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Effect of De-Awning on Physical Properties of Paddy

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Abstract: The effect of de-awning on physical properties of paddy were evaluated as a function of grain moisture content at 5 levels ranging from 6.92 to 23.16% d.b. The average length, width, thickness, geometric mean diameter and sphericity of the grain increased from 10.19 to 10.27, 2.29 to 2.42, 1.84 to 1.93, 3.502 to 3.634 mm and 0.344 to 0.354, respectively, as the moisture content increased from 6.92 to 23.16% d.b. In the case of awned paddy, the thousand grain mass increased from 24.324 to 28.038 g, bulk density from 316.76 to 357.60 kg m^{-3}, true density from 1326.2 to 1384.6 kg m^{-3} and the porosity decreased from 76.11 to 74.17, the angle of repose increased from 37.42 to 45.71°. The static coefficient of friction was significantly different on three structural surfaces namely, mild iron (0.464 to 0.511), galvanized iron (0.432 to 0.471) and rubber (0.496 to 0.558) at the moisture content range considered. In the case of de-awned paddy, the thousand grain mass increased from 23.980 to 27.734 g, bulk density from 546.10 to 593.00 kg m^{-3}, true density from 1352 to 1397 kg m^{-3} and the porosity decreased from 59.62 to 57.55, the angle of repose increased from 34.46 to 42.68°, the static coefficient of friction increased from 0.434 to 0.518, 0.416 to 0.464 and 0.477 to 0.538 for mild steel, galvanized iron and rubber, respectively as moisture content increased from 7 to 23% d.b.

Key words: Paddy, physical properties, de-awning, moisture content

INTRODUCTION

Rice (*Oriza sativa* L.) is an important staple food in Iran. It is grown on an area of about 615 thousand ha with a total paddy production of about 3.0 million t. Main areas of rice cultivation in Iran are Mazandaran and Gilan provinces producing 75 percent of Iran's rice crop (Anonymous, 2005). Production of local rice varieties such as Hashemi and Sadri is common in these regions. One of the specific traits of local varieties is the presence of awns at the tip of the lemma. The presence of awns influences the physical and morphological characteristics of the grains. Awns tend to cling to each other, bridge-over and cause seed to adhere in a mass. This causes difficulty in flow through chutes and orifices. Thus knowledge of physical properties of these type of paddy is essential for the adequate design of equipment for cleaning, handling, separation and specially in milling process.

Some physical properties of rough rice have been determined by other researchers. Wratten *et al.* (1969) and Morita and Singh (1979) measured physical and thermal properties of rough rice. Arora (1991) determined physical and aerodynamic properties of paddy at different moisture contents. Tado *et al.* (1999) measured some physical and aerodynamic characteristics of two paddy varieties and reported that the dimensions, sphericity, geometric mean diameter and terminal velocity of the grains increased with increasing moisture content. Reddy and Chakraverty (2004) determined some moistute-dependent physical properties of raw and parboiled paddy. However, there is a death of information on the effects of paddy de-awning on variations of its physical properties. Hence, this study was conducted to investigate the effects of de-awning and moisture content on some physical properties of paddy, namely, linear dimensions, sphericity, thousand grain mass, bulk and true density, porosity, angle of repose and static coefficient of friction.

MATERIALS AND METHODS

The long grain local variety of paddy named, *Hashemi* used in the present study was obtained from Rice Research Institute of Iran (RRII) Farm in 2004 during the summer season near the city of Rasht. Paddy was cleaned manually to remove all foreign and broken or immature grains. To obtain de-awned samples of paddy,

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awns were removed manually without any damage to grains. The initial moisture content of the grains was determined using oven drying method at 103±1°C for 48 h (Sacilik *et al*., 2003). The initial moisture content of the grain was determined to be 15.09% d.b.

Samples with the desired moisture level above 15% d.b. were obtained by spraying with pre-calculated amounts of distilled water as calculated from the following relation (Sacilik *et al*., 2003):

$$\phi = \frac{W_i(M_f - M_i)}{(100 - M_f)} \quad (1)$$

Where, ϕ is the mass of water added in kg; W_I is the initial mass of the sample in kg; M_i and M_f are the initial and the final moisture content of the sample in % d.b.

