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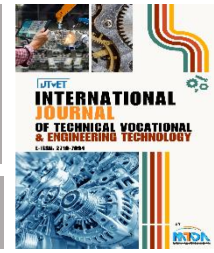

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The Production of Briquette Charcoal from Coconut Shell and Palm Shell as A Renewable Energy Source

K. A. Rahman[1]*, A. M. Leman[2], F. I. T John[3]

[1]Department of Petrochemical Engineering, Politeknik Tun Syed Nasir Syed Ismail,
[2]Faculty of Engineering Technology, Tun Hussein Onn Malaysia University

**Corresponding Author's Email: khairunnisa.a.r@ptsn.edu.my*

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ABSTRACT
The escalating environmental concerns surrounding fossil fuel usage have spurred exploration into alternative, sustainable energy sources, with biomass emerging as a promising solution. Biomass carbon production, specifically from agricultural waste, stands out as a large-scale industrial means of energy conversion that is both safe and cost-effective. This study focuses on utilizing coconut shells as a substitute material in the production of briquette charcoal, presenting a viable eco-friendly alternative to fossil fuels. The primary objectives of this research are to assess the combustion and mechanical properties of coconut shell-derived briquette charcoal, evaluating its potential as a replacement for fossil fuels in the carbonization process. Additionally, the study investigates the viability of coconut shell and palm shell as alternative sources for producing briquette charcoal. Compliance with American Society of Testing and Materials (ASTM) standards ensures a comprehensive analysis, covering characteristics such as 1.0m toughness, 360 minutes burning duration at an optimum temperature of 788 ˚C, 40 seconds ignition duration, calorific value of 4787 kcal/kg, 3.48% ash content, 9.32% moisture content, 60.28% volatile matter, 26.92% fixed carbon, 0.217 kN compaction force, and a density of 1.27 g/cm3. Moreover, the incorporation of an organic binder, comprising cassava starch and water, enhances the physical and combustion properties of the briquette charcoal. In conclusion, this study provides valuable insights into the sustainable utilization of biomass, particularly coconut shells, as an eco-conscious substitute for traditional fossil fuels, thereby mitigating environmental concerns.

1.0. Introduction

Fossil fuels are the most significant sources of energy and consumption is rising every day owing to the growing population and industrial development in developing and developed nations (Franco & Diaz, 2009; Zakaria, Kamarudin, Abd Wahid, & Abu Hassan, 2021). It consists of deposits of ancient living organisms that take over a century to shape. Basically, fossil fuels consist of hydrogen and carbon bonds. There are three major types of fossil fuel which are coal, oil and natural gas for the usage of energy provision. Coal is one of the non-renewable has the most important energy sources from which utilization at the highest possible extent (Zakaria et al., 2021). The usage of fossil fuels has raised environmental concerns. Replacing this power is essential in reducing atmospheric pollution. One of the ideal alternatives to replace fossil fuels is using biomass sources. Biomass energy can easily collect from natural resources (Kang et al., 2020). Biomass is regarded widely available in rural areas. Apart from that, the sources of biomass from agricultural waste are functionally used as a replacement for fossil fuels. Biomass can be transformed into gas and fluid fuels (bio-oil, biodiesel and bioethanol) through gasification and pyrolysis, transesterification and fermentation (Razzak, Lucky, Hossain, & DeLasa, 2022; Chen, Hsu, Lu, Lee, & Lin, 2011).

Briquette is also a method of forging and pressurizing and, if burned, will generate a tiny quantity of smoke (Fikri & Sartika, 2018). The common forms of briquettes are coal briquettes and biomass briquettes. Biomass briquettes originate from mostly agricultural residues. Biomass is clean, renewable and environmentally friendly energy. In addition, briquettes are solid materials created by compressing and exerting pressure, and if burned, it will produce a minimal amount of smoke. Charcoal briquettes, also known as bio-charcoal, are charcoal that has been processed with a pressing system using adhesive, so that a briquette-shape can be obtained for use. Briquettes offer economic benefits as they can be easily manufactured, possess high heat value, and utilize raw materials readily accessible in the industry, allowing them to compete effectively with other fuel sources (Fikri & Sartika, 2018).

