Jurnal Ilmu Fisika
Vol. 15, No. 2, September 2023, pp. 81–90
ISSN: 1979-4657 (Print); 2614-7386 (Online)
https://doi.org/10.25077/jif.15.2.81-90.2023

Jurnal Ilmu Fisika
Open Access

Utilization of Waste from LDPE, Coconut Husk, and Coconut Shell with Tapioca Adhesive as Bio-briquettes

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Article Info

Article History:

Received November 27, 2022
Revised February 28, 2023
Accepted April 19, 2023
Published online April 29, 2023

Keywords:

bio-briquettes
LDPE
coconut husk
coconut shells
tapioca starch

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ABSTRACT

Bio-briquettes of organic waste can be used as alternative energy to solve the waste problem. This study aimed to determine the quality of bio-briquettes made of LDPE, coconut husk, and coconut shell with tapioca adhesive. The coconut husk and shell were carbonized at 300 °C for 60 minutes. Charcoal that has been ground and sieved with 40 mesh is mixed with tapioca flour adhesive, and pieces of LDPE are added. Then, the sample is pressed with a cylindrical mold with a matrix strength of 5 tons. Bio-briquettes were dried in an oven at 80 °C for 12 hours. The quality of the briquette was evaluated through proximate analysis, including the calorific value, moisture content, ash content, volatile matter content, and fixed carbon content. The calorific value of all samples complied with the regulation of the Ministry of Energy and Mineral Resources (ESDM) No. 047 of 2006, which is above 4400 cal/g. The maximum moisture content is 15%, which fulfills SNI 06–3730-1995 standards, and the ESDM regulation, especially for the composition of 40% shell: 40% coconut: LDPE 20%. The ash content, volatile matter content, and fixed carbon content of all samples did not comply with SNI briquette standards and ESDM regulations.

1. INTRODUCTION

Daily garbage accumulation is a global problem. According to 2019 Ministry of Environment and Forestry data, Indonesia produces approximately 64 million tons of waste yearly. Garbage pollutes the environment, but only 30% of the total waste can be recycled (Sumartiningtyas, 2020). Some of the waste generated is in the form of plastic waste. Unmanaged plastic waste produced in Indonesia each year reaches 4.8 million tons, based on data from The National Plastic Action Partnership (NPAP). The accumulation of plastic waste will increase by 5% annually (Situmorang, 2021). Processing plastic waste as an alternative fuel is a smart solution amid fuel scarcity.

The diminishing existence of fossil fuels makes the availability of energy fuels worldwide dwindle. One of the countries that have experienced the scarcity of fossil fuels is Indonesia. In fact, according to the Ministry of Energy and Mineral Resources statement in October 2021, fuel shortages occurred in various regions in Indonesia (Umah, 2021). Data from the National Energy Council show that in 2009 oil production was 346 million barrels and continued to decline. In 2018 only 283 million barrels of oil can be produced (Tim Sekretaris Jenderal Dewan Energi Nasional, 2019). The solution to dealing with the scarcity of fossil fuels is to create alternative energy in the form of briquettes.

Bio-briquettes can be made from organic waste and inorganic waste by forming solid materials into a more compact form with a certain pressure so that they become products that are more effective, efficient, and easy to use (Asip et al., 2014). Bio-briquettes can replace the use of direct fuels from nature, such as firewood which can potentially damage forest ecology (Huroeroh et al., 2021). The properties of briquettes are influenced by several factors, namely the specific gravity of the charcoal powder, carbonization temperature, powder size, compression technique, and briquette composition (Nurhudah, 2018). In addition, the conditions for a good briquette are a high calorific value, easy to ignite, produces good coals, does not smoke or emit toxic materials, does not smell, does not mold when stored for a long time, does not burn quickly (low combustion rate), low ash content, and low gas emission (Asip et al., 2014). Briquettes should refer to market segments where economic and environmental value are obtained efficiently (Faizal et al., 2018). Referring to the market segment in that briquettes must obtain economic value, the raw materials for making briquettes can also be processed from waste. One of the materials that can be used as a candidate for briquette raw materials is plastic waste, where the calorific value of plastic is quite high, around 11,095.24 Cal/g (Amelia & Boedisantoso, 2010). Previous research has used LDPE as a raw material for briquettes with a calorific value of 11,172 cal/g. However, the volatile matter content is still very high, so briquettes from LDPE raw materials run out quickly (Faizal et al., 2018). To overcome this problem, another raw material with a low volatile matter content is needed, which can be mixed with the LDPE raw material.

