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Effects of Moisture Content on Physical Properties of Black Kabuli Chickpea (*Cicer arietinum* L.) Seed

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The physical properties of black kabuli chickpea seed were determined as a function of moisture content in the range of 9.29 to 16.82 % dry basis (d.b.). The average length, width and thickness were 6.85, 5.08 and 4.72 mm, at a moisture content of 9.29 d.b., respectively. In the moisture range from 9.29 to 16.82 % d.b., studies on rewetted black kabuli chickpea seed showed that the thousand seed mass increased from 100.18 to 110.44 g, the projected area from 0.163 to 0.251 cm^2, the sphericity from 0.799 to 0.821, the porosity from 39.90 to 40.48 % and the terminal velocity from 2.078 to 2.135 m s^{-1}. The bulk density decreased from 780.58 to 745.85 kg m^{-3} and the true density from 1298.84 to 1253.15 kg m^{-3} with an increase in the moisture content range of 9.29 to 16.82 %. The static coefficient of friction of black kabuli chickpea seed increased the linearly against surfaces of four structural materials, namely, rubber (0.336 to 0.416), aluminium (0.221 to 0.266), stainless steel (0.172 to 0.205) and galvanized iron (0.282 to 0.331) as the moisture content increased from 9.29 -16.82 % d.b.

Key Words: Black kabuli chickpea seed, Physical properties, Moisture content.

INTRODUCTION

Legume grains comprise an important part of the human diet in developing countries in tropical and subtropical areas, where their nutritional contribution is of paramount importance as a large segment of the populations in these areas have limited access to food of animal origin[1]. Turkey has about 650 000 ha of chickpea harvested area, 610 000 t chickpea production per annum and therefore is one of the foremost chickpea production of the word[2]. Chickpea (*Cicer arietinum* L.) is a major food legume in Southern Europe, North Africa, India and Middle East countries[1]. It is cultivated mainly in Algeria, Ethiopia, Iran, India Mexico, Morocco, Myanmar, Pakistan, Spain, Syria, Tanzania, Tunisia and Turkey[3]. Although most chickpeas are produced for human consumption, they provide the livestock industry with an

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alternative protein and energy feedstuff[4]. During the last decades there has been an increase in interest in their role in animal diets[5], due to ban of animal origin proteins and dissemination of using genetically modified organism products[6]. Chickpea seed contains 29 % protein, 59 % carbohydrate, 3 % fiber, 5 % oil and 4 % ash. Chickpea protein is rich in lysine and arginine but most deficient in sulphur-containing amino acids methionine and cystine[7]. Chickpea is also a good source of absorbable Ca, P, Mg, Fe and K[1].

In order to design equipment for the handling, conveying, separation, drying, aeration, storing and processing of black kabuli chickpea seed, it is necessary to determine their physical properties as a function of moisture content. However, no published work seems to have been carried out on the physical properties of black kabuli chickpea seed and their relationship with moisture content. Hence, this study was conducted to investigate some moisture dependent physical properties of black kabuli chickpea seed namely, sphericity, thousand seed mass, projected area, bulk density, true density, porosity, terminal velocity and static coefficient of friction against different materials.

EXPERIMENTAL

The dry seeds of black kabuli chickpea cultivar, local variety were used for all the experiments in present study. The seeds were cleaned manually to remove all foreign matter such as 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 °C for 24 h[8,9]. The initial moisture content of the seeds was 9.29 % dry basis.

The samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the following relation[10].

$$Q = \frac{W_i (M_f - M_i)}{(100 - M_f)} \tag{1}$$

The samples were then poured into separate polyethylene bags and the bags sealed tightly. The samples were kept at 5 °C 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[9,11].

All the physical properties of the seeds were determined at four moisture contents in the range of 9.29 to 16.82 % d.b. with ten replications at each moisture content. These values are near moisture contents for black kabuli chickpea seed recommended for safe module storage as 13.64-16.28 % dry basis (12-14 % wet basis) at 20 and 30 ºC for 3 and 9 months[12].

To determine the average size of the seed, 100 seeds were randomly picked and their 3 linear dimensions namely, length L, width W and thickness T were measured using a micrometer with a accuracy of 0.01 mm[13,14].

