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Some Engineering Properties of Paddy (var. Sazandegi)

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ABSTRACT

Physical and engineering properties of agricultural grains are necessary for the design of storage, handling and processing equipment. In this study, some physical properties of raw paddy (var. Sazandegi) are discussed briefly. At moisture content of 10% (wet basis), the average grain length, width and thickness were 8.54, 2.47 and 1.83 mm, respectively while the equivalent mean diameter, surface area and volume were 3.4 mm, 32.58 mm^2 and 21.06 mm^3, respectively. The sphericity and aspect ratio were 39.88 and 0.29%, respectively. True density, bulk density and porosity were 1193.38 kg m^{-3}, 471.16 kg m^{-3} and 60.37%, respectively while the static coefficient of friction varied from 0.2186 on glass sheet to 0.4279 on plywood. The angle of repose for emptying was 35.83^o. Nonlinear model for describing the mass of paddy grain was investigated, too. In this regard mass was estimated with single variable of kernel length with a determination coefficient as 0.869.

Key Words: Raw paddy; Physical properties; Rice milling; Var. Sazandegi

INTRODUCTION

Rice (*Oryza Sativa* L.) is one of the leading food crops of the world and is second only to wheat in terms of annual production for food use. The world's rice production increased from 520 million tones in 1990 to 605 million tones in 2004, while the Iran's rice production increased from 1.3 million tones in 1980 to 3.4 million tones in 2004 (FAOSTAT, 2005). The increasing economic importance of food materials, together with the complexity of modern technology for their production, handling, storage processing, preservation, quality evaluation, distribution and marketing and utilization demands comprehensive information on physical properties of these materials. For this purpose, size, volume, surface area, thousand grain weights, density, porosity, angle of repose, coefficient of friction are of prime importance. These properties influence the design and evaluation of rice processing including drying, husking, whitening and polishing as well as grading machines, storage and grain moving equipment. For example the knowledge of the coefficient of friction of paddy on the equipment wall and on the silo wall surfaces are necessaries and fundamentals for a rational and safe design of grain moving handling equipment, processing and storage (Lawton, 1980; Mohsenin, 1986; Milani, 1993; Suthar & Das, 1996).

The knowledge of friction coefficients of grain is needed for designing conveying equipment. For instance friction between an un-consolidated material and a conveyor belt affects the maximum angle with the horizontal, which the conveyor can assume when transporting the solid. Husking characteristics of paddy are dependent upon its shape and size (Shitanda *et al*., 2001). Some physical characteristics of rice such as grain thickness has a major effect on the volume expansion ratio of the cooked rice followed by degree of milling and then by apparent amylase content of the grain (Mohapatra & Bal, 2007). To obtain better quality-milled rice, the knowledge of physical properties of paddy grain is necessary for modeling of dynamic abrasion in a rice milling operation as well as for designing of suitable polishing systems (Mohapatra & Bal, 2004). The knowledge of physical properties such as dimension characteristics and determination of milled rice quality parameters by image processing techniques will enable regular monitoring of milling operation in an objective manner and thus the operator to quickly react within a few minutes to changes in material properties (Yadav & Jindal, 2001).

Thousand weight of paddy grain is used for calculating the head rice yield (HRY). Data on actual milling output were obtained from the millers and were expressed in percentage of paddy fed for milling. Expected milling output was determined at the laboratory by taking the 1000 grain weights of milled head rice and the corresponding weight of thousand grain of paddy and then expressing the weight of milled head rice as a percentage of the weight of the paddy. Any shortfall in actual milling output was considered as the milling loss due to breakage of grain (Sarker & Farouk, 1989). Ehsanullah *et al*. (2000) conducted a study to evaluate the effect of direct seeding versus transplanting on yield and quality of fine rice. They used 1000-grain weight of rice as a physical property to determine the highest yield and quality of fine rice Basmati-370. Also, using of the latter property as a characteristic affecting grain yield was reported by Mahmood *et al*. (2003).

Gravitational and frictional properties of grain can be useful in analyzing harvesting operation performance. Based on investigation performed by Srivastava *et al*. (1990), grain bulk density and angle of repose are related to separator performance, while harvesting grain, such that increasing grain density increases separator capacity, while increasing the grain angle of repose has the opposite effect.

Physical properties of paddy have been investigated and reported by several researchers (Wratten *et al*., 1969; Morita & Singh, 1979; Steffe & Singh, 1980; Arora, 1991; Kachru *et al*., 1994; Reddy & Chakraverty, 2004; Correa *et al*., 2007). However, a comprehensive study of the physical properties of paddy grain is needed. Present study was conducted to determine some of the paddy physical properties such as linear dimensions, sphericity, equivalent diameter, surface area, volume, bulk and true density and static coefficient of friction against selected surfaces and angle of repose.

