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Note

Physical properties of coriander seeds at different moisture content

S. Balasubramanian[1]*, *K.K. Singh*[2], *and R.Kumar*[1]

[1]Central Institute of Post Harvest Engineering and Technology, Ludhiana - 141 004, Punjab, India
[2]Indian Council of Agricultural Research, New Delhi - 110 114, India

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A b s t r a c t. Physical properties of coriander seeds were determined at moisture content of 3.5-17.7%, d.b. The major axis and 1 000 seeds mass were found to decrease nonlinearly with increase in seed moisture. The medium and minor axes, geometric mean diameter, sphericity, unit volume, surface area and angle of repose increased linearly. Bulk density decreased linearly, however the true density increased non-linearly. The coefficient of static friction increased nonlinearly for different surfaces with increase in moisture level and its maximum was found for plywood surface. The rupture force and energy absorbed decreased linearly with increasing moisture content.

K e y w o r d s: coriander, seed, physical properties, moisture content

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an annual herb from the family *Apiaceae* and native to southern Europe and North Africa to southwestern Asia. The coriander seeds are almost ovate globular and there are many longitudinal ridges on the surface. Data concerning the physical and mechanical properties of agricultural food materials are of importance to plant breeders, engineers, machine manufactures, food scientists, processors and consumers. Those properties are useful in postharvest unit operations for the design of cleaning, grading, sorting, transportation, handling, aeration, sizing, storing, size reduction, packaging and other processing equipment (Sahay and Singh, 2001). Several investigators have reported the moisture dependence of physical and mechanical properties of chosen agricultural materials *ie* for black pepper (Murthy and Bhattacharya, 1998), fenugreek (Altuntas *et al.*, 2005); fruit and kernel (Sahoo *et al.*, 2009); rapeseed (Izli *et al.,* 2009); bay laurel seeds (Yurtlu *et al.,* 2010); lentil seed (Bagherpour *et al.*, 2010). Chang (1988) determined the density and porosity of grain kernels using a gas pycnometer. Coskuner and Karababa (2007) determined some physical properties of coriander seeds at different moisture content and reported that the axial dimensions, sphericity, seed volume and surface area, true density, angle of repose, 1 000 seeds mass and coefficient of static friction increased with increase in moisture content except for bulk density.

The present work was carried out to understand the physical and mechanical properties of coriander seeds at different moisture content.

MATERIALS AND METHODS

Coriander seed (RCR-4) was procured from the National Research Centre for Seed Spices, Ajmer (India). The seeds were cleaned manually and broken, and foreign matter, split, deformed and immature seeds were discarded before the samples were prepared for the experiment. The initial moisture content of seed was determined by vacuum oven method (Ranganna, 1986) at 80°C and pressure of 13.33 KPa. The seeds were stored at room temperature (25°C) for 2 to 3 weeks. Initial moisture content of coriander seed was found to be 7.0% d.b. For experimentation, a predetermined quantity of coriander was dried in a tray dryer at 55°C to achieve a desired low moisture content level. To achieve high moisture contents, calculated amount of water was added and mixed thoroughly (Murthy and Bhattacharya, 1998). Samples were packed in low density polyethylene (LDPE) pouches and kept at 5°C for 48 h in a refrigerator for uniform distribution of moisture throughout the seed. For measurement of physical and mechanical properties, samples were allowed to reach ambient temperature. Thus, five levels of moisture content (3.5, 7.0, 9.8, 14.8 and 17.7% d.b.) were selected.

*Corresponding author's e-mail: balaciphet@gmail.com

Axial dimensions of 100 randomly selected coriander seeds (major, medium and minor) were measured using a digital vernier caliper (± 0.01 mm accuracy) and the average geometric mean diameter and sphericity were determined as well as porosity (Mohsenin, 1986). Average bulk density was determined using the standard method by filling a measuring cylinder with the seeds from a constant height (Balasubramanian and Viswanathan, 2007) and it was expressed as the ratio of mass by volume. Average true density is the ratio of mass of the seed to its pure volume and was determined using gas pycnometer (model2: Hymipyc and make IQI, USA). Before starting the experiment, the pycnometer was calibrated using a calibration kit and standard volume (1.0725 cm^3) of steel ball. After calibration, duplicate weighed samples were put into a sample chamber, true volume was measured and expressed as true density. 1 000 seeds mass was measured by counting a 1 000 seeds randomly and weighing on electronic balance (0.001 g accuracy, TB-403, Denver Instruments, Bohemia, NY). Angle of repose was calculated from the measurement of height of heap of seeds on a circular plate. Coefficient of static friction (μ) was determined for various surfaces *ie* plywood (PW), galvanized iron (GI), mild steel (MS) and aluminium sheet (Al). Texture analyser (model: TA-HDi, Stable Micro Systems Ltd, Surrey, UK) was used for measurement of compression force of seed at different moisture levels. Individual seeds were loaded between probe (P-5) and base plate of the machine and compressed at the preset condition until rupture point (failure) occurred in the force deformation curve and the curve reached the peak force. The deformation was taken as change in the dimensions/original dimensions of seed, and the energy absorbed was calculated by measuring the area under the force deformation curve. Analyses of variance (ANOVA) were carried out using MS-Excel 2000 to test the effect of moisture content with respect to all properties.

