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Coly Briq: Biomass Briquette Made from Water Hyacinth (*Eichhornia crassipes*) and Coconut (*Cocos nucifera)* Shell as an Alternative Fuel

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ABSTRACT

This study aimed to address the issue of the depletion of natural resources and the pollution caused by biomass waste by utilizing water hyacinth and coconut shells as an alternative fuel. The study sought to determine the best percentage of charcoal briquettes between water hyacinth and coconut shells and identify the difference between conventional briquettes in density, moisture content, ash content, volatile matter, and calorific value. Three set-ups were prepared consisting of three ratios of fine charcoal powder between water hyacinth and coconut shells were used which are Set-up A 75% water hyacinth and 25% coconut shells, Set-up B composed of 50% and 50% of both materials and Set-up C consisting of 25% water hyacinth and 75% coconut shells, with a cornstarch binder of 10% of the weight of each sample, approximately 30g, produced with a compaction pressure of 2 metric tons in a hydraulic press. The quantitative method, specifically the true experimental design, utilized simple random distribution with 25 samples per set-up. Descriptive statistics was used to analyze the results of the study. In comparing the best set-up briquette in each variable and the conventional briquette, the results show that set-up C, with an ash content of 20.5% and calorific value at 5,033 cal/g, and set-up B's moisture content at 1.90%, shows better properties compared to the conventional briquette. The findings show that water hyacinth and coconut shells are viable alternative fuels for briquettes. The implication highlights the need for future researchers to improve temperature control during carbonization and the mixing techniques for briquetting, as exploring other methods could improve the production process.

Keywords: alternative fuel, biomass, briquette, coconut shell, water hyacinth

Natural resources are essential for survival as they provide clean air, water, and soil for production. However, over-utilization of resources such as forests, minerals, and water can result in pollution, loss of biodiversity, and soil erosion (Huo & Peng, 2023). The production of wood products such as wood fuel or charcoal is a significant cause of deforestation, leading to the depletion of natural resources. Charcoal, primarily wood-made, is commonly used for grilling in domestic barbecues or charcoal restaurants. Charcoal can emit harmful chemicals like carbon monoxide, nitrogen oxide, particulate matter, and toxic metals, posing environmental and health risks to the community (Mencarelli *et al.,* 2023). Briquettes can be a potential alternative to charcoal. Briquettes are compact blocks of organic waste materials or biomass commonly used for heating and cooking. Biomass is compressed through briquetting to create a denser fuel, which can be utilized as a solid fuel like firewood and charcoal (Oladeji, 2015).

Water hyacinth (*Eichhornia crassipes*), also known as water lily in the Philippines, is considered the world's most invasive aquatic weed due to its ability to grow and spread rapidly (Bote *et al*., 2020). It can multiply within 5-15 days through both sexual and asexual reproduction (Dersseh *et al.,* 2019). Water hyacinth results in water pollution and is a significant problem rooted in human and natural factors, which causes harmful effects on human health and the ecosystem, (Lin *et al.,* 2022). Due to its invasive nature, bodies of freshwater are clogged by water hyacinths. As a result, it decreases the oxygen-level for aquatic animals and causes disease-carrying mosquitoes to find a suitable condition for their egg production, affecting human health and the ecosystem negatively (Wang, 2022). However, a recent study by Mibulo *et al.* (2023) shows that water hyacinth can be utilized as an energy source along with different biomass. The result of the study shows that water hyacinth has a low moisture content that is appropriate for making briquettes.

The process for producing this type of biofuel has not been discovered and if invented could improve operation in many industries by ensuring a reliable fuel source. Automating briquette manufacturing could provide many industries with sustainable fuel sources like the maritime industries. The maritime industry and shipping companies produce large amounts of carbon emissions containing sulfur and other harmful chemicals that could pollute the atmosphere on a massive scale (Wilcox, 2024). It is expected that this special type of briquette could provide a less polluting alternative.

