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Moisture Dependent Physical Properties of *Castorbean* Seeds

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Abstract: A range of physical properties of *Castorbean* (*Ricinus communis* L.) were determined as a function of moisture content. As the moisture content increased from 5.09% to 16.40% (w.b.), the average length, width, thickness and the geometric mean diameter varied from 10.63 to 11.09, 7.27 to 7.99, 5.27 to 6.02 and 7.41 to 8.09 mm, respectively. Within the same moisture range, studies on *Castorbean* showed that, sphericity, surface area, thousand seed mass and true density increased from 69% to 73%, 23.26 mm^2 to 25.42 mm^2,401 g to 468.8 g and 704.75 kg m^{-3} to 761.74 kg m^{-3}, respectively. When the moisture content increased from 5.09% to 16.40% w.b., bulk density decreased from 447.5 kg m^{-3} to 434.75 kg m^{-3} whereas the angle of repose and porosity increased from 30.2 to 34.8° and 36.5% to 42.9%, respectively. The static coefficient of friction of Dragons head grains increased linearly against surfaces of three structural materials, namely, glass (0.26–0.47), plywood (0.36-0.55) and galvanized iron (0.31–0.47) as the moisture content increased from 5.09 % to 16.40% w.b.

Key words: Castorbean · Angle of repose · Static coefficient of friction · Bulk density · True density

INTRODUCTION

Castorbean (Fig. 1) is cultivated for the seeds which are fast-drying and produce non-yellowing oil and mainly used in industry and medicine. Produced oil is used in coating fabrics and other protective coverings, in the manufacture of high-grade lubricants, transparent typewriter and printing inks, in textile dyeing (when converted into sulfonated Castor Oil or Turkey-Red Oil, for dyeing cotton fabrics with alizarine), in leather preservation and in the production of 'Rilson', a polyamide nylon-type fiber [1].

The seeds contain 5.1%–5.6% moisture, 12.0%–16.0% protein, 45.0%–50.6% oil, 3.1–7.0 NFE, 23.1–27.2% CF and 2.0–2.2% ash. Seeds are high in phosphorus, 90% in the phytic form. The castor oil consists of ricinoleic acid with only small amounts of dihydroxystearic, linoleic, oleic and stearic acids. The unsaponifiable matter contains β-sitosterol. The oil-cake from crushing whole seeds contain 9.0% moisture, 6.5% oil, 20.5% protein, 49.0% total carbohydrate and 15.0% ash. The manural value is 6.6% N, 2.6% P_2O_5 and 1.2% K_2O [2]. There are 60 mg/kg uric acid and 7 ppm HCN in the seed. The seeds contain a

Fig. 1: The *Castor bean* seeds

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powerful lipase, employed for commercial hydrolysis of fats, also amylase, invertase, maltase, endotrypsin, glycolic acid, oxidase, ribonuclease and a fat-soluble zymogen. Sprouting seeds contain catalase, peroxidase and reductase.

Knowledge of the physical properties of *Castorbean* is essential to facilitate and improve the design of equipment for handling, harvesting, processing and storing the seed. Various types of cleaning, grading and separation equipment may be designed on the basis of the physical properties of the seed. The purpose of this study was to determine moisture-dependent physical properties of *Castorbean* seed, including, size, thousand seed mass, sphericity, surface area, bulk density, true density, porosity, angle of repose and the static coefficient of friction within the moisture range from 5.09% to 16.40% w.b.

MATERIALS AND METHODS

The *Castorbean* seeds used in this study were obtained from the local market in Urmia, Iran. The samples were cleaned manually of all foreign materials. The initial moisture content of seed was determined to be 5.09% w.b, by oven drying at 105±1°C for 24h [3].

