Journal of Food Legumes 32(2): 101-104, 2019

Effect of moisture content on engineering properties of urdbean (*Vigna mungo*)

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(Received : July 11, 2018 ; Accepted : January 07, 2019)

ABSTRACT

Some engineering properties of urdbean were determined by increasing its moisture content (from 10 to 14%). The average length, width and thickness of the 20 urdbean seeds varied from 3.61 to 4.10 mm, 2.75 to 3.11 mm and 3.04 to 3.44 mm, respectively as the moisture content increased. The mean value of sphericity decreased from 0.86 to 0.81 with decrease in bulk density. True density was increased from 1013.43 to 1231.03 kg m^{-3} with increased moisture content. Also the porosity of urdbean seeds was increased linearly from 30.68 to 44.02 per cent and an angle of repose was found increased from 27.82° to 30.38°. The coefficient of friction was observed to be increased from 0.34 to 0.42, 0.32 to 0.38 and 0.30 to 0.37 in the case of plywood, cardboard and mild steel surfaces, respectively. The hardness of urdbean decreased from 5.98 to 3.75 kgf with increase in moisture content from 10 to 14%.

Key words: Effect of moisture, Engineering properties, Moisture content, Urdbean, *Vigna mungo*

Urdbean or urad is one of the most important pulse crop in India. Being the largest producer and consumer of urdbean in the world about 70% of the world's urdbean production comes from India. As known a urdbean is a rich protein food contains about 26 percent protein which is almost three times that of cereals. It is consumed in the form of a split pulse as well as whole pulse, becomes an essential supplement of cereal-based diet. In simple words, it is as dal and used as an ingredient in snacks like idli, dosa, vadaand papad and urad production in the country is largely concentrated in five states *viz.,* Uttar Pradesh, Andhra Pradesh, Maharashtra, Madhya Pradesh and Tamil Nadu. These five states together contribute for about 66% of total urad production in the country. Apparently all pulses have a similar structure but differ in colour, shape, size, and thickness of the seed coat. So there was a need to identify the engineering properties such as size bulk density, porosity and particle density the angle of repose the coefficient of friction and hardness for urdbean which were done in this study.

MATERIALS AND METHODS

In order to determine the engineering properties of urdbean the bulk quantity of urdbean was procured from the local market of Coimbatore. The knowledge of size, shape, gravimetric and frictional properties of urdbean obtained from a different location was helped in the processing system. The engineering properties of food materials decide the performance and design of the processing system. The method used to determine the engineering properties such as size, bulk density, porosity, and particle density, the angle of repose, the coefficient of friction and hardness for urdbean is given below.

Moisture content: To find out the moisture content of urdbean three samples (weighing 30g each) were selected and determined with the help of hot air oven drying method. The samples were oven dried at 130! using hot air oven for 1 hour until the mass of grain remains constant. Weight loss on drying to final constant rate was recorded as moisture content by AOAC, 1984 recommended method (Liny *et al.* 2013) for dehulling of urdbean, 9-10 per cent (d.b.) moisture required. Given engineering properties were measured at different moisture content such as 10,12 and 14 per cent (d.b).

Dimensional properties

Size, geometric mean diameter, sphericity index and surface area: The samples of urdbean were randomly chosen for measuring dimension length width and thickness and each urdbean grain was measured by using Vernier calliper (least count 0.01 cm) Ten observations were made to get the average value of length, width and thickness of urdbean seed (Mohsenin 1986). Geometric mean diameter (D_g) and Sphericity (Φ) were calculated using the following formulas.

$$D_g = (LWT)^{\frac{1}{3}} \qquad \ldots 1$$

$$\Phi = \frac{D_g}{L} \qquad \ldots 2$$

Where,

L = length of grain (mm)

W= Width of grain (mm)

T = thickness of grain (mm)

D_g = Geometric mean diameter (mm)

Φ = Sphericity

Bulk density, particle density and porosity: Bulk density was determined by filling a circular container of known volume gently tapped and weighing the content. Meanwhile care was taken to avoid compaction of the sample during tapping into the container and filled to full volume. The measurement was replicated twenty times and the mean was recorded. Bulk density was calculated as the ratio between mass and bulk volume of the sample.

$$\text{Bulk density } \rho_b = \frac{m}{v_c} \quad ..... 3$$

Where,

ρ_b = bulk density (*kg/m*^{3})

m = mass of grain (*kg*)

v_c = volume of container (m^3)

The particle density was calculated from the known values of bulk density and porosity of urdbean by using following formula (Mohsenin 1986)

$$\text{Particle density } (\rho_t) = \frac{\text{bulk density}}{1 - \text{porosity}} \quad ...4$$

Where ρ_t = particle density (*kg/m*^{3})

