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Moisture-Dependent Physical Properties of Onion (*Allium cepa* L.) Seed

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The physical properties of onion seed were determined as a function of moisture content in the range of 7.81 to 23.99 % dry basis. The average length, width and thickness were 2.98, 1.97 and 1.41 mm, at a moisture content of 7.81 % dry basis, respectively. In the moisture range from 7.81 to 23.99 % dry basis, studied the rewetted onion seed showed increase in the thousand seed mass from 3.85 to 4.33 g, the projected area from 2.27 to 3.43 mm^2, the sphericity from 0.680 to 0.688, the porosity from 49.82 to 51.85 % and the terminal velocity from 4.80 to 5.23 m s^{-1}. The bulk density decreased from 550.18 to 521.68 kg m^{-3} and the true density from 1096.49 to 1083.46 kg m^{-3} with an increase in the moisture content range of 7.81-23.99 % dry basis. The static coefficient of friction of onion seed increased linearly against the surfaces, namely, rubber (0.227 to 0.309), aluminium (0.159 to 0.228), stainless steel (0.149 to 0.195) and galvanized iron (0.189 to 0.244) as the moisture content increased from 7.81-23.99 % dry basis.

Key Words: Onion seed, Physical properties, Moisture content.

INTRODUCTION

Onion (*Allium cepa* L.) is grown in most of the countries. According to the United Nations Food and Agriculture Organization, there are an estimated 2.7 million hectares of onions in the world, producing 48 million tonnes each year. Approximately 8 % of this global onion production is traded internationally. Leading onion producing countries are China, India, United States, Turkey and Pakistan[1].

Onion is low in calories yet add abundant flavour to a wide variety of foods. With only 30 calories per serving, onion has sodium, fat, is cholesterol free and provide dietary fibre, vitamin C, vitamin B_6, potassium and other key nutrients. In addition, onion contains a variety of other naturally occurring chemicals known as organosulphur compounds that have been linked to lowering blood pressure and cholesterol levels. Onion supply vitamin C, folate and fibre and small amounts of a range of other vitamins and minerals. Research indicate that phytochemicals in onions, including antioxidants and sulphur compounds may result in a number of health benefits from cancer protection and heart disease protection through reduction in symptoms of osteoporosis, asthma and diabetes[2].

The physical properties of onion seed, like those of other grains and seeds, are essential for the design of equipment for handling, transporting, cleaning, separating, packing, drying, storing and processing or determining the behaviour of the product for its handling. Various types of cleaning, grading and separation equipment are designed on the basis of physical properties of seeds[3]. Recently scientists have made great efforts in evaluating basic physical properties of agricultural materials and have pointed out their practical utility in machine and structural design and in control engineering[4]. Recent scientific developments have improved the handling and processing of bio-materials through mechanical, thermal, electrical, optical and other techniques, but little is known about the basic physical characteristics of bio-materials. Such basic information is important not only to engineers but also to food scientists, processors, plant breeders and other scientists who may find new uses[5]. Dimensions are important to design the cleaning, sizing and grading machines. Bulk density and porosity are major considerations in designing the drying and aeration and storage systems, as these properties affect the resistance to air flow of the mass[4]. Terminal velocity is very important in the design of pneumatic conveyor[6,7]. Coefficient of friction is important in designing equipment for solid flow and storage structures. The coefficient of friction between seed and wall is an important parameter in the prediction of seed pressure on walls[4].

Several investigators determined the physical properties of seeds at various moisture contents such as Shepherd and Bhardwaj[8] for pigeon pea, Amin *et al.*[4] and Çarman[9] for lentil seed, Ogunjimi *et al.*[10] for locust bean seed and Konak *et al.*[11] for chickpea seeds. However, no literature is available on the physical properties of onion seed and their relationship with moisture content. Hence, this study was conducted to investigate some moisture dependent physical properties of onion seed such as, sphericity, thousand seed mass, projected area, bulk density, true density, porosity, terminal velocity and static coefficient of friction against different surfaces.

EXPERIMENTAL

The local variety of dry seeds of onion cultivar were used for all the experiments in this study. The seeds were cleaned manually to remove dust, dirt, stones and chaff as well as immature, broken seeds. The initial moisture content of the seeds was determined by oven drying at 105 ± 1 ºC for 24 h[12,13]. The initial moisture content of the seeds was 7.81 % dry basis.