Furthermore, coconut shells (*Cocos nucifera)*, a byproduct of processing various coconut products such as water, milk, and oil, are biomass waste that can be converted into a briquette. A recent study by Kabir Ahmad *et al.* (2021) shows that coconut is a widely grown agricultural product in tropical countries. This study explains that using coconut shell biomass as a fuel source has many benefits due to its unique characteristics. One significant advantage is that coconut shells have a higher energy value than other biomass types.

The rising demand for alternative fuel sources has led to various studies on biomass briquettes made from agricultural and organic waste. While most of the existing studies have been conducted to examine the properties of biomass briquettes, however, only a few have compared them to conventional briquettes in terms of density, moisture content, ash content, volatile matter, and calorific value. In addition, there are limited findings on the issue of carbonization and mixing that affect the quality of the briquette.

Lastly, this study seeks a more sustainable biomass briquette alternative by finding the appropriate percent ratio of the mixture of water hyacinth and coconut shell charcoal powder. This study will also analyze the properties of the biomass briquette with the conventional briquettes. The study highlights the structural production obstacles of briquettes and also recommends approaches to fill the gap for future research work toward the development of biomass energy.

REVIEW OF RELATED LITERATURE AND STUDIES

Biomass Briquettes. According to National Geographic (2022), biomass is made up of organic matter that comes from plants, animals, and excretory waste from other living things. Briquettes represent a kind of fuel obtained from biomass wastes pressed together to create more sustainable coal (Marreiro *et al*., 2021). Aynharan *et al.* (2024) showed that biomass briquettes are an eco-friendly way to produce clean and renewable energy. The U.S. Energy Information Administration (2022) and Wang *et al*. (2022) further describe biomass briquettes as clean renewable fuels which are carbon-neutral energy sources with carbon emissions less than those of normal coal. Briquettes hence produce a net-zero carbon dioxide emissions balance. Biomass fuels are shown to be more sustainable and cheaper than fossil fuels and coal made from wood.

The dependent variables used in this study to determine the quality of the briquette included density, moisture content, ash content, volatile matter, and calorific value. Abimbola *et al.* (2020) described density as how tight a substance is in a volume. Moisture content is the water content in a fuel. Water present in fuel lowers its energy efficiency, hence a lower moisture content is preferred (Sunardi *et al.,* 2019). Ash content refers to the inorganic residue that remains after the briquette has burned entirely and this affects the briquette's combustibility (Saeed *et al.*, 2021). Volatile matter refers to gases like oxygen which evaporates once the briquette is ignited. A higher volatile matter content enables a briquette to ignite faster (Ajimotokan *et al*., 2019). The calorific value is the amount of heat energy released when the briquette is burning (Arifianti *et al*., 2020). The above properties can be used as bases for evaluating the quality and suitability of a briquette as an alternative for fuel.

Water Hyacinth. Water hyacinth (*E. crassipes*), is an abundant invasive aquatic plant located mostly in tropical and subtropical parts of the world. It causes negative environmental impacts and is reported to cause water pollution worldwide. Lubembe *et al.* (2024), described that the widespread infestation of water hyacinth in different parts of Africa greatly threatens environmental conservation, socio-economic development, and public health in the infested areas. De Vera-Ruiz (2020) discussed in Manila Bulletin the water hyacinth invasion in the Pasig River.

Most waste materials collected at the river site are household and water hyacinths that float into the place from Laguna de Bay. Thus far, no policies have ever been implemented effectively against the invading water hyacinths.

Studies show that water lily can be used for producing briquettes due to its high growth yield and abundant availability. Additionally, converting water hyacinth biomass into briquettes is also a more environmentally friendly process, as co-firing it with coal can reduce greenhouse gas emissions (Harun *et al*., 2021). Water lily is also known for its many uses such as fertilizer, in paper production, in medicine, as a source of bioenergy, in wastewater treatment, and as animal feed (Amalina *et al*.., 2022).

Sukarni *et al.* (2019) said that water hyacinth can become a material for biomass production as water hyacinth (on a dry basis) has a high volatile matter of 64.4%, which means that the briquette is susceptible to reactivation during the combustion process. Onyango *et al.* (2020) showed that water hyacinth has components of cellulose and hemicellulose that can be converted to sugars, which can then be used for generating energy, like biofuel briquettes.