Agriculture is one of the important economies in Malaysia. Agricultural activities have a lot of variety which lead to an abundance of wastes that dispose inefficiency. This issue has become serious as it involves pollutants to the environment. Traditionally, wood is used to produce charcoal. This activity of cutting wood for producing charcoal leads to deforestation and erosion. The forest ecosystem has undergone significant disturbances and changes due to the escalating rates of tree cutting for furniture production, charcoal manufacturing, and firewood extraction. As a result, deforestation has reached alarming levels, leading to increased environmental pollution (Tomen, Diboma, Bot, & Tamba, 2023). In this research, the use of coconut shell and palm oil shell are used as alternative materials for briquette charcoal production. These two biomass sources are considered ideal for creating briquette charcoal.

2.0. Problem Statement

It is well known that fossil fuels have restricted potential and harmful effects on the environment. The production of biofuels as an energy sources from biomass wastes and the potential applications of biomass wastes as valuable resources for environmental protection were discussed among researchers (Oluyinka et al., 2022). Moreover, the significant utilization of fossil fuels for the production of energy and transportation is believed to be a major factor contributing to the greenhouse effect (Razzak et al., 2022). Among several types of biomass, agricultural residues have become one of the most promising options (Fikri & Sartika, 2018). In Malaysia, the important agricultural plant industry are coconut and palm oil industry. As the increasing interest of the palm oil and coconut in industrial sector, this problem prone to increasing of agricultural waste (Fadzil & Othman, 2021). Globally, 998 million tons of agricultural waste are generated annually and 1. 2 million tons of agricultural waste are disposed of annually in landfills in Malaysia (Agamuthu, 2009). It is estimated that 15% of the total waste generated in Asia is agro-waste, with agricultural waste generation in Malaysia at approximately 0.122 (kg/cap/day) in 2009 which is projected to reach 0.210(kg/cap/day) by 2025 (Agamuthu, 2009).

Increasing the quantity of agricultural waste generates environmental issues such as climate change, decreases acid rain, soil erosion, air pollution, and landfill pressure. Scientific studies have found that many potential energy sources abound in agricultural residues or waste (NEH, 2020). While there are many agricultural residues and waste produced in the nation, wastes are poorly used and poorly managed, as most of these wastes are left to decompose or are burned, leading in pollution and degradation of the environment (Fadzil & Othman, 2021). Agricultural biomass waste through briquetting can significantly displace fossil fuel, decrease greenhouse gas emissions and provide renewable energy to individuals in developing nations (Fadzil & Othman, 2021). In this study, the use of palm shell and coconut shell in briquette charcoal is carried out. These two materials fit the best materials used to replace the current briquette charcoal in terms of their combustion and physical properties.

This study is to conduct an experimental testing to determine the performances of briquette charcoal containing biomass products which is palm shell and coconut shell as alternative to fossil fuels. The objectives of this research are:

i. To determine the combustion properties of palm shell and coconut shell as briquette charcoal.
ii. To identify the mechanical properties of briquette made from biomass product in carbonization process as a replacement material of fossil fuels.
iii. To investigate the potential of coconut shell and palm shell as an alternative to produce briquette charcoal.

3.0. Literature review

3.1. Agricultural Waste

The agricultural industry plays an important role in global economic growth. Malaysia is one of the countries that rapidly growing in economic sector due to its increasing in energy needs and soaring population. The goals of emphasizing are to alter the current mix to a new concept of sustainable and renewable energy. Agricultural industry is captivated in contributing high economy in Malaysia. Palm oil and coconut industries are well known as the one of most essential agricultural industries in Malaysia (Fadzil & Othman, 2021). Due to Malaysia's tropical warm and humid climate, it is regarded the world's leading producer and exporter of palm oil. These sectors are quickly growing year by year, resulting in increasing quantities of agricultural waste. Agricultural waste produced by burning or destroying methods leading to air pollution. The use of this agricultural waste is based on the premise that it can substitute the current material used in the business product in order to decrease costs or enhance the mechanical characteristics of the composite material (NEH, 2020).

However, many of these waste products can be recycled and, if correctly managed, can become a resource for industrial manufacturing or energy generation. In order to ascending the million tons of agricultural waste, the waste must be transformed into useful energy such as biomass. The exact quantity of waste generated in developing countries is difficult to determine as there are many inconsistencies in information collection techniques, definitions and seasonal differences (Onukak, Mohammed-Dabo, Ameh, Okoduwa, & Fasanya, 2017). Therefore, it is important to provide new method in agricultural waste management system in order to achieve sustainable agriculture (NEH, 2020). In this study, the appropriate way of agriculture waste management is by reusing the waste and converting it into product by producing briquette charcoal. Briquette charcoal is made up from biomass products from agricultural wastes which are coconut shell and palm shell.

