HEAT QUANTITY OF DRIED *Cocos nucifera* (COCONUT) SPADIX AS SOLID FUEL (BRIQUETTE)

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ABSTRACT

The production of solid fuels, including wood charcoal, is often associated with environmental impacts, particularly as consumption gradually increases. One of the most widely cited consequences of wood charcoal production is deforestation (Chidumayo et al., 2012). Various studies have been conducted to address these issues by producing sustainable solid fuel briquettes from agricultural waste. However, gaps remain, particularly regarding the heat output and burn time of these solid fuels when ignited. According to Bioresource Technology Reports (2021), solid fuel briquettes are compressed blocks of coal dust or other flammable biomass. The characteristics of coconut *(Cocos nucifera)* spadix make it a suitable candidate for use in solid fuel briquettes. This study aimed to evaluate the heat output and burn duration of coconut spadix as a potential solid fuel briquette. The experiment involved two treatments: Treatment 1 (coconut spadix as a solid fuel) and Treatment 2 (commercial solid fuel). A Completely Randomized Design (CRD) was used for the experimental setup. After 12 days of preparation, the coconut spadix briquettes were tested for heat transfer and burn duration, comparing them to commercial solid fuel. Temperature (°C), weight (g), and burn time (minutes) were measured. Microsoft Excel's Analysis ToolPak was used to calculate means and perform a t-test. The results indicated a significant difference between the two treatments, suggesting a comparable performance.

Background of the Study

The need to use solid fuel is increasing along with energy consumption as the population continues to grow. Solid fuel production, including wood charcoal production, is often perceived to have an environmental outcome as consumption gradually increases. One of the most cited impacts of wood charcoal production is deforestation-the clearance of forest or woodland (Chidumayo E.N. et al., 2012).

Due to the adverse impacts of the traditional way of making charcoal, a variety of studies had been conducted in an attempt to replace wood as a solid fuel. Few of them was the study of Tanko J. et al. (2020), who had evaluated the characteristics of rice husk and coconut shell briquettes as an alternative solid fuel by determining the physical properties of briquettes based on the thermo-physical properties. On the other hand, Tesfaye A. et al. (2022), had studied the characterization of coffee husk fuel briquettes as an alternative energy source. Both studies pointed out the moisture and ash content, calorific value, and the fixed carbon content of the husks they had used as briquettes. However, there were lacking elements that needed to be determined that were not given consideration in both studies, which were the briquettes' duration as a fuel, and the amount of heat collected when being burned.

These characteristics allowed us to assess the briquettes' practical effectiveness as a dependable fuel source. Without them, research gaps continue as the potential of alternative fuels is not fully realized.

To address these research gaps, the researchers decided to conduct this study to determine the heat quantity of dried *Cocos nucifera* (coconut) spadix briquettes as a potential solid fuel. Coconut trees are found everywhere in coastal tropical regions, they are versatile with many uses. For instance, research on other coconut by-products, such as shells and husks, highlighted the significant calorific value of coconut shell and husk, with high lignin content contributing to effective charcoal production (Pathiraja et al., 2015). Similarly, according to Tambunan et al. (2014), coconut shells and husks demonstrated favorable properties for bioenergy, with high energy potential and low ash content. Based on similar lignocellulosic traits, results implied that coconut roots might have valuable fuel qualities. These suggest that more research is necessary to ascertain whether coconut roots are a viable source of renewable energy.

Thus, this study aimed to fill the existing research gaps by examining the heat quantity of *Cocos nucifera* (coconut) spadix briquettes, which had yet to be properly investigated as a viable solid fuel source. Based on the promising qualities of other coconut byproducts, the researchers speculated that coconut spadix might have comparable qualities. This study sought to contribute significant data to the ongoing quest for alternative renewable fuel sources. The findings might have helped global efforts to decrease dependency on traditional wood-based charcoal production and lessen its environmental impacts by providing insights into new sustainable fuel production approaches.

Statement of the Problem

This study aimed to assess the heat quantity of *Cocos nucifera* (coconut) spadix as potential solid fuel (briquette).

Specifically, this study aimed to answer the following questions:

1. What is the time duration for *Cocos nucifera* (coconut) spadix briquettes to last as a solid fuel when being lit?
2. What is the heat quantity (in Calories/gram) of *Cocos nucifera* (coconut) spadix briquettes per kilogram when being tested for water boiling?

3. Is there a significant difference in the heat quantity of dried *Cocos nucifera* (coconut) spadix briquettes and commercial solid fuel when used for water boiling test?

Hypothesis

There is no significant difference in the heat quantity of *Cocos nucifera* (coconut) spadix briquettes compared to commercial solid fuel when measured for boiling water and heat quantity

Conceptual Framework

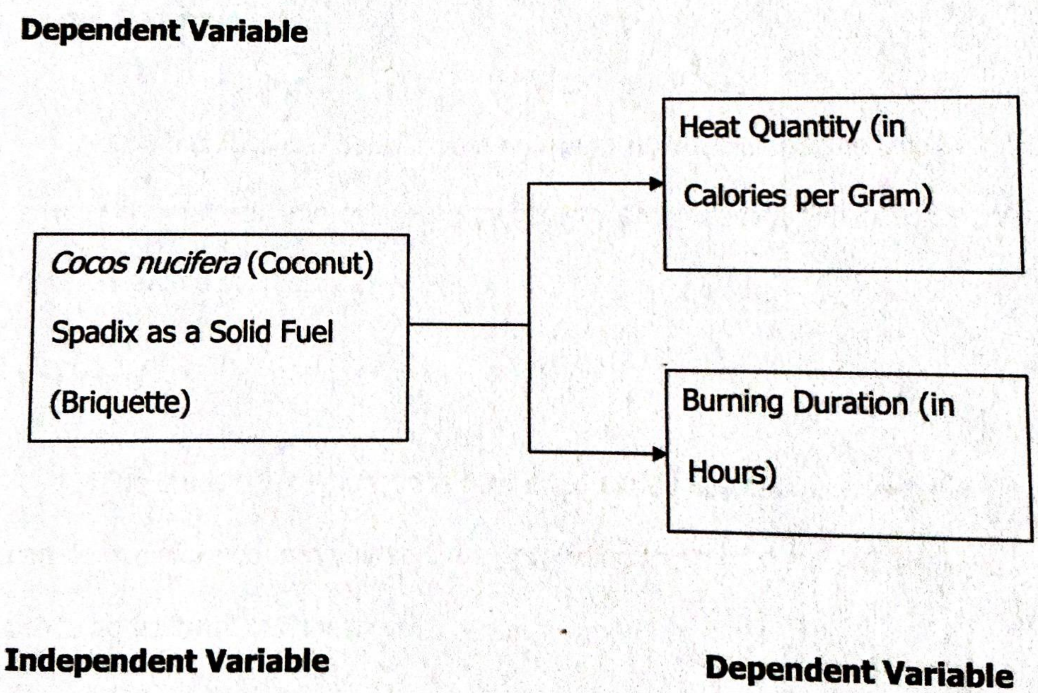

Figure 1.1. Conceptual Framework of the Study

Figure 1.1 illustrates one independent variable and two dependent variables in the study. The independent variable is the dried *Cocos nucifera* (coconut) spadix, which is used to create a solid fuel briquette. The dependent variables, heat quantity and burning duration, are then analyzed based on the characteristics of the briquette.

