PERSPECTIVE ANALYSIS OF THE PHYSICAL AND ENGINEERING PROPERTIES OF CORIANDER SEED AT DIFFERENT MOISTURE CONTENTS

Abstract

Coriander (*Coriandrum sativum L.*) is an important leafy vegetable of family Umbelliferae with small fruits of great medicinal and nutritional value used as spice and condiment. As a marginal spice crop it is cultivated worldwide since centuries but its genetic diversity has rarely been documented. Threshing is one of the major problems associated with coriander production in India. In spite of the food and nutritional importance of the crop to human diet, its threshing has been and remains a serious problem to the farmers. The techniques for threshing coriander in most rural areas are still the traditional methods of seed separation which are uneconomical, labourous and time consuming. Under the present investigation coriander crop was selected for study. Physical, aerodynamic and frictional properties of above seeds were determined in order to decide parameters for the purpose of designing and performance evaluation of a thresher to threshing coriander.

Keywords: Coriander Seed, Moisture, Sphersity, friction, thresher.

1. INTRODUCTION

Spices are high value and low volume commodities of commerce in the world market. All over the world, the fast growing food industry depends largely on spices as a taste and flavor. India ranked first in the production of spices, during 2012-13. Out of all spices, coriander crop is one of the important spice which requires threshing process. In India, major producer of coriander crop are Rajasthan, Madhya Pradesh, Assam, Gujarat, Andhra Pradesh, Orissa and Uttar Pradesh etc. Total production of coriander seed in India is 523.88 MT with an area of 543.98 thousand ha.

"Coriander (*Coriandrum sativum* L.) is an annual *Apiaceae* herb mostly grown for its leaves and seed fruit as spice and condiment. It is an important member of *Umbelliferae* family having 2n=22 chromosomes and mostly considered native to Mediterranean basin. It is cultivated throughout the world for its aromatic leaves and spicy seed due to its wide adaptation to range of eco-geographic conditions" (**Purseglove *et al*, 1981; Simon 1990)**. **"**It is leafy vegetable rich in vitamins, proteins and dietary elements while seed fruit contains 13-29% vegetable oil (petroselinic acid) and 0.35% essential i.e., linalool" **(Diederichsen, 1996;**

Ramadan and Mörsel, 2002; Singh *et al*., 2003; Msaada *et al*., 2007). **"**Coriander is considered important herb due to its extensive use as medicine for curing capabilities against many diseases due to presence of active ingredients in its leaves and fruit" **(Kubo *et al*., 2004)**. "Most importantly it is well known for its fraction of volatile essential oil composition like terpenoids and phenolic constituents which are of great importance in the field of pharmacology" **(Sriti *et al*, 2013)**. "In addition, its oil also contains different antioxidants, anticancer, antibacterial and anti-mutagenic agents as trace compounds" **(Mataysoh *et al*., 2009)**. In literature multiple medicinal uses of coriander have been reported by authors such as antifertility agent **(Al-Said *et al*., 1987)**, hypotensive **(Burdock and Carabin, 2008)**, anti-like operating irrigation equipment, threshers/shellers/cleaners/graders and other post harvest equipment. In this paper we are going to research on the physical and engineering properties at different moisture level for the designing of a thresher.

1 . Historical Background

Mohsenin (1970); Saxena (1991); **Singh (1996)** reported that "the ever-increasing importance of agricultural products together with the complexity of modern technology for their production, processing and storage need a better knowledge of their engineering properties so that machines, processes and handling operations can be designed for maximum efficiency and the highest quality of the final end products". **Singh *et al.* (2002); Coskuner *et al.* (2007)** designed, fabricated and tested the thresher for the purpose of threshing and pearling grains of mandua and mandira based on the physical and rheological properties of mandua/mandira grain. It works on the principle of impact and shear on the grain for the purpose of threshing, dehusking and pearling. **Balasubramanian *et al*. (2012); Zare *et al*. (2013)** studied "the physical properties of cumin and caraway seeds were measured and compared at constant moisture content of 7.5 % w.b". **Unal *et al.* (2013)** investigated "various moisture-dependent physical and nutrional properties of fennel seed (*Foeniculum vulgare* Mill.)"

2. MATERIAL AND METHODS

Under the present investigation coriander crop was selected for study. Physical, aerodynamic and frictional properties of above seeds were determined in order to decide parameters. Therefore, taking into account the machine and crop parameters, the necessary of design and development were made and performance evaluation was carried out on coriander crop.

2.1 Physical and Engineering Properties

Physical and engineering properties are useful and necessary in the design and operation of the various equipments employed for agricultural operations (**Sahay and Singh, 1994**). The present investigation involves threshing and cleaning of seed. The engineering properties of coriander seed (Pant-Haritma) To design of spice thresher requires the knowledge of engineering properties such as physical (shape and size, roundness, sphericity, surface area, volume, bulk density, true density, porosity etc.), aerodynamic (terminal velocity) and frictional (angle of repose and coefficient of friction) properties of coriander seed.