3.2. Briquette Charcoal

According to Fikri & Sartika (2018), agricultural waste is an ideal source of charcoal. The objective of producing briquette charcoal is to replace the coal that is widely used in industrial heating processes such as heating, steam generation, and power generation. Briquetting biomass is a densification method that increases its handling features, increases its volumetric calorific value, decreases transport costs and generates a uniform, clean, stable fuel or input for further refining (Fikri & Sartika, 2018). These can be burnt clean and therefore are eco-friendly also those advantages that are associated with the use of biomass are present in the briquettes. The characteristics of a strong ignition such as flammable, long enough burning period, do not cause soot, little smoke and vanish rapidly and the heat value is high enough (Tomen et al., 2023).

Briquetting is a product of greater density than the raw materials compaction of residues. It can be used to generate heat in households and small-scale household sectors or even to generate electricity in big sectors (Kaliyan & Morey, 2009). A briquette is a solid substance formed by compressing and applying pressure, and when it is burned, it releases only a minimal amount of smoke. Charcoal briquettes, also known as bio-charcoal, are created by processing charcoal using a pressing method that incorporates an adhesive. This allows for the formation of briquette-shaped pieces that can be used effectively. Briquettes offer economic benefits due to their simple production process, high heat value, and readily available raw materials within the industry (Fikri & Sartika, 2018). As a result, they can effectively compete with other fuel sources. Researchers has attempted to develop plenty of different composite and material on producing briquette from agricultural waste. Yerima & Grema (2018) investigated characteristics of composite rice straw and coconut shells as biomass energy resources. While, Hamid et al., (2016) investigated on development of briquette from coir dust and rice husk blend as an alternative energy source. Onukak, Mohammed-Dabo, Ameh, Okoduwa, & Fasanya (2017) determine the production and characterization of biomass briquettes from tannery solid waste. These previous researchers conducted the development depending on the agricultural waste that is available during the moments. According to Adapa, Tabil, & Schoenau (2009), there two important aspects to be considered in the compaction of biomass material which are the ability of the particles to form briquette with extensive mechanical strength and the ability of process to enhance the durability of the biomass material. Briquettes are made using briquetting machine of either manual, screw and hydraulic types (Adapa et al., 2009).

3.3. Coconut Shell

According to Tomen et al. (2023), agricultural waste is an ideal source of charcoal. The objective of producing briquette charcoal is to replace the coal that widely used in industrial heating. Coconut plantation is the fourth important industrial crop in Malaysia after palm oil, rubber, and paddy. Coconut is also known as one of the oldest in agro-based industries. Coal made from coconut shells produces extremely high-performance filters. Coconut trees take one year for the fruit to fully ripe. Huge amount of coconut being harvest each year, which produce greater number of wastes produced in processing milling. Yerima & Grema (2018) claimed that the coconut husk and shells are an attractive biomass fuel and are also a good source of charcoal. Besides that, they said the main benefit of using coconut is that it is a permanent crop and available throughout the year, thus providing a steady whole year supply. Coconut shells can be easily collected in places as the stock of coconuts is abundant. Technically, briquette charcoal made from coconut shell is easy to produce.

Other than that, briquetting coconut shells do not require high spec technology and the most important is the price is much cheaper compared to another raw materials in making charcoal (Yerima & Grema, 2018).

3.4. Palm Kernel Shell

Oil palm is the most important product of Malaysia that has helped to change the scenario of its agriculture and economy. In 2020 Malaysia was responsible for 25.8% and 34.3% of global palm oil production and exports, respectively. When considering other oils and fats produced within the country, Malaysia accounted for 9.1% and 19.7% of the world's total production and exports of oils and fats during the same year. In response to the government's push for enhanced industrialization, the refining of crude palm oil began in the early 1970s. This development brought about the establishment of refineries and the introduction of a diverse array of processed palm oil products (Malaysian Palm Oil Council (MPOC), 2023). Othman & Jafari (2014) stated that oil palm contributes substantially both to the rural employment and to the economy of Malaysia by means of the plantations and by small-holder schemes. The palm kernel shell brings abundant special characteristics that fit as the replacement of industrial coal. According to a study, the equilibrium moisture content for the briquettes made of palm fibre and palm shell is about 12 mf wt.% (Husain, Zainal, & Abdullah, 2002).

