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The Effect of Corncob Composition and Torrefaction Temperature on the Calorific Value of Silk Tree Wood Pellets

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ABSTRACT: This study presents the effect of corncob composition with torrefaction process treatment to obtain a calorific value to get a quality of wood pellets. This process was carried out by producing Silk Tree wood pellets using a composition of corn cobs and Silk Tree wood bypercentages ratio of 0%: 100%, 25%: 75%, 50%: 50% with temperature variations of the torrefaction process being 225°C, 250°C and 275°C. The pelleting process was carried out using a Richi KL 120 P pelleting machine. The wood pellets were then tested for calorific value using a bomb calorimeter. The results of this study showed that increasing the composition of corn cobs and the torrefaction temperature in the pelleting process will increase the calorific value produced by the pellets.The effect of the percentage of corn cob composition on the highest calorific value was obtained at a percentage of 50% with a calorific value of 4092 cal/g. Meanwhile, the highest calorific value was obtained in the torrefaction process at a temperature of 275°C with a calorific value of 4160 cal/g, and the lowest calorific value was obtained in the torrefaction process at a temperature of 225°C with a calorific value of 3266.3 cal/g.

KEYWORDS: pellet, corncob, torrefaction temperature, calorific value

I. INTRODUCTION

The increasinguse of fuel oil, as the Central Statistics Agency (BPS) noted that 82.78% of Indonesian households used LPG gas fuel for cooking in 2021. This percentage is the largest compared to the use of other fuels. Based on Government Regulation Number 79 of 2014 concerning the National Energy Policy which explains about maximizing the use of renewable energy by paying attention to the level of the economy and minimizing the use of petroleum and utilizing natural gas and new renewable energy in the form of biomass. Biomass is a solid waste that can be used as a source of fuel. To make agricultural waste biomass more useful as fuel, carbonization and briquetting can be done. The important properties of briquettes include calorific value, water content, specific gravity, ash content, fixed carbon, and volatile matter [1].

Wood pellets are biofuels made from compressed organic materials or biomass. In biomass used for combustion energy such as wood pellets, one of the important factors is the calorific value. The calorific value or in other terms called heat of combustion is a standard measure of the energy content of a fuel. The quality of biomass wood pellets in many cases exceeds the proper moisture content required for the pelletization process, which is between 6-18% [2].

The higher the water content in the wood pellets, the lower the calorific value, so there are several treatments to avoid low calorific value with torrefaction treatment and the addition of a mixture of other types of biomasses. Several researchers have conducted research on wood pellets made from silk tree wood with a torrefaction process. The calorific value was found in silk tree wood powder with a fineness of 60 mesh, with a pressing temperature of 250 °C, which was 3766.25 cal/g [3]. The results of these studies indicate that the calorific value produced is still relatively low. This study succeeded in finding a way to obtain a higher calorific value, namely by varying the mixture of corn cobs and torrefaction temperature on the raw materials for making silk tree wood pellets. This study is a development of existing wood pellet production, so that the results can be used as an alternative renewable energy.

The process of producing wood pellets on a large scale using controlled equipment and machinery has several stages of the process starting with biomass supply, biomass crushing (chipping & milling), drying, pellet forming (pelleting), cooling, packaging and distribution [2]. Each stage determines the quality of the pellets, so a production operating system is needed that is consistent with the process. In general, the process of wood pellet production in large-scale industry is shown in Figure 1.

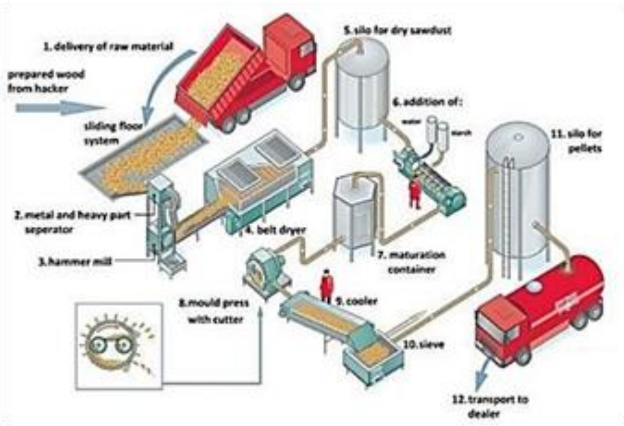

Figure 1. Wood pellet making process

Wood pellets are materials formed from wood processing and/or wood waste in the form of compacted powder and have a cylindrical shape [4]. Wood pellets are generally made from wood waste raw materials, including sawdust, shavings, and wood chips, which are by-products of the manufacture of lumber, furniture, and other forest products. Wood pellets have a standard diameter of about 4-10 mm and are colored according to the raw material used to make them.

