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Research Article

PHYSICAL PROPERTIES AND MILLING CHARACTERISTICS OF RICE (*Oryza sativa* L.)

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Abstract- The physical properties of grains are necessary for effective design of processing and storage machinery. Various physical properties of paddy, brown rice and head rice were determined for Hamsa variety of rice at 9.61% wet basis (w.b) and the milling characteristics of rice were found at 8, 10 and 12 % (w.b) moisture content (m.c) of brown rice. Geometric mean diameter, sphericity, test weight, true density, porosity and angle of repose for paddy were3.54 mm, 0.39, 22.09 g, 1160 kg.m^{-3}, 48.19 % and 31.44°, respectively. The corresponding values 2.88 mm, 0.46, 19.31 g, 1510kg.m^{-3}, 38.90%, and 30.22° were for brown rice and 2.86 mm, 0.47, 17.32 g, 1430kg.m^{-3}, 44.43% and 30.16° for head rice, respectively. For this variety, the maximum degree of polishing of 15.08% was obtained at 8% m.c of brown rice polishing for 60 s and the maximum head rice yield of 89.05% was obtained at 8% m.c of brown rice for polishing time of 15s. The head rice yield decreases and broken content increases with the increase in m.c and polishing time.

Keywords- Brown rice, Head rice, Moisture content, Paddy, Polishing time.

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Introduction

Rice (*oryzasativa*. L) is rich in genetic diversity with thousands of varieties grown throughout the world. Rice has been one of man's most important foods. Today, this unique grain helps sustain two-thirds of the world's population. Rice provides 20 % of the world's dietary energy. It is deeply embedded in the cultural heritage of their societies. About four-fifths of the world's rice are produced by small-scale farmers and are consumed locally.

Rice is the main source of nutrition for majority of people in India. Thus, rice milling becomes the largest agro-based industry in India comprising about 1,74,296 rice milling units [6]. India is the second largest producer of rice in the world next to China. Rice production in India crossed the mark of 100 million MT in 2011-12 accounting for 22.81% of global production in that year 2012. Andhra Pradesh is one of the major paddy cultivated state in India with 47.51 lakh hectares with an output of 144.18 lakh tonnes. Andhra Pradesh stands second in rice productivity with 3035 kg.ha^{-1} after Punjab (3828 kg.ha^{-1}).

Mohapatra and Bal [8] and Billiris et al. [3] assessed the effect of degree of milling (DOM) on cooking quality of rice. Roy et al [13] determined the effect of DOM on overall energy consumption and quality of rice. Peter et al. [11] studied the effect of sun-drying on milling and the quality of rice in terms of milling yield and percentage of broken grains. Abud et al. [1] studied various factors responsible for rice breakage during milling. Zhou et al. [21] determined the effect of ageing of stored rice on physical and chemical properties of rice.

Notation

b	Width of grain, mm	m.c	Moisture content
D	Diameter of the base plate, cm	R^2	Coefficient of determination
D_p	Degree of polishing, %	t	Thickness of grain, mm
GMD	Geometric mean diameter, mm	V	Volume of the grains, m^3
H	Height of cone, cm	W_1	Weight of brown rice, g
l	Length of grain, mm	W_2	Weight of head rice, g
M	Mass of the grains, kg	w.b	Wet basis
Φ	Angle of repose, ^{0}	ε	Porosity, %

The optimum paddy moisture content for milling process was 12 to 14 % (w.b) and using three abrasive polishers in series and one friction polisher as a polisher had the least rice breakage [2]. Zhang et al. [20] measured mechanical properties of sound and fissured rice kernels. Lamberts et al. [7] determined the effect of degree of milling on colour and nutritional properties of rice. Correa et al. [4] determined the physical and mechanical properties of rough rice, brown rice and milled rice of different varieties. Yadav and Jindal [16, 18, 19] monitored milling quality of rice and determined the kernel dimensions during soaking and cooking of milled rice. Yadav et al. [17] determined physicochemical and cooking properties of some Indian rice cultivars. Das et al. [5] introduced enzymatic polishing of rice by xylanase and cellulase enzymes. Sayafutri et al. [14] analyzed effect of different varieties and cooking methods on physical and chemical properties.

The main objectives of this study are

1) To determine the physical properties of Paddy, Brown rice and Head rice.
2) To determine milling characteristics of rice in a laboratory abrasive polisher at different polishing time and moisture content of brown rice

Material and Methods

'Hamsa' variety of paddy with 9.61 % (w.b) moisture content was selected for determining physical properties of paddy, brown rice and head rice, same variety of paddy was used for the determination of moisture content on milling characteristics.