The samples were then poured into separate polyethylene bags and the bags sealed tightly. The samples were kept at 5 ºC in a refrigerator for a week to enable the moisture to distribute uniformly throughout the sample. Before starting a test, the required quantity of the seed was taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2 h[14-16].

All the physical properties of the seeds were determined at 4 moisture contents in the range of 7.81-23.99 % dry basis with 10 replications at each moisture content.

These values are within the range of moisture contents for onion seed recommended for safe module storage as 18 % dry basis[17].

To determine the average size of the seed, 100 seeds were randomly picked and their 3 linear dimensions namely, length, width and thickness were measured using a micrometer with an accuracy of ± 0.01 mm[16,18,19].

The sphericity of seeds was calculated by using the following relationship[5]:

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

where ϕ = sphericity in %; L = length of seed in mm; W = width of seed in mm and T = thickness of seed in mm.

One thousand seed mass was determined by means of an electronic balance reading to 0.001 g[18,20].

The projected area of a seed was measured using a scanner connected to a computer. For this purpose, a special computer program was used[15,19].

The average bulk density of the onion seed was determined using the standard test weight procedure reported by Singh & Goswami[14] by filling a container of 500 mL with the seed from a height of 150 mm at a constant rate and then weighing the content.

The average true density was determined using the toluene displacement method. The volume of toluene displaced was found by immersing a weighed quantity of onion seed in the toluene[14,21].

The porosity was calculated from the following relationship[5]:

$$P_f = (1 - \rho_b / \rho_t) \times 100 \qquad (2)$$

where P_f = porosity in %; ρ_b = bulk density in kg m^{-3} and ρ_t = true density in kg m^{-3}.

The terminal velocities of seeds at different moisture contents were measured using a cylindrical air column[6,22,23]. For each experiment, a sample was dropped into the air stream from the top of the air column, up which air was blown to suspend the material in the air stream. The air velocity near the location of the seed suspension was measured by a hot wire anemometer having a least count of 0.01 m s^{-1}.

The static coefficient of friction of onion seed against different surfaces, namely rubber, aluminium, stainless steel and galvanized iron was determined. A polyvinylchloride cylindrical pipe of 50 mm in diameter and 50 mm in height was placed on an adjustable tilting plate, faced with the test surface and filled with the seed sample. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was raised gradually with a screw device until the cylinder just started to slide down and the angle of tilt was read from a graduated scale[12,14]. The coefficient of friction was calculated from the following relationship:

$$\mu = \tan\alpha \qquad (3)$$

where μ = coefficient of friction; and α = angle of tilt in degrees.

RESULTS AND DISCUSSION

Seed dimensions and size distribution: The mean dimensions of 100 seeds measured at a moisture content of 7.81 % dry basis are: length 2.98 ± 0.16 mm, width 1.97 ± 0.15 mm and thickness 1.41 ± 0.11 mm. The frequency distribution curves for the mean values of the dimensions show a trend towards a normal distribution. About 86 % of the seeds have a length ranging from 2.8 to 3.2 mm, *ca.* 88 %, width ranging from 1.8 to 2.2 mm and *ca.* 94 %, a thickness ranging from 1.2 to 1.6 mm at 7.81 % dry basis moisture content.

One thousand seed mass: One thousand onion seed mass increased linearly from 3.85 to 4.33 g as the moisture content increased from 7.81-23.99 % dry basis (Fig. 1). An increase of 12.46 % in 1000 seed mass, was recorded within the above moisture range. The linear equation for 1000 seed mass can be formulated to be:

$$m_{1000} = 3.5916 + 0.092M_c \qquad (R^2 = 0.9683) \qquad (4)$$

A linear increase in 1000 onion seed mass as the seed moisture content increases has been noted by Singh and Goswami[14] for cumin, Baryeh and Mangope[3] for QP-38 variety pigeon pea and Ögüt[21] for white lupin.

