Production of Coconut Shell (Cocos nucifera) and Empty Palm Oil Fruit Bunch Briquettes Using Banana Pseudostem Starch as Binding Agent

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ABSTRACT

Briquettes are solid fuels produced as an alternative energy source, derived from biomass after undergoing a series of processes, including carbonization, molding, and the addition of a binding agent. The objective of this research were to analyze the financial feasibility of briquette production and to determine the characteristics of briquettes with varying ratios of coconut shell charcoal and empty palm oil fruit bunch charcoal mixtures: 100%:0% (control), 75%:25% (P1), 50%:50% (P2), 25%:75% (P3), with a binding agent concentration of 15% banana pseudostem starch. The testing methods used in this study were moisture content, ash content, burn rate, drop test, yield, and financial analysis in the form of profit margin, payback period, B/C ratio, break-even point (BEP) of selling price, and BEP of production volume. The results showed that the best concentration ratio for coconut shell and empty palm oil bunch briquettes with banana pseudostem starch binder was 75%:25% (P1), yielding 5.06% moisture content, 5.96% ash content, a drop test failure index of 0.70%, a burn rate of 0.14 g/min, and from a financial feasibility perspective, a profit margin of 68.64%, a payback period of 21 days, a net B/C ratio of 3.19 (>1), a selling price BEP of IDR 5,644, and a production volume BEP of 1,468 kg, making this business viable to pursue.

Keywords: Financial Analysis, Briquettes, Coconut Shell, Empty Palm Oil Fruit Bunch

1. Introduction

In Indonesia, the utilization of briquettes has evolved into an innovative and effective solution for optimizing abundant natural resources and has even become one of the country's energy export commodities. Data from Trademap (2022) shows that Indonesia is one of the largest briquette exporters in the world, with an export volume of 467,050 tons and an export value of USD 172,677,000. Briquettes are solid fuels produced as an alternative energy source, derived from biomass after undergoing processes such as carbonization, molding, and the addition of binding agent The benefits of briquettes extend beyond energy, contributing to the reduction of organic waste, particularly biomass, as an active effort to improve waste management, reduce environmental impacts, and enhance the national economy.

Waste materials that have potential as briquette feedstock include coconut shells (Cocos nucifera) and empty palm oil fruit bunches (EPOFB). Coconut shells and EPOFB are abundant waste sources in Indonesia, particularly in the West Kalimantan Province, Sanggau Regency. The potential for these two waste materials to be used in briquette production is significant, given their sustainable availability. According to data from the West Kalimantan Central Statistics Agency (BPS) (2022), the coconut plantation area covers 94,846 hectares, with a production volume of 79,307 tons/year, while palm oil plantations span 317,446 hectares, producing around 1,067,179 tons/year. According to Siregar et al. (2022), EPOFB waste is generated in large quantities by palm oil mills in Indonesia, with every 1 ton of fresh fruit bunches (FFB) processed producing 22–23% or 220–230 kg of EPOB. The sustainable availability of this waste can be processed into various products such as solid compost (Mustangin et al., 2023), and briquettes offer a viable solution for managing this waste. Processing waste into briquettes not only reduces the negative environmental impacts of waste accumulation but also utilizes natural resources efficiently and sustainably, providing an alternative energy source to replace fossil fuels such as coal, which is more environmentally friendly and has potential economic value.

The binding agent plays a crucial role in the briquette production process, alongside the raw waste materials. The binding agent in briquettes not only serves to hold the charcoal particles together, but selecting the appropriate binding agent can also enhance the calorific value of the briquettes. The binding agent used in this study is starch derived from banana pseudostem. The choice of banana pseudostem starch is based on two factors: first, to utilize waste, and second, due to the starch content in banana pseudostem. Banana pseudostem contain 76% starch and 20% water (Nafianto, 2019). Starch consists of two types of carbohydrates: amylose, which provides hardness, and amylopectin, which creates stickiness, making starch a commonly used binding agent in industry (Saleh, 2013).

Briquettes made from a mixture of coconut shells and EPOFB, with banana pseudostem starch as a binding agent, represent an alternative energy product with economic value, making it essential to conduct a physical characterization and financial analysis.

