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Original Research Article

Sustainable Waste Management Breakthrough: Transforming Plastic Waste into Eco-Friendly Briquette Charcoal

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Abstract
Plastic waste has emerged as an important environmental concern. Among the various types of plastic waste, such as Polyethylene Terephthalate (PET) and Polypropylene (PP), these two contribute the most to the overall plastic waste problem need to be efficiently managed. The purpose of this research is to study the manufacture of briquettes from PET and PP plastic waste with the help of starch adhesive. This research is expected to reduce the negative impact of plastic waste. In this study, the data to be obtained were the calorific value of the briquettes, ash content, moisture content, volatile content and bound carbon content. The results show that the best raw material combination in terms of the calorific value of the resulting charcoal briquettes is the raw material mixture with the addition of PET. The results of the PET type plastic briquettes were superior with the results of the calorific value test of 10.129 cal/gram, the proximate test results of 3.11% ash content, 4.98% moisture content, 65.31% volatile matter content, and 78% bound carbon content 79%. While the PP type plastic briquettes obtained a calorific value test result of 9,949 cal/gram, the calorific value was lower than the PET type plastic briquettes.

Keywords: Briquettes plastic charcoal; management waste solid; participation society; waste bank.

1. Introduction

Economic progress relies on both human resources and the availability of natural resources, including energy. On a daily basis, the demand for energy in Indonesia, specifically fossil fuels (BBM), has risen to 215 L/day, surpassing the domestic production of 178 million L/day. The growth in energy consumption is increasing by 7% annually, driven by the accelerating economic growth (6.3% per year) and population growth. Presently, there is growing criticism concerning the sustainability of non-renewable resources, particularly petroleum. Evaluating the ratio of energy reserves to production, it is evident that the potential lifespan for coal, natural gas, and oil is only 50, 30, and 10 years respectively. Consequently, it is imperative for society to explore alternative resources. On the other hand, the exponential increase in municipal solid waste due to population growth, urbanization and economic development has encouraged development and engineering to suppress and reduce existing waste generation (Puspita and Budihardjo et al., 2023). This situation is also evident in Tangerang Regency. It has become a familiar sight to witness garbage scattered along the roadside in Tangerang Regency. People have developed a habit of disposing their household waste in plastic bags on the roadside early in the morning before heading to work. This cultural practice has persisted for years, resulting in a polluted and untidy environment. To address this issue, a comprehensive waste management system is crucial for effective pollution control (City Risk Diagnostic for Urban Resilience, n.d.). Therefore, heaps of waste can be mined to be used as fuel such as briquettes or RDF (Budihardjo and Yohana et al., 2022).

The Tangerang Regency Government is working with waste banks. Tangerang District has more than 120 Waste Banks. Waste banks have a receptacle called the Waste Bank Forum Tangerang Regency. Waste Bank Forum coordinates and socializes handling trash in every village in Tangerang District. With this forum, the public lots get knowledge about hygiene, the environment, and trash management can increase the economy and society. Waste Bank Forums is a community waste that is part of the community organization in Indonesia in managing organic waste on an environmental scale and is a solution for problem waste management (Rachman et al., 2021). Recently, in Tangerang Regency, waste produced began to decrease because waste and organic materials were burned in briquettes, which means an increase in the community's economy. As a result, old trash scattered on the streets is now decreasing. Tangerang Regency already has a recycling center that handles waste sorting in several places. The factors influencing waste management's success are cooperation between the government and society to participate in environmental improvement, hold seminars, and contribute to serving the public (Rahman et al., 2022).

People's lifestyles significantly affect the amount and type of waste. There are lots, not biodegradable plastic packages due date to belong to people's habit in the purchase fast food and packaging for household needs. Much domestic organic waste comes from kitchen activities (Rachman et al., 2016). Public awareness of sorting and utilizing waste has yet to be formed. Today's society has started throwing away waste to location disposal waste which is later thrown out at the appropriate landfill with government recommendations as well as campaigns for waste segregation and solicitation of the government to become members of bank rubbish (Rachman et al., 2021). The problem of waste is interesting to discuss because apart from its wide-reaching impact, the problem of waste is also experienced by almost all countries. As is well known, Indonesia produces 64 million tons of waste annually (Seminar et al., 2019). On the other hand, the problem of municipal waste is getting more complicated due to limited land and the increasing amount of waste generated.

