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Effect of Water Soaking on Physical and Engineering Properties of Paddy (Basmati-370)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Physical and engineering properties of paddy seeds plays a crucial role in designing and development of drum's orifice shape and size in drum seeder. The physical and engineering properties of dry, soaked (12 hours soaking) and pregerminated (24 hours soaking + 12 hours incubation) paddy (Bsmati-370) seeds were studied to finalize these dimensions. The average value for; length, width, thickness and equivalent diameter (mm) varies from 9.95 to 10.55, 10.98 to 11.61, 12.01 to 12.53 mm; 1.95 to 2.12, 2.41 to 2.57, 2.67 to 2.90 mm; 1.70 to 1.74, 2.06 to 2.18, 2.29 to 2.48 mm; and 3.07 to 3.20, 3.55 to 3.68, 3.81 to 4.11 mm for dry, soaked and pre germinated seeds respectively. The aspect ratio and sphericity were found to be 0.19, 0.24, 0.28 and 30, 32.88 and 34.70% for dry, soaked and pregerminated seeds respectively. There was an increase in volume, aspect ratio and terminal velocity by 21, 26.31 and 15.31 % and 39.98, 47.36 and 18.91% for soaked seed and pre germinated seed over the dry seed respectively.

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1. INTRODUCTION

Rice is a key staple food consumed by more than half of the world's population [1]. As a consequence, rice production systems must boost production to meet global food demand [2]. About 25 % of world's rice is grown in India, contributing to 21 % of global rice production [3]. In order to meet the global rice demand, it is projected that an additional 96 million tons of milled rice will be needed by 2040 as compared to 2015 [4]. The Direct-seeded rice (DSR) technique have emerged to address timely sowing, labor and water scarcity, as well as rising costs of cultivation. Dry-DSR in South Asia has shown potential to improve economic sustainability and reduce the environmental footprint of rice cultivation.

In order to design and develop a seed drum for DSR technique the knowledge of physical and engineering properties is important. The DSR technique makes use of dry, soaked or pregerminated seeds depending upon the other cultivation conditions. Basmati-370 variety (GI of Jammu and Kashmir) has a special aroma and flavor, along with fine quality long grain, which fetches two to three times the price of non-basmati and has huge export potential [5,6]. Therefore, the present study was carried out to study various physical and engineering properties of dry, soaked and pre germinated Basmati-370 paddy seeds.

2. MATERIALS AND METHODS

As per DSR sowing techniques, Basmati-370 can be used as dry, soaked (12 hours) and pre-germinated (24 hours soaking and 12 hours incubation) conditions (Fig. 1).The experiments to measure the physical and engineering properties were carried out for these forms of seeds in the laboratory. The standard procedure for sampling were adopted and following properties were studied.

2.1 Physical Properties

A sample of 100 kernels were randomly selected and the axial dimensions of paddy grain such as length (*L*), width (*W*), thickness (*T*) were measured. A digital vernier caliper having a least count of 0.01 mm (Fig. 2) was used for measurement. The following expressions were used to determine equivalent diameter (D), surface area (S), volume (V), aspect ratio (R_a) and Sphericity (∅)as given by Mohsenin [7] and Ravi and Venkatachalam [8].

$$D = [4L(W + L/4)^2]^{\frac{1}{3}} \quad \text{----------} \quad (i)$$

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W + T)^2\right] \quad \text{----------} \quad (ii)$$

$$S = \frac{\pi B L^2}{2L - B} \quad \text{----------} \quad (iii)$$

$$\text{Where, } B = \sqrt{WT} \quad \text{----------} \quad (iv)$$

$$R_a = \frac{W}{L} \quad \text{----------} \quad (v)$$

$$\emptyset = \left(\frac{LWT}{L}\right)^{\frac{1}{3}} \quad \text{----------} \quad (vi)$$

2.2 Terminal Velocity

Terminal velocity is the maximum velocity (speed) attainable by an object as it falls through a fluid (air) and it is determined by relationship [9] given below.

$$V_t = \sqrt{\frac{2mg}{\rho A C_d}} \quad \text{----------} \quad (vii)$$

Where,

V_t = terminal velocity, m = mass of the falling object, g = acceleration due to gravity, C_d = drag coefficient, = density of the fluid through which the object is falling, A = area projected by the object.