Significance of the Study

The results acquired in this study will benefit the following:

Local Communities

Communities can benefit from access to affordable and sustainable energy alternatives, improving energy security and reducing dependence on non-renewable sources.

Farmers

The study will demonstrate how dried *Cocos nucifera* (coconut) spadix can be transformed into valuable fuel, providing them with innovative ways to utilize agricultural residues.

Future Researchers

The results of this study can be used as a basis for conducting further studies.

Definition of Terms

For the purpose of clarity and understanding, the following terms were specified with their conceptual and operational definitions.

Heat Quantity. The change of energy due to the energy transport as a result of a purely thermal interaction (National Library of Medicine, 2021).

In this study, heat quantity was referred to the amount of thermal energy released from burning dried *Cocos nucifera* (coconut) spadix briquettes, measured by the calorific value of the briquette.

***Cocos nucifera* dried (coconut) spadix**. The spadix is a stout and erect, its erect axis is enclosed by a tough spathe. It bears both male and female flowers of *Cocos nucifera* (coconut) plant. (TNAU Agritech Portales, Horticulture, 2014).

In this study*,* *Cocos nucifera* (coconut spadix was referred to the part of coconut inflorescence that is a spike-like structure that produces flowers which will be used as a material in making solid fuel (briquette).

Solid fuel (briquette). Are compressed blocks of coal dust or any other flammable biomass, such as peat, charcoal, straw, wood chips, cobs, sawdust, and paper (Bioresource Technology Reports, 2021).

In this study, solid fuel (briquette was referred to as a compact form of *Cocos nucifera* (coconut) spadix designed for use as a fuel source.

Scope and Delimitation

The purpose of this study was to determine the heat quantity of dried *Cocos nucifera* (coconut) spadix as a potential solid fuel (briquettes). The coconut spadices were collected from Barangay Lutac, Cabatuan, Iloilo. This study was conducted at Brgy. Ayaman, Cabatuan, Iloilo from the month of January to March 2025. Materials required for the study included coconut spadix and various apparatuses for the briquette production. The researchers carried out this investigation under the supervision of the research supervisor.

CHAPTER II

REVIEW OF RELATED LITERATURE

This Review of Related Literature consists of the following parts: I.) *Cocos nucifera* (coconut) spadix, taxonomic classification and names, morphological structure, distribution, and related studies. II.) Heat quantity, definition, importance, procedure in testing heat quantity, materials used, and related studies. III.) Solid fuel (briquette), definition, importance, material used, and related studies.

I. *Cocos nucifera* spadix

Morphological structure. The woody spathe, which is 70-100 cm long, splits lengthwise to reveal the spadix. Each spadix has 40-60 branches or spikelets that bear the flowers along a main axis that is 1-1.5 meter long. Three female flowers are carried at the base of each spikelet, while many hundred male flowers are carried above (Australian Tropical Rainforest Plants 2020). Stout and upright, the spadix is surrounded with a strong spathe that divides when the inflorescence is grown. The inflorescence's axis is branching, and the branches bear both pistillate and staminate sessile flowers (Horticulture, 2014). Coconut palms produce spadices from leaf axils, with the number of female flowers varying from 10-50 per inflorescence. The spadix is stout and erect, enclosed by the tough spathe which splits when inflorescence is mature. This varies from variety to variety and agroclimatic conditions (ResearchGate 2017).

Distribution. *Cocos nucifera* (coconut) spadix, *Cocos nucifera*, also known as coconut palm, is a tall tree native to tropical islands in the western Pacific. It is commonly planted in frostfree areas worldwide, including coastal areas, beaches, parks, residential yards, and golf courses. The palm has a single-trunked trunk with a crown of green fronds and fragrant yellow flowers (Plant Finder n.d.). Davao Region was the top producer of coconut in Q3, with 461.07 thousand metric tons. Northern Mindanao and Zamboanga Peninsula followed with 13.3% and 12.8% respectively. From January to June, coconut planting increased by 0.6%. (Philippine Statistics Authority 2023). The coconut palm (*Cocos nucifera* spadix) is native to the coastal regions of tropical Asia and the Pacific. Its primary center of origin is the subject of speculation, but it is widely distributed in all tropical and subtropical regions, thriving along shorelines where it can establish itself on sandy and coralline coasts (Ohler J., & Magat S. 2024).

Chemical constituents. A well-known agricultural byproduct, the *Cocos nucifera* (coconut) shell is distinguished by its high carbon (C), low ash level, and volatile content. *Cocos nucifera* (coconut) shell has a low moisture content (7.67%), which makes it a good fuel for combustion applications with the potential for increased performance. Additionally, since higher heat produced during combustion results in higher temperatures in a variety of thermal applications, its higher calorific value suggests favorable properties for combustion. With a high carbon (C) content that makes it appropriate for combustion operations, the elemental composition of *Cocos nucifera* (coconut) shell, as determined by final analysis utilizing the multilinear regression approach (MR model) equations, closely connects to the heat of combustion. (Preeti et al., 2024) *Cocos nucifera* (coconut fiber is a completely natural material derived from the mesocarp tissue of the coconut palm, composed of cellulose, hemicellulose, and lignin. It is known for its high mechanical strength, low density, and excellent natural durability. The fiber is resistant to rodents and insects, does not decay when dry, and is unaffected by fungi. *Cocos nucifera* (coconut) fibers are classified under fire protection class B2, meaning they are considered normally flammable. As a result, they are unsuitable for projects requiring high fire resistance. However, coconut fiber insulation is effective at regulating moisture, helping to prevent mold growth (Alcequiez, 2021).