Kpalo *et al.* (2020) described binding as adding of a substance to the biomass to compact it and provide more stability. Binding also reduces the tensile stress to better consolidate the biomass constituents. Sinha *et al*. (2019) described pressing as using hydraulic press, roller press, screw extrusion press, and piston press (Sanjit, 2019). The materials are molded into shapes and densified to create the prepared shape of the briquette. Finally, the briquette is dried, which removes any excess moisture (Mappoji, 2022). Due to its formation from organic matter and being carbon neutral, biomass has emerged as one of the most potential renewable fuels and recommendation for a source of briquette production. Burnt biomass, when used as fuel, does not contribute to atmospheric emissions, unlike fossil fuels. Additionally, the biomass briquettes need to undergo testing with the following qualities: density, moisture content, ash content, volatile matter, and calorific value.

Coconut Shells. Coconut (*C. nucifera*) is primarily grown in tropical regions worldwide. Coconut is primarily produced in countries such as the Philippines, Indonesia, India, Malaysia, Hawaii, Africa, South America, the Pacific islands, and other regions with tropical climates. Globally, coconut production spans nearly 10 million hectares across 92 countries, with Asian countries contributing 75% of the total production (Kabir Ahmad *et al*., 2021). Moreno *et al.* (2020) state that the Philippines is the second biggest producer of coconuts globally. The country's central area for coconut production is in Mindanao, particularly the Davao Region, Northern Mindanao, and Zamboanga Peninsula. Coconut shell waste yields an annual production of 62.5 million tons and is most prevalent in over 90 countries across the globe (Azeta *et al*., 2021). Coconuts are one of the promising materials for briquette production since it has a very high calorific value. Siharath *et al.* (2024) put the calorific value of coconut shells 6,683 MJ/kg, and their ash content at about 77 g. give them higher potential as briquette compared to bamboo and mixed charcoal.

Briquetting. Briquetting is described as the collection of biomass, carbonization, adding binder agents, and compressing with pressure. It involves the process of converting organic waste materials into compressed blocks called briquettes. Kpalo *et al*., (2020) mentioned common use of briquettes in the domestic and industrial sectors. Yunusa *et al.* (2020) enumerated the processes of briquetting as carbonizing, grinding, sieving, compacting, and drying. Malini *et al.* (2023) described carbonization as the process of heating the materials and preventing oxidation to convert them to carbon-based contents. There is also removal of components other than carbon from their carbon-based structure. Marreiro *et al*. (2021) included grinding of the wastes where the biomass materials are pulverized using the sieving method.

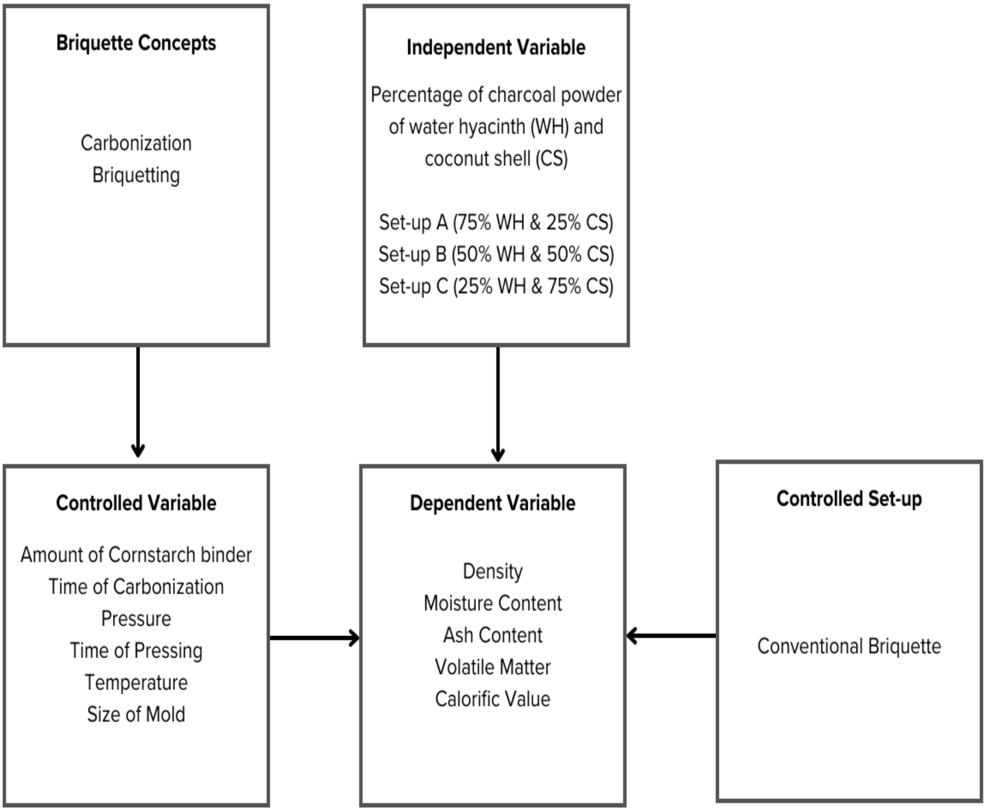
Recent studies claimed that water hyacinths and coconut shells are the possible materials that can undergo the briquetting process. The utilization of water hyacinth and coconut shells can reduce environmental pollution with water hyacinth and reduction of wastes by coconut shells.

