Moisture Dependent Physical Properties of Anise Seeds

R.K. Singh[1], M.K. Vishal[1] and R.K. Vishwakarma[2,*]

[1]*National Research Centre on Seed Spices, Ajmer-305206 (Rajasthan), India*

[2]*Central Institute of Post-Harvest Engineering and Technology, Ludhiana-141004 (Punjab), India*

Abstract: A study on the anise seeds (Ajmer Anise-1) was performed to investigate the effect of seeds moisture content on their physical properties as these are very important to design post harvest equipments. The physical properties of the anise were evaluated as a function of moisture contents in the range of 4.85 % to 24.81% dry basis (d.b.). Seed geometric parameters such as average length, width, thickness, geometric mean diameter, volume, sphericity and surface area increased with the increase in seed moisture. The 1000-seed mass increased linearly with increase in moisture. Bulk density and true density of anise decreased when seed moisture content was raised while the porosity of anise increased. The angle of repose and coefficients of static friction on four different surfaces (plywood, mild steel, galvanized iron and glass) and terminal velocity increased with increase in seed moisture.

Keywords: Physical properties, Anise seed, Spatial dimensions, Bulk density.

INTRODUCTION

Anise (*Pimpinella anisum* L.) is an annual herb belongs to the family Apiaceae. It is generally grown in winter season. The fruit which is called aniseed is short, hairy, brownish, ovoid schizocarp splits at maturity in two mericarps containing a single seed. The seeds are brown in colour and have a characteristic sweet smell and pleasant aromatic taste. This is used in pharmaceutics, perfumery and food industry. The fruits as well as essential oils are characterized as antioxidant, antispasmodic, antimicrobial, insecticidal and antifungal effects [1-5]. The seed contains around 1.5-5% essential oil mainly composed of volatile phenylpropanoids like trans-anethole with around 90% [6].

For efficient processing operation, knowledge of moisture dependent physical properties such as spatial dimensions, bulk density, true density, and porosity of anise are essential. Better design of storage structures, processing equipments, and processes may be done using these basic data. The frictional properties and aerodynamic properties of food materials are needed for the design of oil extraction, dehulling and hull separation machines.

In the literature, physical properties of various crop seeds have been reported such as pumpkin [7], cumin [8], pigeon pea [9], okra seed [10], caper seed [11], sweet corn [12], red kidney beans [13], chickpea seeds [14], rice [15], locust bean seed [16] and guar [17]. Selected engineering properties of soybean [18], locust bean seed [19], faba bean [20]; cocoa [21], faba bean [22], and barbunia seed [23] have also been studied in the moisture content range of 18.33-32.43% (d.b.). Gharib-Zahedi *et al.,* [24], and Zewdu [25] studied some moisture dependent engineering properties of black cumin and ajwain seeds, respectively.

Limited published literature is available on the physical properties of anise seed as a function of moisture content. The present study was, therefore, aimed to determine moisture dependent physical properties such as spatial dimensions, geometric mean diameter, sphericity, surface area, volume, 1000-seed mass, bulk density, true density, porosity, angle of repose, static coefficient of friction and terminal velocity of anise seeds (Ajmer Anise-1) between 4.85 and 24.81% (d.b.) moisture range, which should be helpful in designing handling, processing and packaging equipments for anise.

MATERIALS AND METHODS

The anise variety (cv. Ajmer Anise-1) was arranged from National Research Centre on Seed Spices, Ajamer (Rajasthan), India. Seeds were cleaned manually to remove all impurities such as dust, chaffs, stone, damaged and unhealthy seeds. Then moisture content of the seeds was determined using standard hot air oven drying method at 105±1ºC for 24 h, AOAC [26]. The physical properties were determined at five moisture levels at 4.85, 9.83, 14.98, 19.76, and 24.81% (d.b.). Samples of the desired moisture contents were prepared by adding measured amount of distilled water followed by thorough mixing and sealing in LDPE bags. The samples were kept at 5ºC in a refrigerator for 7 days to allow uniform distribution of moisture. Required amount of seeds was taken out from the bags and held

*Address correspondence to this author at the Central Institute of Post-Harvest Engineering and Technology, Ludhiana-141004 (Punjab), India, Tel: +91 161 2313167; Fax: +91 161 2308670; E-mail: rkvciphet@gmail.com

E-ISSN: 2408-9826/15

at room temperature (22-25ºC) for 2 h before conducting the tests [27, 18, 8, 23]. All the experiments were replicated five times (except spatial dimensions for which 100 seeds were taken) and the average values were used in the analysis.

