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Investigation Study of Semi-Bio Briquettes and Synthesis Briquettes From Used Polymer Waste Plastic Bottles

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Abstract. Up to 2022, Indonesians will produce 69 million tons of waste, of which 12.5 million tons, or 18.2%, will be plastic waste. Since 1995, the number has been growing dramatically. Recycling shredded waste to reduce its volume and enable processing into other materials is one way to manage plastic waste appropriately. This study specifically converted plastic bottle waste into briquettes for used polymer waste. Briquettes are made from recycled plastic bottles used to make polymer waste. There are two types of briquettes made from this waste: Semi-Bio Briquettes, which are made from recycled plastic bottles that have been used to make polymer waste mixed with natural materials like wood sawdust and coconut fiber and adhered with starch, and Synthesis Briquettes, which are made from recycled plastic bottles that have been used to make patchwork or fabric waste and paper waste. The next tests include (1) the Calorific Value Test (Bomb Calorimeter Method), (2) the Proximate Test following SNI 01-6235-2000, which assesses bound carbon, moisture content, ash content, volatile matter content, and other factors, and (3) the Gas/Smoke Emission Test following 2017 RI Minister of Environment and Forestry Regulation Standards. SEM was used to examine the microstructure of synthetic and semi-bio briquettes. While the calorific values for synthetic briquettes did not satisfy the specifications, the results for semi-bio briquettes met the standards. The proximate test results, however, revealed that the two briquettes did not meet the specifications for bound carbon content while meeting the standards for volatile matter content and moisture level. However, only semi-bio briquettes meet the requirements for ash content. The CO, CO_2, and HC gas/smoke emission tests all yielded data that complied with the 2017 RI Minister of Environment and Forestry Regulation requirements. Semi-bio briquettes' microstructure observations were less hollow and denser than those of synthetic briquettes.

Keywords: Semi-bio briquettes, synthesis briquettes, calorific value, proximate test, gas/smoke emission test used plastic bottle polymer waste

INTRODUCTION

Due to their practicality and affordability, plastic materials have remained a popular choice. Due to its exceptional qualities, which include low weight, strength, resistance to corrosion, transparency, and effective insulation, it predominates in product manufacturing as an alternative to metal and wood. Food packaging items, home appliances, and automotive product components are all examples of applications for plastic materials. Because of this, the rising demand for necessities has led to an increase in the consumption of plastic materials every year. Plastic trash has started to appear, along with the rise in the usage of plastic materials, and adequate management is needed to combat the rise. If improper steps are not taken, plastic garbage will continue to grow and pollute the environment. 9.3% of all plastic garbage is made up of waste that is disposed of by households [Rifdah & Tahdid, 2013]. Most plastic trash is discovered in Indonesia, where 3.22 million metric tons (millions of metric tons/MMT) of plastic garbage are produced, or 25.6 parts per 100 square meters of coral reefs in the ocean [Lamb et al., 2018]. Data from the Indonesia National Plastic Action Partnership, published in April 2020, shows that the country generates 6.8 million tons of plastic garbage annually, of which about 620,000 tons end up in rivers, lakes, and the ocean. According to the Economic Daily Balance Sheet, Indonesia will be the world's second-largest contributor of plastic garbage in 2022. Indonesians will produce 69 million tons of waste in 2022, of which 12.5 million tons, or 18.2%, will be plastic waste. Since 1995, the number has been increasing significantly. **[https://www.kompas.com/properti/read/2023/06/15/180000421/sepanjang-tahun-2022-ada-12-54-juta-ton-sampah-plastik-di-indonesia]**

The brand audit results are consistent with Indonesian data on solid waste. According to the data, plastic water bottles and cups contributed 11.6 million tons, or 17% of Indonesia's total national garbage production in 2021, to the volume of plastic waste. This includes plastic straws. Comparing this sum to a decade ago, it has doubled. In the meantime, 10.4 billion bottles of drinking water (AMDK) for plastic cups are produced annually. The market leader in this area, AMDK, is a part of the 5,300 tons of trash plastic cups produced annually. The production of 5.5 billion plastic bottles annually also results in AMDK industrial waste. Nearly half of the plastic garbage produced by the AMDK industry—83 thousand tons—was created from plastic bottles. The bottled water waste generation market leader accounts for half of all bottled garbage. **[https://www.neraca.co.id/article/169752/sampah-botol-plastik-ini-paling-banyak-ditemukan-di-sungai-ciliwung].**