The *Castorbean* seeds at the different moisture levels were prepared by adding calculated quantity of water mixing thoroughly and then sealing in separate polyethylene bags. The seeds were kept at 5°C in a refrigerator for 9 days to allow the moisture to distribute uniformly throughout the sample. Before each test, the required quantities of the samples were taken out of the refrigerator and allowed to warm up to room temperature. All the physical properties of the seeds were determined at moisture contents of 5.09%, 11.07% and 16.40% (w.b.). To determine the length, width and thickness of seeds in each moisture content, samples of 50 seeds were randomly selected. Baryeh [4] have measured these dimensions for Millet grains in similar manner to determine size and shape properties. Materials were measured by a micrometer_caliper with an Accuracy of 0.01 mm. The geometric mean diameter D_g, the arithmetic mean diameter D_a in mm and sphericity ö of *Castorbean* was calculated using the following relationships [5]:

$$D_g = (abc)^{1/3} \tag{1}$$

$$D_a = \left(\frac{a+b+c}{3}\right) \tag{2}$$

$$\phi = \frac{(abc)^{1/3}}{a} \tag{3}$$

where a is the length, b is the width and c is the thickness, all in mm.

The surface area of seeds was found by analogy with a sphere of the same geometric mean diameter, using the following equation cited by Saçılık [6], Tunde-Akintunde and Akintunde [7] and Altuntaş *et al.* [8]:

$$s = \pi D_g \tag{4}$$

where s, is the surface area in mm^2.

To obtain the unit mass seeds, thousand seed mass was measured by a digital electronic balance to an accuracy of 0.001 g. To evaluate the thousand seed mass, 50 randomly selected seeds from the bulk sample were averaged.

The true density of a seed is defined as a ratio of the mass of a sample of a seed to soiled volume occupied by the sample. It was determined by the toluene displacement method [9]. The bulk density is the ratio of the mass of a sample of a seed to its total volume. This was determined by filling a Aluminum's container of 10 cm height and 5 cm diameter with seed from a constant height, striking the top level and then weighing the constants [10-13]. The porosity of bulk seed was calculated from bulk and true densities using the relationship given by Mohsenin [5], as follows

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right)100 \tag{5}$$

Where, ε is the porosity in %; ρ_b is the bulk density in Kg/m; and ρ_t is the true density in kg m^{-3}.

The coefficient of static friction was determined against different surfaces: plywood, glass and galvanized iron. A hollow metal cylinder of diameter 75mm and depth 50mm and open at both ends was filled with the seeds at the desired moisture content and placed on an adjustable tilting surface such that the metal cylinder did not touch the surface. Then the surface was raised gradually until the filled cylinder just started to slide down [14].

The static angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using the apparatus that consisted of a plywood box of 140×160×35mm and two plates: fixed and adjustable. The box was filled with the sample and then the adjustable plate was inclined gradually allowing the seeds to flow and assume a natural slope [15].

NOTATION

a	length, mm	s	surface area, mm^2
b	width, mm	Θ	angle of repose, deg
c	thickness, mm	μ	static coefficient of friction
D_g	geometric mean diameter, mm		
μ_{pw}	static coefficient of friction on plywood		
D_a	arithmetic mean diameter, mm		
μ_{gi}	static coefficient of friction on galvanized iron		
M	moisture content, % w.b.μ_{gl} static coefficient of friction on glass		
m_{1000}	Thousand seed mass, g		
ε	porosity, %		
ρ_b	bulk density, kg m^{-3}		
ρ_t	true density, kg m^{-3}		
φ	sphericity, %		

RESULTS AND DISCUSSION

Means and standard errors of the axial dimensions of *Castorbean* seeds at different moisture contents are given in Table 1. This table shows that as the moisture content of seed increased from 5.09 to 16.40% w.b., the average length, width and thickness of seeds increased to 11.09, 7.99, 6.02 mm, respectively. The average diameters calculated by the arithmetic mean and geometric mean are also presented in Table 1. The average diameter increased with increasing moisture content as an axial dimension. The arithmetic and geometric mean diameter ranged from 7.72 to 8.36 mm and 7.41 to 8.09 mm, respectively, as the moisture content increased from 5.09% to 16.40%.

The sphericity of *Castorbean* increased from 69% to 73% while the moisture content increased from 5.09 to 16.40% w.b. (Fig 2a). A similar trend has been reported for other crops including, by Baümler *et al.* [16] for safflower seeds, Selvi *et al.* [17] for Linseed and Altunas *et al.* [18] for Fababean grain.

