Evaluation of Some Physical and Engineering Properties of Chhattisgarh Popular Paddy Varieties for Suitability of Flaked Rice (POHA)

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A B S T R A C T

Designing the equipment for processing, sorting, sizing and other post-harvesting equipment of agricultural products requires information about their physical properties. The objective of this work was to determine some of the physical properties of three different type of rice variety which may influence the rice processing operations. In this study, various physical properties of rough rice variety were determined at a moisture content of about 12% (dry basis). In the case of Rajeshwari variety, the average thousand kernel weight, geometric mean diameter, surface area, volume, sphericity, aspect ratio, true density, bulk density and porosity were 21.64 g, 4.08 mm, 49.38 mm^2, 39.01 mm^3, 41.38%, 30.03%, 1350.43 kg/m^3, 695.77 kg/m^3, and 48.51%, respectively. The corresponding values were 30.28 g, 3.43 mm, 38.13 mm^2, 23.03 mm^3, 28.50%, 25.21%, 1110.47 kg/m^3, 580.18 kg/m^3, and 47.74% for Durgeshwari variety and 35.54 g, 3.74 mm, 44.02 mm^2, 28.16 mm^3, 40.42%, 30.13%, 1056.86 kg/m^3, 615.12 kg/m^3, and 42.23% for Mahamaya variety. Rajeshwari variety, the average static coefficient of friction varied from 0.24 on glass to 0.36 on plywood, while for Durgeshwari variety the corresponding value varied from 0.25 on glass to 0.44 on plywood and for Mahamaya variety, varied from 0.25 to 0.40 for the same surfaces. Angle of repose values for Rajeshwari, Durgeshwari and Mahamaya variety were 34.58°, 30.80 and 33.31° respectively.

Introduction

The grain, called rice (*Oryza sativa* L.) for more than 8000 years, has been the companion of human kind. It is the most important food commodity in Asia, particularly in South and South-East Asia, where more than 90% of rice is produced and consumed. Paddy (*Oryza sativa L.*) is a major food grain in India. It is

grown under wide agro-climatic conditions. Several varieties of paddy are being grown in the world. India produces varieties of rice depending upon the climate, cultivation situation, rainfall and socio-economic factors and such as numerous varieties of paddy are produced India. However, there are over 7,000 varieties of rice around the world. Before the rice grain is consumed, paddy undergoes

several post harvest operations. The maximum recovery of head rice, yield and the quality of rice depends mainly on the variety of paddy as well as the parboiling characteristics of paddy.

Rice is a regular component of the African diet, usually consumed as a whole grain; which contributes more to the total calorie intake. In the major rice consuming countries, rice quality dictates the market value of the commodity and plays an important role in the development and adoption of new varieties (Juliano, 2003; Fitzgerald *et al.,* 2009). A significant variation in physical, milling and cooking quality has been shown among rice varieties produced in different parts of world due to diverse genetic and environmental factors (Singh *et al.,* 2005; Izawa, 2008).

Paddy (*Oryza sativa L.*) is one of the most important staple food crops which is a major source of nutrients in many parts of the world. Paddy is second largest major cereal crop a member of grass family (Graminaceae), which produces starchy seeds. Rice is used as an important staple food by the people in many parts of the world after wheat. Rice is used as a source of nourishment for more than half of the world's population (Dahare *et al.,* 2017).

Physical properties of rice varieties are important factors that have to be considered when designing equipment for handling, conveying, separation, dehusking, drying and storage. The grain weight, diameter, surface area, bulk density, thickness, length and width of rice variety have to be factored into the design and optimal performance of grain threshing machines (Simonyan *et al.,* 2007). The principal axial dimension of grain is useful in power calculation for milling and in selecting sieve sizes for optimal separation (Singh *et al.,* 2015), while bulk density values are useful in determining the size of grain hoppers and storage facilities.

The paddy grain is made up of hull or husk (l8 - 28%) and the caryopsis or the brown rice (72 - 83%). The brown rice consists of a brownish outer layer (pericarp, tegmen and aleurone layers) called the bran (5 - 8%), the germ or embryo (2 - 3%) connected on the ventral side of the grain, and the edible portion endosperm, (89 - 94%) (Ray Lantin, 1999). Apart from production the success of rice industries depends on the milling quality of rice. According to the qualities of rice, it is used for different industrial purpose. Chalky, medium, bold rice is more preferred by *"Poha"* Industries, than translucent for rice grain varieties having translucent character fine, slender, with better Head Rice Recovery (HRR) are preferred. HRR is an important trait of rice makes the variety important for industrial purpose. If in any variety HRR is more it has better economic importance, but this trait varied within the varieties if grown in different seasons.

