International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; SP-8(6): 422-426

https://www.mathsjournal.com
Received: 26-08-2023
Accepted: 01-09-2023

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Studies on physical properties of rice varieties

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Abstract
Physical properties of three different varieties of paddy were measured which helps in designing the equipment's for application in plantation, harvesting, transportation, storage and processing operations of rice. The length, width and thickness of the varieties JR 206 (V1) are 6.74 mm, 2.35 mm, 1.81 mm, MTU 1010(V2) are 6.94 mm, 2.15 mm, 1.86 mm, and JR 81(V3) are 7.06 mm, 2.10 mm, 1.76 mm respectively. The L/B ratio, size, volume and test weight are 2.86, 3.06, 15 and 21.4 g for V1, 3.23, 3.02, 14.52 and 22.2 respectively for variety V2, 3.36, 2.96, 13.66 and 20.8 g respectively for variety V3. Sphericity ranges from 41.9 to 45.4 percent which revealed that the grains could not be considered as spherical in shape. Bulk density and true density 768, 778, 746 kg/m^3 and 1376.43, 1434.33 and 1323.83 kg/m^3 respectively.

Keywords: Paddy, rice, moisture content, size, shape, volume, density

Introduction
Rice (*Oryza sativa* L.) has occupied the position of one of the leading food crops of the world and is the staple food of over approximately one half of the world's population. (Singh *et al*., 2003) [2]. Rice is widely cultivated throughout the world and is the second most important cereal crop in terms of cultivation after wheat.

Rice is a unique major food crops of the world by virtue of the extent and variety of its uses and its adaptability to a broad range of climate and cultural condition. It is usually grown under shallow floods or "wet paddy" conditions. Although rice appears to have a high-water requirement, it is not much different from that of other field crops. Unlike most cereal crops, however, rice benefits from standing water. It has capability of anaerobic respiration and has aerenchyma tissue in the aerial organs through which oxygen diffuses to the roots. It is a member of Poaceae family and its domestication started from ancient civilization native to Southeast Asia.

Rice is consumed principally as a whole grain and the texture of the whole grain is a matter of great concern. Rice quality of great importance for all people involved in producing, processing and consuming rice, because it affects the nutritional and commercial value of grains.

Rice contains starch (77%), protein (8.9%), minerals (0.17%). The oil content of brown rice is 2-3% and almost the entire oil is present within an outer thin layer (Sharma, 2012) [3]. The vitamins are more in the bran layers than outer parts of the seed (FAO, 1964). By calculation, 65% of thiamine of brown rice is in the bran, 13% in the polish, 22% in the milled rice fraction. Corresponding values of riboflavin are 39% of the bran, 8%of the polish, 53%of the milled rice fraction (Juliano, 1985) [2].

The old popular traditional milling machine i.e, huller produces about 20-40% head rice with 20-30% broken, this is a great loss. The modern rice mill produces about 62-65% HR depending upon variety. China is the largest producer, accounting for 30%of the production, followed by India (24%), Bangladesh (7%), Indonesia (7%), Vietnam (5%) and Thailand (4%). In terms of consumption: China is the largest consumer (29% of global consumption), followed by India (21%), Bangladesh (7%), Indonesia (7%), Vietnam (4%), and the Philliphines (3%).

Export patterns are little different from the 44 million of tons of milled rice exported in 2019/2020, India is the top exporting country with 13 million of tons, accounting for 30% of global exports. India is the 2nd largest rice producer in the world after China, with more than 11% of the global production. The world's largest rice producers as far are China and India. Although its harvested area is lower than India's, China's rice production is greater due to higher yields because nearly all of the China's rice area is irrigated, whereas less than half of India's rice area is irrigated.

Using the population projection from the United Nations and income projections from the Food and Agricultural Policy Research Institute (FAPRI), global rice demand is estimated to rise from 439 million tons (milled rice) in 2010 to 496 million tons in 2020 and further increase to 555 million tons in 2035.

This is an overall increase of 26% in the next 25yrs, but the rate of growth will decline from 13% for the first 10yrs to 12% in next 15yrs as population growth drops and diversity from rice to other foods.

The marketing value of rice as an agricultural product depends on its physical qualities after processing.to design equipment's for application in plantation, harvesting, transportation, storage and processing operations of rice, the knowledge of various physical and mechanical properties as a function of moisture content is important.