Coconut shells exhibit promising characteristics for thermochemical conversion, particularly for charcoal production. They possess a high density (412 kg/m3), calorific value (19.4 MJ/kg), and volatile matter content (70.8%), making them an efficient fuel source. Additionally, their low moisture (5.6%), ash (1.8%), and heavy metal content eliminate the need for pre-treatment, making them ideal for direct conversion. The coconut shell's unique structure, containing both amorphous and crystalline carbonaceous materials, combined with its high surface area and porosity, makes it suitable for various applications beyond charcoal, including activated carbon, insect repellent, and fillers. These remarkable properties position coconut shells as a valuable, carbon-rich, and environmentally friendly alternative energy source compared to other biomass and coal materials (Ahmad et al., 2021).

Related studies. This study analyzed the fuel properties of briquettes made from coconut husk, Bitanghol-sibat bark, and their blends (90:10, 80:20, and 70:30). Coconut husk briquettes had higher volatile matter (37.13%), aiding ignition, while Bitanghol-sibat bark briquettes showed better fuel properties, including lower moisture (1.4%) and ash content (13.52%), higher fixed carbon (56.78%), and greater energy value (5168 Kcal/kg). Blended briquettes, particularly the 70:30 ratio, performed best, combining coconut husk's ignition potential with the bark's higher carbon content. This blend had lower moisture, ash, and sulfur, higher calorific value, and reduced environmental impact, demonstrating coconut husk's value in enhancing briquette fuel properties (Mendoza et al., 2020).

The study evaluates the combustion properties of briquettes made from coconut husk and male inflorescence of Elaeis guineensis in Nigeria. The experiment uses three particle sizes of coconut husk, oil palm tree male inflorescence, and cassava starch as binder. The results show that the briquettes with the least fixed carbon (6.5%) have better performance. The highest percentage of volatile matter (74.6%) comes from the coconut husk, male inflorescence, and starch, while low fixed carbon (18.8%) comes from the male inflorescence and starch (Lawal et al., 2019).

The study explores the use of coconut husks as a sustainable alternative to traditional charcoal. With tropical production increasing, there is a surplus of unused coconut husks, offering a potential alternative. The study evaluated the physical and chemical properties of coconut husk charcoal, comparing it with conventional charcoal. The experimental methodology produced two types: briquettes and flakes. The results showed that coconut husk charcoal maintains fire intensity and reduces greenhouse gas emissions, making it a viable and sustainable alternative (Bitos., R., et al., 2024).

II. Heat Quantity

Definition. Specific heat capacity (Cp) refers to the heat required to increase the temperature of one unit weight by one degree Celsius without changing its phase, measured in J/(kg•°C) or 3/(kg K) for pavements (Sreedhar & Biligi, 2016). It denotes the energy needed to alter the temperature of a mass unit by one degree (Sadeghinezhad et al., 2016). While there has been minimal research focused on the specific heat capacity of graphene nanofluid, methods such as calorimetry and differential scanning calorimetry (DSC) are utilized to measure it in other materials like pultruded FRP. These techniques differ in sample size and offer insights into how specific heat capacity can vary with temperature. According to physical theory, the specific heat capacity generally increases with temperature due to the relationship between heat and atomic vibrations in the material's lattice structure (Corrie et al., 2015).

Importance. Heat capacity is a critical parameter across various fields, enabling efficient energy use and temperature regulation. In thermal energy storage systems, materials with high heat capacity, like water and phase change materials, store and release heat to enhance renewable energy use and reduce reliance on fossil fuels. It is essential in temperature regulation for designing efficient HVAC systems and industrial temperature control. In calorimetry, heat capacity helps measure heat changes in chemical reactions and phase transitions, aiding in thermodynamic studies. In climate science, the oceans' high heat capacity regulates global climate patterns and energy distribution, crucial for climate modeling.

Additionally, heat capacity is used in material characterization techniques like Differential Scanning Calorimetry to identify and analyze materials in fields such as materials science and geology (Fei, 2023). It is also stated that specific heat capacity is a significant criterion for designers when developing reactors and cooling systems. The findings of specific heat capacity might indicate the samples' average heat capacity as a function of temperature. DSC measurement is a rapid and straightforward method for assessing a material's specific heat capacity (Asim et al., 2015). The determination of heat capacity is vital since it is a key metric in predicting heat transfer capacity (Mercan et al., 2022). In nanofluid applications, specific heat capacity can decrease or increase depending on the particle and the kind of base fluid.

Procedure in testing heat quantity. To determine the calorific value (Q) of briquette fuel, start by weighing the mass of the briquettes and preparing one liter of water. Ignite the briquettes on a briquette stove and place a pan containing the water on the stove. Record the temperature of the water and the coals every two minutes until the water boils and reaches its maximum temperature. Continue recording until the briquettes are completely burned.

Finally, measure the mass of the remaining ash and the water after the boiling process (Ajinomotokan et. al., 2019). Each substance has a different heat quantity to increase the temperature of a certain mass. The calculation of heat given to substances as shown in equation (3).

(3) Q= m•c (t2-t1)

where: Q is calories needed (J, m is mass (kg), c is specific heat capacity (l/kg•C) and (t2-t1) is the temperature difference (4 C).

In addition, a Water Boiling Test (WBT) was conducted to compare the efficiency of selected briquetted samples and charcoal in heating water. A stopwatch was used to measure the time (t_b) taken for the water to reach 100°C, starting from the moment the briquettes ignited. A thermometer was used to monitor and record temperature changes. This test helped determine the optimal and most efficient fuel source based on heating performance (Oladosu et al., 2023).

Materials used. To determine the calorific value (Q) of briquettes, the materials and tools required include briquettes (made from a mixture of rice husk, corn cob, or other biomass), one liter of water, a briquette stove, a pan to hold the water, a thermometer to measure the temperature of the water and coals, and a weighing scale to measure the mass of the briquettes and the ash. These items are used to conduct the boiling and combustion test, allowing for the calculation of the heat energy released during the process (Ajinomotokan et al., 2019). To analyze the important properties of biomass and charcoal briquettes, the materials and tools required include briquettes (made from a mixture of wood waste and charcoal), a briquette stove, a weighing scale, and a thermometer to measure the temperature of the briquettes and surrounding environment. Starch is used as a binder for charcoal briquettes. The moisture content, ash content, volatile matter, and calorific value of the briquettes are measured using standard procedures. These measurements allow for the evaluation of combustion efficiency and fuel performance, assessing the impact of solid and hollow briquettes on burning characteristics (Kumar et al., 2020).

