Moisture dependent physical properties of Black gram

M. Esther Magdalene Sharon, C.V.KavithaAbirami*,K.Alagusundaram, J. Alice R.P.S.

(*Indian Institute of Crop Processing Technology (IICPT), Thanjavur-613005, India*)

Abstract: Physical properties of Black gram are important during harvesting, cleaning and drying with machines and also during improvement of these machines. This study was conducted to evaluate some moisture-dependent physical properties of Black gram namely, grain dimensions, thousand grain mass, surface area, sphericity, bulk density, true density, porosity and angle of repose. As the moisture content increased from 8.69% to 21.95% d.b., the three axial dimensions of the Black gram increased and the arithmetic and geometric mean diameter ranged from 3.73 ±0.14 to 4.27 ±0.14 mm and 3.79 ±0.13 to 4.32 ±0.13 mm respectively. The hundred grain mass of Black gram were 42.52 ±1.03 and 48.18 ±0.45 kg. The sphericity values of Black gram increased from 79.69% to 82.82%. The bulk and true densities values for Black gram decreased with increase in moisture content. The porosity and angle of repose of Black gram increased from 38.06% to 42.60% and 28.4° to 32.2° respectively with increase in moisture content from 8.69% to 21.95% d.b.

Keywords:physical properties, Black gram, sphericity, surface area, density, porosity

Citation: Sharon, M.E.M,Abirami,C.V. K, Alagusundaram, K, and Alice J.R.P.S. 2015. Moisture dependent physical properties of black gram. AgricEngInt: CIGR Journal,17(1), 181-187.

1 Introduction

Black gram (*Vignamungo* L.), commonly known as Urad in India is a highly valued pulse which contributes a wonderful taste to South India dish like 'Vada' and 'Dal makhni' of North India. It contains on average 10.9% moisture, 24% protein, 1.4% fat, 0.9% fibre and 59.6% carbohydrate as main component (Gopalan et al., 1995). India produced 1.11 million tons of Black gram in 1.92 Million Hectare area with a yield of 578 kg/hain 2008-2009 (GoI, 2010).

The knowledge of physical properties is important and essential engineering data for storage and processing, size reduction, handling and conveying (Bhattacharya et al., 2005). These data are not only valuable to engineers but also to food scientists, processors, and other scientists who may exploit these properties and find newer uses (Mohsenin, 1970; BalasubramanianandViswanathan, 2010). Physical properties vary widely with moisture content and are important because postharvest operations like drying, soaking, blanching, cooking and washing of seeds involve hydration (Murthy and Bhattacharya, 1998; Sharon et al., 2014). In addition, pulses are purchased with varying moisture content.

Research findings on the physical properties have been reported for different legumes, such as Soybean (Deshpande et al., 1993), Kidney bean (Isik and Unal, 2007), Chick pea (Konak et al., 2002), Pigeon pea (Baryeh and Mangope, 2002), Red gram (Shepherd andBhardwaj, 1986), Green gram (Nimkar and Chattopadhyay, 2001), Bengal gram (Dutta et al., 1988), and lentil (Amin et al., 2004; Carman, 1996).

Despite extensive research on black gram, sufficient published data on the detailed physical properties of Black gram of moisture content in the range of 8.69%–21.95% d.b. is not available. Therefore, an investigation was carried out to determine

Received date: 2014-01-19 **Accepted date:**2014-12-02

***Corresponding author:Abirami,C.V. K.**, Indian Institute of Crop Processing Technology,Thanjavur, India.E-mail: kaviabi@iicpt.edu.in

moisture-dependent physical properties of Black gram in 8.69%, 11.11%, 13.63%, 19.04% and 21.95% d.b. moisture contents.

The objective of this study was to investigate a few moisture- dependent physical properties like, axial dimensions, arithmetic and geometric mean diameters, sphericity, thousand grain mass, surface area, bulk density, true density, and porosity of Black gram.

Nomenclature

A_s surface area, mm^2	R^2 coefficient of determination
D_a arithmetic mean diameter of grain, mm	Q mass of water to added, kg
D_g geometric mean diameter of grain, mm	T thickness of grain, mm
L length of grain, mm	W width of grain, mm
M_{1000} thousand grain mass, g	W_i initial mass of sample, kg
M_i initial moisture content of sample, % d.b.	θ angle of repose, degree
M_f final moisture content of sample, % d.b.	ρ_b bulk density, kg/m^3
M moisture content, % d.b.	ρ_t true density, kg/m^3
P_f porosity, %	Φ sphericity of grain

2 Material and methods

The Black gram variety, ADT-5 used in the study was obtained from a Soil and Water Conservation Department (Thanjavur, India). The initial moisture content of the grains was determined by hot air oven method at 103℃ for 72h.