RESULTS AND DISCUSSION

All the values of physical and mechanical properties of coriander seeds are presented in Table 1. The major axis of coriander seeds decreased nonlinearly from 4.09 to 3.97 mm, however the medium and minor axes increased linearly from 3.20 to 3.64 and 2.91 to 3.31 mm, respectively, with the increase in moisture content from 3.5 to 17.7% d.b. The coefficients of determination (R^2) of the axial dimensions (major, medium and minor) were 0.836, 0.924 and 0.952. These dimensional changes of coriander seeds with moisture

T a b l e 1. Physical and mechanical properties of coriander seeds

Properties		Moisture content (%, d.b.)				
		3.5	7.0	9.8	14.8	17.7
Dimensions (mm)	Major	4.09±0.3	4.09±0.4	4.09±0.4	4.08±0.2	3.97±0.3
	Medium	3.20±0.3	3.21±0.3	3.33±0.3	3.62±0.3	3.64±0.4
	Minor	2.91±0.3	2.91±0.3	3.08±0.3	3.22±0.2	3.31±0.4
GMD (mm)		3.36±0.2	3.36±0.3	3.46±0.2	3.61±0.1	3.62±0.3
Sphericity (%)		82.2±5.7	82.5±5.2	85.3±7.0	88.6±3.4	91.1±4.4
Unit volume (mm^3)		16.28±4.1	16.43±4.7	18.42±3.8	21.54±3.0	22.83±6.1
Surface area (mm^2)		31.56±5.0	31.69±6.1	34.17±4.6	37.71±3.4	38.83±6.9
Bulk density (kg m^{-3})		291.89±1.5	290.65±0.8	289.76±1.6	288.75±0.6	288.66±0.5
True density (kg m^{-3})		806.76±1.0	796.89±0.9	789.87±1.6	785.13±0.7	797.75±0.7
Porosity (%		63.8±0.9	63.5±1.2	63.3±1.3	63.2±0.1	63.8±0.5
1 000 seeds mass (g)		8.1±0.1	9.1±0.1	9.7±0.1	9.8±0.1	9.9±0.1
Angle of repose (°)		22.7±0.1	23.7±0.1	28.3±0.1	30.1±0.2	33.5±0.1
Coefficient of friction	PW	0.94±0.02	0.95±0.01	0.96±0.03	0.96±0.03	0.97±0.01
	MS	0.81±0.07	0.83±0.04	0.89±0.02	0.93±0.02	0.93±0.03
	GI	0.80±0.05	0.80±0.02	0.87±0.02	0.88±0.02	0.92±0.02
	Al	0.70±0.03	0.76±0.02	0.78±0.03	0.82±0.04	0.86±0.03
Mechanical properties	Rupture force (N)	8.75±1.2	8.00±1.1	7.02±1.1	6.09±1.5	5.3±1.21
	Deformation (mm)	0.74±0.2	0.90±0.1	0.85±0.1	0.88±0.1	0.92±0.10
	Energy absorbed (kJ)	6.54±0.7	6.6±0.9	6.02±0.8	5.4±0.6	4.85±0.6