Classification of rice

Recommended model for grading system in International trade (FAO/WHO) -1) SIZE (according to length of kernel - L) - Extra-long (L>=7.0 mm), Long
(L=6.0-6.99 mm), Medium (L=5.0-5.99 mm) &Short (L<5.0mm).
2) SHAPE (according to length/width ratio - L/B) - Long - slender or Superfine
(L/B>3.0), Medium - slender or Fine (bold) (L/B=2.0-3.0) & Short-slender or Common (round) (L/B<2.0).
3) WEIGHT (at 14% m.c.) - Extra-heavy (test wt.>25 gm), Heavy (test wt.= 20
25 gm) and Moderately heavy (test wt.<20gm).

Materials and Methods

Sample collection

The laboratory experiment was conducted in the Department of Post -Harvest Processing and Food Engineering, J.N.K.V.V, Jabalpur (M.P). For this purpose, paddy samples of three varieties namely JR 206, MTU 1010 and JR 81 were procured from the Department of Plant Breeding and Genetics. The procured samples are stored in the cotton bags at room temperature for analysis.

Physical properties of paddy

To study the following physical properties one hundred seeds were randomly selected to determine the size and shape of the rice kernels of different samples. Three principal linear dimensions namely length (l), width (w) and thickness (t) were measured using a digital dial gauge (accuracy-0.01 mm).
Length: The largest intercept of the kernel at resting position,
Breadth: The largest intercept perpendicular to the length, and
Thickness: The largest intercept perpendicular to the length and breadth.
Then length breadth ratio, size, sphericity, volume, thousand grain weight and engineering properties including Angle of repose, bulk density, true density, and porosity was investigated.

L/B ratio

In India most of the rice varieties grouped on the basis of L/B ratio are Common (<2,5), Fine (<3), Superfine (>3) respectively. Size and shape of the rice affects many other properties, namely, sieving, dehusking, polishing, storage and cooking.

Size

Size and shape are important physical properties. Size measurement analysed behaviour of grain during handling, processing, storage and designing the machinery using the following expression. Similarly, shape is also a dimensionless parameter and can be described in terms of length, width, thickness or diameter size.

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

$$\text{Size} = (L \times B \times T)^{\frac{1}{3}}$$

Sphericity

Sphericity(ϕ) is defined as the ratio of the surface area of the sphere, which has the same volume has the same volume as that of the solid, to the surface area of the solid. Higher values of sphericity and roundness indicate that the object's shape is closer being spherical.

$$\Phi = \frac{(L \times B \times T)^{\frac{1}{3}}}{L^3}$$

Volume

The unit volume of the rice kernels was calculated by the following relationship (Varnamkhasti *et al*.,2007) [5]:

$$\text{Volume (V)} = \frac{\pi \times l \times b \times t}{6}$$

Where
V = unit volume in mm^3
l, b, t = length, breadth and thickness in mm.

Thousand grain weight

In handling and processing of grains, it is customary to know the weight of 1000 grain kernels. The 1000 grain weight is a good indicator of the grain size, which can vary relative to growing conditions and maturity, even for the same variety of a given crop. Thousand grain weight of different paddy varieties can be determined by counting 100 grains and weighing them on a weighing balance and then multiplying them with a factor of 10 (Yadav *et al*., 2007) [6].

Density

The density of the grains used in the design of storage bins and silos, separation of desirable materials from impurities, cleaning and grading, evaluation of the grain maturity etc.
The bulk density of cereal grains is determined by measuring the weight of a grain sample and placing it in a cylinder and volume of the cylinder (including voids) is noted down. The bulk density of the grain sample is obtained simply by dividing the weight of the sample by the volume of the container. The bulk density gives a good idea of the storage space required for a known quality of particular grain. From the storage point of view, it is important to determine the effect of moisture content on the bulk density of grains because the bulk density of some grains increase with an

increasing moisture content, whereas, it decreases for some other grains.

$$\text{Bulk density } (\rho b) = \frac{\text{Mass of sample (kg)}}{\text{Total volume } (m^3)}$$

The true density of the rice kernels is the density of grains excluding voids. This was determined by the toluene (C_7H_8) displacement method. In this method, 20ml of toluene was filled in a measuring cylinder and then the same volume of sample that was taken for bulk density was put into the vessel containing 20ml of toluene. The displacement of toluene level in the vessel on putting rice kernels was noted down. The ratio of mass of rice kernels to the volume of displaced toluene gives the true density:

$$\text{True density } (\rho t) = = \frac{\text{Mass of sample (kg)}}{\text{Volume of displaced toluene } (m^3)}$$

Porosity

The porosity of the rice grains refers to the fraction of the pore spaces in the bulk grain that is not occupied by the grain. It is calculated from the values of true density and bulk density by the following relationship:

$$\text{Porosity } (\varepsilon) = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \text{ X } 100$$

Where
True density = ρt
Bulk density = ρb

Results and Discussions

The experiment was stared in the month of January 2021, by procuring cleaned and graded paddy form department of Plant Breeding JNKVV, Jabalpur. Dehusking and polishing was carried out in rice milling lab to prepare brown and different degree polished rice (time). The husk content was determined by using lab model Rubber roll sheller in the laboratory. The husk percentage of different varieties V_1, V_2 and V_3 was found to be 19.5%, 21.22% and 20.74% respectively.