Waste Bank is claimed to be a method for increasing public awareness and participation in a healthy environment and managing trash (Ulhasanah & Goto, 2018). Previous studies have only focused on factors that can affect the sustainability of waste banks as community-based recycling facilities. Based on this scientific gap, this study examines the potential for community participation and develops several waste management strategies in waste banks in Tangerang Regency. The community develops several waste management strategies through the Waste Bank Forum, with members in eight districts: subdistrict Tigaraksa, Panongan, Balaraja, Pagedangan, Legok, Curug, Solear, and Jambe. This study begins with a desk review to find out the current waste management carried out by waste bank officers in each village and see and learn the potential benefits of a circular economy for the environment. This study will provide examples of successful community participation, several strategies for recycling and managing waste, and potential circular economy benefits for the environment, one of which has economic value, namely recycling plastic into briquettes. Plastic is an inorganic material composed of chemicals that are harmful to the environment. Therefore, this research is the answer to reduce environmental pollution.

Briquettes are an alternative energy source to substitute fuels made from coal, organic waste, factory waste, and urban waste by converting solid raw materials into compaction products that are more effective, efficient, and easy to use (Nurlatifah et al., 2022). One is the issue of using plastic cups of processed mineral water in briquette fuel through briquette management training by Chemical Engineering lecturers and students and Engineering Environment UNIS. Polyethylene Terephthalate (PET), mineral water glass plastic waste, and Polypropylene (PP) plastic bag waste are plastic waste that has yet to be processed and utilized, but the production is still relatively high.

Plastic is an inorganic material composed of chemicals that are harmful to the environment. Initially, the materials for making plastic were oil and gas as natural resources (Dogu et al., 2021). In its development, these materials were replaced with synthetic materials to obtain the desired plastic properties (Thyavihalli Girijappa et al., 2019). Plastics have two physical properties: thermoplastic (plastic that can be recycled or re-molded by a reheating process) and thermosetting (plastic that cannot be recycled or re-printed by a reheating process). The plastic used in the research is included in the group plastic with thermoplastic is rubbish plastic which is included in the type of plastic PP (polypropylene) with a melting point of 160 °C and mineral water bottle plastic waste is included in the type of PET (polyethylene) plastic terephthalate) with the point, the melt is higher at 250°C (Schirmeister and Mülhaupt, 2022).

The briquettes are used for domestic and industrial purposes in both rural and urban areas. The domestic purposes include heating, cooking, and barbequing, while the industrial purposes include agro-industries and food processing. Based on the description problem above drawn explicitly, the objective aims to examine the manufacture of briquettes from PET and PP plastic waste with the help of starch adhesive. Briquette testing was carried out by testing the calorific value and proximate test. The application of the technology developed in this study is expected to reduce the negative impact of plastic waste and significantly improve the quality of waste processing, especially plastic waste so that higher income can be obtained to enhance the welfare of the local community. In addition, this effort can also benefit the industry and the government because, if followed up, plastic waste briquettes can drive generators and power plants, thereby reducing production costs. Paguyuban, engaged in waste processing and sorting, can reduce waste by using technology to convert plastic waste into charcoal briquettes.

2. Methods

This study uses method experimental which begins with a literature study on research on the manufacture of briquettes from various sources and various materials possibly used for alternative fuels. Fuel is any material that can be converted into energy (Nurlatifah et al., 2022). The material used is PET plastic waste mineral water cup and PP plastic bag waste. In this study, the data to be obtained is the calorific value of briquette burning, ash content, moisture content, and volatile content, and bonded carbon content. The tools used in this study were *bomb calorimeters, ovens*, desiccators, briquettes printing machine, material scales, porcelain dishwasher, analytical scales, spatula, *stopwatch*, filter, container (wok), stirrer, dead and pestle, furnace, cup equipment, drums. Collection and processing of samples and printing of briquettes then a proximation test was carried out by determining the moisture content, ash content, unstable substance content and mark calories.

