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Corn Cob and Cocoa Shell Waste: A Renewable Energy Source Solution

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ABSTRACT

This study aims to assess the potential of corn cob and cocoa shell waste as a renewable energy source and develop effective technology to convert these wastes into renewable energy, as well as test the efficiency and safety of using alternative fuels produced from corn cob and cocoa shell waste. The stages of this research start from the stage of making briquettes and testing the physical briquettes and water boiling tests. The results showed that corn cob and cocoa shell waste can be converted into biomass that can be used as an energy source. The charcoal briquettes produced from corn cob waste and cocoa peels have a high calorific value, so they can be used as an effective energy source. In addition, the use of corn cob and cocoa shell waste as an energy source can reduce the amount of waste generated and environmental pollution caused by burning waste. Corn cobs and cocoa pods have good thermal properties to be used as biomass fuel in renewable energy generation systems. The study evaluated the physical quality based on variation of corn cobs and cocoa shells mixture composition. The physical quality to be analyzed were stability, density, thermal properties, and heat of combustion. With the right process, these two wastes can be a solution for environmentally friendly energy needs, while providing economic benefits for farmers. Proper management of these wastes can accelerate the shift towards renewable energy, reduce waste and mitigate negative environmental impacts.

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INTRODUCTION

The overall oil production has been decreasing over years. This decline in production is due to the fact that potential oil reserves have not yet been discovered, and most of the current production were sourced from old wells that are already under-producing. The increasing use of fossil fuels will increase the depletion of petroleum reserves. Therefore, alternative solutions are needed to prevent an energy crisis (Utomo Putro et al., 2024). Biomass is a renewable energy source obtained from organic waste. Biomass is organic material obtained from leaves, twigs, dead grass, agricultural waste, and forestry waste. This biomass waste can be used as an energy source for daily household needs, especially cooking (Hidayat et al., 2022). However, the use of biomass waste alone is not very effective as it has high moisture content, low density, high ash content, and low calorific value. It needs to be reprocessed to produce a more efficient fuel (Eka Putri & Andasuryani, 2017).

In Indonesia, corn is an agricultural commodity grown for human food or animal feed. Indonesia's maize production reached 19.99 million tons with an average of around 1.67 million tons per hill in 2023. According to BPS data for 2023 (https://www.bps.go.id). Corn contains approximately 20% of the cob after the grain is removed. (Frenly Simanullang, 2021). Usually, farmers throw their crops directly into the trash. This will cause new problems for the environment.

Other than corn cobs, there are also cocoa shells which are rarely utilized by farmers. In 2022, cocoa production reached 667.3 thousand tons. The peak production was recorded in 2012 with 740.5 thousand tons. (https://bisip.bsip.pertanian.go.id). Cocoa hulls are present in large quantities as the entire cocoa shell consists of about 75% hulls and 25% cocoa beans. (Sukmawati et al., 2024) After the cocoa beans are extracted, the pods are discarded. The pods waste could become an environmental problem to the landfil. Given the potential of corn cobs and cocoa shells, these biomasses can be used as alternative fuels. Among the various alternative fuel processes that have been developed, briquetting is a simple way to convert solid raw materials into cheap and easy-to-use fuels (Firmanto, 2023). Briquetting is a method used to convert biomass energy sources to other biomass by compressing them into a more regular shape (Maryono et al., 2013).

From the description above, it can be concluded that the problem of corn cobs and cocoa shells in this study is because corn cob and cocoa shell waste is very abundant and has not been optimally utilized, besides that the waste has high energy potential and can be converted into alternative fuels, and the use of corn cobs and cocoa shells as alternative fuels can reduce the environmental impact caused by burning fossil fuels.

Research on making charcoal briquettes from a combination of corn stover and coconut shells with polyvinyl acetate (PVAc) as an adhesive was conducted by (Rachma & Supriyo, 2022). This study used a factorial design with eight experiments and the temperature variations used were 400°C and 500°C. This study found that the best briquettes were made from 10 grams of coconut shell and 8 grams of corn cob with a carbonization temperature of 500°C. The calorific value of these briquettes was 7220.12 Cal/g, ash content was 7.913%, and moisture content was 7.1%. (Rachma & Supriyo, 2022).