MATERIALS AND METHODS

The paddy rice grain used in this study was obtained from a local market in Esfahan, a central province in Iran. The grains were cleaned manually and the foreign matter, as stones, straw and dirt was removed. The moisture content of the grains (10% wet basis) was determined using a moisture meter (SP-1D2 kitte). Rough rice grains (var. Sazandegi) were randomly selected and their three principle dimensions were measured using a venire caliper to an accuracy of 0.05 mm. The equivalent diameter D_p in mm considering a prolate spheroid shape for a rough rice grain, was calculated through the following expression (Mohsenin, 1986).

$$D_P = (4L(\frac{W+T}{4})^2)^{\frac{1}{3}} \quad (1)$$

The sphericity ϕ expresses the characteristics shape of a solid object relative to that of a sphere of the same volume and defined as the ratio or the surface area of the sphere having the same volume as that of the grain to the surface area of the grain, was determined as (Mohsenin, 1986).

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (2)$$

Thousand-grain seed weight was determined by counting 100 kernels and weighing them in an electronic balance and then multiplied by 10 to give the mass of 1000 grains (Nalladulai *et al*., 2002). Jain and Bal (1997) have stated grain volume, V and grain surface area, S may be given by:

$$V = 0.25\left[(\frac{\pi}{6})L(W+T)^2\right] \quad (3)$$

Because the volume obtained from the equation presented in proof is very low while the volume magnitude obtained from the above equation is reasonable with regard to true density and grain mass magnitudes.

$$S = \frac{\pi B L^2}{(2L - B)} \quad (4)$$

Where

$$B = \sqrt{WT} \quad (5)$$

The aspect ratio (R_a) is used in classification of grain shape and it was calculated as:

$$R_a = \frac{W}{L} \quad (6)$$

The true density defined as the ratio between the mass of paddy and the true volume of the grain, was determined using the toluene (C_7H_8) displacement method. Toluene was used in place of the water, because it is absorbed by grains to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of paddy in the toluene (Mohsenin, 1986; Singh & Goswami, 1996; Demir *et al*., 2002; Selvi *et al*., 2006). The bulk density is the mass of a group of individual particles divided by the space occupied by the entire mass, including the air space and was determined using the relationship (Fraser *et al*., 1978) by filling an empty plastic container or predetermined volume and tare weight with the grains by pouring from a constant height, striking off the top level and weighting. The density ratio is expressed as ratio of mass density to bulk density in percent, while porosity ε is the percentage of air between the particles compared to a unit volume of grains and it was computed (Jain & Bal, 1997) as:

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

The emptying angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using the apparatus (Fig. 1) consisting of a plywood box of 140 mm by 160 mm by 35 mm and two plates (fixed & adjustable). The box was filled with the sample and then the adjustable plate was inclined gradually allowing the seeds to follow and assume a natural slope; this was measured as emptying angle of repose (Tabatabaeefar, 2003). The static coefficient of friction against different surfaces (plywood, glass & galvanized iron sheet) was determined using a cylinder of diameter 75 mm and depth 50 mm filled with grains (Fig. 2). With the cylinder resting on the respective surface, the surface was raised gradually until the filled cylinder just started to slide down (Singh & Goswami, 1996; Tabatabaeefar, 2003; Tunde-Akintunde & Akintunde, 2004). For analyzing the obtained data, SPSS 13 was used and EXCEL software was exploited for plotting the chart.

RESULTS AND DISCUSSION

A summary of the results of the determined physical parameters is shown in Table I. The average paddy (var.

Fig. 1. Apparatus for measuring emptying angle of repose

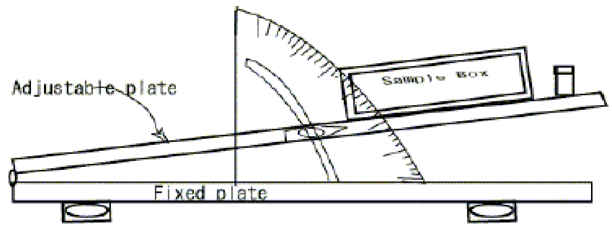
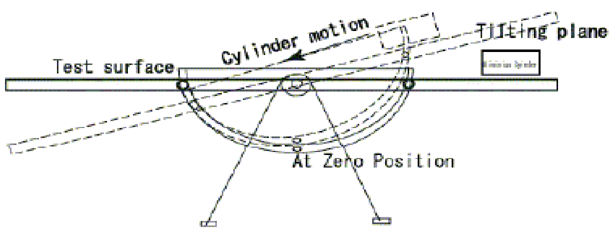


Fig. 2. Apparatus for measuring of static coefficient of friction



Sazandegi) length, width and thickness were found to be 8.54, 2.47 and 1.83 mm, respectively. Corresponding value for the raw paddy (IR-36 variety) were 9.81, 2.47 and 1.93 mm, while 7.3, 3.3 and 2.3 mm were reported for Akitakomachi variety (Shitanda *et al*., 2001). The Sazandegi variety was smaller than IR-36 but longer than Akitakomachi. The importance of these and other characteristics axial dimensions in determining aperture sizes and other parameters in machine design have discussed by Mohsenin (1986) and highlighted lately by Omobuwajo *et al*. (1999).

