Asian Journal of Chemistry Vol. 20, No. 4 (2008), 3097-3103

Some Physical and Engineering Properties of Black Cumin (*Nigella sativa* L.) Seed

M. ÇETIN*, I. YALÇIN and E. SIMSEK
Department of Agricultural Machinery, Faculty of Agriculture
Adnan Menderes University, Aydin, Turkey
E-mail: mcetin06@gmail.com

The physical and engineering properties of black cumin seed were determined as a function of moisture content in the range of 6.94 to 18.22 % dry basis. The average length, width and thickness were 3.19, 1.62 and 1.08 mm, at a moisture content of 6.94 % dry basis, respectively. In the moisture range from 6.94 to 18.22 % dry basis, studies on rewetted black cumin seed showed that the thousand seed mass increased from 2.99 to 3.17 g, the projected area from 2.13 to 3.35 mm^2, the sphericity from 0.557 to 0.566, the porosity from 46.88 to 49.28 % and the terminal velocity from 5.11 to 5.60 $m\ s^{-1}$. The bulk density decreased from 564.48 to 533.37 kg m^{-3} and the true density from 1062.75 to 1051.53 kg m^{-3} with an increase in the moisture content range of 6.94-18.22 % dry basis. The static coefficient of friction of black cumin seed increased linearly against surfaces of four structural materials, namely, rubber (0.265 to 0.334), aluminium (0.228 to 0.288), stainless steel (0.172 to 0.251) and galvanised iron (0.247 to 0.307) as the moisture content increased from 6.94-18.22 % dry basis.

Key Words: Black cumin seed, Physical and Engineering properties, Moisture content.

INTRODUCTION

Black cumin (*Nigella sativa* L) is an annual herbaceous plant belonging to the Ranuculacea family. Mature seeds are consumed for edible and medical purposes. The seeds are used as seasoning for vegetables, legumes and different types of baked products[1,2]. Another use of black cumin seeds is as seasoning for foodstuffs like bread and pickles, especially wide-spread among Turkish people[3]. Proximate analysis of whole mature nigella seeds showed that the moisture content ranged from 5.52 to 7.43 %, crude protein from 20 to 27 %, ash from 3.77 to 4.92 %, ether-extractable lipid from 34.49 to 38.72 % and carbohydrates from 23.5 to 33.2 %[1,4,5].

In order to design equipment for the handling, conveying, separation, drying, aeration, storing and processing of black cumin seed, it is necessary to determine their physical and engineering properties as a function of moisture content. However, no published work seems to have been carried out on the physical and engineering properties of black cumin seed and their relationship with moisture content. Hence, this study was conducted to investigate some moisture dependent physical and engineering properties of black cumin 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 cumin cultivar, local variety were used for all the experiments in this 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[6,7]. The initial moisture content of the seeds was 6.94 % dry basis.

The samples of the desired moisture contents were prepared by adding calculated amounts of distilled water on the seeds[8]. 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[6,9].

The black cumin seeds needed to be stored at relative humidity not more than 85 %[10]. All the physical properties of the seeds were determined at four moisture contents in the range of 6.94-18.22 % dry basis with ten replications at each moisture content.

To determine the average size of the seed, 100 seeds were randomly picked and their three linear dimensions namely, length (L), width (W) and thickness (T) were measured using a micrometer with a accuracy of ± 0.01 mm[11,12].

The sphericity of seeds (ϕ) was calculated by using the following relationship[13].

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

The one thousand seed mass was determined by means of an electronic balance reading to ± 0.001 g accuracy[14,15].

The projected area of a seed was measured by a scanner connected to a computer. For this purpose, a special computer program was used[6].

The average bulk density of the black cumin seed was determined using the standard test weight procedure reported by Singh and Goswami[16] 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 cumin seed in the toluene[16-18]. The porosity was calculated from the following relationship[13]:

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

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[11,12,19]. 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 cumin seed against four 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[7,16,20]. The coefficient of friction was calculated from the following relationship:

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

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 6.94 % dry basis are: length 3.19 ± 0.59 mm, width 1.62 ± 0.56 mm and thickness 1.08 ± 0.63 mm. The frequency distribution curves for the mean values of the dimensions show a trend towards a normal distribution. About 76% of the seeds have a length ranging from 3.0 to 3.5 mm; about 88 %, a width ranging from 1.4 to 1.9 mm and about 92 %, a thickness ranging from 0.8 to 1.2 mm at 18.33 % dry basis moisture content.