Other research from (Salamah et al., 2019) measured moisture content, density, water absorption, flexural strength, fracture strength, and thermal properties. This particle board was made with 5 variations of cocoa pod powder that passed the 149, 177, 250, 400, and 841 µm sieve with a bagasse fiber length of 3 cm. The composition of cocoa pods and bagasse is 50:50 and the content of isocyanate adhesive is 16%. The results of physical properties obtained are the value of water content ranging from 9.27-13.05%, density values ranging from 0.89-1.23 g/cm*3* and water absorption values ranging from 11.13-52.28%. The mechanical properties test results obtained are the flexural strength value of 2.8×103 -7.8×103 kg/cm^2 and the fracture strength value ranging from 1.43×104 - 2.48×104 kg/cm^2. The results of testing the thermal conductivity properties obtained ranged from 7.26×10-3-9.0×10-3 W/m°C. The particle size of cocoa pod husk that is good as particle board material is 149 µm.

Research conducted by (Salcedo-Puerto et al., 2025) showed that cocoa shell waste can be used as a fuel that generates additional income from discarded waste which can increase the economic value of the community by using alternative fuels that are effective and environmentally friendly. Another study conducted by (Ajewole et al., 2022) showed that cocoa shells can be used as an alternative fuel that has a high calorific value and can reduce greenhouse gas emissions.

METHOD

The method used in this research is the analysis of physical properties and thermal properties of corn cob waste and cocoa shells. Analysis of physical properties by identify stability, density, shatter index, compressive strength and thermal properties by the water boiling test. The tools and materials used in this research are briquette molds, compacting tools, scales, calipers, sieves, stopwatches, furnaces, pans, thermocouples, meters, corn cobs and cocoa shells.

a

b

Figure 1 (a). Corn cob powder (b) Ground cocoa pods

a. Briquette Making

   Briquetting Steps

   1. Prepare briquette compacting tools

Figure 2. Briquette Compacting Device

2. Putting the mixed materials into the mold and performing compaction
3. After reaching a pressure of 150 psi, hold the compression for 60 seconds
4. After completion, removing the briquettes from the mold

95%J+5%K 90%J+10%K 85%J+15%K 80%J+20%K

Figure 3. Briquette Composition Variation

b. Testing Procedure

The briquette composition variations of the tests denote by J-code which stands for corn cobs, and K-code for cocoa shell.

1. Stability

   The test variables on stability include moisture content, ash content, density and particle size using caliper. This test is carried out at the beginning of the briquette out of the mold until the time for 10 days. When the briquettes came out of the mold, the height and diameter of the briquettes were measured. Then measured again gradually from the first day to the 10th day.

2. Density

   Variable density testing in this study uses the gravimetric method, which is a method of measuring the density of a material using the principle of gravity. This method is based on the law of gravity which states that every object has a mass proportional to its weight. Density is the measurement of the weight of each unit volume of an object, the density of each object is the total weight divided by its total volume. Weight testing is done by weighing the weight of the briquettes, then measuring the height and diameter of the briquettes to find the volume. Compact density observations were made when fresh out of the mold and relaxed density observations were made on day 10.

3. Shatter Index

   Shatter index is a parameter used to measure the resistance of fuel to physical damage, such as rupture or destruction of testing variables by first weighing the specimen using a digital scale to determine the initial weight of the briquette. Then the briquette is dropped at a height of 1 meter with the surface of the anvil must be flat and smooth 10 times. After being dropped, the specimen is reweighed to determine the weight that has been lost from a briquette.

4. Compressive strength

   This method uses a compressive strength testing device consisting of a press and a deformation measuring device. The briquette is placed on the anvil of the test apparatus, then the loading starts until the briquette cracks, and the pressing force is recorded.

5. Thermal Properties

   First prepare the test furnace, briquettes, and water, then measure the initial temperature of the water and weigh the initial mass of the briquettes. After that, turn on the briquette and place a pot containing 0.5 liters of water on the furnace and record the time while boiling 100ºC water, reweigh the remaining briquettes and the test is complete.

RESULTS AND DISCUSSION

1. Stability

   Stability testing to determine changes in diameter and changes in height of the briquettes. In 95%J+5%K briquettes, 90%J+10%K briquettes, and 85%J+15%K briquettes. It can be seen that the stability of the briquette diameter occurs from day 4 to day 6 to day 10. (Kalsum, 2016) that in less than 10 days the briquettes are stable. If it exceeds 10 days, then the briquette can be said to fail. This test is useful in the storage process before using the briquettes. In the 80%J+20%K briquette, the diameter decreased from day 3 to day 10. This is because the 20% cocoa shell mixture has a high-water content so that it allows evaporation which results in the diameter of the briquette decreasing since leaving the mold. The results of changes in diameter are presented in graphical form in Figure 4.

