Optimization of the Biopellet Manufacturing Process: Effect of Adhesive Concentration with Recycled Coffee Grounds and Cocopeat on Biopellet Properties

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***Abstract*-. Biopellets are an environmentally friendly organic waste management solution. The use of biopellets can help reduce negative impacts on the environment and create a cleaner and healthier environment. In this study, coffee grounds and cocopeat waste were used as the main raw materials for the biopellet making process with a ratio of 1:1, The quality testing of biopellets includes ash content, calorific value, moisture content, and combustion rate due to the effect of tapioca flour adhesiv concentration with variations in composition of 10%, 15%, and 20%. The results of this study show that the concentration of tapioca flour adhesives has a significant impact on the quality of biopellets. The adhesive's concentration increases with moisture and ash content, while decreasing its calorific value. Biopellets with an adhesive concentration of 10% have the lowest moisture content and ash content values of 5.76% and 2.02% and the highest calorific value of 4842.33 Cal/gr with a combustion rate of 2.0 gr/min. Overall, biopellets that meet the SNI 8675:2018 standard are biopellets with adhesive concentrations of 10% and 15%, while biopellets with adhesive concentrations of 20% have not met because the calorific value is still less than 4000 Cal/gr.**

Keywords; Biopellets, Coffee Grounds, Cocopeat, Adhesive Concentration Effect

I. Introduction

Indonesia's population is increasing, with a population of 275,77 million people in 2022, a 1.133% increase from the previous year [1]. This growth is primarily due to the increasing demand for energy, particularly from fossil fuels like coal and oil [2]. However, the increase in energy consumption from fossil fuels is also contributing to the rise in global greenhouse gas emissions [3].

Indonesia possesses a 50,000 MW potential for biomass energy derived from diverse agricultural waste materials, including but not limited to palm coconut, peat grinding, plywood, cocoa, and by-products of sugar factories [1] [4].

Biopellets are a sustainable alternative to traditional fossil fuels, made from organic materials such as wood, agricultural residues, and food waste [5][6]. Biopellets are a type of waste-based solid fuel that is smaller than the size of a brick [7]. The cylinder-shaped biopelet is smaller than the brick size and has a length of about 6-25 mm with a diameter of 10-12 mm [7][8]. The advantages of biopellets as fuel include high density, easy storage and handling. The main factors affecting the strength and durability of the pellets are raw materials, water content, particle size, welding conditions, adhesion of adhesives, densification tools, and post-production treatment [9]. Biopellets have a high combustion efficiency and produce lower emissions compared to fossil fuels. Waste Recycling: Encourages the recycling of biomass waste into energy sources, reducing environmental impact.

Biopellets can be used as alternative fuel solutions in industry, for example in heating and power plants: Biopelets can be used as fuel in industrial heating systems and used for biomass power plants [10]. In manufacturing industries used in manufacturing industry as a source of energy for production processes. In forestry and agriculture industries, forest biomass and agricultural waste can be processed into biopellets, creating added value for this sector.

The manufacturing process involves several key steps, starting with the collection and sorting of raw materials. Once the materials are gathered, they undergo a complex transformation process to create products while minimizing waste generation and optimizing energy and material consumption. This shift towards a more integrated industrial ecosystem emphasizes recycling, conservation, and the use of alternative materials [11]. The final step in the manufacturing process is cooling and packaging the biopellets for distribution and use. Biopellets are gaining popularity as a renewable energy source due to low carbon emissions, sustainable waste management, and potential role in transitioning to a cleaner future [12][13].

Biopellets offer versatility in residential heating, industrial processes, and power generation, making them a sustainable, environmentally friendly alternative to fossil fuels. They reduce energy costs and create job opportunities in renewable energy.

By making the switch to biopellets, these individuals and companies are not only reducing their impact on the environment but also contributing to the growth of the renewable energy industry. This shift towards more sustainable energy sources has the potential to create new job opportunities in manufacturing, distribution, and installation of biopellet systems. Additionally, as more businesses and households make the transition to biopellets, the demand for these renewable energy sources will continue to grow, further driving innovation and investment in the sector. Ultimately, the widespread adoption of biopellets has the potential to revolutionize the way we heat our homes and power our industries, leading to a cleaner and more sustainable future for all [14][5].