The sphericity of seeds was calculated by using the following relationship[15]:

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

One thousand seeds mass was determined by means of an electronic balance reading to 0.001 g[16,17].

The projected area of a seed was measured by a scanner connected to a computer. For this purpose, a special computer program was used[9].

The average bulk density of the black kabuli chickpea seed was determined using the standard test weight procedure reported by Singh and Goswami[18] 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 black kabuli chickpea seed in the toluene[18-20].

The porosity was calculated from the following relationship[15]:

$$P_f = (1 - \rho_b / \rho_t) \times 100 \quad (3)$$

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

The terminal velocities of seeds at different moisture contents were measured using a cylindrical air column[13,14,21]. 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 black kabuli chickpea seed against 4 different structural materials, 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 α was read from a graduated scale[8,18,22]. The coefficient of friction was calculated from the following relationship:

$$\mu = \tan \alpha \quad (4)$$

where μ is the coefficient of friction and α is the 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 9.29 % d.b. are as, length 6.85 ± 1.61 mm, width 5.08 ± 1.26 mm and thickness 4.72 ± 1.13 mm. The frequency distribution curves for the mean values of the dimensions show a trend towards a normal distribution. About 51 % of the seeds have a length ranging from 6.5 to 7.0 mm; about 53 %, a width ranging from 5.0 to 5.5 mm and about 67 %, a thickness ranging from 4.5 to 5.0 mm at 9.29 % dry basis moisture content.

One thousand seed mass: One thousand black kabuli chickpea seeds mass increased linearly from 100.18 to 110.44 g as the moisture content increased from 9.29 -16.82 % d.b. (Fig. 1). An increase of 10.24 % in the 1000 seeds mass was recorded within the above moisture range. The linear equation for 1000 seeds mass can be formulated to be:

$$m_{1000} = 89.077 + 1.2936 M_c \qquad (R^2 = 0.967) \qquad (5)$$

A linear increase in 1000 black kabuli chickpea seed mass as the seed moisture content increases has been noted by Sacilik *et al.*[10] for hemp, Çetin[23] for barbunia bean seed, Yalçin and Özarslan[20] for vetch and Sing and Goswami[18] for cumin.

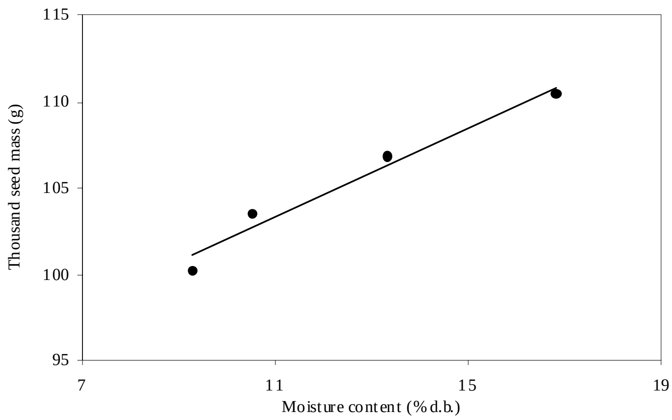

Fig. 1. Effect of moisture content on thousand seed mass

Projected area of seed: The projected area of black kabuli chickpea seed increased from 0.163 to 0.251 cm^2, when the moisture content of seed increased from 9.29 to 16.82 % d.b. (Fig. 2). The variation in projected area with moisture content of corn seed can be represented by the following equation:

$$A_p = 0.0804 + 0.0104 M_c \qquad (R^2 = 0.8869) \qquad (6)$$

Similar trends have been reported by Tang and Sokhansanj[24] for lentil, Abalone *et al.*[25] for amaranth and Konak *et al.*[26] for chick pea seed.

Sphericity: The sphericity of black kabuli chickpea seed increased from 0.799 to 0.821 with the increase in moisture content (Fig. 3). The relationship between sphericity and moisture content M_c in 9.29-16.82 % d.b. can be represented by the following equation:

$$\phi = 0.7759 + 0.0027 M_c \qquad (R^2 = 0.9477) \qquad (7)$$

Similar trends have been reported by Aydin *et al.*[27] for Turkish mahaleb, Çetin[23] for barbunia bean seed, Gupta *et al.*[28] for sunflower seed and Sahoo *et al.*[29] for okra seed.