The thousand seed mass of *Castorbean* (m_{1000}) increased from 401 g to 468.8 g as the moisture content increased from 5.09 to 16.40% w.b. (Fig 2b). This relationship can be represented by the the following Equation:

$$m_{1000} = 6.003M + 371.24 \qquad r = 0.99 \qquad (6)$$

Table 1: Means and standard errors of the axial dimensions of *Castorbean*

M.C. (%)	a, mm	b, mm	c, mm	Da, mm	Dg, mm
5.09	0.008±10.63	0.005±7.27	0.004±5.27	7.72	7.41
11.07	0.010±10.89	0.006±7.6	0.005±5.41	8.33	8.03
16.40	0.012±11.09	0.011±7.99	0.009±6.02	8.36	8.09

Similar trends have been reported by Aviara *et al.* [19] for guna seeds, Selvi *et al.* [3] for linseed, Baryeh *et al.* [4] for millet and Coşkuner [20] for Flaxseed.

The surface area of seeds (Fig. 2c) increased linearly as the moisture content increased from 5.09% to 16.40% w.b. Variation of moisture content with surface area can be expressed by the following equation:

$$S = 0.194M + 22.53 \qquad r=0.85 \qquad (7)$$

Similar trends have been reported by Baryeh ***et al.*** [4] for Millet and by Selvi ***et al.*** [3] for Linseed.

The bulk density of *Castorbean* seeds at different moisture contents varied from 447.5 Kg/m^3 to 434.5 Kg/m^3. Result showed a decrease in bulk density with an increase in moisture content from 5.09 to 16.40 % w.b. Negative relationship of bulk density with moisture content was linear as shown in Fig 2d and can be expressed as:

$$\rho_b = 454.07\text{-}1.11M \qquad r = 0.94 \qquad (8)$$

similar results were found by özarlash [21], Coşkun *et al.* [22] and Selvi *et al.* [6].

The true density varied from 704.76 to 761.75 kg/m^3 when the moisture level increased from 5.09% to 16.40% w.b. (Fig 2.e). Seed true density and moisture content can be correlated as:

$$\rho_t = 680.4+5.05M \qquad r = 0.99 \qquad (9)$$

The increase in true density of seeds with increase in moisture content showed that the increase in weight gain in the sample is greater than volume increase of seed. This is consistent with the findings of Baryeh *et al.* [4], Coşkun *et al.* [22], Selvi *et al.* [17] and Altunas *et al.* [18].

Porosity calculated from Eq. (5), using the data on bulk and true densities of the *Castorbean* seed. Variations of porosity depending on moisture content are shown in Fig. 2f. The porosity values of *Castorbean* at moisture contents between 5.09% and 16.40% varied between 36.5% and 42.91%. The relationship between porosity value and moisture content was found to be as:

$$\varepsilon = 0.56+33.64M \qquad r = 0.99 \qquad (10)$$

Selvi *et al.* [6] for linseed and Coşkuner *et al.* [20] for Flaxseed showed that as the moisture content increased, the porosity value also increased.

