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Effect of biomass characteristics on durability of Cassava stalk residues pellets

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Abstract

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This study aims at investigating the effect of the main biomass characteristics (moisture content and particle size) on durability of Cassava stalk residues pellets. This durability is necessary to consider design of the material handling, processing equipment, storage and transportation of biomass pellets. The raw biomass materials were ground and screened into four range sizes and pelletization was done at three different percentage levels of moisture conditions defined as percentage of added water by mass of raw material. Pellets in each condition were analysed for durability. The result showed that the highest durability occurred in particle size 1.7 mm but less than 3.35 mm and 10% moisture content by mass of raw biomass material. The mean durability in the best conditions was 99.02%. This information is important for the design and efficient preparation of biomass material for pelletization to achieve the high quality pellets with high durability for handling, transportation and storage.

Keywords: cassava stalk; residues; biomass; durability; pellet

Thailand is predominantly an agricultural country (FAO 2010). After harvesting season, plenty of agricultural residues are abundant in the fields which can be converted to sustainable biomass energy. Cassava (*Manihot esculenta Crantz*) is one of the most important economic crops in Thailand. It is cultivated in the third largest area after rice and maize (Poramacom et al. 2013; OAE 2014). Cassava roots are processed into dry chips, pellets for export, into animal feed and starch for domestic use and export (FAO 2011), while Cassava stalks are collected for the next cultivation season (approximately 30%) and 70% are left in the agricultural farms as residues (FAO 2008). These residues are abundant and have the high potential for biomass energy. However, there are many disadvantages of the agricultural residues such as high moisture content and low bulk density as well as their sizes and shapes (Adapa et al. 2013). These problems can be solved through a densification technology that increases their homogeneity, density and thermal efficiency (Miranda et al. 2012). The densified product may be used for fuel purposes, of which the most popular is pellet (Poddar et al. 2014). The use of pellets also reduces the cost associated with handling, transportation and storage due to increased bulk density (Garcia et al. 2015). However, high durability of pellets is necessary for prevention of breaking during the above-mentioned operations. The final quality of pellets depends on

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the raw material characteristics and pelletization process (Samuelsson et al. 2009). The quality of raw material depends on the biomass characteristics (Gilbert et al. 2009) and the pelletization process can be controlled to optimize the production process and improve quality of the final product (Carone et al. 2011).

The objective of this study was to investigate the effect of biomass raw material (particle size and moisture content) on durability of the Cassava stalk pellets. The pellets in each treatment were tested for their durability using a tumbling box device. The contributions of this study are useful for preparation of raw material, handling, transportation and storage of the Cassava stalk pellets.

MATERIAL AND METHODS

Raw material. Cassava variety Kasatsart 50 was used as feedstock because this variety is the most popular and cultivated in Thailand (Thai Tapioca Development Institute 2006). Cassava stalks were collected manually from the agronomy field in the Khon Kaen province and delivered to the Department of Industrial Engineering, Khon Kaen University on the harvest day. They were chopped and milled immediately to about 5 mm particle size to save energy (Kaewwinud et al. 2017). Then the milled Cassava stalks were dried prior to sieving into four different size groups (G1= less than 0.85 mm, G2 = 0.85 but less than 1.7 mm, G3 = 1.7 but less than 3.35 mm and G4 = 3.35 to 5 mm). Before pelletization, water was added into biomass material in order to obtain specific moisture content, which was defined as percentage of water added by mass of raw material. There were three levels of moisture content (10%, 20% and 30%).Hence, there were 12 treatments altogether (4 particle sizes × 3 moisture contents).

Pelletization process. Pelletization process was performed using a flat die pellet machine model ZLSP-D 200C (Anyang Gemco Energy Machinery Co., Ltd, China) of 7.5 kW. The pellet die diameter was 260 mm and the thickness was 26 mm with 6 mm hole diameter. The speed of pelleting was 275 rpm and the capacity of this machine was 80–120 kg/h. After pelletization process, the pellets were left to cool down at the room temperature. Then they were kept in the closed plastics zip bags waiting for the durability test.

Durability. The mechanical durability of pellets was investigated according to the ASAE Standard S269.4 (ASAE standards 1993) as our testing system conforms to this standard. A sample of 100 g pellets was put in a tumbling box device that was a rectangular stainless steel container with inner dimension of 300 mm × 300 mm × 125 mm (Agricultural Machinery and Postharvest Technology Center, Faculty of Agricultural Engineering, Khon Kaen University, Khon Kaen, Thailand). The rotation speed was adjusted to 50 rpm and the rotation time was 10 minutes. After tumbling, the pellets were sieved manually to remove fines. Fines were determined by screening a sample on the appropriate wire sieve having openings just smaller than the nominal pellet diameter. Then, the pellets were weighed, and durability was calculated using the following formula:

$$\text{Durability (\%)} = \frac{\text{mass of pellets after tumbling}}{\text{mass of pellets before tumbling}} \times 100$$

In each treatment, the randomly selected pellets were tested at three replications so the durability testing comprised 36 results (12 treatments × 3 replications) in this experiment.

Statistical analysis. Two factors (particle size and moisture content) were investigated for their effect on durability of pellets made from the Cassava stalks. A statistical evaluation was employed to analyse the level of each factor by using the software SPSS Statistics, version 19.0. This analysis process started from checking adequacy model by investigating normal distributions for all treatments using the Shapiro-Wilk's test (p-value > 0.05) because the data contain less than 50 results. Next, a two-way analysis of variance (ANOVA) at a 95% (a = 0.05) confidence interval was carried out to test differences between two or more means. Finally, the Duncan's multiple range test was used to compare the means of the four levels of particle size and three levels of moisture content.

