Effect of Adding LDPE, PP and Biodegradable Plastic Waste on Physical Properties, Calorific Value and Proximate Analysis of Peanut Shell Waste Briquettes

by Yusraida Khairani Dalimunthe FTKE

IJE TRANSACTIONS A: Basics Vol. 38, No. 01, (January 2025) 54-64

International Journal of Engineering

Journal Homepage: www.ije.ir

Effect of Adding LDPE, PP and Biodegradable Plastic Waste on Physical Properties, Calorific Value and Proximate Analysis of Peanut Shell Waste Briquettes

Y. K. Dalimunthe*[a], L. Satiawati[a], H. Widiyatni[a], W. Dahani[b], M. A. Rahman[a], S. S. Nursyam[a], A. Lagrama[c]

[a] *Department of Petroleum Engineering, Faculty of Technology Earth and Energy, Universitas Trisakti, Jakarta, Indonesia*
[b] *Department of Mining Engineering, Faculty of Technology Earth and Energy, Universitas Trisakti, Jakarta, Indonesia*
[c] *Department of Electrical Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños, Philippines*

PAPER INFO

Paper history:
Received 26 January 2024
Received in revised form 27 May 2024
Accepted 01 July 2024

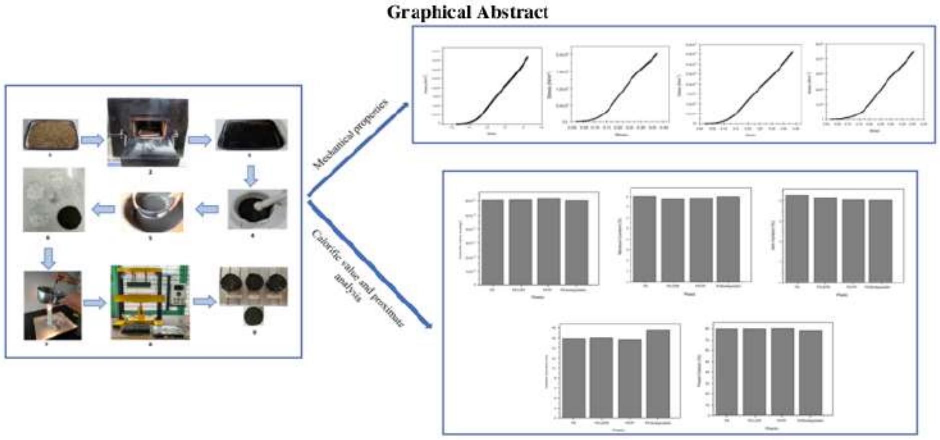
Keywords:
Biomass
Briquette
Compressive Strength
Plastic Waste
Proximate Analysis

ABSTRACT

Peanut shell (PS) waste and plastic waste are abundant in Indonesia and have the potential to pollute the environment. The limited availability of fossil fuels also makes all parties look for other energy sources. This research aims to find a solution to this problem. The effect of adding low density polyethylene (LDPE), polypropylene (PP), and biodegradable plastic to briquettes made from peanut shell waste was investigated in this research. Briquettes were made using starch adhesive and a compaction pressure of 70 N/m^2 using a laboratory scale piston. The compression test is essential because, during the stacking process, the briquettes must withstand loads from external pressure, which significantly influences the quality of the briquettes during storage and transportation. This research found that adding biodegradable plastic increased the modulus of elasticity and compressive strength of briquettes, namely 20 MPa and 4.45 MPa, compared to briquettes without plastic. The highest calorific value of briquettes in this study was obtained from the addition of PP plastic, amounting to 6185 cal/g. Based on the quality of the briquettes, the lowest moisture content was obtained from the addition of LDPE plastic at 7.71%, and the lowest ash content was obtained from the addition of biodegradable plastic at 4.01%, the lowest volatile content was obtained from the addition of PP plastic amounting to 15.71%. The most considerable fixed carbon content was obtained from adding PP plastic, amounting to 80.25%.

doi: 10.5829/ije.2025.38.01a.06

Graphical Abstract



*Corresponding Author Email: yusraida@trisakti.ac.id (Y. K. Dalimunthe)

Please cite this article as: Dalimunthe YK, Satiawati L, Widiyatni H, Dahani W, Rahman MA, Nursyam SS, Lagrama A. Effect of Adding LDPE, PP and Biodegradable Plastic Waste on Physical Properties, Calorific Value and Proximate Analysis of Peanut Shell Waste Briquettes. International Journal of Engineering, Transactions A: Basics. 2025;38(01):54-64.

NOMENCLATURE

η_v	percentage of volume change (%)	MC	moisture content (%)
V_m	mold volume (mm^3)	AC	ash content (%)
V_b	volume of briquette after compressing (mm^3)	VC	volume content (%)
DS	dimensional stability (%)	FC	fixed carbon (%)
m	mass of briquette (gr)	W	weight of briquette sample
π	constant of mathematic	ρ	density (kg/m^3)
r	briquette radius (mm)	MoE	Modulus of Elasticity (MPa)
H	height of briquette (mm)	CS	Compressive Strength (MPa)

1. INTRODUCTION

The foundation of a nation's prosperity and the sustainable promotion of economic development lies in its energy resources (1). The world is confronted with an array of formidable energy predicaments, comprising deficiencies in fossil fuel reserves, the release of emissions resulting from combustion processes, a shortage of hydroelectric power supplies, limited availability of contemporary energy technologies, and exorbitant expenses associated with investments in energy-efficient systems (2-4). The global demand for energy is impacted by various factors, including urbanization, population growth, and improved living standards. The world is faced with multiple environmental challenges on a global scale, which has led to the gradual depletion of the existing fossil fuel energy reserves (5, 6). Indonesia is not exception. Diversification of energy sources plays a pivotal role in contemporary society. It serves as a driving force for researchers to investigate diverse energy sources and enhance the functionality of the current energy infrastructure (7). The triumph of implementing renewable energy facilities for electricity generation, like wind energy, is accomplished through persistent endeavor and enhancement of its framework (8). Biomass is also a solution to overcome energy-related problems by making it into briquette fuel.

Biomass energy resources in Indonesia are abundant, with 52% of the land covered by forests, 13% designated as arable land, 12% dedicated to permanent crops, approximately 6% allocated to pastures, and 17% classified as other types of land (9). Indonesia's highly biodiverse forests serve as a source of biomass that can be utilized as renewable alternative energy (10-12). Biomass is any organic substance derived from plants through photosynthesis and can manifest as products or waste (13-15). The substantial capacity of biomass to function as a global energy source includes the additional capability to reduce the reliance on fossil fuels, which has declined for several years (16). Indonesia has a biomass potential of around 146.7 million tonnes per year, equivalent to 470 gigajoules per year (17). Biomass is believed to mitigate future greenhouse gas issues (18, 19) potentially. Biomass contributes around 5.8 percent (%) of global electricity to 8.9% from 2000 to 2023. It is estimated that by 2050, biomass will be able to produce 3,000 terawatt hours (TWh) of electricity, which is believed to be able to overcome the annual emissions problem of 1.3 billion tonnes (Bt) of carbon dioxide equivalent (20).