Biomass energy, also referred to as biofuel, is a renewable energy source derived from biological materials. These materials encompass plants, agricultural produce, plantation crops, and organic waste generated by industries and households. While often overlooked, biomass possesses considerable untapped potential as an environmental waste product. Forest wood, rice, corn, cassava, coconut, palm oil, and sugarcane residues represent the most abundant biomass waste sources [5], [6].

Biomass is composed of cellulose, hemicellulose, lignin, ash, and other substances. The specific composition varies based on plant species, tissue type, growth phase, and environmental factors.Nonetheless, cellulose, hemicellulose, and lignin (lignocellulose) constitute the primary components of most biomass. In general, some wood pellet specifications required by consumers are the durability of pellet combustion, ash content (Ash, % of weight) the greater the ash value, the lower the quality of the wood pellets. While the high-water content in the raw material will cause the wood pellet product to be easily cracked or damaged, the pellet surface is not smooth and the pellet calorific value is low [7]. The characteristics of wood pellets are explained in the following table 1.

Table 1. Quality Standard of Wood Pellet

Properties	Unit	Condition
Density	g/cm^3	Min.0,8
Ash Content	%	Max.1,5
Volatile Subst/Lost Parts	%	Max.80
Carbon Content	%	Min.14
Calorific value	cal/g	Min.4.000

Wood pellets are formed from the processing of the main raw material of wood which is usually sawdust waste. One of the most widely used types of wood is silk tree wood. Because the price is quite economical, silk tree wood is widely used for construction, furniture and raw materials for paper pulp. Therefore, waste from silk tree wood is quite a lot and can be utilized, one of which is for making wood pellets. In addition to abundant raw materials, silk tree wood has good chemical properties to form quality wood pellet products as following table 2.

Table 2. Chemical Properties of Silk Tree Wood

Contents (%)	Position		
	Base	Middle	Tip
Extractive substances	2.3426	3.5067	3.8305
Lignin Content	23.7778	22.8571	16.6939
Holocellulose Content	76.0363	88.3328	69.1693
Cellulose Content	61.5566	74.2138	57.1184

Corn cobs are one of the biomass sources from corn-based food processing that has not been widely utilized. Currently, corncob biomass has been widely developed for alternative energy, such as pellet production, because corncobs themselves contain cellulose (45%), hemicellulose (35%), and lignin (15%), which are good for the combustion process [8].

Torrefaction is a thermochemical treatment process for biomass at a temperature range of 200-300°C under anaerobic conditions and low heating rates or long residence times, approximately 30 minutes to 2 hours. In addition to increasing the calorific value, torrefaction also increases the hydrophobicity of the fuel, reduces energy consumption during milling, and can prevent degradation by fungi and microbes during storage and transportation [9].

Calorific value is the heat produced by the perfect combustion of a unit weight, such as a kilogram of solid or liquid fuel, or even a cubic meter or unit volume of gaseous fuel, under standard conditions. The gross calorific value or "Gross Heating Value" or "High Heating Value" (HHV) is the heat released by the combustion of a given mass of fuel units, the products of which are ash, nitrogen, SO_2, water and CO_2 gas, and does not include steam or evaporated water [10].

The operating principle of the bomb calorimeter is to determine the heat released by a fuel and oxygen at a constant volume. There are three types of bomb calorimeters, which are distinguished according to their principles, namely isothermal oxygen bomb calorimeters, adiabatic oxygen bomb calorimeters, and ballistic oxygen bomb calorimeters [11]. The amount of heat measured in the calorimeter is the total energy of the material or sample. Bomb Calorimeter Principle to determine this total energy, the chemical energy in a material or sample is converted to heat energy and the amount of heat produced is measured.

II. RESEARCH METHOD

2.1 Research Variable

This study employed a true experimental research methodology, which involves manipulating one or more independent variables to observe their effects on dependent variables. The experiment included two independent variables: 1) The proportion of corncob powder added to the raw materials. 2) The temperature applied during the torrefaction of wood pellet raw materials.