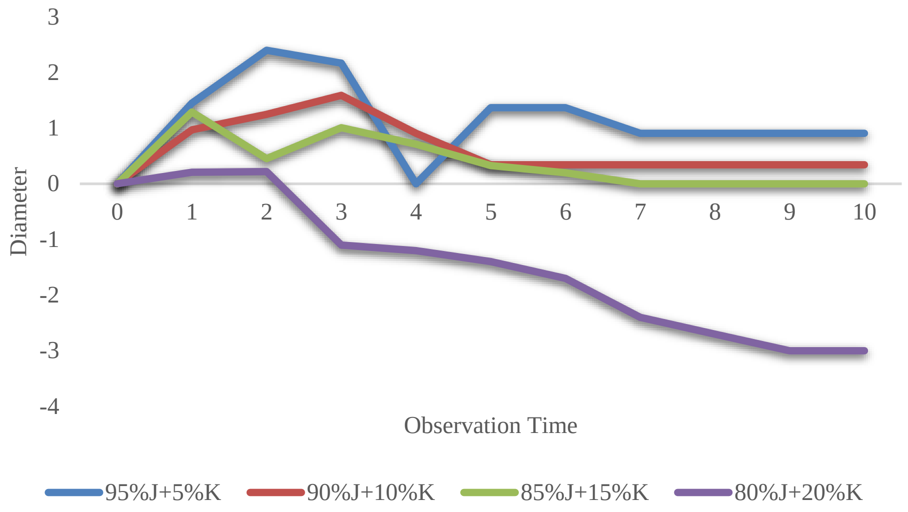

Figure 4. Relationship between observation time and diameter change

The highest incremental value of briquette height was obtained in 95%J+5%K briquettes at 15.34% and stabilized on day 7 with a percentage of 11.37%. The small mass of cocoa husk as a binder causes weak binding power so that it continues to increase in height. Meanwhile, the lowest value of increase in 80%J+20%K briquettes was 0.34%. This low incremental value is due to the mass of cocoa husk as much as 20% has a strong binding power so that the value of high increment is not too large. The results of the height change are presented in graphical form in Figure 5.

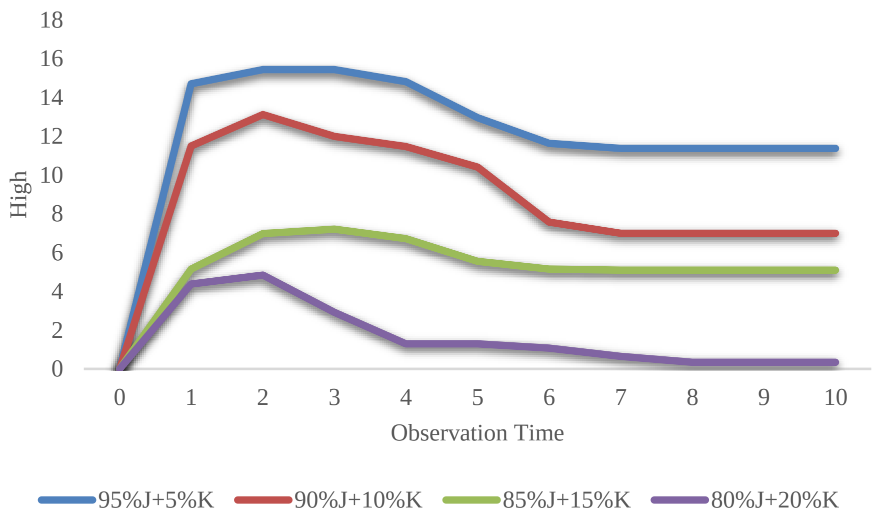

Figure 4. Relationship between height and observation time

2. Density

Based on observations, as time increases, the density decreases. The 95%J+5%K briquettes had a compact density of 0.45 gr/cm³ and relaxed density of 0.27 gr/cm³, which decreased by 41%. The 80%J+20%K briquette with the highest amount of adhesive has a compact density value of 0.44 gr/cm³ and relaxed density of 0.29 gr/cm³, the density decreases as the briquette relaxes by 34%. The 85%J+15%K briquette has a density value reduced by 35% after relaxation and the briquette that has the lowest density reduction value is the 80%J+20%K type briquette by 34%, compact density of 0.44 gr/cm³ and relaxed density of 0.28 gr/cm³. The lowest density change result is in the 80%J+20%K briquette. This change is possibly because the high amount of adhesive added, so the volume increases not too much. The results of density measurements are presented with a graph in Figure 6.