One source of biomass that is abundantly available in Indonesia is peanut plants. In the last four years, peanut production reached 570,477 tons in 2016. In 2017, peanut production decreased to 495,447 tons. In 2018, it increased by 512,198 tons (21). Peanut plants are plants in the form of shrubs consisting of stems, leaves, skin and seeds. Peanut seeds are widely used in the food industry to make peanut butter, peanut cakes, egg nuts and other processed peanut foods. However, most peanut shells are burned or buried, which can cause environmental pollution, including in Indonesia. Peanut shell waste contains 38.31% cellulose, 27.62% hemicellulose, and 21.10% lignin, so peanut shell waste can be used to make briquettes (22).

Another type of waste that is abundant in Indonesia is plastic waste. The polymer itself is a material used to make plastic. The physical properties of polymers also vary so that they can produce various materials with different functions. For example, plastic made for food packaging has many advantages, not only it is cheap, but it is also adequate in quality. However, its existence impacts severe environmental damage because plastic cannot naturally decompose. As a result, plastic waste pollutes the environment on land, rivers and the sea. Recent research conducted by Lestari et al. (23) and Sharma et al. (24) reported the presence of microplastics that pollute rivers and seas. This differs from biodegradable plastic. It is environmentally friendly, compostable, stable, easy to obtain, non-toxic, cheap, and has excellent mechanical properties (25). Even though biodegradable plastic can naturally decompose, in reality, plastic waste is still everywhere in everyday life, reducing the aesthetic value of the environment, including piles of biodegradable plastic itself.

Based on environmental problems related to peanut shell waste and plastic waste, as well as the availability of petroleum as fuel, as mentioned above, one solution that can be taken to the waste problem is to make it into briquettes for alternative fuels as a substitute for fossil fuels. This research aims to provide a solution to this problem.

Research has been carried out on making briquettes from biomass waste with the addition of plastic waste. Adding High Density Polyethylene (HDPE) plastic to the torrefaction of fruit waste can increase the calorific value of briquettes, besides increasing the density and compressive strength of straw briquettes by 3.5 MPa to 5.3 MPa (26). Research conducted by Emadi et al. (27) also reported that the addition of 6% Low Density Polyethylene (LDPE) plastic to wheat briquettes was able to increase the density value by 1.7% and 1.8%, and the addition of 10% LDPE plastic was able to increase the density value of wheat briquettes by 253% and 280%. Research conducted by Guo et al. (28) regarding addition of Polypropylene (PP) plastic to briquettes made from fungus bran waste found that adding PP plastic could increase heating value, reduce ash content and act as a binder. Using LDPE plastic waste by adding pine cones into briquettes can produce calorific value and electrical energy of 3182[illegible]Q(J) and 3183.39W(J). It has water and ash content according to the Indonesian National Standard (SNI) (29). Research conducted by Harussani et al. (30) reported that Polypropylene (PP) powder originating from waste isolation gowns for Corona Virus Disease 2019 (COVID-19) was subjected to slow down pyrolysis to produce charcoal, which was then mixed with palm sugar starch to produce briquettes. The results found that the compressive strength of briquettes increased in line with increasing briquette loading. LDPE and PP were used as binders for making sawdust briquettes; the results showed that plastic waste and lignocellulosic biomass produced solid fuel with high durability, hydrophobicity and moderate to high calorific value (31). Research conducted by Gwenzi et al. (32) reported that briquettes made from a mixture of coal dust, biowaste and post-consumer plastic had a significant effect on water absorption capacity, rupture index, compressive strength and energy value but had no effect on density. Briquettes from elephant grass charcoal with the addition of Polyethene Terephthalate (PET) and High Density Polyethylene (HDPE) can increase the mechanical strength of the briquettes, and the results obtained show that briquettes produced with the addition of HDPE are more robust than those produced with the addition of polyethylene terephthalate PET (33). Research conducted by Suwinarti et al. (34) reported that the addition of 70% waste oil and 30% used plastic as additional material for briquettes made from plantation bark affected the performance of briquette formation with the highest calorific value of 33.56 MJ/kg or equivalent to 8015.66 cal/g. The addition of PET plastic to rice husk briquettes carried out by Hariyanto et al. (35) meets the criteria according to SNI 01-6235-2000, namely compressive strength, calorific value, moisture content and ash content of the briquettes. Research conducted by Nwabue et al. (36), which mixed sub-bituminous coal and locally available plastic waste (used water sachet bags, plastic bags, sawdust and corn husks) showed that the briquettes produced were of medium to high quality In terms of combustion and cooking characteristics, these briquettes are smokeless, environmentally friendly and have muscular mechanical strength. Research on sawdust and date palm stems mixed with waste from electrical and electronic equipment (WEEE), plastics (halogen-free cables and printed circuit boards (PCBs)) and automotive crushing residues (ASR) reported that the physical properties of briquettes, such as density and strength resistance increases with increasing temperature, date palm stems provide better results than sawdust (37).

Even though there has been much research on adding plastic waste to various types of biomass, as far as the references the author has been referred, there has yet to be research discussing combining peanut shell waste and plastic waste into briquettes. Therefore, it is necessary to carry out research combining peanut briquettes with three types of LDPE, PP, and biodegradable plastic to look at the physical properties, heating value, and proximate analysis of each briquette. Furthermore, it was reported that adding <10% plastic mixed into biomass for making briquettes did not negatively impact pollutant emissions. However, there was a significant increase in the physiochemical properties of briquettes (38). Finally, the results of this research are presented, and this research is one of the studies that contribute to the sustainable development of biomass resources and solutions for fast processing of plastic waste.

2. MATERIALS AND METHODS

2. 1. Preparation of Raw Materials

The research utilizes a range of apparatus, including a furnace, pestle, 60 mesh sieve, pan, candle, matches, spoon, digital balance, hydraulic briquette press, measuring cup, calculator, vernier caliper, Tensile Strength Tester Sinowon / 19814, and Digital Bomb Calorimeter C2000 (IKA®-Werke GmbH & Co. KG, Germany). The components needed to make briquettes include peanut shell waste from local trash. PP, LDPE, and biodegradable packaging plastic were obtained from a local market, starch produced by Rosebrand Indonesia, and water.

2. 2. Carbonization and Preparation of Mixtures

The peanut shell waste is cleaned, and the carbonization process is carried out using a furnace at a temperature of 500^{0}C. The charcoal formed was ground, and the charcoal powder was filtered using a 60 mesh sieve, which was then weighed at 20 g for each briquette sample. LDPE, PP, and biodegradable plastic were chopped to a size of (0.5 x 0.5) cm, each weighed 0.8 g or the equivalent of 4% of the peanut shell charcoal powder mass used for each sample preparation. This value was taken based on (38), which states that adding <10% plastic to biomass as a material for making briquettes does not negatively affect pollutant emissions and instead increases the physiochemical properties of the briquettes. Next, the adhesive was made by mixing 2 gr of starch and 15 ml of water for each sample. The mixture was heated using three candles to a temperature of 256^{0}C, stirring until it boiled and formed glue for approximately 3 minutes.