Several variables were controlled to ensure experimental consistency: Wood pellet diameter (3 mm); Wood pellet shape (cylindrical); Pelleting machine rotation speed (230 rpm); Wood pellet raw material particle size (20 mesh); and Torrefaction process time (15 minutes).

2.2 Research Implementation

- The raw materials for the production of wood pellets are sengon wood waste and corn cob waste (Figure 2).

Figure 2. Raw material preparation

- After obtaining the waste materials, they are processed by machining to be ground into a homogeneous size using a chopper and disk mill machine (Figure 3).

Figure 3. Powder process of raw material

- After the machining process is carried out to refine the raw materials, the raw materials are then filtered using a 20 mesh sieve (Figure 4).

Figure 4. Filtering process

- Adjusting the raw materials between silk tree sawdust and corn cobs with a ratio adjusted to the percentage of the variables using the SF-400 scale, where the silk tree sawdust is weighed per 300 grams until the number of samples is fulfilled in each container, according to the table 3 and the figure 5.

Table 3. Mixed composition

Sampel (%)	
Silk Tree Powder	**Corncob Powder**
100 (600 g)	0
50 (300 g)	50 (300 g)
75 (450 g)	25 (150 g)

Figure 5. Raw material weighing

- Raw materials that have been packed in plastic containers according to the percentage composition between corn cob powder and silk tree wood powder are measured for water content using a moisture meter (Figure 6).

Figure 6. Raw material mixing

- Raw materials are torrefaction processed with temperature variations so that the water content decreases to enter the wood pellet moulding process (Figure 7).

Figure 7. Oven process

- Raw materials that have undergone the torrefaction process are checked for water content again with a moisture meter because the water content of pellet moulding must be 6-18%.
- The pelleting process is carried out using a Richi KL 120 P pellet mouldings machine with a diameter of 3 mm and after printing is complete, the water content is checked for each treatment (Figure 8).

Figure 8. Pellet moulding

The calorific value test was carried out on wood pellets using a bomb calorimeter (Figure 9), with the following steps: a. Prepare the wood pellet sample; b. Setting the bomb calorimeter until the vessel conditioning is in the bucket of the bomb calorimeter; c. Providing or inputting the identification and weight of the sample in the bomb calorimeter to adjust the energy that will be released by the bomb calorimeter for the heat test process; d. Wait until the bomb calorimeter indicator light turns on and the value of the wood pellet heat can be displayed.

Figure 9. Calorific value in bomb calorimeter

III. RESULTS AND DISCUSSION

The following data are the results of this research. The study aims to determine the effect of the two independent variables on the dependent variable and also to determine the interaction of the two independent variables on the dependent variable. The data results of the study in the form of Table 4.

Table 4. Results of data collection on calorific value

Corncob Composition (%)	Temp. (ºC)	Caloric Value Repeating I	II	III	Sum	Avg.
50	200	4112	4136	3998	12246	4082
	225	4055	4112	4388	12555	4185
	250	4235	4131	4273	12639	4213
25	200	3655	3622	3739	11016	3672
	225	3985	3877	3994	11856	3952
	250	4122	4201	4130	12453	4151
0	200	1745	1801	2103	5649	1883
	225	3986	4123	3903	12012	4004
	250	3895	3856	3985	11736	3912

Apart from being presented in the table 4 above, the calorific value of each treatment of mixing corncob composition and torrefaction temperature is presented in the following factorial plot Figure 10 to determine the effectiveness of each treatment.

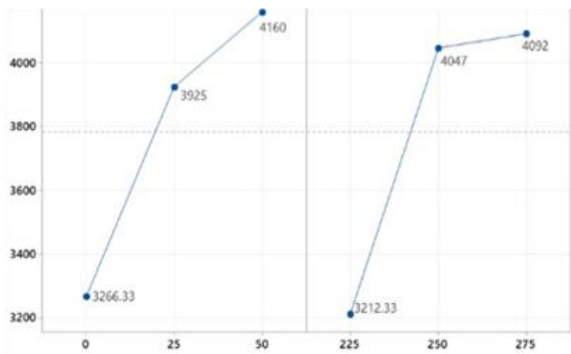

Figure 10. Factorial plot graph

In Figure 10, the highest calorific value is obtained in the torrefaction process with a temperature of 275 °C with an average calorific value of 4160 cal/g and the lowest calorific value is obtained in the torrefaction process with a temperature of 225 °C with an average calorific value of 3266.3 cal/g, while in the percentage variable of corn cob composition, the highest calorific value is obtained at a percentage of 50% with an average calorific value of 4092 cal/g and the lowest calorific value is obtained at a percentage of 0% with an average calorific value of 3212.3 cal/g.