The recycling of shredded waste to lessen its volume and enable processing into other materials is one way to manage plastic waste appropriately. In this investigation, old plastic bottles, in particular, were converted into briquettes. A block of combustible material called a briquette is used as fuel to ignite and sustain a flame. The cheapest alternative fuel is briquettes, a solid fuel formed from a blend of biomass that can be produced in large quantities quickly thanks to the equipment and technologies that are reasonably straightforward. While the term "biomass" refers to all forms of organic material created through photosynthesis [Anita D et al., 2019]. Because of its many advantageous qualities, including its ability to be used sustainably since it is a renewable resource, its relative lack of sulfur so that it does not pollute the air, and its ability to increase utilization efficiency, biomass energy can be used to replace fossil fuels (petroleum)—resources from the forest and agriculture.

To conduct research, lignocellulosic materials (sawdust, rice husks, and coconut shells) with lignocellulosic diameters (40 and 60 mesh) were combined with mixed plastic trash. Water content, volatile solid (VS) content, fixed carbon (FC) content, ash content, bulk density, calorific value, and flash point are the test variables for briquette quality features. The test results revealed that by adding polyvinyl acetate (PVAc) glue, plastic, and lignocellulosic waste may be converted into eco briquettes, with 20% mixed plastic and 80% lignocellulose from coconut shells making for the best eco briquette composition. These outcomes meet the criteria for a quality outlined in the Minister of Energy and Mineral Resources Circular No. 47 of 2006 [Yulinah Trihadiningrum et al., 2007]. While M. Afif Almu et al. (2014) studied the production of briquettes using a blend of rice husks and “nyamplung” fruit (Calophyllum inophyllum) in the ratios of 1:1, 2:1, 3:1, 1:2, and 1:3. Checking the water content and calorific value. The sample with a ratio of 3:1 yielded the findings with the maximum calorific value of 4792.40 cal/gr and the lowest water content of 21.52% in the 1:1 sample.

Biomass waste, namely water hyacinth (Eichhornia crassipes), sawdust, and cocoa shells, are made into briquettes. Making briquettes is done by drying, carbonization, and mixing charcoal with 50% pine resin adhesive; the composition of the ingredients is (90:10, 75:25, and 50:50). The result is that the standard density value is the ratio of sawdust: cocoa husk (75:25), which is 1.05 kg/cm3. The highest compressive strength value was in the ratio of cocoa shell to water hyacinth (50:50), which was 2.32 kg/cm2. Meanwhile, in the ratio of sawdust and water hyacinth of 90:10, all have high values for calorific value, moisture content, ash content, and bound carbon content. [Samsinar, 2014].

Two types of plastic trash, polypropylene (PP) plastic bags and polyethylene terephthalate (PET) mineral glass water plastic waste, were used in Hendri Sawir's 2016 research to create briquettes. The purpose is to determine the briquettes' quality and suitability in replacing the coal used in PT Semen Padang's kilns. The briquettes made from PP plastic bag waste had a calorific value of 10,112 calories per gram, 3.9% ash percentage, 0.36 percent moisture content, and 94.7 percent volatile matter content. Briquettes made from

PET plastic waste have a calorific value of 10.844 calories per gram, a moisture content of 0.42%, a volatile matter content of 99.27%, and an ash content of 0.27%. When compared to the specifications of the coal used in PT Semen Padang's Indarung IV kiln, which have a calorific value of 5200 - 5600 cal/gram, a maximum ash content of 20%, and a maximum moisture content of 10%, the results show that briquettes made from PET mineral glass water plastic waste have a higher calorific value. Overall, the two fuels—PP plastic bag waste and PET mineral glass water plastic waste—can be used in PT Semen Padang's Indarung IV kiln as a substitute for coal. Based on a comparison of calorific value and average coal use of 35 tons per hour, the ratio of coal used to briquettes made from PP plastic bag waste and PET mineral glass water is 1:0.53 and 1:0.50, respectively. [Hendri Sawir, 2016]