2. Research Methodology

The equipment used in the production of briquettes includes a 60-mesh sieve (1 unit), basins (2 units), a cabinet dryer (1 unit), a drum (1 unit), 1-inch and 2-inch PVC pipes as molds (1 unit), a grinder (1 unit), and an OHAUS analytical balance (1 unit). The analytical tools used for testing ash content include a desiccator (1 unit), hotplate (1 unit), porcelain crucibles (12 units), fume hood (1 unit), mortar (1 unit), muffle furnace (1 unit), trays (2 units), analytical balance (1 unit), oven (1 unit), weighing bottles (12 units), tongs (1 unit), spatulas (2 units), measuring tape (1 unit), ruler (1 unit), matchsticks (1 unit), and a stopwatch (1 unit).

The materials used in the production of briquettes include coconut shells from the Central Market of Sanggau Regency, empty oil palm fruit bunches from PT. MPE in Sanggau Regency, aged banana pseudostem collected from plantations in the Sungai Batu area, Sanggau Regency, West Kalimantan, and water.

The procedure for briquette production, as modified from Masthura (2018), includes the following steps: 1). Coconut shell charcoal powder and empty oil palm fruit bunch charcoal powder are prepared; 2). The coconut shell charcoal powder is mixed with the empty oil palm bunch charcoal powder in varying concentration ratios: 100% (200 g) : 0% (0 g) (as control), 75% (150 g) : 25% (50 g) Treatment 1 (P1), 50% (100 g) : 50% (100 g) Treatment 2 (P2), and 25% (50 g) : 75% (150 g) Treatment 3 (P3); 3). The mixed charcoal powder is then added to a binding agent made from banana pseudostem starch at a concentration of 15% of the charcoal weight, dissolved in water at a ratio of 3:1 for the banana pseudostem starch; 4). The mixture is stirred until evenly combined and then molded; The molded briquette dough, using 1-inch PVC pipes, is dried in an oven for 6 hours at a temperature of 100°C.

The procedure for producing coconut shell charcoal powder, as modified from Budi (2017), involves the following steps: 1). The coconut shells are oven-dried for 2 hours at 100°C; 2). The coconut shells are reduced in size; 3). The coconut shells are carbonized into charcoal for 2 hours and 30 minutes at 350°C; 4). The coconut shell charcoal is pulverized using a grinder; 5). The coconut shell charcoal is sieved using a 60-mesh sieve.

The procedure for producing empty oil palm bunch charcoal powder, as modified from Purnama et al., (2012), includes the following steps: 1). The EPOFB are separated from unusable parts, such as adhered dirt; 2). The EPOFB are oven-dried for 2 hours at 100°C; 3). The dried EPOFB are cut into pieces of approximately 1-2 cm to facilitate carbonization; 4). The EPOFB are carbonized using a coffee tin by pyrolysis for 1 hour and 30 minutes at 400°C; 5). The resulting charcoal is then ground using a grinder and sieved using a 60-mesh sieve.

The observed parameters include financial feasibility analysis (Pardjer et al., 2024), Thermogravimetric Moisture Content (SNI 01-6235-2000), Ash Content (SNI 01-6235-2000), Drop Test (ASTM D 440-86 R02. 2002), and Burn Rate Determination (Romadhon, 2022).

3. Results

Briquette Yield Results.

Table 1. Briquette Yield Results.

Sampel	Total Waste Weight (g)	Rendemen (%)
Control	727	31,90
P1	884	26,58
P2	1.041	21,43
P3	1.198	17,45
Total	**3.850**	**23,35**

Based on Table 1, the Yield Results of Briquettes indicate that the total yield obtained was 23.35%, while the yield for each treatment ranged between 17.45%-31.90%, with Treatment P1 producing the highest yield (aside from the control). To achieve this yield, 3,850 grams of coconut shells and EPOFB were required. Weight loss during the production of charcoal briquettes occurs through various stages, starting with the carbonization process. Carbonization is the incomplete combustion of organic material with a limited oxygen supply, breaking down organic compounds into water vapor, methanol, acetic acid, and hydrocarbons. This process is divided into four stages: first, the evaporation of water and the decomposition of cellulose into distillate; second, more intensive cellulose decomposition, resulting in gas production; third, lignin decomposition, producing tar; and fourth, hydrogen gas formation, which helps purify the resulting charcoal (Fachry et al., 2010). This process significantly contributes to weight loss, where almost half of the initial material weight can be lost due to the decomposition of organic substances like lignin and hemicellulose, thus affecting the final briquette yield.