Coconut shell is very potential for making bio-briquettes. Charcoal from coconut shells is made into bio-briquettes; it has a higher calorific value. This is because the coconut shell has a high calorific value. The calorific value produced by the coconut shell is around 7283.5 cal/g (Nurhilal, 2018). Using coconut shells as a raw material for bio-briquettes in previous studies has met quality standards based on PERMEN No.47 and Japanese briquette quality standards. The most optimal raw material for bio-briquettes is coconut shell mixed with LDPE plastic and palm shell with a proportion of 40% coconut shell, 50% coconut shell at a carbonization temperature of 500°C and 10% LDPE plastic, and added starch adhesive as much as 2% of the sample weight briquettes. However, the weakness of bio-briquettes from coconut shells is that they are easily destroyed (Asip et al., 2014). Besides shell waste, coconut husk waste is very large and has not been utilized optimally. The use of coconut husk in bio-briquettes has been studied before. Obtained by mixing the raw materials for coconut husk and egg shells as raw materials, the bio-briquettes meet the briquette SNI standards. Mixing coconut husk: with egg shells, with a ratio of 3:1 and 2:1, has in accordance with SNI bio-briquettes No 1/6235/2000 (Priyanto & Putri, 2017). This study aims to determine does the quality of briquettes by utilizing LDPE plastic waste, coconut shell, and coir waste with starch adhesive comply with SNI and PERMEN ESDM briquette standards or not.

2. METHOD

2.1 Bio-Briquette Sample Production

The research consisted of three stages: the carbonization process, bio-briquette pressing, and proximate analysis. In the carbonization process, the coconut shell and coconut husk were dried for two days under exposure to the sun. These materials were put into the furnace alternately for the carbonization process. Setting the furnace at 300 °C for 60 minutes, the temperature dropped to 30°C for carbonization charcoal. Previous studies have shown that carbonization begins at 300 °C decomposition of lignin and cellulose, resulting in new crystallite structures. Forming a new crystallite structure is very beneficial for manufacturing carbon structures in charcoal (Pari, 2011). Carbonized charcoal was separated from the remaining ash for further processing. In the bio-briquette pressing process, the charcoal of each raw material from the carbonation process was pounded and sieved through a 40-mesh sieve. The charcoal powder was mixed with LDPE plastic and cut into small pieces with the composition ratio, as shown in Table 1, with a total mass of 5 grams per sample. To make an adhesive solution from starch, mix starch powder with a mass of 10% of the total mass of charcoal mixed with

1.8 ml of aquadest until everything is mixed evenly. The adhesive solution was heated and stirred on the hotplate until it thickened. The charcoal mixture was sifted, and the adhesive solution was stirred, printed with a cylindrical mold, and pressed with a matrix strength of 5 tons. Charcoal bio-briquettes that were pressed were dried in an oven at 80 °C for 12 hours (Faizal et al., 2018). The proximate analysis is included five types, calorific value, moisture content, ash content, volatile matter content, and fixed carbon content.

Table 1 Ratio of Composition Bio-briquette

Sample	Ratio of Composition	Composition
CS:LDPE	80:0:20	4 g coconut shell + 0 g coconut husk + 1 g plastic LDPE + 0.5 g tapioca + 1.8 ml water
CH:LDPE	0:80:20	0 g coconut shell + 4 g coconut husk + 1 g plastic LDPE + 0.5 g tapioca + 1.8 ml water
CS:CH:LDPE	40:40:20	2 g coconut shell + 2 g coconut husk + 1 g plastic LDPE + 0.5 g tapioca + 1.8 ml water

2.2 Proximate Analysis

2.2.1 Calorific Value

The calorific value is the total heat of combustion of the elements that comprise the raw material. The calorific value is the amount of heat contained in a material and will be released when the material is burned. The calorific value can be measured using a bomb calorimeter. A bomb calorimeter is a tool used to measure the calorific power of a material; in analyzing the calorific value with a bomb calorimeter for bio-briquettes that still contain water, namely Gross Energy (GE) or gross calorific value using the equation (Almu et al., 2014).

$$C = \frac{(T_2 - T_1) \times c}{m} \tag{1}$$

where C is Calorific Value (cal/g), c is the determination of each material that is burned to raise 10 °C temperature of the water and calorimeter device (2575,6 Cal/°C), T_2 is final temperature (°C), T_1 is initial temperature (°C).