content caused that their shape became much more globular. The axial dimensions 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 showed by Coskuner and Karababa (2007) for coriander seeds. Geometric mean diameter and sphericity of coriander seeds increased linearly from 3.36 to 3.62 mm and 82.2 to 91.1%, respectively, as the moisture content increased and the R^2 values were 0.930 and 0.961, 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 unit volume and surface area increased linearly from 16.28 to 22.83 mm^3 and 31.56 and 38.83 mm^2, respectively, with the increase in moisture content from 3.5 to 17.7% d.b. and R^2 values were 0.956 and 0.953, respectively. Similar trends of results have been reported for wheat straw (Tavakoli *et al*., 2009) and for laurel seeds (Yurtlu *et al.*, 2010). Bulk density of coriander seeds decreased linearly from 291.89 to 288.66 kg m^{-3} with the increase in moisture content; on the other hand, the true density initially decreased nonlinearly from 806.76 to 789.87 kg m^{-3} in the moisture content from 3.5 to 9.8% d.b. and then increased nonlinearly from 785.13 to 797.75 kg m^{-3} in the moisture content from 14.8 to 17.7% d.b. R^2 values for bulk density and true density were 0.945 and 0.895, respectively. 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 fenugreek (Altuntas *et al.*, 2005) and coriander seeds (Coskuner and Karababa, 2007). The increasing trend of true density 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 some seeds, grains and nuts. Initial porosity was found to be 63.8% and reduced nonlinearly to 63.2 at 14.8% d.b. Similar trend of porosity of coriander seed and other grains was reported by Altuntas *el al.* (2005) and Coskuner and Karababa (2007). 1 000 seeds mass increased nonlinearly from 8.1 to 9.9 g while the angle of repose increased linearly and varied from 22.7 to 33.5° with the increase in moisture content from 3.5 to 17.7% (d.b.). R^2 values for the 1 000 seeds mass and angle of repose were 0.979 and 0.951, respectively. Similar trends were reported for cumin (Altuntas *et al.*, 2005), coriander seeds (Coskuner and Karababa, 2007), and soybeans (Davies and Okene, 2009).

T a b l e 2. ANOVA table representing the effect of moisture content on mechanical properties of coriander seed

Source	d.f.	Mean square	F-value	P-value
Rupture force	1	30.68	1.76	0.2207
Deformation	1	235.15	14.32*	0.0054
Energy absorbed	1	54.07	3.24	0.1096

$F_{1, 8, 0.05} = 5.32$, *significant at $P \leq 0.05$.

The coefficient of static friction for plywood (PW), mild steel (MS), galvanized iron (GI) and aluminium sheet (Al) were ranged from 0.94 to 0.97, 0.81 to 0.93, 0.80 to 0.92 and 0.70 to 0.86, respectively. R^2 values for plywood, mild steel, galvanized iron and aluminium sheet were 0.889, 0.934, 0.891 and 0.986, respectively. The values of the coefficient of static friction were found lower against aluminium surface at all moisture levels. This may be due to the smoother and more polished surface of aluminium sheet compared to the other test surfaces. The coefficient of static friction increased nonlinearly with respect to moisture content for all the structural surfaces. The coefficient of static friction was found the highest for plywood sheet, followed by mild steel sheet, galvanized iron sheet and aluminium sheet, respectively. The coefficient of static friction increased with increasing moisture content for all structural surfaces studied. At higher moisture content, seeds become rougher and sliding characteristics are diminished, therefore the coefficient of static friction increases. Similar trends were found for coriander seeds (Coskuner and Karababa, 2007) and lentil seed (Bagherpour *et al.,* 2010). It was observed that with the increase in moisture content, the rupture force and energy absorbed decreased linearly from 8.75 to 5.30 N and 6.54 to 4.85 kJ, respectively, and were affected non-significantly ($P \leq 0.05$). On the other hand, the deformation increased linearly from 0.74 to 0.92 mm with the increase in moisture content and the difference was significant ($P \leq 0.05$) (Table 2). The R^2 values of rupture force, energy absorbed and deformation were 0.993, 0.934 and 0.969, respectively. The decrease in rupture force and energy absorbed may be attributed to the fact that the inner core of seed becomes markedly softer and requires less force at higher moisture content, whereas at the lower moisture content, only outer coat of seed absorbs moisture and requires higher force. Similar results were reported for black pepper seed (Murthy and Bhattacharya, 1998) and wheat kernel (Dziki *et al.*, 2010).

CONCLUSIONS

1. Average major, medium and minor principal dimensions, geometric mean diameter, sphericity and surface area of coriander seeds (RCR-4) varied from 4.09-3.97, 3.20-3.64, 2.91-3.31, 3.36-3.62 mm, 82.2 to 91.1% and 31.56 to 38.83 mm^2 in the moisture content range from 3.5 to 17.7% d.b.

2. Unit volume and 1 000 seeds mass increased linearly from 16.28 to 22.83 mm^3 and 8.1 to 9.9 g, respectively. Bulk density decreased from 291.89 to 288.66 kg m^{-3}, while true density decreased from 806.76 to 797.75 kg m^{-3}.

3. Angle of repose and coefficient of static friction for various surfaces increased with increasing moisture content.

4. Rupture force and energy absorbed were decreased linearly. Deformation increased linearly as a function of moisture content.

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