After carbonization, the resulting charcoal undergoes grinding and sieving. At this stage, many small particles are formed and often disperse into the air, leading to a significant weight loss. Additionally, during this process, charcoal may spill from the container, especially due to the use of manual equipment, resulting in a considerable amount of wasted charcoal. The molded briquettes must then be dried to remove moisture. This drying process is crucial as the removal of water not only reduces the briquette's weight but also impacts the quality and strength of the briquette itself. According to Panigoran (2007), a tightly controlled briquette-making process with uniform material size can yield briquettes with a range of 27%-35%. This means that the yield from all treatments in this study fell below that range, whereas Treatment P1 and the control met the criteria, yielding 26.58% and 31.90%, respectively. The low briquette yield occurred because during the molding process, much of the briquette mixture spilled and was left in the mold, resulting in a lower yield.

According to the research results, all raw materials were perfectly converted into charcoal. A high briquette yield is essential in briquette production as it increases material efficiency by reducing waste, lowers production costs by minimizing raw material needs, and ensures consistent product quality and optimal density. Furthermore, an efficient production process with high yields can save energy and reduce environmental impact, which in turn supports business sustainability by improving profitability and reducing the ecological footprint.

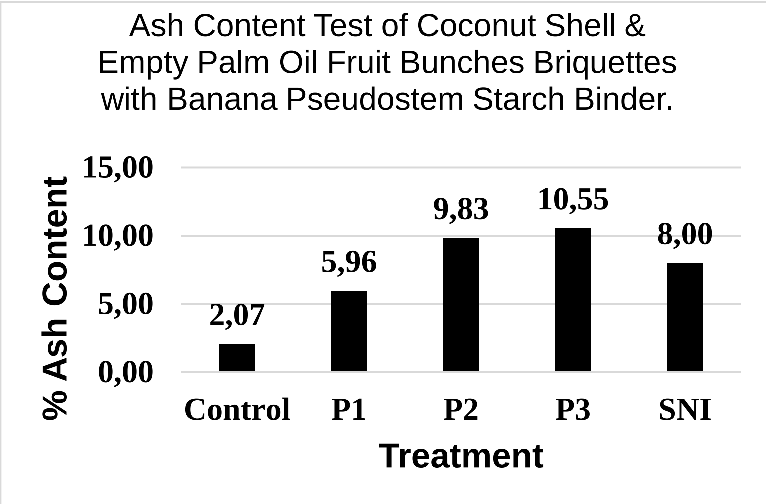

Figure 1. Bar Chart of the Briquette Moisture Content Test

Based on Figure 1, the Bar Chart of Briquette Moisture Content Test, it is evident that all treatments met the SNI standard for moisture content of less than 8%, with Treatment P1 being the best (aside from the control) at 5.06%. These results are consistent with the findings of Marbun and Sinaga (2019), where the same materials were used—comparing EPOFB charcoal and coconut shell charcoal. A ratio of 100% EPOFB : 0%

coconut shell produced a moisture content of 2.81%, a ratio of 75%:25% produced 1.64%, a ratio of 50%:50% produced 1.66%, a ratio of 25%:75% produced 1.43%, and a ratio of 0%:100% produced 0.91%. These findings indicate that the more EPOFB charcoal is added, the higher the moisture content of the briquette produced.

Another study by Siregar et al. (2023) showed similar results, where a 50%:50% ratio of EPOFB and rubber seed shell produced the lowest average moisture content at 5.11%, a 60%:40% ratio had an average of 5.93%, and a 70%:30% ratio had the highest average of 6.57%. This further confirms that increasing the amount of EPOFB charcoal results in higher moisture content in the briquettes produced.

According to Siregar et al. (2023), this occurs because EPOFB charcoal has smaller particle sizes and more pores, allowing the briquettes to absorb more water and air from their surroundings. EPOFB also contains a significant amount of fiber and chemical components such as 45.80% cellulose, 25.90% hemicellulose, 71.88% holocellulose, and 42.65% moisture content, all of which can contribute to the high moisture content. This statement is supported by Ristianingsih et al. (2015), who stated that high moisture content in briquettes is influenced by insufficient drying of the raw materials, leaving a significant amount of moisture in the briquettes, as well as the fine particle size of the charcoal, which easily absorbs water. This can lead to deviations in the moisture content of EPOFB briquettes produced through pyrolysis.