One thousand seed mass: The one thousand black cumin seed mass m_{1000} increased linearly from 2.99 to 3.17 g as the moisture content increased from 6.94-18.22 % dry basis (Fig. 1). An increase of 6.02 % in the one thousand seed mass, was recorded within the above moisture range. The linear equation for one thousand seed mass can be formulated to be:

$$m_{1000} = 2.8816 + 0.0157 M_c \qquad (R^2 = 0.9963) \quad (4)$$

A linear increase in the one thousand black cumin seed mass as the seed moisture content increases has been noted by Sacilik *et al.*[8] for hemp, Yalçin and Özarslan[18] for vetch and Sing and Goswami[16] for cumin.

Projected area of seed: The projected area of black cumin seed increased from 2.13 to 3.35 mm^2, when the moisture content of seed increased from 6.94 to 18.22 % dry basis (Fig. 2). The variation in projected area with moisture content of corn seed can be represented by the following equation:

$$A_p = 1.4135 + 0.1096\ M_c \qquad (R^2 = 0.9789) \qquad (5)$$

Similar trends have been reported by by Tang and Sokhansanj[21] for lentil, Abalone *et al.*[22] for Amaranth and Konak *et al.*[23] for chick pea seed.

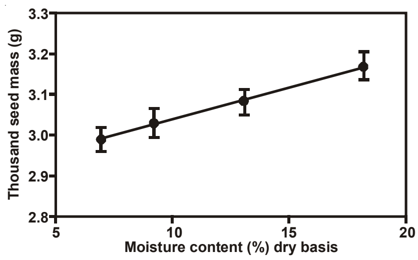

Fig. 1. Effect of moisture content on thousand seed mass

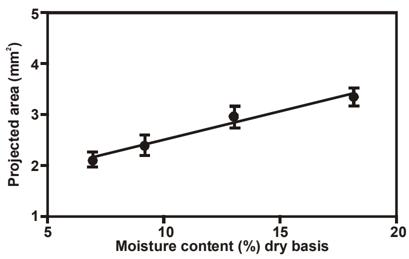

Fig. 2. Effect of moisture content on projected area

Sphericity: The sphericity of black cumin seed increased from 0.557 to 0.566 with the increase in moisture content (Fig. 3). The relationship between sphericity and moisture content M_c in 6.94-18.22 % dry basis can be represented by the following equation:

$$\phi = 0.5523 + 0.0008\ M_c \qquad (R^2 = 0.9710) \qquad (6)$$

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

Bulk density: The values of the bulk density for different moisture levels varied from 564.48 to 533.37 kg m^{-3} (Fig. 4). The bulk density of seed was found to bear the following relationship with moisture content:

$$\rho_b = 581.61 - 2.7457\ M_c \qquad (R^2 = 0.9706) \qquad (7)$$

A similar decreasing trend in bulk density has been reported by Sahoo and Srivastava[26] for okra, Coskun *et al.*[11] for sweet corn and Gupta and Das[25] for sunflower seed.

True density: The true density varied from 1062.75 to 1051.53 kg m^{-3} when the moisture level increased from 6.94 to 18.22 % dry basis (Fig. 5). The true density and the moisture content of seed can be correlated as follows:

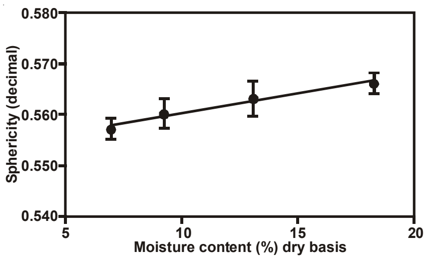

Fig. 3. Effect of moisture content on sphericity

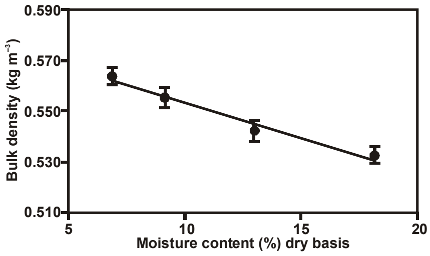

Fig. 4. Effect of moisture content on bulk density

$$\rho_t = 1068.8 - 0.9628\ M_c \qquad (R^2 = 0.9864) \qquad (8)$$

The results were similar to those reported by Özarslan[6] for cotton, Abalone *et al.*[22] for Amaranth, Dursun and Dursun[27] for caper and Singh and Goswami[16] for cumin seed.