To determine the spatial dimensions of anise, 100 seeds were selected randomly and length (L), width (W), and thickness (T) of the seeds was measured using digital micrometer ((least count 0.01 mm; Mitutoyo Corporation, Japan). Arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (φ) and volume (V) were calculated by using the relationships [28, 29]:

$$D_a = (L + W + T)/3 \quad (1)$$

$$D_g = (LWT)^{1/3} \quad (2)$$

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

$$V = \pi B^2 L^2 / 6(2L - B) \quad (4)$$

where, $B = (WT)^{0.5}$ (5)

The surface area (A_s) was determined by analogy with a sphere of same geometric mean diameter using the following relationship: [28]

$$A_s = \pi D_g^2 \quad (6)$$

To determine the mass of 1000 seeds (M_t), about 250 seeds were separated randomly from the lot and weighed (M) on an electronic balance (least count 0.001 g). Then the number of seeds (n) in the sample was counted [18]. The mass of 1000 seeds was calculated as;

$$M_t = \frac{M}{n} \times 1000 \quad (7)$$

Bulk density (ρ_b) was determined using the procedure suggested by Singh & Goswami [8] by filling a 500 mL cylinder with the seeds from a height of 150 mm at a constant rate and then weighing the contents. Bulk density is generally used for determination of space required for storage of seeds. Thus the compaction of seed results change in the seed volume. Therefore the seeds were not compacted during the test.

True density (ρ_t) was determined using the toluene displacement method. Toluene was used in place of water as anise absorb toluene to a lesser extent than other liquids like water and its low surface tension allowed filling of shallow dips in seeds with low dissolution power. [28] The volume of toluene displaced was obtained by immersing a weighed quantity of anise in the toluene. [28, 8]

The bed porosity (ε) of a sample mass is the ratio of spaces in the bulk to its bulk volume. The ε was calculated using the following equation: [28]

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho t}\right) 100 \quad (8)$$

For measuring angle of repose (θ), a plywood box of 10×10×10 cm size attached with a removable front panel was taken. The box was filled with anise seeds and then front panel was removed quickly which allowed the seeds to flow and assume a natural slope. [7, 30] The diameter (D) and height (H) of the slope were measured. The angle of repose (θ) was calculated by using:

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad (9)$$

The static coefficient of friction (μ) is a dimensionless quantity required for calculating the friction force. It was determined against four different surfaces; plywood, mild steel, galvanized iron and glass, which are commonly used for handling and processing of anise and construction of storage and drying bins. For determination of μ, a wooden box of 100-mm length, 100-mm width and 40-mm height without base and lid was filled with the sample and placed on an adjustable tilting plate, faced with the test surface. The sample container was raised slightly (0.5-1.0 mm) so that the bottom not to touch the surface. The inclination of the test surface was increased slowly with a screw device until the box just started to slide down and the angle of tilt (α) was noted from a graduated scale. The μ was taken as the tangent of this angle [7, 8, 31].

$$\mu = \tan \alpha \quad (10)$$

Terminal velocity of anise was determined using a cylindrical column in which the material was suspended in the air stream [17, 32]. The minimum air velocity that held the seeds under suspension was recorded using a digital anemometer (±0.1 m/s) [7].

The data analysis of this study was done using the Statistca 6 software. The differences between the mean values of physical characteristics of anise samples were tested for significance using t-test. The relationship between moisture content and physical properties of anise seeds was determined using linear regression analysis.

