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Effect of moisture content on physical properties of paddy (Ratnagiri-7)

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Abstract
The physical properties depend on moisture content of agricultural grains are important to design post harvest equipments. 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. In the current study, various physical properties of paddy Ratnagiri-7 was determined at three moisture content levels of 10, 15 and 20%. The physical properties were found to increase from 10% to 20% M.C. The average length, width and thickness were increased from 8.26mm, 2.38 mm and 1.81 mm to 8.32 mm, 2.60 mm and 1.95 mm. Also size, surface area, volume, sphericity and equivalent diameter were increased from 35.86 mm^3, 36.13 mm^2, 19.14 mm^3, 0.40 and 3.31 mm to 42.09 mm^3, 40.25 mm^2, 22.53 mm^3,0.42 and 3.50 mm respectively. The gravimetric and frictional properties of paddy were also found to increase with increase in moisture content from 10% to 20% moisture content. The bulk density, true density, porosity, angle of repose and thousand grain weight were found to increase from 527.20 kg/m3, 1085.24 kg/m3, 50.17%, 34.37° and 19.46 g to 537.80 kg/m3, 1220.40 kg/m3, 56%, 37.23° and 21.67 g respectively. Static coefficient of friction of paddy against various surfaces namely GI sheet, MS sheet, glass and wooden surface were found to increase from 0.45, 0.62, 0.42 and 0.49 to 0.64, 0.73, 0.50 and 0.64 respectively.

Keywords: Post harvest equipment, three level of moisture content, paddy variety, physical and engineering properties etc.

1. Introduction
Paddy (*Oryza sativa* L.) is one of the most important food crops of the world and is the second emerging crop in India after wheat [11]. Rice is a grain belonging to the grass family. Rice is considered as a critical source of food for more than 3 billion people yearly (Approximately 680 million tons of rice is grown annually, second to wheat for the most food produced around the world [7]. Globally, India stands first position in paddy area and second in paddy production, after China. It contributes 21.5 per cent of global paddy production. It feeds more than 50% of the world's population [12].
The global production of rice has been estimated to be at the level of 500 MT and the area under rice cultivation is estimated 156 million ha. The total area under rice cultivation in India is about 44.11 million ha with a rough rice production of 115.62 million tones. In Maharashtra state, rice is the second important food grain of the people, which grown over an area of 15.57 lakh hectares. Konkan region is a major rice producing area of Maharashtra. Nearly 3.69 lakh ha area of Konkan is under rice crop with rough rice production of 15.70 lakh tones. The average rough rice productivity of the Konkan region is 4.25 t/ha. [1].
There are many varieties of rice cultivated in India. Among them red rice variety (Ratnagiri-7) which is cultivated in Konkan region has many health benefits. Ratnagiri-7 consists of 28.50% (17.35 ppm) and 32.7% (7.9 ppm) high iron content and zinc content in brown and polished rice respectively. It also having low glycemic index (53). Ratnagiri-7 having high milling (64.17%) and head rice recovery percentage (60.65%) with good cooking quality. With the view of these benefits the rice variety Ratnagiri-7 recommended for release for commercial cultivation in Konkan region of Maharashtra in the year 2017. In addition of being nutritive and having medicinal value, red rice possesses many other special features [14]

2. Material and Methods
The paddy Ratnagiri-7, used for this study was obtained from the research station, Vakavali. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Vidyapeeth, Dapoli. The variety used in the current study was variety in Konkan. The variety used in the current study was variety in Konkan. The samples were manually cleaned. The initial moisture content of the samples was determined by oven drying method at 130ºC for 2 h [2].

$$MC, \%(\text{ w.b.}) = \frac{W2-W3}{W2-W1} \times 100 \ldots\ldots\ldots(1)$$

The initial moisture contents of grains 10% for paddy variety Ratnagiri-7, respectively. Samples that their moisture content should be raised were moistened with a calculated quantity of distilled water by using the following Eq. and conditioned to raise their moisture content to the desired two different levels [3]:

$$Q = \frac{W_i(M_f - M_i)}{100 - M_f}$$

In order to obtain three desired level of moisture content below the initial moisture contents, the samples were kept in an oven at a constant temperature greater than 43°C until the desired moisture contents of the samples were obtained [14]. After making three levels of moisture contents, for selected paddy, the samples were poured in polyethylene bags and the bags sealed tightly. All the physical properties of the grains were determined at moisture levels of 10, 15 and 20% for the selected paddy variety.