2. 3. Briquette Production Peanut shell charcoal powder is mixed with adhesive. Then LDPE, PP and biodegradable plastic are added to each sample according to the composition listed in Table 1 to form a dough. The finished mixture is put into the briquette mould, then positioned in a hydraulic press, and the pressing process is carried out with a pressure of 70 N/m^2 for 10 minutes. This press machine has a cylindrical mould measuring (43 mm in diameter and 35 mm in height). Finally, remove the briquettes from the mould and dry them in the oven at 105^{0}C for 2 hours (39). The process of making briquettes can be seen in Figure 1.

3. ANALYTICAL METHODS

3. 1. Physical Properties After the briquettes are removed from the mould, based on research conducted

TABLE 1. Composition for each briquette sample

Sample	Peanut Shell (g)	Starch adhesive (g)	Water (ml)
PS	20	2	15
PS-LDPE 4%	20	2	15
PS-PP 4%	20	2	15
PS-Biodegradable 4%	20	2	15

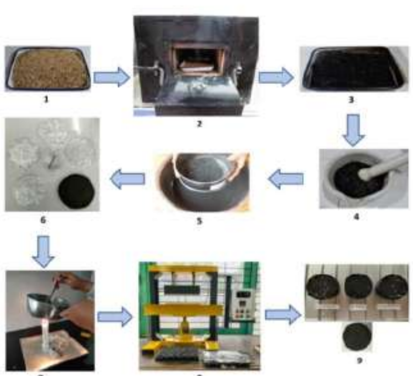


Figure 1. Process of making briquette samples

by Mainkaew et al. (40) Jiao et al. (41), the percentage change in volume and dimensional stability of the briquettes can be calculated using Equations 1 to 3:

$$\eta_v = [(V_m - V_b/V_m)] \times 100 \quad (1)$$

where V_m is mold volume (mm^3), V_b is the volume of briquette after compressing (mm^3) and η_v is the percentage of volume change (%).

$$DS = 100 - [((V_t - V_0)/V_0) \times 100] \quad (2)$$

where V_t is the volume of the briquette after release (mm^3), V_0 is the volume of the briquette after production (mm^3) and DS is dimensional stability (%).

$$\rho = \frac{m}{\pi \times r^2 \times H} \quad (3)$$

where m is the mass of the briquette (g), π is constant of the mathematics, r is briquette radius (mm), H is the height of the briquette (mm) and ρ is the density of the briquette (g/mm^3).

Next, to calculate the modulus of elasticity (MoE) and compressive strength (CS) values of each briquette, a Tensile Strength Tester Sinowon / 19814 was used.

3. 2. Calorific Value and Proximate Analysis The calorific value and proximate analysis of briquettes are measured after measuring the physical properties. Measurement of the calorific value of briquettes was carried out using a Digital Bomb Calorimeter C2000 (IKA®-Werke GmbH & Co. KG, Germany), and proximate analysis of briquettes was carried out based on ASTM-D7582 standards using Equations 4 to 7:

$$MC\ (\%) = \frac{(W-B)}{W} \times 100 \quad (4)$$

where MC is moisture content, W is mass of test specimen used (g), and B is mass of test specimen after drying in moisture test (g).

$$AC\ (\%) = \frac{(F-G)}{W} \times 100 \quad (5)$$

where AC is ash content, F is mass of crucible and ash residue (g) and G is mass of empty crucible (g).

$$VC\ (\%) = \frac{(B-C)}{W} \times 100 \quad (6)$$

where VC is volatile content, C is mass of test specimen after heating in volatile matter test (g).

$$FC\ (\%) = 100 - (M + A + V) \quad (7)$$

where all values are on the same moisture reference base.

4. RESULT AND DISCUSSION

4. 1. Physical Properties The physical condition of the four briquettes that have been dried can be seen in Figure 2, where the diameter of the briquettes does not have a significant difference. The percentage change in volume of each briquette that has undergone compression can be seen in Table 2, between 41.67%-48.54%. There is a significant difference in briquettes without added plastic. This may occur because the bonds between particles are more homogeneous than other briquettes that have added plastic, thus causing changes in the volume of the briquettes to be greater than other briquettes.

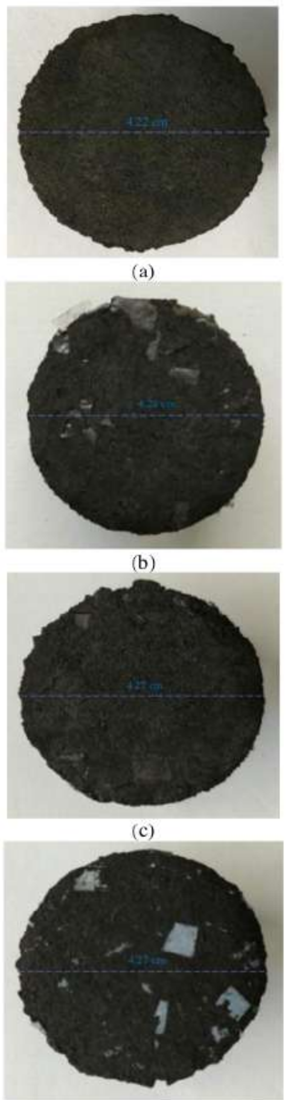


Figure 2. Briquette of (a) PS, (b) PS- LDPE, (c) PS-PP and (d) PS-Biodegradable

TABLE 2. Physical properties of briquette

Physical properties	PS	PS-LDPE	PS-PP	PS-Biodegradable
Volume change (%)	48.54	41.68	41.96	41.67
Dimensional Stability (%)	99.94	98.46	99.03	96.53
Density (kg/m^3)	935.41	870.83	850.18	835.62

Furthermore, compared with research conducted by Mainkaew et al. (40), briquettes made from elephant dung had a larger volume change percentage value, namely 79%. This may occur due to differences in the properties of the raw material for making briquettes between peanut shells and elephant dung, such as the mechanical properties of the raw material, moisture content, chemical structure and morphology, briquette formation process, temperature and pressure processes, as well as additives and additional materials, such as plastic and the type of adhesive used.

The dimensional stability value for each briquette did not differ significantly between 96.53%-99.94%. This is also not much different from research conducted by Mainkaew et al. (40), where briquettes made from elephant dung had a dimensional stability value of 95%. Furthermore, the density values for the four briquettes are between 835.62 kg/m^3 - 935.41 kg/m^3. This shows that briquettes can be accepted as fuel because they are within the range of acceptable briquette density values of 600 kg/m^3 - 1.300 kg/m^3 (42).

The results of measuring the elastic modulus and compressive strength of the briquettes were obtained through measurements using a Tensile Strength Tester Sinowon/ 19814, which ultimately produced a stress versus strain curve, as shown in Figure 3.

Every object can change its shape when subjected to force. Some objects can revert to their original shape when the applied force is removed, while others may undergo deformation when specific forces are applied. Elasticity describes the properties of an object experiencing temporary deformation. An object is considered perfectly elastic if it returns to its original shape after the force causing its deformation is removed. The modulus of elasticity can be used to measure an object's elasticity.