RESULTS AND DISCUSSION

Geometrical Parameters

Dimensional parameters, surface area and volume of anise seeds at selected moisture contents are reported in Table **1**. The L, W, T, D_a, D_g, and V values of anise increased significantly ($p<0.05$) with increase in moisture content. The linear increase in spatial dimension might be due to expansion of seeds due to moisture uptake in the intercellular spaces. This indicated that drying of anise at higher moistures may result in shrinkage of seeds due to decrease in seed dimensions. Increase in seeds dimensions for black cumin, ajwain, soybeans and pigeon pea have been reported by Gharib-Zahedi *et al.* [24] Zewdu, [25] Deshpande *et al.* [18] and Baryeh & Mangope [9], respectively. The geometric mean diameter of the seed was found more than its width and thickness and less than seed length. It indicated that the seeds were nearly ellipsoidal in shape. Sphericity value of 0.65 also indicates that the anise might be considered ellipsoidal in shape.

The relationship between L, W, T and D_g and moisture content (m) can be represented by the following equations.

$$L = 3.253 + 0.013m \qquad (R^2 = 0.98) \qquad (11)$$

$$W = 1.942 + 0.008m \qquad (R^2 = 0.99) \qquad (12)$$

$$T = 1.475 + 0.009m \qquad (R^2 = 0.97) \qquad (13)$$

$$D_g = 2.102 + 0.01m \qquad (R^2 = 0.99) \qquad (14)$$

The sphericity and surface area of the anise increased with increase in moisture content (Table **1**). Zewdu, [25] Deshpande *et al.* [18] and Sobukola & Onwuka [16] reported increase in sphericity of ajwain, soybean and locust bean seeds, respectively.

Seed Mass (of 1000 Seeds)

Change in 1000-seed mass of anise seeds with moisture content is shown in Figure **1**. The 1000-seed mass of anise increased linearly from 4.15 to 4.68 g (12.8% increase) with increase in moisture content from 4.85-24.81%. Similar results have been reported for barbunia beans, [23] black cumin, [24] locust bean seed, [16] ajwain [25] and guar seeds [17]. The relationship between 1000-seed mass and moisture content can be expressed by the following relationship.

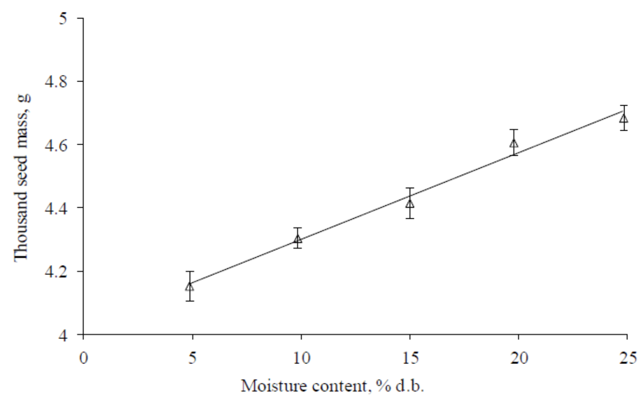

Figure 1: Effect of moisture content on 1000-grain weight of Anise seeds (R^2=0.98, bars show standard deviation from mean).

Table 1: Dimensional Properties of Anise (cv. Ajmer Anise-1) at Different Moisture Content (%, d.b.)

Particulars	Moisture content (%, d.b.)				
	4.85	9.83	14.98	19.76	24.81
Length (mm)	3.33±0.17[a]	3.37±0.14[a]	3.44±0.09[b]	3.50±0.11[b]	3.59±0.12[c]
Width (mm)	1.98±0.15[a]	2.03±0.10[a]	2.06±0.12[ab]	2.10±0.08[bc]	2.15±0.13[c]
Thickness (mm)	1.53±0.10[a]	1.55±0.09[a]	1.60±0.06[b]	1.66±0.06[c]	1.71±0.09[d]
Arithmetic mean diameter (mm)	2.28±0.10[a]	2.32±0.06[a]	2.37±0.06[b]	2.42±0.05[c]	2.48±0.08[d]
Geometric mean diameter (mm)	2.16±0.09[a]	2.20±0.05[a]	2.25±0.06[b]	2.30±0.05[c]	2.36±0.08[d]
Sphericity	0.65±0.02[a]	0.65±0.02[ab]	0.65±0.02[ab]	0.66±0.02[b]	0.66±0.02[b]
Surface area (mm^2)	1.33±0.07[a]	1.34±0.09[ab]	1.34±0.07[ab]	1.36±0.07[b]	1.36±0.07[b]
Volume (mm^3)	3.60±0.47[a]	3.77±0.29[a]	4.04±0.36[b]	4.37±0.30[c]	4.73±0.51[d]

figures in a row followed with different superscripts are significant ($p<0.05$).