Biopellet production can be improved by reducing waste and increasing efficiency, making it more cost-effective for consumers and benefiting the environment. The production of Refused Derived Fuel (RDF) pellets from food and garden waste offers a sustainable approach to waste diversion, bio-energy generation, and soil enhancement. The pellets demonstrate a notable calorific value, economic viability, and minimal ash residue, making them a promising alternate solid fuel for household and industrial applications [16][18]

II. MATERIAL

The research is intended to conduct research on the utilization of agricultural waste as an alternative solution to biopelet raw materials (environmentally friendly solid fuels) to support green energy in Indonesia. The agricultural debris used in this study is coffee grounds and cocopeat. So far, agricultural waste is often simply disposed of or burned, which can lead to environmental problems such as air pollution and soil contamination or merely becoming a growing medium. The calorie content of dry coffee amps ranges between 19.3-24.9 MJ/kg (± 4610-5947 kcal/kg) [17][19].

The calorific value of cocopeat waste is affected by the amount of non-combustible material (ash) and the moisture content of the pellet. Pellets produced from cocopeat have an ash content of 6.14%, which is higher than existing standards due to the fragility of cocopeat compared to wood pellets or other biomass resources. Mixing cocopeat with other biomass materials can improve pellet quality [16][17][20]. The calorie value of cocopeat waste is about 17.5-19.8 MJ/kg (±4180-4740 kcal/kg). The higher ash content and fragility of cocopeat waste pellets compared to traditional biomass resources like wood pellets can affect their calorific value. However, by mixing cocopeat with other biomass materials, the quality of the pellets can be improved. Despite these challenges, the calorie content of cocopeat waste is still significant, ranging between 17.5-19.8 MJ/kg (±4180-4740 kcal/kg), making it a viable option for energy production[21] [22].

III. METHODS

This research was conducted to determine the quality of biopellets from the combined of recycled coffee grounds and cocopeat by the addition of tapioca flour adhesive composition mixtures with adhesive percentages of 10%, 15%, and 20% with 100 mesh. Testing was carried out to assess the quality of the biopellets based on SNI 8675:2018, which includes ash content, heating value, water content, and burning rate. The research procedure is explained in detail below :

1. *Preparation Stage*
   At the raw material preparation stage, the dirt adhering to the materials is cleaned with running water, then dried under sunlight for 2 days to reduce the moisture content.
2. *Pre-Treatment Stage*
   Re-drying is carried out using an oven at a temperature of 100 °C for 30 minutes. After completely dry, the raw material is crushed with a crusher, and the result is sieved with a 100 mesh size.
3. *Biopellet Production Stage*
   Raw material with a particle size of 100 mesh in Cocopeat: Coffee grounds in a 1:1 ratio are then mixed with an adhesive, where the adhesive used is tapioca with adhesive concentrations of 10%, 15%, and 20% of the total raw materials.
4. *Densification Stage*
   At this stage, biomass will undergo a densification process through compaction (pressing) so that its mass density or potential energy density increases. The densification process of these biopellets uses a vertical pellet press.
5. *Drying stage*
   The bio-pellets that have been molded are dried under the sun for 2 days.
6. *Torefaction Stage*
   Bio-pellets are dried again through a torrefaction process at a temperature of 200 °C for 30 minutes.
7. *Characteristic Testing Stage*
   The tests conducted include parameters such as water content, ash content, heating value, and burning rate based on SNI 8675:2018.

IV. RESULT AND DISCUSSION

The biopellet trial's outcomes, which included cocopeat and coffee ground with tapioca flour adhesive modifications at 10%, 15%, and 20% with 100 mesh, are displayed in Figure 1.

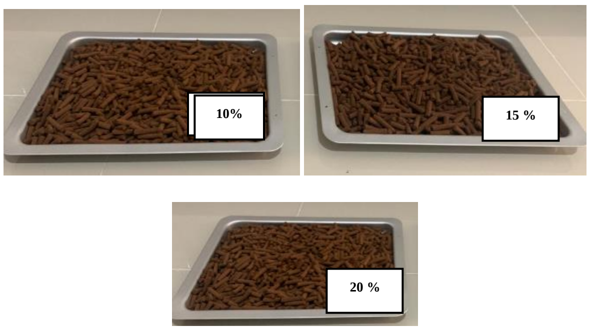

Fig.1. Biopellet from the combined of recycled coffee grounds and cocopeat by the addition of tapioca flour adhesive composition mixtures with adhesive percentages of 10%, 15%, and 20%.

The biopelets from the three varieties appear to have nearly the same texture at first glance. On the other hand, if an examination of its traits is done. There will be multiple distinct values obtained. The compressive strength of biopellets containing 10% tapioca flour binder is lower than that of biopellets containing 15% and 20% tapioca flour binder. Furthermore, compared to the other two versions, biopellets containing a 20% tapioca flour binder have a greater capacity for water absorption. Therefore, it can be said that the features of the final biopellets are influenced by variations in the tapioca flour adhesive.