2.2 Physical properties of the coriander

The methods followed for determining the physical properties of coriander were to decide dimensions of the different machine components, these are dimensions of seed, roundness, thousand seed weight, sphericity, surface area, volume, porosity, moisture content, bulk density, true density and straw-seed ratio were determined as per the standard procedure.

2.3 Dimensions of the seed

For the selected Variety, to determine the size of the seeds, three groups of samples consisting of thirty seeds of coriander were randomly taken and their linear dimensions – length (L), width (B) and thickness (T) were determined by the digital Vernier caliper having 0.01mm accuracy.

2.4 Arithmetic and geometric mean diameter

For selected variety of coriander seed, the length, width, thickness and mass of seed were measured on randomly selected 30 seeds. The length, width and thickness of seeds were measured using a digital caliper with an accuracy of 0.01 mm. The arithmetic mean and geometric mean diameter were calculated by the three axial dimensions. It is useful for deciding sieve size and lower concave bar spacing and concave clearance. “The arithmetic mean diameter (Da) and geometric mean diameter (D_g) of the seeds were calculated by using the following equations” (**Mohsenin, 1970**).

$$D_a = \sum_{n=1}^{30} \frac{(L+W+T}{3}\text{, mm} \quad (1)$$

$$D_g = \sum_{n=1}^{30} (L+W+T)^{1/3}\text{, mm} \quad (2)$$

Where, L = Length, mm, B = Width, mm, T = Thickness, mm

2.5 Sphericity

Sphericity is defined as the ratio of the surface area of a sphere with the same volume as the seed to the surface area of the seed. Thirty seeds from each crop were taken randomly for estimating sphericity. For deciding shape of sieve, diameters along the three major axis (length, width and thickness) were determined. Lesser the sphericity then elongated shaped sieve should be used and more sphericity means round shaped sieve. This measurement was determined using the following equation (**Mohsenin, 1970**).

$$\text{Sphericity} = \frac{(L \times B \times T)^{1/3}}{L} \quad (3)$$

Where, L = Length, mm, B = Width, mm, T = Thickness, mm

2.6 Surface area and volume

The surface area (S) of an agricultural product is generally indicative of its pattern of behavior in a flowing fluid such as air, as well as the ease of separating extraneous materials from the product during cleaning by pneumatic means. The surface area of seeds was found by analogy with a sphere of the same geometric mean diameter. The surface area of seed was calculated by using the following formula (**Mohsenin, 1970**).

$$S = (\pi \times D_g^{\,2}) \quad (4)$$

Volume of seed is measured by using following formula (**Jain and Bal, 1997**).

$$V = \frac{\pi \times B^2 \times L^2}{6(2L - B)},\ \text{mm}^3 \quad (5)$$

Where, $$B = (WT)^{0.5} \quad (6)$$

2.7 Bulk density

The bulk density (ρ_b) of coriander seed was determined using the standard test procedure reported by **Singh and Goswami, 1996**). The procedure involves filling a container of 500 ml with the seed to a height of 150 mm at a constant rate and then weighing the content. It is useful for sizing the seed hoppers and storage facilities. Three replications were done to determine the bulk density by using following formula

$$\rho_b = \frac{M}{V},\ \text{g/cm}^3 \quad (7)$$

$$\rho_b = \frac{4M}{\pi D^2 h} \quad (8)$$

Where, M = Mass of the seed sample, g, V = Volume of glass jar sampler, cm^3, D = Diameter of glass jar sampler, cm and h = Height of glass jar sampler, cm

2.8 True density

" True density is used in design of hoppers, storage bins, and separation of desirable materials from impurities. The apparatus used for measuring true density of seeds consists of a 100 ml measuring jar and a weighing balance. 50 ml of toluene was taken in a measuring jar. A known weight of seed sample was poured to the measuring jar and rise in the toluene level was recorded as the true volume of the seeds without void space. The true density of the seed was calculated by using the following formula" (**Mohsenin, 1970**).

$$\text{True Density (g/cc)} = \frac{\text{weight of seeds, g}}{\text{volume of seeds excluding void space, cc}} \quad (9)$$

2.9 Porosity

The porosity is the fraction of the space in the bulk seeds which is not occupied by the seeds. The porosity of bulk seed was calculated from the values of true density and bulk density using the relationship gives by **Mohsenin (1980)** as follows

$$\varepsilon = \frac{\rho t - \rho b}{\rho t} \quad (10)$$

2.10 Moisture content

The moisture content of coriander seeds and straw was determined by oven drying method. The three seed and straw samples were kept for 24 hours at 105 °C temperature in oven according to IS code 7052-1973 and moisture content was calculated accordingly. It is an important property because it affects threshing efficiency and resists load impact. The moisture content can be determined on dry basis using following equation:

$$M_c\,(\%) = \frac{W_w - W_d}{Wd} \times 100 \quad (11)$$

Where, M_c = Moisture content, (d.b.), %, W_w = Weight of material before oven drying, g, W_d = Weight of material after oven drying, g

2.11 thousand seeds weight

"For measuring the weight of the seeds, digital electronic weigh balance having the accuracy of 0.01 g was used. In order to determine the one thousand seeds weight (W_{1000}), three samples of one thousand coriander seeds were counted by manually and weighed by an electronic balance" (Mohsenin, 1970).