$M_t = 4.027 + 0.027m \quad (R^2 = 0.98) \quad (15)$

Bulk Density

Bulk density of anise seeds decreased from 348.53 to 319.01 kg/m^3 (8.46% decrease) with increase in moisture content from 4.85% to 24.81% (Figure **2**). This decrease was observed due to the higher increase in volume (Table **1**) relative to the increase in seeds mass. Change in bulk density of anise with moisture content can be expressed as:

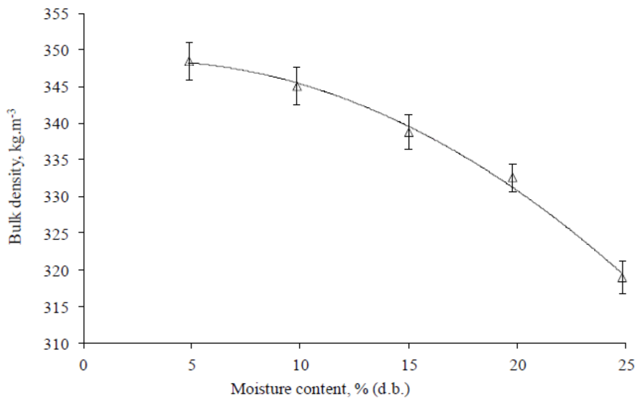

Figure 2: Effect of moisture content on bulk density of Anise seeds (R^2=0.99, bars show standard deviation from mean).

$\rho_b = 348.04 – 0.323m - 0.059m^2 \quad (R^2 = 0.99) \quad (16)$

Similar relationships have been reported for chickpea [33], locust bean seed [16] and black cumin. [24] However, increase in bulk density with moisture content was reported for cashew nut by Balasubramanian. [34] Zewdu [25] reported non-significant decrease in bulk density of ajwain seeds.

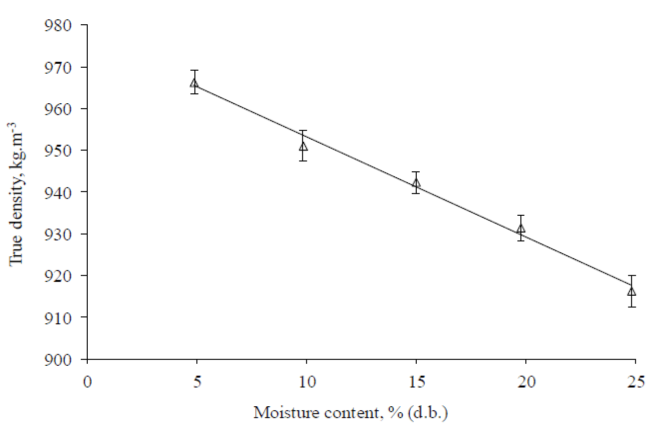

Figure 3: Effect of moisture content on true density of Anise seeds (R^2=0.99, bars show standard deviation from mean).

True Density

True density of anise decreased from 966.35 to 916.37 kg/m^3 (5.17% decrease in value) with increase in moisture content (Figure **3**). The decrease in true density with increase in moisture content was mainly due to the significant increase in volume, which was higher than the corresponding increase in the mass of the material. The variation of true density mass with moisture content can be expressed as:

$\rho_t = 977.17 – 2.398m \quad (R^2 = 0.99) \quad (17)$

The behaviour of true density with moisture content is contradictory as reported in the literature. Increase in true density with moisture content has been reported by Singh and Goswami, [8] Altuntas & Yildiz [22] and Gharib-Zahedi *et al.* [24] for cumin, faba bean, and black cumin, respectively. These seeds have lower volume change in comparison to change in weight with moisture content. However, Tunde-Akintunde & Akintunde, [35] Cetin [23] and Zewdu [25] reported decrease in true density of beni seeds, barbunia seeds and ajwain with moisture content. The true density of the anise was higher than that of bulk density at all moisture contents.