2.3 Density and Porosity

The bulk density was determined by filling an empty 100 ml graduated cylinder with the seed and weighed (Mohsenin 1980). To achieve uniformity in bulk density, the graduated cylinder was tapped 10 times for the seeds to consolidate.

$$\rho_b = \frac{M}{v} \quad (viii)$$

True density was determined using Toluene displacement method. Toluene (C_7H_8) was used in place of water because paddy absorbed toluene to a lesser extent [10].

$$\rho t = (W/V) \quad (ix)$$

Porosity was calculated using the formula given by [7]:

$$\epsilon = \frac{\rho t - \rho b}{\rho t} \times 100 \quad (x)$$

Fig. 1. Dry, Soaked and Pre-germinated seeds of Basmati-370 used for present study

Fig. 2. Vernier caliper

Where,

M - mass of the paddy (kg), *v*- volume of container (m^3), ϵ - porosity, %, ρ_b - bulk density, $kg{\cdot}m^{-3}$,ρ_t - true density, $kg{\cdot}m^{-3}$, V = Displaced volume (cm^3)

2.4 Angle of Repose

The angle of repose was determined by keeping vertically a plastic cylinder (inner diameter 70 mm and height 270 mm) on horizontal plywood sheet and filled with sample (Waziri and Mittal, 1983). The cylinder was tapped during filling to obtain uniform packing and to minimize the wall effect. The cylinder was raised slowly above so that whole material could slide and form a heap. The height (H) and the diameter (D) of the heap were measured with the help of measuring scale, and the angle of repose (Φ) of paddy seed was computed using the following expression:

$$\Phi = \tan^{-1}\frac{2H}{D} \qquad \text{(xi)}$$

2.5 Coefficient of Static Friction

A tabletop arrangement (Fig. 3) was used to determine the coefficient of staticfriction [11] for wood, aluminium and mild steel. The coefficient of static friction was computed by the following expression given below.

$$\mu = (W_2-W_1)/W \qquad \text{(xii)}$$

Where,

W = Weight of sample, W_1= Weight at which empty box just started to slide, W_2 = Weight at which filled box started to slide

2.6 Experimental Details

The data for studying physical and engineering properties was analyzed statistically using OPSTAT software at 5% level of significance for three soaking conditions and seven replications.

Fig. 3. Apparatus for measuring of static coefficient of friction

3. RESULTS AND DISCUSSION

The data pertaining to the effect of water soaking on the physical and engineering properties of paddy shows that there was significant effect of soaking on the physical and engineering properties of paddy at 5% level of significance. The individual effect of water soaking is described here under.

3.1 Effect of Water Soaking on Physical Properties of Paddy

In general, the axial dimension increases with soaking and pre germination. The average length, width, thickness and equivalent diameter was 10.29, 2.03, 1.72 and 3.14 mm for dry seeds and 11.25, 2.5, 2.1 and 3.59 mm for soaked seeds and 12.23, 2.8, 2.4 and 3.98 mm for pre germinated seeds (Table 1). The average surface area of paddy seed increased significantly from 40 $mm^2$for dry seed to 55 $mm^2$for soaked seed and 58 mm^2 for pre germinated seed, respectively. Zareiforoush et al. [12] and Pandiselvam and Thirupathi [13] also reported similar findings for paddy.

The volume increased significantly from 16.38 mm^3 in case of dry seed to 19.82 mm^3 for soaked seeds and 22.93 mm^3 for pre germinated seeds, respectively. Ndirika and Oyeleke [14] reported a similar trend. The aspect ratio of paddy increased significantly from 19 % for dry seed to 24 % for soaked seed and 28% for pre germinated due to soaking and pre germinated. Similar results were reported by Ghadge et al. [15] for rice.

The sphericity of paddy seeds increased with soaking and pre germination. The sphericity of the dry paddy seed increased significantly from 30.00 to 34.7% for pre germinated paddy seed [16].The result further showed that there was 9.30, 23.15, 22.09 and 14.33% increase in length, width, thickness and equivalent diameter for 12 hours soaking over dry seed (Fig. 4). Similarly, there was 18.8, 37.93, 39.50 and 26.75% increase in 24 hours soaking with 12 hours incubation over dry seeds, respectively. Similarly for surface area and sphericity it is 37.50% and 9.60% for soaked seeds and 45% and 16% for pre germinated seeds over the dry seeds.

Table 1. Effect of water soaking on axial dimensions of paddy

Type of seed	Length (mm)	Width (mm)	Thickness (mm)	Equivalent diameter (mm)	Surface area	Volume (mm^3)	Aspect ratio (%)	Sphericity (%)
Dry	10.29	2.03	1.72	3.14	40	16.38	0.19	30.00
Soaked	11.25	2.5	2.1	3.59	55	19.82	0.24	32.88
Pre germinated	12.23	2.8	2.4	3.98	58	22.93	0.28	34.7
CD	0.220	0.075	0.048	0.061	0.948	0.512	0.005	0.611
CV	1.658	2.595	1.984	1.446	1.579	2.206	1.680	1.596

3.2 Effect of Water Soaking on Porosity, Bulk and True Density of Paddy

The results indicated that the bulk density of paddy increased significantly from 0.67 g/cc for dry seed to 0.78 g/cc for soaked seed and 0.92 g/cc for pre germinated (Table 2). This was probably because an increase in mass owing to moisture gain in the sample was higher than accompanying volumetric expansion of the bulk [17]. In case of true density, it was 1.53 g/cc for dry seeds, 1.42 g/cc for soaked seeds and 1.3 g/cc for pre germinated seeds. The results indicated that the soaking and pre germination increased true density significantly similar to those reported by Reddy and Chakraverty (2004).