The palm kernel shell brings abundant special characteristics that fit as the replacement of industrial coal. According to a study, the equilibrium moisture content for the briquettes made of palm fibre and palm shell is about 12 mf wt.% (Husain et al., 2002). Carbonized palm oil shells are used as charcoal which can be pressed into fuel briquette. Oil palm waste is very reliable source of renewable energy due to its availability, continuity and capacity (Abdullah, Sulaiman, Safana, & Abdullahi, 2016). Palm shell contains residues of palm oil, which produce slightly higher heating value than average lignocelluloses. It is easy to handle and crush. The natural density of palm shell can be 1.1 g/cm3 which is light and easy for storage. Palm shell briquette suitable to generate thermal power with lower coal consumption and less carbon dioxide. Palm shell fuel can be fully burned, and the thermal efficiency is high.

3.5. Binder

Das, Jeevan, Palan, & Anne (2018) claimed that, in the production of briquettes, the materials can be compressed without addition of adhesive, while in others adhesive materials called binders are added to assist in holding the particles of the material together depending on the type of raw material used for the production. While, Han, Duan, & Yuan, (2014) stated that good densified briquettes obtained from loose biomass depends on several factors such as type of binder used, moisture content, particle size, shatter index, density and compaction temperature and pressure. Both researchers agree that a suitable binder is vital in producing briquette charcoal. Doing it without the binder is more convenient but it requires sophisticated and costly presses and drying equipment which makes such processes unsuitable in a developing country like Nigeria (Onukak et al., 2017). Physical properties such as density, compressive strength and impact resistance index of briquettes also show significant improvement because of binders (Das et al., 2018). Binders such as molasses, starch, tar, etc. are added to produce fuel briquettes, and the addition of starch binder, as well as gum Arabic binder improves the caloric value of biofuel briquettes (Zakari, Ismaila, Sadiq, & Nasiru, 2013). Typically, there are two types of binder which are organic and inorganic. The example of organic binders are crude oil, starch and molasses. The advantage of using organic binder compared to inorganic are more effective at lower dosage levels, which translates into lower storage and transportation costs. Han et al. (2014) said that another advantage of organic binders is that they have low ash contents, and therefore, most of the binder burns off during the briquette firing operation. An ideal binder should essentially leave no residual chemical after the briquette is firing at the optimum temperature.

4.0. Methodology

In this research, the methodology is divided into several main processes which is preliminary process, sieving process, secondary process, testing and data analysis. Figure 1.1 shows the flow chart of the whole process for this research.

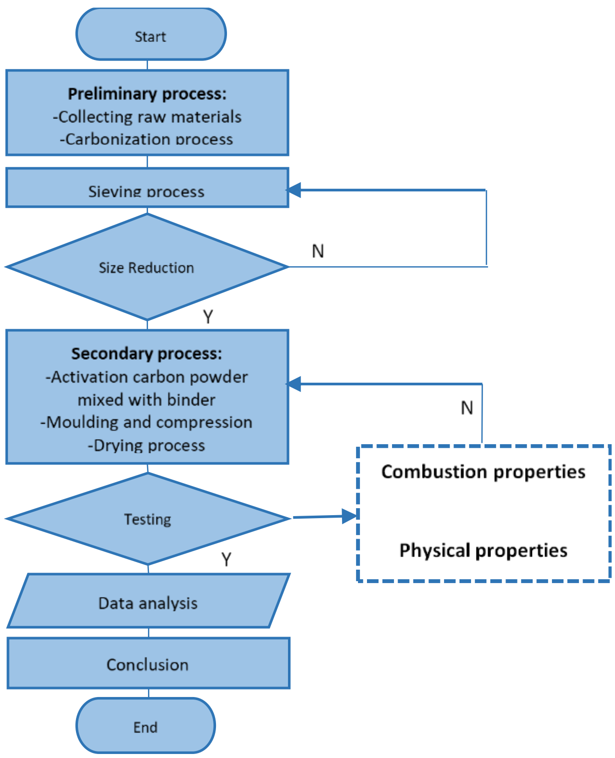

Figure 1.1: Flowchart of the process

4.1. Preliminary Process

In this thesis, there are two essential processes in producing briquette charcoal. On the preliminary process stage, there are three processes that exist namely collecting raw materials, carbonization process and sieving process. The aim of this process is to obtain the activated carbon in powder form. In this study, the briquette charcoal that is going to be produced are materials that consists of coconut shells and palm shells, cassava starch and water. Coconut shell and palm shell as shown in Figure 1.2; (a) and (b), are the replacement material in briquette charcoal according to proportion set. The raw materials which are coconut shell and palm shell are collected at different ports where coconut shells are collected at coconut shells factory located in Sungai Ambat, Mersing. While the palm shells are collected at palm oil shell factory in Klang, Selangor.