The samples of the desired moisture contents were conditioned by adding calculated amount of distilled water determined using Equation 1.

$$Q = \frac{W\,(M_f - M_i)}{(100 - M_f)} \qquad (1)$$

The conditioned grains were stored in tightly sealed polythene bags and refrigerated at 5℃ for a week to enable uniform distribution of moisture throughout the sample. Before conducting the experiment, the required quantity of grain were taken from the refrigerator and allowed to equilibrate to the room temperature for 2h.

The grains are usually harvested at around 20% d.b. moisture content and dried to desired moisture content of 10% and 12% d.b for safe storage. All the physical properties were assessed at five selected moisture content 8.69% to 21.95% d.b. with five replications at every moisture content.

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 digital verniercaliper (Mitutoyo, Japan) of least count 0.01 mm. The average diameter of grain wascalculated by using the arithmetic mean and geometric mean of the three axial dimensions. The arithmetic mean diameter D_a and geometric mean diameter D_g of the grain were calculated by using the following Equation 2 and Equation 3(Mohsenin, 1970; Isik and Unal, 2007).

$$D_a = \frac{(L+W+T)}{3} \qquad (2)$$

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

The sphericity (Φ) of grains was calculated by using the following relationship (Mohsenin, 1970; Pandiselvam et al., 2014) (Equation 4):

$$\Phi = \frac{(LWT)^{1/3}}{L} \qquad (4)$$

The surface area A_s in mm^2 of Black gram were found by analogy with a sphere of same geometric mean diameter, using the following relationship (Mohsenin, 1970; Singh et al., 2010) (Equation 5).

$$A_s = \pi\ D_g^2 \qquad (5)$$

Thousand grain mass were determined using electronic balance (Citizon, India) with least count 0.001 g. The average bulk density of Black gram at five moisture levels were found by filling a circular container of 500 ml capacity with grains from a height of 150mm without manual compaction (Singh and Goswami, 1996; Subhashini, 2013) and then the weight (W) of 500 ml grains of all samples were recorded. The bulk density was assessed using the Equation 6:

$$\rho_b = \frac{W}{500} \times 10^6 \quad (6)$$

The average true density was determined using the toluene displacement method. The volume of toluene (C_7H_8) displaced was found by immersing a weighed quantity of Black gram in the toluene (Singh andGoswami, 1996; Sologubik et al., 2013).

The porosity of Black gram at the five selected moisture content was calculated from the following Equation 7 (Mohsenin, 1970; Banuu, 2010):

$$P_f = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (7)$$

A box of size 220 mm * 130 mm *130 mm, having one side sliding and removable was used to determine the dynamic angle of repose 'θ'. The box was filled with grain and the sliding side of the box was quickly removed, allowing the grains to flow to their natural slope. The angle of repose was calculated by measurement of grain free surface depth at the end of the box and midway along the slope surface and horizontal distance from the end of the box to this mid-point (Dutta et al., 1988; Baryeh and Mangope, 2002).All the results obtained were subjected toanalysis of variance (ANOVA) and DUNCAN test using SPSS 21.0 software and regression analysis using Matlab 2012b.

3 Results and discussion

3.1 Grain dimension

The three axial dimensions of Black gram at different moisture contents are presented in Table 1. As can be seen in Table 1, the three axial dimensions increased with increase in moisture content from 8.69% to 21.95% d.b. The mean dimensions of grains measured at a moisture content of 8.69% d.b. are: length 4.74 ±0.18 mm, width 3.45 ±0.2 mm and thickness 3.19 ±0.26 mm. The mean dimensions of grains measured at a moisture content of 21.95% d.b. are: length 5.19 ±0.19 mm, width 3.99 ±0.2 mm and thickness 3.77 ± 0.26 mm. Differences of between values are statistically important at $P < 0.05$.