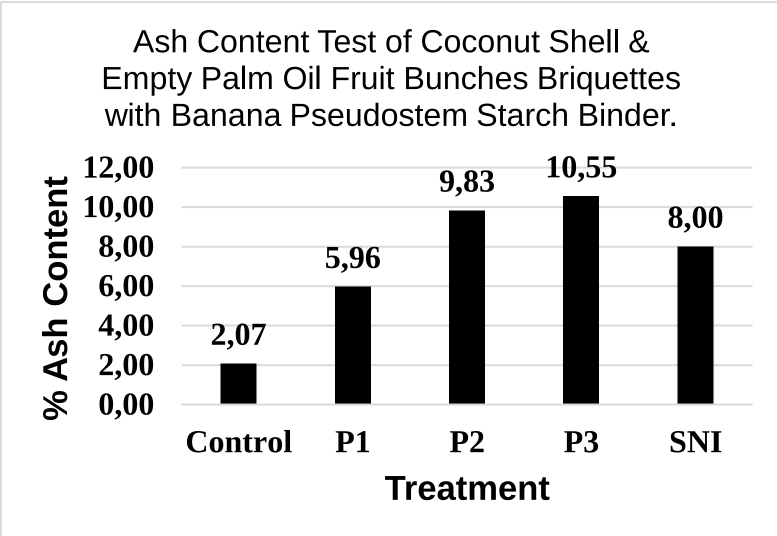

Figure 2. Bar Chart of the Briquette Ash Content Test

Based on Figure 2, the Bar Chart of Briquette Ash Content Test, it can be observed that among the three treatments (excluding the control), P1 is the best treatment that meets the SNI standard for ash content <8%, with an ash content of 5.96%. These results indicate that the less EPOFB charcoal added, the lower the ash content, and conversely, the more EPOFB charcoal added, the higher the ash content. This is consistent with the research conducted by Marbun and Sinaga (2019), where a treatment with a ratio of 100% EPOFB:0% coconut shell produced the highest ash content of 20.00%, while a ratio of 25%:75% produced the lowest ash content of 7.94%.

Another study by Ristianingsih et al. (2015), using EPOFB and starch as a binding agent, resulted in ash content ranging from 12.96% to 17.86%. Ramadhan's (2019) research, using a 70%:30% ratio of EPOFB and rice husks, produced ash content ranging from 7.66% to 27.17%. Siregar et al. (2022) found that briquettes made from EPOFB and arpus binding agent had an ash content of 13.26%, while Efendi (2020) reported that briquettes made from coconut shells and hibiscus leaf binding agent had ash content ranging from 4.01% to 3.30%. These findings suggest that EPOFB tends to produce higher ash content compared to coconut shells.

According to Kurniawan et al. (2020), this occurs as EPOFB has a high ash content, around 21.60%. This ash is composed of potassium and other minerals. The minerals in EOPB come from its nutrient-rich environment or fertilization when the soil does not provide enough essential elements, as well as external impurities such as soil and sand attached to the EPOFB (Prismantoka et al., 2017). In research by Saleh and

Anggraini (2016), the minerals in EPOFB ash consist of 6% potassium, 0.4% phosphorus, 2% calcium, and 1% magnesium.

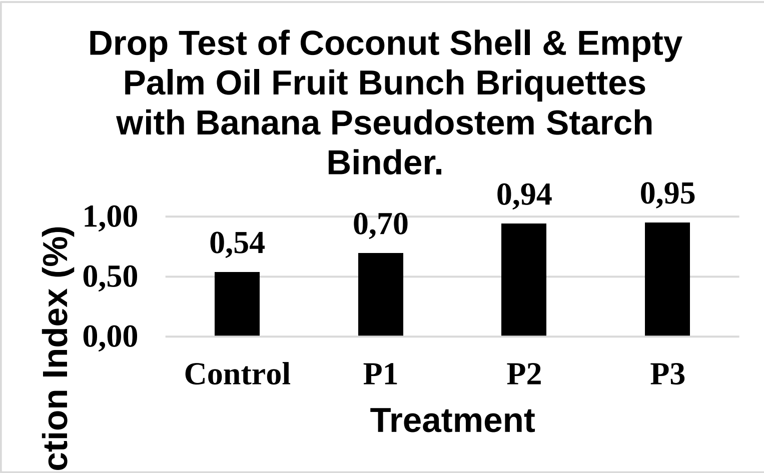

Figure 3. Bar Chart of the Briquette Drop Test.

