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Some Engineering Properties of Selected Paddy Varieties

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ABSTRACT

Physical and engineering properties of agricultural grains are necessary for the design of storage, handling and processing equipment. The present study was undertaken to study dimensional, gravimetric, and frictional characteristics of selected paddy (var. Chhattisgarh Madhuraj, Hanthipanjra and Mahamaya) and its initial moisture content were found 11.81 %, 11.23 %, and 11.05% on wet basis. In paddy varieties the average values of length were 8.47 mm, 11.15 mm, 9.40 mm and width 2.95 mm, 3.17 mm and 2.88 mm and thickness 2.13 mm, 2.30 mm and 2.18 mm for Madhuraj, Hanthipanjra and Mahamaya varieties respectively while the geometric mean diameter, surface area and volume were 3.75 mm, 4.33 mm, 3.89 mm and 44.23 mm^2, 58.89 mm^2, 47.66 mm^2 and 28.43 mm^3, 43.65 mm^3, 31.60 mm^3. The aspect ratio and sphericity were 34.78 %, 28.45 %, 30.77 % and 44.36, 38.82, and 41.47. True density, bulk density and porosity were 1093.98 kg m^{-3}, 1039.86 kg m^{-3}, 1058.48 kg m^{-3} and 593.56 kg m^{-3}, 527.29 kg m^{-3}, 615.96 kg m^{-3} and 45.72 %, 49.28 %, 41.69 % respectively. The angle of repose was 32.69°, 29.85°, and 32.98° for Madhuraj, Hanthipanjra and Mahamaya varieties while the static coefficient of friction on glass, plywood and mild steel were 0.45, 0.35, 0.42 and 0.41, 0.38, 0.38 and 0.78, 0.63, 0.64 respectively.

Key word: *Physical properties; dimensional, gravimetric, frictional, Var. Chhattisgarh Madhuraj, Hanthipanjra, Mahamaya*

INTRODUCTION

Paddy (*Oryza sativa* L.) is the most important and extensively grown food crop in the World and the staple food of more than 60 percent of the world population. The total production of rice in Chhattisgarh state during 2014-15 and 2015-16 is 6.32 million tonnes and 6.09 million tonnes. Chhattisgarh state has seventh position for the percentage share of producing rice to all India and its share production during 2014-15 and 2015-16 is 5.99% and 5.84% Agricultural Statistics at a Glance[2]. Rice production, processing and marketing constitute the biggest industry in the country. Physical and engineering properties are important in many problem associated with the design of machines and the analysis of the behavior of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying.

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Solutions to problems in these processes involve knowledge of their physical and engineering properties. Principal axial dimensions of paddy grains are useful in selecting sieve separators and in calculating power during the rice milling process. They can also be used to calculate surface area and volume of kernels which are important during modeling of grain drying, aeration, heating and cooling. Thousand grain mass of paddy grain is used for calculating the head rice yield (HRY is the mass percentage of paddy that remains as head rice). Head rice is ¾ or more of the whole milled kernels separated from the total milled rice *et al*[28].

Knowing the grain's bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities: they can affect the rate of heat and mass transfer of moisture during the aeration and drying processes. A grain bed with low porosity will have greater resistance to water-vapor escape during the drying process, which may lead to the need for higher power to drive the aeration fans. Cereal-grain kernel densities have been of interest in breakage susceptibility and hardness studies[14].

The knowledge of the morphology and size distribution of grains is essential for the adequate design of the equipment for cleaning, grading and separation. Gravimetric properties are important for the design of equipment related to aeration, drying, storage and transport *et al*[7]. The angle of repose is used to measure the flow ability of agricultural grains. This is a measure of the internal friction between grains and can be useful in hopper design, since the hopper wall's inclination angle should be greater than the angle of repose to ensure the continuous flow of the materials by gravity. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through chute. Such information is useful in sizing motor requirement for grain transportation and handling *et al*[12]. Physical properties of paddy have been investigated and reported by several researchers[4,5,6,7,8,11,12,14,15,18,20,24,25,28]. However, a comprehensive study of the physical properties of paddy grain is needed. Present study was conducted to determine the physical properties of paddy such as linear dimension, sphericity, aspect ratio, equivalent diameter, surface area, volume, porosity, thousand kernel weight, bulk density, true density, static coefficient of friction and angle of repose.