(a) (b)

Figure 1.2: Raw material of (a) coconut shell and (b) palm shell

Once the raw materials are free from any dirt, coconut shells and palm shells are sun dry to remove moisture. The next stage of producing briquette charcoal is called the carbonization process. The formation of briquette charcoal is black and composed of carbon. It also indicates the amount of charcoal obtained as the carbonization temperature increases, the lagging mass starts to decrease.

4.2. Sieving Process

In this research, there are two essential processes involved in the production of briquette charcoal. Firstly, after the crushing process, the mixture of coconut shells and palm shells were ready for sieving process. During this process, the intended product was in powdered state. The fine charcoal was then passed through a 50-micron sieve for screening. The mixture underwent multiple sieving cycles to gather the desired activated carbon powder.

4.3. Secondary Process

There were three stages of process in this stage which were activated carbon mixed with binder, molding and compression process and drying process. Every stage of this secondary process is important before proceeding into the testing.

4.3.1. Activated Carbon Powder Mix with Binder

In this stage, the briquette charcoal paste was carried out. The cassava starch was selected as a binder. The 300g of cassava starch powder, 400ml of boiled tap water, and 800g of activated carbon were prepared. The boiled water then poured into the cassava starch and mixed properly to obtain the starch gel. While the starch gel was still warm, the activated carbon powder was gradually added into the starch gel. The mixture was stirred together by hand until the black sticky compound was formed.

4.3.2. Moulding and Compression

In order to briquetting the charcoal, the special mould that produce the briquette shaped must be prepared. Some amount of the paste is then manually pressed in the mould. The pressure was applied to pressing and compressing the briquette charcoal out from the mould. The cylindrical shape of briquette charcoal was ready. In this study, the briquette charcoal moulding machine was designed to replace the current moulding compacter. The briquette charcoal moulding machine design is attached in Appendix. The design of the briquette moulding machine is designed using SOLIDWORK 2018 software. In the new briquette moulding machine, there are five parts which are middle part, top, spring, base and die.

4.3.3. Drying Process

In this state, the briquette charcoal was ready for sun dry for 21 days from the moulding day. The briquette charcoal must be moisture free totally. The briquette then kept in the dry state. Figure 1.3 shows the drying process of briquette.

Figure 1.3: Drying process of briquette

4.4. Testing

There were several tests that were conducted to determine the optimum results of briquette charcoal from coconut shell and palm shell. In every test, the briquette charcoal is compared with coal. The tests were all conducted in Universiti Tun Hussein Onn Malaysia, in Pagoh Campus where few numbers of laboratories were involving in order to complete the testing phase. The tests in this thesis were classified into two classes which were combustion and physical properties.

5.0. Results and Analysis

The physical and combustion properties of briquette charcoal from coconut shell and palm shell were determined by conducting seven experimental testing, which are drop test, ignition test, burning test, calorific test, percentage of volatile matter, percentage of ash content, percentage of moisture content and percentage of fixed carbon. Each testing that has been carried out are consisting of two samples which is briquette charcoal and charcoal. All results were analyzed as a comparison of overall performance between briquette charcoal and charcoal as samples in this study. Table 1.1 shows the summary of results for each testing that was conducted for combustion properties and physical properties.

Table 1.1: Summarize table for each testing

Classes	Testing	Results	Analysis and Summary
Combustion properties	*Calorific Test - Calorific value*	The calorific value of the briquette charcoal is 4787 kcal/kg.	-Lower the moisture content, higher is the calorific value (Deepak & Jnanesh, 2016). Based on the comparison, the value of calorific that coconut and palm shell is in the ranged of ideal domestic usage. (Loo & Koppejan, 2008); Akowuah, Kemausuor, & Mitchual, 2012). -The moisture content of briquette is lower than charcoal.
	Percentage of volatile matter	The percentage of volatile matter was observed on a value of 60.28%.	The high volatile matter content indicates that during combustion, most of the briquette will volatize and burn as gas in the cookstove (Akowuah et al., 2012).
	Percentage of moisture content	The percentage of moisture content showed that the result is 6.8%	The percentages of moisture content of briquette are low enough does not give seriously negative impact on the