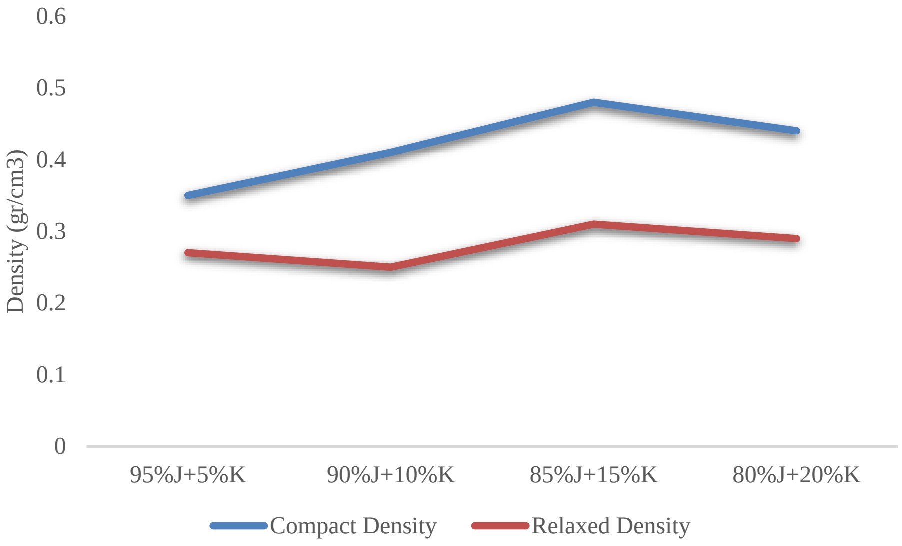

Figure 6. Relationship between briquette type and density

3. Shatter Index

This test was conducted by dropping the test object from a height of 1 meter for 10 times. The briquettes with a mixture of corn cob and cocoa husk had a drop strength value of 0%, all types of briquettes after testing were destroyed and had a final mass of 0 grams. It is possible that the adhesion of cocoa husk to corn cob is weak when dropped.

4. Compressive Strength

Based on the compressive strength test, the more cocoa shell mixture, the greater the compressive strength. The highest compressive strength value was for the 80%J+20%K briquette at 5.59 N/cm² and the lowest compressive strength value was for the 95%J+5%K briquette at 3.67 N/cm². The 80%J+20%K briquette with a compressive strength of 5.59 N/cm² is the highest, this is because the cocoa husk mixture of 20% has a high binding force so that it has the highest hardness among other types of briquettes. Briquettes with a 20% cocoa husk mixture have high cohesiveness, this is said by (Qistina et al., 2016) the compressive strength of the briquettes is lower as the mixture of cocoa husk is less. The lowest compressive strength value is found in 95%J+5%K briquettes, because the cocoa shell mixture is only 5%. The lack of adhesive mixture causes the 95%J+5%K briquettes to have low hardness values. The test results are shown in Figure 7.

Figure 7. Relationship between briquette type and compressive strength

5. Thermal Test

The results of thermal testing showed that the highest burning rate was in 90%J+10%K briquettes and 85%J+15%K briquettes at 4.4 gr/min. Meanwhile, the 80%J+20%K briquette with the most cocoa shell mixture of 20% has a burning rate of 3.7 gr/min. While the 95%J+5%K briquette has the lowest combustion rate value of 3.4 gr/min. in the 95%J+5%K briquette which has the least cocoa shell mixture value of 5% with the lowest combustion rate value of 3.4 gr/min. This is because in the test, the briquettes have experienced relaxation. So that the 95%J+5%K briquettes with 5% adhesive mixture were destroyed during combustion. The destruction of the briquettes caused the briquettes to lose their shape and the combustion fire to spread. The 80%J+20%K briquette that uses 20% cocoa shell adhesive has a burning rate of 3.7 gr/min. It is possible that 20% cocoa husk has a higher water content than other types of briquettes, so the heat first evaporates the water in the briquette before burning the briquette. The test results are shown in Figure 8.