TABLE 3. Modulus of elasticity (MoE) and Compressive Strength (CS) of briquette

Sample	MoE (MPa)	CS (MPa)
PS	10	3.71
PS-LDPE	9	2.02
PS-PP	10	3.60
PS-Biodegradable	20	4.45

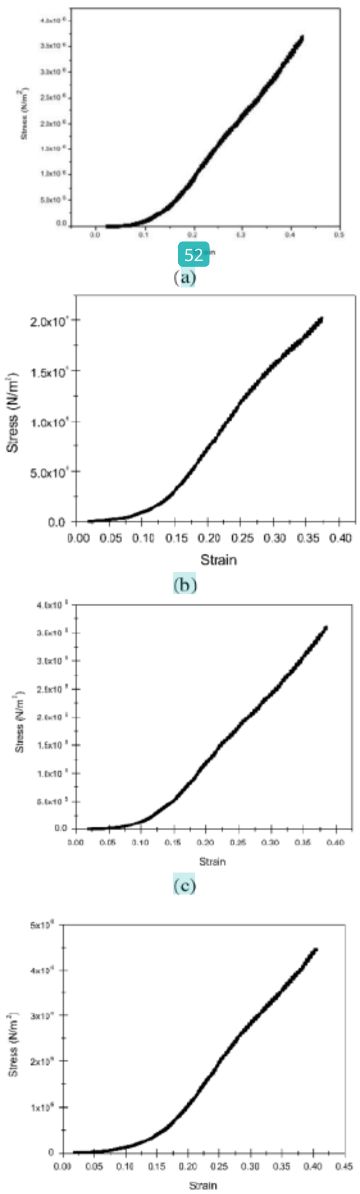


Figure 3. Stress and strain curves of (a) PS, (b) PS-LDPE, (c) PS-PP and (d) PS-Biodegradable briquette

As summarized in Table 3, the elastic modulus value of briquettes is between 9 MPa – 20 MPa, where the highest elastic modulus value of briquettes is produced from briquettes with the addition of biodegradable plastic. This aligns with the statement [25], which states that biodegradable plastic has good mechanical properties. It is very good that it can increase the elastic modulus value of the briquettes.

In compression tests, ultimate strength describes the maximum stress value that an object can withstand before breaking. Ultimate strength is determined from the relationship between stress and strain. Ultimate strength is obtained from the highest point of the stress versus strain curve.

From Figure 3, it can be seen that the four curves have a similar shape, which describes the curve of a perfectly brittle material, which has a yield strength value equal to compressive strength and fracture, which results in the compressive strength value being taken from the highest end of the curve.

As stated in Table 3, the compressive strength value of briquettes is between 2.02 MPa – 4.45 MPa, where the highest compressive strength value is produced from briquettes with the addition of biodegradable plastic. This result confirms the highest elastic modulus value, which is also produced by briquettes with the addition of biodegradable plastic so that it is in line with the reported data [25] which states that biodegradable plastic has very good mechanical properties so that it can increase the compressive strength value of briquettes.

4. 2. Calorific Value and Proximate Analysis

Figure 4 in this study shows that the calorific value of briquettes with the addition of PP plastic is higher than that of other briquettes. The calorific value of the briquettes produced in this study is 6017 cal/g – 6185 cal/g. Based on the calorific value of plastic materials, PP plastic has a more excellent calorific value, namely 46.4 MJ/kg or equivalent to 11082 cal/g (43) when compared to other types of plastic, including LDPE plastic, which has a calorific value of 4.67 MJ/kg or equivalent with 10674 cal/g (44). This is also in line with research conducted by Widayani et al. (45) on briquettes made from palm oil shell waste, which were added with PP and

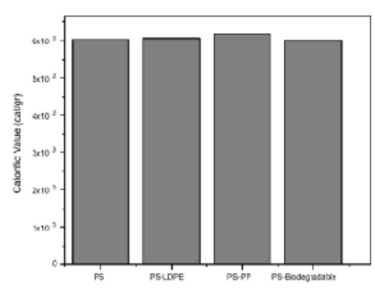


Figure 4. Calorific value of briquette

PE plastic, where briquettes that added PP plastic had a more excellent calorific value, namely 6616 cal/g compared to briquettes that added PE plastic. Namely 6482 cal/g. However, when compared to the calorific value produced in this study, the calorific value of briquettes made from palm oil shells with added plastic by Widayani et al. (45) has a more excellent calorific value than the calorific value of briquettes made from peanut shells with added plastic in this study.

However, when compared with a calorific value of sawdust and PP plastic, peanut shells combined with PP plastic exhibit a higher calorific value. Briquettes made from sawdust and PP plastic have been reported to fall within 20.27 MJ/kg – 21.99 MJ/kg (equivalent to 4841.40 cal/g to 5252.22 cal/g). Similarly, compared to the calorific value of sawdust and LLDPE plastic, peanut shells combined with LLDPE plastic demonstrate a higher calorific value. The calorific value of briquettes made from sawdust and LLDPE plastic is reported to be in the range of 20.67 MJ/kg – 22.33 MJ/kg (equivalent to 4936.94 cal/g – 5333.42 cal/g) (31).

The lower the moisture content, the better the quality of a briquette. Figure 5 shows the moisture content values in the research, namely between 7.71% - 8.04%, where the lowest moisture content was produced from peanut shell briquettes with the addition of LDPE plastic, and the highest moisture content was produced by briquettes made from peanut shells without the addition of plastic.

LDPE and PP are two plastic types with covalent bonds consisting mostly of carbon and hydrogen atoms. This chemical structure makes it non-polar. Because of their non-polar nature, LDPE and PP do not tend to interact with water because water, as a polar molecule, is more likely to interact with materials with a polar charge. Because there are no significant polar interactions between water molecules and LDPE or PP, they tend not to absorb water. Meanwhile, biodegradable plastics can have polar or non-polar properties depending on the basic materials used. In this research, the biodegradable plastic used came from the Yogya local market in Bandung, Indonesia.

Based on the plastic properties above, this research proves that peanut shell briquettes without added plastic have the greatest moisture content because they have the potential to absorb more water than briquettes with added plastic, which cannot absorb water.

Figure 6 shows that the ash content value of briquette is in the range of 4.01% - 4.30%, where the lowest briquette ash content value is produced from peanut shell briquettes with the addition of biodegradable plastic and the highest briquette ash content value was produced by briquettes made from peanut shells without the addition of plastic.

Compared to the ash content value briquette of elephant grass charcoal (EGC) and PET plastic, the ash content value briquette of peanut shells, LDPE, PP and biodegradable plastics is lower. The ash content value of briquettes made from elephant grass charcoal (EGC) and PET plastic is reported to be in the range of 12.38% – 13.44%, as well as the ash content value of elephant grass charcoal (EGC) and HDPE plastic, the ash content value of peanut shells and plastic LDPE, PP and biodegradable are also lower. The ash content value of briquettes made from elephant grass charcoal (EGC) and HDPE plastic is reported to be in the range of 13.04% – 14.36% (33). This difference in value occurs due to differences in the raw materials for making briquettes, which have different properties such as mechanical and chemical properties, as well as additives and additional materials such as plastic and the type of adhesive used.

In this research, it was found that the addition of plastic affected the amount of ash content in the briquettes. Briquettes with added plastic have less ash content than briquettes without added plastic.