2.2.2 Moisture Content

Moisture content was determined by calculating the weight loss of bio-briquettes when heated in an oven at standard temperature. The test sample used a sample weight of ± 1 gram of bio-briquettes and then put in the oven for 1 hour with a temperature of 104 °C - 110 °C. The water content can be obtained using the equation (Sulistyaningkarti & Utami, 2017).

$$KA = \frac{X_1 - X_2}{X_1} \times 100\% \tag{2}$$

where KA is moisture content (%), X_1 is Bio-briquette sample weight before heating in the oven (gram), X_2 is Bio-briquette sample weight after heating in the oven (gram).

2.2.3 Ash Content

The ash content is the amount of ash that occurs after the bio-briquette ashing process. Determining the ash content requires weighing the remaining results of burning bio-briquettes from standard conditions to perfect ashing. The ash content was measured by weighing the cup without the lid, then taking a sample of bio-briquettes with a mass of ±1 gram and putting them in the furnace at 450℃ - 500℃ for 1 hour, then increasing the temperature 700 ℃ - 750 ℃ for 2 hours. Furthermore, the ashing process was heated at 900 ℃ - 950 ℃ for 2 hours (Sulistyaningkarti & Utami, 2017). The cup and sample were cooled in a desiccator, and the ash content was weighed. The amount of ash content can be obtained from the equation (Faizal et al., 2018).

$$A = \frac{b-c}{a-c} \times 100\% \quad (3)$$

where A is ash content, a is Bio-briquette sample weight before the ashing process (grams), b is Bio-briquette sample weight after the ashing process (grams), c is cup weight.

2.2.4 Volatile Content

Volatile matter content is a hydrocarbon compound that evaporates during combustion with minimal oxygen. The level of this volatile substance shows the amount of material that burns when heat is given (Sawir, 2016). The volatile matter was determined by heating the bio-briquettes in the furnace. First, weigh 1 gram of the bio-briquette sample, then place it in the cup. The cup filled with bio-briquette samples was put into the furnace with a temperature of 750 ± 20 ℃ for 7 minutes, after which the sample was cooled in a desiccator and weighed; the volatile matter content is calculated by the following equation (Ningsih et al., 2020).

$$V = \frac{W_0 - W}{W_0} \times 100\% \quad (4)$$

where V is volatile matter (%), W is sample weight after heating (grams), W_0 is sample weight before heating (grams).

2.2.5 Carbon Fixed Content

Fixed carbon content is a parameter of bio-briquette quality. The fixed carbon content indicates the combustible carbon content after the expulsion of volatile materials (Ningsih et al., 2020). The level of fixed carbon will significantly affect the ignition of bio-briquettes. The higher the fixed carbon content, the easier the bio-briquettes are ignited (Qistina et al., 2016). The fixed carbon content in bio-briquettes is influenced by the carbonization process, the specific gravity of the raw material, and the level of volatile matter (Rindayatno et al., 2017). The high fixed carbon content in bio-briquettes is excellent because carbon compounds are needed to react with oxygen during the combustion process to produce high heat (Hapid et al., 2018). Determination of the bonded carbon content is by the following equation (Sulistyaningkarti & Utami, 2017).

$$FC = 100\% - (KA + V + A)\% \quad (5)$$

where FC is fixed carbon content(%), KA is moisture content (%), V is volatile matter (%), A is ash content (%).

