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RESEARCH ARTICLE

Effect of Moisture on Engineering Properties of Pigeon Pea

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ABSTRACT

Engineering properties of food grains have an important role in the post-harvest equipment design. Some engineering properties of pigeon pea variety CO7 were determined at three different moisture contents via 8%, 10% and 15% w.b. The length, width, thickness, geometric mean diameter and sphericity of pigeon pea increased from 5.37 mm to 6.81 mm, 5.37 mm to 5.96 mm, 4.41 mm to 4.79 mm, 5.34 mm to 5.74 mm and 0.83to 0.87 respectively. The bulk density, true density and porosity decreased linearly from 843.47 kg.m^{-3} to 782.81 kg.m^{-3}, 1318.32 kg.m^{-3} to 1189.63 kg.m^{-3}, 0.36 to 0.34 respectively. Variation of thousand grains mass and angle of repose was from 86.86 g to 99.13 g and 21.57^0 to 26.57^0. Static coefficient of friction on mild steel, card board and galvanized iron surfaces also increased with moisture content in the range of 0.26 to 0.47.

Keywords: *Pigeon pea, Moisture content, Engineering properties, Equipment design*

INTRODUCTION

India ranks first in the production, consumption and import of pigeon pea. In India, nearly 80% of pulses are consumed in the form of dehusked split dhals. There are about 15,000 dhal mills in India. Most of the machines in dhal milling industry are developed through trial and error procedure, thus not giving the expected output in terms of good quality dehusked split dhal. Systematic procedures need to be adopted for the design and development of new dhal mills in order to reduce the dehulling losses and improve the quality of dhal obtained.

The design of any post-harvest machinery requires a detailed knowledge of the engineering properties of the grains to be processed. The moisture content of grain will not be the same at the time of harvest, transportation, processing and storage. Thus knowledge of the relationship of engineering properties of grains with moisture content is also essential for the proper design of agricultural equipment (Khanbarad *et al.*, 2014).

The effect of moisture content on engineering properties like size, shape, bulk density, true density, porosity, angle of repose and static coefficient of friction of red gram (Khan *et al.*, 2017; Shepherd *et al.*, 1986), green gram (Nimkar *et al.*, 2001), soy bean (Deshpande *et al.*, 1993) and chick pea (Konak *et al.*, 2002) have been investigated. A linear dependence of engineering properties such as size, shape, bulk density, true density, porosity, angle of repose and static coefficient of friction with moisture content was reported for red gram (Khan *et al.*, 2017), mungbean seeds (Ghasemlou *et al.*, 2010) and soybean (Deshpande *et al.*, 1993).

MATERIAL AND METHODS

Size of the material

Three principal dimensions, namely major diameter (length), minor diameter (thickness) and intermediate diameter (width) were measured using a vernier calliper with a least count of 0.01 mm. Geometric mean diameter and sphericity (Mohsenin, 1986) was calculated using the following equations:

$$\text{Geometric mean diameter GMD} = (LWT)^{(1/3)} \quad \text{------------- (1)}$$

$$\text{Sphericity, } \phi = \frac{(LWT)^{1/3}}{L} \quad \text{------------- (2)}$$

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where,

L - Length, mm

W- Width, mm

T - Thickness, mm

Bulk density

To determine the bulk density, grain was filled in a circular container of 0.0005 m^3 capacity without manual compaction and then the mass of grain was recorded using electronic weighing balance with a least count of 0.01g. The bulk density was calculated by using the following formula:

$$\rho_b = \frac{W}{V} \qquad \text{-----------------} (3)$$

where,

ρ_b - Bulk density, $kg.m^{-3}$

W - Weight of material, kg

V - Volume of the container, m^3

True density

Liquid displacement technique was used to determine the true density of pigeon pea grains. The true density was calculated as the ratio of mass of grains (kg) to the volume of water displaced (m^3) by using the following formula

Where

$$\rho_t = \frac{W}{V} \qquad \text{-----------------} (4)$$

ρ_t - True density, $kg.m^{-3}$

W - Mass of the grains, kg

V - Volume of water displaced, m^{-3}

Porosity

The porosity was calculated from the measured values of bulk density and true density using the following relationship (Mohsenin, 1986):

$$\varepsilon = \left(\frac{\rho_g - \rho_b}{\rho_g}\right) \text{x } 100 \qquad \text{-----------------} (5)$$

where

ε - Porosity, %

ρ_b - Bulk density, $kg.m^{-3}$

ρ_t - True density, kg.m-3

Thousand kernel mass

One kilogram grain was taken and divided into 10 portions. From each portion 100 grains were picked randomly. The selected grains were mixed thoroughly. The thousand grains picked were then weighed using electronic weighing balance with a least count of 0.01g.