Utilization of biomass waste into briquettes as an environmentally friendly alternative fuel continues to be encouraged. Briquettes are made from coconut shell and sawn teak wood with varying compositions of 45% sawn teak + 45% coconut shell + 10% starch, 75% sawn teak + 15% coconut shell + 10 starch, sawn teak 60% + coconut shell 30%+10% starch adhesive, and sawn teak wood 45%+ coconut shell 45%+10% starch adhesive. The results obtained the highest calorific value for the composition of 45% sawn teak wood + 45% coconut shell + 10% starch. In the composition of sawn teak wood 60%+ coconut shell 30%+10% starch adhesive and sawn teak wood 45%+ coconut shell 45%+10% starch adhesive, 1 liter of water boiled in 8 minutes with the color of burnt briquettes. Red-orange coal and not soot. [Suhartoyo dan Sriyanto,2017]

Low-density polyethylene (LDPE) plastic waste combined with kapok fruit skin (KBK) is used in research on bio-briquettes production. Utilizing a range of carbonization temperatures, including 400, 500, and 600 °C. 100% KBK: 0% LDPE, 95% KBK: 5% LDPE, 90% KBK: 10% LDPE, and 85% KBK: 15% LDPE were the composition variables. The only substance employed as an adhesive is starch, which makes up 10% of the total weight of the biobriquettes. At a carbonization temperature of 500 C, bio briquettes of the highest quality were produced, consisting of 85% KBK and 15% PLDPE, with a calorific value of 6985.35 cal/g, bound carbon content of 51.12%, moisture content of 4.65%, ash content of 4.23%, and volatile matter content of 39%. [Muhammad Faizal, 2018]

Briquettes made from snack packaging and bottle cap waste from previous research have a composition of 10:90, 50:50, and 90:10 with tapioca flour as an adhesive. Waste from bottle caps and snack food packaging is pyrolyzed at temperatures of 450°C for bottle caps and 280°C for snack food packaging over 60 minutes. The charcoal was produced in various particle sizes, including 40.60 and 100 mesh. The measurements were 5.47% moisture content, 4.95% ash content, 13% volatile matter content, 76.58% bound carbon content, and an 8565.914 cal/gram energy density. The outcomes complied with SNI requirements. [Erlinda et,al, 2020]. Briquettes made from LDPE plastic waste and pinecones can also be used. The results for the ash content and water content according to SNI were 3182.4 cal/gram of calorific value and 3183.39 J of electrical energy produced.[Haswin,2021]

Two types of briquettes will be produced from the studies above: the first type, Semi-Bio Briquettes, is made from polymer waste from used plastic bottles combined with natural materials like coconut coir wood sawdust and starch adhesive. The second type, Synthesized Briquettes, is made from polymer waste from used plastic bottles combined with patchwork or fabric waste and paper waste and is adhered with Sidoarjo mud (Lapindo mud). The long-term objective is for these briquettes to function as substitute fuels.

METHODS

The Steps Involved in Producing Carbonization, Including Grinding, Crushing, Combining Adhesives, Printing, Compressing, and Drying.

Briquettes are made from used plastic bottle waste in two different ways. The first type is Semi-Bio Briquettes, which are made by mixing used plastic bottle waste with natural materials like coconut fiber, sawdust, and wood sawdust with starch adhesive. The second type is Synthesis Briquettes, made by mixing used plastic bottle waste with used patchwork or fabric waste, paper waste, and adhesive made from Sidoarjo mud (Lapindo mud).