Conceptual Framework

Briquette properties are based on variable factors. For instance, Abimbola *et al.* (2020) attributed to density which is the concentration of the mass of some material in a given volume, the hardness of the briquette which in turn contributes to the maintenance of the shape of the briquette. Moisture content, according to Carnaje *et al*. (2018) is the quantity of water within the material. Carnaje *et al.* (2018) further showed that lower ash residue after combustion indicates higher combustibility of the material. Sunardi *et al.* (2019) showed that volatile matter significantly influences which is of course important for combustion efficiency. Suryaningsih *et al.* (2017) defined calorific value as the quantity of heat given off by a particular mass of material when combusted at constant pressure in a bomb calorimeter.

Density, moisture content, volatile matter, and calorific value are the properties used to evaluate the efficiency of the biomass in this study. Water hyacinths contain high cellulose content that is responsible for the high combustion efficiency and reactivity of briquette (Onyango *et al*., 2020). Coconut shells produce a higher calorific value that could further elevate the energy fuel of the briquette (Anggita *et al*., 2023).

Figure 1
Conceptual Framework



Research Objectives

The general objective of the study is to determine whether water hyacinth and coconut shells are viable source of alternative fuel based on their qualities.

The specific objectives are:

1. To determine the best ratio from among the following set-ups: Set-up A (75% water hyacinth and 25% coconut shell), Set-up B (50% water hyacinth and 50% coconut shell), and Set-up C (25% water hyacinth and 75% coconut shell) that would yield optimum values for Density (g/cm^3), Moisture Content (%), Ash Content (%), Volatile Matter (%) and Calorific Value (cal/g)

2. To compare the set-up with the best ratio to the conventional briquettes in terms of the above-mentioned parameters

Significance of the Study

The use of briquettes from organic waste, specifically biomass briquettes made from water hyacinth and coconut shells contributes to efforts to address the need for sustainable and cost-effective heat energy production. People from provincial areas are the primary beneficiaries due to their need for affordable heating. The briquettes could provide a sustainable solution to their prevalent problem. The researchers' biomass briquettes will benefit business owners in the food industry, particularly those who rely on charcoal for grilling and cooking. Lastly, the researchers aim to contribute to the knowledge gaps by providing data on the optimal ratio of water hyacinth and coconut shell for efficient combustion and to be a foundation for future studies for the production of briquettes.

Scope and Limitation of the Study

Some factors were beyond the control of the researchers such as temperature, weather, and mixing of the powdered charcoal. The temperature from the fire used in carbonization was unstable and the primary materials were exposed to high heat levels. Weather conditions, which affect the sun-drying process of biomass vary with each day. Achieving a uniform distribution of powdered charcoal was challenging. Therefore, some briquettes did not maintain the intended ratio of water hyacinth and coconut shell charcoal as the fine charcoal particles did not mix evenly. This inconsistency in the mixing process may have affected the accuracy of the briquette compositions, resulting in variations in their properties and performance.

