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RESEARCH NOTE

Study on physical properties of IR-64 rice (*Oryza sativa* L.) at different thermal conditions

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A study was conducted to determine some of the physical properties of IR-64 rice.Standard procedures were followed for determination of the physical properties of IR-64 rice variety having initial moisture content of 11% (w.b.). The grains were conditioned for three different moisture levels (22, 24 and 26%w.b.). The results revealed that the length, width and thickness of IR-64 rice variety ranged from 6.42 to 7.28 mm, 1.78 to 2.36 mm and 1.72 to 1.89 mm, respectively. The geometric mean diameter varied from 2.69 to 3.15 mm and the arithmetic mean diameter varied from 3.30 to 3.84 mm. The surface area and unit volume ranged from 22.73 to 31.17 mm^2 and 3.27 to 5.41 mm^3, respectively. The sphericity and aspect ratio were observed to be in the range of 41.90 to 45.22 percent and 27.72 to 32.41 per cent, respectively. The bulk density, true density and porosity were found to be ranged from 782.52 to 715.33 kg. m^{-3}, 1204.33 to 1279.63 kg. m^{-3} and 38.16 to 49.23 percent, respectively whereas the thousand grain weight varied from 18.45 to 23.65 g.

Key words: Moisture content, Physical properties, Rice

Paddy is the most important and extensively grown food crop in the world. It is one among the three leading food crops of the world namely, rice, wheat and maize. Paddy *(Oryza sativa* L.) is the second largest major cereal crop, a member of grass family (*Germinaceae*), which produces starchy seeds. Although grown practically in all continents, climates and altitudes, about 90 per cent of the world's rice crop is grown as well as consumed in East, South-East and South Asia. The United States Department of Agriculture (USDA) estimates that the world rice production in 2019-20 is 497.86 million metric tonnes. In India, paddy has been cultivated since ancient period and is the staple food for 65 per cent of the population in India (Anon., 2018-19).

The paddy production in Karnataka during 2017-18 with anarea of 9.92 lakh hectares was 29.07 lakh tonnes with an average yield of 2.93 tonnes per hectare. Hyderabad-Karnataka region is considered as the rice bowl of Karnataka. The net area in the region during 2017-18 under paddy was 3.83 lakh hectares with a production of 12.99 lakh tonnes and an average yield of 3.01 tonnes per hectare. (Anon., 2017-18).

Processing of paddy plays an important role in the economy of the farmers of this region. Paddy varieties namely, Sona massuri (BPT-5204), RNR, Kaveri etc., are being processed either in the form of raw rice or parboiled rice. The rice variety (IR-64) is mainly processed in to puffed rice. Puffed rice is considered to be a better option for those who are trying to lose weight as it is low in calorie and highly nutritious, contains no cholesterol or sodium. It is also known to provide minerals like potassium, iron, phosphorus, calcium and trace amounts of zinc, manganese, fluoride and selenium with vitamin B- thiamine, riboflavin, niacin, pantothenic acid. Due to the absence of gluten, puffed rice can easily take over the place in bakery foods that cause discomfort especially people suffering from celiac disease. The nutrition status of puffed rice was found to be 76.92 g of carbohydrate, 6.49 g of protein, 0.94 g of fat, 0.91 g of dietary fibre and 0.46 percent of ash (Khan *et al.,* 2017).

Puffed rice is being produced in cluster of small units often located in urban areas. Among various states in India, Karnataka state has largest number of clusters of puffed rice making unit. Most of the processing units in Karnataka are either small or cottage based industries. It is estimated that there are about 2000 such units in Karnataka state and the major clusters are situated in Davanagere, Hubballi, Dharwad, Raichur and Belagavi (Raviteja *et al.,* 2015).

Presently, puffed rice is produced by employing sand roasting method, which is unhygienic and adding pollutants to the environment. It is very much necessary to develop an alternative method/equipment that suffices food safety aspects and eco-friendly. The design of different components of rice puffing unit requires important physical properties of IR-64 rice variety which have not been reported. In this context, a study was carried out to explore some of the physical properties of IR-64 rice grain for design of a rotary drum type of rice puffing machine.