RESULTS AND DISCUSSION

The durability of Cassava stalk pellets was investigated using 12 treatments, at which four levels of particle size and three levels of moisture content were examined by the tumbling box device. Three replications of durability testing were investigated in each treatment and the statistical analysis was

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Table 1. Statistical data and the Shapiro-Wilk's test results of Cassava stalk pellets for 12 treatments

Particle Size	Moisture (%)	Durability (%)		Shapiro-Wilk's test (*p*-value)
		Mean	S.D.	
G1	10	98.13	0.3029	0.253
	20	94.46	0.6458	0.237
	30	78.45	1.1437	0.201
G2	10	97.92	0.6921	0.152
	20	92.55	0.8356	0.927
	30	74.21	0.2747	0.492
G3	10	99.02	0.1823	0.696
	20	75.24	3.7532	0.361
	30	60.82	2.0076	0.191
G4	10	97.13	0.0950	0.942
	20	75.04	3.7696	0.068
	30	53.03	2.6023	0.919

S.D. – standard deviation

done using the software SPSS V19.0 (IBM SPSS Statistics). The data were examined in the model adequacy checking using the Shapiro-Wilk's test for normal distribution. The results showed that the durability data were normally distributed (p-value > 0.05) as shown in Table 1.

Two-way analysis of variance (ANOVA) at the 95% confidence interval was employed to investigate two main effects of the biomass characteristics (particle size and moisture content) on the durability of Cassava stalk pellets. The factors were considered separately and aggregately. The ANOVA revealed that the durability of Cassava stalk pellets was significantly affected by particle size and moisture content. Moreover, the interaction between particle size and moisture content significantly affected the durability (p-value < 0.05) as shown in Table 2.

Then Duncan's multiple range test was used to compare the range of a subset of durability on particle size and the range of a subset of durability on moisture content. The results showed that there are significant differences in durability among all pairs of particle size at the 95% confidence interval, similarly to the results in all pairs of moisture content at the 95% confidence interval as shown in Table 3. The results of the Duncan's multiple range test of particle size and moisture content showed that in terms of particle size, the durability increased significantly with decreased particle size, hence the smallest particle size resulted in the highest durability; in terms of moisture content, the durability increased significantly with decreasing moisture content, hence the lowest moisture content resulted in the highest durability. However, there was an interaction between the two factors; the relationships between the factor settings (particle size and moisture content) and the response (mean durability) were plotted. The mean durability graph in

Table 2. The two-way ANOVA test of the effect of particle size and moisture content on durability of Cassava stalk pellets

Source	df	Sum of squares	Mean square	*F*-value	*P*-value
Particle size	3	1,492.322	497.441	141.416	0.000
Moisture content	2	5,953.812	2,976.906	846.294	0.000
Particle size × moisture content	6	778.466	129.744	36.885	0.000
Error	24	84.422	3.518		
a. *R* squared = 0.970 (adjusted *R* squared = 0.956)					

df – degrees of freedom; dependent variable – durability

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Table 3. The Duncan's multiple range test of particle size and moisture content

N	Duncan's multiple range test on particle size			
	Subset for α = 0.05			
	G1	G2	G3	G4
9	90.3489			
9		88.2278		
9			78.3589	
9				75.0667
Sig.	1.000	1.000	1.000	1.000

N	Duncan's multiple range test on moisture content		
	Subset for α = 0.05		
	10%	20%	30%
12	98.0483		
12		84.3225	
12			66.6308
Sig.	1.000	1.000	1.000

N – sample size; Sig. – significant

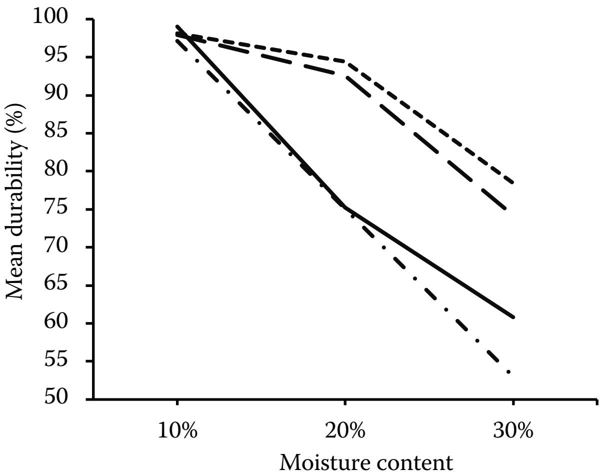

Fig.1. Mean durability versus particle size and moisture content

Fig. 1 indicates that the highest mean durability was at G3 and 10% moisture content and the lowest mean durability was at G4 and 30% moisture content. This means that to maximize durability, Cassava stalks should be milled to an appropriate particle size and at the right moisture content before pelletization.

CONCLUSION

In this study, the effect of particle size and moisture content significantly affected the durability of Cassava stalk pellets. The best conditions to produce the mean highest durability in this study is particle size 1.7 mm but less than 3.35 mm (G3) and 10% moisture content by mass of raw biomass material. The mean durability of pellets processed in these best conditions was 99.02%. This result could be helpful for producing high quality pellets from Cassava stalks as the durability is necessary for handling, transportation and storage of the biomass pellets.

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