The results of the calorific value table are then processed using multiple linear regression analysis. Before performing the multiple linear regression analysis, a classical assumption test is performed, starting with a residual normality test. This normality test is performed using the Kolmogorov-Simirnov method, as shown in Figure 11.

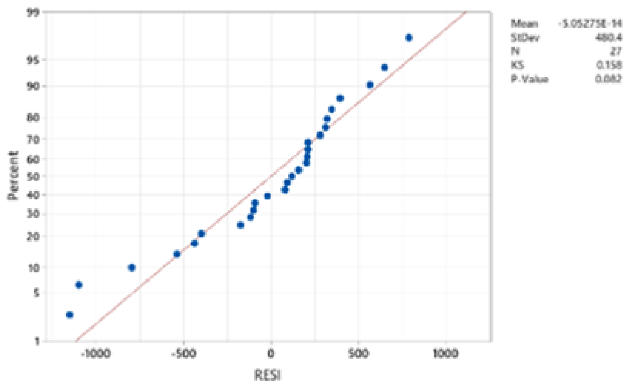

Figure 11. Normal probably plot graph

Furthermore, a polynomial regression test was carried out with a quadratic model fitted line plot feature to determine the significance of the variance of each variable on the calorific value of silk tree wood pellets, as shown in Figure 12.

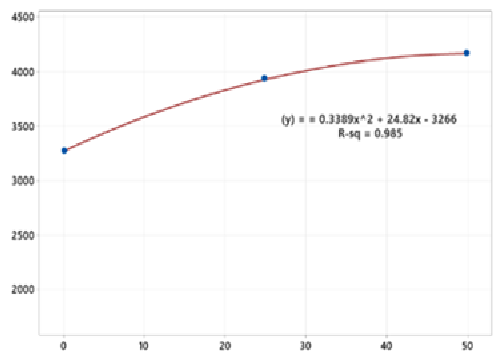

Figure 12. Graph of the Effect of Corncob Composition on the Calorific Value

In the graph above (Figure 12) there is a curved horizontal line that shows the relationship between the composition of corncobs and the calorific value of silk tree wood pellets with a quadratic equation (y) = $0.3389x^2 + 24.82x - 3266$ and there is an $R^2 = 0.985$ which mean the corncob composition variable has a significant effect on the calorific value of silk tree wood pellets.

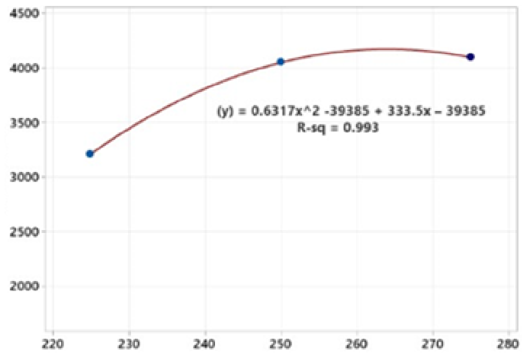

Figure 13. Graph of the effect of torrefaction temperature on the calorific value

In the graph above (Figure 13) there is a curved horizontal line that shows the relationship between the temperature torrefaction and the calorific value of silk tree wood pellets with a quadratic equation (y) = $0.6317x^2$ -39385 + 333.5x - 39385 and there is an $R^2 = 0.993$ which mean the variable composition of corn cobs has a significant effect on the calorific value of silk tree wood pellets.

IV. CONCLUSION

The results indicate a strong correlation between corncob composition and the calorific value of silk tree wood pellets. Increasing the proportion of corncobs in the pellet mixture led to a corresponding increase in calorific value. The optimal corncob composition was determined to be 50 %, yielding the highest calorific value of 4092 cal/g.

Torrefaction temperature significantly influenced the calorific value of silk tree wood pellets. Higher torrefaction temperatures resulted in higher calorific values. The maximum calorific value of 4160 cal/g was achieved at a temperature of 275 °C, while the minimum value of 3266.3 cal/g was observed at 225°C.

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