The samples were sealed well in separate polythene bags and kept in a refrigerator at 5°C for 7 days for the moisture to distribute uniformely throughout the sample. Before starting a test, the required quantity of the sample was taken out of the refrigerator and allowed to warm up to the room temperature. To obtain the desired moisture levels below 15% d.b., the samples were kept in an oven at a constant temperature of 43±1°C until the desired mass of the samples were obtained. All the physical properties of the grains were assessed at moisture contents in the range of 6.92 to 23.31% d.b., since harvesting, transportation, storage and processing operations of the crop are performed in this moisture range.

To determine the average size of the grain, 100 grains were randomly picked and their three linear dimensions namely, length L, width W and thickness T were measured using a micrometer (Miutoyo, Japan) reading to 0.01 mm. The geometric mean diameter D_g was then calculated from the actual dimensions using the relationship (Mohsenin, 1986):

$$D_g = (LWT)^{1/3} \quad (2)$$

Where: L is the length of the grain in mm; W is the width of the grain in mm; and T is the thickness of the grain in mm. The sphericity of the grain ϕ was determined by using the following relationship (Jha, 1999):

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (3)$$

The one thousand mass of the awned and de-awned paddy was determined by means of an electronic balance (Sartorius, Germany) reading to 0.001 g. The bulk density ρ_b of the awned and de-awned paddy at different moisture contents was determined by filling a 500 ml cylindrical metallic container with the grain from a height of about 150 mm at a constant rate and then weighing the container. No separate manual compaction of grains was done. The bulk density was then calculated from the mass of grains and the volume of the container (Sacilik *et al*., 2003). The true density (ρ_t) as a function of moisture content, was determined using the toluene (C_7H_8) displacement method. The volume of toluene displaced was found by immersing the weighed quantity of grain in toluene (Suthar and Das, 1996).

The porosity ε for the awned and de-awned paddy at different moisture contents was determined using the following relationship (Singh and Goswami, 1996).

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (4)$$

The angle of repose θ was measured by means of an apparatus consisting of a plywood box of 0.3 m by 0.3 m by 0.3 m, a circular platform of 120 mm diameter fitted inside and a discharge gate at the bottom of the box. The box was filled with paddy (awned and de-awned, separately) and the gate was quickly removed. The height of the grain pile retained on the circular platform was measured with a gauge reading to 0.01 mm. The angle of repose was then calculated as (Reddy and Chakraverty, 2004):

$$\theta = \tan^{-1}\left(\frac{2H_c}{D_c}\right) \quad (5)$$

Where, θ is the dynamic angle of repose in degrees; H_C is the height of the grain pile in mm and D_C is the diameter of disk in mm.

The static coefficient of friction μ for awned and de-awned paddy was determined on three different structural materials, namely mild steel, galvanized iron and rubber. A plastic cylinder of 100 mm diameter and 50 mm height was placed on an adjustable tilting plate, faced with the test surface and filled the sample about 150 g. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was inclined gradually, until the cylinder just started to slide down and the angle of tilt was read from a graduated scale (Nimkar and Chattopadhyay, 2001). The static coefficient of friction was calculated using the following relationship:

$$\mu = \tan \alpha \quad (6)$$

Where, μ is The static coefficient of friction and α is the angle of tilt in degrees.

RESULTS AND DISCUSSION

Seed dimensions: It can be seen from Table 1 that the three axial dimensions increased with moisture content in the range of 6.92 to 23.16% d.b. The increases in length, width, thickness, geometric mean diameter and sphericity were 0.78, 5.68, 4.89, 3.77 and 2.91%, respectively. The results were similar to those reported for raw and parboiled paddy (Reddy and Chakraverty, 2004); Vetch seed (Yalcin and Ozarslan, 2004); cotton seed (Ozarslan, 2002). The relationship between the grain dimensions and moisture content M_C was found to be linear and can be expressed by the regression equations as shown in Table 2. Such dimensional changes are important in determine aperture size in the design of grain handling and processing machinery.

Thousand grain mass: The thousand grain mass of awned and de-awned paddy increased from 24.324 to 28.038 g and 23.980 to 27.734 g, respectively as moisture content increased from 6.92 to 23.16% d.b. (Fig. 1). In each moisture content level, the thousand grain mass of the awned paddy was significantly ($p \leq 0.01$) higher than that of the de-awned paddy. The difference in thousand grain mass between awned and de-awned paddy are important in the design of separation and cleaning equipment. The relationship between the thousand grain mass and moisture content are presented in Table 3. A linear increase in the thousand grain mass as the seed moisture content increases has been noted for hemp seed (Sacilik *et al.*, 2003), quinoa seed (Vilche *et al.*, 2003), Turkey okra seed (Calisir *et al.*, 2005), raw paddy (Reddy and Chakraverty, 2004) and many other seeds.