The length, width and thickness of paddy grains were measured in randomly selected 100 paddy grains. The length, width and thickness of grains were measured using vernier calipers to an accuracy of 0.01 mm.

Size of the seeds (S) was calculated with the following formula proposed by [9]

$$S = L \times W \times T \ldots\ldots\ldots(2)$$

For measuring the Surface area (S) of paddy grain following equation was used to calculate the S [9].

$$S = \frac{\pi BL2}{2L-B} \ldots\ldots\ldots(3)$$

Volume of paddy is given by following equation proposed by [8]

$$V = 0.25[\left(\frac{\pi}{6}\right) L(W+T)^2] \ldots\ldots\ldots (4)$$

Sphericity (Ø) is defined as the ratio of surface area (S) of having same volume (V) as that of the particle to the S of the particle. The sphericity is expressed in percent [9]

$$\varnothing = \frac{(L \times W \times T)^{1/3}}{L} \times 10 \ldots\ldots\ldots(5)$$

The bulk density was calculated by the ratio of the weight of the paddy to the volume of the cylinder container. The hectolitre apparatus was used for determination of bulk density of paddy. Paddy grains were poured into a calibrated container up to its top from a height of about 15 cm. Excess paddy grains were removed by strike-off plate of hectolitre apparatus indicating that volume of remaining of paddy was 1000 cm3. The paddy grains were weighed on an electronic balance; and the bulk density was estimated.

The bulk density was calculated by.

$$\rho b = \frac{M}{V} \ldots\ldots\ldots(6)$$

True density of paddy was determined by the toluene displacement method. In this method, a paddy, was weighed and dropped in 20 ml toluene taken in measuring cylinder of 1000 ml capacity. The increase in volume of sample was noted. The ratio of the mass of sample to the incremented volume gave the true density. The replications were taken and the average value of true density was reported and expressed as kg/m^3.

$$\rho t = \frac{W}{V2 - V1} \ldots\ldots\ldots(7)$$

The porosity of paddy 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:

$$\epsilon = 1 - \frac{\rho t}{\rho b} \times 100 \ldots\ldots\ldots(8)$$

The equivalent diameter of paddy (Dp) in mm was calculated through the following formula [8].

$$Dp = (\, 4L \left(\frac{W+T}{4}\right)^2)^{\frac{1}{3}} \ldots\ldots\ldots(9)$$

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 five replications was taken.

The angle of repose of the paddy was measured which helped to design the hopper and collection unit of rice mill. The angle of repose is the angle made by paddy with the horizontal wooden surface when piled from a known height with help of empty cylindrical cone of particular height and particular diameter. Paddy sample was piled over a horizontal surface. The radius of the pile was calculated from the circumference of the pile and the height of the pile was determined. The angle of repose was calculated using the formula [8].

$$\theta = \tan^{-1} (H/r) \ldots\ldots\ldots(10)$$

The static co-efficient of friction of paddy was determined against four different structural materials namely: plywood, galvanized steel sheet, mild steel sheet and glass. The static angle of friction was recorded when the paddy grains just began to slide. It is given by formula [10].

$$\mu = \tan \alpha \ldots\ldots\ldots(11)$$

The data were analyzed statistically using Microsoft Excel software. The mean and standard deviation of dimensions and other characteristics of paddy grain were determined using Microsoft Excel software program.