Other variables such as burning rate and emission levels were excluded from this study due to limited samples, materials, and time. The decision to focus on the selected parameter was made to keep the study manageable within the available resources, while still addressing the important variables influencing the briquette’s quality. In conclusion, the chosen dependent variables are sufficient to provide data on the briquette’s quality to be used as an alternative.

MATERIALS AND METHODS

The main focus of this research is to determine the effectiveness of the two primary materials of alternative briquette, using water hyacinth and coconut shell, with the following dependent variables: density, moisture content, ash content, volatile matter, and calorific value. The research was carried out within 2-3 months for the making and testing of the prototype. The testing was conducted at the University of the East-Caloocan Engineering Building and availed a testing service provided by the Department of Energy (DOE).

Research Design

This study used a true experimental design with an experimental group that involved different set-ups of percentages of water hyacinth and coconut shells charcoal, and a control group consisting of the conventional briquette.

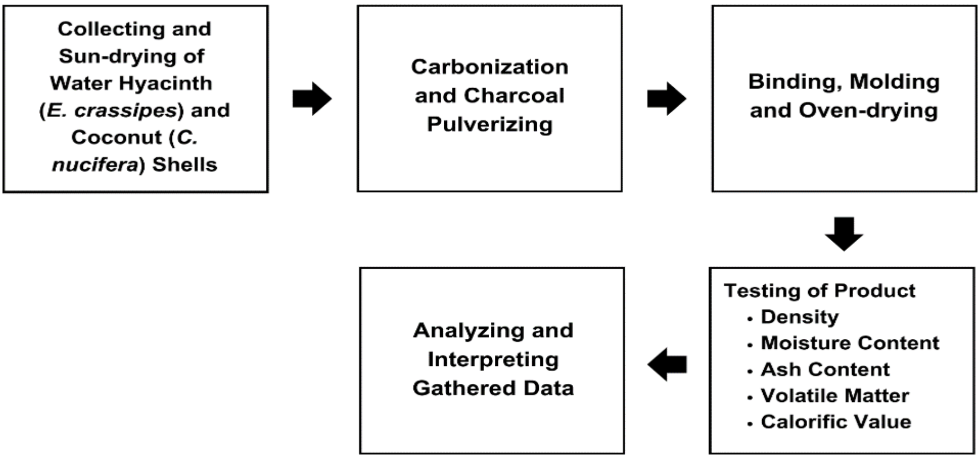
Sample and Population

This research analyzed a total of seventy-five (75) samples with an average weight of 30 grams each. Fifty-one (51) samples were used to test for the DOE (Department of Energy) testing services, while nine (9) were used in the University of the East-Caloocan Engineering Building for testing the density. Simple random sampling was used to determine the best percentage of water hyacinth and coconut shells briquettes and compared them to conventional briquettes.

Data Gathering Procedure

The procedures used are shown in Figure 2 that included collecting the biomass materials to interpreting the data results.

Figure 2
Flowchart



Carbonization and Charcoal Pulverizing. The chopped biomass materials were placed in a kiln drum measuring 40 cm x 50 cm (Markham, 2019). The biomass materials underwent carbonization individually at a 300°C temperature, which is the temperature when lignin decomposition starts (Anggita *et al*., 2023). Carbonization is crucial in converting biomass into charcoal. The charcoals were ground with an electric mixer and sieved through a 40-mesh sieve to eliminate large particles for briquette compacting (Sirun *et al*., 2018). The water hyacinth was carbonized for 1 hour as recommended by Pramadhana *et al*. (2019), while the coconut shell for 4 hours following Tanko *et al.* (2020). To calculate the percent by mass for each configuration, the pulverized charcoal was weighed using an analytic balance.

