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Original Research Article

Physical Properties of Different Local Glutinous Rice Cultivar (*Susu* and *Siding*) and Commercial Thai Cultivar (*Susu*)

Norzahirah Zainal[1], Rosnah Shamsudin[1]*

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

*Corresponding author: Rosnah Shamsudin, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; rosnahs@upm.edu.my

Abstract: Glutinous rice *(Oryza sativa var. glutinosa)* is known as waxy rice or sticky rice and it has an opaque and small size grain cultivar distinct from common white rice. In outlining the equipment for processing, storage, sorting, sizing and other post-harvest equipment, the physical properties are very important. Two different cultivars of Malaysian local glutinous rice known as *Susu* and *Siding* were evaluated in this study. The objective of this study is to compare the physical properties of two different local cultivars in designing the rice processing equipment. For *Susu* cultivar, the average of length, width and thickness were 6.63 mm, 1.88 mm and 1.50 mm, respectively. The corresponding values were 6.24 mm, 1.98 mm and 1.48 mm for *Siding* cultivar. For *Susu* cultivar, the average of aspect ratio, sphericity, volume, surface area, bulk density, true density, porosity, 1000 weight kernel and angle of repose were 0.28, 0.40%, 9.81 mm^3, 19.02 mm^2, 800.54 kg/m^3, 1500.36 kg/m^3, 46.65%, 18.88 g and 39.45°, respectively. The corresponding values were 0.32, 0.42%, 10.25 mm^3, 19.45 mm^2, 772.73 kg/m^3, 1229.51 kg/m^3, 37.15%, 17.04 g and 40.08° for *Siding* cultivar. The physical properties of the same cultivar (*Susu*) showed no significant difference, but apparently *Siding* was higher in bulk density, which requires a larger-sized silo compared to *Susu* cultivar in term of equipment design.

Keywords: Glutinous rice; physical properties; *Susu*; *Siding; Susu* Thai

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1. Introduction

Rice (*Oryza sativa L.*) is one of the leading food crops in the world and is the staple food of more than half of the world's population. Food Agriculture Organization (FAO) (2018) stated global consumption of rice has been slightly increasing to 490.27 million metric tonnes from 437.18 million metric tonnes in 2008. Thousands of rice cultivars are available throughout the world and glutinous rice (*Oryza sativa var. glutinosa*) is one of the most popular known cultivars, commonly known as sticky rice or waxy rice. In Malaysia, during the Malay festive seasons, the glutinous rice is very high in demand. It can be divided into short- or long- grained rice that are sticky when being cooked. Different type of cultivars are being aggressively demanded by the fellow consumers in improving the quality, acceptability and marketability of the particular rice cultivar. While, for designing and outlining an appropriate machinery for grain-processing operations such as sorting, drying, threshing, milling and optimization catered for each specific cultivar are probably relied on the information and knowledge towards the physical properties of rice grain materials (Mir *et al*., 2013).

Nowadays, Malaysia only imports the glutinous rice from Thailand. According to the Global Agricultural Information Network (2017), about 15% of glutinous rice has been imported out of 891,000 metric tonnes of total rice imported into Malaysia. Therefore, since Langkawi Island is consistently hot and humid every year, Langkawi has the potential to become one of the local glutinous rice producers. Thai glutinous rice is popular in Malaysia, since Malaysia has stopped cultivated them in the 1980's. This can be proven by the Malaysian Agricultural Research and Development Institute (MARDI) research (Husain, 1984). In comparison to *Susu* Thai cultivar, Thailand and Langkawi Island have a quite similar conducive weather and both situated at the northern Malaysia region. On the other hand, the area of plantation for both local cultivars are planted about 14.76 ha and 24.2 ha for *Susu* and *Siding*, respectively in Langkawi Island. By physical appearance, *Susu* cultivar is easier to be differentiated in comparison to *Siding*. The *Susu* cultivar is significant by the size of the leaves, which is much wider than *Siding*. Moreover, *Susu* cultivar seed is germinated on the top of their leaves, while *Siding* cultivar seed is germinated below their leaves.

The prior properties of grain are meant to be their physical properties or characteristics. Solutions to problems in the post-harvest process include knowledge of their engineering and physical properties (Irtawange, 2000). During fabrication of bulk storage facilities and the calculation of the dimensions of intermediate holding bins of a given capacity in a mill, these two properties are significant. Surface area and volume of the kernels can be calculated, since they are essential for modelling in drying process, aeration, heating and cooling process. Grain size and shape are the prior quality criteria in developing rice cultivars for commercial production. They are primary factors in marketing, grading and processing (Singh *et al*., 2005).

