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RESEARCH ARTICLE

STUDIES ON PHYSICAL PROPERTIES OF SELECTED VARIETIES OF PARBOILED RICE POPULAR IN CHHATTISGARH FOR RICE PUFFING

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ABSTRACT

This study was undertaken to generate useful information regarding the physical properties of parboiled rice. Under this study, three parboiled rice varieties, namely IR1010, *Mahamaya* and *Swarna* were selected, which are commonly used for the preparation of puffed rice in the Chhattisgarh state of India. Physical properties, namely length, width, thickness, geometric mean diameter, arithmetic mean diameter, surface area, sphericity, aspect ratio, thousand grain weight, angle of repose, bulk density, true density, porosity, and coefficient of friction on different surfaces, were investigated. A slight variation in the length, width, and thickness was observed due to the varietal differences. The aspect ratio was nearly similar for all three varieties. The mean value of thousand grain weights and angle of repose for IR1010, *Mahamaya* and *Swarna* varieties were found to be 23.40 g, 24.67 g, 22.73 g, and 27.68°, 24.15°, and 24.80°, respectively. The true and bulk densities of IR1010 were slightly lower as compared to *Mahamaya* and *Swarna.* A similar trend was also observed for porosity. In the *Swarna* variety, lower coefficient of friction was observed as compared to IR1010 and *Mahamaya.* The present study will be beneficial in fabricating machines for the parboiled rice processing industry, such as puffing, flaking, etc., which would be helpful in eliminating various losses during processing and the development of quality products.

INTRODUCTION

Paddy (*Oryza sativa* L.) is a semi-aquatic monocot cereal crop belonging to the Gramineae family and widely domesticated for cultivation. The starchy kernel obtained after dehusking paddy serves as a common culinary ingredient for a major segment of the population in India and abroad. The world's major rice-producing countries are China, India, Indonesia, Bangladesh, and Vietnam, and 90 percent of the world's rice cultivation area belongs to Asian countries. It is a popular staple meal in many nations throughout the world, particularly in Asia, and Africa but less so in the European Union (Kumar and Prasad, 2018). The parboiling process is a big share of the global rice processing industry. It was reported that about one-fifth of the world's rice is parboiled (Bhattacharya, 1985). Parboiling is a hydrothermal treatment given to rough rice to produce nutritionally rich rice. This process consists of soaking, steaming, and drying. As a result, the physicochemical properties of the rice are changed, which affects the milling quality, nutritional value, and storability of the grain.

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This treatment also leads to the final product of the cooked parboiled rice having a favourable texture for those who eat it (Islam *et al*. 2001). Though a large number of rice cultivars are available, people prefer only certain varieties specific for each purpose, like the preparation of cooked rice, puffed rice, rice flakes (flattened rice), idli, and dosai (Thayumanavan and Sadasivam, 1984). Physical properties of biological materials are important while designing the equipment and machines for different unit operations such as cleaning, sorting, grading, separation, milling, grinding, heating and cooling, roasting, puffing, transportation, and storage, etc. Without considering physical properties, a poorly designed machine may lead to poor functioning quality and reduced efficiency. Loss of raw material is also possible in such poorly designed machines. Product quality may also deteriorate if the machine is developed without prior knowledge of the engineering properties of grains. These reasons all ultimately lead to significant commercial losses. Only a limited amount of work has been done to study the physical properties of parboiled rice; hence, this study was undertaken to provide useful information to machine manufacturers and end users about the physical properties of three popular varieties of parboiled rice.

MATERIALS AND METHODS

Materials: Three varieties of parboiled rice, namely *Mahamaya, Swarna,* and IR1010, were obtained from the local market in Raipur city. The study was carried out using only analytical grade reagents.

Moisture content: The moisture content of parboiled rice was determined following the standard oven drying method (AOAC, 2010). The test sample of 5 g was kept in a hot air oven at 105 ± 2°C for 24 hours. The sample was removed from the oven after 24 hours or until a constant weight of ± 0.001 g was achieved and placed in desiccators to cool to room temperature. The weight of the sample was then precisely measured. The moisture content was calculated using the following expression:

$$\text{Moisture content (\%, wb)} = \frac{W_1 - W_2}{W_1} \times 100$$

$$\text{Moisture content (\%, db)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,
W_1 = Initial weight of sample, g
W_2 = Final weight of sample, g

Principal dimensions: The principal dimensions, *viz.*, length (L), width (W), and thickness (T), of a single parboiled rice kernel were determined using a digital vernier calliper (Mitutoyo Corporation, Japan) with an accuracy of 0.01 mm. To eliminate dimensional error, measurements were repeated for 20 randomly selected parboiled rice kernels, and the result was represented as mean ± SD (Swarnakar *et al.*, 2014; Kumar *et al.*, 2017; Saha and Roy, 2022).