The following processes are involved in creating Synthesis Briquettes and Semi-bio Briquettes: milling, combining with adhesive, molding/pressing, carbonization, and drying. Cutting or slicing the debris from discarded plastic bottles into little pieces is the first step. To create carbonization, 2.5 kg of chopped old plastic bottle waste is added to an iron drum that has been covered with a lid and fitted with an iron pipe chimney after burning 1 kg of wood charcoal for 10 minutes to turn it into coals. At a temperature of 300 ^{o} C, the carbonization process lasts for around two to three hours. Please leave it to become charcoal for one night. Like wood charcoal is produced from chopped waste plastic bottles, up to 1.5 kg of coconut shells are also used in producing charcoal.

The next step in producing Semi-Bio Briquettes is the milling process, which entails grinding/smoothing the charcoal, a mixture of used plastic bottle waste, wood charcoal, and coconut shell charcoal. Each of these materials is ground/mashed with a mortar until it takes on the consistency of finer granules or powder and is sieved/sifted. With a sieve with a mesh size of 40–60. Wood sawdust is sifted through a 40–60 mesh sieve to produce a finer powder. As a result, three powders are obtained: wood sawdust, coconut shell charcoal powder, and charcoal powder made from used plastic bottle waste. These powders have the following compositions per 100 grams: 50 grams of used plastic bottle waste charcoal powder with wood charcoal, 30 grams of coconut shell charcoal powder, and 20 grams of sawdust.

Only charcoal is generated from used patchwork or fabric and paper waste, although the procedure for making Synthesis Briquettes is the same as for making Semi-Bio Briquettes. This produces three powders: wood charcoal powder made from used plastic bottle waste, cloth charcoal powder, and paper charcoal powder, each with a composition ratio of 50: 30: 20 for every 100 grams. In other words, for every 100 grams, 50 grams of wood charcoal powder made from used plastic bottle waste, 30 grams of cloth charcoal powder, and 20 grams of paper charcoal powder.

The next step is the mixing process with the adhesive. All the materials for Semi-Bi Briquettes are mixed with 20 grams of starch adhesive mixed with 50 milliliters of water, which has been cooked. The next step is printing/pressing. So, after the briquette dough has been created, it is printed into a cylindrical mold with a 3.5 cm diameter and 3.5 cm height. Once it is excellent, apply pressure using a manual press. The drying procedure comes last. After printing, the semi-bio briquettes can dry for 20 hours in the sun. They can also be cured for 3 hours in an oven. Figure 1.1a displays the Semi-bio Briquettes in their completed state.

All of the ingredients for Semi-Bio Briquettes are combined with Sidoarjo mud/Lapindo mud glue while Synthesis Briquettes are being made. Before being used as an adhesive, Sidoarjo mud undergoes a one-day sun-drying procedure. The mud is removed from the pebbles after drying. After adding 40 cc of water, dry Sidoarjo mud is combined with wood charcoal, plastic bottle charcoal, cloth waste charcoal, and paper waste charcoal before thoroughly blending. The aforementioned mixture of charcoal powder and Lapindo mud adhesive has a 92:8 ratio, which means that to manufacture 100 grams of briquette mixture, 92 grams of charcoal powder and 8 grams of Sidoarjo mud adhesive are used. A manual press machine also prints the briquette dough onto a cube-shaped mold that is 3.5 cm x 3.5 cm x 3.5 cm in size. According to Wisnu B. (2009), pressure is necessary for the adhesive to spread flawlessly across the charcoal powder's surface and into any fractures. The density and porosity of the produced charcoal briquettes will vary depending on the amount of pressing pressure used.

The final step of printing Synthesis Briquettes results is a drying process. The objective is to lower the water content in the briquettes in compliance with current standards and to make burning the briquettes easier. The Synthesis Briquettes and Semi-Bio Briquettes can be dried in the sun for 20 hours or in an oven for 3 hours to complete the drying process. Figure 1b shows the final Synthesis Briquettes.

(a)
Figure 1(a) Semi-bio Briquettes

(b)
Figure 1(b) Synthesis Briquettes

Briquette Testing Process

Tests carried out on the two types of briquettes, namely semi-bio briquettes and synthetic briquettes, were tested (1). Calorific Value Test (Bomb Calorimeter Method), (2). The Proximate test, according to SNI 01-6235-2000, includes moisture content, ash content, volatile matter content, and bound carbon content, and (3). Gas/Smoke Emission Test (Gas emission Analyzer).