Sizing grain hoppers and storage facilities are helpful by determining the bulk density, true density and porousity (the ratio of inter granular space to the total space occupied by the grain). The condition and design of storage facilities can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Grain bed with low porousity will have a greater resistance to water vapour escape, during the drying process, in which this may cause high electrical power to drive the aeration fans.

Rice cannot be considered to have uniform properties, since grain property variation is wide when considering different cultivars. Remarkable variation in the processing quality of the grain is a result from differences in grain properties. Therefore, the aim of this study is to determine the physical properties such as dimension, shape, bulk density, true density, porosity, sphericity, 1000 weight kernel and angle of repose of different cultivars of local glutinous rice kernel (*Susu* and *Siding*) with *Susu* Thai glutinous rice, act as reference, which can facilitate in the plan or design of processing, handling and processing for rice yield.

2. Materials and Methods

2.1 Rice Sample

Local glutinous rice kernel from *Susu* cultivar was chosen from a rice plantation at the Langkawi Island and *Siding* from a plantation in Kedah, while commercial glutinous rice kernel from Thailand, *Susu* cultivar, was used as a reference. Both local *Susu* and *Siding* cultivars' grains were cleaned and milled by Padiberas Nasional Berhad (BERNAS).

2.2 Grain Shape and Dimension

There are three principal dimensions of the grains: length (l), width (w), and thickness (t) were required to be determined and characterised. These measurements were recorded by using Vernier caliper to an accuracy of 0.05 mm. 20 grains of milled rice from each sample were collected at random and the dimensions were measured to obtain the average length (l) in millimeter (mm), width (w) in mm, breadth (b) in mm, and thickness (t) in mm. Figure 1 shows the measurement of grain dimension of rice.

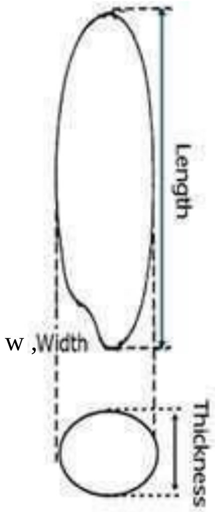

Figure 1. Dimension of rice grain.

2.3 1000 Weight Kernel

The 1000 weight kernel of each sample were counted randomly in triplicate and weighed separately to determine 1000 kernel weight by weighing them onto the analytical balance (Singh *et al*., 2003).

2.4 Surface Area, Aspect Ratio and Sphericity

The surface area (S) in mm^2, aspect ratio (R_a) unitless, and sphericity (∅) in unit % of rice was determined by measurement of the grain dimension. All of the properties were calculated as follows (Jain & Bal, 1997):

$$S = \frac{\pi b l^2}{(2l - b)} \quad (1)$$

Where $b = \sqrt{wt}$

$$R_a = \frac{w}{l} \quad (2)$$

$$\emptyset = \frac{(lwt)^{1/3}}{l} \quad (3)$$

2.5 Bulk Density, True Density and Porousity

Grain volume (V) in unit mm^3 were calculated by using formula (Jain & Bal,1997) below:

$$V = 0.25[\left(\frac{\pi}{6}\right) l(w + t)^2] \quad (4)$$

The bulk density (ρb) in unit kg/m^3 was computed when rice was filled into 100 ml beaker and then mass of the rice grain (M_g) was weighed. The weight of the rice was divided with the volume of the beaker (V_b) (i.e. 100 ml). The same procedure was repeated for five times (Fraser *et al*., 1978). The formula for bulk density is stated as below:

$$\rho_b = \frac{M_g}{V_b} \quad (5)$$

The true density (ρt) in unit kg/m^3 was computed by pouring 50 ml of distilled water into the 100 ml beaker and then adding 3 g sample of rice. The water displacement (V_{dw}) by rice was recorded. The measurement was replicated five times (Shittu *et al*., 2012):

$$\rho_t = \frac{M_{gt}}{V_{dw}} \quad (6)$$

The porousity (ε) in unit % determination is based on the bulk density and true density of the rice grain. The porousity of rice grain was calculated by using the following formula (Jain & Bal, 1997):

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (7)$$

2.6 Angle of Repose

Angle of repose is a parameter that measured the ability of material to stand, when heaped, whereby the granular material steepest angle of descent or dip is relative to the horizontal plane. This was determined by using the apparatus consisting of a plywood box of 140 x 160 x 35 mm and two plates: fixed and adjustable. The box was filled with the sample, and then the adjustable plate was inclined gradually allowing the seeds to follow and assuming a natural slope, this was measured as emptying angle of repose (Tabatabaeefar, 2003).