Related heat quantity studies. The study of Oriabure et al., (2017) on the heating value of briquettes produced from Terminalia mentalis leaves and Daniela oliveri sawdust highlights their potential as alternative energy sources. The heating value, which indicates the energy content of a fuel, ranged from 9704 kcal/kg for briquettes to 11053 kcal/kg for the mixed briquettes. This high energy output suggests that these biomass briquettes can serve as a sustainable substitute for conventional fuelwood, reducing environmental degradation. The heating value is influenced by the composition, density, and carbon content of the briquettes, demonstrating the importance of selecting appropriate raw materials for efficient combustion and energy generation.

The calorific value of a fuel is a crucial measure of its energy content and efficiency in combustion processes. In the study on bio coal briquettes from Nigerian sub-bituminous coal, the calorific value was assessed to determine the optimal blend of coal and sawdust for fuel applications. The results showed that the 50/50 bio coal briquettes from Ogboyaga and Okaba coal deposits exhibited superior combustion characteristics compared to other blends. Notably, the Ogboyaga OG 90/10 briquette had the highest calorific value of 29.55 MJ/kg, indicating its potential as a high-energy, environmentally friendly alternative to raw coal. The study of Adekunle et al. (2015), highlights how blending coal with biomass can enhance fuel properties while reducing harmful emissions, making bio coal a viable option for domestic and industrial heating applications.

Calorific value is a key indicator of fuel efficiency, representing the amount of heat released during complete combustion with oxygen. In the study, a bomb calorimeter (Leco - AC350) was used to measure the calorific value of bio-briquettes, following ASTM D 5865 standards. The testing involved crushing and refining the briquettes to a fine consistency, ensuring uniformity through a 60-mesh screen. With oxygen pressurized at 400 psi and controlled combustion initiated using an eight cm wire with a fuse heat of 4.1 Btu/cm, the change in water temperature (AT) was recorded to determine the energy output. Results showed that bio-briquettes from coconut husks achieved a calorific value of 5267 cal/g, which, while lower than coal (6158 cal/g), was significantly higher than woody charcoal (3158 cal/g). This demonstrates that higher calorific values correlate with better fuel quality, making bio-briquettes a promising alternative energy source with a balance between efficiency and sustainability (Suryaningsih et al., 2019). Heat of vaporization, also known as enthalpy of vaporization (Todd Helmenstine, 2019), represents the heat energy required to transform a liquid into a gas at a constant temperature and pressure. This is distinct from the calorific value discussed earlier, which pertains to the heat released during combustion. The heat of vaporization is a crucial property in various applications, including steam generation, refrigeration, and industrial processes involving evaporation. For instance, the high heat of vaporization of water (M.B. Kirkham, 2014) makes it an effective coolant, while the heat of vaporization of refrigerants is fundamental to refrigeration cycles.

The enthalpy of vaporization (Anand Krishnasamy et al., 2021) specifies the heat required to vaporize a unit mass of a substance under constant conditions. This is directly related to the heat of vaporization, with the difference being primarily in the context and units used. As with heat of fusion, the heat of vaporization/condensation represents the heat exchanged during a phase shift (K.M. Stewart et al., 2022). The same amount of heat is absorbed during vaporization as is released during condensation. For water, this is approximately 540 cal/g, a significant amount of energy.

In contrast to the heat involved in phase changes, heat transfer (Hussin Mamat, 2019) describes the movement of thermal energy between substances. While seemingly distinct, heat transfer is intimately linked to both calorific value and heat of vaporization.

III. Solid Briquette

Definition. Briquettes are compressed blocks of coal dust or any other flammable biomass, such as peat, charcoal, straw, wood chips, cobs, sawdust, and paper. (Bioresource Technology Reports, 2021). The bio-briquettes product is suitable as an energy source commonly used for electricity generation, heat, and cooking fuel. They are the perfect replacement for wood logs (Philip Donald Cabuga Sanchez et al., 2022). Briquette fuel from agricultural waste is a renewable source of energy which is environmentally friendly (Abubakar Hamzat et al., 2019).

Importance. Various studies have pointed out the importance of solid fuel briquettes, and one among them is David Cacciola et al. (2015), they described in their study that solid fuel briquettes replace fossil fuels with sustainable and environmental-friendly energy resources, which help reduce carbon emissions in the environment. On the other hand, solid fuel briquettes that are made from human waste can help address the energy shortages and improve sanitation in developing regions, as they promote preservation of the environment through waste utilization, according to the study conducted by BarbaraJ. Ward et al. (2014). Furthermore, the study of Assefa Tefaye et al. 2022) shows that fuel briquettes are friendly in nature and briquettes can produce good results without costing a lot of money, and importantly, they can reduce deforestation compared to firewood.

Procedure in testing briquettes

Heat Quantity. The Water Boiling Test (WBT) is widely recognized for assessing the heat output and combustion efficiency of biomass fuels. In the study by Abimbola Adegoke Idowu et al. (2020) WBT was used to evaluate the thermal efficiency of sesame hull briquettes. For their test, they utilized 500 mL of water and measured the time it took to bring it to a boil using specific quantities of briquettes. Two types of briquettes were tested: Sample A, which contained 100% binder, and Sample B, which had a 50% binder. The briquettes were ignited, and the time to boil the water was recorded. The boiling time was considered an indicator of the briquette's heat output and overall combustion efficiency. Sample A (100% binder) was found to boil the water in 4.02 minutes, demonstrating a higher heat output compared to Sample B, which took a longer time. This procedure allowed the researchers to quantify the heat produced by the briquettes, further supported by calorific value measurements. The study highlights the effectiveness of the WBT in assessing biomass briquette performance.

Briquetting procedure. Assefa Tesfaye et al. (2022) explored the production and characterization of coffee husk fuel briquettes as an alternative energy source. They used a manual molder and carboniser kiln to convert 15 kg of raw coffee husk into six kg of carbonised char in 25 minutes, achieving a conversion efficiency of 40.12%. The briquettes showed a higher heating value of 30.54 Kcal/kg, indicating their potential as an energy source.

The briquetting procedure for sugarcane bagasse involves compressing the material into dense, uniform shapes, improving its handling and pre-processing for energy production. This step helps address issues such as low bulk and energy densities, high moisture content, and the wide range of particle sizes and shapes that make bagasse difficult to utilize directly. Briquetting enhances the bagasse's suitability for gasification, a more efficient energy recovery method compared to traditional combustion. This process helps make bagasse a more viable feedstock for thermochemical conversion systems Anukam et al., 2016).