Carbonation process material, PP plastic is cleaned and chopped using a machine plastic chopper with a small size, less more 5mm. Then prepare a iron drum with a capacity of 60 liters as a container for the carbonization process. Then 1 kg of wood charcoal is put into the drum and heated until it smolders for 10 minutes, after which 2.5 kg of chopped plastic cups are placed in the drum. Blowers are used to enlarging the flame, then the drum is closed with a drum lid that has been modified with the iron pipe as a chimney. Carbonization is carried out for 2–3 hours at temperatures up to 300°C. The shards of plastic cups that have turned into charcoal are left in the drums during One Evening.

After the carbonation process, the briquette printing proses is carried out. The briquette molding process is the crushed charcoal plastic cupsmortar until it becomes a finer grain or powder. Then the plastic cup charcoal which has become powder is sieved using a 40-60 mesh sieve. After that, the ingredients that have been sifted are used as much as 500 grams. 20 grams of starch is mixed with 50 milliliters of water, then cooked until it becomes a sticky dough. The briquette powder is then mixed with starch adhesive with a composition ratio of 100: 20, that is, every 100 grams of briquette powder is added 20 grams of starch adhesive (Asmara et al., 2023), then stirred until it becomes a briquette mixture. Starch adhesive we used tapioca flour. Tapioca flour, cassava flour, and starch is flour obtained from cassava roots or in Indonesian it is called cassava. Tapioca has similar properties to sago, so the uses of the two can be interchanged. This flour is often used to make food, adhesives, and many traditional foods that use tapioca as a raw material (Muhammad Faizal et al., 2018). Then the briquette dough is printed into a cylindrical mold with a diameter of 3.5 cm and a height of 3.5 cm, then it is pressed using a manual press until it is completely solid. The printed briquettes were then dried in the sun for 20 hours. Can also be dried in the oven for 3 hours. The last one is briquette analysis. At stage, this calorific value test and *proximate test* include moisture content, ash content, volatile matter content, and bound carbon content. Tests on the quality of plastic briquettes were carried out in the laboratory using a *Bomb Calorimeter PARR 1261* for testing the heat of combustion, and an *Automatic proximate analyzer* for *proximate tests* (Garrido et al., 2017).

For processing the data using the following formula:

$$\%\ \text{Water content} = \frac{\text{lost weight}}{\text{sample weight}} \times 100\% \quad (1)$$

$$\%\ \text{Ash content} = \frac{\text{ash weight}}{\text{sample weight}} \times 100\% \quad (2)$$

$$\%\ \text{Unstable content} = \frac{\text{lost weight}}{\text{sample weight}} \times 100\% \quad (3)$$

The benefits of this research will be able to reduce waste/plastic waste and Utilizing waste/plastic waste to make briquettes that are useful as alternative fuels and increase productivity and economic value at the Asy Syifa Berkah Waste Bank. **Figure 1** represents picture briquettes that have been printed from processing briquettes.

Figure 1. Briquettes PET and PP plastic waste

Furthermore, by explaining several factors that influence testing the quality of briquettes, including calorific value and bonded carbon value. The content of bound carbon content determines the calorific value of the resulting fuel, which is characterized by volatile matter and ash content. The amount of volatile matter and ash content is inversely proportional to the value of the bound carbon content (Fernanda et al., 2022). A good solid fuel depends on the size of the carbon content to produce a high calorific value. Furthermore, the level of compaction pressure affects the energy density content and has no effect on the heating value (Priyadi et al., 2022).

3. Result and Discussion

3.1 Location Study

This research was conducted at Asy Syifa Berkah Waste Bank located at Pasirnangka Pete Village, Subdistrict Tigaraksa Regency Tangerang Banten Province. Asy Syifa Blessing Trash Bank was established in 2015 and inaugurated year 2018 for facilitating every Waste Bank activity. Asy Syifa Berkah Waste Bank activities no only balance waste but also recycle waste become various craft hand which has a resale value. There is also a waste-saving system that will be swapped into pennies that help enhance the economy waste bank community in Tangerang Regency. Every month waste bank community is reduce plastic waste by around 17 tons. Plus making briquettes charcoal increases again income of members of the waste bank. Initially rubbish become blessing.

3.2 Calories Mark Analysis on Briquettes

The calorific value is a measure of the heat or energy produced and is measured as the bottom calorific value (NKB or gross calorific value) or net calorific value (NKA or net calorific value). The difference between NKA and NKB is determined by the latent heat of condensation from water vapor produced during the combustion process. Meanwhile, NKA assumes that all the steam produced during the combustion process is fully condensed. NKB assumes that the water that comes out with condensation products is not completely condensed (there is still water content in the product) (Trihadiningrum, 2007). The calorific value test is carried out to determine the calorific value of the briquettes made of PET plastic and PP with starch adhesive. Table 1 it is explained results from value test results calories that have done.