Binding, Molding, and Drying. Cornstarch which has high adhesive properties was used to bind and strengthen the briquette. A 10% binder was used as recommended by Zanella *et al*. (2016). The binder solution was made by a 1:5 ratio of cornstarch and water mixed to form a gelatinized starch solution (Zubairu & Gana, 2014). Starch was mixed with the powdered charcoal. Once the ideal consistency is reached, the mixture was poured into a metal pipe with a dimension of 30mm and 85mm, and then two plungers with a height of 10mm and 25mm between the cylinder, were used to enclose the fine charcoal inside. Finally, the molder is pressed using a hydraulic press at 2 metric tons. The size of the biomass briquette was 30mm-50mm following Waluyo *et a.l*. (2018). Following Okwu and Omonigho (2018), the briquette was molded in a hydraulic press for 5 minutes and then dried using a convection oven for 2 hours at 105° C to eliminate excess moisture and improve combustion qualities.

Testing

Four dependent variables, specifically moisture content, ash content, volatile matter, and calorific value, were lab-tested by the Energy Research and Testing Laboratory Services (ERTLS) Department of Energy (DOE), using one trial per test.

Figure 3
DOE ERTLS Logo

Figure 4
Testing for Density

Density. A dial caliper was used to determine the diameter and height of the briquette as well as its volume. The volume was determined using the following formula.

Equation #1
Volume Formula:

$$Volume = \pi\left(\frac{diameter\ of\ the\ briquette\ (cm)}{2}\right)^2 x\ height\ of\ the\ briquette\ (cm)$$

Density was determined once the volume was determined. This equation utilizes the briquette's volume and weight. The measured weight proves the calculation of the briquette's density using the equation by Ambiola *et al*. (2020).

Equation #2
Density Formula:

$$Density = \frac{mass\ of\ the\ briqutte\ (g)}{volume\ of\ the\ briquette\ (cm^3)}$$

Sample Preparation for DOE. Based on DOE's sample preparation, ISO 5069 was used to sieve the sampled briquettes. The sample briquettes were crushed and refined through a 60-mesh sieve and placed in an air-tight bag or ziplock, as required by the DOE before testing.

Moisture Content. The DOE used ISO 5068:1983 to find the briquette's moisture content. Following the DOE's Manual for Coal Analysis (2018), 1.0 g of the sample was weighed and placed in a vessel and then in a nitrogen oven with a non-corrosible tray. The nitrogen gas was emitted by opening the valve on the gas cylinder and slowly adjusting it to achieve a pressure of 0.4 bar and was opened at a flow rate of 300 cc/min. The sample was then exposed to nitrogen gas for 30 minutes. Then, the samples were dried for 1 hour at 110°C and were cooled for 15 minutes in a desiccator. Lastly, the sample was weighed, and the percentage of moisture content was calculated using the formula below.

Equation #3:
Moisture Content Formula

$$\%\,Moisture = \frac{Final\ weight\ of\ the\ sample\ (g)}{Initial\ weight\ of\ the\ sample\ (g)}\ x\ 100$$

Ash Content. Ash content of the set-ups was determined using the instruction from DOE based on ISO 1171: 2010, and the preparation method based on DOE, 2018. The crucible was first preheated for one hour in an electric furnace to at least 815℃ and left in the desiccator for 15 minutes before the crucible was used. One (1) gram of the sample was then placed in the crucible and was placed in a cold ash furnace at 815℃ for 4 hours. Finally, it was put inside a desiccator for 15 minutes and was weighed and calculated by using the formula given below.

Equation # 4

Ash Content Formula

$$\% Ash = \frac{Final\ weight\ of\ the\ sample\ (g)}{Initial\ weight\ of\ the\ sample\ (g)} \text{ x } 100$$

Volatile Matter. The DOE used ISO 562:2010 for testing the volatile matter. Following the DOE's Manual to determine volatile matter, 1g of the sample was placed in in a crucible and placed in the muffled furnace at 900°C for 7 minutes. It was then cooled and placed in the desiccator for 5 minutes. Finally, the crucible was weighed, and the percentage of volatile matter was calculated using the following formula.