Bed Porosity

Bed porosity of anise increased from 63.93% to 65.19% with the moisture content (d.b.) as shown in Figure **4**. The variations in ε with moisture content was significant ($p<0.05$). The variation of porosity with moisture content can be expressed as:

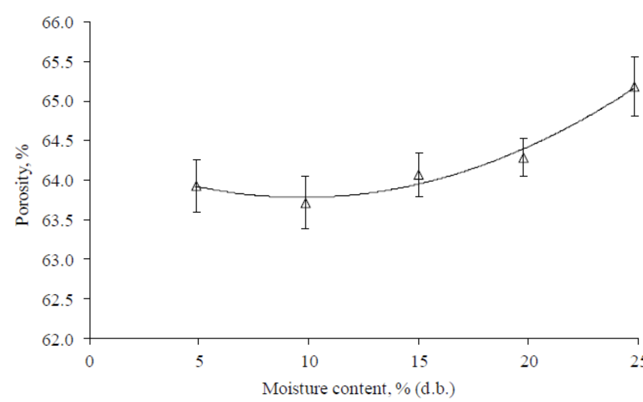

Figure 4: Effect of moisture content on porosity of Anise seeds (R^2=0.97, bars show standard deviation from mean).

$\varepsilon = 64.347 - 0.117m + 0.006m^2 \quad (R^2 = 0.97) \quad (18)$

Tunde-Akintunde & Akintunde, [35] Joshi *et al.* [7] and Shepherd & Bhardwaj [36] observed decrease in porosity of ajwain, beniseeds, pumpkin and pigeon pea seeds, respectively with increased moisture content. However, Singh and Goswami, [8] Altuntas & Yildiz [22] and Gharib-Zahedi *et al.* [24] reported increase in porosity with moisture content for cumin, faba bean and black cumin seeds, respectively. Higher porosity values of bulk may result in better aeration and water vapor diffusion during deep bed drying.

Angle of Repose

Angle of repose of anise seeds increased linearly from 35.05º to 37.55º with moisture content (Figure **5**). Similar behavior has been observed for cumin, black cumin, and guar seeds by Singh and Goswami, [8] Gharib-Zahedi *et al.* [24] and Vishwakarma *et al.,* [17] respectively. Variation of angle of repose with moisture content can be expressed as:

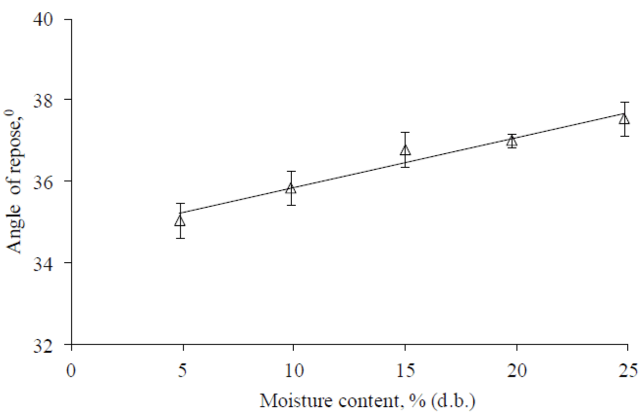

Figure 5: Effect of moisture content on angle of repose of Anise seeds (R^2=0.96, bars show standard deviation from mean).

$$\Theta = 34.606 + 0.124m \quad (R^2 = 0.96) \quad (19)$$

At higher moisture content, seeds tend to stick together, causing less flow ability and angle of repose is increased. The data may be useful for design of hoppers, and storage bins for the anise.