The IR-64 rice variety selected for the present study was procured from local market of Raichur, Karnataka and other equipments required for the determination of physical properties were availed from the Department of Processing and Food Engineering, College of Agricultural Engineering, Raichur.

Conditioning of rice

During puffing operation conditioning of raw rice is important.Rice conditioning is a hydrothermal treatment carried out to expel out any air voids inside the rice kernel and to maintain optimum moisture content of kernel.The process flowchart adopted for conditioning of rice is as under (Hoke *et al*., 2005).

Raw rice with moisture content 11% w.b.

↓

Addition of water (60, 70 and 80 mL.200g^{-1}) and salt (5 g)

↓

Mixing thoroughly to obtain conditioned rice having MC 22, 24 and 26%(w.b.)

↓

Drying in shade for 9 h and heaping overnight (tempering)

Process flow chart for conditioning of raw rice

Moisture content

According to standard procedure of AOAC methods 2005, 5g of the sampletaken in a container was recorded as W_1. The

box was placed in the hot air oven at 105°C for 24 h. After drying, the box was kept in the desiccators for around 10-15 min and then weighed. The mass of the dried sample was recorded as W_2. All measurements were triplicate and average value of moisture content was calculated. The moisture content of the sample was calculated by using the following equation and expressed in percentage.

$$\text{Moisture content \% (w.b.)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Initial weight of sample, g

W_2 = Final weight of sample, g

Shape and size

Shape and size are inseparable for any physical object and both are generally necessary if the object has been satisfactorily described. The shape of the raw and conditioned rice was determined by measuring the longitudinal and lateral diameters using the digital vernier caliper having a least count of 0.01 mm. The dimensions were compared with the shapes as described in the standard chart (Mohsenin,1986).The average size of rice was calculated from randomly selected 100 rice grains in terms of their linear dimensions such as length, width and thickness.

Size measurement affects behaviorof grain during handling, processing, storage and helps in designing the machine (Tiwari *et al.,* 2017).The size of IR-64 rice was determined using following equation.

$$\text{Size} = (\text{length} \times \text{width} \times \text{thickness})^{1/3}$$

Geometric mean diameter

The geometric mean diameter (Dg) (considering a spheroid shape for a rough rice grain) was calculated by using the following expression.

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

Where,

D_g = Geometric mean diameter, mm

L= Length, mm

W= Width, mm

T = Thickness, mm

Sphericity

Sphericity is defined as the ratio of the diameter of a sphere of the same volume as that of the object to the diameter of the smallest circumscribing sphere. IR-64 rice was calculated by using the following formula (Sahay and Singh, 2012).

$$\text{Sphericity} = \frac{(L \times W \times T)^{\frac{1}{3}}}{L}$$

Surface area

The surface area of rice sampleswere determined by analogy with a sphere of same geometric mean diameter using the following relationship (Sahu *et al.,* 2014).

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

Where,

S = Surface area, mm^2

D_g = Geometric mean, mm

Unit volume and aspect ratio

The unit volume and aspect ratio of raw and conditioned rice grain were calculated by using the following equations (Wani *et al.,* 2014).

$$\text{Unit volume (V)} = \frac{(L \times W \times T)}{6}$$

$$\text{Aspect ratio } (R_a) = \frac{W}{L}$$

Where,

R_a =Aspect ratio

V = Unit volume, mm^3

Bulk density

The bulk density of the agricultural produce plays an important role in many applications such as grain hoppers and storage structures (Heridarbeigi *et al*., 2009). The bulk density of raw and conditioned rice of variety IR-64 was determined by using a container of known volume. The container was weighed using electronic balance. The bulk density was calculated by using the following formula (Mohsenin, 1986).

$$\text{Bulk density } (kg.m^{-3}) = \frac{\text{Weight of material (kg)}}{\text{Volume of material including pore space } (m^3)}$$

True density

The apparatus used for measuring the true density of raw and conditioned rice consists of a 100 mL measuring jar and a weighing balance. 50 mL of toluene was taken in a measuring jar. A known weight (10 g) of rice was poured into the measuring jar and rise in the toluene level was recorded as the true volume of the rice grains without void space. The true density of rice grain was calculated by using the following formula (Mohsenin, 1986).