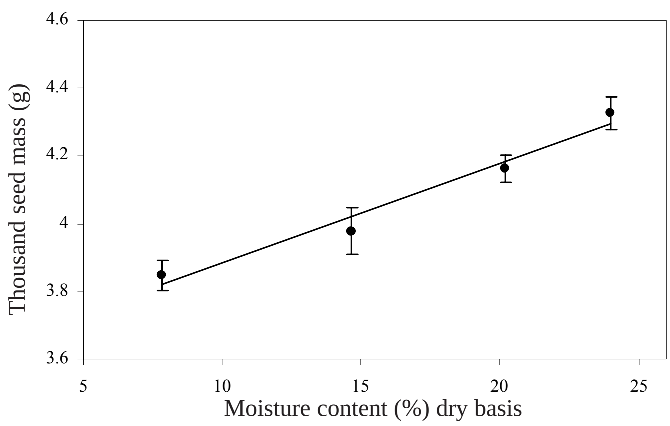

Fig. 1. Effect of moisture content on 1000 seed mass

Projected area of seed: The projected area of onion seed increased from 2.27 to 3.43 mm², when the moisture content of seed increased from 7.81 to 23.99 % dry basis (Fig. 2). The variation in projected area (A_p) with moisture content (M_c) of onion seed can be represented by the following equation:

$$A_p = 1.6755 + 0.0682M_c \qquad (R^2 = 0.9509) \qquad (5)$$

Similar trends have been reported by Baryeh[23] for millet, Özarslan[15] for cotton and Konak *et al.*[11] for chick pea seed.

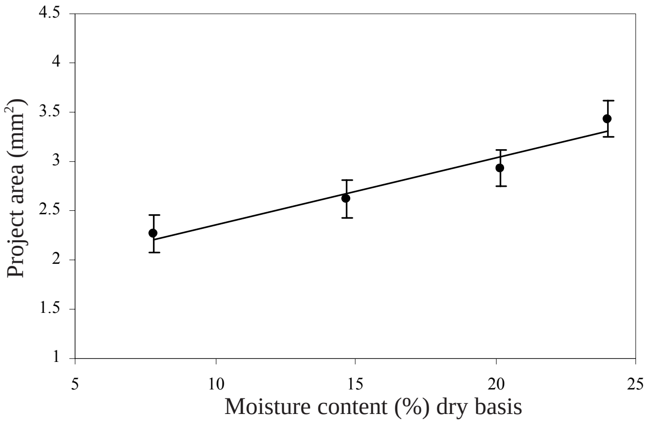

Fig. 2. Effect of moisture content on projected area

Sphericity: The sphericity of onion seed increased from 0.680 to 0.688 with the increase in moisture content (Fig. 3). The relationship between sphericity (ϕ) and moisture content (M_c) in 7.81-23.99 % dry basis can be represented by the following equation:

$$\phi = 0.6763 + 0.0005M_c \quad (R^2 = 0.9839) \tag{6}$$

Similar trends have been reported by Aydin *et al.*[24] for Turkish mahaleb, Saçilik *et al.*[25] for hemp seed and Sahoo and Srivastava[26] for okra seed.

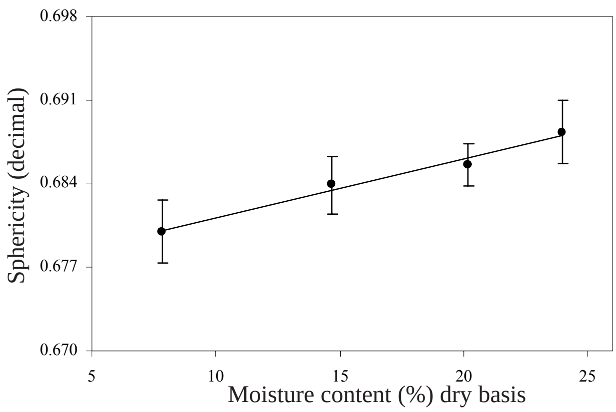

Fig. 3. Effect of moisture content on sphericity

Bulk density: The values of the bulk density for different moisture levels varied from 550.18 to 521.68 kg m^{-3} (Fig. 4). The bulk density (ρ_b) of seed was found to bear the following relationship with moisture content (M_c):

$$\rho_b = 564.47 - 1.6906M_c \quad (R^2 = 0.9706) \tag{7}$$

A similar decreasing trend in bulk density has been reported by Sahoo *et al.*[26] for okra, Konak *et al.*[11] for chick pea and Gupta and Das[27] for sunflower seed.