The porosity of urdbean was determined using porosity apparatus by using following formula

$$\text{Porosity } (\varepsilon) = \frac{P_1 - P_2}{P_2} \times 100$$

Where,

P_1 = the air pressure (P_1) inside the bottle

P_2 = New pressure in porosity apparatus

Angle of repose: The angle of repose was determined from the height and diameter of naturally formed heap of urdbean on a circular plate. It was calculated from the following formula (Theer tha *et al.* 2014).

$$\theta = \tan^{-1} \frac{2H}{D} \quad ...6$$

Where,

θ = angle of repose (degree)

D = diameter of heap (mm)

h = height of heap (mm)

Coefficient of friction: The experimental apparatus used in the friction studies was similar to that reported by Pandiselvem (2012). The apparatus consisted of a frictionless pulley fitted on a frame, a bottomless cylindrical container (94 mm diameter and 98 mm height), loading pan and test surfaces. The bottomless container placed on the surfaces was filled with a known quantity of urdbean and weights were added to the loading pan until the container began to slide. The mass of urdbean and the added weight represent the normal forces and frictional force, respectively. The coefficient of static friction was calculated as the ratio of frictional forces to the normal forces as,

$$\mu = \frac{F}{N_f} \quad ..... 7$$

Where,

μ = Coefficient of friction

F = Friction force (kg)

N_f = Normal force (kg)

The experiment was performed using test surfaces of plywood cardboard and mild steel.

Hardness: Hardness is a measure of resistance offered by the substance to retain its parameter shape and size when force is applied on it. For measuring the hardness of urdbean, hardness tester (Japan Model) machine was used. The measurement was repeated for three times and the mean was reported (Mohsenin 1986).

RESULTS AND DISCUSSION

***Size, geometric mean diameter, sphere city index and surface area*:** The dimensions diameter of urdbean were measured along three mutually perpendicular axes and the result of each principal dimension appeared to be linearly dependent on the moisture content as shown in Fig 1. Urdbean expands in length width and thickness due to absorption of moisture in the range of 10 to 14 per cent (d.b) The average length, width and thickness of the 20 seeds varied from 3.61 to 4.1 mm, 2.75to 3.11 mm and 3.04 to 3.44 mm respectively as the moisture content increase from 10 to 14 percent (d.b).The variation in the geometric mean diameter of a urdbean at different moisture contents is shown in Fig. 4.2. From the Figure it is shown that the geometric mean diameters of seed increased with increase in moisture content and established a linear relationship and the regression equation developed is given below.

$$D_{geo} = 0.0275M + 3.0633, (R^2 = 0.9356) \quad ....9$$

Where

D_{geo} = geometric mean diameter mm

High coefficient of determination (R^2> 0.93) show the best fit of the model to describe the change in mean diameter of urdbean within the experimented moisture range.

The shape of the urdbean measured in terms of sphere city at different moisture contents is shown in Fig 4.3. From the Figure, it is observed that the mean value of sphere city decreased from 0.86 to 0.81 as the moisture content increased from 10 to 14 percent (d.b). From the Figure it is shown that a linear relationship exists between moisture content and shape of urdbean and was given by the following regression equation.

$$\phi = -0.0093\,M + 0.9507, (R^2 = 0.7497) \quad .... 10$$

Bulk density and particle density: The bulk density of urdbean at different moisture levels varied from 702.44 to 688.99 kg m^{-3} as shown in Fig: 4.4 From the Figure it was found that bulk density decreased with an increase in moisture content from 10 to 14 percent (d.b.). This was due to a decrease in the mass as a result of moisture gained in the sample which was higher than the accompanying volumetric expansion of the bulk as stated by Nimkar *et al.* (2001). The bulk density ($\tilde{n}_b$) of the urdbean was found to have the linear relationship with the moisture content.

Pb= -3.3643M+736.92, $R^2 = 0.9562$ 11

The particle density of urdbean seeds at different moisture contents (10 to 14 per cent) increased from 1013.43 to 1231.03 kg m^{-3}, as shown in Fig 4.5. This was because of a decrease in airspace with an increase in the moisture content.

Porosity: The porosity of urdbean seeds increased linearly from 30.68 to 44.02 percent as the moisture content increased from 10 to 14 percent (d.b.) as shown in Fig 4.6. The linear decrease in bulk density and increase in particle density with increased moisture level produced higher values of porosity.

Angle of repose: The experimental results for the angle of repose with respect to moisture content are shown in Fig 4.7. The values were found to be increasing from 27.82º to 30.38º in the moisture range of 10 to 14 per cent (d.b.) This increasing trend in the angle of repose with moisture content occurs because of the surface layer of moisture surrounding the particle holds the aggregate of grain together by the surface tension (Nimkar *et al.* 2001). The angle of repose (θ) of the urdbean was found to have the following relationship with the moisture content.