The results of the quality test of biopellets made from coffee grounds and cocopeat are shown in Table 1. Biopellets made from a mixture of coffee grounds and cocopeat show satisfactory results in terms of quality. Table 1 provides a detailed overview of the quality tests conducted.

Table 1. Result biopellets made from coffee grounds and cocopeat

Material	Adhesive percentage	Water content (%)	Ash Content (%)	Heating Value (Kal/gr)	Burning Rate (gr/minute)
Cocopeat: Coffe Ground	10%	5.76	2,02	4842.33	2,0
	15%	7.87	3.35	4380.64	2,2
	20%	8.36	4.63	3289.84	1,95
Test Methode		SNI 01-1506	ASTM E1755	SNI 01-6235	-
SNI 8675:2018	Household	12% maximum	5% maximum	3940,95 Kal/gr minimum	-
	Industry	10% maximum	5% maximum	3940,95 Kal/gr minimum	-

A. Water Content

Water content is the ratio between total water inside a substance with its dry weight. Material quality is significantly impacted by water content. One of the key factors in determining the quality of biopellets is their water content. This has to do with smoke, the rate of ignition, and the storage of biopellets. Figure 2 shows the water content of the biopellet.

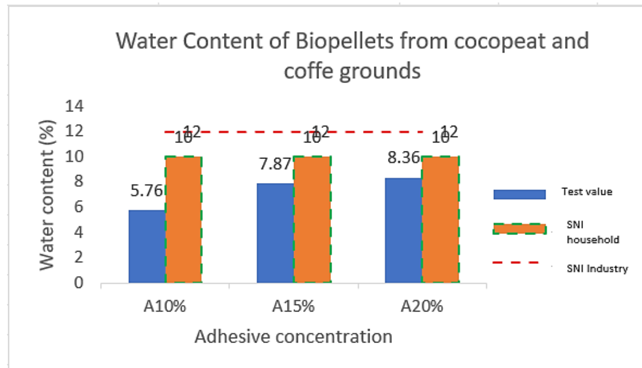

Fig. 2. Water Content of Biopellets from cocopeat and coffe grounds

The results of the quality test of biopellets made from coffee grounds and cocopeat show that with the addition of 20% adhesive, the highest water content is 8.36%. Meanwhile, with the addition of 10% adhesive, the water content is the lowest at 5.76%. This shows that the addition of adhesive to biopellets can significantly affect their moisture content. However, out of the 3 test samples, all of them fell within the range according to the SNI 8675:2018 standard. Thus, it can be concluded that the biopellets made from coffee grounds and cocopeat with the addition of adhesive still meet the established quality standards. Although its water content varies, it remains within the permitted limits.

B. Ash Content

Ash content is an inorganic component that residues from the burning of organic matter. One crucial factor in the grade of biopellet production is the amount of ash. Weight is used to determine the amount of ash present when organic matter is perfectly burned at a high temperature (500–600 °C). Evaporation of organic materials leads to weight reduction. This residue is made up of oxides and salts that include cations like sodium, potassium, calcium, magnesium, iron, and manganese, as well as anions such as phosphates, chlorides, sulfates, and other halides. Fig. 3 shows the ash content of the biopellet.

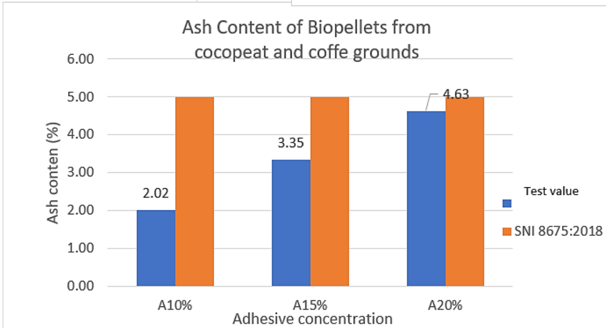

Fig. 3. Ash Content of Biopellets from cocopeat and coffe grounds

The highest ash content in the 20% adhesive mixture is 4.36%. Meanwhile, the lowest value in the 10% adhesive mixture was 2.02%. All bio-pellets still meet the SNI standard for a maximum ash content of 5%. This shows that the produced bio-pellets still meet the established quality standards.