Briquetting charcoal fines involves mixing the fines with a binder, typically starch, to enable agglomeration. The mixture is screened, hammer-milled, and then pressed into briquettes. These briquettes are dried in an oven to solidify the binder. Optional additives like waxes can be included to improve combustion. While viable in high-price markets or when fines are low-cost, briquetting is often economically unfeasible in developing countries due to the high costs of equipment, binders, and labor. (Chapter 11 - Briquetting of Charcoal, n.d.).

The earth pit carbonization process involves digging a pit, filling it with wood, and covering it with earth to create a gas-tight seal. The wood is heated slowly, starting at one end of the pit and progressing toward the other. This process, which takes 20-30 days for carbonization, relies on hot gases passing through the wood to dry and heat it to about 280°C. As the process continues, the earth covering may sink, and any cracks must be sealed. After 40 days of cooling, the charcoal is unloaded, separating it from uncarbonized wood and earth. The entire cycle typically lasts 82 days, including preparation and unloading. (Chapter 5 - Earth Pits for Charcoal Making, n.d.)

Materials used. Imeh E. Onukak et al.'s 2017 study utilized cassava starch, aluminum foil, leather shavings, lime fleshing, and distilled water to create solid fuel briquettes. The equipment involved are oxygen bomb calorimeter, oven, milling machine, briquette molder, and furnace.

oxygen bomb calorimeter. Abdulmalik Dantanis et al. (2020) study utilized an oxygen bomb calorimeter to measure the energy content of briquettes through heat of combustion, examining their fuel efficiency and combustion properties.

oven. lain Davidson (2023) explains that convection ovens consist of zones with a single heater, circulation fan, extraction fan, and flue to circulate air and eliminate moisture.

milling machine. Samir Mekid et al. (2023) highlighted that milling machines are versatile tools used for processing and shaping various metal and non-metal-based materials for specific applications.

briquette molder. In the study by Aries Roda D. Romallosa et. al. 2018), briquette molder which is composed of molders, handles and frames are used for processing materials into briquettes through compaction and compression.

furnace. Industrial furnaces according to Sedat Vatandas et al. (2018), is used in metallurgical production for smelting at high temperatures, in heat treatment, tempering, in some areas such as the food industry, for drying, and for fermentation at low temperatures. The experimenter starts by getting the calorimeter's support structure ready. It is determined which holes in a small can will be used to attach the support. The experimenter can use smaller holes and secure the support with metal wire, or they can use larger holes to accommodate the support, depending on how tall the cans are. Avoiding the use of glue is essential since heat might cause it to break down. Then three needles are chosen, and the blunt ends of the needles are placed into a cork so that the sharp edges stick out and impale the food sample. To lower its height, the cork can be cut lengthwise and placed on its cut side if needed. The cork with the needles is positioned in the center of an aluminum pie pan that has been placed on a heat-resistant surface for assembly. After that, the smaller can is suspended within the larger can, which is set on top of the cork. The water, which will be heated by burning the food sample, is supposed to be kept in the smaller can. The experimenter measures and fills the smaller can with water to about half its capacity using a graduated cylinder. For accurate recording, the amount of water is measured in milliliters in the lab notebook (Science Buddies n.d.).

Related Studies. The study by Tanko et al. (2020) investigated the thermo-physical properties of coconut shell and rice husk as potential substitute fuels for briquettes, finding that coconut shell had the highest calorific value and lower ash content suggesting that it could be a useful substitute to solid fuel.

The study of Sanka et al. (2024), highlighted the potential of utilizing various waste materials, including sludge and biomass, to produce sustainable fuel briquettes. While the specific combination of sewage sludge from wastewater treatment and wood shavings may not have been extensively studied, the existing research indicates that such an approach could be promising for sustainable energy production and waste management.

Imeh E. Onukak et al. 2017) study analyzed biomass briquettes from tannery solid wastes (TSWs), revealing their calorific values, durability, and energy values. The study suggests that TSWs can be used to produce fuel briquettes, offering a cost-effective, eco-friendly, and sustainable energy alternative.

To summarize, the heat quantity and material properties of dried Cocos nucifera (coconut) spadix are key factors in its potential as a solid fuel. The Cocos nucifera spadix, with its high carbon content and calorific value, aligns with biomass fuel studies, demonstrating strong energy potential. Its structural and chemical properties, including lignocellulosic composition, contribute to its effectiveness as a fuel source. The heat capacity of materials like Cocos nucifera spadix directly impacts energy output, with research showing that higher specific heat capacity correlates with greater heat release during combustion. Briquettes made from agricultural waste, including coconut shells and husks, offer an eco-friendly energy alternative by reducing emissions and deforestation. The briquette manufacturing process, incorporating binders like cassava starch and carbonized biomass, enhances fuel efficiency and sustainability. In conclusion, this synthesis highlights the unique properties of Cocos nucifera spadix, demonstrating its potential as a renewable, efficient, and environmentally sustainable biofuel when used in briquette form.

CHAPTER III

METHODOLOGY

This chapter presents and describes the material that was used and the procedures that were employed in this study. For an overview, see Figure 3.1

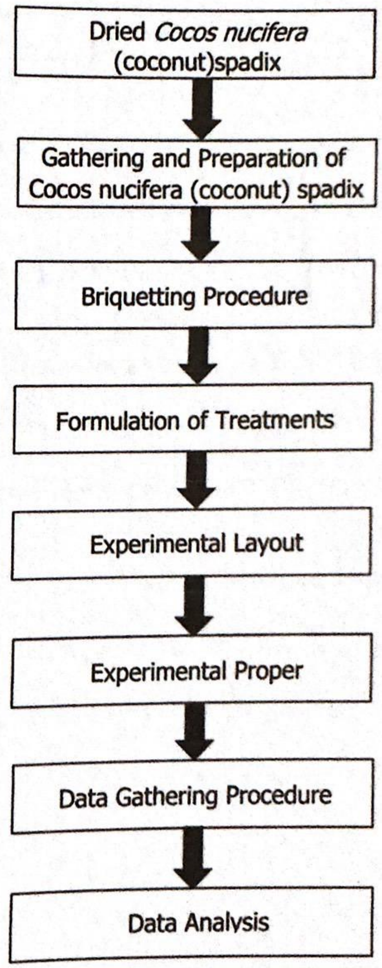

Figure 3.1. Schematic Diagram of Research Methodology

Description of Study Variables

Cocos nucifera (coconut) spadix. It is dried, dirty, dark brown fibrous spike-like structure spadix of Cocos nucifera (coconut), the researchers specifically gathered dried old spadix which were generally brown in color. 20 kilograms of Cocos nucifera (coconut) spadix was obtained by the researchers from Brgy. Lutac, Cabatuan, Iloilo.