$\theta = 0.6407M+21.392$, (R^2=0.9989) 12

Static coefficient of friction: The static coefficients of friction of urdbean on three different surfaces (plywood, cardboard, mild steel sheet) for moisture content in the range of 10 to 14 per cent (d.b). is shown in Fig. 4.8. It was observed that the static coefficient of friction increased with an increase in moisture content for all contact surfaces. The reason for the increase in friction coefficient at higher moisture content may be owing to the water present in the grain offering a cohesive force on the surface of contact. An increase of 0.34 to 0.42, 0.32 to 0.38 and 0.30 to 0.37 were recorded in the case of plywood cardboard mild steel surfaces respectively as the moisture content increased from 10 to 14 percent (d.b). At all moisture content values the maximum friction was offered by plywood, followed by cardboard sheet and mild sheet. The least static coefficient

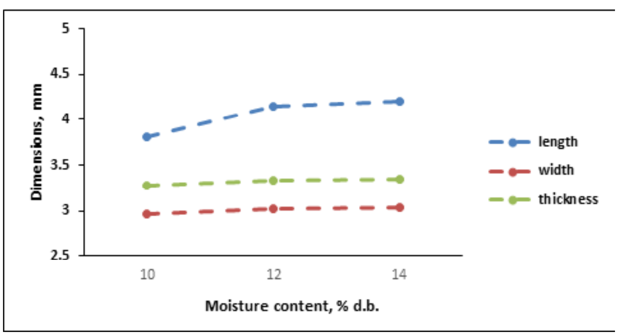

Fig 1. Effect of moisture content on urdbean dimension

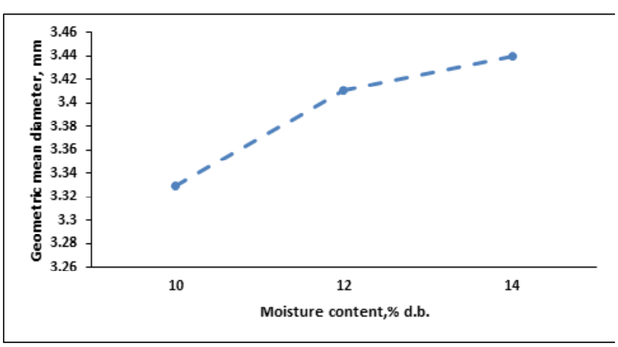

Fig 2. Effect of moisture content on Geometric mean diameter of urdbean

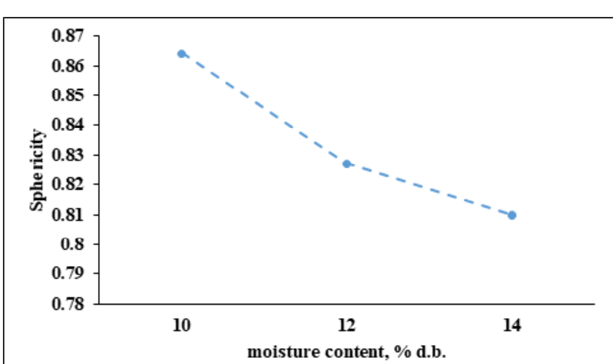

Fig 3. Effect of moisture content on sphericity

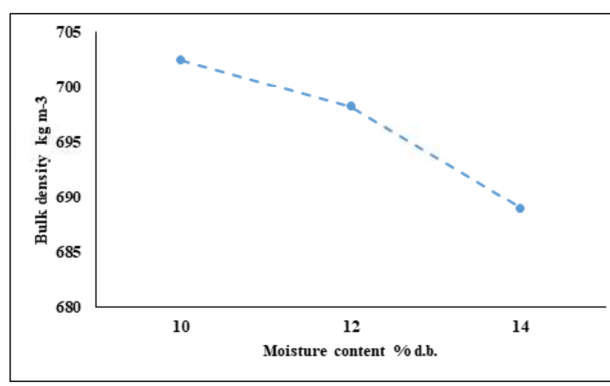

Fig 4. Effect of moisture content on bulk density

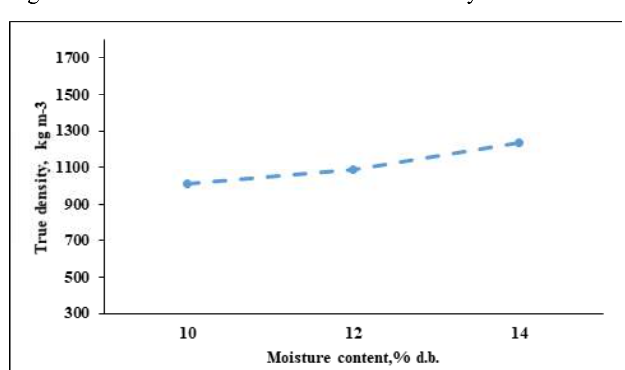

Fig 5. Effect of moisture content on particle density

of friction may be owing to a smoother and more polished surface of the mild steel compared to the other materials used.