Table 1. Results calorific value test

No	Briquettes Sample	Testing	Results	Unit
1	Water cup mineral	Calorie Value	10.129	cal/gr
2	Pocket plastic	Calorie Value	9.949	cal/gr

From **Table 1,** can be seen that the quality of briquettes made from plastic waste, mineral water cups and bag waste has met the quality requirements for briquettes based on right SNI No. 1/6325/2000. The calorific value that meets the requirements SNI is ≥ 5,000 cal/gram. The higher the calorific value of the briquettes, the higher the quality of the products produced, so that the briquettes have more potential as alternative fuels (Ruslinda et al., 2017). From Table 1 calorific value for cup of mineral water is 10,129 cal/gram and for plastic bag 9,949 cal/gram far above the benchmark mark SNI heat.

The calorific value of burning briquettes from plastic waste to a cup of mineral water is higher than the calorific value of briquettes from plastic bag waste. The calorific value of Hydrocarbon compounds occur due to the presence of energy due to chemical reactions, the breakdown of bonds between atoms in reacting compounds, and the recombining of reacting atoms to form a new compound (Fitriani et al., 2022). The longer the chain of atomic bonds in a compound, the greater the energy produced is also higher which reason the calorie mark is also higher (Kaplan & Saccuzzo, 2009).

Plastic bag briquettes made of *Polypropylene* (PP) type plastic are molecular in nature the formula $(C_3H_6)x$ and the wake formula is $(-CH-CH_3-CH_2)n$. From the building formula, it can be seen that PP-type plastic has short chain bonds so that it becomes atomic bonds solving reaction produces small energy compared to plastic (Fitriani et al., 2022) briquettes from cup water minerals made from *polyethylene Terephthalate* (PET) plastic. PET own formula molecule $(-CO-C_6H_5-CO-O-CH_2-CH_2-O)n$. From That molecular formula, can be seen that PET plastic's own chain has more atomic bonds long so that generated energy bigger (Muliadi, 2019). In addition, the increase in heating value can also be affected by the carbonization process. The carbonization process aims to convert the raw material into charcoal so as to increase the carbon content and increase the calorific value of the briquettes (Ruslinda et al., 2017).

3.3 Analysis Proximate on Briquettes

Proximate testing was carried out to determine the value of water content, ash water content, vapor content, and bound carbon content (Mongkito et al., 2020) resulting from plastic cup waste briquettes and plastic bag waste with starch adhesive. *Proximate* test results are served in **Table 2**.

Table 2. Test results *proximate* on briquettes

No.	Briquettes Sample	Parameter	Results	SNI
1	Plastic waste	To the top to ash (%)	3.11	≤ 8
	Cup water mineral	To the top to air (%)	4.98	≤ 8
		Bonded carbon content (%)	78.79	≥ 77
		Evaporated substance content (%)	65.31	≤ 15
2	Rubbish pocket plastic	To the top to ash (%)	5,71	≤ 8
		To the top to air (%)	6.01	≤ 8
		Bonded carbon content (%)	78.27	≥ 77
		Evaporated substance content (%)	59.22	≤ 15

Source: (Joseph et al., 2021)

Based on **Table 2.** nearby briquettes test results from mineral water cup and plastic bag waste with starch adhesive, using a ratio of 500 gr plastic and starch composition adhesive composition from 100 gr: 20 gr produce values from waste briquettes plastic cups are better than plastic bag waste with the resulting value rate ash as big 3.11%, moisture content 4.98%, substance content evaporate 65.31%, and carbon bound as big 78.79%.