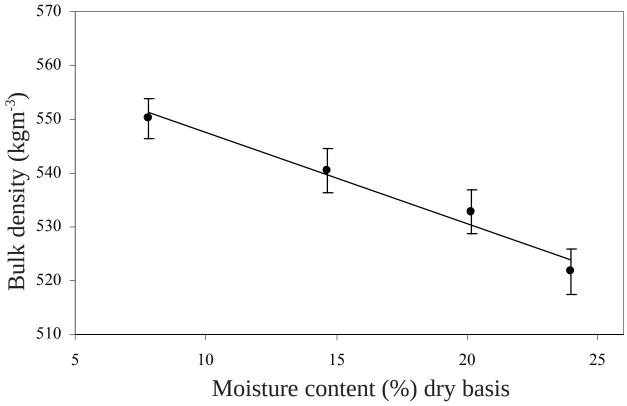

Fig. 4. Effect of moisture content on bulk density

True density: The true density varied from 1096.49 to 1083.46 kg m^{-3} when the moisture level increased from 7.81 to 23.99 % dry basis (Fig. 5). The true density (ρ_t) and the moisture content (M_c) of seed can be correlated as follows:

$$\rho_t = 1103.5 - 0.7924 M_c \quad (R^2 = 0.9655) \tag{8}$$

The results were similar to those reported by Özarslan[15] for cotton, Abalone *et al.*[28] for amaranth, Dursun and Dursun[7] for caper and Singh and Goswami[14] for cumin seed.

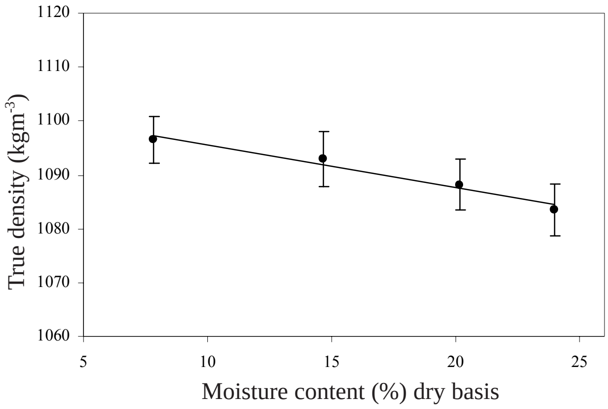

Fig. 5. Effect of moisture content on true density

Porosity: The porosity of onion seed increased from 49.82 to 51.85 % with the increase in moisture content from 7.81 to 23.99 % dry basis (Fig. 6). The relationship between porosity (P_f) and moisture content (M_c) can be represented by the following equation:

$$P_f = 48.821 + 0.1195 M_c \quad (R^2 = 0.9687) \tag{9}$$

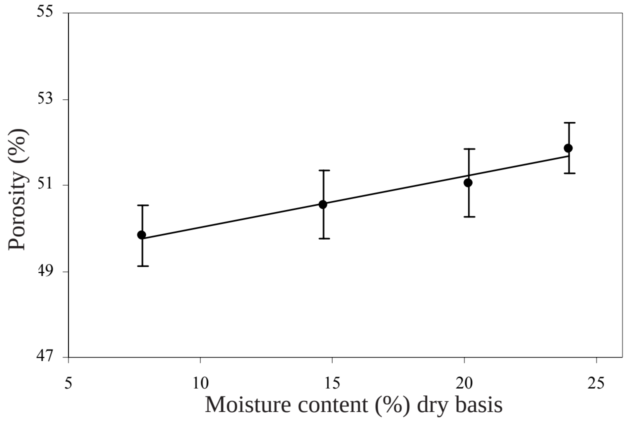

Fig. 6. Effect of moisture content on porosity

Konak *et al.*[11], Gupta and Das[27] and Yalçin and Özarslan[13] reported similar trends in the case of chick pea, sunflower and vetch, respectively.

Terminal velocity: The experimental results for the terminal velocity of onion seed at various moisture levels are shown in Fig. 7. The terminal velocity was found to increase linearly from 4.80 to 5.23 m s^{-1} as the moisture content increased from 7.81 to 23.99 % dry basis. The relationship between terminal velocity (V_t) and moisture content (M_c) can be represented by the following equation:

$$V_t = 4.6173 + 0.0249 M_c \qquad (R^2 = 0.9651) \qquad (10)$$

Similar results were reported by Gupta and Das[27], Suthar and Das[12] and Joshi *et al.*[22] in the case of sunflower, karingda and pumpkin seeds, respectively.