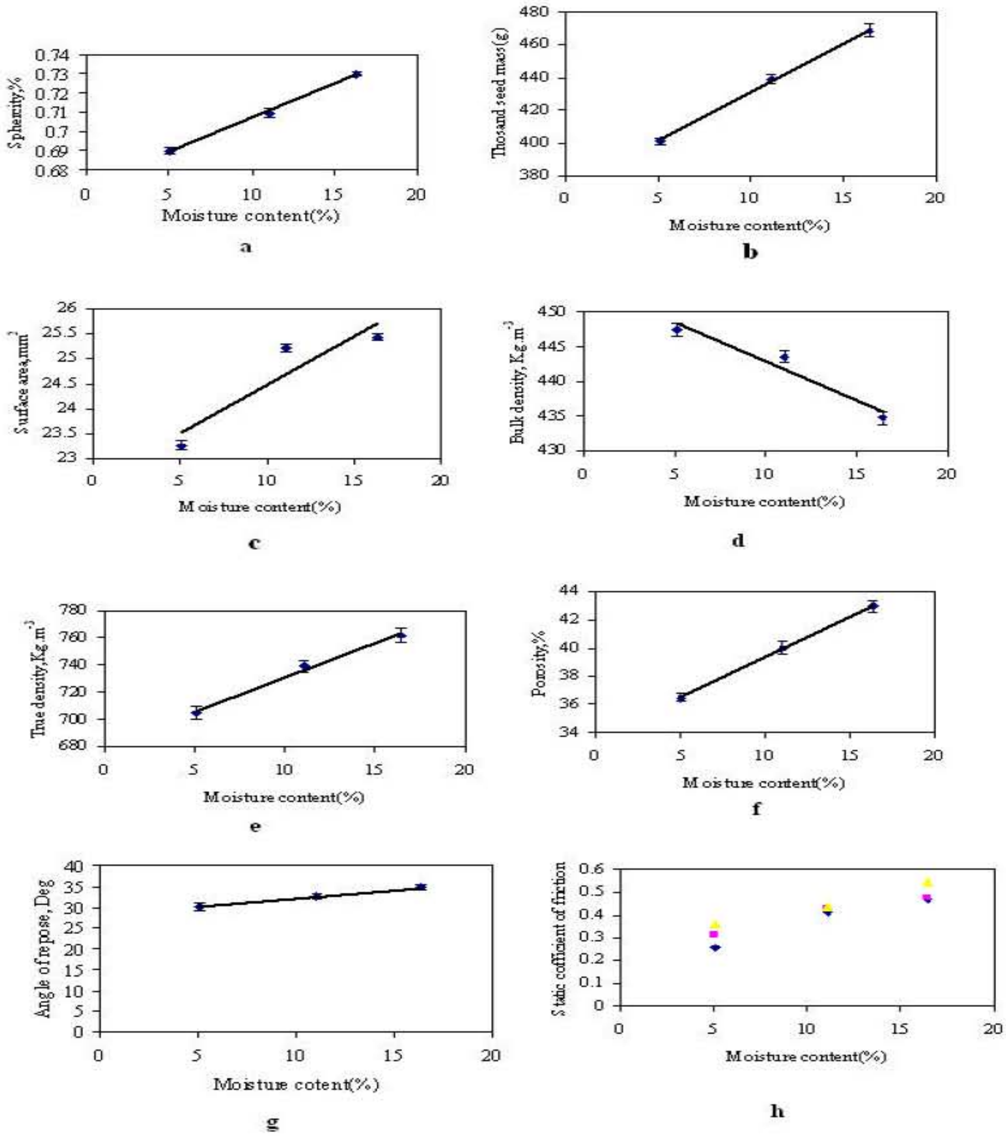

Fig. 2: Variations of various parameters with moisture content for *Castorbean* seed

The variations of angle of repose θ (in degree) with respect to moisture content are plotted in Fig. 2g. It increased linearly from 30.23° to 34.83° by increasing the moisture content from 5.09% to 16.40% w.b. The relationship between moisture content and angle of repose can be represented by equation 11 as:

$$\Theta = 28.11+0.406M \quad r=0.99 \tag{11}$$

a linear increase in angle of repose when the seed moisture content increases has also been noted by Gupta and Das [11], Amin *et al*. [23] and Selvi *et al*. [3] for sunflower seed, lentil seed and linseed.

The static coefficient of friction for *Castorbean* seed, determined against three different structural surfaces, are given in Fig 2h. our study results showed that the static coefficient of friction increased with increasing moisture content on all surfaces. Similar results have been reported by other studies [12,23-25]. At all moisture contents, the static coefficient of friction was greatest against plywood (0.36 -0.55), followed by galvanized iron sheet (0.31–0.47) and glass sheet (0.26–0.47). Differences in three surface was not striking in any moisture level, The relationship between moisture content and static coefficients of friction on all test surfaces can be represented by the following equations:

$$\mu_{pw} = 0.27+0.016M \quad (12)$$

$$\mu_{gi} = 0.25+0.014M \quad (13)$$

$$\mu_{gl} = 0.16 + 0.0107M \quad (14)$$

Where μ_{pw}, μ_{gi} and μ_{gl} refer to coefficients of friction on plywood, galvanized iron sheet and glass sheet, respectively. The values of the coefficient of determination (r) for μ_{pw}, μ_{gi} and μ_{gl} were 0.98, 0.95 and 0.93, respectively.

CONCLUSION

Results from this research determined a range of physical properties of *Castorbean* seed and showed that modification of moisture content caused a variation in seeds physical properties. The average length, width, thickness of seed increased with increasing of moisture content of seed. Thousand seed mass, sphericity, surface area, true density, porosity and angle of repose increased linearly with increasing of moisture content. Bulk density linearly decreased with increasing of moisture content.