There are differences in the results of testing the ash content and moisture content of the two types of plastic briquettes that have been made. From Table 2 it can be seen that the ash content from briquettes from waste pocket plastic is 5.71%, higher compared to the ash content from briquettes from plastic waste mineral water cups which is only 3.11%. Ash is the residue of unburned material after complete combustion which is closely related to the inorganic materials in it (Trihadiningrum, 2007). K is ash showing the amount of dirt contained in the material. The lower the ash content from a fuel, the better the quality of the fuel. At the time of heating, all the hydrocarbon compounds will evaporate, and what remains as rate ash is compound metal which is not will evaporate at the time of heating. Her height rate ash on briquettes rubbish plastic bags caused because own plastic bag is a recycled plastic repeat, which are substances impurity will lots carried away during the recycling process repetition (Hopewell et al., 2009). The substances in the briquettes affect the ash content produced, the lower the ash content, the better the quality of the briquettes (Anggita et al., 2023). Raw material factors greatly affect the high and low ash content of the resulting charcoal briquettes. This is due to the fact that the raw materials used have different chemical compositions and amounts of minerals, resulting in different ash content of the charcoal briquettes produced (Hendra, 2007). High ash content in briquettes can be caused by raw materials that have high levels of carbonate, potassium, calcium, magnesium and silicate salts. The high silicate content will cause the resulting ash content to be higher, because silicate does not burn (Ruslinda et al., 2017). The amount of volatile matter will affect the amount of smoke produced, this is influenced by the reaction of carbon monoxide with alcohol derivatives (Anggita et al., 2023). In addition, the high ash content will complicate the operation and maintenance of the kiln. To maintain comfort in the use and maintenance of combustion equipment and reduce dust emissions in the furnace, the high ash content in briquettes must be reduced (Trihadiningrum, 2007).

The moisture content in the briquettes has an effect on increasing heat loss, due to evaporation and overheating of the steam, helping to bind the fine particles together, and helping radiant heat transfer (Trihadiningrum, 2007). Differences in Briquette water content in waste mineral water plastic cups and waste plastic bags are caused by external factors from briquettes that occur during the cooling process with water to make briquettes become dense and hard. The high water content will lower mark heat in briquettes. Briquettes quality are also determined by the grade of substance evaporate or the volatile content of the substance (Sunardi et al., 2019). The moisture content in the briquettes will affect the value of the power and combustion power. The higher the value of the water content, the lower the calorific value and combustion power. High water content can complicate the process of lighting briquettes (Ruslinda et al., 2017).

Volatile content is the amount of substance that evaporates in hydrocarbon compounds when heated to 900°C in oxygen-poor conditions (Heymes et al., 2020). Volatile levels also indicate how fast a material will burn when given heat. The longer the atomic chain bonds of a hydrocarbon compound, the more the substance will evaporate when heated (Waluyo et al., 2018). The effect of volatile content on briquettes is directly proportional to the increase in flame length, assists in the ignition of briquettes, and affects air requirements and distribution aspects (Trihadiningrum, 2007). The greater the volatile content in the briquettes, the faster they will burn, but this will result in a short life time for the briquettes. The value of volatile content depends on the type of raw material used in making briquettes (Ruslinda et al., 2017). From Table 2 it can be seen that the volatile content of briquettes from plastic mineral water cup waste is higher than the volatile content of briquettes from plastic bag waste. This is because briquettes from mineral water cup plastic waste have longer hydrocarbon chain bonds than briquettes from plastic bag waste. Comparison of the test results of the briquettes with the SNI standards can be seen that the calorific value, moisture content, and ash content of the briquettes as well as the content of the bonded carbon of the briquettes have met the standards, the volatile matter content of the briquettes has not met the standards because still too high.

4. Conclusions

Based on the research that has been done, the results show that the process of processing mineral glass plastic waste and plastic bags can produce useful products in the form of briquettes. Raw material factors affect the physical and chemical properties of charcoal briquettes which include the calorific value of the fuel, the value of the moisture content, the value of the resulting ash, and the volatile value. The best combination of raw material mixtures in terms of the calorific value of the resulting charcoal briquettes is the raw material mixture with the addition of PET. The results of the PET type plastic briquettes were superior with the results of the calorific value test of 10.129 cal / gram, with the proximate test results of 3.11% ash content, 4.98% moisture content, 65.31% volatile matter content, and 65% volatile matter content. 31%. Unstable material content bonded carbon of 78.79%. While the PP type plastic briquettes obtained a calorific value test result of 9.949 cal / gram, the calorific value was lower than that of the PET type plastic briquettes. Some suggestions that can be given by the authors from the research results are that it is necessary to test gas emissions, and it is necessary to measure the compressive strength when printing briquettes.

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