3. RESULTS AND DISCUSSION

3.1 Calorific Value

Figure 1 shows that the calorific value of bio-briquette CS: LDPE is higher than bio-briquette CH: LDPE because of cellulose, lignin, and hemicellulose levels of coconut shell is higher than those of coconut husk. The carbon content of the coconut shell is large enough so that the carbon quickly reacts with oxygen during combustion, which produces gas and heat, which is relatively high (Qistina et al., 2016). That is why the calorific value of bio-briquette CS: LDPE with the composition of coconut shell and LDPE has the highest value. Non-carbonized coconut shell has a calorific value of 4300 cal/g, higher than a non-carbonized coconut husk which only has a calorific value of 3300 cal/g (Nurhilal, 2018). The calorific value of bio-briquettes CS:CH: LDPE decreases due to the addition of coconut husk composition, which has a lower calorific value.

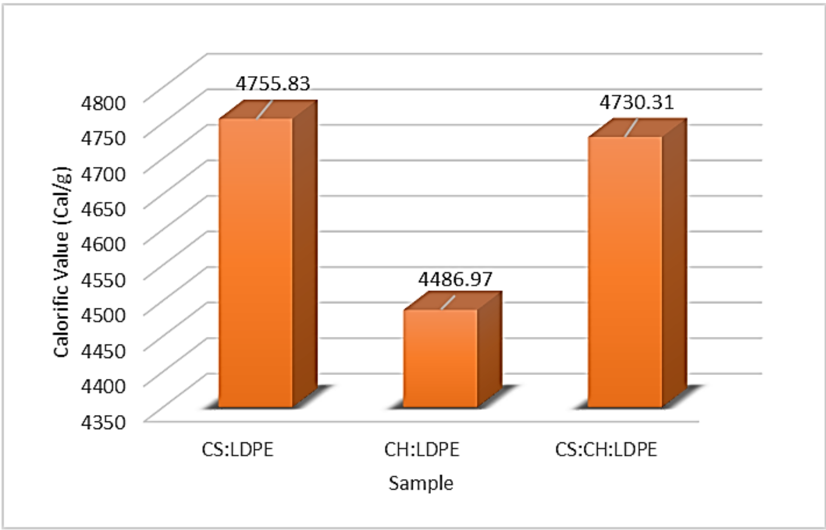

Figure 1 Calorific value of bio-briquette

The calorific value with the addition of LDPE to all bio-briquettes is high. This is because LDPE plastic waste has a high calorific value. The amount of energy used to break the bonds between the atoms of the reacting compounds is what causes the high calorific value of LDPE. The longer the atomic chain bonds of a compound, the greater the energy needed to break the bonds and the greater the calorific value (Sawir, 2016). Previous research found that the calorific value of bio-briquettes increased with the addition of LDPE because the moisture content and ash content after adding LDPE decreased and increased the calorific value (Faizal et al., 2018). When all bio-briquette samples are compared with the standard calorific value of coal bio bio-briquettes, which has a value of 4400 cal/g according to PERMEN ESDM No. 047 of 2006 (Trihadiningrum et al., 2007), all bio-briquette samples in this study fulfilled the coal bio bio-briquette standards.