Milling is an important unit operation in rice processing as the accuracy of milling largely determines the market value. Milling consists of the removal of husk and bran to obtain the edible portion (endosperm) to a level that is acceptable and suitable for human consumption (Singh *et al.,* 2015)

Practical applications

The machinery and operations when improperly designed may generate rice kernel cracking and breakage and consequently a low marketing price. The knowledge of the physical properties of the agricultural products is of fundamental importance during the harvesting of grains, transporting, design and dimensioning of correct storage procedure, manufacturing and operating different equipments used in post harvesting main processing operations of these products (Ghadge *et al.,* 2008a). Information related to porosity and specific gravity, within other

physical characteristics of the agricultural products, are of paramount importance for studies involving heat and mass transfer and air movement through the bulk grain. Effect of different processing methods on physical characteristics of whole pigeon pea (Ghadge *et al.,* 2008b).

The different processing methods affect the physical characteristics of whole legume. Faster reconstitution of precooked, frozen and cabinet dried samples was due to increased porosity as indicated by lowest bulk density and relatively higher water absorption and higher sedimentation values. Higher sedimentation value also indicates higher dispersability, which reveals the importance of physical properties. Therefore, the objective of present study was to evaluate some evaluation of some physical and engineering properties of Chhattisgarh popular paddy varieties for suitability of flaked rice (*poha*).

Materials and Methods

This work was carried out in the Department of Agricultural Processing and Food Engineering, located at the SV College of Agricultural Engineering and Technology and Research Station, India Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

Sample preparation

The rice (*Oryza sativa* L.) of variety Rajeshwari, Durgeshwari and Mahamaya paddy was procured from Indira Gandhi Agricultural University, Raipur. The kernels were cleaned in an air classifier to remove lighter foreign matter such as dust, dirt, chaff, immature and broken kernels. The initial moisture content of the kernels was determined using hot air oven method (Gupta and Das, 2000).

Physical properties

The dimensional characteristics of the material are called size. To determine the average size of the grain, a sample of 100 randomly selected grains were used. Their three principal dimensions, length (L), width (W) and thickness (T) were measured using a digital vernier caliper having the least count of 0.01 mm.

The geometric mean diameter, D_g of the particle is also called as the "equivalent diameter". The D_g of the paddy grains was calculated using the following relationship (1) (Mohsenin, 1980; Sahay and Singh, 2007).

$$D_g = (LWT)^{\frac{1}{3}}$$

Nomenclature

List of symbols				
L	Length		P_t	True density
W	Width		P_b	Bulk density
T	Thickness		P	Porosity
D_g	Geometric mean diameter		θ	Angle of repose
R_a	Aspect ratio		μ	Static coefficient of friction
S	Sphericity			

Sphericity is defined as the ratio of surface area of sphere having same volume as that of the seed. Sphericity of the grain was determined by using following equation (2) (Mohsenin, 1980).

$$\varphi = \frac{(LWT)^{1/3}}{L}$$

Aspect ratio is the ratio of width to length of grains. Aspect ratio (R_a) of the grain was determined by using following equation (3) (Maduako and Faborode, 1990; Bhattacharya, 2010).

$$R_a = \frac{Width\ (mm)}{Length\ (mm)}$$

Volume, Surface Area and L/B ratio were determined by following relationships (McCabe *et al.,* 2005).

$$V = \frac{\pi(LWT)}{6} = \frac{\pi D_g^3}{6}$$
$$S = \pi D_g^2$$
$$\frac{L}{B}\ ratio = \frac{Length\ (mm)}{Width\ (mm)}$$

Thousand kernel weight, true density, bulk density and porosity

The 1000 grain/kernel weight was determined by selecting different lots of 1000 sound grains by counting from a general lot. Weighing them using electronic balance. The average value of three replicate was taken.

The kernel density of kernel is defined as the ratio of mass of seed to the solid volume occupied (Deshpande *et al.,* 1993). The seed volume was determined using liquid displacement technique. Toluene was used in spite of water so as to prevent the absorption during measurement and also to get the benefit of low surface tension of selected solvent (Sitkei, 1986; Ogut, 1998). Kernel density was evaluated using the methods suggested by (Williams *et al.,* (1983). The porosity (ε) of bulk seed was computed from the values of kernel density (ρt) and bulk density (ρb) using the following equation (7) given by Mohsenin (1986).