Bulk and true density: The bulk density of awned and de-awned paddy increased from 316.76 to 357.60 kg m^{-3} and 546.10 to 593.00 kg m^{-3}, respectively as moisture content increased from 6.72 to 23.30% d.b. (Fig. 2). The increase in bulk density with increase in grain moisture content was mainly due to the higher rate of increase in weight than volume for both awned and de-awned paddy. The bulk density of awned paddy was significantly ($p \leq 0.01$) less than that of de-awned paddy at all moisture content levels tested. This may be attributed to the presence of awns, which is bulky and occupies space by keeping paddy grain apart such that it caused a reduction in the total mass per unit volume occupied by the grains. The positive linear relationship of bulk density with moisture content was also reported by other research workers (Baryeh and Mangope, 2002; Paksoy and Aydin, 2004; Reddy and Chakraverty, 2004).

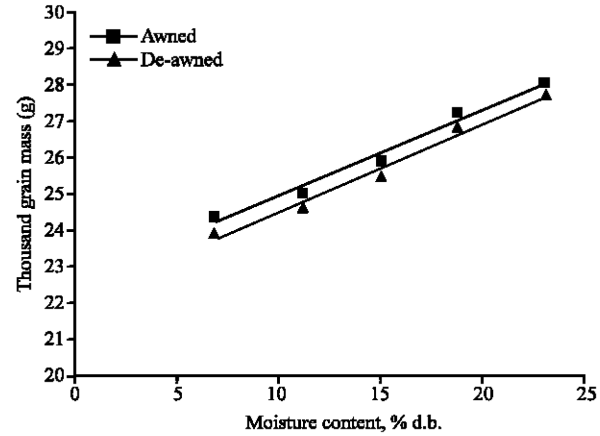

Fig. 1: Effect of moisture content and de-awning on thousand grain mass of paddy

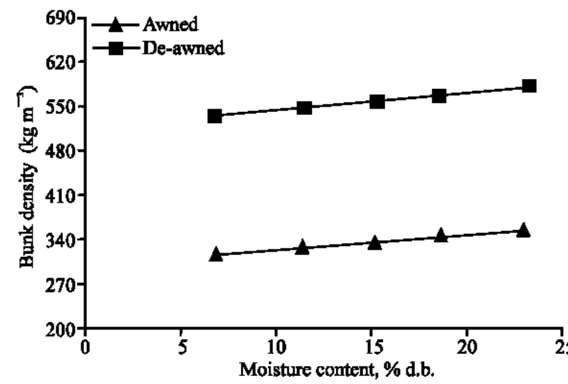

Fig. 2: Effect of moisture content and de-awning on bulk density of paddy

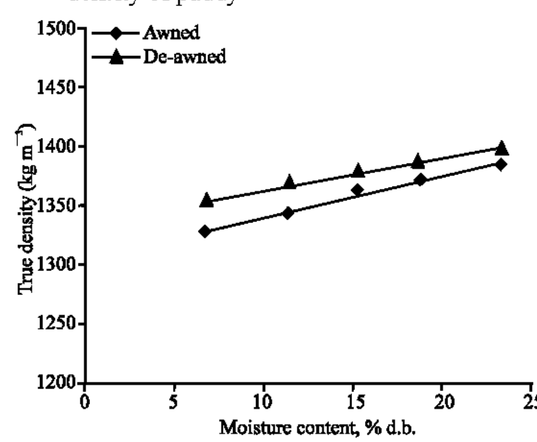

Fig. 3: Effect of moisture content on true density of awned and de-awned paddy

The true density for awned and de-awned paddy was found to increase from 1326.2 to 1384.6 and 1352.6 to 1397 kg m^{-3}, respectively as moisture content increased from 6.72 to 23.3% d.b. (Fig. 3). The linear

Table 1: Dimensional properties of awned paddy at different moisture contents (values in parenthesis represent the standard deviation)