Briquettes. A small block made from coal dust or peat, used as fuel in a fire. In this study, a single briquette weighing 20 - 22 g with a length of 1.5 inches and a width of 1.1 inches was made by the researchers.

Cassava starch. Cassava starch is a fine white, tasteless powder made by grating and drying the fibrous cassava root. In this study, 600 grams was utilized by the researchers from Cabatuan Public Market, Iloilo.

Water. Water appears as a clear, nontoxic liquid composed of hydrogen and oxygen, essential for life, and the most widely used solvent. 1000 ml of hot water was used by the researchers from Brgy. Lutac, Cabatuan, Iloilo.

Gathering and Preparation of Dried Cocos nucifera (coconut) Spadix

The primary material used in this study was the dried Cocos nucifera (coconut) spadix, with a total weight of 20 kg, collected from Brgy. Lutac, Cabatuan, Iloilo. The spadix was sourced from the same local environment and delivered to the Department of Agriculture. Only mature, dried spadices, ranging from 30 to 60cm in length, were selected for collection. These were then cut into smaller pieces for further processing. Following collection, the spadices were cleaned by gently wiping off dirt with damp towels. They were then sun-dried for a period of 5 days to reduce their moisture content. The drying process was carefully monitored, with drying times adjusted based on prevailing weather conditions to ensure the spadices reached an optimal moisture level for use as fuel.

Procedure in Making Briquettes

Size Reduction

This process was based on the study by Assefa Tesfaye et al. (2022), with subtle modification. After sun-drying the collected coconut spadix for three to four days, the spadices underwent size reduction. The dried spadix, which measured 60cm in length, was cut into smaller pieces, each approximately three inches in length.

Carbonization Process

The carbonization of dried Cocos nucifera (coconut) spadix, which was three inches in length, followed a traditional method of charcoal production using soil to limit oxygen. This process slowly burned the material, transforming it into charcoal over a period of 10 to 20 hours.

The process began with the ground preparation, and putting a layer of dried hay, it was spread to help ignite the fire. The dried spadix was then placed on top, followed by a layer of dried hay to retain heat. Four bamboo poles with small holes were inserted to allow air flow, assisting in controlling the burning process. The entire pile was covered with soil, leaving a small opening for lighting the fire.

Once the fire was lit, the smoke was monitored to ensure proper burning. When it was confirmed that the material inside was burning effectively, the opening was sealed to restrict oxygen and control the fire. Over time, the spadix gradually turned into charcoal. After 10 to 20 hours, the soil cover was removed, and the finished charcoal was collected for further processing.

Pulverization process

After carbonization, the pieces of dried Cocos nucifera (coconut) spadix were pulverized using a blender, resulting in particles that were measured with a weighing scale to determine the total weight of each pulverized spadix.

Following the grinding process, the material was sieved using a two mm mesh sieve to ensure uniformity in particle size. Any particles that did not pass through the sieve were returned for further grinding.

Briquette Formation

The carbonized coconut spadix material was then mixed with a binding agent, specifically cassava starch and hot water. The binding agent was stirred until it reached a paste-like consistency. For every 825 g of ground char spadix, 200 grams of binder was used. The 200 grams binder mixture per kilogram of ground charcoal consisted of 50g of cassava starch and 150 mL of water. A total of 3300 grams of coconut spadix was used, requiring 800g of binder for the entire mixture.

The binder solution was prepared in four separate batches, each with the same proportions, resulting in a total of 200g of cassava starch and 600 mL of hot water. The ground coconut spadix charcoal and binder were then thoroughly mixed until a uniform consistency was achieved. Once fully combined, the mixture was compressed into briquettes using a manually operated briquette molder with a mold size of 1.5 inches in diameter and 60 centimeters in length, ensuring consistency in size. After molding, the briquettes were cut into 1.5-inch pieces in every briquette made by the briquette molder, and a hole was created in each briquette. The briquettes were then placed in a suitable tray and left to sun-dry for four days before testing.

Formulation of Treatments

The experimental treatment was obtained using four kilograms of pulverized and carbonized dried Cocos nucifera (coconut) spadix with a constant solution of binder mixture, weighing 200 grams per 825g of ground charcoal, consisted of 50g of cassava starch and 150mL of water.

The first treatment, labeled as Treatment 1(1), was prepared using four kilograms of pulverized dried Cocos nucifera (coconut) spadix. The pulverized spadix was divided into four portions, each weighing 825 grams. For every 825 grams of ground charcoal, 200 grams of binder was added. The final mixture consisted of 75% dried Cocos nucifera spadix and 25% binder solution (cornstarch and water).

The positive control, labeled as Treatment 2 (T2), was set up using commercially available briquettes to compare the efficiency and performance of the formulated treatments against Cocos nucifera (coconut) spadix.

Experimental Layout

Completely Randomized Design (CRD) was then used as the experimental design of the study. Two treatments were used and were replicated thrice. The treatments were assigned for easy random assignment of treatments to different experimental units, helping reduce any biases.

T1R1	T2R3	T2R2
T2R1	T1R2	T1R3

Table 3.1. Experimental Layout of the

Study Legend:

T1 - 75% of dried *Cocos nucifera* (coconut) spadix and 25% of binder solution (cassava starch and water)

T2 - Commercially available briquettes (Positive Control)

R1 - First Replication

R2 - Second Replication

R3 - Third Replication

Experimental Proper

Heat Quantity Testing of Briquettes

Creation of Improvised Calorimeter

To design an improvised calorimeter for testing briquettes, we followed a systematic approach involving the selection and modification of containers, steel bars, and a steel screen. The primary materials needed for this construction were three steel containers, steel bars, and a steel screen with a 3x3 square mesh.

The process began by selecting three steel containers of varying sizes: one large, one medium, and one small. The largest container was modified by creating holes in its bottom to allow air to flow through, facilitating the combustion of the briquettes. Two steel bars were placed inside this container to serve as a base for positioning the medium-sized container.

The dimensions of the steel bars were tailored to the container's size, measuring 17 inches in height and 16 inches in width. The medium-sized container was then prepared by covering its bottom with the steel screen, providing a stable surface for the briquettes to be placed on. Steel bars were placed on top of the medium container, serving as a base for the smallest container to rest upon. The size of the steel screen and bars was customized to the medium container's dimensions, which were 15 inches in height and 11 inches in width. The smallest container, measuring seven inches in height and nine inches in width, was designated for boiling. A hole was made in the lid of this container to accommodate a thermometer, with the hole's size adjusted to fit the thermometer securely. Once all components were prepared and modified, the three containers were assembled, resulting in the creation of the improvised calorimeter. This setup provided a functional system for conducting experiments to test the thermal properties of the briquettes.