DISCUSSION

Calorific Value Test Results

The calorific value test was carried out to determine the calorific value or overall energy [Farel, H. N, 2006] produced from Semi-Bio Briquettes and Synthesis Briquettes. The method used is the bomb calorimeter. The results of the calorific value test for Semi-Bio Briquettes and Synthesis Briquettes are presented in Table 1 and Figure 1. Table 1 shows that the calorific value of semi-bio briquettes is higher than that of synthetic briquettes, meaning that the calorific value or amount of energy contained in semi-bio briquettes is greater than that of synthetic briquettes. This is because the adhesive in Semi-bio Briquettes, namely starch, agglomerates more closely with the ingredients for the manufacture of Semi-bio Briquettes than the adhesive on briquettes.

Table 1 Calorific Value Test Results for Semi-bio Briquettes and Synthesis Briquettes

No	Type of Briquettes	Testing	Result	Unit	Method of Testing
1	Semi-bio Briquettes	Calorific Value	23,48 5608	MJ/kg kal/gr	Bomb Calorimeter
2.	Synthesis Briquettes	Calorific Value	19,75 4717	MJ/kg kal/gr	Bomb Calorimeter

Lapindo mud/Sidoarjo mud adhesive for synthesis. Additionally, starch glue has the ability to absorb moisture from the air, lowering the humidity of the briquettes and increasing their calorific and energy content. The SNI 01-6235-2000 standard specifies a minimum calorific value of 5600 cal/gr, and while semi-bio briquettes' calorific value meets this requirement, synthetic briquettes' heating value does not meet SNI 01-6235-2000 standards.

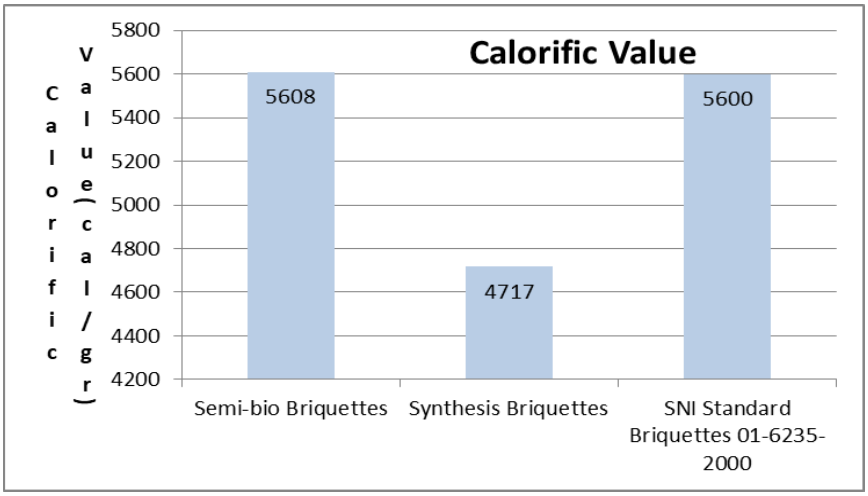


Figure 2 Calorific value test results for Semi-Bio Briquettes and Synthesis Briquettes.