Further, the porosity depends on the bulk as well as on true densities, the magnitude of variation in porosity depends on these factors only. The porosity of paddy grains decreased significantly from 72 % for dry seeds to 65 % for soaked seeds and 62 % for pre germinated seeds with increase in moisture content. The bulk density increased by 16.41% for soaked type of seed and 37.31% for pre germinated seed whereas true density decreased by 7.10% for soaked type of seed and 17.69% for pregerminated type of seed over the dry of seed (Fig 4). Similar trends of decrease have been reported by Pandiselvam and Thirupathi [13].

3.3 Effect of Water Soaking on Frictional Coefficient, Terminal Velocity and Angle of Repose of Paddy

The data pertaining to the static coefficient of friction for Basmati 370 on wood, M.S sheet and aluminium for dry, soaked and pre germinated conditions is given in Table 3. The average value of coefficient of friction was found to be 0.58, 0.54 and 0.56 for wooden, MS and aluminum surface respectively and all the values are statistically significant. Static coefficient of friction was highest on wooden surface and the least on mild steel surface. Zareiforoush et al. [12] found similar trends with respect to wood, aluminum and mild steel surfaces for Alikazemi and Hashemi varieties of paddy respectively. The coefficient of friction for wood shows an increase in friction of 29.16 % for soaked seed and 33.33% for pregerminated seed, in case of M.S it is 26.66 % and 33.33% for soaked and pre germinated seed, similarly as aluminium surface it has shown an increase in friction of 25.53% and 31.91% for soaked and pre germinated seed over the dry seed (Fig. 4).

The terminal velocity was observed to increase significantly from 5.55 for dry seed to 6.4 for soaked seeds and 6.6 for pre germinated paddy seeds, respectively (Table 3). The increase in terminal velocity with the increase in moisture content may be due to increase in size and mass of the seed.

There was significant increase in angle of repose on water soaking and pre germination. The average angle of repose was found to be 30.79^o, 36^o and 42^o for dry, soaked and pre germinated seeds. These results were in agreement to the findings of Kanchana et al. [18] and Zareiforoush et al. [12] for Alikazemi and Hashemi paddy cultivars.

Table 2. Effect of water soaking on Bulk and true density of paddy

Type of seed	Bulk density (g/cc)	True density (g/cc)	Porosity (%)
Dry	0.67	1.53	72
Soaked	0.78	1.42	65
Pre germinated	0.92	1.3	62
CD	0.023	0.014	1.600
CV	2.471	0.827	2.048

Table 3. Effect of water soaking on frictional coefficient, terminal velocity and angle of repose of paddy

Type of seed	Coefficient of friction			Terminal Velocity (m/sec)	Angle of repose (Degree)
	Wood	M.S.	Aluminium		
Dry	0.48	0.45	0.47	5.55	30.79
Soaked	0.62	0.57	0.59	6.4	36
Pregerminated	0.45	0.6	0.62	6.6	42
CD	0.014	0.011	0.008	0.171	0.775
CV	2.069	1.695	1.182	2.350	1.814

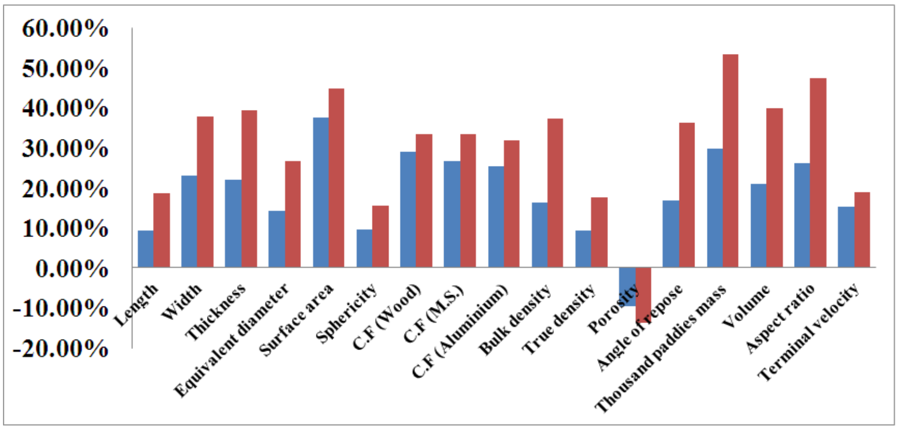

Fig. 4. Effect of water soaking on physical and engineering properties

4. CONCLUSION

The water soaking of paddy (Basmati-370) significantly increased the physical and engineering property like length, width, thickness, equivalent diameter and aspect ratio. However, the porosity decreased with soaking and pre germination.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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