$$\text{True density } (kg.m^{-3}) = \frac{\text{Weight of material (kg)}}{\text{Change in Volume of totuene } (m^3)}$$

Porosity

The porosity is the percentage of volume of voids in the test sample at given moisture content. The porosity of raw and conditioned rice was calculated as the ratio of the difference in true and bulk densities to the true density value and expressed in percentage and it was calculated by using the following equation (Kenghe *et al*., 2013).

$$\text{Porosity } (\varepsilon) = \frac{P_t - P_b}{P_t} \times 100$$

Where,

ε = Porosity, %

ρ_t= True density, kg. m^{-3}

ρ_b= Bulk density, kg. m^{-3}

Thousand grain weight

The weight of 1000 raw and conditioned rice grains was determined by measuring the weight of randomly taken 100 grains by using an electrical balance and then multiplying by 10 to obtain the weight of 1000 raw and conditioned rice (Amin *et al.,* 2004).

The mean values of moisture content (w.b.) for raw and conditioned rice of variety IR-64 are presented in Table 1 and the values were found to be 11% for raw rice and 22, 24, 26% for conditioned rice.

The moisture content of raw rice procured from the local market was found to be 11% and it was increased to 22, 24 and 26% (w.b.) afterconditioning of rice used for puffing purpose. The increase in moisture content after conditioning was due to the addition of water during conditioning process to the raw rice. A similar result of moisture content of (10 to 14%) was observed by Kibar *et al.* (2010) for Osmancik-97 variety of rice.

Shape and size

The shape of raw and conditioned rice was found to be oval. The average values of linear dimensions *viz*., length, width and thickness of raw and conditioned rice were found to be 6.42, 1.78 and 1.72 mm for raw rice, 6.61, 2.12 and 1.80 mm for rice having moisture content of 22%, and 6.65, 2.15 and 1.88 mm for 24% and 7.28, 2.36 and 1.89 mm for 26%, respectively.

The variation in linear dimension of rice at different moisture contentsis shown in Fig.1. The size increased with the increase in the moisture content and the trend found has been similar to the finding reported by Kibar *et al*. (2010) for rice grain which showed an increase in length from 8.27 mm to 9.01 mm, width from 3.10 mm to 3.48 mm and thickness ranging from 2.05 mm to 2.26 mm. The change in dimensions of rice could be due to the increase in moisture uptake in the intracellular space within the grains due to soaking process.

Geometric mean diameter

The mean values of geometric mean diameter were found to be 2.69 mm for raw rice and 2.95 mm, 2.98 mm and 3.07 mm for conditioned rice after having moisture content of 22%, 24% and 26%, respectively.

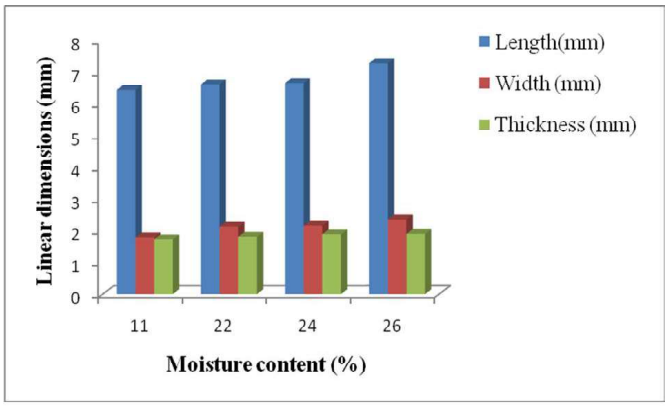

Fig. 1. Effect of moisture content on linear dimensions of IR-64 rice

The values of geometric mean diameter obtained from the linear dimensions of rice ranged from 2.69 to 3.15 mm in the geometric mean diameter there was an increasing in the geometric mean diameter after increasing moisture content. The recorded values were similar to the findings of Kibar *et al*. (2010) for rice variety Osmancik-97 in which it was reported that, there was an increase in geometric mean diameter from 3.75 mm to 4.13 mm as the moisture content increased from 10 to 14%. There was slight difference between the experimental and literature values, this might be due to the varietal differences of the rice.