Equation #5

Volatile Matter Formula

$$\% VolatileMatter = \frac{Final\ weight\ of\ the\ sample(g)}{Initial\ weight\ of\ the\ sample\ (g)} x10\} - \% Moisture$$

Calorific value. DOE used ASTM D5865/D5865-19 for determining the calorific value. It is indicated from the manual that a PARR 6200 bomb calorimeter was used. The process would begin with filling the combustion capsule with samples of about 0.8g and was followed by placing about 1 ml of distilled water inside the bomb. To control the water level to 4 inches, a PARR 6510 water handling system was used. Then, the pressure was adjusted to 450 psi in the oxygen tank valve. The combustion capsule was then submerged in the bomb calorimeter which then took over recording and computing the result.

Data Analysis

The researchers used descriptive statistics in describing the results. Data on density, moisture content, ash content, volatile matter, and calorific value setups were summarized and compared. Density is the only parameter included in the mean and standard deviation since multiple trials were made to measure density compared to only one trial conducted for the tests measuring other parameters. Jamovi was used to confirm and analyze the data's validity.

Equation #6

Mean Formula

$$Mean = \frac{Sum\ of\ all\ values\ \ (g/cm^3)}{Number\ of\ values}$$

Equation #7

Standard Deviation Formula

$$StandardDeviation = \sqrt{\frac{\Sigma(Value\ of\ each\ set - Mean)}{Number\ of\ values\ - 1}}$$

Ethical Consideration

Standard procedures were followed and overharvesting of materials was avoided. Machines like carbonizers were used with extreme caution to avoid the production of deadly fumes. Waste disposal was conducted in compliance with the Waste Management Hierarchy which considers the importance of waste treatment in a five-stage plot pyramid, starting with the most favored option, prevention, and ending with the least chosen option, disposal. Safety and ethical practices were adhered to in the conduct of the research.

RESULTS AND DISCUSSION

Table 1 shows the three set-ups with their respective compositions.

Table 1

Percentage by mass per set-up

Set-up	Water hyacinth charcoal	Coconut shell charcoal	Cornstarch Binder
A	75% (506.25 g)	25% (168.75 g)	75 g
B	50% (337.5 g)	50% (337.5 g)	75 g
C	25% (168.75 g)	75% (506.25 g)	75 g

Table 2 below shows the comparison of the density of the three set-ups. Set-up A has the lowest mean of 0.531, while Set-up C has the highest mean of 0.610. This means the briquettes in Set-up C are packed tighter than those in the other set-ups. Based on Bello's (2020) findings, briquettes with higher density tend to burn slower and last longer. This is because higher density limits airflow, reducing the amount of oxygen that reaches the fuel, which slows down the burning process. As a result, Set-up C is likely to have the longest burning time compared to the other set-ups in Table 2.

Table 2
Description of Density per Set-up

Set-ups	Mean (g/cm^3)	SD
A	0.531	0.0411
B	0.594	0.0063
C	0.610	0.0348

Table 3 presents DOE results for moisture, ash, volatile matter, and calorific value. Set-up B has the lowest moisture content at 1.9%, while Set-up C has the highest at 3.2%. High moisture content indicates a great amount of water in the briquettes. A greater amount of water in the briquette makes it harder to reach the right temperature for combustion since the water needs to evaporate first before the burning process effectively begins. According to Carnaje *et al.* (2018), higher moisture percentage usually result in lower combustion efficiency. This implies that Set-up B is expected to have better combustion performance compared to the other set-ups.

Table 3
Description for Moisture, Ash Content, Volatile Matter, and Calorific Value per Set-up

Set-ups	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Calorific Value (cal/g)
A	2.6	53.0	21.3	2206
B	1.9	36.7	20.7	3538
C	3.2	20.5	19.0	5033

For ash content, Set-up C has the lowest at 20.5%, while Set-up A has the highest at 53.0%. Ash is what is left over after the fuel has burned. Lower ash content is preferred because it usually indicates that more of the material has burned away and that the briquettes have more flammable material. Saeed *et al.* (2021) explained that lower ash content often has a higher heating value. This means that Set-up C is expected to produce more heat when burned, making it more effective.