$\mu = 0.015M+0.1933, (R^2=0.9643)$ (Plywood) 13

$\mu = 0.015M+0.1693, (R^2=0.9985)$ (Card board) 14

$\mu = 0.0175M+0.1257$ $(R^2=0.9989)$ (Mild sheet) 15

Hardness: The hardness of urdbean decreased with increase in the seed moisture content. The hardness decreased from 5.98 to 3.75 kgf with an increase in moisture content from 10 to 14per cent (d.b.) and is shown in Fig 4.9. A greater force was necessary to rupture the grains at low moisture content. The small rupturing force at higher moisture content might have resulted from the fact that the urdbean might have a soft texture at high moisture content. The relationship between hardness of grain and moisture is given by the equation.

Hardness = $-0.5589M+11.582$, $(R^2= 0.9999)$ 16

All the values of properties were linearly associated with the moisture content of urdbean as varied from 10 to 14% (d.b.). The linear dimensions *viz.,* length width thickness were increased or decreased as moisture content was increased or decreased. Consequently it was concluded that as the moisture content increases or decreases there was an increase or decrease in physical properties urdbean as well as a similar change in coefficient of friction on different materials. Highest values of R^2 (>0.9) indicate that, the formulated equations are able to predict variations in the values of engineering properties of a urdbean for its moisture variations.

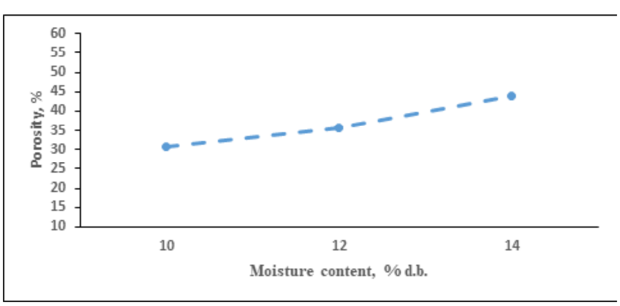

Fig 6. Effect of moisture content on porosity

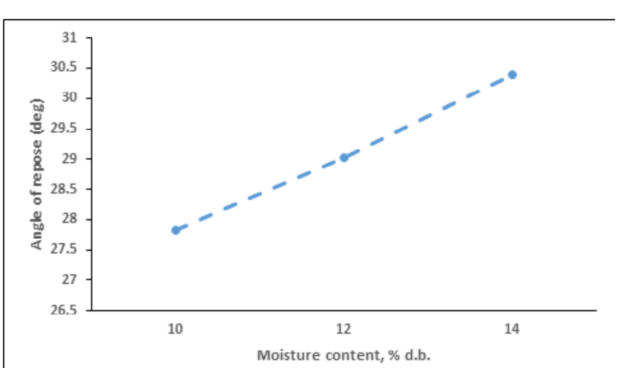

Fig 7. Effect of moisture content on angle of repose

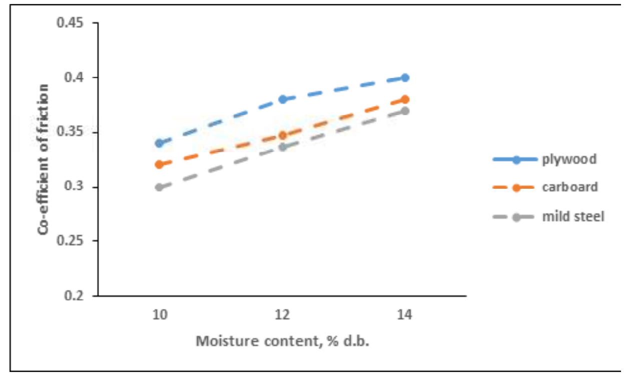

Fig 8. Effect of moisture content on co-efficient of friction

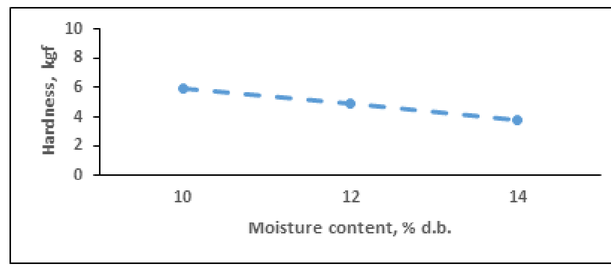

Fig 9. Effect of seed moisture content on hardness

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