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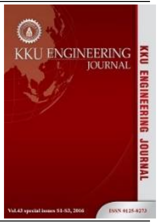

Effect of moisture content on physical properties of cassava stalk pellets

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Abstract

Cassava stalk residues are abandoned after the harvesting period. One of the possible ways to manage cassava stalk residues is by converting them into biomass energy by pelletization. The pelletization was started with the cassava stalks were milled and sieved to make them uniform. The moisture content was defined as percentage of water adding by mass of raw material. The pelletization was performed using conventional pelletizer. The physical properties of Cassava pellets (particle density, bulk density and porosity) were evaluated. The best condition to pelletize Cassava stalk pellets was at water adding 10% by mass of raw material. The range of pellet's particle density, bulk density and porosity are between 1062.56 to 1262.57 kg m^{-3}, 311.89 to 718.18 kg m^{-3} and 43.10 % to 70.62 %, respectively.

Keywords: Agricultural residues, Moisture content, Physical property, Pellet

1. Introduction

Thailand is an agro-industrial country since the main area use is for agricultural purposes. After harvest there is a lot of agricultural biomass residue that is abandoned in the fields. These residues are a raw material for biomass production for electric energy and heat production [1] that is considered clean, safe and environmentally friendly because of the reduction in carbon dioxide emission into the atmosphere. Moreover, due to an increasing price and an enormous amount of utilization of fossil fuels in the world market, interest in renewable energy development and utilization has risen, especially wood energy and other biomass energy. However, biomass residue characteristics from agricultural processes such as high moisture content, irregular shape and size, and low bulk density have made biomass very difficult to handle, transport, store, and utilize in its original form. These problems of biomass can be minimized through densification [2]. The need for densification has prompted significant interest in developing countries in recent years as a technique for utilization of residues as an energy source [3]. This technology can increase bulk density, improve handling and storage operations and reduce transportation costs [4].

The physical properties of various biomass sources from agriculture and forestry have been studied [5-7]. However, there is no information available about the physical properties (particle density, bulk density and porosity) of pellets from Cassava stalk. Therefore, the purpose of this study was to determine the influence of moisture content on the particle density, bulk density and porosity of Cassava stalk pellets to study the physical properties, so that the physical properties can be improved, space saved and better handling processes.

2. Materials and methods

2.1 Raw material

Cassava (Manihot esculenta), Kasatsart 50 variety, was collected from cassava fields in Khon Kaen Province, Thailand. Cassava stalks were picked randomly and delivered to the Industrial Engineering Faculty of Khon Kaen University. The cassava leaves and twigs were manually cut from the cassava stalk. Then, the stalk samples were left at room temperature until their moisture content was under 10 % wet basic. The samples were milled using a hammer mill and sieved with ASTM sieve mesh no.20 with aperture size 850 µm. The particle size of Cassava stalks was less than 850 µm.

2.2 Moisture content determination

The initial moisture content of biomass was set at three moisture levels. Water was added to the milled material at 10%, 20% and 30% by mass of raw material before pelletization.

2.3 Pelletization process

The pelletization process was performed in a flat die pellet machine Model ZLSP-D 200C, power 7.5 kW and capacity 80-120 kg/h. 2 kg of milled material with no binder

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Table 1 Effect of moisture content on the pellets' physical properties

Moisture Content (%)	Particle Density ($kg\ m^{-3}$)		Bulk Density ($kg\ m^{-3}$)		Porosity (%)	
	Avg	SD	Avg	SD	Avg	SD
10	1262.57	15.85	718.18	20.62	43.10	2.11
20	1141.83	42.99	493.40	2.77	56.75	1.66
30	1062.56	46.04	311.89	10.29	70.62	1.26

material was pelletized at different moisture contents and process temperature of 75 °C - 85 °C, die speed 275 rpm and die diameter 6 mm.

2.4 Particle density

The particle density of pellets was determined by three randomly selected pellet samples
with different moisture content. The dimensions and weights were determined using a digital vernier caliper and weight balance scale. Then particle density ($kg\ m^{-3}$) was calculated using the following equation [2, 7].

$$\text{Particle density} = \frac{\text{Mass of pellet}}{\text{Volume of pellet}}$$

2.5 Bulk density

The bulk density of pellets was determined by filling a container of a known volume with the sample pellets. Then the container was dropped several times before adding additional pellet samples and striking off the excess sample pellets level with the top edge. Finally the container and sample pellets were weighed [6-7]. The bulk density ($kg\ m^{-3}$) was calculated using the following equation.

$$\text{Bulk density} = \frac{\text{Total mass of the pellets}}{\text{Total volume of container}}$$

2.6 Porosity

Porosity is the fraction of the volume of voids over the total volume and voids spaces in the material. The porosity was calculated using the following equation. [4]

$$\text{Porosity} = \left(1-\frac{\text{Bulk Density}}{\text{True Density}}\right) \times 100$$

2.7 Statistical analysis

The Cassava stalk pellets with different moisture content were measured the physical properties by three replications. The results of the physical property experiments were investigated for the adequacy model with normal distribution using Shapiro-Wilk test. Then these physical properties data was analyzed by using the one-way analysis of variance (ANOVA) at the 95% confidence interval and Duncan's multiple range test at the 0.05 level procedures in SPSS statistics19.