Coefficient of Static Friction

Variations of static coefficient of friction for anise seeds against four surfaces (plywood, mild steel, galvanized iron and glass) with moisture content are presented in Figure **6**. The static coefficient of friction increased significantly ($p<0.05$) with moisture content for all the surfaces. This was due to the increased adhesion between the seeds and the material surfaces at higher moisture values. The seeds may become rougher and sliding characteristics are diminished at higher moisture contents so that the static coefficient of friction is increased. Variation of μ with moisture content of anise can be expressed mathematically as follows:

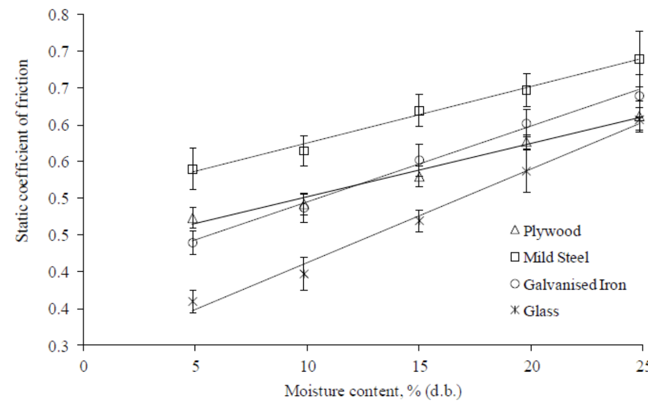

Figure 6: Effect of moisture content on static coefficient of friction of Anise seeds (bars show Standard Deviation from mean).

$$\mu_{pb} = 0.429 + 0.007m \quad (R^2 = 0.98) \quad (20)$$

$$\mu_{ms} = 0.498 + 0.008m \quad (R^2 = 0.99) \quad (21)$$

$$\mu_{gi} = 0.391 + 0.010m \quad (R^2 = 0.99) \quad (22)$$

$$\mu_{g} = 0.285 + 0.013m \quad (R^2 = 0.98) \quad (23)$$

where μ_{pb}, μ_{ms}, μ_{gi}, and μ_g are static coefficient of friction of anise seeds against plywood, mild steel, galvanized iron and glass surfaces, respectively.

The coefficient of friction at all moisture contents was highest against mild steel. The μ increased drastically with increase in moisture content beyond 15%, except for plywood. The order of decrease in coefficient of friction reported for cumin seeds, [8] karingda seeds [37] and locust bean seed [16] was plywood followed by mild steel and galvanized iron. However, Amin *et al.* [38] have reported that no variation existed between plywood and galvanized iron for lentil seeds.

Terminal Velocity

Terminal velocity (V_t) of anise seeds exhibited significant increase ($p<0.05$) from 2.71 to 3.69 m/s as the moisture content increased from about 4.85% to 24.81% (d.b.) (Figure **7**). The relationship between terminal velocity and moisture content is represented as:

$$V_t = 2.486 + 0.049m \quad (R^2 = 0.99) \quad (24)$$

Singh and Goswami, [8] Baryeh and Mangope, [9]

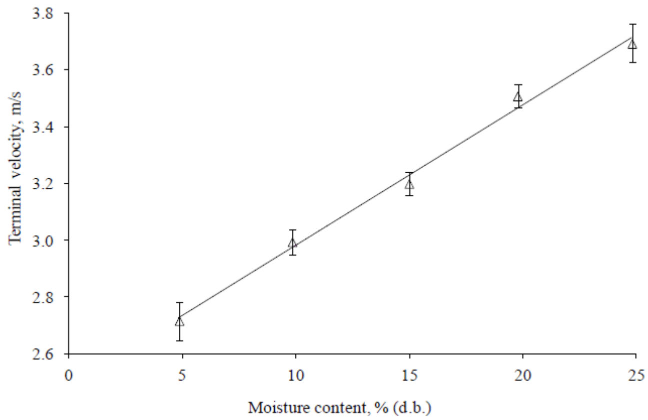

Figure 7: Effect of moisture content on terminal velocity of Anise seeds (R^2 = 0.98; bars show standard deviation from mean).

Isik and Unal [13] and Gharib-Zahedi *et al.* [24] have reported a linear increase in terminal velocity with moisture content for cumin, pigeon pea, white speckled kidney beans and black cumin, respectively. The increase in terminal velocity with increase in moisture content within the study range can be attributed to the increase in mass of the individual seed per unit frontal area presented to the airflow.