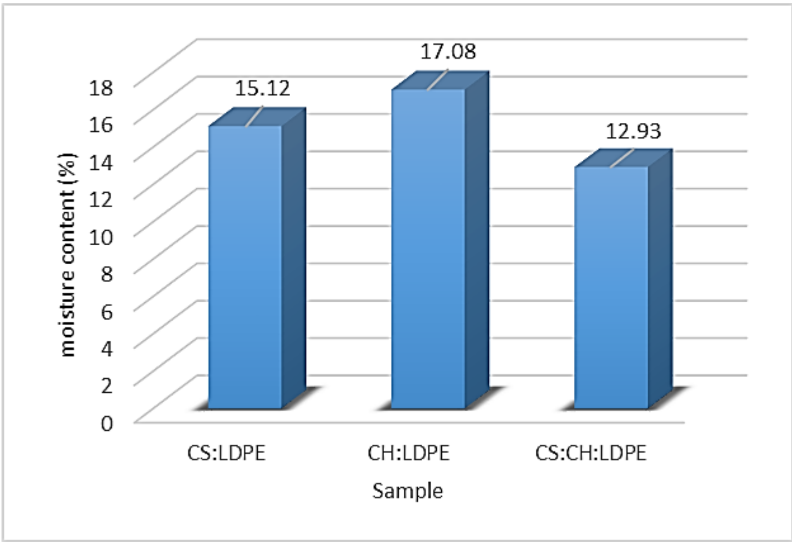

Figure 2 Moisture content of bio-briquette

3.2 Moisture Content

Bio-briquette CH: LDPE has a higher moisture content than bio-briquette CS (Figure 2). The high moisture content of bio-briquette CH: LDPE is consistent with previous research that the husk has a higher moisture content than the shell (Nurhilal, 2018). The high moisture content of coconut husk in bio-briquettes CH: LDPE is due to the characteristics of coconut husk having a low specific gravity so that it can absorb the humidity of the surrounding air, which results in high moisture content in coconut husk bio-briquettes (Hendra, 2007). The high water content of CH: LDPE bio-briquettes will reduce the calorific value because the heat during combustion is used to remove the water contained in the bio-briquettes first, then produce heat for combustion (Muhammad et al., 2013).

The moisture content of bio-briquettes decreases with the increase in coconut shell composition. The moisture content decreased due to the shell's moisture content being smaller than the moisture content of the coconut husk (Nurhilal, 2018). The decrease in moisture content in the bio-briquettes CS:CH: LDPE was due to the mixing between the shell powder and husk powder, which filled each other's pores. Mixing the charcoal powder with different ingredients causes finer particles to fill each other's pores, so less water is bound in the charcoal pores (Hapid et al., 2018). The size of the lignocellulosic particles causes a decrease in moisture content; the larger the size of the lignocellulosic particles, the lower the moisture content (Trihadiningrum et al., 2007). The coconut shell has larger lignocellulose particles than the husk (Nurhilal, 2018). This affects the decrease in moisture content in bio-briquettes CS:CH: LDPE. Moisture content according to SNI standards 06–3730-1995 and ESDM Ministerial Regulation No. 047 of 2006 is a maximum of 15%. The bio-briquette sample that meets SNI standards and ESDM Ministerial Regulation based on the percentage of moisture content is bio-briquette CS:CH: LDPE.

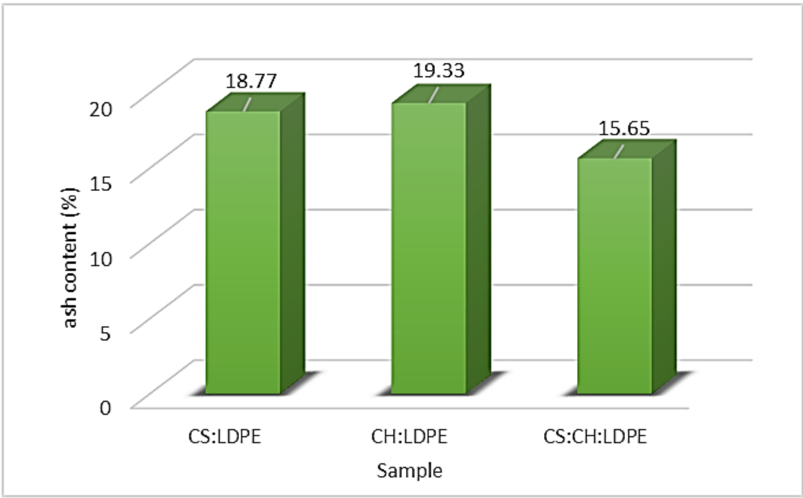

Figure 3 Ash content of bio-briquette

3.3 Ash Content

Figure 3 show that bio-briquette CS:LDPE is lower than the bio-briquette CH:LDPE. The silicate content of the material strongly influences the ash content. The Ash content of the shell is lower than the husk. The shell's low ash content is due to its low silicate content, so it produces little ash (Karamoy et al., 2019). Previous research also showed that the ash content of shell bio-briquettes was 1.72% lower than the ash content of husk, which was 10.37% (Hendra, 2007). Besides silicate content, ash content is also affected by the specific gravity of the bio-briquette material. The ash content increases when the specific gravity of the material gets smaller (Rindayatno et al., 2017). Previous studies have found that the specific gravity of the husk is lower than the specific gravity of the shell (Hendra, 2007). Other studies have shown that the residue of the shell after burning is lower than that of the husk, thereby reducing the ash content and increasing the calorific value (Nurhilal, 2018).