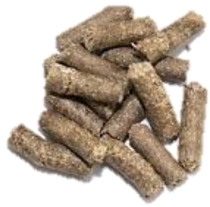
3. Results

3.1 Physical properties of the cassava stalk pellets

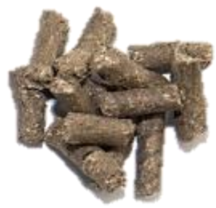
The Cassava stalk pellets which pelletized at 10% (a) 20% (b) and 30% (c) water added by mass of raw material. The results of pelletization were shown in Figure 1.

The results of the moisture content on the pellets from Cassava stalk is shown in Table 1. The best pellet condition was with added moisture content of 10 % by mass of raw material, while the worst pellet condition was with added moisture content at 30 % by mass of raw material.

a) 10% by mass of raw material



b) 20% by mass of raw material



c) 30% by mass of raw material

Figure 1 Cassava stalk pellets

3.2 Statistical analysis of the cassava stalk pellet

The three replications of particle density, bulk density and porosity experiments were analyzed the adequacy model. The results showed all physical property data was normal distributions (p-value or Sig. > 0.05) and the ANOVA results showed that there were significant differences ($P < 0.05$) in the particle density, bulk density and porosity with increasing moisture content as the result in Table 2.

Moreover the Duncan's multiple range test at the 0.05 level showed that there are also significant differences between moisture content in these physical properties as the results in Table 3.

4. Discussion

In this study, there were significant differences from moisture content on the physical properties of pellets. The pellets with low moisture content had the highest particle density and also had the highest bulk density but low porosity values, as compared to those with higher moisture content. Similarly, results of previous studies about biomass pellets found that the particle density of maize powder decreased with increasing moisture content [5], low moisture content involved higher bulk density in biomaterial characteristics, pelletizing properties and biofuel pellet quality [8], while pellets with relatively high moisture content had a low bulk density [4]. The porosity of the low moisture content pellets

Table 2 ANOVA of particle density, bulk density and porosity of Cassava stalk pellet

		Sum of Squares	df	Mean Square	F	Sig.
Particle_density	Between Groups	657.009	2	328.505	542.425	.000
	Within Groups	3.634	6	.606		
	Total	660.643	8			
Bulk_density	Between Groups	60865.604	2	30432.802	21.636	.002
	Within Groups	8439.636	6	1406.606		
	Total	69305.240	8			
Porosity	Between Groups	1135.501	2	567.750	193.437	.000
	Within Groups	17.610	6	2.935		
	Total	1153.111	8			

Table 3 Duncan's multiple range test at the 0.05 level

Moisture (%)	N	Particle Density			Bulk Density			Porosity		
		1	2	3	1	2	3	1	2	3
10	3	1262.57			718.18			43.10		
20	3		1141.83			493.40			56.75	
30	3			1062.57			311.89			70.62
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

is lower than those with high moisture content. This shows that the particles with low moisture were closer together than those with high moisture, and thus the porosity results relate to the results for particle density and bulk density.

5. Conclusions

In this study, the physical properties (particle density, bulk density and porosity) of the Cassava pellets at different moisture content levels in raw biomass material were evaluated. Based on the study results, the moisture content had significant effects on the physical properties. The best condition for the Cassava stalk pelletization was at 10% by mass of raw material with the highest value in particle density (1262.57 kg m^{-3}) and bulk density (718.18 kg m^{-3}), whereas the porosity was the lowest (43.10). This study is useful for pelletization to produce an optimized pellet fuel.

6. Acknowledgements

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7. References

[1] Obidzinski S, Piekut J, Dec D. The influence of potato pulp content on the properties of the pellets from buckwheat hulls. Renewable Energy 2016;87:289-297.

[2] Poddar S, Kamruzzaman M, Sujan SMA, Hossain M, Jamal MS, Gafur MA, Khanam M. Effect of compression pressure on lignocellulosic biomass pellet to improve fuel properties: Higher heating value. Fuel 2014;131:43-48.

[3] Garcia-Maraver A, Rodriguez ML, Serrano-Bernardo F, Diaz LF, Zamorano M. Factors affecting the quality of pellets made from residual biomass of olive trees. Fuel Processing Technology 2015;129:1-7.

[4] Stelte W, Holm JK, Sanadi AR, Barsberg S, Ahrenfeldt J, Henriksen UB. A study of bonding and failure mechanisms in fuel pellets from different biomass resources. Biomass and Bioenergy 2010;35(2):910-918.

[5] Barnwal P, Kadam DM, Singh KK. Influence of moisture content on physical properties of maize. International Agrophysics 2011;26:331-334.

[6] Miranda MT, Arranz JI, Rojas S, Montero I. Energetic characterization of densified residues from Pyrenean oak forest. Fuel 2009;88:2106-2112.

[7] Theerarattananoon K, Xua F, Wilson J, Ballard R, Mckinney L, Staggenborg S, Vadlani P, Pei ZJ, Wang D. Physical properties of pellets made from sorghum stalk, corn stover, wheat straw, and big bluestem. Industrial Crops and Products 2011;33:325-332.

[8] Samuelsson R, Thyrel M, Sjostrom M, Lestander TA. Effect of biomaterial characteristics on pelletizing properties and biofuel pellet quality. Fuel Process Technology 2009;90:129-1134.