Water Boiling Test

The Water Boiling Test involved burning briquettes, each weighing an average of 20 to 22 grams, and commercial charcoal samples separately on an improvised calorimeter to compare their heat quantity and determine which fuel boiled water more quickly. One liter of water was used for the test, with temperature readings taken every minute using a thermometer until the water began to boil. The time taken for each sample to burn to ash was recorded with a stopwatch. Each treatment and replication had a fixed duration of ten minutes for the water boiling test.

Data Gathering Procedure

To determine the heat output of the briquettes, the water boiling test was conducted. The tools used to collect the research data included a weighing scale, stopwatch, container, and thermometer. The thermometer was used to measure the temperature of the water as it was being heated using the briquettes compared to commercial charcoal, with the test performed over three replications.

The weighing scale was used to measure the weight of the briquettes and commercial charcoal. To obtain the accurate weight, the weight of the containers was first recorded, and then the weight of the container with the briquettes or charcoal was measured. The weight of the container was subtracted to determine the exact mass of the briquettes and commercial charcoal. The weight of the briquettes and commercial charcoal was measured both before and after the water boiling test in order to calculate the heat quantity by observing the change in weight. This process was repeated three times, and the measurements obtained were substituted into the designated formula to calculate the heat quantity produced by the briquettes and commercial charcoal.

The formula used was:

$$Q = mc\Delta T + mc\Delta T + Lm$$

Where Q was the heat capacity. The first $mc\Delta T$ calculates the heat absorbed by water, where mis the mass of water, cis its specific heat, and 4Tis the temperature change. The second $mc\Delta T$ accounts for the heat absorbed by the metal container, using its mass and specific heat. Lastly, Lm represents the heat required for water evaporation, where L is the latent heat of vaporization, and mis the mass of water lost as steam. After obtaining the total heat energy of the briquettes using this formula, the result is then divided by the total amount of briquettes consumed (in grams) to determine their energy efficiency per gram.

Data Analysis

The collected data was analyzed using statistical tool Microsoft Excel Analysis Tool Pact and made comparisons with commercial solid fuels, specifically the wood charcoal fuel, ensuring a comprehensive evaluation of the potential of dried Cocos nucifera (coconut spadix briquettes as a reliable fuel briquette.

Microsoft Excel Analysis Tool Pact:

Mean. Used to determine the dried Cocos nucifera (coconut) spadix briquettes average heat production, which serves as an essential indicator of how well they work.

Standard Deviation. Used to quantify the degree to which the briquettes performance exceeded the standard in terms of heat production.

t-Test. This was used to determine if there was a significant difference in the heat quantity of dried Cocos nucifera (coconut) spadix briquettes. It will determine whether the difference in heat production is statistically significant at a significance level of a=0.05.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the results and discussion of the study with reference to the aim of the study which was to determine the heat quantity (in cal/g) and time duration (in minutes) of dried Cocos nucifera (coconut) spadix briquettes to last. Findings were analyzed using t-Test: Independent Sample Test for the Heat Quantity in (cal/g) of the treatments after exposure to water boiling test and stopwatch for time duration (in minutes).

Table 4.1. Heat Quantity (in cal/g) of Dried *Cocos nucifera* (Coconut) Spadix Briquettes

Treatments	Replications			Total	Mean	*S.D*
	I	II	III			
Dried *Cocos nucifera* (coconut) Spadix Briquettes	338.47	251.33	322.63	912.43	304.14	37.90
Commercial (+)	651.48	615.89	431.32	1698.69	566.23	96.50
Grand Total				2611.12		
Grand Mean					435.19	

The t-Test showed that there is a significant difference among the heat quantities of Cocos nucifera (coconut) spadix and commercial charcoal (positive control).

Table 4.2 t-Test: Independent Sample Test for the Heat Quantity (in cal/g) of the Treatments After Exposure to Water Boiling Test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Heat Quantity	Equal variances assumed	4.222	.109	-3.575	4	.023	-262.08667	73.30724	-465.62020	-58.55313
	Equal variances not assumed			-3.575	2.603	.047	-262.08667	73.30724	-516.88151	-7.29182

The t-Test results indicated that the total heat quantity generated by the experimental treatment, Cocos nucifera (coconut) spadix, is significantly lower than that of the positive control, commercial charcoal. This statistical finding suggests that dried Cocos nucifera (coconut spadix briquette is less efficient in terms of heat quantity (in cal/g) compared to the commercial charcoal.

The briquettes composed of dried Cocos nucifera spadix exhibited a burn time of 1 hour, 22 minutes, and 4 seconds during the Water Boiling Test. In contrast, the commercial coal demonstrated a significantly longer burn time of 3 hours, 36 minutes, and 27 seconds, which is characteristic of commercial wood, specifically mahogany. This substantial difference in burn duration highlights the relatively lower combustion efficiency and heat retention of Cocos nucifera spadix briquettes compared to commercial coal, suggesting that although the coconut spadix briquettes may serve as a potential alternative fuel, their shorter burn time indicates the need for further optimization to enhance their performance.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study aimed to determine the heat quantity of dried Cocos nucifera (coconut) spadix briquettes. The study was conducted on March 2-3, 2025, at Brgy. Ayaman, Cabatuan, Iloilo with the assistance and supervision of a Research teacher.

The spadices of dried Cocos nucifera (coconut) were gathered from Brgy. Lutac, Cabatuan, Iloilo and were size-reduced and carbonized. There was only one treatment used in the study with three replications respectively: the experimental (dried Cocos nucifera (coconut) spadix briquettes), positive control (commercial charcoal). Completely Randomized Design was used as the experimental layout. The heat quantity of dried Cocos nucifera (coconut) briquettes were determined based on the procedure of Tesfaye, Workie, & Kumar (2022). The heat quantity (in Cal/g) produced was analyzed using t-Test.

Results revealed that the heat quantity (in Cal/g) of the experimental treatment is significantly lower compared to the positive control.