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad .....2$$

Frictional properties of samples

Angle of repose

The angle of repose is the angle with the horizontal at which the material will stand when pile. This was determined by using topless and bottomless cylinder of 20 cm diameter and 30 cm height. The cylinder was placed at the centre of a raised circular plate having a diameter of 20 cm and filled with the paddy grains. The cylinder was raised slowly until it formed a cone on the circular plate. The height of the cone was measured and the angle of repose was calculated by using the following formula (Razavi and Millani, 2006).

$$\theta = \tan^{-1}\left[\frac{2H}{D}\right] \quad ......6$$

Static coefficient of friction

The static coefficient of friction of paddy grains of different varieties was measured. The static coefficient of friction of paddy grains were determined on 3 different structural materials, namely, plywood, mild steel sheet and glass. The experimental apparatus used in the coefficient of static friction studies of a frictionless pulley on a frame, an open-ended rectangular metallic box (8×8×4 cm) to contain the sample, loading pan and test surfaces (Visvanathan *et al.,* 1996).

The grains are filled in a metallic box which is place on a table. A flat plate of the material chosen for friction test is taken and allowed to rest on the surface of the seeds filled box. A known weight is placed over the plate to exert normal force, N over the surface of the seeds in contact with the surface of the plate. Weights were then added to the loading pan until the container began to slide. The weight

of the seeds and the added weights comprise the normal force and frictional force, respectively. The static coefficient of friction was calculated from following equation (Dabbi and Dhamsaniya, 2010).

$$\mu_s = \frac{F}{N}$$

Statistical analysis

In the present study, all results are find out using spread excel sheet and results are expressed as mean and standard deviation (S.D.).

Results and Discussion

A summary of the results for all the parameters measured and determined is shown in following three Tables. The moisture content of the kernels at the time of experiment was $12.43 \pm 0.20\%$ dry basis. The moisture content found can help to suggest the stability in storage of rice.

Physical properties

The length (L) of paddy ranged from 9.34 ± 0.40 mm, 9.21 ± 0.50 mm and 9.26 ± 0.37 mm for varieties of Rajeshwari, Durgeshwari and Mahamaya paddy variety respectively. The width (W) of paddy ranged from 2.75 ± 0.16 mm, 2.41 ± 0.12 mm and 2.79 ± 0.13 mm for the varieties of Rajeshwari, Durgeshwari and Mahamaya paddy variety respectively. The thickness (T) of paddy ranged from 2.45 ± 0.12 mm, 1.83 ± 0.12 and 2.03 ± 0.07 mm for varieties of Rajeshwari, Durgeshwari and Mahamaya paddy variety respectively (Table 1).

The sphericity of paddy, indicate central tendency. The values of sphericity ranged from 41.93 ± 1.61 %, 28.50 ± 1.63 % and 40.42 ± 1.29 % for varieties of Rajeshwari, Durgeshwari and Mahamaya paddy variety respectively. The aspect ratio (R_a) of paddy ranged from 30.06 ± 2.20 %, 25.21 ± 1.63 % and 30.13 ± 1.90 % for varieties of Rajeshwari, Durgeshwari and Mahamaya paddy variety respectively (Table 1). The lower sphericity values thus suggest that the kernels tend towards a cylindrical shape (Omobuwajo *et al.,* 2000). Thus, the lower values of the aspect ratio and sphericity generally indicate a likely difficulty in getting the kernels to roll than that of peas like spheroid grains. They can, however, slide on their flat surfaces. This tendency to either roll or slide should be necessary in the design of hoppers for milling process. However, the surface area ranged from 49.38 ± 3.43 mm^2, 38.13 ± 2.83 mm^2 and 44.02 ± 2.32 mm^2 for varieties of Rajeshwari, Durgeshwari and Mahamaya paddy variety respectively. The surface area is a relevant tool in determining the shape of the seeds. This will actually be an indication of the way the kernels will behave on oscillating surfaces during processing (Alonge and Adigun, 1999).

Gravimetric properties

The thousand kernel weight of paddy varieties namely Rajeshwari, Durgeshwari and Mahamaya paddy varieties, was found to be 31.64 ± 0.49 g, 30.28 ± 0.83 g and 35.54 ± 0.68 g (Table 2). Weight is an important parameter to be used in the design of cleaning grains using aerodynamic forces (Oje and Ugbo, 1991). The true density of Rajeshwari, Durgeshwari and Mahamaya paddy varieties varies between 1350.43 ± 0.21 kg/m^3, 1110.47 ± 0.13 kg/m^3 and 1056.86 ± 0.15 kg/m^3 respectively. The true density was higher in Rajeshwari and the lower value of true density in Durgeshwari paddy variety. The value of true density indicates that, the kernel density is higher than water, which is the important property in case of food grains during wet cleaning, as kernel does not float on water. The porosity values of Rajeshwari, Durgeshwari and Mahamaya paddy varieties vary between $48.51\pm1.25\%$, $47.74\pm2.86\%$ and $42.23\pm2.84\%$ respectively.