REFERENCES

1. Reed, C.F., 1976. Information summaries on 1000 economic plants. Typescripts submitted to the USDA.
2. C.S.I.R. (Council of Scientific and Industrial Research). 1948-1976. The wealth of India. 11 vols. New Delhi.
3. Selvi, K.Ç., Y. Pınar and E. Yeşiloğlu, 2006. Some physical properties of linseed. Biosystems Engineering, 95(4): 607-612.
4. Baryeh, E.A., 2002. Physical Properties of Millet. Journal of Food Engineering, 51: 39-46.
5. Mohsenin, N.N., 1970. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.
6. Saçılık, K., R. Öztürk and R. Keskin, 2003. Some physical properties of hemp seed. Biosystems Engineering, 86(2): 191-198.
7. Tunde-Akintunde, T.Y. and B.O. Akintunde, 2004. Some physical properties of sesame seed. Biosystems Engineering, 88(1): 127-129.
8. Altuntaş, E., E. Özgöz and Ö.F. Taşer, 2005. Some physical properties of fenugreek (*Trigonella foenum-graceum* L.) seeds. Journal of Food Engineering, 71: 37-43.
9. Mohsenin, N.N., 1986. Physical Properties of Plant and Animal Materials, second ed. Gordon and Breach Science Publishers, New York.
10. Deshpande, S.O., S. Bal and T.P. Ojha, 1993. Physical properties of soybean. J.Agric. Eng. Res., 56: 89-98.
11. Gupta, R.K. and S.K. Das, 1997. Physical properties of sunflower seeds. Journal of Agricultural Engineering Research, 66(1): 1-8.
12. Konak, M., K. Çarman and C. Aydin, 2002. Physical properties of chick pea seeds. Biosystems Engineering, 82(1): 73-78.
13. Paksoy, M. and C. Aydin, 2004. Some physical properties of edible squash (*Cucurbita pepo* L.) seeds. J. Food. Eng., 65: 225-231.
14. Razavi, S. and E. Milani, 2006. Some physical properties of the watermelon seeds. African J.Agric. Res., 13: 65-69.
15. Tabatabeefar, A., 2003. Moisture-dependent physical properties of wheat. Int. Agrophysics. 17: 207-211.
16. Baümler, A. E., Cuniberti, S.M. Nolasco and I.C. Riccobene, 2006. Moisture-dependent physical and compression properties of safflower seed. Journal of Food Engineering, 79: 134-140.
17. Selvi, K.Ç., Y. Pınar and E. Yeşiloğlu, 2006. Some physical properties of linseed. Biosystems Engineering, 95(4): 607-612.
18. Altuntaş, E. and M. Yıldız, 2007. Effect of moisture content on some physical properties of faba bean grain. Journal of Food Engineering, 78: 174-183.
19. Aviara, N.A, M.I. Gwandzang and M.A. Haque, 1999. Physical properties of guna seeds. Journal of Agricultural Engineering Research, 73(2): 105-111.
20. Coşkuner, Y. and E. Karababa, 2007. Some Physical Properties of Flaxseed. Journal of Food Engineerin,. 78: 1067-1073.
21. Özarslan, C., 2002. Some physical properties of cotton seed. Biosystems Engineering, 83(2): 169-174.
22. Coşkun, M.B., I. Yalçın and C. Özarslan, 2005. Physical properties of sweet corn seed (*Zea mays* saccharata Strut). Journal of Food Engineering, 74: 523-528.

23. Amin, M.N., M.A. Hossain and K.C. Roy, 2004. Effect of moisture content on some physical properties of lentil seeds. Journal of Food Engineering, 65: 83-87.
24. Çarman, K., 1996. Some physical properties of lentil seeds. Journal of Agricultural Engineering Research, 63(2): 87-92.
25. Suthar, S.H. and S.K. Das, 1996. Some physical properties of karingda [*Citrullus lanatus* (thumb) mansf] seeds. Journal of Agricultural Engineering Research, 65(1): 15-22.
26. Nimkar, P.M. and P.K. Chattopadhyay, 2001. Some physical properties of green gram. Journal of Agricultural Engineering Research, 80(2): 183-189.