Table 1 Grain dimensions at different moisture content

Moisture content (%d.b.)	Axial dimensions (mm)			Average diameters (mm)	
	Length, L	Width, W	Thickness, T	Arithmetic mean, Da	Geometric mean, Dg
8.69	4.74 ± 0.18^{a}	3.45 ± 0.2^{a}	3.19 ± 0.26^{a}	3.73 ± 0.14^{a}	3.79 ± 0.13^{a}
11.11	4.79 ± 0.22^{a}	3.50 ± 0.21^{ab}	3.26 ± 0.26^{ab}	3.79 ± 0.14^{ab}	3.85 ± 0.14^{ab}
13.63	4.95 ± 0.19^{ab}	3.73 ± 0.2^{ab}	3.47 ± 0.29^{abc}	4.02 ± 0.14^{bc}	4.05 ± 0.13^{bc}
16.27	5.07 ± 0.19^{ab}	3.88 ± 0.2^{bc}	3.69 ± 0.25^{bc}	4.17 ± 0.12^{cd}	4.21 ± 0.12^{cd}
19.04	5.12 ± 0.2^{ab}	3.89 ± 0.2^{bc}	3.71 ± 0.24^{bc}	4.19 ± 0.12^{cd}	4.24 ± 0.12^{cd}
21.95	5.19 ± 0.19^{b}	3.99 ± 0.2^{c}	3.77 ± 0.26^{c}	4.27 ± 0.14^{d}	4.32 ± 0.13^{d}

Note: Values in the same columns followed by different letters are significant ($P < 0.05$).

The average diameter calculated by arithmetic mean and geometric mean method isalso presented in Table 1. It is evident from the table that mean diameter of Black gram increases with increase of moisture content. The arithmetic and geometric mean diameter ranged from 3.73 ±0.14 to 4.27 ±0.14 mm and 3.79 ±0.13 to 4.32 ± 0.13 mm as the moisture content increased from 8.69% to 21.95% d.b., respectively ($P < 0.05$).

3.2 Sphericity

The experimental results of sphericity of Black gram with increase in the moisture content areshown in Figure 1.The Figure indicated that the sphericity increased with increase in moisture content.

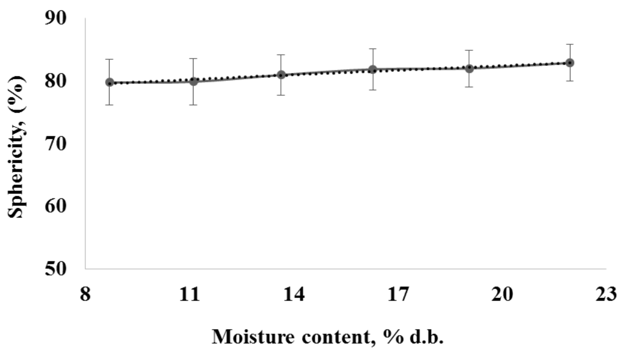

Figure 1Effect of moisture content on sphericity

The values of sphericitywerefound increased from 79.69% to 82.82% as the moisture content increased from 8.69% to 21.95% d.b. ($P < 0.05$). The increase in sphericity upon addition of moisture hasbeen reported for moth gram (Nimkar et al., 2005) and pea (Yalcin et al., 2007). The relationshipbetweensphericity and moisture content can be represented by Equation 8.

$$\Phi = 76.94 + 0.3165M - 0.0023M^2 \ (R^2 = 0.96) \quad (8)$$

3.3 Surface Area

The variation of the surface area with moisture content of Black gram is plotted in Figure 2. The figure indicates that the surface area increases with increase in moisture content. The surface area of Black gram increased from 43.91 ±3.20 mm^{2}to 57.40 ±3.77mm^2 ($P < 0.05$) when the moisture content increased from 8.69% to 21.95% d.b. The variation of moisture content and surface area can be expressed using Equation 9.

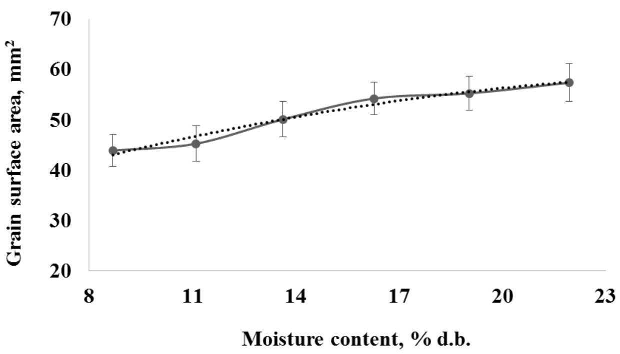

Figure 2Effect of moisture content on Surface area

$$A_s = 25.947 + 2.3219M - 0.0402M^2 \ (R^2 = 0.97) \quad (9)$$

Similar trends have been reported by Deshpande et al. (1993) for soybean and Tekin et al., (2006) for Bombay bean.