3. Results and Discussion

3.1 Grain Dimensions

The effect of moisture content on the three axial dimensions of paddy grain, namely, length, width and thickness is shown

in table 1,2 and 3. As it can be seen, upon moisture absorption, the paddy grain expands in length, width and thickness within the moisture range of 10 to 20% (d.b.). The average length, width and thickness of the 100 grains increased from 8.26mm, 2.38 mm and 1.81 mm to 8.32 mm, 2.60 mm and 1.95 mm, respectively, as the moisture content increased from 10 to 20% (d.b.).

3.2 Size
The variation of size for the paddy grain with moisture content is shown in Table 1, 2 and 3. It can be seen that the surface area of paddy grain increases linearly from 35.86 to 42.09 mm when the moisture content increases from 10 to 20% (d.b.).

3.3 Surface area
The variation of surface area for the paddy grain with moisture content is shown in Table 1, 2 and 3. It can be seen that the surface area of paddy grain increases linearly from 36.13 to 40.25 mm^2 when the moisture content increases from 10 to 20% (d.b.).

3.4 Volume
The variation of volume for the paddy grain with moisture content is shown in Table 1, 2 and 3. It can be seen that the surface area of paddy grain increases linearly from 19.14 to 22.53 mm^3 when the moisture content increases from 10 to 20% (d.b.).

3.5 Sphericity
The average values of the grain sphericity at different moisture contents are presented in table 1, 2 and 3. As shown, the sphericity of the paddy grain increased significantly from 0.40 to 0.42% as the moisture content increased from 10 to 20% (d.b.) [6] and [3] considered the grain as spherical when the sphericity value was more than 0.70 and 0.80, respectively. In the current study, Paddy grain should not be treated as an equivalent sphere for calculation of the surface area.

3.6 Equivalent Diameter
The experimental results of the equivalent diameter of the paddy grain at different moisture contents are given in table 1, 2 and 3. As shown in Table 1, 2 and 3, the equivalent diameter of paddy grain increased from 3.31to 3.50 mm, as the moisture content increased from 10 to 20% (d.b.).

Table 1: Physical properties of paddy Ratnagiri-7 at 10% moisture content

Particulars		Length, mm	Breadth, mm	Thickness, mm	Size, mm	Surface area	Volume	Sphericity	Equivalent diameter
Paddy	Mean	8.26	2.38	1.81	35.86	36.13	19.14	0.40	3.31
	Max	9.85	2.80	2.06	50.68	44.56	26.80	0.44	3.71
	Min	7.13	2.06	1.15	19.40	28.30	11.01	0.32	2.76
	S.D	0.46	0.18	0.14	5.72	3.99	3.05	0.02	0.18

Table 2: Physical properties of paddy Ratnagiri-7 at 15% moisture content

Particulars		Length, mm	Breadth, mm	Thickness, mm	Size, mm	Surface area	Volume	Sphericity	Equivalent diameter
Paddy	Mean	8.29	2.57	1.96	41.89	39.61	22.38	0.42	3.49
	Max	9.96	3.61	2.26	62.33	63.28	35.87	0.47	4.09
	Min	7.30	2.11	1.20	23.46	30.44	13.68	0.34	2.97
	S.D	0.58	0.24	0.15	6.81	5.14	3.72	0.03	0.19

Table 3: Physical properties of paddy Ratnagiri-7 at 20% moisture content

Particulars		Length, mm	Breadth, mm	Thickness, mm	Size, mm	Surface area	Volume	Sphericity	Equivalent diameter
Paddy	Mean	8.32	2.60	1.95	42.09	40.25	22.53	0.42	3.50
	Max	9.86	3.15	2.17	55.84	48.88	30.29	0.45	3.87
	Min	7.78	2.27	1.27	27.53	52.50	16.32	0.36	3.15
	S.D	0.41	0.18	0.11	4.75	3.87	2.61	0.02	0.13

3.7 Thousand Grain Mass
Mean values of the thousand grain mass of paddy at different moisture contents are shown in table 4. As the moisture content increased from 10 to 20% (d.b.), the thousand grain mass of paddy increased significantly from 19.46 to 21.67g.