2.12 Straw-seed ratio

Three samples of the seeds with straw were selected, each weighing about one kg and separated the seeds from stalks and husk manually for each sample. The mass of the seed and dry matter were measured separately.

$$\text{Straw- seed ratio} = \frac{weight\ of\ straw}{weight\ of\ seed} \qquad (12)$$

2.13 Aerodynamic properties

"Aerodynamic properties of agricultural products are important and required for design of air conveying systems and the separation equipment" (**Sahay and Singh, 1994**).

2.14 Terminal velocity

Terminal velocity is to decide the winnowing velocity of air blower for separation of lighter materials (**Sahay and Singh, 1994**). Terminal velocity was calculated by following relationship. (Mohesenin)

$$N_R = \frac{v_t \times d \times \rho_f}{\eta} \qquad (13)$$

Where, N_R = Reynolds number, V_t= Terminal velocity, v/s, d = Effective diameter of sphere, mm, ρ_f = Density of air, kg/m^3 and η = Absolute viscosity of air (1.98 x 10^{-5} kg/m s)

$$CN^2_R = \frac{8W\rho_f(\rho_p - \rho_f)}{\pi\eta^2\rho_p} \qquad (14)$$

Where, C = Drag coefficient, W = Weight of the seed, g and ρ_P = Density of seed

After calculating CN^2_R value, the graph between CN^2_R and N_R was used to find the Reynolds number. After getting N_R value, it was substitute in equation no. 4.13 and the value of terminal velocity was calculated.

2.15 Frictional properties

The frictional properties such as angle of repose and coefficient of friction are important in designing of hoppers, chutes, pneumatic conveying systems, screw conveyors and forage harvesters, storage bins etc. in this the frictional properties are help in designing of outlet.

2.16 Angle of repose

"For measuring the angle of repose, a rectangular box filled with seeds was kept horizontal. The seeds were then allowed to fall on a horizontal circular disc kept below the box. The flow of seeds was stopped after the seeds were fully heaped on the disc. The radius of the base of the heap and height of heap were measured and angle of repose was calculated using the following expression" (**Sahay and Singh, 1994**).

$$\Theta = \tan^{-1}\frac{H_0}{r} \qquad (15)$$

Where, θ = Angle of repose, degree, H_0 = Height of heap, m and r = Radius of heap, m

2.17 Coefficient of external and internal friction

Coefficient of external friction was determined on wooden surface by the tilting surface method. It consists of a wooden plank which is hinged to one end and a rectangular wooden box was kept at hinged side. For determining coefficient of external friction between seed and wooden surface an upper plank was gradually raised by rope and pulley arrangement. The height at which rectangular box having seeds started sliding down was measured. The observations were repeated three times. The tangent of angle with the horizontal was calculated which gives angle of external friction between seed and wooden surface. It is useful to determine the angle at which chutes must be positioned in order to achieve consistent flow of material through the outlet chute.

Coefficient of internal friction was measured by using same procedure mentioned above, but to determine the internal friction angle two rectangular boxes are used which are open both side and placed one upon another. After placing, hinged wooden plank was gradually raised by rope arrangement and the height is measured at which upper box starts sliding. The observations were repeated three times. The tangent of angle with the horizontal was calculated which gives angle of internal friction between seed and wooden surface.

3. RESULTS AND DISCUSSION

In this section, the results pertaining to engineering and physical properties of coriander for the purpose of designing and evaluation of a thresher.

3.1 Dimensions of Coriander Seed

One variety of coriander crop (Pant Haritma) was selected for present study. The axial dimensions of 30 seeds such as length, width and thickness were measured at different moisture contents (7.95 to 15.24 %).

. The mean values are shown in Table 1.