3.4 Mass of 1000 grains

The one thousand Black gram grains mass, M_{1000} increased from 42.53 ±1.03 to 48.18 ±0.45 g ($P < 0.05$) as the moisture content increased from 8.69% to 21.95% d.b. (Figure 3). The relationship for one thousand grain mass and moisture content can be formulated usingEquation 10.

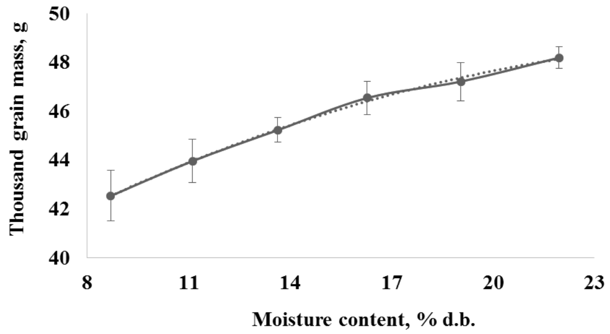

Figure 3Effect of moisture content on thousand grain weight

$$M_{1000} = 35.92 + 0.89\ M - 0.01M^2, \ (R^2 = 0.99) \quad (10)$$

Similar trends for results of the effect of grain moisture content on thousand grains mass have been reported for pigeon pea (Shepherd and Bhardwaj, 1986), green wheat (Al-Mahasneh and Rababah, 2007), and lentil seed (Amin et al., 2004). However, Sahoo and Srivastava (2002) reported logarithmic relationship between the thousand grains mass and moisture content.

3.5 Bulk density

The bulk densities decreased from 883.62 ±3.66 to 777.63 ±2.61kg/m^{3}when the moisture content increased from 8.69% to 21.95% d.b. and showed polynomial trend as shown in Equation 11 (Figure 4).

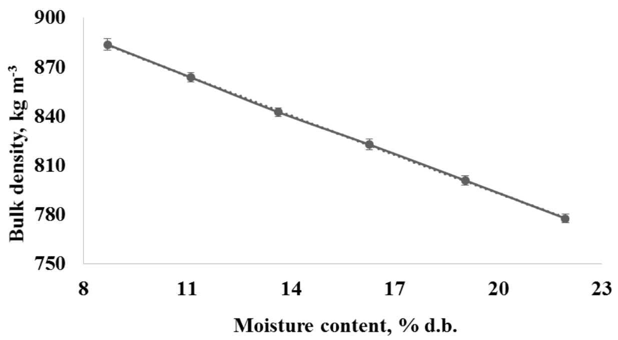

Figure 4Effect of moisture content on bulk density

$$\rho_b = 956.51 - 8.59M + 0.02M^2 \quad (R^2 = 0.99) \qquad (11)$$

The decrease in bulk density for Black gram with increase in moisture content indicated that the increase in mass owing to moisture gain in the grain sample was lower than accompanying volumetric expansion of the bulk (Kaleemullaha and Gunasekar, 2002). Similar trend was found by Singh and Goswami (1996) for cumin seed;Baryeh and Mangope, (2002) for millet. However, Altuntas and Yildiz (2007); IsikandUnal (2007) and Sahoo and Srivastava (2002) reported linear decrease in bulk density with increase of moisture content in faba bean, kidney bean grain and okra seed respectively.

3.6 True density

The true density varied from 1426.54 ±2.05 to 1354.54 ± 2.73 kg/m^3 ($P < 0.05$) when the moisture level increased from 8.69% to 21.95% d.b. (Figure 5). The true density and the moisture content of Black gram can be correlated Equation 12 as follows

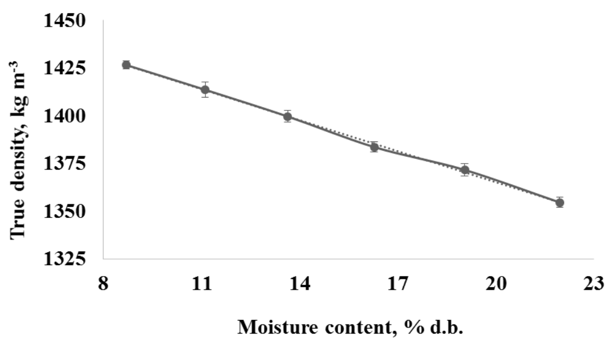

Figure 5Effect of moisture content on true density

$$\rho_t = 1473.4 - 5.4114M \quad (R^2 = 0.99) \qquad (12)$$

The decrease in true density was mainly due to the increase in grain volume in compared to their masses. Similar trend was reported by Cetin (2007) for Barbunia.