Geometric mean diameter: The geometric mean diameter (D_g) of parboiled rice kernels was calculated using the pre-determined values of its length (L), width (W), and thickness (T) using the following relationship described by Mohsenin (1996); Kumar *et al.* (2017); Saha and Roy (2022).

$$D_g = (LWT)^{1/3}$$

Where,
D_g = Geometric mean diameter, mm
L = Length, mm
W = Width, mm
T = Thickness, mm

Thousand grain weight: The thousand grain weight of parboiled rice was determined by randomly selecting one thousand sound rice kernels and weighting them accurately using an analytical balance (Shimadzu, Japan, accuracy of 0.0001 g). Three determinations were performed, and the average was recorded (Joshi, 2014; Kamaraddi and Prakash, 2015).

Sphericity: The sphericity (ϕ) of a single kernel of parboiled rice was calculated using the grain length (L), width (W), and thickness (T) as per the following equation described by Mohsenin (1996); Kumar *et al.* (2017); Saha and Roy (2022).

$$\phi = \frac{(LWT)^{1/3}}{L} \times 100$$

Where,
ϕ = Degree of sphericity, %
L = Length, mm
W = Width, mm
T = Thickness, mm

Surface area: The surface area (S_a) of a single kernel of parboiled rice was calculated using the pre-determined value of the geometric mean diameter using the following relationship (McCabe *et al.*, 1996; Kumar *et al.*, 2017; Saha and Roy, 2022).

$$S_a = \pi(D_g)^2$$

Where,
S_a = Surface area, mm^2
D = Geometric mean diameter, mm

Aspect ratio: Aspect ratio is defined as the ratio of width (W) to length (L) of the single kernel. The aspect ratio of parboiled rice was calculated using the following relationship (Saha and Roy, 2022).

$$\text{Aspect ratio} = \frac{W}{L}$$

Where,
W = Width, mm
L = Length, mm

Bulk density: The bulk density of parboiled rice was determined using the weight by volume method. The sample of parboiled rice was taken in a 100 ml measuring cylinder up to a known height and recorded as the volume of particulates (kernels). The sample was then weighed precisely using an analytical balance. The ratio of the weight of the sample to the volume occupied is expressed as the bulk density and calculated using the following relationship (Kumar *et al.*, 2017; Saha and Roy, 2022).

$$\text{Bulk density } (g/cm^3) = \frac{\text{Weight of sample (g)}}{\text{Volume occupied by the sample } (cm^3)}$$

True density: The true density of parboiled rice was determined by the liquid (toluene) displacement method as suggested by Saha and Roy, 2022. The true density of the sample was calculated as the ratio of the weight of the sample to its true volume as give below

$$\text{True density } (g/cm^3) = \frac{\text{Weight of grain (g)}}{\text{True volume } (cm^3)}$$

Porosity: Porosity is the ratio of the volume of pores between the particle to its bulk volume. It was calculated as the ratio of the difference in true density and bulk density to the true density and determined using the following relationship (Kumar *et al.*, 2017; Saha and Roy, 2022).

$$\text{Porosity} = \frac{\text{True density - Bulk density}}{\text{True density}}$$

Angle of repose: The angle of repose for the parboiled rice was determined by the method suggested by Basavaraj *et al.*

(2015) and Kumar *et al.* (2017). The angle of repose was determined by the following relationship

$$\theta = \tan^{-1}\frac{2H}{D}$$

Where,

θ = Angle of repose, °
H = Height of the cone, mm
D = Diameter of the circular disc (cone base), mm

Coefficient of friction: The coefficient of static friction for parboiled rice was determined against three different surfaces (mild steel sheet, glass, and aluminium sheet). Its determination was done following the procedure laid out by Basavaraj *et al.* (2015). The coefficient of friction was calculated from the following relationship (Eqn. 11).

$$\mu = \tan\alpha$$

Where,
μ = Coefficient of static friction
α = Angle of tilt in degrees

RESULTS AND DISCUSSION

Moisture content (M.C.): The initial moisture content of the parboiled rice varieties IR1010, *Mahamaya,* and *Swarna* at the time of experiment was 10.91 ± 0.47, 10.55 ± 0.14 and 9.90 ± 0.05% (wb), respectively, and corresponding values on a dry basis are presented in Table 1.