LDPE and PP are conventional plastics with volatile components, especially when heated or exposed to high temperatures. However, most LDPE and PP plastics tend to have relatively low volatile content compared to biodegradable plastics. This is because LDPE and PP generally consist of long polymer chains with few functional groups, which tend to produce few volatile components. Meanwhile, biodegradable plastics tend to

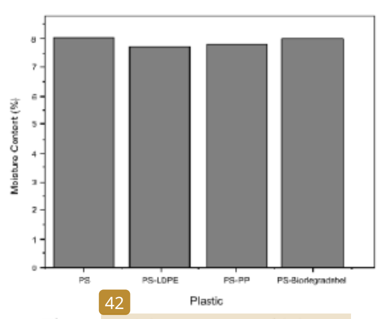


Figure 5. Moisture content of briquette

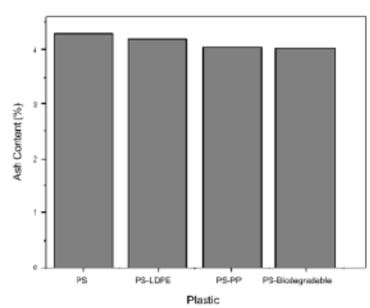


Figure 6. Ash content of briquette

have a higher volatile content, especially those made from organic materials such as starch, cellulose, or PHA (polyhydroxyalkanoates). This is because the organic components in biodegradable plastics can decompose or evaporate at lower temperatures, causing a more significant release of volatile components.

Based on the volatile plastic components above, it was proven in this study that briquettes with the addition of biodegradable plastic produced the highest volatile content values compared to other briquettes.

Figure 7 shows that the volatile content value of briquettes is in the range of 15.71% - 17.48%, where the lowest volatile content value of briquettes is produced from peanut shell briquettes with the addition of PP plastic and the highest volatile content value of briquettes is obtained from the addition of biodegradable plastic.

Compared to the volatile content value of elephant grass charcoal (EGC) and PET plastic, the volatile content value of peanut shells and LDPE, PP and biodegradable plastics is lower. The volatile content value of briquettes made from elephant grass charcoal (EGC) and PET plastic is reported to be in the range of 24.94% - 28.02%, as well as the volatile content value of elephant grass charcoal (EGC) and HDPE plastic, the volatile content value of peanut shells and plastic LDPE, PP and biodegradable are also lower. The volatile content value of briquettes made from elephant grass charcoal (EGC) and HDPE plastic is reported to be in the range of 21.55% – 27.63% (33). This difference in value occurs due to differences in the raw materials for making briquettes, which have different properties such as mechanical and chemical properties, as well as additives and additional materials such as plastic and the type of adhesive used.

LDPE and PP are conventional types of plastic that consist of long carbon and hydrogen polymer chains. LDPE and PP are polyolefins made from ethylene monomers (C_2H_4) for LDPE and propylene (C_3H_6) for PP. Because their chemical composition is dominated by carbon and hydrogen, LDPE and PP plastics have significant fixed carbon content. Meanwhile, in biodegradable plastics, the fixed content in the plastic depends on the basic materials used in its manufacture. Biodegradable plastics are made from organic materials such as starch, cellulose, or polyhydroxyalkanoates (PHAs), consisting of various proportions of carbon, hydrogen, and oxygen. However, LDPE and PP plastics generally have a greater fixed carbon content than biodegradable plastics.

Based on the chemical structure of the three plastics above, it was proven in this study that briquettes with the addition of PP plastic produced the highest fixed carbon value compared to other briquettes.

Figure 8 shows that the fixed carbon value of briquettes is in the range of 78.50% - 80.25%, where the lowest fixed carbon briquette value is produced from peanut shell briquettes with the addition of biodegradable plastic and the highest fixed carbon briquette value is obtained from the addition of PP plastic.

Compared to the fixed carbon value of elephant grass charcoal (EGC) and PET plastic, the fixed carbon value of peanut shells and LDPE, PP and biodegradable plastics is higher. The volatile content value of briquettes made from elephant grass charcoal (EGC) and PET plastic is reported to be in the range of 59.60% – 62.03%, as well as the fixed carbon value of elephant grass charcoal (EGC) and HDPE plastic, the fixed carbon value of peanut shells and plastic LDPE, PP and biodegradable are also higher. The fixed carbon value of briquettes made from elephant grass charcoal (EGC) and HDPE plastic is reported to be in the range of 58.40% – 65.41% (33). This difference in value occurs due to differences in the raw materials for making briquettes, which have different properties such as mechanical and chemical properties, as well as additives and additional materials such as plastic and the type of adhesive used.

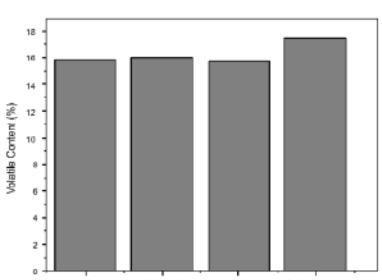


Figure 7. Volatile content of briquette

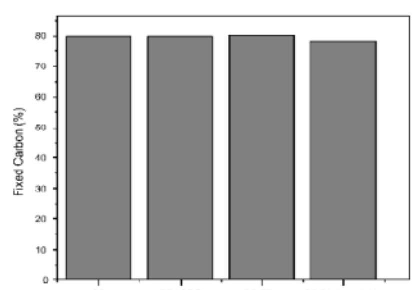


Figure 8. Fixed carbon of briquette

5. CONCLUSION

In this research, it can be concluded that based on its physical properties, peanut shell briquettes with the addition of biodegradable plastic can increase the mechanical properties of the briquettes in the form of modulus of elasticity and compressive strength.

The calorific value of briquettes is 6017 cal/g - 6185 cal/g, where the highest calorific value of briquettes is obtained from the addition of PP plastic. The moisture content value of briquettes is 7.71% - 8.04%, where the lowest briquette moisture content value is produced from peanut shell briquettes with the addition of LDPE plastic. The ash content value of briquette is in the range of 4.01% - 4.30%, where the lowest briquette ash content value is produced from peanut shell briquettes with the addition of biodegradable plastic. The volatile content value of briquettes is 15.71% - 17.48%, where the lowest volatile content value of briquettes is produced from peanut shell briquettes with the addition of PP plastic. The fixed carbon value of briquettes is 78.50% - 80.25%, where the highest fixed carbon briquette value is obtained from the addition of PP plastic.

6. ACKNOWLEDGEMENT

The authors express gratitude to LPPM Universitas Trisakti, Jakarta, Indonesia, for supporting the work via the PUF (2023) research fund. The authors also express gratitude to Faculty of Mathematics and Natural Sciences ITB for permission to use the Tensile Strength Tester Sinowon / 19814 and Digital Bomb Calorimeter C2000 (IKA®-Werke GmbH & Co. KG, Germany) instruments.