The geometric mean diameter ranged from 3.03 to 3.71 mm, while the corresponding surface area ranged from 25.62 to 37.28 mm^2. The geometric mean of the axial dimensions is useful in the estimation of the projected area of a particle moving in the turbulent or near- turbulent region of an air steam. This projected area of the particle (grain) is generally indicative of its pattern of behavior in a flowing fluid such as air, as well as the ease of separating extraneous materials from the particle during cleaning by pneumatic means (Omobuwajo *et al*., 1999). The sphericity was 39.88%, which indicated that the shape of the grains makes it difficult to roll on surface. This was higher than corresponding value of 37% reported for L201 variety but close to 41% reported for Delta variety (Shitanda *et al.,* 2001). The aspect ratio, an indicator of a tendency toward an oblong shape, was 0.29 and a corresponding value of 0.25 was reported for raw paddy (IR-36) at moisture content 8.4% (Reddy & Chakraverty, 2004). Corresponding value for ITA 318, TOX 3108 and Emo Fitaa were 0.31, 0.34 and 0.44, respectively (Adu-Kwarteng *et al*., 2003).

Thousand-grain weight of paddy was 20.52 g. This parameter is a useful index to "milling outturn" in measuring the relative amount of dockage or foreign material in a given lot of paddy and the amount of shriveled or immature kernels (Luh, 1980).

The true density, bulk density and porosity were 1193.38 kg m^{-3}, 471.16 kg m^{-3} and 60.37%, respectively. This showed that grains were heavier than water. This characteristic can be used to design separation or cleaning process for grains since lighter fractions will float. Corresponding value for rough rice (Jequitiba variety) were 1524.73 and 548.47 kg m^{-3} and 64.02%, while 1348, 566 kg m^{-3} and 58% were reported for IR-36 at 27.86 M.C (Reddy & Chakraverty, 2004). Corresponding value of 1208.71 and 678.19 kg m^{-3} and 43.89% reported for Iranian milled rice (Tarom Mahali variety) by Kashaninejad *et al.* (2007).

The average values of static coefficient of friction against galvanized iron sheet, plywood and glass sheet were 0.3153, 0.4279 and 0.2186, respectively (Table II). The static coefficient of friction is used to determining the angle at which chutes must be positioned in order to achieve

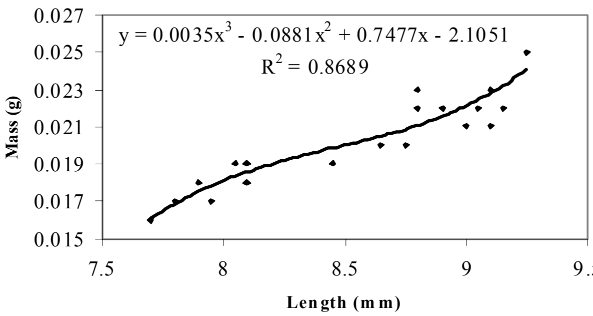
Table I. Some physical properties of paddy (var. Sazandegi)

Property	Number of observation	Mean value	Standard deviation	Minimum value	Maximum value
Length (mm)	100	8.54	0.41	7.70	9.50
Width (mm)	100	2.47	0.13	2.10	2.75
Thickness (mm)	100	1.83	0.12	1.50	2.00
Geometric mean diameter (mm)	100	3.40	0.13	3.03	3.71
Sphericity (%)	100	39.88	1.37	37.30	43.20
Aspect ratio	100	0.29	0.02	0.26	0.33
Volume (mm^3)	100	21.60	2.45	16.54	26.75
Surface area (mm^2)	100	32.58	2.50	26.30	38.46
Bulk density (kg m^{-3})	5	471.21	0.29	471.12	471.36
True density (kg m^{-3})	5	1193.38	81.80	1126.10	1284.43
Porosity (%)	5	60.37	2.66	58.13	63.33
Thousand weight of grains	5	20.52	0.51	19.47	21.57
Angle of repose (degree)	5	35.83	1.04	35.00	37.00

Table II. Static coefficients of friction paddy (var. Sazandegi) on different surfaces

Surface	Number of observation	Mean value	Standard deviation	Minimum value	Maximum value
Plywood	5	0.4279	0.016	0.4142	0.4452
Glass	5	0.2186	0.005	0.2217	0.2125
Galvanized steel	5	0.3153	0.009	0.3057	0.3249

Fig. 3. Variation of paddy grain mass with length of kernel



consistent flow of material through it (Olajide & Igbeka, 2003).

The angle of repose of paddy was 35.83°, which was lower than that reported for pumpkin (42° Joshi *et al*., 1993) but higher than that reported for groundnut seeds (Olajide & Igbeka, 2003) and Ackee apple seeds (Omobuwajo *et al*., 2000). The angle of repose determines the maximum angle of a pile of grain in the horizontal plane, and is important in the filling of a flat storage facility when grain is not piled at a uniform bed depth rather is peaked (Mohsenin, 1986). Non-linear relation between rough rice kernel mass and length was obtained by regression method. Kernel mass can be estimated by length with determination coefficient of 0.869 (Fig. 3).

In conclusion, the information on engineering properties of paddy var. Sazandegi, which may be useful for designing equipment used for paddy processing.

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