Determination of physical properties

The principle dimensions of the grains were measured using Vernier Calipers having a least count of 0.001 mm by taking two replications; each replication consists of a sample size of 25 grains. Similar procedure was adopted for measuring the size of head rice and brown rice. Geometric mean diameter is the diameter of a sphere having same diameter as the particle. Sphericity is defined as the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest inscribing sphere. The geometric mean diameter and sphericity were calculated with following equations [10].

$$\text{GMD, mm} \ = \left(l\frac{(b+t)^2}{4}\right)^{\frac{1}{3}} \quad [1]$$

$$\text{Sphericity} = \frac{GMD}{l} \quad [2]$$

The test weight of the paddy, brown rice and head rice were determined by counting 1000 grains (paddy, brown rice and head rice) manually and weighing them on an electronic balance.

Bulk density of the grains (paddy, head rice and brown rice) was determined by weighing the weight of seeds of known volume. The procedure was replicated five times to get average value of bulk density. The bulk density of grains was determined by the following [Eq-3].

$$\text{Bulk density, kg. m}^{-3} \ = \frac{\text{M}}{\text{V}} \quad [3]$$

True density is defined as the actual density. It is determined using toluene displacement test. A sample of 50ml toluene is taken into a measuring cylinder and filled with a measured amount (10g) of grains (paddy, brown rice and head rice) and the change in volume is recorded. The true density is calculated by [Eq-4].

$$\text{True density, kg. m}^{-3} \ = \frac{\text{Weight of grains}}{\text{Displaced volume of toluene}} \quad [4]$$

The angle of repose is the angle with the horizontal at which the material will stand when piled [15]. The angle of repose is measured by taking a flat plate of known radius. The diameter of the plate is 10 cm. Grains (paddy, head rice and brown rice) are slowly poured at the centre of the plate with uniform speed till the plate completely filled and the excess grains started dropping downward from the plate. The height of heap was measured. The process is repeated five times and the mean angle of repose is calculated. The angle of repose is calculated by using [Eq-5] [10].

$$\text{Angle of repose } (\Phi) = \tan^{-1}\frac{2\text{H}}{\text{D}} \quad [5]$$

Porosity (ε) is defined as the pore spaces present in the bulk of grains and it is calculated by the [Eq-6] [10].

$$\text{Porosity, \%} \ = \left(1 - \frac{\text{Bulk density}}{\text{True density}}\right) \times 100 \quad [6]$$

Effect of moisture content of brown rice on milling characteristics

The effect of moisture content of brown rice on milling characteristics was determined in laboratory. The material and methods used in the laboratory were given below.

Rubber Roll Sheller

The main objective of this test was to determine the potential total rice yield or outturn (the total quantity of whole and broken rice recovered from the sample) and the head rice yield (the quantity of whole grains recovered from the sample).The cleaned paddy is fed between two rubber rolls where de-husking takes place. The brown rice and husk fall through an airstream that permits the brown rice to drop through while the air picks up the immature grains and husk. The immature grains and the husk is separated in the attached cyclone. The rubber rolls are about 35 mm wide and 100 mm in diameter and have adjustable clearance. Paddy samples were weighed before feeding the husker. After husking, the brown rice and husk are weighed separately. Brokens and paddy are separated from brown rice.

Polisher

The polisher operates with an abrasive cone surrounded by a screen. The white rice and bran are collected separately in plastic trays beneath the polisher. The brown rice sample was weighed before and after each test to determine the percent of bran removal. The machine uses an adjustable timer, the time adjusted for the polisher was 15, 30, 45 and 60 seconds to obtain different degrees of polishing. The polisher (Model No.BPL140, BP lab Solutions, India) used in lab was driven by 0.5 Hp motor running at 1425 rpm. Degree of polishing is defined as the amount of bran removed from brown rice [12] and is calculated using [Eq-7].

$$\text{Dp, \%} = \frac{\text{W}_1 - \text{W}_2}{\text{W}_1} \times 100 \quad [7]$$

Results and Discussions

Determination of physical properties of paddy, brown rice and head rice

The physical parameters studied include size, test weight, bulk density, true density, and porosity, angle of repose, geometric mean diameter and moisture content as presented [Table-1].