3.8 Bulk Density
The effect of moisture content on the bulk density of paddy grains was significant is presented in table 4. The results showed that the grains bulk density increases linearly from 527.20 to 537.80kg/m^3 with an increase in moisture content from 10 to 20% (d.b.). This was due to the fact that an increase in mass owing to moisture gain in the sample was higher than accompanying volumetric expansion of the bulk.

3.9 True Density
Variation of the true density of paddy grains at different moisture contents is given in table 4. The true density of paddy grains found to be increased from 1085.24 to 1220.40kg/m^3 as the moisture content increased from 10 to 20% (d.b.).

3.10 Porosity
The variation of porosity in accordance with the moisture content is shown in table 4. The results indicated that as the moisture content of paddy grains increases from 10 to 20% (d.b.), the porosity increases linearly from 50.17 to 56%.

3.11 Angle of Repose
The average values of the angle of repose relative to the moisture content are presented in table 4. The angle of repose of paddy grains increases significantly from 34.37° to 37.23°in the moisture range of 10– 20% (d.b.).
This is due to the fact that increasing in moisture absorption

leads to create a larger surface layer of moisture surrounding the particles, holding the aggregate of grains together by producing higher surface tension.

3.12 Static Coefficient of Friction

As it can be seen, the static coefficient of friction of paddy grains increases linearly with increase in moisture content, for all the evaluated surfaces due to the fact that the water present in the grain offering a higher cohesive force on the surface of contact as it seen table 4.The results also showed that at all levels of moisture contents, the maximum static coefficient of friction was offered by mild steel sheet, followed by plywood, galvanized iron sheet and glass surfaces 0.62, 0.49, 0.45 and 0.42 to 0.73, 0.64, 0.64 and 0.50 respectively. The least static coefficient of friction may be owing to smoother and more polished surface in the case of glass comparing with the other surfaces evaluated.

Table 4: Gravimetric and frictional properties of paddy Ratnagiri-7 at 10%, 15% and 20% mc

Sr. No.	Properties	Moisture Content		
		10%	15%	20%
1	Bulk Density, kg/m3	527.20	536.40	537.80
2	True Density, kg/m3	1085.24	1190.80	1220.40
3	Porosity, %	50.17	55	56
4	Angle of Repose, deg	34.37°	36.41°	37.23
5	Thousand grain weight, g	19.46	21.25	21.67
6	Static coefficient of friction			
	Galvanized iron surface	0.45	0.60	0.64
	Mild steel surface	0.62	0.63	0.73
	Glass surface	0.42	0.49	0.50
	Wooden surface	0.49	0.61	0.64

4. Conclusion

- The mean values of moisture content (w.b.) for Ratnagiri-7 paddy variety were 10%, 15% and 20%.The physical properties of paddy were calculated at these three moisture content.
- It is concluded that all the physical properties were increased with increase in moisture content from 10% to 20%. The length, width and thickness were increased from 8.26mm, 2.38 mm and 1.81 mm to 8.32 mm, 2.60 mm and 1.95 mm. Also size, surface area, volume, sphericity and equivalent diameter were increased from 35.86 mm^3, 36.13 mm^2, 19.14 mm^3,0.40, 3.31 mm to 42.09 mm^3, 40.25 mm^2,22.53 mm^3,0.42 and 3.50 mm respectively.
- The gravimetric and frictional properties of paddy were found to increase with increase in moisture content from 10% to 20% moisture content. The bulk density, true density, porosity, angle of repose and thousand grain weight were found to increase from 527.20 kg/m3, 1085.24 kg/m3, 50.17%, 34.37° and 19.46g to 537.80 kg/m3, 1220.40 kg/m3, 56%, 37.23° and 21.67 g respectively. Static coefficient of friction of paddy against various surfaces namely GI sheet, MS sheet, glass and wooden surface were found to increase from 0.45, 0.62, 0.42 and 0.49 to 0.64, 0.73, 0.50 and 0.64 respectively.

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