Based on Figure 3, the Bar Chart of the Briquette Drop Test indicates that the control treatment is the best among the four treatments, with a destruction index of 0.54%. Treatment P1 is the best among the three treatments (excluding the control) with a destruction index of 0.70%. This suggests that EPOFB significantly affects the durability/strength of the briquettes. As the amount of EPOFB increases, the loss of particles or destruction index also increases.

The drop test aims to determine the briquette's resistance to impact from hard objects, which is crucial during the packaging, distribution, and storage processes. This finding aligns with the research conducted by Artiningsih (2022), which states that increasing the amount of EPOFB in briquette production reduces the briquette's strength. Ramdhan (2019) found that using a 70%:30% ratio of EPOFB and rice husks resulted in a destruction index ranging from 18.66% to 60.32%, indicating that EPOFB influences the destruction index or particle loss during the drop test.

According to Marbun and Sinaga (2019), this occurs because each raw material has different particle densities, resulting in varying strengths. Each type of charcoal raw material with a high specific gravity produces briquettes with high density, while raw materials with low specific gravity yield briquettes with lower density. This means that EPOFB have a lower density due to its lower specific gravity compared to coconut shells, which have a high specific gravity, resulting in a higher density. In addition to particle density, the binding agent also affects the strength and durability of the briquettes, where higher concentrations of the binding agent lead to greater resistance against impacts and pressure. However, according to ASTM (American Society for Testing and

Materials) D 440-86, a particle loss or destruction index of no more than 1% is the threshold set for solid fuel quality in drop tests, indicating that all treatments in this study still meet the standards.

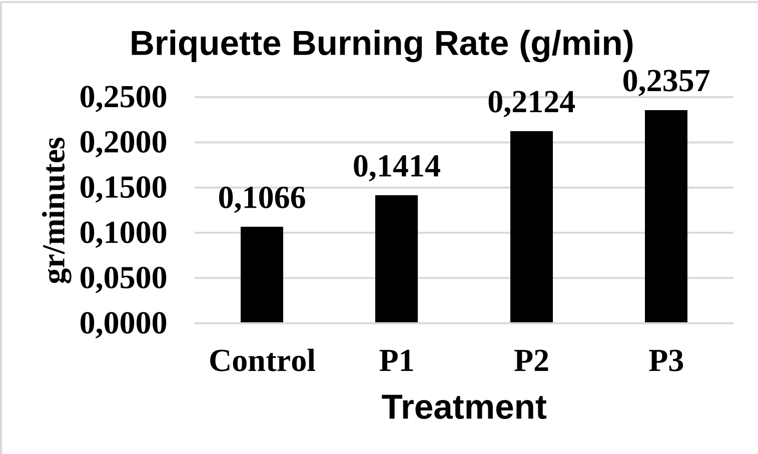

Figure 3. Bar Chart of the Briquette Burning Rate Test.

Based on Figure 4, the Bar Chart of the Briquette Combustion Rate indicates that the control treatment is the best among the four treatments, with a combustion rate of 0.1066 g/min. Treatment P1 is the best among the three treatments (excluding the control) with a combustion rate of 0.1414 g/min. The graph also shows an increase in each treatment, indicating that the addition of EPOFB concentration affects the combustion rate of the briquettes. This aligns with the research conducted by Marbun and Sinaga (2019), where the ratio of EPOFB to coconut shell at 0%:100% resulted in the longest combustion rate of 0.002195 g/s, and the 75%:25% ratio yielded a rate of 0.003575 g/s.

According to Ristianingsih et al. (2015), the combustion rate is influenced by the material's structure, bound carbon content, and hardness level. EPOFB has a lower hardness level than coconut shell due to its lignin content of only 22.60% (Rifdah, 2015), while coconut shell contains 36.51% lignin, classifying it as a hardwood (Tirono and Sabit, 2011). Afriyanto et al. (2014) state that higher ash and moisture content in briquettes affects the combustion rate due to lower heat transfer to the briquette's interior and oxygen diffusion to the briquette's surface during combustion, which can generate dust emissions that cause air pollution and affect combustion volume. Increased density leads to better heat transfer through conduction, allowing heat to easily transfer from one particle to another, resulting in a longer ignition time. Conversely, larger particle sizes create a less compact arrangement, making it difficult for heat to transfer, resulting in a quicker ignition time (Junianti et al., 2024).

Table 2. Financial Feasibility Analysis of the Briquette Business.