3.7 Porosity

The porosity of Black gram increased from 38.26% to 42.60% ($P < 0.05$) with the increase in moisture content from 8.69% to 21.95% d.b. (Figure 6). The relationship between porosity and moisture content can be represented by the following Equation 13:

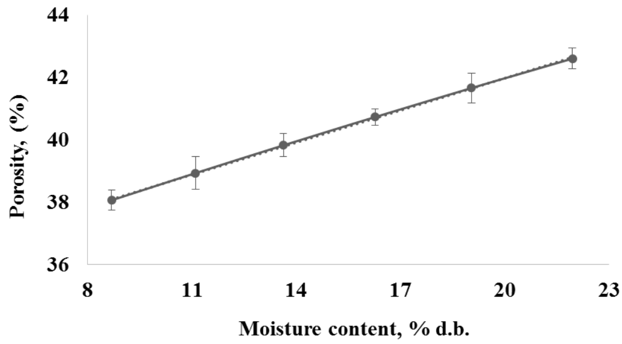

Figure 6Effect of moisture content on porosity

$$P_f = 35.119 + 0.3428M \ (R^2 = 0.99) \ (13)$$

Altuntas and Yildiz (2007), Nimkar et al. (2005) and Tekin et al. (2006) reported similar trends in the case of faba bean, moth gram and Bombay bean, respectively.

3.8 Angle of repose

The dynamic angle of repose of Black gram was observed to increase from 28.4 °to 32.2 °with the increase in moisture content from 8.69% to 21.95% d.b(Figure 7). The values of dynamic angle of repose for Black gram can be shown by the polynomial Equation 14:

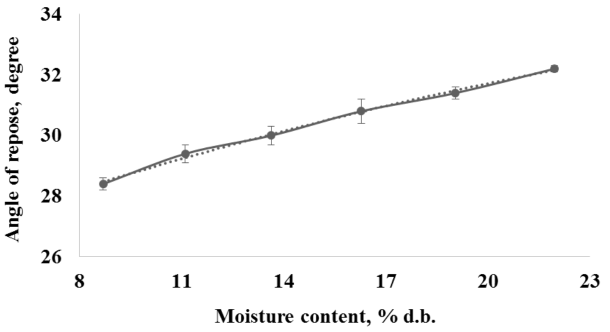

Figure 7Effect of moisture content on angle of repose

θ = 25.151+ 0.4234M -0.0048M^2 (R^2= 0.99) (14)

The increase of dynamic angle of repose may be due to increase of internal friction with increase of contact surface area of Black gram. It is fact that if internal friction among the grain increases the angle of repose will also be increased. Similar trend was observed by Nimkar et al. (2005) in moth grain and Baryeh and Mangope, (2002) in millet.

4 Conclusions

From the investigations of various physical properties of the Black gram the following conclusions can be made:

- As the moisture content increased from 8.69% to 21.95% d.b. the three axial dimensions of the Black gram increased and the arithmetic and geometric mean diameter ranged from 3.73 ±0.14 to 4.27 ±0.14 mm and 3.79 ±0.13 to 4.32 ±0.13 mm
- The mean values of sphericity of Black gram increased from 79.69% to 82.82% as the moisture content increased from 8.69% to 21.95% d.b.
- The hundred grain mass of Black gram were 42.52 ± 1.03 and 48.18 ± 0.45 g at moisture content of 8.69% and 21.95% d.b. respectively.
- The bulk and true densities values for Black gram decreased with increase in moisture content.
- The porosity and angle of repose of Black gram increased with increase in moisture content.
-

References

Al-Mahasneh, A.M.andT.M.Rababah. 2007. Effect of moisture content on some physical properties of green wheat. *Journal of Food Engineering*, 79(4): 1467–1473.

Altuntas, E.andM.Yildiz.2007. Effect of moisture content on some physical and mechanical properties of faba bean (Viciafaba L.) grains.*Journal of Food Engineering*, 78(1), 174–183.

Amin, M.N., M.A. Hossain, and K.C. Roy. 2004. Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering,* 65(1): 83-87.

Balasubramanian, S.andR.Viswanathan.2010. Influence of moisture content on physical properties of minor millets. *Journal of food science and technology*,47(3): 279-284.

Banuu,E.P.P. 2010. Modified Atmospheric Packaging of *Jasminumauriculatum*flowers.Unpublished M.Tech Dissertation, TNAU, Coimbatore, India.