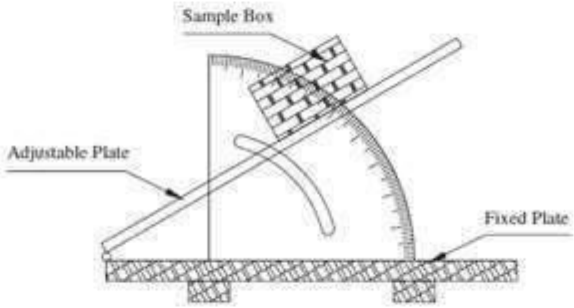

Figure 2. Apparatus for measuring emptying angle of repose.

3. Results

3.1 Physical Properties of Susu and Siding Cultivar

Table 1 shows a summary of the physical properties of local *Susu* and local *Siding*. The *Susu* Thai cultivar is act as a reference.

Table 1. Average value of physical properties: Different glutinous rice cultivars

Properties	Grain/Rice cultivar		
	Susu Thai (reference)	*Local Susu*	*Local Siding*
Length (mm)	6.57±0.28[a]	6.63 ±0.24[a]	6.24±0.42[b]
Width (mm)	1.98±0.09[b]	1.88 ±0.10[a]	1.98±0.08[b]
Thickness (mm)	1.47±0.09[a]	1.50 ±0.07[c]	1.48±0.10[a]
Aspect ratio	0.30±0.02[a]	0.28±0.02[a]	0.32±0.03[a]
L/B ratio	3.58±0.34[a]	3.82±0.06[a]	3.17±0.06[a]
Sphericity (%)	0.41±0.01[a]	0.40 ±0.01[a]	0.42±0.02[a]
Volume (mm^3)	10.25±0.10[a]	9.81±1.15[a]	9.87±0.93[b]
Surface area (mm^2)	20.22±1.36[c]	19.02 ±4.31[a]	19.45±1.73[b]
Bulk density (kg/m^3)	767.22±1.59[a]	800.54 ±1.20[a]	772.73±1.28[a]
True density (kg/m^3)	1206.23±3.89[a]	1500.36 ±6.98[a]	1229.51±26.86[b]
Porosity (%)	36.40±2.15[a]	46.65 ±2.40[c]	37.15±2.20[b]
10000 weight kernel (g)	17.93±0.15[a]	18.88 ±0.10[a]	17.04±0.20[b]
Angle of repose (deg.)	40.08°±1.05[a]	39.45°±1.03[a]	38.85°±0.95[a]

Mean (±SD) with the same letter in the same row do not differ significantly (*P*>0.05)

Length, width and thickness determine the rice grain’s dimension. Based on Table 1, length of *Susu* Thai and local *Susu* did not show a remarkable contrast between them, but, significantly longer than local *Siding* cultivar. At 5% level of likelihood, it shows no notable differences for width and thickness between *Susu* Thai and *Siding* cultivar. However, it shows significant differences to the local *Susu* cultivar. The average value of length, width and thickness for local *Susu* cultivar were found to be 6.63 mm, 1.88 mm and 1.50 mm, respectively, while 6.24 mm, 1.98 mm and 1.48 mm were obtained for *Siding* cultivar. In comparison, *Susu* Thai resulted to 6.57 mm, 1.98 mm and 1.47 mm, respectively, for its length, width and thickness. *Susu* Thai and local *Siding* cultivars were wider compared to local *Susu*. However, local *Susu* cultivar was thicker than *Susu* Thai and local *Siding* cultivars. Length of local *Susu* cultivar similar to the length of *Pulut Malaysia I* cultivar, which was 6.64 mm as per reported by Husain (1984). The length-breadth (L/B) ratio for three of the rice cultivars did not present significant differences. The L/B ratio mean value for *Susu* Thai, local *Susu* and local *Siding* were 3.58, 3.82 and 3.17, respectively. A length to breadth ratio of above 3 is considered as slender (IRRI, 1980). For the local cultivars, both of the seeds can be considered as slender. However, the control sample has the highest L/B ratio, which yielded very significant slender shape grains. L/B ratio shows the dimension of rice grain. This proves that the dimension for different cultivar is similar, since they were from the same glutinous rice type.