Table 1: Physical properties of the coriander seed

Moisture Content (%)	Physical Properties											
	Length (mm)	Width (mm)	Thick-ness, (mm)	Arithm-etic mean, (mm)	Geome-tric mean (mm)	Sphere-city	Surface area, (mm^2)	Volume, (mm^3)	Bulk density, (kg/m^3)	True density, kg/m^3)	Thousand seed weight, (g)	Porosity (%)
7.95	4.21 (0.16)	3.07 (0.18)	2.35 (0.11)	3.21 (0.11)	2.13 (0.02)	0.74 (0.02)	14.21 (0.32)	12.04 (1.20)	227.89	355.43	7.10	35.81
10.04	4.16 (0.15)	3.1 (0.15)	2.4 (0.10)	3.22 (0.10)	2.13 (0.02)	0.75 (0.02)	14.21 (0.28)	11.67 (1.14)	223.90	350.35	7.83	36.02
12.28	4.11 (0.14)	3.16 (0.15)	2.45 (0.09)	3.24 (0.09)	2.13 (0.02))	0.77 (0.02)	14.31 (0.07)	12.62 (1.13)	220.52	346.09	8.53	36.31
15.24	4.06 (0.12)	3.2 (0.14)	2.49 (0.09)	3.25 (0.08)	2.13 (0.02)	0.78 (0.02)	14.34 0.24)	13.04 (1.10)	217.23	343.01	9.21	36.62

Table 2: Aerodynamic properties of the coriander seed

Moisture Content (%)	Engineering Properties			
	Terminal velocity, (m/s)	Angle of repose, (degree)	Coefficient of internal friction	Coefficient of external properties
7.95	2.28	31.89	0.56	0.62
10.04	2.39	32.93	0.61	0.68
12.28	2.50	34.23	0.71	0.77
15.24	2.62	36.10	0.77	0.82

The effect of moisture content on axial dimension is shown in Fig. 1. It was observed that with the change in m.c the dimensional changes of coriander seeds with moisture content caused that the shape became much more globular. Hence the length of coriander seed decreased with increase in moisture content and width and thickness increased with increase in moisture content due to absorption of moisture, which resulted in swelling of capillaries, stretching of longitudinal ridges on the coriander seed surface and, finally, expansion in medium and minor axes. Similar trends were reported by **Balasubramanian et al., 2012** for coriander seeds.

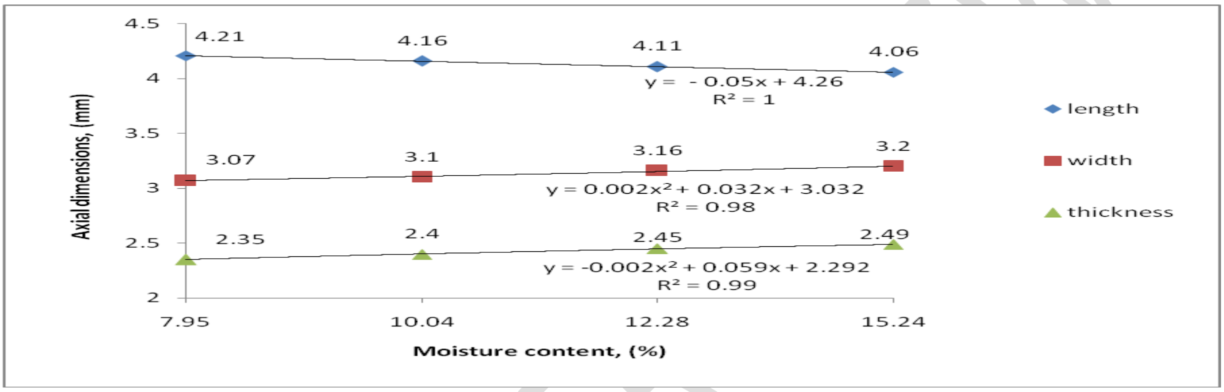

Fig. 1: Effect of moisture content on axial dimensions of coriander seed

3.2 Arithmetic mean, geometric mean and sphericity

Thirty seeds of coriander seeds were selected to determine the arithmetic mean, geometric mean diameter and sphericity. These physical properties are helpful in selecting the sieve size and concave clearance of thresher. As seen from Table 1, at 7.95 % moisture content, the mean value of arithmetic mean, were 3.21, 2.13 mm and 0.74, respectively with standard deviation 0.11, 0.02, and 0.02, respectively and coefficient of variance 0.01, 0.01 and 0.0004, respectively. At 10.04 % m.c, the mean value of arithmetic mean, geometric mean and sphericity were 3.22 2.13 mm and 0.75, respectively with standard deviation 0.10, 0.02, and 0.02, respectively and coefficient of variance 0.009, 0.0004 and 0.0004, respectively. At 12.24 % m.c, the mean value of arithmetic mean, geometric mean and sphericity were 3.24 2.13 mm and 0.77, respectively with standard deviation 0.09, 0.02, and 0.02, respectively and coefficient of variance 0.007, 0.008 and 0.0004, respectively. At 15.24% m.c, the mean value of arithmetic mean, geometric mean and sphericity were 3.25 2.14 mm and 0.78 respectively with standard deviation 0.09, 0.08, and 0.02 respectively and coefficient of variance 0.0067, 0.0003 and 0.0003, respectively.