Conclusion

The study evaluated the potential of Cocos nucifera (coconut spadix briquettes as a solid fuel by analyzing their burn duration and heat quantity. Results revealed that the burn time of Cocos nucifera spadix briquettes (1 hour, 22 minutes, and 4 seconds) was significantly shorter than that of commercial coal (3 hours, 36 minutes, and 27 seconds), indicating a lower combustion duration. Additionally, the heat quantity (cal/g) of the Cocos nucifera spadix briquettes was lower compared to commercial briquettes. Statistical analysis showed a significant difference in heat quantity between the two treatments. Therefore, while Cocos nucifera spadix briquettes can serve as an alternative solid fuel, further research and optimization are recommended to enhance their performance.

Recommendation

This study showed that the dried Cocos nucifera (coconut) spadix has lower efficiency as a solid fuel, with its heat transfer and levels exhibiting similar traits to commercial alternatives. However, several recommendations for future research include exploring other plant materials and agricultural wastes for further exploration to improve efficiency and heat transfer, optimizing spadix and binder concentrations for better combustion, and examining properties such as ash content, which could affect performance and sustainability. Additionally, assessing durability, smoke emissions, combustibility level, and conducting long-term testing and field trials would provide a more comprehensive evaluation of the briquettes' viability. These recommendations aim to improve the development and performance of alternative solid fuel briquettes as substitutes for commercial options.

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APPENDICES

APPENDIX A

CALENDAR OF ACTIVITIES

MONTH OF AUGUST 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14		16	17
18	19	20	21	22 Formulating 5 Research Titles	23	24
25	26	27 Formulating Statement of the Problem	28	29	30	31

MONTH OF SEPTEMBER 2024						
SUN	MON	TUE	WED	THUR	FRI	SAT
1	2	3 Formulating another 5 research titles and Statement of the Problem.	4	5	6	7
8 Finalizing chosen research topic	9	10	11	12	13	14
15	16	17	18 Working on chapters 1-3	19 Working on chapters 1-3	20	21
22	23	24	25	26	27	28
29	30					

MONTH OF OCTOBER 2024						
SUN	MON	TUES	WED	THURS	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24 Gathering of *Cocos nucifera* (coconut) roots	25	26 D.A. confirmation of *Cocos nucifera* (coconut) roots
27	28	29	30	31		

MONTH OF DECEMBER 2024						
SUN	MON	TUES	WED	THURS	FR I	SAT
1	2	3 Making Preliminary Pages of Chapter 1-3	4	5	6	7
8	9	10	11	12 Revision of research proposal	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

MONTH OF JANUARY 2025						
SUN	MON	TUE	WED	THUR	FRI	SAT
		.	1	2	3	4
5	6	7	8	9	10	11
12	13	14 Revision of Preliminary Papers	15	16	17	18 Gathering of *Cocos nucifera* (coconut) spadix
19	20 D.A. confirmatio n of *Cocos nucifera* (coconut) spadix	21	22	23	24	25 Gathering of *Cocos nucifera* (coconut) spadix
26 Sun Drying of *Cocos nucifera* (coconut) spadix	27 Sun Drying of *Cocos nucifera* (coconut) spadix	28 Sun Drying of *Cocos nucifera* (coconut) spadix	29 Sun Drying of *Cocos nucifera* (coconut) spadix	30 Sun Drying of *Cocos nucifera* (coconut) spadix	31 Sun Drying of *Cocos nucifera* (coconut) spadix	

MONTH OF FEBUARY 2025

SUN	MON	TUE	WED	THUR	FRI	SAT
						1
2 Size Reduction of *Cocos nucifera* (coconut) spadix	3 Carbonization of *Cocos nucifera* (coconut) spadix	4 Pulverization of *Cocos nucifera* (coconut) spadix	5 Briquetting Formation of C*ocos nucifera* (Coconut) spadix	6	7	8
9	10 Sun Drying of *Cocos nucifera* (coconut) spadix briquette	11 Sun Drying of *Cocos nucifera* (coconut) spadix briquette	12 Sun Drying of *Cocos nucifera* (coconut) spadix briquette	13 Sun Drying of *Cocos nucifera* (coconut) spadix briquette	14 Sun Drying of *Cocos nucifera* (coconut) spadix briquette	15 Sun Drying of *Cocos nucifera* (coconut) spadix briquette
16	17	18	19	20	21	22
23	24	25	26	27	28	

MONTH OF MARCH 2025

SUN	MON	TUE	WED	THUR	FRI	SAT
						1 Creation of Improvised Calorimeter
2	3 Water boiling Testing of Briquettes	4	5	6 Making of Appendices	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

APPENDIX B

EXPENDITURES

Item Material	Quantity	Cost Per Unit (PHP)	Total Cost
Coconut Spadix	20 kg	0	0
Starch	2	60	120
Briquette Molder	1	0	0
Printing	60	2	120
Transportation	8	20	400
Parilya	1 meter	80	80
Total Expenses			720

APPENDIX D

PICTORIALS

Plate 1. Gathering of *Cocos nucifera* (coconut) spadix

Plate 2. Sun drying of *Cocos nucifera* (coconut) spadix

Plate 3. Size reduced *Cocos nucifera* (coconut) spadix

Plate 4. Carbonization of *Cocos nucifera* (coconut) spadix

Plate 5. Gathering of carbonized *Cocos nucifera* (coconut) spadix

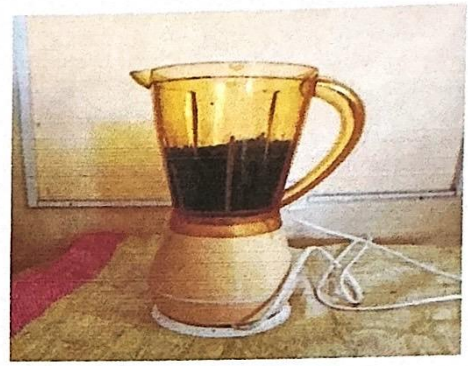

Plate 6. Pulverization of carbonized *Cocos nucifera* (coconut) spadix

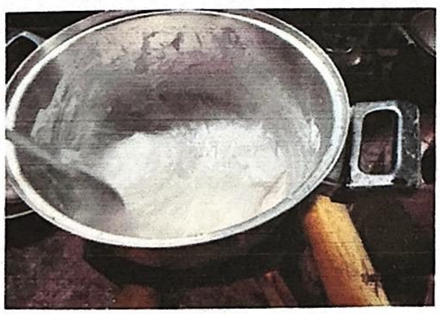

Plate 7. Making of binder solution

Plate 8. Mixing of concentrations

Plate 9. Briquetting formation

Plate 10. Drying of briquettes

Plate 11. Improvised bomb calorimeter

Plate 12. Experimental proper

Plate 13. *Cocos nucifera* (coconut) spadix after water boiling testing