7. REFERENCES

1. Gan Q, Xu J, Peng S, Yan F, Wang R, Cai G. Effects of heating temperature on pore structure evolution of briquette coals. Fuel. 2021;296:120651. 10.1016/j.fuel.2021.120651
2. Celestino JMT, Lating PO, Nabuuma B, Yiga VA. Effects of clay, gum Arabic and hybrid binders on the properties of rice and coffee HUSK briquettes. Results in Engineering. 2023;20:101488. 10.1016/j.rineng.2023.101488
3. Abbasi M, Sharafi Miyab M, Tousi B, Gharehpetian GB. Using dynamic thermal rating and energy storage systems technologies simultaneously for optimal integration and utilization of renewable energy sources. International Journal of Engineering, Transactions A: Basics. 2020;33(1):92-104. 10.5829/ije.2020.33.01a.11
4. Tiara T, Agustina T, Faizal M. The effect of air fuel ratio and temperature on syngas composition and calorific value produced from downdraft gasifier of rubber wood-coal mixture. International Journal of Engineering, Transactions C: Aspects. 2018;31(9):1480-6. 10.5829/ije.2018.31.09c.02
5. Adji RB, Rahman RA. Increasing the feasibility and storage property of cellulose-based biomass by forming shape-stabilized briquette with hydrophobic compound. Case Studies in Chemical and Environmental Engineering. 2023;8:100443. 10.1016/j.cscee.2023.100443
6. Chiang LE, Castro FA, Molina FA. Socioeconomic and environmental benefits of substituting firewood with charcoal briquettes produced from biomass residues in the Forestry Belt in Chile. Energy for Sustainable Development. 2023;77:101341. 10.1016/j.esd.2023.101341
7. Nugraheni RD, Syafira NN, Setyorini [illegible], Koesmawardani WT, Suliestyah S, Nuryana SD, editors. Physical and combustion properties of solid fuel briquettes made of plastic waste as a green energy alternative. AIP Conference Proceedings; 2023: AIP Publishing. 10.1063/5.0120211
8. Bamisaye A, Ige AR, Adegoke KA, Adegoke IA, Bamidele MO, Adeleke O, et al. H2SO4-treated and raw watermelon waste bio-briquettes: Comparative, eco-friendly and machine learning [illegible]ics. Fuel. 2024;358:129936. 10.1016/j.fuel.2023.129936
9. Amrullah A, Syarief A, Saifudin M. Combustion behavior of fuel briquettes made from ulin wood and gelam wood residues. International Journal of Engineering. 2020;33(11):2365-71. 10.5829/ije.2020.33.11b.27
10. Favero A, Daigneault A, Sohngen B. Forests: Carbon sequestration, biomass energy, or both? Science advances. 2020;6(13):eaay6792. 10.1126/sciadv.aay6792
11. Yustanti E, Muharman A, Mursito AT. The effect of wood tar and molasses composition on calorific value and compressive strength in bio-coke briquetting. International Journal of Renewable Energy Development. 2022;11(3):600-7. 10.14710/ijred.20[illegible]9298
12. Dalimunthe YK, Kasmungin S, Sugiarto E, Sugiarti L, Lagrama A. Making briquettes from waste of coconut shell and peanut shell. Indonesian Journal of Urban and Environmental Technology. 2021:196-209. 10.25105/urbanenvirotech.v4i2.7417.x
13. Saputra B, Tambunan KGA, Suri IF, Febryano IG, Iswandaru D, Hidayat W. Effects of torrefaction temperature on the characteristics of betung (Dendrocalamus asper) bamboo pellets. Jurnal Teknik Pertanian Lampung. 2022;11(2):339-53. 10.23960/jtep-l.v11i2.339-353
14. Hazbehiean M, Mokhtarian N, Hallajisani A. Converting the cigarette butts into valuable products using the pyrolysis process. Global Journal of Environmental Science and Management. 2022;8(1):133-50. 10.22034/gjesm.2022.01.10
15. Samimi M, Mansouri E. Efficiency evaluation of Falcaria vulgaris biomass in Co (II) uptake from aquatic environments: characteristics, kinetics and optimization of operational variables. International Journal of Phytoremediation. 2024;26(4):493-503. 10.1080/15226514.2023.2250462
16. Dhanasekar S, Sathyanathan R. Bioenergy potential of Chlorella vulgaris under the influence of different light conditions in a bubble column photobioreactor. Global Journal of Environmental Science and Management. 2023;9(4):789-804. 10.22035/gjesm.2023.04.09
17. Rhofita EI, Rachmat R, Meyer M, Montastruc L. Mapping analysis of biomass residue valorization as the future green energy generation in Indonesia. Journal of Cleaner Production. 2022;354:131667. 10.1016/j.jclepro.2022.131667
18. Samimi M, Shahriari-Moghadam M. Isolation and identification of Delftia lacustris Strain-MS3 as a novel and efficient adsorbent for lead biosorption: Kinetics and thermodynamic studies, optimization of operating variables. Biochemical Engineering Journal. 2021;173:108091. 10.1016/j.bej.2021.108091
19. Samimi M, Shahriari-Moghadam M. The Lantana camara L. stem biomass as an inexpensive and efficient biosorbent for the adsorptive removal of malachite green from aquatic environments: kinetics, equilibrium and thermodynamic studies.

International Journal of Phytoremediation. 2023;25(10):1328-36. 10.1080/15226514.2022.2156978

20. Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R. The role of renewable energy in the global energy transformation. Energy strategy reviews. 2019;24:38-50. 10.1016/j.esr.2019.01.006

21. Statistik BP. Statistik Indonesia 2018. Jakarta: Badan Pusat Statistik. 2018.

22. ISNAWATI EW, PRAMONO E, SURYANTI V, editors. Isolation of microcellulose from peanut shell (Arachis hypogaea) and its potential application. Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia; 2023. 10.13057/psnmbi/m090121

23. Lestari P, Trihadiningrum Y, Firdaus M, Warmadewanthi I, editors. Microplastic pollution in Surabaya river water and aquatic biota, Indonesia. IOP conference series: materials science and engineering; 2021: IOP Publishing. 10.1088/1757-899X/1143/1/012054

24. Sharma B, Shekhar S, Sharma S, Jain P. The paradigm in conversion of plastic waste into value added materials. Cleaner Engineering and Technology. 2021;4:100254. 10.1016/j.clet.2021.100254

25. Vassallo E, Pedroni M, Aloisio M, Pietralunga SM, Donnini R, Saitta F, et al. Plasma Treatment of Different Biodegradable Polymers: A Method to Enhance Wettability and Adhesion Properties for Use in Industrial Packaging. Plasma. 2024;7(1):91-105. 10.3390/plasma7010007

26. Hanaffi Mohd Fuad MA, Faizal HM, Rahman MRA, Latiff Z. Torrefaction of densified empty fruit bunches with addition of plastics waste. Biofuels. 2020;11(4):491-501. 10.1080/17597269.2018.1457312

27. Emadi B, Iroba KL, Tabil LG. Effect of polymer plastic binder on mechanical, storage and combustion characteristics of torrefied and pelletized herbaceous biomass. Applied Energy. 2017;198:312-9. 10.1016/j.apenergy.2016.12.027

28. Guo S, Liu L, Zhao D, Zhao C, Li X, Li G. Optimization of briquette fuels by co-torrefaction of residual biomass and plastic waste using response surface methodology. Molecules. 2023;28(6):2568. 10.3390/ molecules28062568

29. Basir A, editor Manufacture of LDPE Plastic waste briquettes as Mixed Pine Needles and Clay with various compositions as alternative fuels. IOP Conference Series: Earth and Environmental Science; 2022: IOP Publishing. 10.1088/1755-1315/1083/1/012009