The relationship between moisture content and arithmetic mean as well as geometric mean is shown in Fig. 2. The moisture content increased from 7.95 to 15.24 %. The value of arithmetic mean, geometric mean and sphericity of coriander seeds increased linearly from 3.21 to 3.25 mm, 2.13 to 2.14 and 0.74 to 0.78, respectively. It was found that the geometric mean diameter was lower than the major axis. Sphericity of coriander seeds was much lower than the reported values of spherical shaped black pepper and okra seeds, and higher than for locust and faba bean seeds (**Murthy and Bhattacharya, 1998**). The relationships between arithmetic mean (Da), geometric mean (Dg), spherecity (θ) and seed moisture content (x) can be expressed using the regression equations shown in Figs. 4 to 7 and the R^2 values were 0.98, 0.93 and 0.98, respectively.

Arithmetic mean ranged from 3.21 to 3.25 for selected variety (Table 1) and sphericity ranged from 0.74 to 0.78 which indicates globular shape of seeds. Hence, the round circular shape types of screens were selected for cleaning purpose.

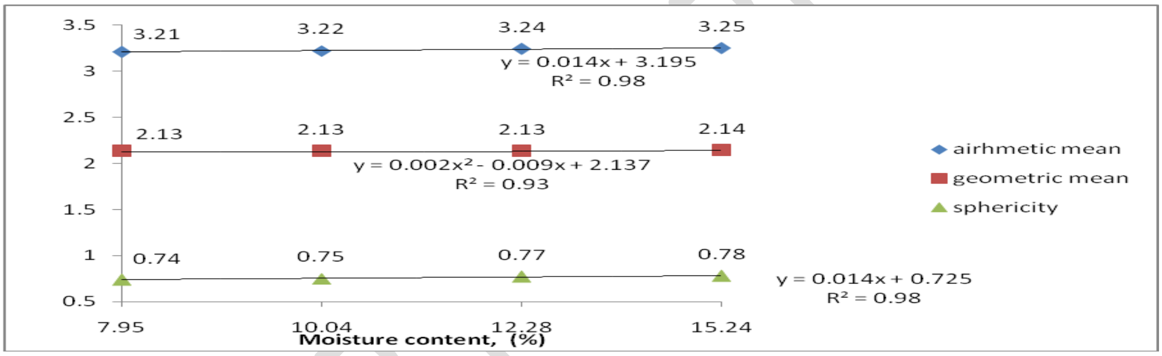

Fig. 2: Effect of moisture content on arithmetic mean, geometric mean and spehericity

3.3 Surface area and volume

As seen from Fig. 3, the surface area and unit volume increased linearly from 14.21 to 14.34 mm^2 and 12.04 and 13.04 mm^3, respectively, with the increase in moisture content from 7.95 to 15.24 % d.b. and R^2 values were 0.89 and 0.84, respectively. The volume of seed was decreased with increase in m.c. from 7.95 to 10.04 % and thereafter increased as m.c. increased from 10.04 to 15.24 %. Similar trends of results have been reported for laurel seeds (**Yurtlu et al., 2010**). The effect of moisture content on surface area and volume are shown in Fig. 2.

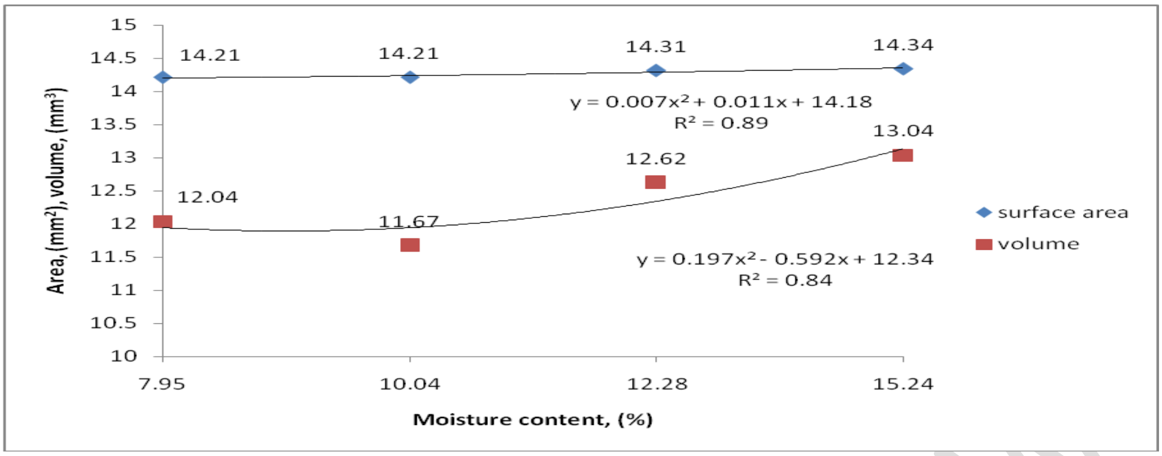

Fig. 3: Effect of moisture content on surface area and volume

3.4 Bulk density and true density

Bulk density and true density were important factors for deciding the hopper size and bins for storage of seed. As clear from Table 1, bulk density of coriander seeds decreased linearly from 227.89 to 217.89 kg m^{-3} with the increase in moisture content. On other hand, the true density initially decreased nonlinearly from 355.43 to 347.77 kg m^{-3} when the moisture content was increased from 7.95 to 10.24 % d.b. However, with the further increase in m.c. from 10.24 to 15.24, it increased from 347.77 to 352.89 kg m^{-3}. The decrease in bulk density of coriander seed with increase in moisture content indicates that the increase in volumetric expansion in the sample is greater than sample mass. Similar decreasing trend in bulk density has been reported for coriander seeds by **Coskuner and Karababa, 2007.**

