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Determination of *Leucaena Leucocephala Sp* Pellet Qualities under Different Percentage of Cassava Binders

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ABSTRACT

The utilization of plant materials as a source of biomass is very encouraging nowadays. *Leucaena leucocephala* sp is one of the dedicated energy crops planted for the purpose of producing biomass sources. Correct composition of the required materials is crucial in producing quality fuel sources. Therefore, the objective of this study was to determine the effect of different starch percentage on pellet structure and to determine the most applicable percentage of cassava starch to be used in order to obtain high energy pellet. Six percentages of the cassava starch were used in this study which are 0%, 20%, 40%, 60%, 80% and 100%. The raw material that had been weighed were mixed thoroughly with 10% water and the respective cassava starch percentages The mixture was compressed into pellet form and density, durability, moisture content and energy content testing were performed. The results showed that a mixture of 20% cassava starch, 10% water and 80% of raw materials produced the best compositions from all. This is because the pellets in this composition proven to provide the highest durability value of 94.09% and the lowest moisture content by 9.32%. The value of density increases with the increases in percentage of cassava binders. Although the energy value of this composition is lower at 16.34 MJ/kg, it shows an increases in energy content to 16.53MJ / kg at 40% cassava starch. As a conclusion, applying different amount of cassava starch resulted in different effects on the quality of the pellets.

Keywords:
Biomass pellet, binder; *Leucaena leucocephala sp;* durability; calorific value; pellet qualities

1. Introduction

Today, the depletion of fossil fuel moves along with the increases on the global energy demand forced industry to find alternative energy resources to overcome this situation. With the concerning on the environmental pollution, the biomass materials are more preferable. The suitable energy crops for biomass generally produce high yield with low energy input and growing fast with short rotation [1]. *Leucaena leucocephala sp*, or locally known as 'Petai Belalang' is one of the potential energy crops to be used as it has high density wood yields, fast growth and strong adaptability thus making it suitable for energy generation purposes as an alternative to fossil fuels. *L. leucocephala* has

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been used as wood chips and pellets as biomass fuel supply for boilers in factories [2]. Besides, this plant species produces a medium hardwood that is widely used as a firewood, producing little ash and smoke. The wood produced a satisfactory pulp, which can be used for paper and rayon.

Over the last decade, densification technology has been widely used in industry; i.e. the pelletization process of biomass materials. Pellet is a form of any material that has been densified under several processes. Pelletization is one of the densification process of materials which involved reduction in sizes and volume occupied by the materials. Mechanical densification of solid fuels from biomass material has shown numerous advantages, such as increase in density, uniformity, and alleviate storage, reduced the costs of transportation as well as raised the energy conversion efficiency. It was reported that the densified fuel pellets impose numerous benefits such as the fuel was free-flowing, which facilitates the handling process and flow control rate [3].

Pellets are usually made in cylindrical and uniform shape while the length and diameter are measured using digital vernier calliper (0.01 resolution) [4]. The pellet's dimension must meet the standard requirement of Pellet Fuel Institute Standard Specifications (PFI) premium which has greater than 38.1 mm long and diameter ranges between 5.84 mm and 7.25 mm. Pellets are formed by using mechanical compressor or pellet mills. The pellet mills may vary depending on the purpose of pelletization, types of mills, and also the varieties of die used. There were two common types of pellet mills used in industry which were the flat die pellet mill and the ring die pellet mill [5].

The use of biomass materials is also environmentally friendly as there is no need to add any additives or artificial binders as the presence of lignin in biomass materials acts as natural binder in pellet making. However, the application of binder in densification process sometimes is crucial in order to get the stable pellet products. Biomass materials consist of lignin, cellulose and lignocellulose which act as natural binders to bind up the particle bonding [6]. Unfortunately, the presence of natural binder itself cannot retain the pellet structure. Hence, the binding agents must be added to reduce the impact and destruction on pellets during handling and transportation. In determining the pellet properties, density, durability, moisture content and calorific value are important parameters to be studied in order for biomass pellets to be marketable.