30. Harussani M, Sapuan S, Rashid U, Khalina A. Development and characterization of polypropylene waste from personal protective equipment (PPE)-derived char-filled sugar palm starch biocomposite briquettes. Polymers. 2021;13(11):1707. 10.3390/polym13111707

31. Song B, Cooke-Willis M, Theobald B, Hall P. Producing a high heating value and weather resistant solid fuel via briquetting of blended wood residues and thermoplastics. Fuel. 2021;283:119263. 10.1016/j.fuel.2020.119263

32. Gwenzi W, Ncube RS, Rukuni T. Development, properties and potential applications of high-energy fuel briquettes incorporating coal dust, biowastes and post-consumer plastics. SN Applied Sciences. 2020;2(6):1006. 10.1007/s42452-020-2799-8

33. Vieira SMdM, Knop MdC, Mesquita PdL, Baston EP, Naves FL, Oliveira LFCd, et al. Physicochemical properties of a solid fuel from biomass of elephant grass charcoal (Pennisetum Purpureum Schum.) and recyclable pet and HDPE. Materials Research. 2020;23(4):e20190350. 10.1590/1980-5373-MR-2019-0350

34. Suwinarti W, Amirta R, editors. Production of high-calorie energy briquettes from bark waste, plastic and oil. IOP Conference Series: Earth and Environmental Science; 2018: IOP Publishing. 10.1088/1755-1315/144/1/012034

35. Hariyanto S, Usman MN, Citrasari N, editors. Briquettes of rice husk, polyethylene terephthalate (PET), and dried leaves as implementation of wastes recycling. AIP Conference Proceedings; 2017: AIP Publishing. 10.1063/1.4985404

36. Nwabue F, Unah U, Itumoh E. Production and characterization of smokeless bio-coal briquettes incorporating plastic waste materials. Environmental Technology & Innovation. 2017;8:233-45. 10.1016/j.eti.2017.02.008

37. Garrido MA, Conesa JA, Garcia MD. Characterization and production of fuel briquettes made from biomass and plastic wastes. Energies. 2017;10(7):850. 10.3390/en10070850

38. Song B, Hall P. Densification of biomass and waste plastic blends as a solid fuel: hazards, advantages, and perspectives. Frontiers in Energy Research. 2020;8:58. 10.3389/fenrg.2020.00058

39. Rudiyanto B, Ulma Z, Prasetyo DA, Piluharto B. Utilization of cassava peel (Manihot utilissima) waste as an adhesive in the manufacture of coconut shell (Cocos nucifera) charcoal briquettes. International journal of Renewable Engineering Development. 2023. 10.14710/ijred.2023.48432

40. Mainkaew A, Kaewluan S, Pattiya A, Jansri SN. The characteristics and emissions of low-pressure densified torrefied elephant dung fuel briquette. International Journal of Renewable Energy Development. 2023;12(4). 10.14710/ijred.2023.53986

41. Jiao W, Tabil L, Xin M, Song Y, Chi B, Wu L, et al. Optimization of process variables for briquetting of biochar from corn stover. BioResources. 2020;15(3):6811. 10.15376/biores.15.3.6811-6825

42. Ramírez-Ramírez MA, Carrillo-Parra A, Ruíz-Aquino F, Hernández-Solís JJ, Pintor-Ibarra LF, González-Ortega N, et al. Evaluation of selected physical and thermal properties of briquette hardwood biomass biofuel. BioEnergy Research. 2022;15(3):1407-14. 10.1007/s12155-022-10391-8

43. Islami AP, Sutrisno S, Heriyanti H. Pirolisis sampah plastik jenis polipropilena (PP) menjadi bahan bakar cair-premium-like. JC-T (Journal Cis-Trans): Jurnal Kimia dan Terapannya. 2019;3(2):1-6. 10.17977/um0260v3i22019p001

44. Tantika F, Lasman AN, Maulana E. Analisis Konversi Lmbah Plastik LDPE (Low Density Polyethylen) Dengan Metode Pirolis Menjadi Bahan Bakar Alternatif. Teknobiz: Jurnal Ilmiah Program Studi Magister Teknik Mesin. 2021;11(2):75-9. 10.35814/teknobiz.v11i2.24[illegible]

45. Gusnia Y, Aditya ID. Calorific Values and Mechanical Compression Property of Briquettes Made of Palm Shell with Plastic Addition. Philippine Journal of Science. 2023;152(5). 10.56899/152.05.23

Persian Abstract

چکیده

ضایعات پوسته بادام زمینی (PS)و زباله های پلاستیکی در اندونزی به وفور یافت می شوند و پتانسیل آلودگی محیط زیست را دارند. در دسترس بودن محدود سوخت های فسیلی همچنین باعث می شود که همه طرف ها به دنبال منابع انرژی دیگر باشند. هدف این تحقیق یافتن راه حلی برای این مشکل است. اثر افزودن پلی اتیلن با چگالی کم (LDPE)، پلی پروپیلن (PP)و پلاستیک زیست تخریب پذیر به بریکت های ساخته شده از ضایعات پوسته بادام زمینی در این تحقیق مورد بررسی قرار گرفت. بریکت ها با استفاده از چسب نشاسته و فشار تراکم ۷۰ نیوتن بر متر مربع با استفاده از پیستون مقیاس آزمایشگاهی ساخته شدند. آزمایش تراکم ضروری است زیرا در طول فرآیند انباشته شدن، بریکت ها باید بارهای ناشی از فشار خارجی را تحمل کنند، که به طور قابل توجهی بر کیفیت بریکت ها در طول ذخیره سازی و حمل و نقل تأثیر می گذارد. این تحقیق نشان داد که افزودن پلاستیک زیست تخریب پذیر باعث افزایش مدول الاستیسیته و مقاومت فشاری بریکت ها یعنی ۲۰ مگاپاسکال و ٤.٤٥ مگاپاسکال در مقایسه با بریکت های بدون پلاستیک می شود. بیشترین ارزش حرارتی بریکت ها در این مطالعه از افزودن پلاستیک PP به میزان ٦١٨٥ کالری در گرم به دست آمد. بر اساس کیفیت بریکت ها، کمترین میزان رطوبت از افزودن پلاستیک LDPE با ۷/۷۱ درصد و کمترین میزان خاکستر از افزودن پلاستیک زیست تخریب پذیر با ٤/۰۱ درصد، کمترین میزان فرار از افزودن پلاستیک PP به میزان ۱۵.۷۱٪ بیشترین میزان کربن ثابت از افزودن پلاستیک PP به میزان ۸۰.۲۵ درصد به دست آمد.