The effect of moisture content on bulk density and true density were shown in Fig. 4. The increase of true density with m.c. may be attributed to the possible higher weight increase of seeds in comparison to their volume expansion with moisture gain and discrepancies could be due to the cell structure, and the volume and mass increase characteristics of grains and seeds as moisture content increases. Also, many researchers have reported linear decreasing or increasing trends in true density for coriander seeds (**Coskuner and Karababa, 2007**).

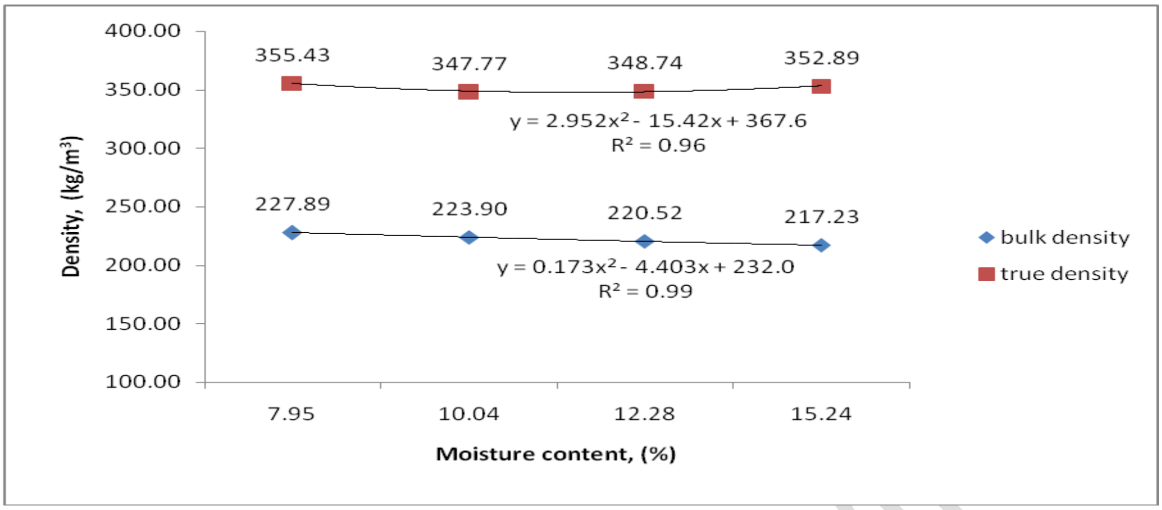

Fig. 4: Effect of moisture content on bulk density and true density

3.5 Porosity, thousand seed weight and angle of repose

It is evident from Fig 6, that the 1000 seeds weight increased from 7.1 to 9.21 g with increase in moisture content due to the increase in weight with increase in water content from 7.95 to 15.24 % m.c. while the angle of repose increased linearly and varied from 31.89 to 36.1° with the increase in moisture content from 7.95 to 15.24 % (Fig.7).

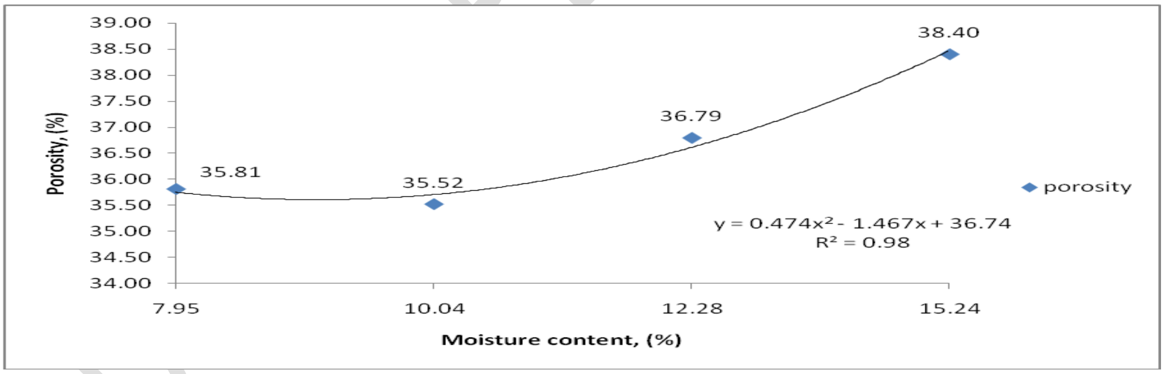

Fig. 5: Effect of moisture content on porosity

Similar trends were reported for cumin by **Altuntas *et al.***, 2005, coriander seeds by **Coskuner and Karababa**, 2007.