MATERIAL AND METHODS

The determination of various physical properties of paddy varieties was done using standard techniques. The Chhattisgarh Madhuraj Paddy-55 (Chaptigurmatiya), Hanthipanjra, and Mahamaya paddy grains were selected for the present research work. The samples of paddy varieties was procured from Department of Plant Molecular Biology and Biotechnology, Department of Plant Breeding and Genetics and National Seed Project, IGKVV, Raipur (Chhattisgarh). The sample materials were properly cleaned and graded to have a uniform sample.

Physical properties

The different physical properties *viz.*, length, width, thickness, thousand grain mass, geometric mean diameter, aspect ratio, surface area, sphericity, volume, bulk density, true density and porosity. Hundred grains were randomly selected and their three principle dimensions (length, width and thickness) were measured using a vernier calliper to an accuracy of 0.01 cm. The 1000 grain mass was determined by selecting different thousand grains counted manually and were recorded for their corresponding weights by the use of digital weighing balance with an accuracy of 0.001 g. The average value of three replications was taken. The geometric mean diameter also known as the equivalent diameter of rice sample was determined by using the following equation[17, 23].

Geometric Mean Diameter, $D_g = (LBT)^{1/3}$ (1)

Where, L = grain length (cm), B = grain width (cm), and T = Grain thickness (cm)

Aspect ratio is the ratio of width to length of grains, which was determined by using this expression. The surface area (S_a)

was calculated using the relationship given by McCabe *et al*[16]. The sphericity ϕ, defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface of the grain, was determined as[17].

$$\text{Aspect ratio, } R_a(\%) = \frac{\text{Width, cm}}{\text{Length, cm}} \times 100 \quad (2)$$

$$\text{Surface Area, } S_a = \pi (D_g)^2 \quad (3)$$

$$\text{Sphericity, } \phi = \frac{(LBT)^{1/3}}{L} \times 100 \quad (4)$$

Bulk density (ρb), the ratio of sample weight to its total volume, was determined by filling a 100 ml graduated cylinder with known quantity of sample. The cylinder was gradually tapped few times and recorded for its volume[17]. True density was determined by adding 10 g of paddy grains in 20 ml toluene in 100ml measuring cylinder. The final volume was noted and true volume of paddy sample was determined from the difference. The true density of the sample was expressed as the ratio of weight of sample and the true volume, g/ml; [7]. Porosity depends both on bulk and true density and the same quantities are employed for its calculation as per following equation[17]:

$$\text{Bulk density, (g/ml)} = \frac{\text{Weight of grains, g}}{\text{Volume occupied by grains, ml}} \quad (5)$$

$$\text{True density, (g/ml)} = \frac{\text{Weight of grains, g}}{\text{True volume, ml}} \quad (6)$$

$$\text{Porosity} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100 \quad (7)$$

Frictional Properties

The angle of repose for the grain was determined by the method suggested by Waziri and Mettal[26]

$$\text{Angle of repose, } \theta = \tan^{-1} \frac{2H}{D} \quad (8)$$

Where, H and D = height of the cone and diameter of circular disc in mm

The static coefficient of friction through horizontal method was calculated from following equation[9].

$$\text{Coefficient of static friction} = \frac{W1 - W2}{W1}$$

Where, W1 = Weight of empty sliding box, (gm), W2 = Weight of sliding box which is filled with grains, (gm) and W = Weight of grains, (gm)

RESULTS AND DISCUSSION

A summary of the results of the determined physical parameters is shown in Table 1, 2 and 3, respectively. The initial moisture content of the paddy varieties namely Madhuraj, Hanthipanjra and Mahamaya at the time of experiment was 11.81 ± 0.39 % (wb), 11.23 ± 0.26 % (wb), and 11.05 ± 0.16 % (wb). In paddy varieties the average values of length was found 8.47, 11.15 and 9.40 mm and width 2.95, 3.17 and 2.88 mm and thickness 2.13, 2.30 and 2.18 mm for Madhuraj, Hanthipanjra and Mahamaya paddy varieties respectively. The average value of bulk density of paddy varieties was found 593.56, 527.29 and 615.96 kg/m^3 for Madhuraj, Hanthipanjra and Mahamaya. The average value of true density of paddy varieties was found 1093.98, 1039.86 and 1058.48 kg/m^3 for Madhuraj, Hanthipanjra and Mahamaya. The average value of porosity of paddy varieties was found 45.72, 49.28 and 41.69 % for Madhuraj, Hanthipanjra and Mahamaya. The average value of angle of repose (AOR) of paddy varieties was found 32.69, 29.85 and 32.98(degree) for Madhuraj, Hanthipanjra and Mahamaya. The average value of coefficient of friction of the paddy varieties for Madhuraj, Hanthipanjra and Mahamaya varieties 0.45, 0.35 and 0.42 for glass surface and 0.41, 0.38 and 0.38 for plywood. Similarly, 0.78, 0.63 and 0.64 for mild steel surface respectively.