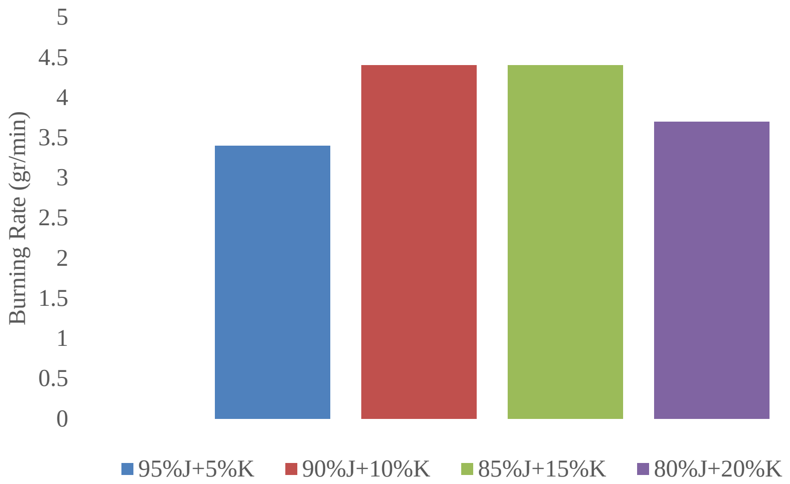

Figure 8. Relationship Between Brike Type and Combustion Rate

Testing of thermal properties is done by burning briquettes, after burning briquettes produces a fire that is used for boiling water. Then the value of the heat of combustion of each briquette is obtained. The highest value of heat of combustion in 85%J + 15%K type briquettes amounted to 3983.39 kJ / kg. The results obtained are slightly above sugarcane bagasse briquettes that use starch adhesives in research (Mustain et al., 2021) which amounted to 3767.40 kJ/kg. The heat of combustion graph shown in Figure 9 shows the lowest heat of combustion value in 80%J+20%K briquettes at 3065.2 kJ/kg, because the 20% cocoa shell mixture has a high-water content.

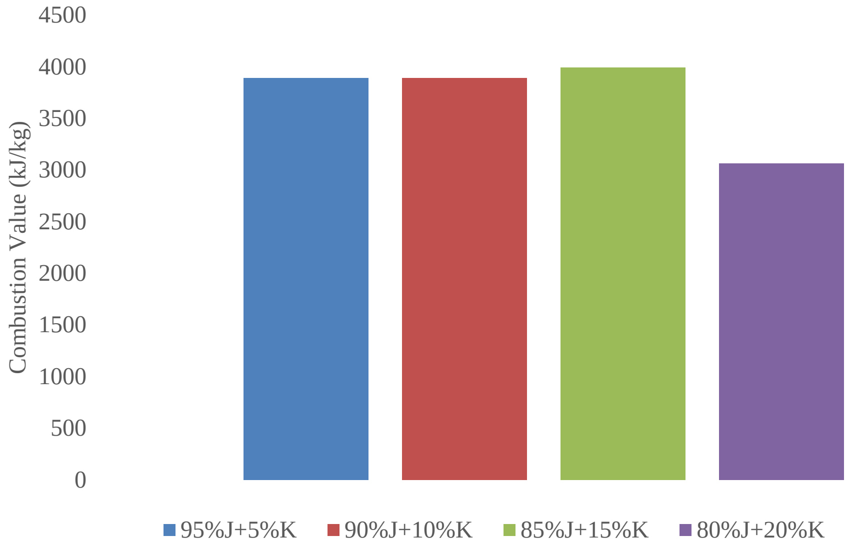

Figure 9. Relationship Between Briquette Type and Heat of Combustion Valve

From the results of the research, it shows:

1. High Energy Potential: The results show that corn cob waste and cocoa shells have high energypotential and can be used as a renewable energy source.
2. Good Fuel Quality: The results show that the fuel produced from corn cob waste and cocoa shells has good quality and can be used as an alternative fuel.
3. Low Environmental Impact: The results show that the use of corn cob waste and cocoa shells as a renewable energy source can reduce the environmental impact caused by burning fossil fuels.
4. Low Production Cost: The results show that the cost of producing fuel from corn cob waste and cocoa shells is relatively low compared to the cost of producing fossil fuels.

The weakness in this research is the lack of support from relevant parties so that the results may not be implemented while there is also a lack of sufficient time to implement the results. Follow-up research by developing effective and efficient processing technology and management strategies for corn cob and cocoa shell waste.

CONCLUSION

1. Corn Cob and Cocoa Shell Waste can be used as a Renewable Energy Source.
2. Variations in the composition of the mixture of corn cobs and cocoa shells affect the physical qualities.
   a. Stability: 85%J+15%K briquettes have a stable height change on day 6
   b. Density: 95%J+5%K briquettes have the highest change between compact and relaxed density.
   c. Compressive strength: 80%J+20%K briquettes had the highest compressive strength
3. Variations in the composition of the mixture of corn cobs and cocoa shells affect the thermal properties.
   a. Burning rate: 90%J+10%K and 85%J+15%K briquettes have the highest burning rate.
   b. Heat of combustion: 85%J+15%K briquettes have the highest heat of combustion value
4. From the results of the research, the briquettes with the best physical properties were 80%J+20%K and the briquettes with the best thermal properties were 85%J+15%K.

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