Moisture content (% d.b.)	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)	Sphericity
6.92	10.19 (±0.43)[a]	2.29 (±0.09)[d]	1.84 (±0.05)[b]	3.502 (±0.09)[c]	0.344 (±0.010)[c]
11.23	10.21 (±0.45)[a]	2.33 (±0.08)[c]	1.86 (±0.06)[b]	3.539 (±0.08)[b]	0.347 (±0.012)[bc]
15.09	10.22 (±0.46)[a]	2.37 (±0.08)[b]	1.87 (±0.08)[b]	3.563 (±0.08)[b]	0.349 (±0.012)[abc]
18.84	10.24 (±0.46)[a]	2.39 (±0.07)[ab]	1.91 (±0.07)[a]	3.603 (±0.07)[a]	0.352 (±0.013)[ab]
23.16	10.27 (±0.47)[a]	2.42 (±0.09)[a]	1.93 (±0.09)[a]	3.634 (±0.09)[a]	0.354 (±0.012)[a]

In each column, means followed by a common letter are not significantly different at the 5% level

Table 2: Linear relationships between grain dimensions and moisture content

Property	Regression equation	R^2
Length (mm)	$L = 0.0047M_c + 10.155$	0.97
Width (mm)	$W = 0.008M_c + 2.2398$	0.98
Thickness (mm)	$T = 0.0057M_c + 1.7959$	0.96
Geometric mean diameter (mm)	$D_g = 0.0082M_c + 3.4452$	0.99
Sphericity	$\phi = 0.0006M_c + 0.3398$	0.99

relationship of true density with moisture content was also observed for medium and long grain rough rice (Wratten *et al.*, 1969), edible squash seeds (Paksoy and Aydin, 2004) and quinoa seed (Vilche *et al.*, 2003). The regression equations of the bulk and true density in the moisture content range for awned and de-awned paddy are shown in Table 3. The difference in bulk and true densities between awned and de-awned paddy affect the capacity of conveying and separation systems in the processing machinery.

Porosity: The porosity of awned and de-awned paddy varied from 76.11 to 74.17 and 59.62 to 57.55%, respectively when the moisture content from 6.72 to 23.30% d.b. (Fig. 4). The porosity of de-awned paddy was significantly ($p\leq 0.01$) less than that of awned paddy at each moisture content level. The increase in porosity of awned paddy is mainly due to the more pronounced reduction of bulk density compared with the de-awned paddy.

The relationship between the porosity of awned and de-awned paddy and moisture content M_c was found to

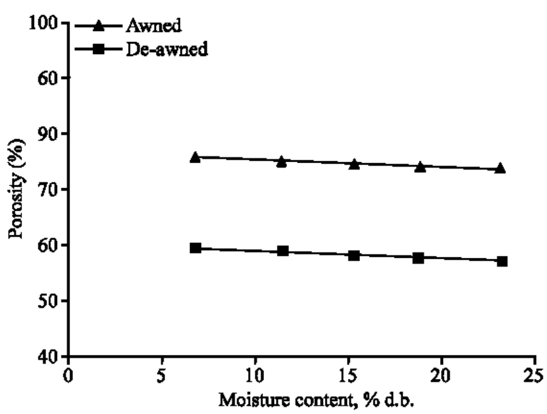

Fig. 4: Effect of moisture content on porosity for awned and de-awned paddy

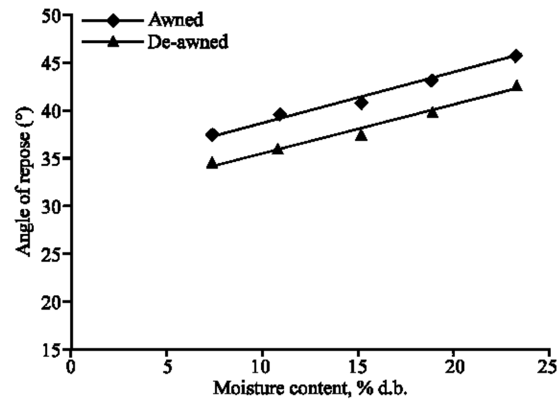

Fig. 5: Effect of moisture content and de-awning on angle of repose of paddy

be linear and can be expressed by the regression equations as shown in Table 3. Porosity values are very important in storage and drying process. Because of an increase in voids, respiration velocity of materials increase during storage. It was found that when the void volume of paddy bulk increases, its resistance to air decreases (Kocabiyik *et al.*, 2004).