3.6 Terminal velocity

Terminal velocity is required to decide the velocity of blower for separation of lighter particles. Terminal velocity was determined by using given relationship in the above equation. As seen from Table 2, the mean value of terminal velocity was 2.28, 2.39, 2.50 and

2.62 m/s at 7.95, 10.04, 12.28 and 15.24% m.c., respectively. The effects of moisture content on terminal velocity are shown in Fig. 8.

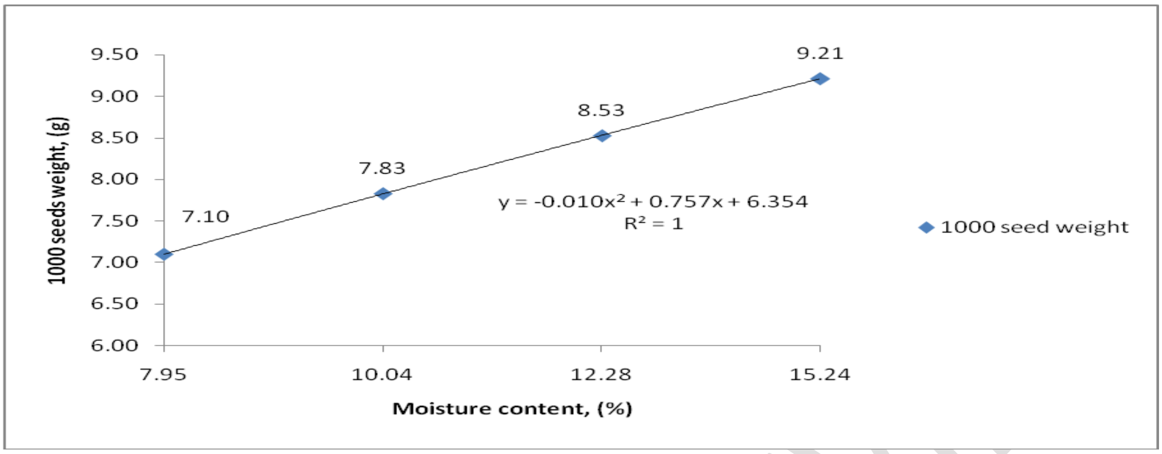

Fig. 6: Effect of moisture content on 1000 seed weight (W_{1000})

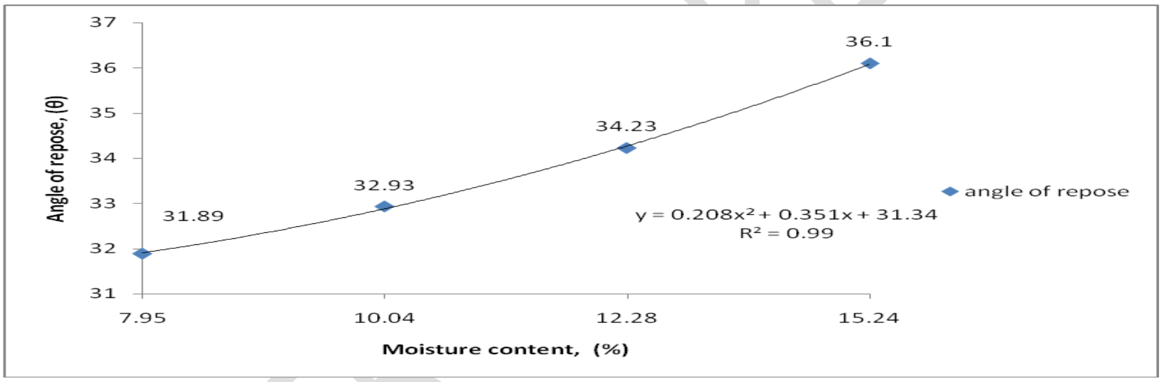

Fig. 7: Effect of moisture content on angle of repose

It is evident from Fig.7 that as the moisture content increased from 7.95 to 15.24 %, the terminal velocity was found to increase linearly from 2.28 to 2.62 m/s.