The percentage for the lowest volatile matter is 19.0% in Set-up C, while the highest value is in Set-up A at 21.3%. Volatile matter explains the gases that are released as the briquettes are heated. These gases determine the rate at which briquettes ignite easily. According to Jimoh *et al.* (2016), higher volatile matter is often related to quicker ignition of coal. As a result, it is assumed that Set-up A will have a faster ignition than the other two set-ups.

Finally, for calorific value, the lowest calorific value of 2206 cal/g, was recorded in Set-up A, whereas the highest calorific value of 5033 cal/g, was recorded in Set-up C. The calorific value determines how much heat energy the briquette would produce after being burnt. Akpenpuun *et al.* (2020) has previously shown that the higher the calorific values, the better the burning efficiency. This implies that Set-up C will burn more and for a longer time.

Table 4 below compares the three set-ups in terms of the best properties. Set-up C has the highest density, the lowest ash content, and the highest calorific value. On the other hand, Set-up B has the lowest moisture content. Finally, Set-up A has the highest volatile matter.

Table 4

The Best Overall Properties per Set-up

Set-ups	Density (g/cm^3)	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Calorific Value (cal/g)
A	0.531	2.6	53.0	21.3	2206
B	0.594	1.9	36.7	20.7	3538
C	0.610	3.2	20.5	19.0	5033

Table 5 shows the conventional briquette's quality and the best result for each variable per set-up. The data shows that the density of the conventional briquette is higher than the density of 0.610 g/cm^3 of Set-up C with a density 0.680 g/cm^3. Bello (2020) states that the higher the density of a briquette, the more slowly that briquette will burn and the longer amount of time that it will last. The results suggest that Set-up C still burns slowly and lasts longer despite the slightly lower density. Similarly, Set-up C contains the least ash and highest calorific value. In addition, a high percentage of coconut shells in set-up C with its lowest ash content and high calorific value is similar to the results obtained previously by Kabir Ahmad *et al.* (2021) and Espina *et al.* (2023), because coconut shell is one of the best energy sources due to its high calorific value.

Table 5
Comparison between the Best Set-up per variables to conventional briquette

Set-ups	Volatile Matter (%)	Moisture Content (%)	Density (g/cm^3)	Ash Content (%)	Calorific Value (cal/g)
A	21.3	-	-	-	-
B	-	1.9	-	-	-
C	-	-	0.610	20.50	5033
Conventional Briquette	43.87	3.85	0.680	23.78	3350

From Table 5, Set-up B shows the lowest moisture content, having a higher combustion efficiency than conventional briquettes. Finally, the conventional briquette has the highest volatile matter among the set-ups Additionally, Set-up A, with a 75% percentage of water hyacinth, is consistent with the findings of Sukarni *et al.* (2019), indicating that water hyacinth is prone to a higher ignition rate due to its highly volatile matter.

CONCLUSION

The research examined the qualities of biomass briquettes made from water hyacinth and coconut shells in different ratios and compared to conventional briquettes. The results showed that Set-up C, with 25% water hyacinth - 75% coconut shell, had the best qualities of all set-ups. Set-up C has the highest density (0.610 g/cm^3), the lowest ash content (20.5%), and the highest calorific value (5033 cal/g). In contrast, Set-up B, with 50% water hyacinth - 50% coconut shell, had the lowest moisture level (1.9%), which has better combustion efficiency. Set-up A, which contains 75% water hyacinth - 25% coconut shell, has the highest percentage of volatile matter (21.3%), which ignites easily.

Although the best result in 3 variables was produced from set-up C, the results revealed that both water hyacinth and coconut shells are potential alternative materials in briquette production. The results indicate that the burning time can be prolonged by increasing the coconut shell percentage in the briquette. However, to use these materials and to ensure that these briquettes can be safely used as a sustainable fuel source, the production process needs to be further studied and tested.

The carbonization process should be controlled or specified since it appears that it has impacted the quality of the briquette produced. More emphasis on these could provide more insights to future researchers. Finally, further experimentation, for example, the long-term durability of the briquettes in household applications, and testing possible cooking applications could help establish the briquettes' viability as an alternative option for fuel.

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