Linear dimensions

Three dimensions *i.e*., length, width, and thickness are the averages of hundred kernels of each variety. The average values of linear dimensions along with the standard deviation are given in Table (1). Length of the kernels of each rice varieties JR 206, MTU 1010 and JR 81 was found to be 6.74 mm, 6.94 mm and 7.06 mm respectively. The width of the kernels was recorded as 2.35 mm, 2.15 mm and 2.10 mm for the three varieties respectively, and the thickness was recorded as 1.81 mm, 1.86 mm and 1.76 mm for three varieties respectively as shown in figure (a).

L/B ratio

The L/B ratio of variety JR 206 was 2.86, grouped to be as fine and MTU 1010, variety with the L/B ratio of 3.23 was grouped as super fine and variety JR 81 with the L/B ratio of 3.36 was also grouped as super fine.

Sphericity

The sphericity of grain was reported in Table (1) along with the standard deviation of each variety. Each value mentioned is an average of hundred grains. The values of sphericity ranged from 41.9 to 45.4 percent which revealed that the grains could not be considered as spherical because the value of sphericity was less than 70 percent (Mayowa *et al*., 2017) [4].

Volume

The calculated values of volumes are reported in Table (1) for every individual grain of each variety by taking the average of thousand grains. The fine variety JR 206 with the L/B ratio of 2.86 has the highest volume of 15 mm^3 amongst all the three varieties. Then, the super fine variety MTU 1010 with L/B ratio of 3.23 has a lower volume of 14.52 mm^3 and the super fine variety JR-81 with the L/B ratio of 2.84 has the lowest volume of 13.66 mm^3.

Test weight

The test weight of raw paddy was different for different varieties (Yadav *et al*., 2007) [6] *i.e*., 21.4, 22.2 and 20.8 for the varieties JR 206, MTU 1010 and JR 81 respectively (Fig.e) which comes under Heavy.

Bulk density

The bulk density was found to be lowest for the variety JR-81 *i.e*., 746 kg/m^3. The value was higher for the variety MTU 1010 *i.e*., 778 kg/m^3 and for variety JR 768 *i.e*., 568.1 kg/m^3 (Fig. f).

True density

The true density of paddy for JR 81, JR 206 and MTU 1010 was determined as 1376.43 kg/m^3, 1434.33 kg/m^3 and 1323.83 kg/m^3 respectively as shown in fig(g).

Porosity

The porosity of the paddy *i.e*., common, fine and super fine varieties depend upon bulk density and kernel density. The calculated values for porosity were 46.02% for JR 206, 47.97% for MTU 1010 and 45.36% for JR 81 respectively fig.(h).

Table 1: Physical properties of paddy varieties

Physical properties	Units	V1	S. D	V2	S. D	V3	S. D
Length	mm	6.74	0.413	6.94	0.38	7.06	0.455
Width	mm	2.35	0.178	2.15	0.09	2.1	0.156
Thickness	mm	1.81	0.063	1.86	0.075	1.76	0.076
Size		3.06	0.179	3.02	0.159	2.96	0.226
Sphericity	%	45.4	2.5	43.5	1.3	41.9	1.1
L/B ratio		2.86	0.322	3.23	0.173	3.36	0.138
Volume	mm^3	15	2.67	14.52	2.35	13.66	3.07
Test weight	gm	21.4	0.4	22.2	0.32	20.8	0.42
Bulk Density	kg/m^3	768	4.5	778	3.2	746	3.4
True Density	kg/m^3	1376.4	1.8	1434.3	1.23	1323.8	3.2
Porosity	%	44.2	0.18	45.77	0.29	43.64	0.08