C. Heating Value (Calorific value)

The main parameter for measurement of biomass fuel is calculated from its calorific value. The energy that is chemically bonded in fuel in typical environmental conditions, such as temperature, water phase (vapor or liquid), and combustion emission (CO2, H2O, etc.), is indicated by the fuel's calorific value.

Based on Figure 4, it can be seen that the higher the addition of the adhesive, the lower the heating value will be. The addition of 10% adhesive has the highest heating value of 4842.33 cal/g. Meanwhile, the addition of 15% adhesive has a heating value of 4380.64 cal/g. And in the 20% adhesive, it is 3289.84 cal/g. The minimum limit of SNI 8675:2018 related to the heating value is 3940.95 Kal/gr, so the 20% adhesive does not yet meet the SNI standard. This shows that excessive addition of adhesive can reduce the calorific value of the fuel. Therefore, further research is needed to find the optimal adhesive proportion to meet SNI standards. In addition, research also needs to be conducted to consider other factors such as combustion efficiency and exhaust emissions. Thus, environmentally friendly and efficient fuel can be produced.

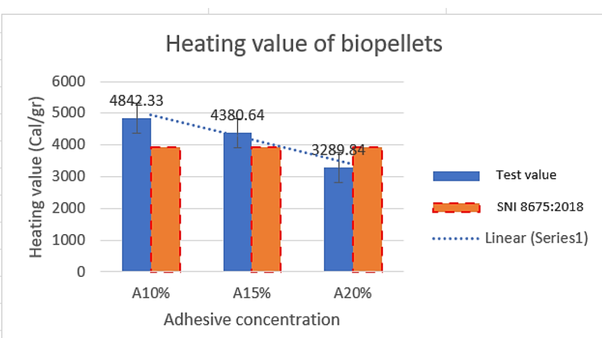

Fig. 4. Water Content of Biopellets from cocopeat and coffe grounds

D. Burning rate

The burning rate of bio-pellets allows them to generate heat quickly and efficiently. The higher the burning rate of the biopellet, the more efficient the utilization of the energy produced by the biopellet.

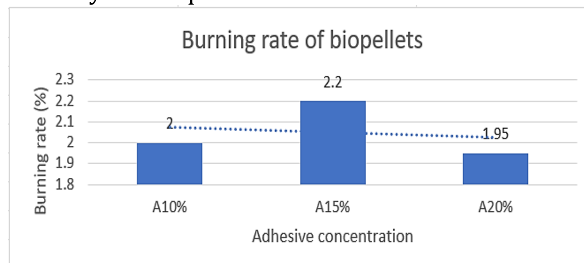

Fig. 5. Burning rate of Biopellets from cocopeat and coffe grounds

Based on Figure 5, it is known that the highest burning rate for the 15% adhesive is 2.2. Next, the highest was with the 10% adhesive and the lowest with the 20% adhesive. This shows that the concentration of the adhesive affects the burning rate of the fuel. The decrease in the burning rate of the 20% adhesive may be due to the excess adhesive content that hinders the combustion process.

The quality test results of bio-pellets made from coffee grounds and cocopeat show that with a binder addition of 20%, the moisture content and ash content are higher, but it has the lowest heating value of 3289.84 Kal/kg. The increase in the adhesive content in the biopellets turns out to affect the water and ash content, resulting in higher levels, but it reduces the thermal energy value produced. Nevertheless, these biopellets can still be used as an environmentally friendly and efficient alternative fuel for generating heat. With further research, it is possible to find an optimal formula to achieve a balance between the quality of the biopellets and the thermal energy value produced.

By optimizing the adhesive content, it may be possible to maintain a higher thermal energy value while still keeping moisture and ash content at acceptable levels. This would enhance the overall efficiency and effectiveness of using bio-pellets as a sustainable fuel source.

IV. CONCLUSION

Based on the results of biopelet berbahan cocopeat and coffee ground, three variations of the perekat 10%, 15%, and 20% memenuhi SNI 8675:2018 based on the categories of water content, ash content, and burning rate; however, the perekat 20% does not meet SNI 8675:2018 for heating value. As a result, it is possible to achieve optimal biopellet quality at a rate of 10% while maintaining optimal values for all parameters except burning rate.

The improvement of biopellet quality can be achieved by finding an optimal formula to balance calorific value and adhesive content. Thus, biopellets can be a more efficient solution for generating heat without compromising their quality. With further research, it is possible to find an optimal formula to achieve a balance between the quality of the biopellets and the thermal energy value produced. Thus, biopellets can be a sustainable solution to the global energy crisis.

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