Arithmetic mean diameter

The mean values of arithmetic mean diameter of raw and conditioned rice were computed and presented in the table. The results were found to be 3.30 mm for raw rice and 3.51 mm, 3.56 mm and 3.84 mm for conditioned rice after having moisture contents of 22%, 24% and 26%, respectively.

The mean values of arithmetic mean diameter of raw rice ranged from 3.30 to3.76 mm. similar changes in arithmetic mean diameter with the increase in moisture content were found by Kibar *et al*. (2010) for Osmancik-97 rice variety (4.47 to 4.92 mm). There was difference between the experimental and literature values for arithmetic mean diameter at different moisture contents might be due to the varietal differences of the rice.

Table1. Physical properties of raw and conditioned rice

Parameters	Raw rice	Conditioned rice			Mean	SD
Moisture content (%) (w.b.)	11	22	24	26	20.83	6.54
Physical properties						
Length (mm)	6.42	6.61	6.65	7.28	6.74	0.37
Width (mm)	1.78	2.12	2.15	2.36	2.10	0.24
Thickness (mm)	1.72	1.80	1.88	1.89	1.82	0.08
Geometric mean diameter (mm)	2.69	2.93	2.99	3.15	2.94	0.19
Arithmetic mean diameter (mm)	3.30	3.51	3. 56	3.84	3.55	0.27
Surface area (mm^2)	22.73	26.97	28.08	31.17	27.24	3.49
Unit volume (mm^3)	3.27	4.20	4.47	5.41	4.34	0.88
Bulk density (kg. m^{-3})	782.52	730.20	719.56	715.33	736.90	31.05
True density (kg. m^{-3})	1204.33	1264.10	1272.00	1279.63	1255.02	34.38
Porosity (%)	38.16	42.62	45.27	49.23	43.82	4.65
Thousand grain weight (g)	18.45	21.58	23.46	23.65	21.79	2.41
Shape	Oval	Oval	Oval	Oval	-	-

Sphericity

Average values of sphericity for raw and conditioned rice were found to be 41.90, 44.32, 44.96 and 45.22 for moisture contents of 22, 24 and 26%, respectively.

The experimental results of sphericity of rice increased with the increase in moisture content as shown in Fig. 2. The rice has the mean values of sphericity of 41.90 at 11% MC and 46.58% with respect to moisture content ranging from 22 to 26%. Results obtained by Kibar *et al*. (2010) reported the sphericity of rice in the range of 43 to 46%.

Surface area

The mean value of surface area of raw rice was found to be 22.73 mm^2 and the values were 26.97 mm^2, 28.08 mm^2 and 31.17 mm^2 for conditioned rice after having moisture content of 22, 24 and 26 %, respectively.

The results indicated that the surface area of rice was found to be increased with respect to the increase in moisture content from 22 to 26 %. The higher surface area could be due to the change in major dimensions of the rice. Due to water absorption similar increasing trend (38.68 to 46.91 mm^2) in surface area was reported by Kibar *et al*. (2010).

Aspect ratio

The average value of aspect ratio for raw rice was found to be 27.72 and 32.07, 32.26 and 32.41 for conditioned rice at moisture contents of 22, 24 and 26%, respectively. The aspect ratio of rice at different moisture contents varied from 27.72 to 33.12 and is presented in Fig.2. It indicated that there was an increase in aspect ratio with the increase in moisture content. Similar to trend in aspect ratio was reported by Tiwari *et al*. (2017).

Unit volume

The mean value of unit volume of raw rice was found to be 3.27 mm^3 at 11% moisture content and for conditioned rice at 22%Moisturecontent, it was found to be 4.20, 4.47 mm^3 at 24% moisturecontentand5.41 mm^3at 26% moisture content.