Porosity: The porosity of black cumin seed increased from 46.88 to 49.28 % with the increase in moisture content from 6.94 to 18.22 % dry basis (Fig. 6). The relationship between porosity and moisture content can be represented by the following equation:

$$P_f = 45.55 + 0.2132\ M_c \qquad (R^2 = 0.9643) \qquad (9)$$

Singh and Goswami[16], Ögüt[17], Gupta and Das[25] and Yalçin and Özarslan[18] reported similar trends in the case of cumin, white lupin, sunflower and vetch, respectively.

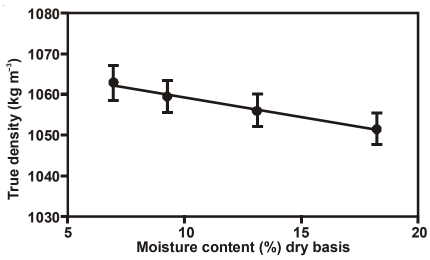

Fig. 5. Effect of moisture content on true density

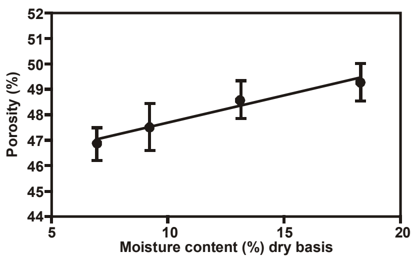

Fig. 6. Effect of moisture content on porosity

Terminal velocity: The experimental results for the terminal velocity of black cumin seed at various moisture levels are shown in Fig. 7. The terminal velocity was found to increase linearly from 5.11 to 5.60 m s^{-1} as the moisture content increased from 6.94 to 18.22 % dry basis. The relationship between terminal velocity and moisture content can be represented by the following equation:

$$V_1 = 4.8403 + 0.0428\ M_c \qquad (R^2 = 0.9827) \qquad (10)$$

Similar results were reported by Gupta and Das[25], Suthar and Das[7] and Joshi *et al.*[19] in the case of sunflower, karingda and pumpkin seeds, respectively.

Static coefficient of friction: The static coefficient of friction of black cumin seed on four surfaces (rubber, aluminium, stainless steel and galvanized iron) against moisture content in the range 6.94 to 18.22 % 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 26.04, 26.32, 45.93 and 24.29 % were recorded in the case of rubber, aluminium, stainless steel and galvanized iron, respectively as the moisture content increased from 6.94 to 18.22 % dry basis.

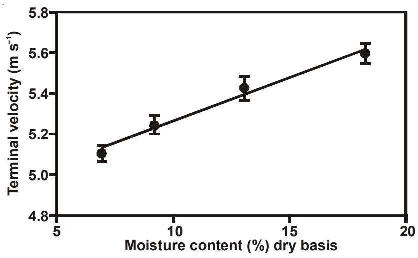

Fig. 7. Effect of moisture content on terminal velocity

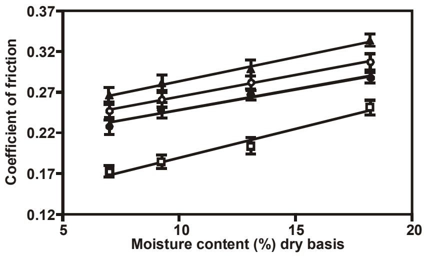

Fig. 8. Effect of moisture content on static coefficient of friction; ▲, rubber; ●, aluminium; ○, galvanized iron; □, stainless steel

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

$$\mu_{ru} = 0.2246 + 0.0059\ M_c \quad (R^2 = 0.9923) \quad (11)$$

$$\mu_{al} = 0.1969 + 0.0051\ M_c \quad (R^2 = 0.9742) \quad (12)$$

$$\mu_{ss} = 0.1209 + 0.0069\ M_c \quad (R^2 = 0.9737) \quad (13)$$

$$\mu_{gi} = 0.2109 + 0.0053\ M_c \quad (R^2 = 0.9981) \quad (14)$$

Similar results were found by Coskun *et al.*[11], Sahoo and Srivastava[26], Özarslan[6], Çarman[28] and Shepherd and Bhardwaj[29] for sweet corn, okra, cotton, lentil and pigeon pea seeds, respectively.

