/cm <sup>3</sup> ) | 0.462     | 0.526     | 0.447     | 0.208 g/cm <sup>3</sup>  |
| Moisture Content (%)         | 4.67      | 2.905     | 4.878     | <10%                     |
| Boiling Time (minutes)       | 11.762    | 12.565    | 11.547    | 11.50 ± 2.11             |
| Ash Content (%)              | 64.043    | 75.125    | 82.62     | 99.2 ± 4.2               |
| Burn Rate (minutes)          | 40.727    | 39.222    | 44.296    | 5-10%                    |
| Shatter Resistance Index (%) | 90.694    | 92.486    | 92.432    | 98%                      |

Based from Table 2, the density should be 0.208 g/cm<sup>3</sup>, to which all the three mixtures failed to be within the range with Mixture 1, 2, and 3 having a density of 0.462, 0.526, 0.447 respectively. For the moisture content, Mixture 3 (4.878%) has the highest average moisture content while Mixture 2 has the lowest moisture content. The resulting moisture contents of these three mixtures fell within the acceptable standard for moisture content. The boiling time for the mixtures is also within the standard, with all three mixtures falling between 9.39 and 13.61 minutes, which is within the required 11.50 ± 2.11 minutes. However, the burn rate for all three mixtures (Mixture 1: 64.043 minutes, Mixture 2: 75.125 minutes, Mixture 3: 82.62 minutes) is lower than the standard requirement, indicating that the briquettes burn faster than desired. The ash content for all mixtures is notably higher than the acceptable range of 5-10%, with values of 40.727%, 39.222%, and 44.296%, respectively, which suggests that the briquettes may produce more waste and be less efficient in combustion. Lastly, the shatter resistance index for all three mixtures (Mixture 1: 90.694%, Mixture 2: 92.486%, Mixture 3: 92.432%) did not fall within the required requirement of 98%, indicating that the briquettes more likely to crumble and break in terms of their durability. Overall, while some parameters like moisture content, boiling time meet the standards, there is a need for improvement in density, burn rate, ash content, and shatter resistance to meet the desired briquette quality.

Ultimately, based on the comparison, Mixture 2 appears to be the optimal formulation, as it demonstrates the proximity to the required standard, which is advantageous for combustion efficiency, the lowest ash content relative to the other mixtures, and the highest shatter resistance index. However, further improvements are required in terms of burn rate and ash content to fully meet the established standards.

#### IV. CONCLUSION

This study successfully utilized and produced briquettes from banana peels and onion skins by determining the optimal mixture proportion or ratio of the briquettes. This study also described the effect of the varying mixture proportions on the physical and mechanical properties of the product. The density

of all three mixtures is relatively similar, with Mixture 1 at 0.462 g/cm<sup>3</sup>, Mixture 2 at 0.526 g/cm<sup>3</sup>, and Mixture 3 at 0.447 g/cm<sup>3</sup>. However, Mixture 2 had the highest density while Mixture 3 being the lowest. The ANOVA analysis confirmed significant differences in density among mixtures, highlighting the impact of composition on density of  $p = 0.032307$ . This suggests that the raw material proportions directly influenced how tightly the briquette components could pack together. Denser materials or mixtures with better compactibility such as those with less fibrous content tend to result in higher density briquettes. Hence, slight variations in the proportions of raw materials can significantly influence the resulting density of the briquettes. The moisture content of Mixture 2 (2.905%) is the lowest, which is a positive factor for efficient combustion, as lower moisture content typically results in more effective burning. Mixture 1 (4.67%) and Mixture 3 (4.878%) have slightly higher moisture levels but are still relatively low, meaning they should still burn fairly well. This low moisture content across the mixtures suggests good combustion characteristics for all three briquettes. The ANOVA analysis confirmed significant differences in moisture content of  $p = 0.000062$  which indicates that the variation in moisture content among the mixtures can be attributed to the differences in the composition of raw materials used.

The water boiling test showed that the three briquette mixtures had relatively similar boiling times: Mixture 1 recorded an average of 11.762 minutes, Mixture 2 at 12.565 minutes, and Mixture 3 at 11.547 minutes. These findings suggest that the combustion efficiency of the briquettes, as measured by their ability to boil water, does not vary significantly across the different formulations. The ANOVA analysis shows  $p = 0.392106$ , which indicates that there is no statistically significant difference in boiling performance among the three mixtures. These results imply that all three briquette compositions perform similarly in terms of combustion efficiency. Thus, the variation in boiling time is likely due to normal experimental variability, not due to the composition of the mixtures. The ash content of the three briquette mixtures was found to be considerably high, with Mixture 1 exhibiting an average ash content of 40.727%, Mixture 2 at 39.222%, and Mixture 3 reaching 44.296%. These values suggest that a substantial portion of the briquette material does not undergo complete combustion, resulting in increased post-combustion residue. High ash content is generally undesirable, as it indicates lower energy conversion efficiency. The ANOVA analysis yielded a  $p$ -value of 0.141067 which suggests that the observed differences in ash content among the three mixtures are not statistically significant, and therefore, likely due to experimental variation rather than actual differences in formulation. Thus, while the ash content is high across all mixtures, no single formulation demonstrated a significantly better performance in terms of minimizing ash production.