Adding LDPE to bio-briquettes CS:CH: LDPE can reduce the ash content. These results are consistent with previous studies, which showed that the ash content decreases with the increase in the LDPE ratio. The ash content decreased due to the very low ash content in LDPE plastic (Faizal et al., 2018). The decrease in the ash content in the bio-briquette samples in the presence of LDPE composition was also due to the presence of inorganic compounds contained in LDPE, which affected the ash content during the combustion process (Ningsih et al., 2020). Previous studies have shown the same thing: adding plastic waste to bio-briquettes reduces the ash content (Ruslinda et al., 2017). The ash content obtained in all bio-briquette samples did not meet the SNI bio-briquette standard, where the maximum ash content was 8%. The ash content of all samples was still higher than the ash content of coal bio-briquettes, with a maximum value of 10%.

3.4 Volatile Matter

Figure 4 shows that the level of volatile matter in all bio-briquette samples is still high. The substances in the bio-briquette material will affect the levels of volatile matter. The smaller the level of volatile matter, the better the quality of the bio-briquettes (Suryaningsih & Pahleva, 2020). The amount of volatile matter will impact the amount of smoke produced. This is due to the reaction of carbon monoxide with alcohol derivatives (Nasution & Simbolon, 2022). The high levels of volatile matter in the bio-briquette samples of this study were due to the addition of LDPE. LDPE is an inorganic hydrocarbon compound with long atomic chain bonds to increase volatile matter, and the burning time is speedy (Ningsih et al., 2020). The high level of volatile matter in the LDPE plastic material is 99.73% which causes high levels of volatile matter in the bio-briquettes added to the composition with LDPE (Asip et al., 2014). Previous research from Faizal (2018) obtained the same results: adding LDPE composition to mixed LDPE bio-briquettes and kapok peels increased the level of volatilization; conversely, the lower the ratio of the addition of LDPE decreased the level of volatilization (Faizal et al., 2018). The same thing was also found in previous studies by adding LDPE to empty fruit bunch bio-briquettes and palm shells causing an increase in the level of volatile matter, causing rapid ignition and a high burning speed (Suryaningsih & Pahleva, 2020).