Conclusion

(1) The thousand seed mass increased from 2.99 to 3.17 g and the sphericity increased from 0.557 to 0.566 with the increase in moisture content from 6.94 to 18.22 % dry basis. The projected area increased from 2.13 to 3.35 mm^2 and the porosity increased from 46.88 to 49.28 %. The bulk density decreased linearly from 564.48 to 533.37 kg m^{-3} and the true density decreased from 1062.75 to 1051.53 kg m^{-3}.

(2) The terminal velocity increased from 5.11 to 5.60 m s^{-1}. The static coefficient of friction increased for all four surfaces, namely, rubber (0.265 to 0.334), aluminium (0.228 to 0.288), stainless steel (0.172 to 0.251) and galvanized iron (0.247 to 0.307).

REFERENCES

1. B.M. Atta, *Food Chem.*, **83**, 63 (2003).
2. G. Üstun, L. Kent, N. Çekin and H. Civelekoglu, *J. Am. Oil Chem. Soc.*, **67**, 958 (1990).
3. L.F. D'Antuono, A. Moretti and A.F.S. Lovato, *Ind. Crop Prod.*, **15**, 59 (2002).
4. C. Nergiz and S. Ötles, *Food Chem.*, **48**, 259 (1993).
5. M.S. Al-Jassir, *Food Chem.*, **45**, 239 (1992).
6. C. Özarslan, *Biosyst. Eng.*, **83**, 169 (2002).
7. S.H. Suthar and S.K. Das, *J. Agric. Eng. Res.*, **65**, 15 (1996).
8. K. Sacilik, R. Öztürk and R. Keskin, *Biosyst. Eng.*, **86**, 191 (2003).
9. E. Baümler, A. Cuniberti, S.M. Nolasco and I.C. Riccobene, *J. Food Eng.*, **73**, 134 (2006).
10. E.M. Zeinab, A.F. Hala, E.D. Mohie and Y.M. Seham, *Radiat. Phys. Chem.*, **60**, 181 (2001).
11. M.B. Coskun, I. Yalçin and C. Özarslan, *J. Food Eng.*, **74**, 523 (2006).
12. C. Vilche, M. Gely and E. Santalla, *Biosyst. Eng.*, **86**, 59 (2003).
13. N.N. Mohsenin, Physical Properties of Plant and Animal Materials, Gordon and Breach Science Publishers, New York (1970).
14. N.A. Aviara, M.I. Gwandzang and M.A. Haque, *J. Agric. Eng. Res.*, **73**, 105 (1999).
15. E.A. Baryeh, *J. Food Eng.*, **51**, 39 (2002).
16. K.K. Singh and T.K. Goswami, *J. Agric. Eng. Res.*, **64**, 93 (1996).
17. H. Ögüt, *J. Agric. Eng. Res.*, **69**, 273 (1998).
18. I. Yalçin and C. Özarslan, *Biosyst. Eng.*, **88**, 507 (2004).
19. D.C. Joshi, S.K. Das and R.K. Mukherjee, *J. Agric. Eng. Res.*, **54**, 219 (1993).
20. S.K. Dutta, V.K. Nema and R.K. Bhardwaj, *J. Agric. Eng. Res.*, **39**, 259 (1988).
21. J. Tang and S. Sokhansanj, *J. Agric. Eng. Res.*, **56**, 313 (1993).
22. R. Abalone, A. Cassinera, A. Gaston and M.A. Lara, *Biosyst. Eng.*, **89**, 109 (2004).
23. M. Konak, K. Çarman and C. Aydin, *Biosyst. Eng.*, **82**, 73 (2002).
24. C. Aydin, H. Ögüt and M. Konak, *Biosyst. Eng.*, **82**, 231 (2002).
25. R.K. Gupta and S.K. Das, *J. Agric. Eng. Res.*, **66**, 1 (1997).
26. P.K. Sahoo and A.P. Srivastava, *Biosyst. Eng.*, **83**, 441 (2002).
27. E. Dursun and I. Dursun, *Biosyst. Eng.*, **92**, 237 (2005).
28. K. Çarman, *J. Agric. Eng. Res.*, **63**, 87 (1996).
29. H. Shepherd and R.K. Bhardwaj, *J. Agric. Eng. Res.*, **35**, 227 (1986).

(*Received*: 24 August 2007; *Accepted*: 18 January 2008) AJC-6220