Table.1 Dimensional properties of different varieties of paddy

Parameters	Rajeshwari	Durgeshwari	Mahamaya
Length (mm)	9.34 ± 0.40	9.21 ± 0.50	9.26 ± 0.37
Width (mm)	2.75 ± 0.16	2.41 ± 0.12	2.79 ± 0.13
Thickness (mm)	2.45 ± 0.12	1.83 ± 0.12	2.03 ± 0.07
Geometric mean diameter (mm)	4.08 ± 0.11	3.43 ± 0.14	3.74 ± 0.09
Aspect ratio (%)	30.06 ± 2.20	25.21 ± 1.63	30.13 ± 1.90
Sphericity (%)	41.93 ±1.61	28.50 ± 1.28	40.42 ± 1.29
Surface area (mm$^{2)}$)	49.38 ± 3.43	38.13 ± 2.83	44.02 ± 2.32
Volume (mm^3)	39.01 ± 3.25	23.03 ± 3.36	28.16 ± 2.31
L/B ratio	3.29 ± 0.18	4.28 ± 0.24	3.32 ± 0.20

Mean ± Standard deviation values

Table.2 Gravimetric properties of different varieties of paddy

Parameters	Rajeshwari	Durgeshwari	Mahamaya
Thousand kernel wt. (gm)	31.64 ± 0.49	30.28 ± 0.83	35.54 ± 0.68
Bulk density (kg/m^3)	695.77 ± 0.05	580.18 ± 0.03	615.12 ± 0.07
True density (kg/m^3)	1350.43 ± 0.21	1110.47 ± 0.13	1056.86 ± 0.15
Porosity (%)	48.51 ± 1.25	47.74 ± 2.86	42.23 ± 2.84

Mean ± Standard deviation values

Table.3 Frictional properties of different varieties of paddy

Parameters	Rajeshwari	Durgeshwari	Mahamaya
Angle of repose (°)	34.58 ± 0.73	30.80 ± 0.45	33.31 ± 0.48
Coefficient of friction (Glass)	0.24 ± 0.04	0.25 ± 0.04	0.25 ± 0.02
Coefficient of friction (Plywood)	0.21 ± 0.03	0.26 ± 0.04	0.26 ± 0.03
Coefficient of friction (MS)	0.36 ± 0.04	0.44 ± 0.03	0.40 ± 0.02

Frictional properties

The frictional properties examined for the kernels are the angle of repose and the coefficient of static friction. Essentially, the angle of repose for Rajeshwari, Durgeshwari and Mahamaya paddy varieties lies between 34.58±0.73^0, 30.80±0.45^0 and 33.31±0.48^0 respectively. The value of angle of repose was higher in Rajeshwari and was lower in Durgeshwari paddy variety. This phenomenon is imperative in food grain processing, particular in the designing of hopper for milling equipments. The value of coefficient of static friction was found 0.25±0.04 on glass, 0.26±0.04 on plywood and 0.44±0.03 on mild steel for Durgeshwari variety and for Rajeshwari paddy variety, the values of coefficient of static friction was 0.24±0.04 on glass, 0.21±0.03 on plywood and 0.36±0.04 on mild steel. Similarly, the value of coefficient of static friction was 0.25±0.02 on glass, 0.26±0.03 on plywood and 0.40±0.02 on mild steel for Mahamaya paddy variety (Table 3). This fact was expected because the milling operation makes the grain surface smoother which agrees with (Mohsenin, 1986), who affirm that the friction and

consequent are affected mainly by nature and types of surface in contact. This investigation into the properties of grains gives rise to a number of conclusions. This study concludes with information on engineering properties of Rajeshwari, Durgeshwari and Mahamaya paddy variety which may be useful for designing much of the equipment used for rice processing. The static coefficient of friction was highest for mild steel, followed by plywood and glass. The static coefficient of friction and angle of repose is necessary to design conveying machine and hopers used in planter machines**.** The physical properties of the paddy grain are very essential for designing and development of process machineries, feed hoppers, storage structure, material handling equipments and packaging purpose. For making good quality of flaked rice we need to good quality of paddy in all attributes like paddy should be large, and bold size of grain In this investigation, we found that the all attribute like dimensional, gravimetric and frictional characteristics is good result for Rajeshwari paddy varieties followed by Mahamaya and Durgeshwari at all time. So, we recommend in future we can make flaked rice with the Rajeshwari paddy variety in instead of Mahamaya paddy variety.

Acknowledgement

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