Table-1 *Some physical properties of paddy, brown rice and head rice*

Property	Paddy	Brown rice		Head rice	
	Mean	Mean	% variation of paddy	Mean	% variation of paddy
Length, mm	9.16	6.28	31.44	6.09	33.52
Width, mm	2.43	2.11	13.17	2.09	13.99
Thickness, mm	1.99	1.78	10.55	1.75	12.06
Geometric mean diameter, mm	3.55	2.87	19.02	2.82	20.53
Sphericity, %	0.39	0.457	-18.11	0.463	-19.52
Test weight, g	22.09	19.31	12.58	17.32	21.59
Bulk density, kg.m^{-3}	596	918	-54.03	878	-47.32
True density, kg.m^{-3}	1160	1510	-30.17	1430	-23.28
Porosity, %	48.19	38.90	19.28	44.43	7.80
Angle of repose, °	31.44	30.22	3.88	30.16	4.07

The average length, width and thickness of paddy were 9.16, 2.43 and 1.99 mm, respectively. However, the length and width of paddy varied from 8.27 to 9.85 mm and 2.21 to 2.62 mm, respectively, whereas the paddy thickness varied from 1.85 to 2.14 mm, respectively. The average geometric mean diameter and sphericity of paddy was 3.54 mm and 0.39 respectively.
The average length, width and thickness of brown rice were 6.28, 2.11 and 1.80 mm, respectively. However, the length and width of brown rice varied from 5.94 to 6.73 mm and 1.83 to 2.43 mm, respectively, whereas the brown rice thickness varied from 1.66 to 1.95 mm respectively. The average mean diameter and sphericity of brown rice was 2.88 mm and 0.46, respectively.
The average length, width and thickness of head rice were 6.09, 2.09 and 1.75 mm, respectively. However, the length and width of head rice was varied from 5.74 to 6.56 mm and 1.78 to 2.24 mm, respectively, whereas the head rice thickness varied between 1.65 to 1.85 mm, respectively. The average geometric mean diameter and sphericity was 2.86 mm and 0.47, respectively.
The average test weight of paddy, brown rice and head rice were 22.09 g, 19.31 g and 17.32 g, respectively. The test weight of paddy, brown rice and head rice varied from 22.06 to 22.14, 19.30 to 19.32 and 17.15 to 17.53 g respectively. The average bulk density for paddy, brown rice and head rice were 592, 915 and 879 kg.m^{-3} respectively. The bulk density of paddy, brown rice and head rice varied between 569 to 619, 903 to 926 and 865 to 892 kg.m^{-3}, respectively.

Table-2 *Appearance of head rice at different moisture content and polishing times*

Moisture content, %	Polishing time, s			
	15	30	45	60
8	 D_p= 3.96 %, Br = 10.95 %	 D_p= 6.50 %, Br = 17.90 %	 D_p= 12.52 %, Br = 17.12 %	 D_p = 15.08 %, Br = 17.31 %
10	 D_p = 2.70 %, Br = 17.38 %	 D_p = 5.95 %, Br = 28.60 %	 D_p = 8.79 %, Br = 31.90 %	 D_p = 11.62 %, Br = 34.42 %
12	 Dp= 4.35 %, Br = 45.56 %	 Dp= 5.45 %, Br = 56.84 %	 Dp= 6.12 %, Br = 61.56 %	 Dp= 8.02 %, Br = 64.96 %

The average true density of paddy, brown rice and head rice were 1160, 1510 and 1430 kg.m^{-3}. The true density of paddy and brown rice varied from 1000 to 1250 and 1430 to 1670 kg.m^{-3}. The average porosity of paddy, brown rice and head rice were 48.19, 38.90 and 44.43%, respectively. The porosity of head rice is lower compared to brown rice due to the removal of germ while polishing thereby increase in pore spaces. The porosity of paddy, brown rice and head rice were found to vary between 38.10 to 54.48, 35.24 to 44.61 and 37.62 to 56.15% respectively.
The average value of angle of repose for paddy, brown rice and head rice were to be found to be 31.44, 30.22 and 30.16 degrees, respectively. Angle of repose for paddy is higher compared to brown rice due to the abrasive property of rice husk and the angle of repose is lesser for head rice compared to brown rice due to the decrease in friction with polishing. The angle of repose of paddy, brown rice and head rice varied from 29.25 to 33.42, 29.25 to 41.75 and 28.37 to 30.96 degrees respectively.