Angle of repose

A set-up consisting of cylindrical container having a discharge port at bottom was used for determining the angle of repose of pigeon pea grains. The container was filled with the sample and then the bottom port was opened, allowing the sample to flow freely and form a heap. Angle of repose was calculated from the following equation.

$$\Theta = \tan^{-1}\left(\frac{2H}{D}\right) \qquad \text{------------------ (6)}$$

where

θ - Angle of repose, degrees

H - Height of cone, mm

D - Diameter of the cone, mm

Coefficient of friction

The apparatus consisted of a frictionless pulley fitted on a frame, a bottomless cylindrical container of 94 mm diameter and 98 mm height, loading pan and different test surfaces. The bottomless container placed on the surface to be tested was filled with a known quantity of pigeon pea grains and weights were added to the loading pan until the container starts to slide. The mass of the grain and the added weight represent the normal forces and frictional force, respectively. The coefficient of static friction was calculated by using the following equation:

$$\mu = \frac{F}{N} \qquad \text{----------------- (7)}$$

where,

μ - Coefficient of friction

F - Friction forces, kg

N - Normal force, kg

RESULTS AND DISCUSSION

Linear dimensions, geometric mean diameter and sphericity

The three principal dimensions via length, width and thickness, geometric mean diameter and sphericity were found to be linearly dependent on moisture content as shown in Fig. 1 (a,b,c,d and e). The values are given in Table 1.1. Similar trend was reported for pigeon pea (Singh *et al.,* 2010) and soybean (Deshpande *et al.,* 1993). Regression equations developed for the three principal dimensions were as follows:

Length, L = 0.1774 M + 4.2806 (R^2 = 0.708) ---------------- (8)

Width, W = 0.0798 M + 4.7911 (R^2 = 0.938) --------------- (9)

Thickness, T = 0.0512 M + 4.0374 (R^2 = 0.952) --------------(10)

GMD = 0.054M+4.9449 (R^2 = 0.945) --------------(11)

Sphericity,ϕ = 0.0052 M + 0.7923 (R^2 = 0.9332) ------------- (12)

where,

GMD = geometric mean diameter, mm

M = moisture content, % w.b.

R^2 = coefficient of determination

Table 1. Dimensions, geometric mean diameter and sphericity of pigeon pea at different moisture contents

Moisture content % (w.b.)	Principal dimensions, mm			Geometric mean diameter, mm	Sphericity
	Length, L	Width, W (normal to L)	Thickness, T (normal to L and W)		
8	5.37±0.10	5.37±0.13	4.41±0.12	5.34±0.06	0.83±0.01
10	6.52±0.12	5.67±0.11	4.60±0.08	5.54±0.06	0.85±0.01
15	6.81±0.07	5.96±0.05	4.79±0.07	5.74±0.04	0.87±0.01

Thousand grains mass

Thousand grain mass of pigeon pea increased from 86.86 g to 99.13 g, as moisture content increased from 8% to 15%. It can be seen from the Fig. 1 (e), that there is a linear relationship between thousand grain mass and moisture content. Similar trend was reported for pigeon pea (Shepherd *et al.,* 1986), soybean (Deshpande *et al.,* 1993) and mungbean seeds (Ghasemlou *et al.,* 2010). The regression equation relating moisture content and thousand grain mass is given below:

Thousand grain mass = 1.5151M + 77.516 ---------------- (13)

$R^2 = 0.7132$

where,

M = moisture content, % w.b.