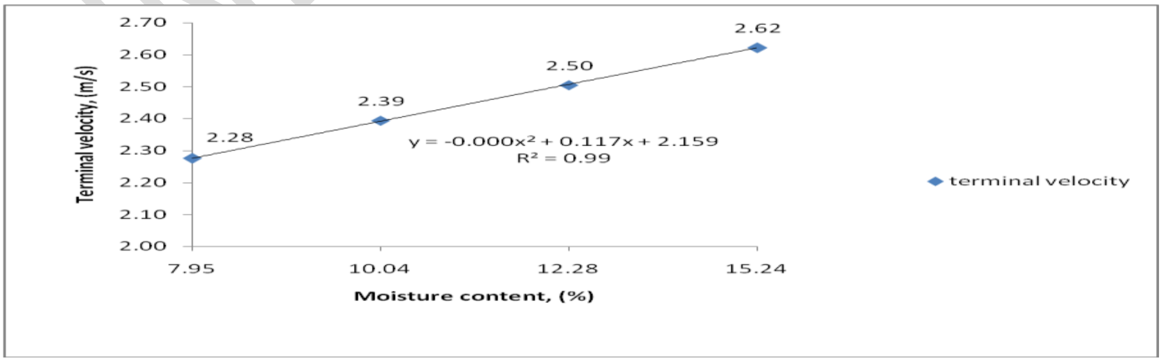

Fig. 8: Effect of moisture content on terminal velocity

The increase in terminal velocity with increase in moisture content can be attributed to the increase in mass of an individual seed per unit frontal area presented to the airflow and also to the friction of the edges of the seed. A similar result was reported for cumin seeds by **D. Zare *et.al*, 2013.**

3.7 Coefficient of internal and external friction

Coefficient of internal and external friction is an important property and it is helpful to decide the inclination of seed outlet or easy flow of material. The angle of inclination of seed outlet should be more than the value of coefficient of external friction to achieve consistent flow.

The mean values of coefficient of internal friction were 0.56, 0.61, 0.71 and 0.77 with respect to the moisture contents 7.95, 10.04, 12.28 and 15.24 %, respectively while values of coefficient external friction were 0.62, 0.68, 0.77 and 0.82. As seen from Fig.9, the coefficient of internal and external friction increased with increase in moisture content. Coefficient of internal friction and coefficient of external friction ranged from 0.56 to 0.77 and 0.62 to 0.82, respectively. The values of the coefficient of internal friction were found lower against wooden surface at all moisture levels. At higher moisture content, seeds become rougher and sliding characteristics were diminished. Therefore, the coefficient of internal and external friction increased. Similar trends were found for coriander seeds by **Coskuner and Karababa, 2007 and for lentil seed by Bagherpour *et al*., 2010.** Hence, the inclination of seed outlet was kept at 35^0 for better flow.

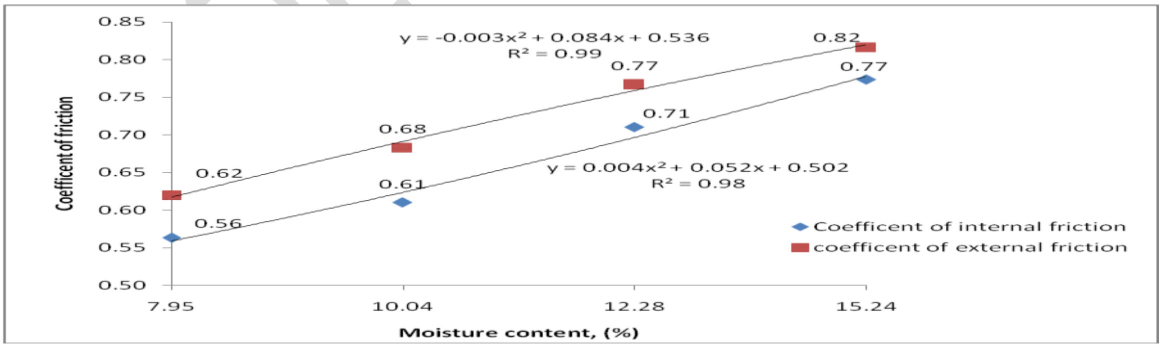

Fig. 9: Effect of moisture content on coefficient of internal and external friction

Conclusion

The physical properties of coriander seeds have been evaluated as a function of seed moisture content, varying from 7.95% to 15.24% (db.). In the moisture range, seed length decreased linearly from 4.21 to 4.06 mm, and width, thickness, arithmetic mean diameter, and geometric mean diameter increased linearly from 3.07 to 3.2 mm, 2.35 to 2.49 mm, 3.21 to 3.25 mm and 2.13 mm, respectively with increase in moisture content. The sphericity, seed volume, and seed surface area increased from 0.74 to 0.78, 12.54 to 13.04 mm^3, and 14.21 to 14.34 mm^2, respectively. One thousand seed weight increased linearly from 7.10 to 9.21 g. The true and bulk density decreased nonlinearly with moisture content from 355.43 to 343.01 kg/m^3 and 227.89 to 217.23 kg/m^3. Also, porosity values of coriander seeds increased nonlinearly from 35.81 % to 36.62 %. The static coefficient of friction increased nonlinearly from 0.62 to 0.82 with increase in moisture content. The angle of repose increased linearly from 31.89^0 to 36.10^0 with the increase of moisture content.

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