The strength and durability of the pellets were influenced by the physical forces that bond the particles together. High durability means high quality of pellets [7]. Another important parameter was calorific value reflects the effectiveness and efficiency of any fuel by determining the amount of heat generated from a unit mass (MJ/kg) [1]. In this study, biomass materials are densified to a pellet form using hydraulic single press machine under various percentage of binder application. The aim of this study was to analyze the pellet properties under various amount of binding agents and produce a better and high energy pellet.

2. Methodology

The experimental set up began with the collection of the raw sample which are the whole parts from the wood trunks of *Leucaena leucocephala sp* at Institute of Sustainable Agro-technology UniMAP (INSAT) located at Padang Besar, Perlis. The wood trunks then were undergone pre-treatment processes which included chipping using wood chipper, grinding, and sieving by using automatic sieve shaker. Cassava starch was used as the binding agent as this type of binder was easy to find, cheap and has strong adhesion properties which aided in strengthening the pellet structure. It was attested that cassava starch can be used as an excellent binding agent due to its purifying level, textural properties, great thickening and may produce better adhesive properties compared to other starches [8].

Table 1 shows the composition mixture to be used from cassava starch for each level. The percentage of water added to the mixture was fixed to 10%. Next, a hydraulic single press machine was used to densify the samples into pellet form followed by several properties testing on pellets.

Table 1
Composition mixture for each level

Level	Percentage of cassava starch (%)	Weight of cassava starch (g)
1	0	0.0
2	20	6.0
3	40	12.0
4	60	20.4
5	80	21.3
6	100	30.3

Analysis of properties testing

Several testing were carried out to determine the pellets properties in order to characterize the quality of bioenergy pellets. The tests included determination of density, durability, moisture content and also calorific value.

Determination of L. leucocephala sp pellet density

Density is the ratio of pellet sample mass over its volume. The analytical balance (Model: FX 300i) was used to measure the weights of the samples and the digital Vernier caliper was used to obtain the volume of pellet sample by measuring diameter and height of pellets. Then, the densities of the samples was calculated by using Equation (1).

$$\rho = \frac{m}{v} \tag{1}$$

Where ρ = density (g/cm^3), m= mass (g) and v = volume (cm^3)

Determination of L. leucocephala sp pellet durability

The durability analysis was done to investigate the strength and structure of the pellets produced based on the pellet durability index (PDI) or percent durability. The pellets were put into a stack of sieves of an automatic sieve shaker for about 15 minutes. The mass of pellet samples before and after sieving was measured by using analytical balance. Later, the PDI or durability was calculated by dividing the weight after the sieving and weight before sieving, multiply by 100. The formula was shown as Equation (2).

$$\text{PDI or durability} = \left[100\% - \left(\frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{ x } 100\%\right)\right] \tag{2}$$

Determination of L. leucocephala sp pellet moisture content

Moisture content of the pellet is another parameter that was used to characterize the pellet quality. Pellets which have lower value of moisture content were more desirable as the heat per unit mass produced by the pellets were much higher. The test was conducted by using moisture analyzer to measure the pellet moisture content. The initial and final weight of the pellet samples were recorded to be used in following formula in Equation (3):

$$\text{Moisture content}(\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{ x } 100\% \quad (3)$$

Determination of L. leucocephala sp pellet calorific value

In this study, a bomb calorimeter (Model: C 2000 Basic) was used to determine the heating value of a pellet. The pellet samples were weighed first before put to the glass holder crucible. Then, the ignition wire was placed in contact with the sample and put into the holder. The equipment was set to dynamic mode at 25°C and the chiller was turned on. During operation, oxygen gas was supplied into the container which then combusted the sample in glass crucible. After about 15 minutes, the calorific value of *L. leucocephala* pellets was displayed on the screen once the equilibrating, calibrating and analyzing of data was finished.

3. Results

Table 2 shows the obtained results from pellet qualities testing which comprise of density, durability, moisture content and calorific value.