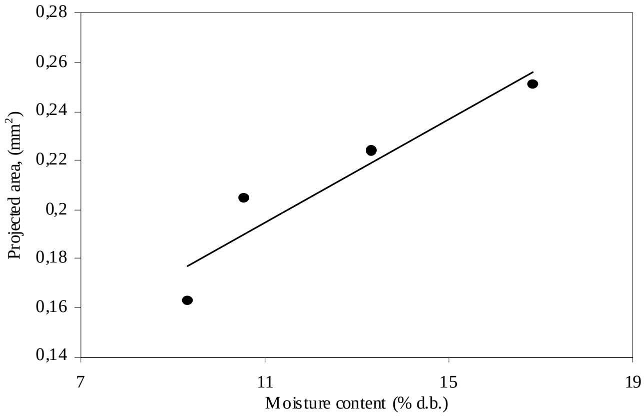

Fig. 2. Effect of moisture content on projected area

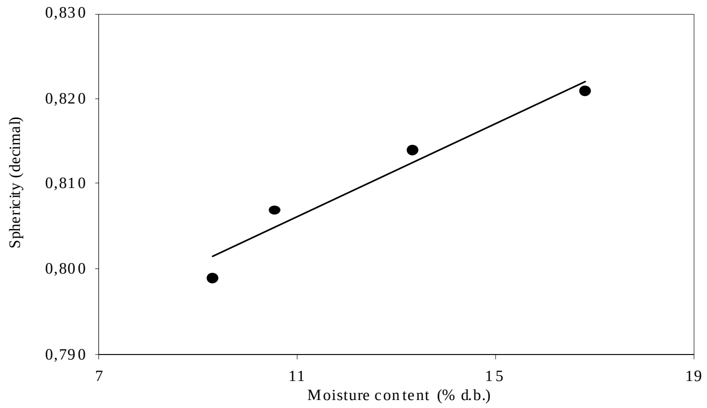

Fig. 3. Effect of moisture content on sphericity

Bulk density: The values of the bulk density for different moisture levels varied from 780.58 to 745.85 kg m^{-3} (Fig. 4). The bulk density of seed was found to bear the following relationship with moisture content:

$$\rho_b = 821.32 - 4.5508 M_c \qquad (R2 = 0.9896) \qquad (8)$$

A similar decreasing trend in bulk density has been reported by Sahoo and Srivastava[29] for okra, Coskun *et al.*[14] for sweet corn and Gupta and Das[28] for sunflower seed.

True density: The true density varied from 1298.84 to 1253.15 kg m^{-3} when the moisture level increased from 9.29 to 16.82 % dry basis (Fig. 5). The true density and the moisture content of seed can be correlated as follows:

$$\rho_t = 1357.1 - 6.2568 M_c \qquad (R^2 = 0.9897) \qquad (9)$$

The results were similar to those reported by Özarslan[9] for cotton, Abalone *et al.*[25] for Amaranth, Çetin *et al.*[30] for black cumin seed, Dursun and Dursun[31] for caper and Singh and Goswami[18] for cumin seed.