Baryeh, E. A.andB. K.Mangope. 2002.Some physical properties of QP-38 variety pigeon pea.*Journal of Food Engineering*, 56(1): 341–347.

Bhattacharya, S., H.V.Narasimha, andS.Bhattacharya. 2005. The moisture dependent physical and mechanical properties of whole lentil pulse and split cotyledon.*International Journal of Food Science and Technology*, 40(2): 213–221.

Carman, K. 1996. Some physical properties of lentil seeds.*Journal of Agricultural Engineering Research*, 63(2): 87–92.

Cetin, M. 2007. Physical properties of barbunia bean (Phaseolus vulgaris L. cv. 'Barbuniz') seed. *Journal of Food Engineering*, 80(1): 353-358.

Deshpande, S. D., S.Bal,andT. P.Ojha. 1993. Physical properties of soybean.*Journal of Agricultural Engineering Research*, 56(2): 89–98.

Dutta, S.K., V.K.Nema, andR.K.Bhardwaj. 1988. Physical properties of gram.*Journal of Agricultural Engineering Research*, 39(4): 259–268.

Government of India (GoI). 2010. Status paper on pulses,Directorate of pulses development, Department of Agriculture and Cooperation, Ministry of agriculture, pp33.

Gopalan, C., G. Ramasastri, and S. C.Balasubramanian. 1995. Nutritive value of Indian foods, National Institute of Nutrition, ICMR, Hyderabad, India.

Isik, E. and H.Unal. 2007. Moisture dependent physical properties of white speckled red kidney bean grains. *Journal of Food Engineering*, 82(2): 209-216.

Kaleemullah, S.andJ.J.Gunasekar. 2002. Moisture-dependent physical properties of arecanut kernels. *Biosystems Engineering*, 82 (3): 331–338.

Konak, M., K.Carman, andC.Aydin. 2002. Physical properties of chick pea seeds.*Biosystems Engineering*, 82(1): 73–78.

Mohsenin, N. N. 1970. Physical properties of plant and animal materials.1st Edition.Gordan and Breach SciencePublishers, Inc. New York.

Murthy, C.T. andS.Bhattacharya. 1998. Moisture dependent physical and uniaxial compression properties of black pepper. *Journal of Food Engineering*, 37(): 193–205.

Nimkar, P. M.andP. K.Chattopadhyay. 2001. Some physical properties of green gram.*Journal of Agricultural Engineering Research*, 80(2): 183–189.

Nimkar, P. M., D. S.Mandwe, andR. M.Dudhe. 2005.Physical properties of moth gram.*Biosystems Engineering*, 91(2): 183–189.

Pandiselvam, R., M. M.Pragalyaashree, R.Kailappan, V.Thirupathi, andP.Krishnakumar.2014. Moisture dependent engineering properties of onion seeds. *Journal of Agricultural Engineering*, 51(2): 36-43.

Sahoo, P.KandA.P.Srivastava. 2002. Physical properties of okra seed. *Biosystems Engineering*, 83 (4): 441–448.

Sharon, M., C. V.Abirami, andK.Alagusundaram.2014.Grain storage management in India. *Journal of Post-Harvest Technology*, 2(1): 12-24.

Shepherd, H. andR.K.Bhardwaj. 1986. Moisture dependent physical properties of pigeon pea. *Journal of Agricultural Engineering Research*, 35(4): 227–234.

Singh, K.KandT.K.Goswami. 1996. Physical properties of cumin seed. *Journal of Agricultural Engineering Research,* 64 (2): 93–98.

Singh, K. P., H. N.Mishra, andS.Saha.2010. Moisture-dependent properties of barnyard millet grain and kernel. *Journal of Food Engineering*, 96(4): 598-606.

Sologubik, C. A., L. A.Campanone, A. M.Pagano, andM. C.Gely.2013.Effect of moisture content on some physical properties of barley.*Industrial Crops and Products*, 43(1): 762-767.

Subhashini, S. 2013. Development of ozone fumigation system for disinfestation of Lasioderma serricorne turmeric, Unpublished M.Tech Thesis, IICPT, Thanjavur, India.

Tekin, Y., E.Isik, H.Unal, andR.Okursoy.2006. Physical and mechanical properties of turkishbombaybeans (Phaseolus vulgaris L.).*Pakistan Journal of Biological Sciences*, 9(12): 2229–2235.

Yalcin, I., C.Ozarsalan, T.Akbas. 2007. Physical properties of pea (*Pisumsativum*) seed. *Journal of Food Engineering*, 79 (2): 731–735.