CONCLUSIONS

The physical properties of anise seeds were found to be function of moisture content. The length, width, thickness, geometric mean diameter, shpericity, surface area and volume of anise seed increased with increase in moisture content. The thousand seed mass increased from 4.15 to 4.68 g, the bed porosity increased from 63.93 to 65.19 with the increase in moisture content. The bulk density decreased linearly from 348.53 to 319.01 kg/m^3 whereas the true density decreased from 966.35 to 916.37 kg/m^3 with increase in moisture content. The terminal velocity increased from 2.71 to 3.69 m/s and angle of repose increased from 35.05 to 37.55° in the moisture range (d.b.). The static coefficient of friction increased on four structural surfaces namely, galvanized iron sheet (0.44 to 0.64), mild steel (0.54 to 0.69), glass surface (0.36 to 0.61) and plywood (0.47 to 0.61) in the experimental moisture range.

ACKNOWLEDGEMENT

The authors are thankful to Director, Central Institute of Post-Harvest Engineering and Technology, Ludhiana-141004 (Punjab), for his kind cooperation and help provided during the course of study.

REFERENCES

[1] Tunc I, Sahinkaya S. Sensitivity of two greenhouse pests to vapours of essential oils. Ento Exp et Appl 1998; 86: 183-7.

[2] Gülcin I, Oktay M, Kirecci E, Küfrevioglu ÖI. Screening of antioxidant and antimicrobial activities of anise (Pimpinella anisum L.) seed extracts. Food Chem 2003; 83: 371-82.

[3] Özcan MM, Chalchat JC. Chemical composition and antifungal effect of anise (Pimpinella anisum L.) fruit oil at ripening stage. Annals Microb 2006; 56: 353-8.

[4] Tepe B, Akpulat AH, Sokmen M, Daferera D, Yumrutas O, Aydin E, *et al.* Screening of the antioxidative and antimicrobial properties of the essential oil of Pimpinella anisetum and Pimpinella flabellifolia from Turkey. Food Chem 2006; 97: 719-24.

[5] Tirapelli CR, Andrade CR, Cassano AO, De Souza FA, Ambrosio SR, Costa FB, *et al.* Antispasmodic and relaxant effects of the hydroalcoholic extract of Pimpinella anisum (Apiaceae) on rat anococcygeous smooth muscle. J Ethnopharm 2007; 110: 23-9.

[6] Tabanca N, Demirci B, Kirimer N, Baser KHC, Bedir E, Khan IA, Wedge DE. Gas chromatographic–mass spectrometric analysis of essential oil from Pimpinella aurea, Pimpinella corymbosa, Pimpinella peregrina and Pimpinella puberula gathered from Eastern and Southern Turkey. J Chrom 2005; 1097: 192-8.

[7] Joshi DC, Das SK, Mukherjee RK. Physical properties of pumpkin grains. J Agric Eng Res 1993; 54(3): 219-29.

[8] Singh KK, Goswami TK. Physical properties of cumin seed. J Agric Eng Res 1996; 64(2): 93-8.

[9] Baryeh EA, Mangope BK. Some physical properties of QP-38 variety pigeon pea. J Food Eng 2002; 56: 59-65.

[10] Sahoo PK, Srivastava AP. Physical properties of okra seeds. Biosys Eng 2002; 83(4): 441-8.

[11] Dursun E, Durson I. Some physical properties of caper seed. Biosys Eng 2005; 92(2): 237-5.

[12] Coskun MB, Yalcin I, Ozarslan C. Physical properties of sweet corn seed (Zea mays saccharata Sturt.). J Food Eng 2006; 74(4): 523-8.

[13] Isik E, Unal H. Moisture-dependent physical properties of white speckled red kidney bean grains. J Food Eng 2007; 82: 209-6.

[14] Nikoobin M, Mirdavardoosti F, Kashaninejad M, Soltani A. Moisture-dependent physical properties of chickpea seeds. J Food Proc Eng 2009; 32: 544-64.