Angle of repose: It was observed (Fig. 5) that the angle of repose of awned paddy increased from 37.42 to 45.71° as the moisture content increased from 7.26 to 23.21% d.b. This range for de-awned paddy was 34.46-42.68°.

The angle of repose for de-awned paddy was significantly ($p\leq 0.01$) less than that of awned paddy. The reason for the increased angle of repose of awned paddy at higher moisture content may be due to an increase in the internal friction with increasing moisture content (Deshpande *et al.*, 1993). Variations in the angle of repose for awned and de-awned paddy with moisture content are presented in Table 3. Similar results were reported by Nimkar and Chattopadhyay (2001) for green gram; Reddy and Chakraaverty (2004) for raw and parboiled paddy; Baryeh and Mangope (2002) for pigeon pea and Paksoy and Aydin (2004) for edible squash seeds. The data on the angle of repose will be useful in hopper design for gravity flow since the angle of inclination of the hopper walls should be greater than the angle of repose to ensure continuous flow of the material.

Table 3: The relationship between paddy moisture content with thousand grain mass, bulk and true density, porosity and angle of repose for awned and de-awned paddy

Property	Awned paddy	R^2	De-awned paddy	R^2
Thousand grain mass (g)	$M_{ta} = 0.2377M_c + 22.538$	0.98	$M_{td} = 0.2409M_c + 22.129$	0.98
Bulk density (kg m^{-3})	$\rho_{ba} = 2.5153M_c + 300.39$	0.99	$\rho b_b = 2.89M_c + 526.11$	0.99
True density(kg m^{-3})	$\rho_{ta} = 3.5658M_c + 1303.60$	0.99	$p_{td} = 2.6616M_c + 1336.3$	0.99
Porosity (%)	$\varepsilon_a = -0.1196M_c + 76.884$	0.95	$\varepsilon_d = -0.1298M_c + 60.573$	0.96
Angle of repose (°)	$\theta_a = 0.5007M_c + 33.798$	0.98	$\theta_d = 0.5101M_c + 30.352$	0.97

Table 4: Means of static coefficient of friction for awned and de-awned paddy at different moisture contents and surfaces*

	Awned paddy			De-awned paddy		
Moisture content (% d.b.)	MS	GI	RU	MS	GI	RU
7.23	0.464^b	0.432^b	0.496^c	0.434^c	0.416^b	0.477^c
11.15	0.470^b	0.441^{ab}	0.503^c	0.441^{bc}	0.423^b	0.483^c
14.81	0.481^{ab}	0.443^{ab}	0.507^{bc}	0.450^{bc}	0.430^b	0.492^{bc}
19.37	0.486^{ab}	0.458^{ab}	0.538^{ab}	0.470^b	0.437^{ab}	0.518^{ab}
23.31	0.511^a	0.471^a	0.558^a	0.518^a	0.464^a	0.538^a

MS: Mild Steel, GI: Galvanized Iron, RU: Rubber *In each column, means followed by a common letter are not significantly different at 5% level

Static coefficient of friction: The static coefficient of friction is recognised by engineers as important property concerned with rational design of seed bins and other storage structures (Vilche *et al*., 2003). The static coefficient of friction for awned and de-awned paddy on three surfaces (mild steel, galvanized iron and rubber) at different moisture contents are shown in Table 4. It was observed that the static coefficient of friction increased with increasing moisture content for all surfaces.

Values of the coefficient of static friction for awned and de-awned grains increased from 0.464 to 0.511 and 0.434 to 0.518 for mild steel, 0.432 to 0.471 and 0.416 to 0.464 for galvanized iron and 0.496 to 0.558 and 0.477 to 0.538 for rubber as the moisture content increased from 7.23 to 23.31% d.b. This is due to the increased adhesion between the grain and the material surfaces at higher moisture contents (Sudajan *et al*., 2001).

The static coefficient of friction ($p \leq 0.01$) of friction of paddy was found to be high on rubber followed by mild steel and galvanized iron. Values of the static coefficient of friction of awned and de-awned paddy(average of the three surfaces) varied between 0.464 to 0.513 and 0.422 to 0.507, respectively, at the grain moisture content range between 7.23 to 23.31% d.b. Due to high friction of the awned paddy and consequent arching and clogging problems through chutes and orifices, de-awning of the paddy would be necessary for facilitating of the grain flow.

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