Effect of Adding LDPE, PP and Biodegradable Plastic Waste on Physical Properties, Calorific Value and Proximate Analysis of Peanut Shell Waste Briquettes

ORIGINALITY REPORT

15%	11%	10%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	trijurnal.lemlit.trisakti.ac.id Internet Source	<1%
2	Submitted to UNESCO-IHE Institute for Water Education Student Paper	<1%
3	ejournal.undip.ac.id Internet Source	<1%
4	Rumana Hossain, Veena Sahajwalla. "Green Manufacturing Utilising the Problematic Plastic Waste and the Future of Green Plastic", Elsevier BV, 2024 Publication	<1%
5	ijred.cbiore.id Internet Source	<1%
6	V.V. Dorokhov, G.S. Nyashina, D.S. Romanov, P.A. Strizhak. "Combustion and mechanical properties of pellets from biomass and industrial waste", Renewable Energy, 2024 Publication	<1%

7	Submitted to College of Southern Nevada, West Charleston Campus Student Paper	<1 %
8	Thuhin K. Dey, Md. Rasel, Tapati Roy, Md. Elias Uddin, Biplob K. Pramanik, Mamun Jamal. "Post-pandemic micro/nanoplastic pollution: Toward a sustainable management", Science of The Total Environment, 2023 Publication	<1 %
9	repository.umi.ac.id Internet Source	<1 %
10	www.pure.ed.ac.uk Internet Source	<1 %
11	Muhammad Numan, Mansoor Asif, Muhammad Waseem Khan, Sarmad Majeed Malik, Fakhar Uddin Khilji. "Impact of Dynamic Thermal Rating on optimal siting and sizing of energy storage systems under Renewable Portfolio Standards requirements", Sustainable Energy, Grids and Networks, 2022 Publication	<1 %
12	www.smujo.id Internet Source	<1 %
13	Submitted to Florida State University Student Paper	<1 %

14	Submitted to Liberty University Student Paper	<1 %
15	Orebotse Joseph Botlhoko, Nomvuyo Nomadolo, Rakgoshi Lekalakala, Sudhakar Muniyasamy. "Durability and Biodegradation of Biopolymers", Elsevier BV, 2024 Publication	<1 %
16	jurnal.unka.ac.id Internet Source	<1 %
17	www.e-journal.trisakti.ac.id Internet Source	<1 %
18	Submitted to RMIT University Student Paper	<1 %
19	Rosmalia Dita Nugraheni, Nadhia Noor Syafira, Dyah Ayu Setyorini, Wildan Tri Koesmawardani, Suliestyah, Suherman Dwi Nuryana. "Physical and combustion properties of solid fuel briquettes made of plastic waste as a green energy alternative", AIP Publishing, 2023 Publication	<1 %
20	journals.bg.agh.edu.pl Internet Source	<1 %
21	Kang Kang, Naomi B. Klinghoffer, Islam ElGhamrawy, Franco Berruti. "Thermochemical conversion of agroforestry	<1 %

biomass and solid waste using decentralized and mobile systems for renewable energy and products", Renewable and Sustainable Energy Reviews, 2021
Publication

22	journal.univpancasila.ac.id Internet Source	<1 %
23	ojs.ummetro.ac.id Internet Source	<1 %
24	Wang, Zhaoxing. "Process Intensification for the Valorization of Lignocellulosic Biomass-Derived Feedstocks", University of Delaware, 2023 Publication	<1 %
25	ph02.tci-thaijo.org Internet Source	<1 %
26	pubs.aip.org Internet Source	<1 %
27	digilib.unila.ac.id Internet Source	<1 %
28	journal2.um.ac.id Internet Source	<1 %
29	scholar.unair.ac.id Internet Source	<1 %
30	Yazdani, M.G., M. Hamizan, and M.N. Shukur. "Investigation of the fuel value and the	<1 %

environmental impact of selected wood samples gathered from Brunei Darussalam", Renewable and Sustainable Energy Reviews, 2012.
Publication

31	journal.uny.ac.id Internet Source	<1 %
32	repository.its.ac.id Internet Source	<1 %
33	jurnal.polines.ac.id Internet Source	<1 %
34	Armelia Sari Widyarman, Muhammad Ihsan Rizal, Moehammad Orliando Roeslan, Carolina Damayanti Marpaung. "Quality Improvement in Dental and Medical Knowledge, Research, Skills and Ethics Facing Global Challenges", CRC Press, 2024 Publication	<1 %
35	journal.unimma.ac.id Internet Source	<1 %
36	"Proceedings of the 6th International Conference on Industrial Engineering (ICIE 2020)", Springer Science and Business Media LLC, 2021 Publication	<1 %
37	Submitted to Sardar Vallabhbhai National Inst. of Tech.Surat	<1 %

Student Paper

38	www.science.gov Internet Source	<1%
39	Submitted to Massachusetts Maritime Academy Student Paper	<1%
40	Submitted to University of Wales Swansea Student Paper	<1%
41	www.researchgate.net Internet Source	<1%
42	Submitted to Asian Institute of Technology Student Paper	<1%
43	Quiroga, A., V. Marzocchi, and I. Rintoul. "Influence of wood treatments on mechanical properties of wood–cement composites and of Populus Euroamericana wood fibers", Composites Part B Engineering, 2016. Publication	<1%
44	portal.amelica.org Internet Source	<1%
45	www.woodj.org Internet Source	<1%
46	Bagus Saputra, Karina Gracia Agatha Tambunan, Intan Fajar Suri, Indra Gumay Febryano, Dian Iswandaru, Wahyu Hidayat. "Effects of Torrefaction Temperature on the	<1%

Characteristics of Betung (Dendrocalamus asper) Bamboo Pellets", Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering), 2022
Publication

47	section.iaesonline.com Internet Source	<1 %
48	telegram.me Internet Source	<1 %
49	www.hindawi.com Internet Source	<1 %
50	R.N. Ossei-Bremang, E. Akyereko-Adjei, F. Kemausuor, T. Mockenhaupt, T. Bar-Nosber. "Effects of compression pressure, biomass ratio and binder proportion on the calorific value and mechanical integrity of waste-based briquettes", Bioresource Technology Reports, 2023 Publication	<1 %
51	af.beallindustry.com Internet Source	<1 %
52	metrica.inrim.it Internet Source	<1 %
53	si.fst.unair.ac.id Internet Source	<1 %

54	Feng Wu, Nan Chen, Renjie Chen, Qizhen Zhu, Ji Qian, Li Li. "“Liquid-in-Solid” and “Solid-in-Liquid” Electrolytes with High Rate Capacity and Long Cycling Life for Lithium-Ion Batteries", Chemistry of Materials, 2016 Publication	<1 %
55	Submitted to Monash University Student Paper	<1 %
56	Rany Puspita Dewi, Trisma Jaya Saputra, Sigit Joko Purnomo. "ANALISIS KARAKTERISTIK BRIKET ARANG DENGAN VARIASI TEKANAN KEMPA PEMBRIKETAN", Media Mesin: Majalah Teknik Mesin, 2022 Publication	<1 %
57	biomech.ceat.uplb.edu.ph Internet Source	<1 %
58	businessdocbox.com Internet Source	<1 %
59	doshisha.repo.nii.ac.jp Internet Source	<1 %
60	media.neliti.com Internet Source	<1 %
61	Chewa Thassana, Witoon Nuleg. "Effect of carbon black on thermal properties of charcoal and salacca leafstalk briquettes", AIP Publishing, 2017	<1 %

Publication

62	R. Rathinamoorthy, S. Raja Balasaraswathi. "Microfibre Pollution from Textiles - Research Advances and Mitigation Strategies", CRC Press, 2024 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		