***Proximate* Test Results**

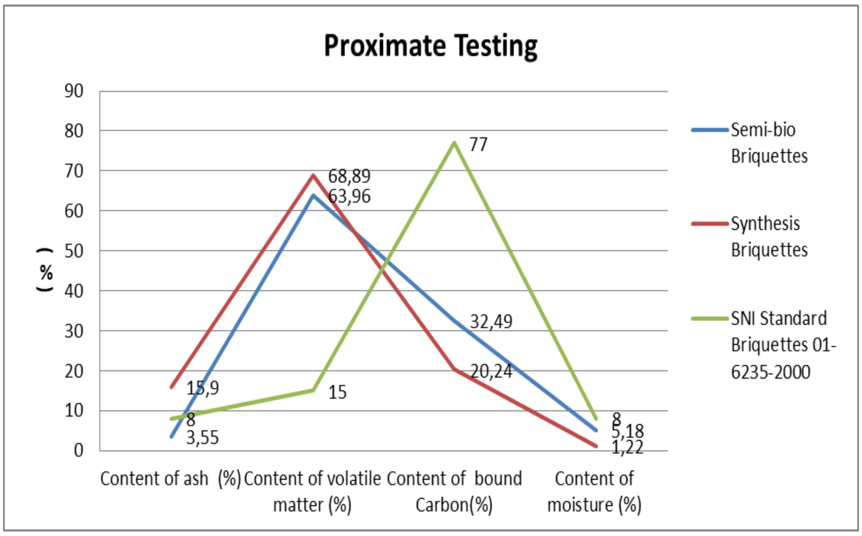
Proximate test results for Synthesis and Semi-bio Briquettes In Table 1.2, briquettes are displayed. Briquette quality is evaluated through proximate testing. According to SNI 01-6235-2000, briquette quality is influenced by factors like moisture content, ash content, volatile matter content, and bound carbon concentration. One of the factors affecting the calorific value, flame of briquettes, combustion power, and amount of smoke created during combustion is moisture content. [Iskandar,et.al, 2019]. Table 2 demonstrates that Semi-bio and Synthesis Briquettes meet volatile matter and moisture content requirements. The amount of volatile stuff impacts how quickly briquettes burn since the more volatile matter there is, the faster they burn [Sawir, 2016]. The Semi-Bio and Synthesis briquettes test results for volatile matter content are above the required threshold of 15%.

However, only Semi-Bio Briquettes of 3.55% (or 8% according to standards) were produced that satisfied the required ash content. The ash concentration shouldn't be high, or more than 8%, because a high ash content in briquettes might lower their calorific value and produce a lot of dust, which lowers their quality [Karim.et.al, 2014].

Table 2 *Proximate* Test

Testing of *Proximate*	Type of Briquettes		Standar
	Synthesis briquettes	Semi-Bio Briquettes	SNI 01-6235-2000
○ Content of ash (%)	15.90	3.55	≤ 8
○ Content of volatile matter (%)	68.89	63.96	≥15
○ Content of bound Carbon (%)	20.24	32.49	≥77
○ Content of moisture (%)	1.22	5.18	≤ 8

The two briquettes failed the test for bonded carbon content since the value was less than 77%, which was the cutoff. After volatile matter has evaporated, the bonded carbon content is a factor that affects burning in solid fuels. Briquettes of high caliber charcoal that burn quickly due to their high quantity of bonded carbon. Figure 2 displays the results of the nearby test.



Gambar 2 Result of proximate testing

Result of Gas Emission Analyzer Testing

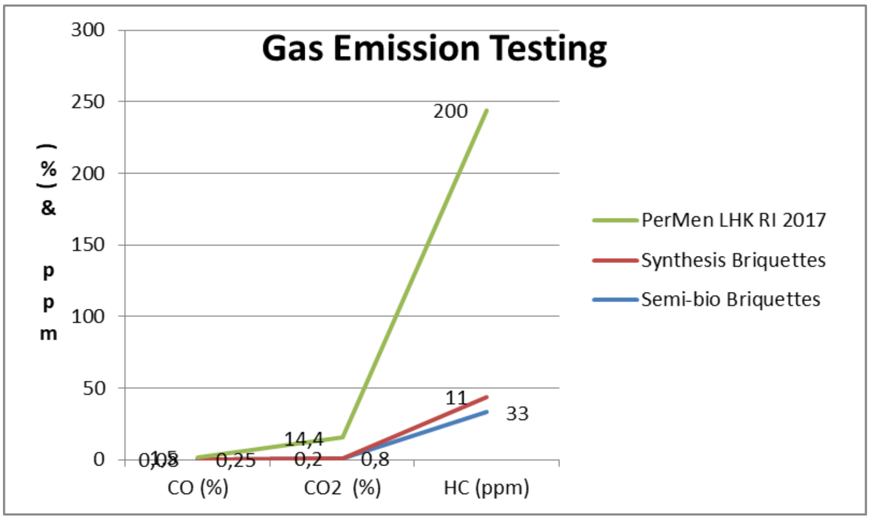
Exhaust emissions are the byproducts of fuel combustion released through the engine exhaust system from internal combustion engines, external combustion engines, and jet engines. Due to imperfect combustion processes and loose particles, the remaining combustion products include water (H_2O), toxic carbon monoxide (CO), CO_2, also known as carbon dioxide, which is a greenhouse gas, NOx, nitrogen oxide compounds, due to flaws in the combustion process and loose particles, and HC in the form of charcoal hydrate compounds. [Mita Amalia Hapsari, 2022].