Effect of moisture content of brown rice on milling characteristics

Degree of polishing

The milling characteristics of rice are determined at 8%, 10%, and 12% moisture contents of brown rice and at different polishing times 15, 30, 45 and 60 seconds. The degree of polishing obtained at different moisture content of brown rice for different polishing times are as shown in [Fig-1]. The maximum degree of polishing of 15.08% was obtained at 8% moisture content of brown rice polishing for 60s. The minimum degree of polishing of 2.70% was obtained at 10% moisture content of brown rice for polishing time of 15 s. the appearance of rice at different moisture contents after polishing at different polishing times as shown in [Table-2].

The regression equation of brown rice of 8, 10 and 12% moisture contents are D_p= 0.2552T, D_p=0.1943 T and D_p=0.0779T+3.065. The Coefficient of determination of brown rice of 8, 10 and 12% moisture contents are 0.968, 0.998 and 0.958.A linear relationship through origin was obtained between degree of polishing and polishing time for 8 and 10% moisture contents of brown rice and a linear relationship with constant was for 12% moisture content, it may be due to the increase in broken content due the decrease in mechanical strength of brown rice. The maximum R^2 value (0.998) was obtained for brown rice with 10% moisture content.

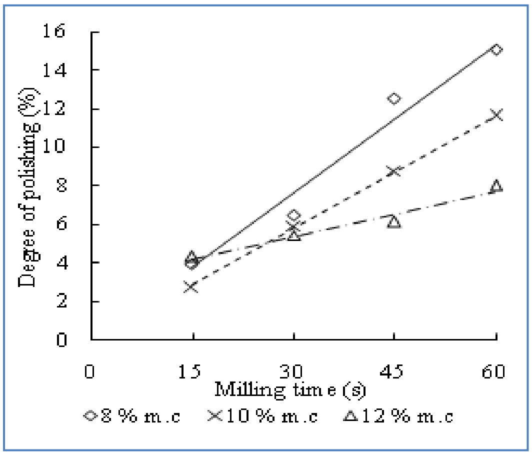

Fig-1 Degree of polishing at different moisture contents of brown rice for different polishing times.

Percentage head rice yield

The head rice yield was calculated by separating the polished rice into head rice and brokens at different polishing times and different moisture contents of brown rice. The percentage head rice obtained was given in the [Fig-2]. The maximum head rice yield of 89.05% was obtained at 8% moisture content of brown rice for polishing time of 15s. The minimum head rice yield of 35.04% was obtained at 12% moisture content of brown rice for polishing time of 60 s.

Percentage broken content

The effect of moisture content on brokens at different polishing times is shown in [Fig-3]. The maximum broken content was 64.96% found at a 12% moisture content of brown rice when polishing for 60 s. The minimum broken content was 10.95% found at a moisture content of 8% and polishing for 15 s. This may be due to decrease in mechanical strength of brown rice with moisture content.

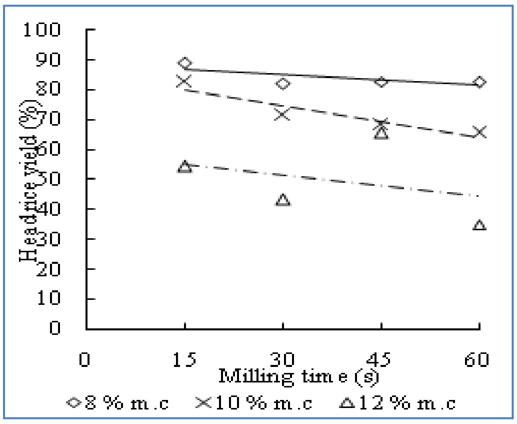

Fig-2 Percentage head rice yield at different moisture contents of brown rice and at different polishing times

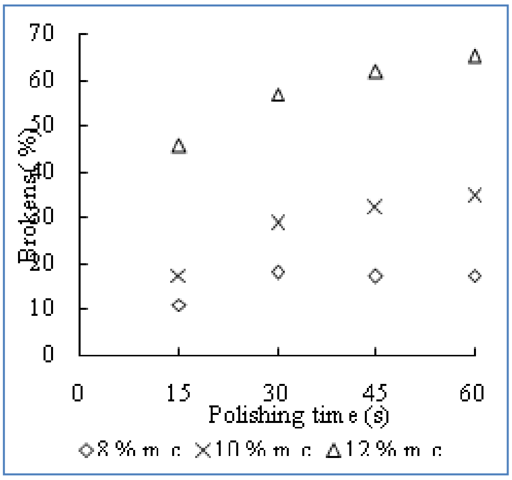

Fig-3 Percentage brokens at different moisture contents of brown rice and at different polishing times

Conclusions

The following conclusions were made from above results.