Table 1: Physical properties of different varieties of paddy

Parameters	Variety	Replication	Max	Min	Mean	Standard deviation
Length (mm)	Madhuraj	100	9.2	7.37	8.47	0.34
	Hanthipanjra		11.72	10.79	11.15	0.21
	Mahamaya		10.01	8.53	9.40	0.37
Width (mm)	Madhuraj	100	3.28	2.48	2.94	0.13
	Hanthipanjra		3.34	2.93	3.17	0.09
	Mahamaya		3.16	2.54	2.88	0.12
Thickness (mm)	Madhuraj	100	2.26	1.90	2.13	0.07
	Hanthipanjra		2.41	2.07	2.30	0.06
	Mahamaya		2.30	1.89	2.18	0.07
GMD (mm)	Madhuraj	100	3.96	3.51	3.75	0.08
	Hanthipanjra		4.45	4.16	4.33	0.06
	Mahamaya		4.08	3.67	3.89	0.09
Aspect Ratio (%)	Madhuraj	100	42.02	29.21	34.78	2.22
	Hanthipanjra		30.43	26.21	28.45	1.06
	Mahamaya		36.18	25.67	30.75	1.90
Sphericity	Madhuraj	100	49.11	40.88	44.36	1.54
	Hanthipanjra		40.19	37.04	38.82	0.74
	Mahamaya		44.72	38.06	41.47	1.29
Surface area (mm^2)	Madhuraj	100	49.27	38.61	44.23	1.87
	Hanthipanjra		62.07	54.40	58.89	1.62
	Mahamaya		52.36	42.34	47.66	2.31
Volume (mm^3)	Madhuraj	100	33.27	23.15	28.43	1.83
	Hanthipanjra		47.26	38.79	43.65	1.84
	Mahamaya		36.25	26.12	31.60	2.31
L/B ratio	Madhuraj	100	3.42	2.38	2.89	0.18
	Hanthipanjra		3.82	3.29	3.52	0.13
	Mahamaya		3.89	2.76	3.26	0.20

Table 2: Means comparison of thousand grain mass, bulk density, true density, porosity and angle of repose for different varieties used in the experiments

Variety	Thousand grain mass (gm)	Bulk density (gm/ml)	True density (gm/ml)	Porosity	Angle of repose
Madhuraj	26.56	593.56	1093.98	45.72	32.69
Hanthipanjra	47.02	527.29	1039.86	49.28	29.85
Mahamaya	35.84	615.96	1058.48	41.69	32.98

Table 3: Static coefficient of friction of paddy on different frictional surfaces

Variety	Glass	Plywood	Mild steel
Madhuraj	0.45	0.41	0.78
Hanthipanjra	0.35	0.38	0.63
Mahamaya	0.42	0.38	0.64

CONCLUSIONS

Current experiments and investigation concludes that the Madhuraj variety was found very similar to Mahamaya variety which shows this variety was good and adoptable for industrial and various purposes i.e for puffing and flaking based on its linear dimension of physical parameters. The Hanthipanjra variety has more better result of physical properties compared to Madhuraj and Mahamaya variety based on linear dimension, which indicates it provides more longer and thinner sized by-products of paddy used for flaking. It has been observed that all the physical, gravimetric and frictional properties of different paddy varieties were significant differences in values. Chhattisgarh Madhuraj (Low Glycaemic Index rice) is a highly beneficial variety can serve as a healthy substitute for the various conventional rice varieties. Based on the above conclusions it can be claimed that Madhuraj and Hanthipanjra variety were good substitute

for making by-products such as flakes and puffed rice, based on its physical and frictional properties after Mahamaya variety available in the market.

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