To quantify the amount of exhaust gas generated when burning the two different types of briquettes, tests for gas/smoke emissions were also conducted on Synthesis Briquettes and Semi-Bio Briquettes. The briquettes are burned first and then placed in a gas emission test container to conduct the test. A gas emission analyzer is also used to examine the briquettes' smoke for 5 to 10 minutes. Figure 1.3 compares CO, CO_2, and HC gas levels to the 2017 Republic of Indonesia Minister of Environment and Forestry Regulation (PerMen LHK) about quality limits for motorized vehicle exhaust emissions. Table 1.3 displays the complete test findings. The findings indicate that the CO gas produced by burning Semi-Bio and Synthesis Briquettes is still below the quality limits established by the Republic of Indonesia's Minister of Environment and Forestry Regulation in 2017. The CO value of Semi-Bio Briquettes is 0.25%, whereas the CO produced by Briquettes has a CO value of 0.08%. Synthesis falls far short of the 1.5% quality requirement of the Republic of

Indonesia's 2017 Minister of Environment and Forestry Regulation. This indicates that the CO gas and smoke created when burning Synthesis and Semi-Bio briquettes are safe.

Table 3 The results of the gas/smoke test coming out of the Semi-Bio Briquettes and Synthesis Briquettes and compared with the Minister of Environment and Forestry Regulation of the Republic of Indonesia 2017

Type of Briquettes	**Result of Gas Emission**		
	CO (%)	**CO_2 (%)**	**HC (ppm)**
Semi-BioBriquettes	0,8	33	0,25
Synthesis briquettes	0,08	0,2	11
PerMen LHK RI 2017	≤1,5	≤14,4	≤200

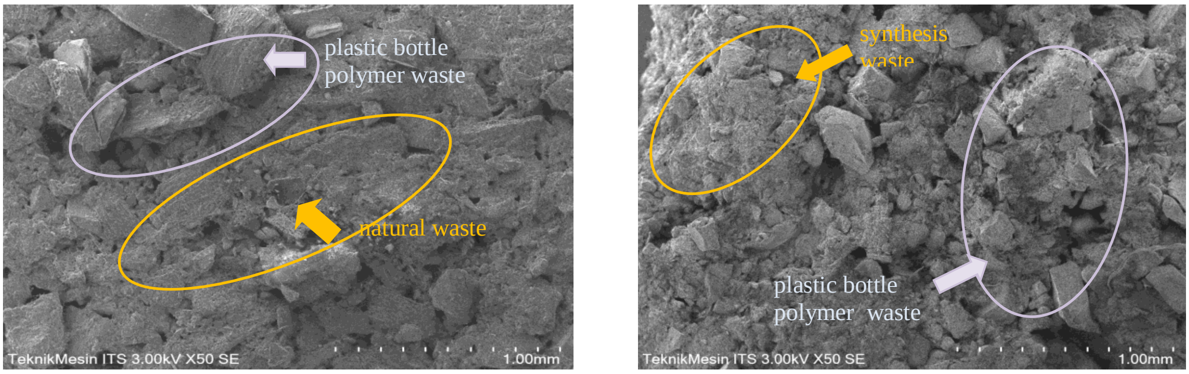


Gambar 3 Result of gas emission testing

Similarly, only 0.8% and 0.2% of the CO2 gas and smoke produced by burning Semi-Bio and Synthesis Briquettes meet the quality standards established by the 2017 Minister of Environment and Forestry Regulation of the Republic of Indonesia. This indicates that the combustion systems of synthetic and semi-bio briquettes are highly effective and flawless. The HC value generated by burning Semi-Bio Briquettes and Synthesis Briquettes is further evidence for this; it is also below the quality standards established by the 2017 Minister of Environment and Forestry Regulation of the Republic of Indonesia, namely below 200 ppm, demonstrating that the combustion process is still in the ideal range.