3.2 1000 Weight Kernel

At the 5% level of probability, the 1000 weight kernel of the local *Susu* and *Susu* Thai cultivars did not present a remarkable contrast. Both cultivars showed higher 1000 weight kernel than local *Siding* cultivar. Local *Susu* showed an average of 1000 weight kernel of 18.88 g against 17.93 g and 17.04 g, respectively, for *Susu* Thai and local *Siding*. To measure the correlative amount of foreign substance in a designated bulk of raw rice and the number of shrink or unripe kernels, normally it is based on the index of milling outturn. So, 1000 grain weight of rice is very crucial in this study (Luh, 1980).

3.3 Surface Area, Aspect Ratio and Sphericity

Surface area and volume are two good parameters to be considered in designing the drying system for these glutinous rice. The result for surface area for *Susu* Thai, local *Susu* and local *Siding* were 20.22 mm^2, 19.02 mm^2 and 19.45 mm^2 respectively. These three cultivars showed remarkable contrasts of surface area values. The grain volume showed significant differences between both *Susu* cultivar and *Siding* cultivar. The average volume values for *Susu* Thai, local *Susu* and local *Siding* were 10.25 mm^3, 9.81 mm^3 and 9.87 mm^3, respectively. Surface area of the grain positively correlated with the volume of the grain. Heat transfer surface importantly influenced the rate or speed of heat transfer or heat exchange within the material. Higher rate of heat transfer occurs when the material has smaller volume per unit surface contact (Varnamkhasti *et al*., 2008). In this study, *Susu* Thai has the highest rate of heat transfer, hence resulted to shorterdrying time. Also, sphericity for the rice grains poorly showed remarkable differences between cultivars. The sphericity ranges from 0.40 % – 0.42 %. For many agricultural materials, raw rough rice falls within ranges from 0.32 to 1% for the sphericity values (Mohsenin, 2001). Thus, result from these three cultivars complied greatly with the previous finding.

3.4 Bulk Density, True Density and Porousity

At the 5% probability, bulk density values showed no remarkable contrast between three cultivars, regardless of being local or commercial rice. In the existing grain of a combined hopper, the design needs to ascertain the volume. So, various approaches were applied in this agricultural industry. Information about bulk density is useful in controlling the load of product in the hopper. The bulk density mean values for local *Susu* and local *Siding* were 800.54 kg/m^3 and 772.73 kg/m^{3,} respectively. Compared to *Susu* Thai cultivar, the mean value bulk density was 767.22 kg/m^3. In outlining the storage bins and silos design, bulk density is useful in this application (Nalladulai *et al*., 2002). Due to the bulk density value for *Siding* was slightly smaller than *Susu* cultivar, *Siding* needs a bigger silo compared to *Susu* cultivar, in relation to the same load of rice kernels.

Then, the true density of local *Siding* showed a significant difference between *Susu* Thai and local *Susu* cultivars. The mean value of true density for *Susu* Thai, local *Susu* and local *Siding* were found to be 1206.23 kg/m^3, 1500.36 kg/m^3 and 1229.51 kg/m^3, respectively. To segregate seeds of cereal crops by true density, pneumatic sorting tables were used. The porousity values for three difference cultivars showed notable differences at the 5 % probability level. The corresponding mean value for local *Susu* porousity was 46.65 % higher than *Susu* Thai and local *Siding,* which was found to be 36.40 % and 37.15 %, respectively. When the porousity of the material is large, the lower ability of material to resist the air combustion product fusion. This results in quick drying process in contrast to the small porousity of materials. This finding can be applied throughout the convective dehydration process accompanied by the forced draft, when the air and combustion product fusion is swept through the grain mass layer of kernels (Varnamkhasti *et al*., 2008).

3.5 Angle of Repose

Between *Susu* Thai, local *Susu* and local *Siding* cultivars, they show no remarkable contrast in the angle of repose. The corresponding mean value for *Susu* Thai, local *Susu* and local *Siding* cultivars were 40.08^o, 39.45^o and 38.85^o, respectively. This angle is important for the design of processing, storage and conveying systems of particulate materials.

Materials with low angle of repose are highly flowable and can be transported using gravitational force or a small energy (Teferra, 2019).

4. Conclusion

This study provides the required information on physical properties of local glutinous rice properties, which are local *Susu* and local *Siding* cultivars, which are useful for designing an intended major equipment used for rough rice processing. The physical properties of the same cultivar (*Susu*) showed no significant difference compared to the *Siding* cultivar. In terms of designing an equipment, *Siding* requires a larger silo than the *Susu* cultivar. Other than physical properties, mechanical, thermal and morphological properties can be determined to supply a justly comprehensive knowledge on design parameters involved in rice processing.

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Conflicts of Interest: The authors declare no conflict of interest of the study.

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