As the moisture content increased, the average unit volume of rice was also increased. Similar increasing trend (from 9.9 to 13.9 mm^3) was observed by Tiwari *et al*. (2017) for brown rice

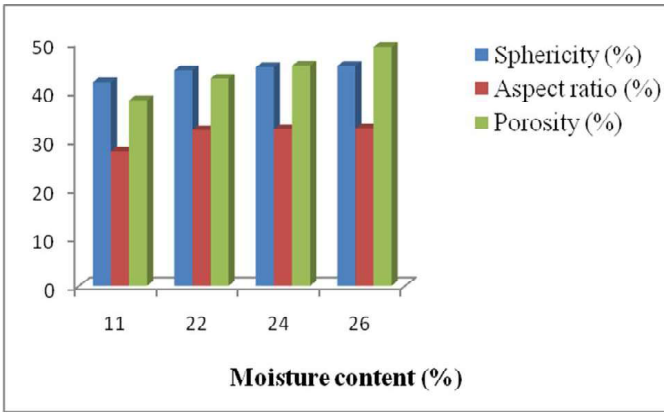

Fig 2. Effect of moisture content on Sphericity, Aspect ratio and Porosity of IR-64 rice

and difference in this experimental and literature values might be due to varietal difference. The volume is dependent on their linear dimensions hence the change in linear dimensions reflected of the change in volume too.

Bulk density

It was observed from the Table 1 that the bulk density decreased with the increase in moisture content and the values were found to be 782.52 $kg.m^{-3}$ for raw rice and 730.20 kg. m^{-3} for conditioned rice at 22% moisture content, 719.56 $kg.m^{-3}$ for conditioned rice containing moisture of 24% and 715.33 kg m^{-3} for conditioned rice containing a moisture content of 26%.

The results indicated a decreasing trend in bulk density with the increase in moisture content This decrease in bulk density might be due to the fact that, the increase in mass due to increase in moisture contend was lower than that of volumetric expansion of bulk grains. The values for bulk density reported by Kibar *et al*. (2010) showed similar decreasing trend for rice (595.5 to 560.5 kg. m^{-3}).

True density

The experimental results in respect of true density were found to be 1279.63 kg m^{-3} for raw rice and that of conditioned rice 1272 kg. m^{-3}, 1264.10 kg m^{-3} and 1204.33 kg. m^{-3} at moisture contents of 22, 24 and 26%, respectively.

The true density values decreased from 1279.63 to 1204.33 kg. m^{-3} for raw and condition rice when the moisture content increased from 11 to 26%. The results obtained were in accordance to the results of Kibar *et al*. (2010) for rice (939.0 to 962.1 kg m^{-3}). The relative reduction in the density at high moisture content could be attributed to the less increase in grain weight due to the added moisture in relation to the concomitant volumetric expansion of the grains.

Porosity

The experimental results (Table 1.) for porosity of rice were found to be increased linearly with the increase in moisture content. The porosity values were found to be 38.16 % for raw rice and 42.62 % for rice having moisture content of 22 %, 45.27 % for rice having moisture content of 24 % and 49.23 % for conditioned rice having moisture content of 26 %.

The porosity of rice was found to be increased linearly (38.16 to 49.23 %) with the increase in moisture content as shown in Fig 2. Kibar *et al.* (2010) reported a similar increasing trend in porosity from 36.61 to 41.97 %. The porosity depends on the bulk as well as true densities; the magnitude of variation in porosity depends on these factors only.

Thousand grain weight

It can be seen from Table 1. that the numerical mean values of thousand grain weight of raw and conditioned rice having moisture content 22, 24, 26% were found to be 18.45 g and 21.58, 23.46 and 23.65 g, respectively.

The weight of 1000 grains was dependent on moisture content and increased linearly from 18.45 to 23.65 g with the increase in moisture content. Tiwari *et al*. (2017) reported similar

increasing trend in 1000 grain weight as the moisture increased and the values were found to be increased from 23.27 to 25.30 g.

Conclusion

The present investigations concluded that the physical properties determined for raw and conditioned rice showed that moisture content of 26 % resulted in larger rice grain size (7.28 mm) as compared to 24 % (6.65 mm), 22% (6.64 mm) and raw (6.42 mm) grain. The shape of the grains was angular for raw and conditioned rice. The maximum linear dimensions for rice like length, width and thickness were observed to be 7.28, 2.36 and 1.89 mm at 26, 24 and 22% moisture content, respectively.

The surface area and unit volume were observed to be highest at 31.17 mm^2 and 5.41 mm^3 for 26% moisture content conditioned rice. The bulk density and true density were highest for raw rice at 11% moisture content (782.52 kg m^{-3}) and (1279.63 kg m^{-3}), respectively.

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