Table 1. Physical properties of parboiled rice varieties

Physical properties	Variety of parboiled rice		
	IR1010	*Mahamaya*	*Swarna*
Moisture content (% wb)	10.91± 0.47	10.55 ± 0.14	9.90 ± 0.05
Moisture content (% db)	12.25± 0.59	11.80 ± 0.18	10.99 ± 0.06
Length, mm	6.73 ± 0.30	6.91 ± 0.28	6.97 ± 0.28
Width, mm	2.43 ± 0.14	2.56 ± 0.15	2.55 ± 0.17
Thickness, mm	1.83 ± 0.10	1.84 ± 0.10	1.85 ± 0.08
AMD, mm	3.66 ± 0.12	3.77 ± 0.12	3.79 ± 0.12
GMD, mm	3.10 ± 0.10	3.19 ± 0.10	3.20 ± 0.09
Sphericity, degree	46.12 ± 1.53	46.20 ± 1.61	45.96 ± 1.38
Surface area, mm^2	30.26 ± 1.91	32.02 ± 2.10	32.22 ± 1.88
Aspect ratio	0.36 ± 0.02	0.36 ± 0.02	0.37 ± 0.03
TGW, g	23.40 ± 0.26	24.67 ± 0.21	22.73 ± 0.31
Angle of repose, degree	27.68 ± 1.63	24.15 ± 0.99	24.80 ± 0.77
Bulk density, g/ml	0.83 ± 0.02	0.85 ± 0.01	0.84 ± 0.01
True density, g/ml	1.39 ± 0.04	1.43 ± 0.01	1.43 ± 0.01
Porosity	0.40 ± 0.01	0.41 ± 0.01	0.41 ± 0.01

Length, width and thickness: The physical dimensions of parboiled rice are an important indicator in determining the quality of the product prepared from it. As in the case of puffed rice, the physical dimension is helpful in getting the optimum elongation ratio. The length, width, and thickness naturally varied widely among varieties of parboiled rice, and the results are presented in Table 1. In this study, the length measured was 6.73 ± 0.30 mm for IR1010, 6.91 ±0.28 mm for *Mahamaya*, and 6.97 ± 0.28 mm for the *Swarna* variety of parboiled rice. The width values measured were 2.43 ± 0.14 mm, 2.56 ± 0.15 mm, and 2.55 ± 0.17 mm for IR1010, *Mahamaya*, and *Swarna*, respectively. Similarly, the thickness values were 1.83 ± 0.10 mm, 1.84 ± 0.10 mm, and 1.85 ± 0.08 mm for IR1010, *Mahamaya,* and *Swarna*, respectively (Table 1). Swarnakar *et al.* (2014) reported similar findings with the average values of length, width, and thickness of IR-36 parboiled rice kernels being 6.652, 2.304, and 1.794 mm, respectively.

Arithmetic mean diameter (AMD) and Geometric mean diameter (GMD): Arithmetic mean diameter was found with a mean value of 3.66 ± 0.12 mm, 3.77 ± 0.12 mm, and 3.79 ± 0.12 mm for IR1010, *Mahamaya,* and *Swarna*, respectively (Table 1). The mean value of geometric mean diameter was found to be 3.10 ± 0.10 mm, 3.19 ± 0.10 mm, and 3.20 ± 0.09 mm for IR1010, *Mahamaya,* and *Swarna*, respectively (Table 1). Kumar and Prasad (2013) have also reported the value of the geometric mean diameter as 2.99 mm for the parboiled rice.

Sphericity: Table 1 shows that the mean value of sphericity was 46.12 ± 1.53°, 46.20 ±1.61°, and 45.96 ± 1.38° for IR1010, *Mahamaya,* and *Swarna*, respectively. The lower sphericity values suggested that the rice tends towards a cylindrical shape. The lower values of sphericity also indicate a probable difficulty in moving rice when compared to pea like spheroid grains. This tendency to either slide or roll is necessary to consider while designing the hoppers of the machines. A similar finding has been reported by Kumar and Prasad (2013) for parboiled rice.

Surface area: The surface area of three parboiled rice varieties, namely, IR1010, *Mahamaya*, and *Swarna,* was 30.26 ± 1.91 mm^2, 32.02 ± 2.10 mm^2, and 32.22 ± 1.88 mm^2, respectively (Table 1). The surface area is a relevant property to determine the shape of the seeds. This is an indication of how rice grains behave on oscillating surfaces during processing. Kumar and Prasad (2013) have reported a surface area of 28.10 mm^2 for parboiled rice.

Aspect ratio: Interestingly, it was found that all three varieties of parboiled rice have nearly similar values of aspect ratio. It was 0.36 ± 0.02 for IR1010 and *Mahamaya*, and 0.37 ± 0.03 for *Swarna.* Similar finding has also been reported by Kumar and Prasad (2013) with an aspect ratio value of 36.77 for parboiled rice.