Microstructural Observation Results

Scanning Electron Microscopy (SEM) analysis of the microstructure of Semi-bio and Synthesis Briquettes reveals that Semi-Bio Briquettes appear to be more evenly distributed and denser than Synthesis Briquettes at 3kV 50K magnification. Figure 1.4(a,b). It means that the waste polymer from old plastic bottles is mixed evenly and densely with organic materials like coconut fiber, wood sawdust, and starch adhesive, which bind more firmly.

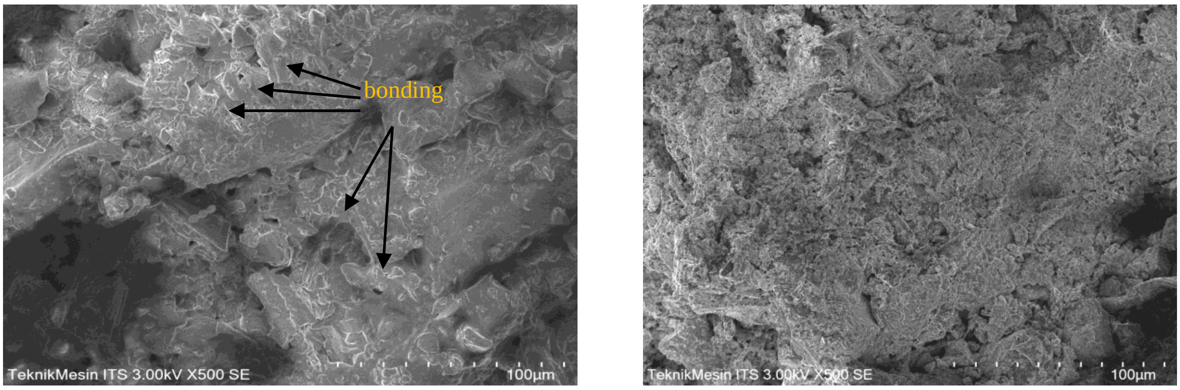


(a) (b)

Figure 1.4 Microstructure (3kV magnification 50K)

(a) Semi-BioBriquettes

(b) Synthesis briquettes



(a) (b)

Figure 1.5 Microstructure (3kV magnification 500K)

(a) There are bonds between the materials that make up Semi-Bio Briquettes

(b) In Synthesis Briquettes, there are no bonds between the constituent materials

The Semi-Bio Briquettes' microstructure can be seen in the 3kV SEM observation at 500K magnification. The edges of the grains have a white hue, which denotes a link between the components that go into making the Semi-Bio Briquettes. In contrast, there is no link between the constituent elements in Synthesis Briquettes (Figure 1.5 a, b).

CONCLUSION

This research resulted in several conclusions, namely:

1. It is now possible to create Semi-Bio Briquettes, made from recycled plastic bottle polymer waste mixed with natural materials like coconut fiber, sawdust/wood sawdust, and starch adhesive. The calorific value, ash content, volatile matter content, and water content of these briquettes all met the standard; the only component that did not was the bonded carbon, as the ideal value of the mixing composition had not yet been attained. While burning Semi-Bio Briquettes, the smoke/gas produced complies with the 2017 RI Minister of Environment and Forestry Regulation Standards.
2. Used polymer waste plastic bottles mixed with used rags or fabric trash and paper waste with adhesives from Sidoarjo mud (Lapindo mud) can also be used to make synthetic briquettes, but only for testing volatile matter content, moisture content, and smoke/gas emissions. However, the heating value, bonded carbon, and ash content of combustion products did not fulfill the norms.
3. In the future, the success of this research will be crucial for producing alternative fuels, educational materials, and scholarly publications that will advance our understanding of science.

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