1. The average length, width and thickness of paddy were 9.16, 2.43 and 1.99 mm whereas for brown rice 6.28, 2.11 and 1.80 mm, respectively. The average length, width and thickness of head rice were 6.09, 2.09 and 1.75 mm, respectively.
2. The average test weight of paddy, brown rice and head rice were 22.093 g, 19.31 g and 17.32 g, respectively.
3. The average values of bulk density for paddy, brown rice and head rice were 592, 915 and 879 kg.m^{-3}, respectively. The average true density of paddy, brown rice and head rice were found to be 1160, 1510 and 1620 kg.m^{-3}, respectively. The average porosity of paddy, brown rice and head rice were 48.19, 38.90 and 44.43% respectively.
4. The average value of angle of repose for paddy, brown rice and head rice were 31.44, 30.22 and 30.16 degrees, respectively. The maximum degree of polishing of 15.08 % was obtained at 8 % moisture content of brown rice polishing for 60 s.
5. The maximum broken content was 64.96% found at 12% moisture content of brown rice when polishing for 60 s. The minimum broken content was 10.9 % found at a moisture content of 8% and polishing for 15 s.

Conflict of Interest: None declared

References

[1] Abud A.M., Courtois F., Bonazzi C. and Bimbenet J.J. (2000) *Journal of Food Engineering* 4, 161-169.

[2] Afzalinia S. Mohammad S. and Ebrahim Z. (2002) ASAE/CSAE *North-Central Intersectional Meeting Sponsored by ASAE and CSAE* Park town Hotel, Saskatoon, Saskatchewan, CANADA September 27-28.

[3] Billiris M.A., Siebenmorgen T.J. and Wang Y.J. (2011) *Journal of Food Engineering* 11, 589–597.

[4] Corrêa P.C., Da Silva F.S., Jaren C., Afonso P.C. and Arana I. (2007) *Journal of food engineering*, 79(1), 137-142.

[5] Das M., Gupta S., Kapoor V., Banerjee R. & Bal S. (2008) *LWT-Food Science and Technology*, 41(10), 2079-2084.

[6] Goyal S.K., Jogdand S.V. and Agrawal A.K. (2012) *Journal of Food science and Technology*, 10, 234- 239.

[7] Lamberts L., De Bie E., Vandeputte G.E., Veraverbeke W.S., Derycke V., De Man W. and Delcour J. A. (2007) *Food Chemistry,* 100(4), 1496-1503.

[8] Mohapatra D. and Bal S. (2006) *Journal of Food Engineering* 80,119–125.

[9] Mohapatra D. and Bal S. (2010) *Food and Bioprocess Technology,* 3(3), 466-472.

[10] Mohsenin N.M. (1986) Gordon and Breach, Science Publishers, New York (1986).

[11] Peter B.I. and Olufayo A.A.(1999) *Bioresource Technology* 74, 267-269.
[12] Prakash K.S., Someswararao C. and Das S.K. (2014) *Innovative Food Science & Emerging Technologies*, *22*, 175-179.
[13] Roy P., Ijiri T., Okadome H. and Nei D. (2008) *Journal of Food Engineering*, 89(3), 343-348.
[14] Syafutri M.I., Pratama F., Syaiful F. and Faizal A.(2016) *Rice Science,* 23(5), 282-286.
[15] Varnamkhasti M.G., Mobli H., Jafari A., Keyhani A.R., Soltanabadi M.H., Rafiee S. and Kheiralipour K. (2008) *Journal of Cereal Science*, 47(3), 496-501.
[16] Yadav B.K. and Jindal V.K. (2001) *Computers and Electronics in Agriculture*, *33*(1), 19-33.
[17] Yadav R.B., Khatkar B.S. and Yadav B.S. (2007a) *Journal of Agricultural Technology* 3(2), 203-210.
[18] Yadav B.K. and Jindal V.K. (2007b) *Journal of food engineering*, 81(4), 710-720.
[19] Yadav B.K. and Jindal V.K. (2007c) *Journal of Food Engineering*, 80(1), 359-369.
[20] Zhang Q., Yang W. and Sun Z. (2005) *Journal of Food Engineering*, 68(1), 65-72.
[21] Zhou Z., Robards K., Helliwell S. and Blanchard C. (2002) *Journal of Cereal Science*, 35(1), 65-78