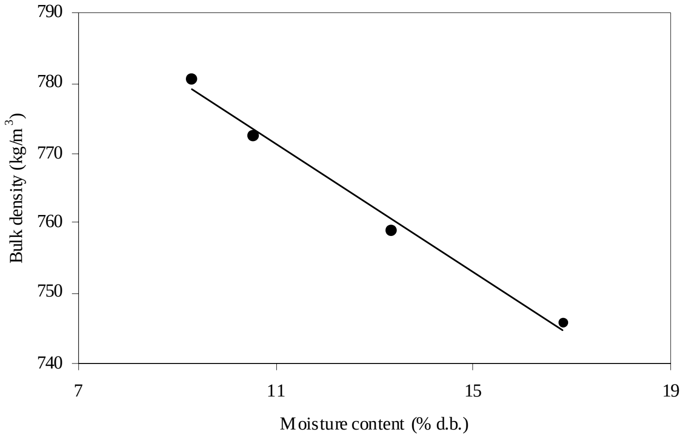

Fig. 4. Effect of moisture content on bulk density

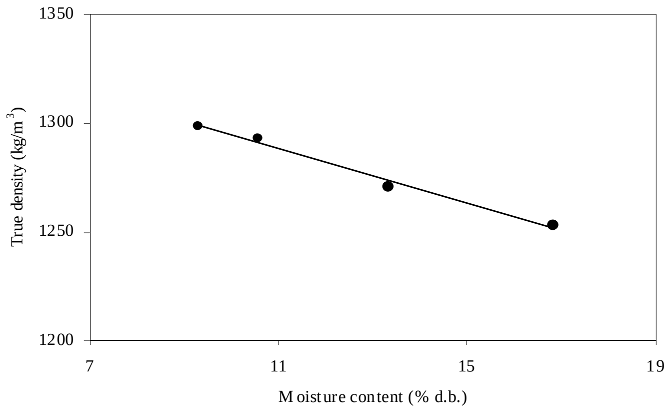

Fig. 5. Effect of moisture content on true density

Porosity: The porosity of black kabuli chickpea seed increased from 39.90 to 40.48 % with the increase in moisture content from 9.29 to 16.82 % d.b. (Fig. 6). The relationship between porosity and moisture content can be represented by the following equation:

$$P_f = 39.429 + 0.0639M_c \qquad (R^2 = 0.7856) \qquad (10)$$

Singh and Goswami[18], Ögüt[19], Çetin *et al.*[30], Gupta and Das[28] and Yalçin and Özarslan[20] reported similar trends in the case of cumin, white lupin, sunflower and vetch, respectively.

Terminal velocity: The experimental results for the terminal velocity of black kabuli chickpea seed at various moisture levels are shown in Fig. 7. The terminal velocity was found to increase linearly from 2.078 to 2.135 m s^{-1} as the moisture content increased from 9.29 to 16.82 % d.b. The relationship between terminal velocity and moisture content can be represented by the following equation:

$$V_t = 2.0154 + 0.0073M_c \qquad (R^2 = 0.9521) \qquad (11)$$

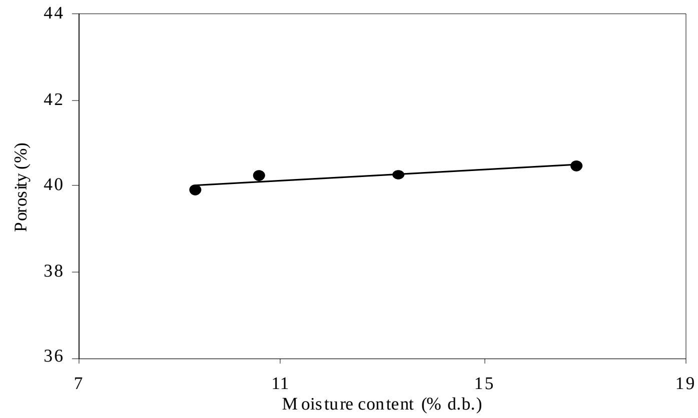

Fig. 6. Effect of moisture content on porosity

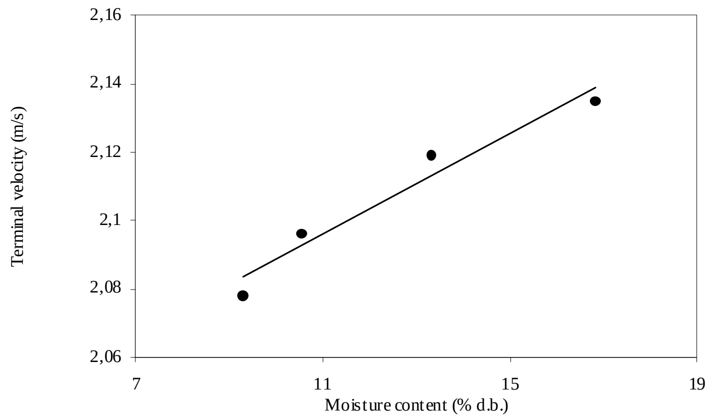

Fig. 7. Effect of moisture content on terminal velocity

Similar results were reported by Gupta and Das[28], Çetin *et al.*[30], Suthar and Das[8] and Joshi *et al.*[21] in the case of sunflower, karingda and pumpkin seeds, respectively.