Thousand grain weight: The average value of the thousand grain weight of all three varieties of parboiled rice was 23.40 ± 0.26 g, 24.67 ± 0.21 g, and 22.73 ± 0.31 g for IR1010, *Mahamaya,* and *Swarna,* respectively. Joshi *et al.* (2014) observed the thousand grain weight of 12 different varieties of Indica rice and reported the value in the range of 11.52-21.14 g.

Angle of repose: The mean value of the angle of repose was 27.68 ± 1.63°, 24.15 ± 0.99°, and 24.80 ± 0.77° for IR1010, *Mahamaya,* and *Swarna* varieties of parboiled rice, respectively. This is imperative in grain processing, particularly in the design of hoppers for processing machines.

Swarna ***Mahamaya*** **IR-1010**

Fig.1. Three varieties of parboiled rice

Bulk and true density: The average bulk density value of parboiled rice varieties was determined as 0.83 ± 0.02 g/ml, 0.85 ± 0.01 g/ml, and 0.084 ± 0.01 g/ml for IR1010, *Mahamaya,* and *Swarna,* respectively. The mean value of true density was 1.39 ± 0.04 g/ml for IR1010 and 1.43 ± 0.01 g/ml for *Mahamaya* and *Swarna*. These properties are important when designing storage structures and conveying machines. Similar results were also found by Joshi *et al.* (2014), with a bulk density of 0.76 g/ml and a true density of 1.43 g/ml for the GR-6 variety of rice.

Porosity: The porosity of parboiled rice was calculated by using bulk and true density, and the mean value of porosity was 0.40 ± 0.01 for IR1010 and 0.41 ± 0.01 for *Mahamaya* and *Swarna*. This property indicates the volume occupied by the air between the particles compared to a unit volume of grain. Biswal *et al.* (2018) reported the porosity value of rice used for puffing as 43.83%.

Table 2. Mean values of coefficient of friction of parboiled rice varieties

Physical properties	Variety of parboiled rice		
Coefficient of Friction	IR1010	*Mahamaya*	*Swarna*
Glass	0.18 ± 0.01	0.17 ± 0.01	0.16 ± 0.02
Aluminium sheet	0.20 ± 0.01	0.19 ± 0.01	0.18 ± 0.01
Mild steel (MS)sheet	0.28 ± 0.01	0.26 ± 0.01	0.26 ± 0.01

Coefficient of friction: The values of the coefficient of friction of all three varieties of parboiled rice on different surfaces are shown in Table 2. The mean value of the coefficient of static friction on the glass surface was 0.18 ± 0.01, 0.17 ± 0.01, and 0.16 ± 0.02 for IR1010, *Mahamaya,* and *Swarna,* respectively. Its value on the surface of aluminium sheet was 0.20 ± 0.01, 0.19 ± 0.01, and 0.18 ± 0.01 and for MS sheet it was 0.28 ± 0.01, 0.26 ± 0.01, and 0.26 ± 0.01 for IR1010, *Mahamaya,* and *Swarna,* respectively. These values for different materials affirm that friction and, consequently, its coefficient are affected mainly by the nature and type of the surface in contact. Kumar and Prasad (2013) reported that the coefficient of friction for parboiled rice on glass, galvanised iron, and ply surfaces was 0.416, 0.435 and 0.440, respectively.

CONCLUSION

The physical properties of three varieties of parboiled rice, namely IR1010, *Mahamaya,* and *Swarna,* were measured at a moisture content of 12.25%, 11.80%, and 10.99% (db), respectively. A slight variation in the length, width, and thickness was observed due to the varietal differences. Accordingly, differences in the calculated values, arithmetic mean diameter, geometric mean diameter, surface area, and sphericity, were also observed; however, the aspect ratio was nearly similar for all three varieties. The mean value of thousand grain weights and angle of repose was between 22.73 and 24.67 g and 24.15 and27.68°, respectively. The true and bulk densities of IR1010 were slightly lower as compared to *Mahamaya* and *Swarna.* A similar trend was also observed for porosity. The true density and porosity value of *Mahamaya* and *Swarna* are similar. *Mahamaya*and *Swarna* have similar coefficients of friction for MS sheet surfaces; however, for MS sheet, higher value was observed for all the three varieties. In the *Swarna* variety, a lower coefficient of friction was observed as compared to IR1010 and *Mahamaya.*

Physical characteristics are important in many problems associated with the design of a specific machine or the analysis of the behaviour of the product in handling the material. All three varieties used in this study are commonly used for puffed rice preparation; hence, this study may be beneficial in designing the machinery for puffed rice and other similar products.

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