R^2 = coefficient of determination

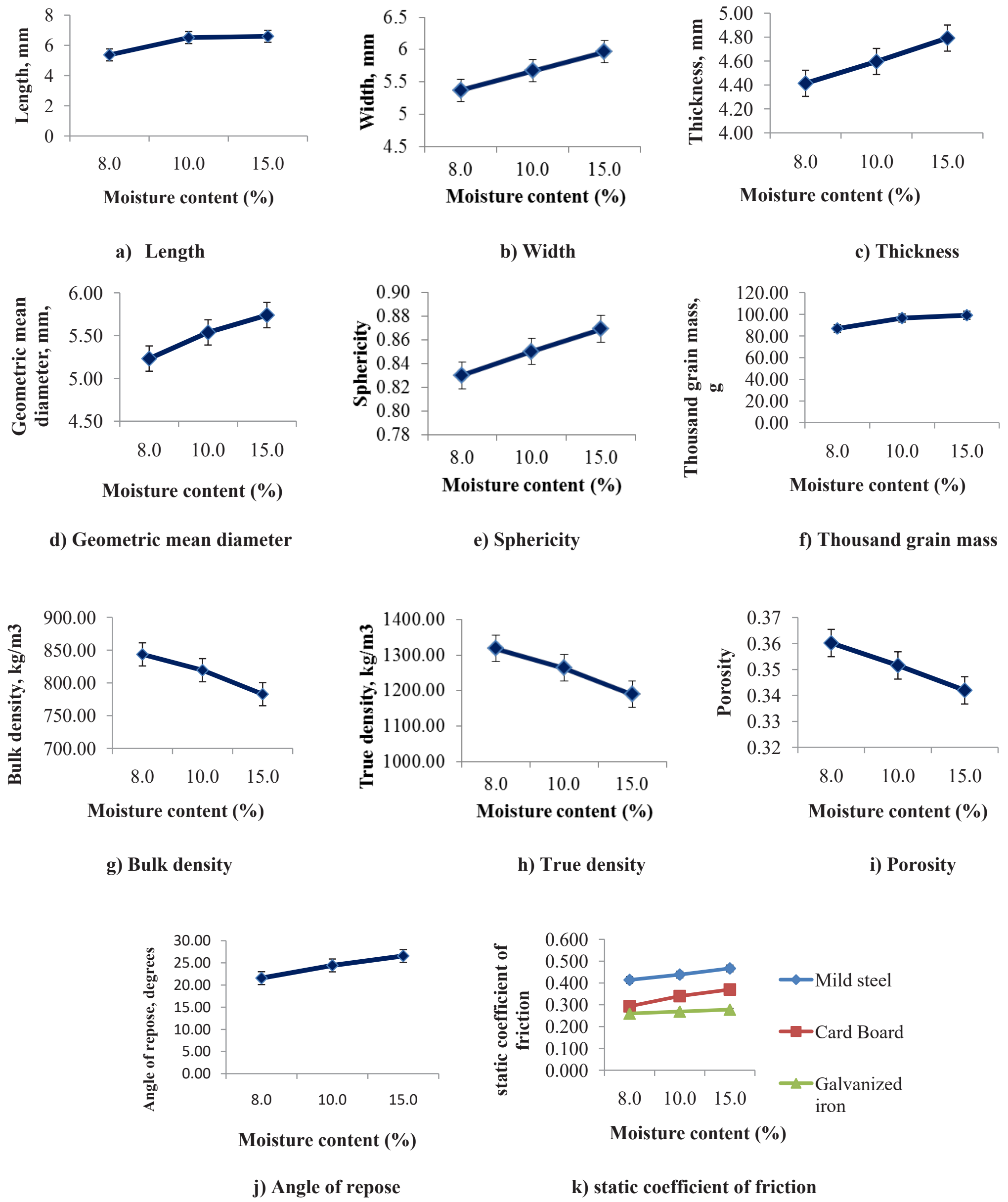

Fig 1. Effect of moisture content on engineering properties of pigeon pea

Bulk density, true density and porosity

Bulk density and true density and porosity of pigeon pea was reduced from 843.47 kg.m^{-3} to 782.81 kg.m^{-3}, 1318.32 kg.m^{-3} to 1189.63 kg.m^{-3} and 0.36 to 0.34, respectively (Fig. 1 (g,h,i)). Similar results were observed for pigeon pea (Shepherd *et al.,* 1986) and soybean (Deshpande *et al.,* 1993). The regression equations are given below:

Bulk density, ρb = $-8.4055\ M + 907.68$ ($R^2 = 0.985$) ---------------- (14)

True density, ρt = $-17.694\ M + 1451.8$ ($R^2 = 0.976$) ---------------- (15)

Porosity, ε = $-0.0025\ M + 0.3784$ ($R^2 = 0.9557$) ---------------- (16)

where,

M = moisture content, % w.b.

R^2 = coefficient of determination

Angle of repose and static coefficient of friction

Variation of angle of repose of grain was from 21.57^0 to 26.57^0 with moisture content. Static coefficient of friction of pigeon pea against mild steel surface, card board and galvanized iron surface increased from 0.41 to 0.47, 0.29 to 0.37 and 0.26 to 0.28 respectively (Fig 1. (j, k)). Similar trend was reported for pigeon pea (Khan *et al.,* 2017)), mungbean seeds (Ghasemlou *et al.,* 2010), green gram (Nimkar *et al.,* 2001). Regression equations relating angle of repose and static coefficient of friction with moisture content is as follows:

Angle of repose, $\theta = 0.659\ M + 16.94$ ($R^2 = 0.8968$) --------------- (17)

$\mu_{ms} = 0.0072\ M + 0.3608$ ($R^2 = 0.961$) --------------- (18)

$\mu_{cb} = 0.01\ M + 0.2239$ ($R^2 = 0.8697$) --------------- (19)

$\mu_{ga} = 0.0024\ M + 0.2423$ ($R^2 = 0.9423$) --------------- (20)

where,

M = moisture content, % w.b.

μ_{ms}, μ_{cb}, μ_{ga} = coefficient of static friction on mild steel, card board and galvanized iron surface, respectively.

R^2 = coefficient of determination

It can be concluded from the study that the engineering properties such as length, width, thickness, geometric diameter, sphericity, bulk density, true density, porosity, thousand grains mass, angle of repose and static coefficient of friction of pigeon pea had a linear dependence on moisture content. As moisture content varied from 8% to 15% w.b., the length, width, thickness, geometric diameter, sphericity, angle of repose and static coefficient of friction of the grain increased whereas bulk density, true density and porosity decreased, linearly.

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