Table 2
Effect of different percentage of cassava starch on properties testing

Percentage of cassava starch (%)	Density (g/cm^3)	Durability (%)	Moisture content (%)	Calorific value (MJ/kg)
0	0.93	91.92	9.88	16.48
20	1.00	94.09	9.32	16.34
40	1.02	92.05	9.71	16.53
60	1.11	92.10	10.76	15.67
80	1.16	95.50	10.43	15.65

3.1 Unit Density

High percentage of binders gave the highest unit density. From the result obtained, the highest mean value was from mixture composition of 80% cassava starch, 20% raw samples and 10% water by 1.16 g/cm3 while the lowest mean unit density was 0.93 g/cm3 from composition mixture of 0% cassava starch, 100% raw samples and 10% water. It was found that different binder percentage had resulted in different pellet density. This was because a huge amount of binders in the mixture produced more compacted pellet than others. The smaller particle sizes of binders enable them to fill up the small spaces between the pores of pellet sample. Therefore, the pellet produced was high in mass hence higher in density compared to another pellets.

3.2 Durability

Theoretically, the higher the percentage of durability, the stronger the structure of pellet. Besides, pellet that has high percentage of durability was not easily broken by the mechanical handling during transferring process. Based on Table 2, the lowest percentage of pellet durability recorded by 100% of raw sample without any binders at 91.92%. This is because of the composition mixture without any binding agents produced weaker bonding between the particles and easily fractured when mechanical forces have been applied. The higher the amount of binding agents that have been added, the higher the pellet durability [7]. However, large amount of cassava starch indeed produced high durability of pellet, but low energy content per unit volume. As a conclusion, the pellets produced by addition of 20% binding agents produced the high durable pellets by 94.08%.

3.3 Pellet Moisture Content

Moisture content was essential to ensure the efficient storage and longevity of pellets. When 0% of cassava binders were used, the resulted pellets moisture content was 9.88%. In the absence of additives except 10% of water, 100% raw samples of *Leucaena leucocephala sp* pellet absorbed the water and bind up to strengthen the pellet structure resulted in 9.88% moisture content. Correspondingly, when 20% of cassava starch has been used, the moisture content drops to the lowest value, 9.32%. This indicates that the most preferable condition to produce the best quality pellets because the lower moisture content may prevent the growth of microorganisms and ease the burning process.

3.4 Pellet Calorific Value

Pellet calorific value is the most important analysis needed to produce the biofuel pellet from biomass. It indicates the energy content per unit volume in a sample. The average calorific value was not significantly decreased as the cassava starch were levels increased. At 0% cassava starch produced 16.48 MJ/kg, 20% cassava starch resulted 16.3 MJ/kg energy, 40% cassava starch consisted of 16.53 MJ/kg calorific value, 60% cassava starch emitted 15.67MJ/kg heat and last but not least 15.64MJ/kg calorific value produced from composition mixture of 80% cassava starch with the raw *Leucaena leucocephala sp* samples. Only mean calorific values at 20% of cassava binders has slightly increase from 16.34 MJ/kg to 16.53 MJ/kg while calorific values at 0%, 40%, 60% and 80% show the declining on caloric values as the amount of binders increased. Therefore, the best quality of pellet produced when adding cassava starches was ranging between 20% and 40% as it produced the increment in heating values.

4. Conclusions

The characterization of pellet quality in terms of density, durability, moisture content and calorific values was the main objective in this research. It was found that 20% cassava starch added into a mixture of 80% *Leucaena leucocephala sp* materials and 10% of water was the best composition to produce high quality pellet. The second objective from this research was to study the effect of different percentage of cassava binders on pellet structure had been accomplished. High percentage of cassava binders produced the strong structure of pellet. A strong structure was expressed by the high durability. Lastly, the third objectives of this research was to determine the most preferable percentage of cassava starch used to obtain a high energy content of pellet also had been achieved effectively as the most applicable percentage of cassava binders was at the range of 20% to 40% due to the increased in calorific values in these ranges.

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