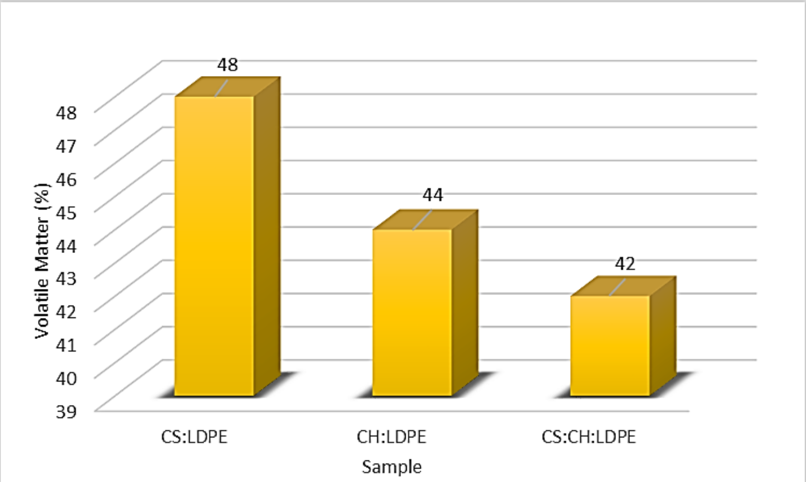

Figure 4 Volatile matter of bio-briquette

The volatile matter content in bio-briquettes CS:LDPE is higher than bio-briquettes CH:LDPE (Figure 4). The increase in volatile matter content with the addition of shell composition is consistent with previous studies due to the imperfection of the carbonization process (Karamoy et al., 2019). The high level of volatile matter is possible because there are still flammable gases, so the calorific value is high. The carbon, oxygen, and nitrogen content in coconut shell bio-briquettes is relatively high, so burning coconut shell bio-briquettes is easier than husk bio-briquettes. This causes the shell's volatile matter levels to be higher than the husk (Qistina et al., 2016). All volatile matter bio-briquette samples did not meet the Indonesian National Standard (SNI) for bio-briquette quality (SNI 01-6235-2000) and the PERMEN ESDM coal bio-briquette standard No. 047 of 2006, which states that the maximum value of volatile matter content in bio-briquettes is 15%. Not in accordance with the level of volatile matter allows the low carbonization temperature at 300 °C; this is in agreement with previous studies, which stated that the high levels of volatile matter were caused by the low carbonization temperature (Nurhilal, 2018).

3.5 Fixed Carbon

Figure 5 shows that the fixed carbon decreased with increasing coconut shell composition. The fixed carbon content is affected by volatile substances. The highly volatile matter will reduce the level of fixed carbon (Rindayatno et al., 2017). This is because the level of shell volatiles is higher than in coconut husk, according to Figure 4. The high level of fixed carbon in bio-briquettes CH: LDPE is possible because the temperature at which the husk is written is not too high, so there is still much lignin left behind. The content lignin is a carbon compound in the briquetting process, which functions as a natural binder (Sjaifudin & Sugiyana, 2016). A good carbonization process can reduce the hydrogen and oxygen levels in charcoal, thereby increasing the levels of bound carbon (Rindayatno et al., 2017). In this study, the temperature of husk carbonization is 300°C which is similar to previous research to retain lignin compounds, the maximum temperature during the husk coaling process is 300°C (Sjaifudin & Sugiyana, 2016). The low level of fixed carbon is due to the addition of LDPE, which has a high level of volatile matter, where the level of fixed carbon is inversely proportional to the level of volatile matter (Faizal et al., 2018). The level of volatile matter in LDPE plastic, which is 99.73%, decreases the fixed carbon content (Asip et al., 2014). All bio-briquette samples had low levels of fixed carbon and did not accordance SNI standards. The low level of fixed carbon is due to the high level of volatile matter (Nasution & Simbolon, 2022).

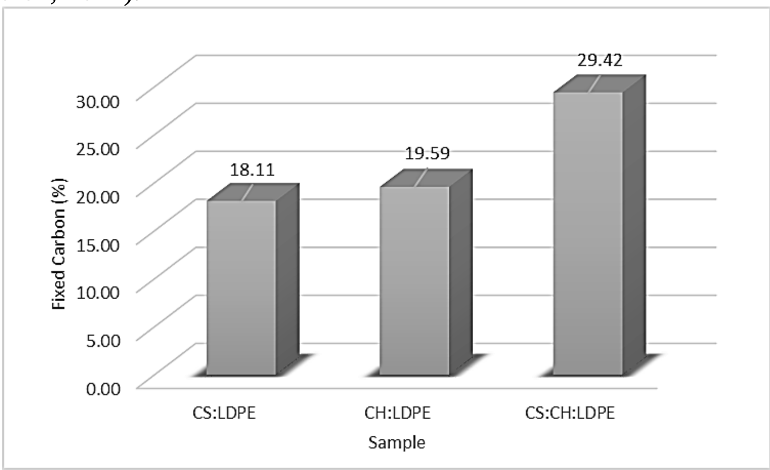

Figure 5 Fixed carbon of bio-briquette

4. CONCLUSION

The calorific value of all sample bio-briquettes in this study exceeded the standards for coal bio-briquettes according to PERMEN ESDM No. 047 of 2006, with a value of above 4400 cal/g. The highest calorific value is bio-briquette CS: LDPE, with a value of 4755.83 Cal/g. As for the water content according to SNI 06–3730-1995 standards and Permen of ESDM No. 047 of 2006 maximum of 15%, a suitable bio-briquette sample is bio-briquette CS:CH: LDPE with a content of 12.93%. In contrast, the ash content, volatile matter content, and bound carbon content of all bio-briquette samples did not meet the standards of SNI briquettes and PERMEN ESDM.

ACKNOWLEDGEMENT

The author would like to thank the LP2M BOPTN UIN Walisongo for financial support in 2022 and all LP2M Reviewers for suggestions in this research.

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