Static coefficient of friction: The static coefficient of friction of black kabuli chickpea seed on four surfaces (rubber, aluminium, stainless steel and galvanized iron) against moisture content in the range 9.29 to 16.82 % dry basis are presented in Fig. 8. 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 23.81, 20.36, 19.19 and 17.38 % were recorded in the case of rubber, aluminium, stainless steel and galvanized iron, respectively as the moisture content increased from 9.29 to 16.82 % d.b. 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 on rubber μ_{ru}, aluminium

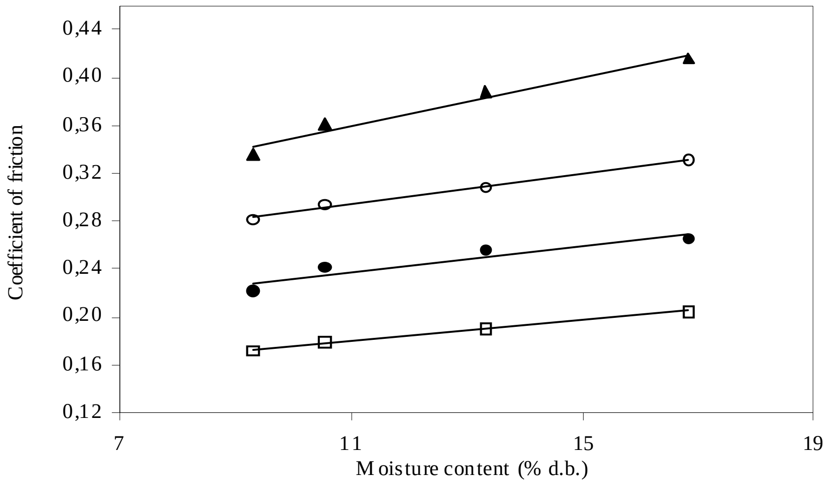

Fig. 8. Effect of moisture content on static coefficient of friction; ▲, rubber; ●, aluminium; ○, galvanized iron; □, stainless steel

μ_{al}, stainless steel μ_{ss} and galvanized iron μ_{gi}, can be represented by the following equations:

$$\mu_{ru} = 0.2492 + 0.0101M_c \qquad (R^2 = 0.9668) \qquad (12)$$

$$\mu_{al} = 0.1781 + 0.0055M_c \qquad (R^2 = 0.8739) \qquad (13)$$

$$\mu_{ss} = 0.1328 + 0.0043M_c \qquad (R^2 = 0.9978) \qquad (14)$$

$$\mu_{gi} = 0.2263 + 0.0062M_c \qquad (R^2 = 0.9894) \qquad (15)$$

Similar results were found by Coskun *et al.*[14], Sahoo and Srivastava[29], Özarslan[9], Çarman[32] and Shepherd and Bhardwaj[33] for sweet corn, okra, cotton, lentil and pigeon pea seeds, respectively.

Conclusion

The thousand seed mass increased from 100.18 to 110.44 g and the sphericity increased from 0.799 to 0.821 with the increase in moisture content from 9.29 to 16.82 % d.b. The projected area increased from 0.163 to 0.251 cm^2 and the porosity increased from 39.90 to 40.48 %. The bulk density decreased linearly from 780.58 to 745.85 kg m^{-3} and the true density decreased from 1298.84 to 1253.15 kg m^{-3}.

The terminal velocity increased from 2.078 to 2.135 m s^{-1}. The static coefficient of friction increased for all the 4 surfaces, namely, rubber (0.336 to 0.416), aluminium (0.221 to 0.266), stainless steel (0.172 to 0.205) and galvanized iron (0.282 to 0.331).

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