Feasibility Financial	Values	Description
Total production cost per year (IDR)	Rp 26.415.309	-
Selling price of the product (IDR/kg)	Rp 18.000	-
Gross profit (IDR)	Rp 57.824.691	-
Net profit (IDR)	Rp 57.824.691	-
Profit margin (%)	68,64	-
PP (Payback Period)	21	Day
Net B/C Ratio	3,19	>1
Feasibility	Decision	Feasible
BEP Selling Price (IDR)	Rp 5.644	-
BEP Production Volume (kg)	1.468	-

The yield used for the financial analysis calculation is the yield from treatment P1, which has a concentration ratio of 75% coconut shell and 25% empty palm fruit bunch (EFB). The selection of treatment P1 is based on its performance, which was determined to be the best based on yield testing, moisture content, ash content, drop tests, and combustion rates.

According to Table 6, Financial Analysis of Briquette Business, the total annual production cost for the coconut shell and EFB briquette business with banana pseudostem starch binding agent is IDR 26,415,309 (Table 2). The annual production cost is derived from the sum of fixed costs, variable costs, and mixed costs.

The selling price for the coconut shell and EFB briquette with banana pseudostem binding agent is IDR 18,000/kg. This selling price follows the market prices, which range from IDR 10,000/kg to IDR 20,000/kg. The price of IDR 18,000/kg is set because the briquettes in this study are classified as quality 2. The gross profit from the coconut shell and EFB briquette business with banana pseudostem starch binding agent is IDR 57,824,691, resulting in a net profit of IDR 57,824,691. The gross profit is obtained by subtracting annual revenue from operational costs, while the net profit is derived by subtracting taxes (0%) from gross profit.

The profit margin achieved is 68.64%. The profit margin is a ratio used to express the net profit margin, which is the comparison of net profit after tax to sales. The profit margin also indicates a company's ability to generate net profit after deductions. A company with a consistently low profit margin will face losses, ultimately leading to financial difficulties due to excessive costs and insufficient profits (Varirera and Adi, 2021). A high profit margin value indicates the company's financial health; thus, a profit margin of 68.64% suggests that the briquette business is worthy of continuation.

The payback period (PP) required to recover the investment in the briquette business is 21 days, assuming the sale of briquettes runs smoothly. This finding indicates that the processing of briquettes from coconut shell and EPOFB with banana pseudostem starch binding agent is feasible for follow-up since the initial capital invested in briquette production can be recovered within 21 days.

The net benefit-cost (b/c) ratio is 3.19. This value indicates that the income from the business exceeds the total costs incurred to achieve it, as the net b/c ratio is greater than 1, meaning the coconut shell and EPOFB briquette business with banana pseudostem starch binding agent is a viable investment. This is consistent with research by Hidayat (2017), which found a net b/c ratio of 3.62 for the coconut shell briquette business, also indicating its feasibility. Research conducted by Budiyanto et al. (2011) on briquette businesses from solid palm oil waste resulted in a net b/c ratio of 1.78, further confirming the viability of briquette ventures.

The break-even price (BEP) for the coconut shell and EPOFB briquette business with banana pseudostem starch binding agent is IDR 5,644, with a production volume break-even point of 1,468 kg. This indicates that the business will reach its break-even point or start to generate profits when the selling price of briquettes is IDR 5,644/kg, with a production or sales volume of 1,468 kg.

5. Conclusion

Based on the data from the research on briquettes made from coconut shell and EPOFB using banana pseudostem starch binding agent, it can be concluded that the briquettes produced from the mixed waste of coconut shell (Cocos nucifera) and EPOFB with banana pseudostem starch binding agent yield 14.98%, with moisture content ranging from 4.85% to 5.71%, ash content between 5.06% and 10.55%, drop test results of 0.54% to 0.95%, and a combustion rate of 0.11 g/min to 0.24 g/min.

The best concentration for producing briquettes from the mixed waste of coconut shell (Cocos nucifera) and EPOFB using banana pseudostem starch binding agent is the briquette with a concentration ratio of 75%:25% (P1), which yields a moisture content of 5.06% and an ash content of 5.96%, in accordance with the SNI 01-6235-2000 standard. The briquette production business using coconut shell and varying amounts of

EPOFB and banana pseudostem starch as a binding agent is viable, generating a profit margin of 68.64%, a payback period (PP) of 21 days, a net B/C ratio of 3.19 (>1), a break-even price (BEP) of IDR 5,644, and a break-even production volume of 1,468 kg.

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