[15] Shittu TA, Olaniyi MB, Oyekanmi AA, Olkeleye KA. Physical and water absorption characteristics of some improved rice varieties. Food Bioproc Tech 2009; DOI 10.1007/s/11947-009-0288-6.

[16] Sobukola OP, Onwuka VI. Effect of moisture content on some physical properties of locust bean seed (Parkia fillicoidea L.). J Food Proc Eng 2010; DOI: 10.1111/j.1745-4530.2009.00511.

[17] Vishwakarma RK, Shivhare US, Nanda SK. Physical properties of guar seeds. Food Bioproc Tech 2010; 5(4): 1364-1371.

[18] Deshpande SD, Bal S, Ojha TP. Physical properties of soybean. J Agric Eng Res 1993; 56(2): 89-8.

[19] Olajide JO, Ade-Omowage BIO. Some physical properties of locust bean seed. J Agric Eng Res 1999; 74: 15-2.

[20] Haciseferogullari H, Gezer I, Bahtiyarca Y, Menges HO. Determination of some chemical and physical properties of Sakiz faba bean (Vicia faba L. Var. major). J Food Eng 2003; 60(4): 475-9.

[21] Bart-Plange A, Baryeh EA. The physical properties of Category B cocoa beans. J Food Eng 2003; 60(3): 219-7.

[22] Altuntas E, Yildiz M. Effect of moisture content on some

physical and mechanical properties of faba bean (Vicia faba L.) grains. J Food Eng 2007; 78(1): 174-3.

[23] Cetin M. Physical properties of barbunia bean (Phaseolus vulgaris L. cv. 'Barbunis') seed. J Food Eng 2007; 80: 353-8.

[24] Gharib-Zahedi SMT, Mousavi SM, Moayedi A, Garavand AT, Alizadeh SM. Moisture-dependent engineering properties of black cumin (Nigella sativa L.) seed. Agric Eng Int: CIGR Journal 2010; 12(1): 194-2.

[25] Zewdu AD. Moisture-Dependent Physical Properties of Ajwain (Trachyspermum ammi L.) Seeds. Philipp Agric Sci 2011; 94(3): 278-4.

[26] AOAC. Official Methods of Analysis, 13th Ed., Association of Official Analytical Chemists 1980, Arlington, VA.

[27] Carman K. Some physical properties of lentil seeds. J Agric Eng Res 1996; 63(2): 87-2.

[28] Mohsenin NN. Physical properties of plant and animal materials. Gordon and Breach Science Publishers 1986; New York.

[29] Jain RK, Bal S. Physical properties of pearl millet. J Agric Eng Res 1997; 66: 85-1.

[30] Paksoy M, Aydin A. Some physical properties of edible squash (Cucurbita pepo L.). J Food Eng 2004; 65: 225-1.

[31] Dutta SK, Nema VK, Bhardwaj RJ. Physical properties of gram. J Agric Eng Res 1988; 39: 259-8.

[32] Nimkar PM, Chattopadhyay PK. Some physical properties of green gram. J Agric Eng Res 2001; 80(2): 183-9.

[33] Konak M, Carman K, Aydin C. Physical properties of chick pea seeds. Biosys Eng 2002; 82: 73-8.

[34] Balasubramanian D. Physical properties of raw cashew nut. J Agric Eng Res 2001; 78: 291-7.

[35] Tunde-Akintunde TY, Akintubde BO. Effect of moisture content and variety on selected properties of beniseed. Agric Eng Int: the CIGR Ejournal 2007; FP 07021. 9, 1-14.

[36] Shepherd H, Bhardwaj RK. Moisture dependent physical properties of pigeon pea. J Agric Eng Res 1986; 35: 227-4.

[37] Suthar SH, Das SK. Some physical properties karingda seeds. J Agric Eng Res 1996; 64: 93-8.

[38] Amin MN, Hossain MA, Roy KC. Effect of moisture content on some physical properties of lentil seeds. J Food Eng 2004; 65: 83-7.

Received on 26-6-2014 Accepted on 8-9-2014 Published on 15-1-2015

http://dx.doi.org/10.15379/2408-9826.2015.02.01.6