The burn rates for all three mixtures are relatively low, with Mixture 1 at 64.043 minutes, Mixture 2 at 75.125 minutes, and Mixture 3 at 82.62 minutes. All three mixtures burn at a slower rate than other types of briquettes, which could be

considered advantageous for longevity but may affect heat intensity. The ANOVA analysis for burn rate confirmed that there are significant differences in burn rates of  $p = 9.0225E-15$ . This indicates that although all trials were conducted under similar and controlled conditions, several factors, such as the temperature and weather on the day of the experiment was done may have affected the results. The Shatter Resistance Index (SRI) of the three briquette formulations demonstrated minimal variation, with Mixture 1 yielding an average value of 90.694%, Mixture 2 at 92.486%, and Mixture 3 at 92.432%. These values indicate that all three formulations possess a high degree of mechanical durability, showing strong resistance to breakage or fragmentation when dropped. The ANOVA analysis with a p-value of 0.199975 indicated that there is no statistically significant difference in the shatter resistance index across the different briquette mixtures.

#### REFERENCES

- [1] ASTM 6347/6347M-05. Standard Test Method for Determination of Bulk Density in the Analysis Sample of Coal.
- [2] ASTM D3173-11. Standard Test Method for Moisture in the Analysis Sample of Coal
- [3] ASTM D3174-8943. Standard Test Method for Ash in the Analysis Sample of Coal.
- [4] Davies, Rotimi Moses, and Davies, Onome Augustina. (2013). Physical and Combustion Characteristics of Briquettes Made from Water Hyacinth and Phytoplankton Scum as Binder. *Journal of Combustion*, 2013, 1 – 7. Retrieved September 2024.
- [5] Galadima, Zakka A., Shaibu, Momoh, Mohammed, Zakari S., Onoja, Emmanuel, & Samaila, Abdullahi. (2024). Utilization of groundnut shells for the production and characterization of Bio- Briquettes for household cooking. *Asian Journal of Science and Applied Technology*, 13(1), 46–50. Retrieved September 2024 from <https://doi.org/10.70112/ajsat-2024.13.1.4232>
- [6] Hassan, L., Sani, Na, Sokoto, Abdullahi, & Tukur, U. (2018). Comparative Studies of Burning Rates and Water Boiling Time of Wood Charcoal and Briquettes Produced from Carbonized *Martynia annua* woody Shells. *Nigerian Journal of Basic and Applied Sciences*, 25(2), 21. Retrieved September 2024 from <https://doi.org/10.4314/njbas.v25i2.4>.
- [7] Kuranc, Andrzej, Stoma, Monika, Rydzak, Leszek, & Pilipiuk, Monika. (2020). Durability Assessment of Wooden Pellets in Relation with Vibrations Occurring in a Logistic Process of the Final Product. *Energies*, 13(22), 5890. Retrieved October 2024 from <https://doi.org/10.3390/en13225890>
- [8] Patel, Sanjay, Das, Devashish, Kim, Sun Chang, Cho, Byung Kwan, Kalia, V. C., & Lee, Jung-Kul. (2021). Integrating strategies for sustainable conversion of waste biomass into dark-fermentative hydrogen and value-added products. *Renewable 69 and Sustainable Energy Reviews*, 150, 111491. Retrieved September 2024 from <https://doi.org/10.1016/j.rser.2021.111491>
- [9] Tarroza, Celweea, (2024). Paper and Powdered Charcoal as Raw Materials for Briquette Production. Retrieved October 2024.
- [10] Torres, Michael V., & Aberilla, Jhud Mikjail O. (2024). Environmental Sustainability Assessment of banana peel briquetting. *IOP Conference Series Materials Science and Engineering*, 1318(1), 012027. Retrieved September 2024 from <https://doi.org/10.1088/1757-899x/1318/1/012027>.
- [11] Velusamy, Sampathkumar, Subbaiyan, Anandakumar, Kandasamy, Senthilkumar, Shanmugamoorthi, Manoj, & Thirumoorthy, Pradeep. (2021). Combustion characteristics of biomass fuel briquettes from onion peels and tamarind shells. *Archives of Environmental & Occupational Health*, 77(3), 251–262. Retrieved September 2024 from <https://doi.org/10.1080/19338244.2021.1936437>
- [12] Zhang, Chengliang, Xu, Tong, Feng, Hualiang, Chen Shaohua. 2019. Greenhouse gas emissions from landfills: A review and bibliometric analysis. *Sustainability*. 11(8):2282. Retrieved September 2024 from <https://doi.org/10.3390/su11082282>.