			combustibility when in used for household industries (Sipahutar, Bizzy, Faizal, & Maussa, 2017).
	Percentage of ash content	The percentage of ash content is 3.72%.	Low ash content of briquette charcoal resulting in higher heating value that particular briquette (Deepak & Jnanesh, 2016).
	Percentage of fixed carbon	The percentage of fixed carbon is 26.92%.	Fixed carbon is an important constituent of charcoal/ briquette. Furthermore, rice husk and sugarcane had a fixed carbon of 10 % and 12% (Das et al., 2018).
Physical properties	*Drop Test - Toughness of the briquette*	The maximum height that briquette can withstand is at 1.1 meter	The result is satisfactory in term of handling, storing and transportation as the toughness of the briquette is average.
	Ignition Test - Duration of ignition and burning	-The duration of ignition of the briquette was examined to have an average duration of 40 seconds to ignite. -The duration of burning is 360 minutes	Raju, Praveena, Satya, Ramya Jyothi, & Sarveswara Rao, (2014) said that briquette with a faster ignition time has a better thermal efficiency and less environmental issue as well. It can be concluded that, the sample with relatively shorter duration of ignition is more efficient.
	Optimum temperature	The optimum temperature of briquette is 788 ˚C	The longer time of combustion of a fuel, the higher energy consume thus better quality of the fuel will produced (Sudding, 2016; Ahmad, Sulaiman, Inayat, & Umar, 2020)
	Compaction pressure	The compaction pressure is 0.219kN	Increased strength causes low absorption of atmospheric humidity and thus increases the briquette durability.
	Briquette density	The density of the briquette charcoal is 1.27kN.	A high bulk density leads to higher energy which is desirable for the purpose of transportation, handling and storage.

In the final analysis, the objectives of the project are successfully achieved. The first objective is to determine the combustion properties of palm shell and coconut shell as briquette charcoal. The combustion properties that are being investigated in this project including calorific value, percentage of volatile matter, percentage of moisture content and percentage of fixed carbon. The results of combustion properties obtained from experimental has concluded that the briquette charcoal made from coconut shell and palm shell has an optimum performance as a briquette charcoal. The calorific value of the briquette charcoal is 4787 kcal/kg. While the percentage of volatile matter was observed on a value of 60.28%. The percentage of moisture content showed that the result is 6.8% and the percentage of ash content is 3.72%. The percentage of fixed carbon is 26.92%. In the second objective, the aim of the project is to determine the physical properties of the briquette charcoal made from coconut shell and palm shell. The physical properties that are being investigated in this project are toughness of the briquette, duration of ignition and burning, optimum temperature, compaction pressure and briquette density. From the result obtained, the maximum height that briquette can withstand is 1.1 meter. The duration of ignition of the briquette was examined to have an average duration of 40 seconds to ignite. In addition, the duration of burning is 360 minutes, and the optimum temperature of briquette is 788 °C. Furthermore, the compaction pressure is 0.219kN and the density of the briquette charcoal is 1.27kN. The results of combustion properties obtained from experimental has concluded that the briquette charcoal made from coconut shell and palm shell has an optimum performance as a briquette charcoal. It proved that the combustion properties of briquette are significantly in the range of specification of coal used for domestic use.

6.0. Conclusion

In this application of using coconut shell and palm shell as a briquette charcoal, proved that the combustion properties of briquette are significantly in the range of specification of coal used for domestic use. Meanwhile, for the physical properties, the result is satisfactory in terms of handling, storing and transportation as the toughness of the briquette is average. Nevertheless, the other properties of the briquette gave an excellent result to produce briquette charcoal. Besides, the problems associated with the disposal of coconut shell and palm shell wastes can be overcome by producing briquette charcoal from this agricultural waste. By conducting this project, briquette charcoal produced provided high temperature, ignited easily without danger, and last longer for burning purposes. The technology of converting biomass products into briquette is affordable, efficient, and environmentally friendly.

Author Contributions

K.A. Rahman Author: Conceptualization, Methodology, Writing-Reviewing and Editing; **A.M. Leman Author**: Methodology, Data Curation, Validation, Supervision; **F.I.T John Author**: Software, Methodology, Testing and Analysis, Writing- Original Draft Preparation

Conflicts Of Interest

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its Submission, and declare no conflict of interest in the manuscript.

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