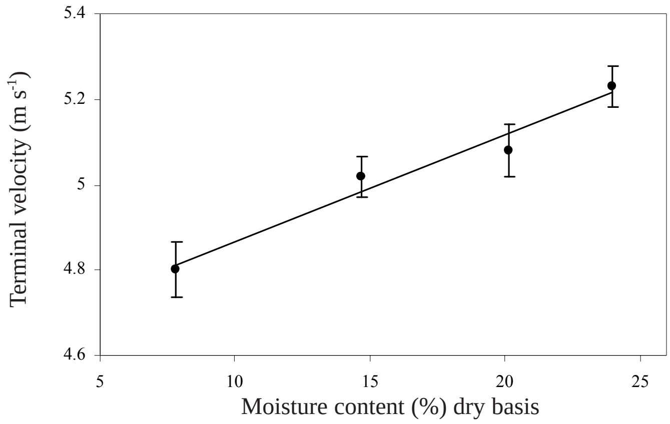

Fig. 7. Effect of moisture content on terminal velocity

Static coefficient of friction: The static coefficient of friction of onion seed on 4 surfaces (rubber, aluminium, stainless steel and galvanized iron) against moisture content in the range 7.81 to 23.99 % dry basis are presented in Fig. 8.

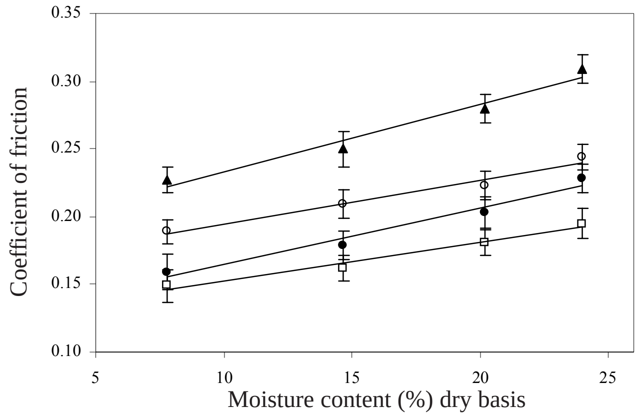

Fig. 8. Effect of moisture content on static coefficient of friction; ▲, rubber; ●, aluminium; ○, galvanized iron; □, stainless steel

It was observed that the static coefficient of friction increased with increase in moisture content for all the surfaces. This is due to the increased adhesion between the seed and the material surfaces at higher moisture values. Increases of 36.12, 43.40, 30.87 and 29.10 % were recorded in the case of rubber, aluminium, stainless steel and galvanized iron, respectively as the moisture content increased from 7.81 to 23.99 % dry basis. At all moisture contents, the least static coefficient of friction was on stainless steel. This may be owing to smoother and more polished surface of the stainless steel sheet than the other materials used. The relationships between static coefficients of friction and moisture content (M_c) on rubber μ_{ru}, aluminium μ_{al}, stainless steel μ_{ss} and galvanized iron μ_{gi}, can be represented by the following equations:

$$\mu_{ru} = 0.1832 + 0.005M_c \qquad (R^2 \text{ of } 0.9696) \qquad (11)$$

$$\mu_{al} = 0.1226 + 0.0042M_c \qquad (R^2 \text{ of } 0.9702) \qquad (12)$$

$$\mu_{ss} = 0.1242 + 0.0029M_c \qquad (R^2 \text{ of } 0.9767) \qquad (13)$$

$$\mu_{gi} = 0.1620 + 0.0033M_c \qquad (R^2 \text{ of } 0.9752) \qquad (14)$$

Similar results were found by Sahoo and Srivastava[26], Özarslan[15], Çarman[9] and Shepherd and Bhardwaj[8] for okra, cotton, lentil and pigeon pea seeds, respectively.

Conclusion

One thousand seed mass increased from 3.85 to 4.33 g and the sphericity increased from 0.680 to 0.688 with the increase in moisture content from 7.81 to 23.99 % dry basis. The projected area increased from 2.27 to 3.43 mm^2 and the porosity increased from 49.82 to 51.85 %. The bulk density decreased linearly from 550.18 to 521.68 kg m^{-3} and the true density decreased from 1096.49 to 1083.46 kg m^{-3}.

The terminal velocity increased from 4.80 to 5.23 m s^{-1}. The static coefficient of friction increased for all the 4 surfaces, namely, rubber (0.227 to 0.309), aluminium (0.159 to 0.228), stainless steel (0.149 to 0.195) and galvanized iron (0.189 to 0.244).

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