Note: S. D- Standard Deviation

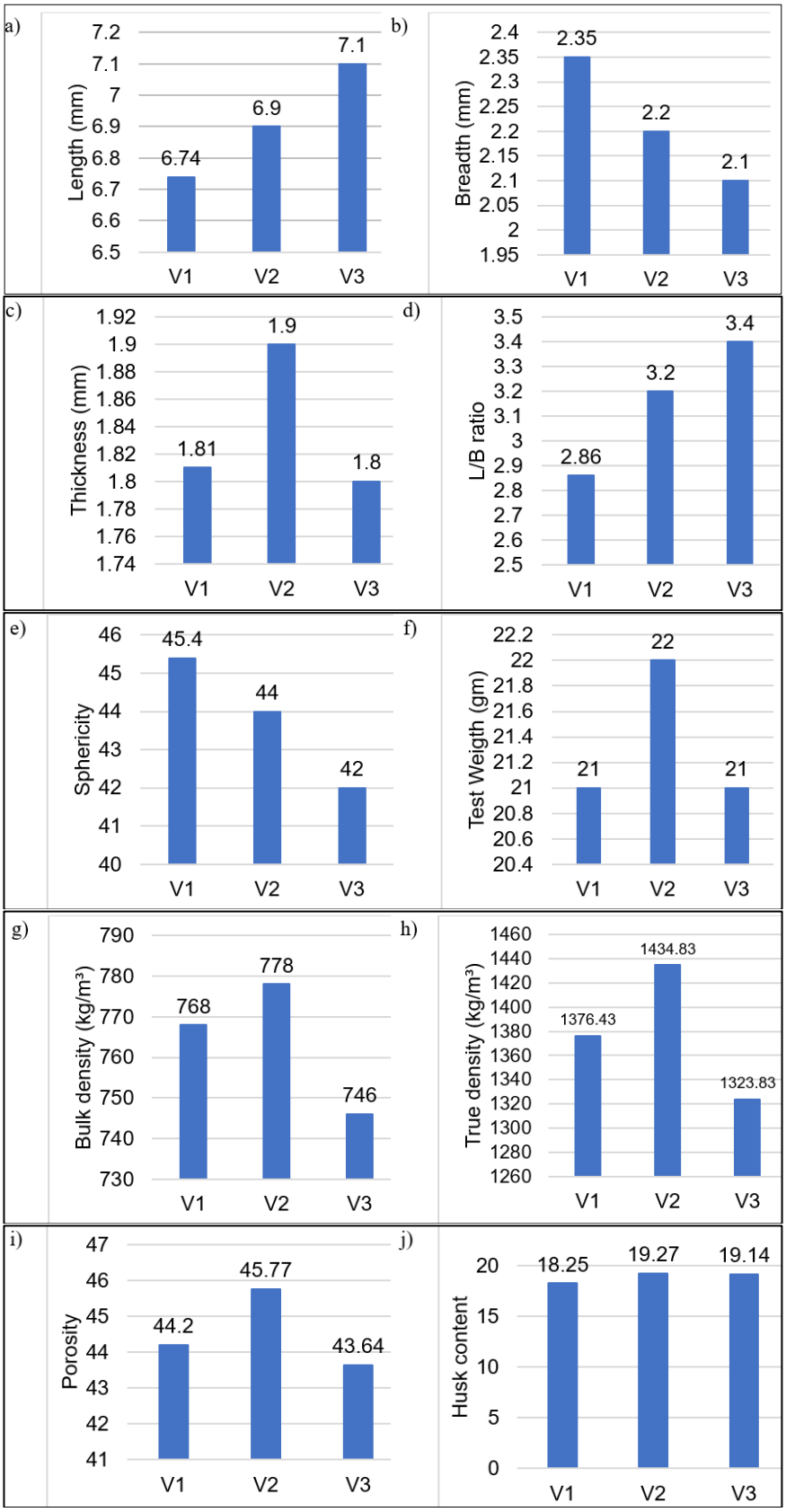

Fig 1: Physical properties of varieties of rice: Linear dimensions a) length, b) breadth, c) thickness, d) L/B ratio, e) Sphericity, f) Test weight, g) Bulk density, h) True density, i) Porosity, and j) Husk content.

Conclusions

1) The physical properties were determined in the laboratory for all the three varieties of paddy:

(a) For the variety V_1 the average length 6.74 mm, width 2.35 mm, thickness 1.81 mm, size 3.06, sphericity 45%, L/B ratio 2.86, volume 15, test weight 21.4 g, bulk density 786 kg/m^3, true density 1376.43 kg/m^3, porosity 44.2% at moisture content 14%.

(b) For the variety V_2 the average length 6.94 mm, width 2.15 mm, thickness 1.86 mm, size 3.02, sphericity 43.5%, L/B ratio 3.23, volume 14.52, test weight 22.2 g, bulk density 778 kg/m^3, true density 1434.83 kg/m^3, porosity 45.77% at moisture content 14%.

(c) For the variety V_3 the average length 7.06 mm, width 2.10 mm, thickness 1.76 mm, size 2.96, sphericity 41.9%, L/B ratio 3.36, volume 13.66, test weight 20.8 g, bulk density 746 kg/m^3, true density 1323.83 kg/m^3, porosity 43.64% at moisture content 14%.

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