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Note

Moisture dependent physical properties of cardamom

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A b s t r a c t. The physical properties of cardamom capsules in the moisture range of 8.41-24.87% (w.b.) were determined. All physical properties, except bulk density and hardness, increased with the increase of moisture content. The highest static coefficient of friction was observed on mild steel surface, followed by aluminium sheet, galvanized iron sheet and stainless steel sheet. The physical properties of cardamom capsules were expressed in the form of regression equations as a moisture content function. High correlation coefficients were found at significance level of 95%.

K e y w o r d s: cardamom, capsules, physical properties, moisture content

INTRODUCTION

Cardamom (*Elettaria cardamomum* L.) is the most versatile spice known to the mankind as it enjoys a unique position in the international spices market. Green cardamom, also known as Malabar cardamom, small cardamom or *Choti elaichi*, is the true cardamom of commerce. It is popularly known as the 'Queen of Spices'. With the increasing awareness for natural products in the flavour sector, cardamom opens up immense possibilities in the food and beverage area (Pruthi, 1992). In order to design equipment for drying, storing, grading and processing the cardamom capsules their physical properties should be known. Their size and shape, for instance, are important in the development of grading machines. Bulk density and porosity are needed in designing near-ambient drying and aeration systems, because these properties affect the resistance to airflow of the stored mass. The theories used to predict the structural loads for storage structures use bulk density as a basic parameter (Nalladurai *et al.,* 2002). The friction coefficient of the capsules on various surfaces helps in designing bins, silos and other storage structures. The angle of repose is important in designing equipment for solid flow structures for storage.

In recent years,the physical properties for various crops have been studied *ie* soybean (Kibar and Öztürk, 2008); nutmeg (Burubai *et al*., 2007); simabouba fruit and kernel (Dash *et al.,* 2008); red bean grains (Kiani Deh Kiani *et al.,* 2008); watermelon seed (Koocheki *et al.,* 2007); and cucurbit seeds (Milani *et al*., 2007). However, there is not much published work relating to moisture dependent physical properties of the cardamom capsules.

The aim of this study was to investigate some moisture dependent physical properties of cardamom capsules, namely, size, thousand capsule mass, sphericity, bulk density, true density, porosity, angle of repose, static coefficient of friction and hardness in the moisture content range from 8.41 to 24.87% (w.b.).

MATERIALS AND METHODS

A quite uniform, bold and healthy cardamom capsules (var. Mysore) were procured from Cardamom Research Station, Pampadumpara, Kerala State, India. The initial moisture content (*MC*) of cardamom capsule was determined by toluene distillation method using Dean and Stark apparatus (ASTA, 1997). The initial moisture content was found as 78.20% (w.b.) after harvesting. Next the cardamom capsules were dried to safe moisture content of 8±0.5% (w.b.) in a kiln drier at 60°C during 24 h. Experiments were conducted in the moisture range of 8.41-24.87% (w.b.). The samples of higher moisture content were prepared by adding calculated amount of distilled water, thorough mixing, sealed in polyethylene bags and kept in a refrigerator at 5°C for an equilibrium period of two weeks (Visvanathan *et al.,* 1996).

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The mean capsule size (d_p) and sphericity (ϕ) were determined by picking twenty capsules randomly and measuring their three principal dimensions using vernier caliper having a least count of 0.01 mm (Koocheki *et al.,* 2007; Mohsenin, 1980; Tabatabaeefar, 2003). The mass was determined at four levels of moisture content from 8.41 to 24.87% (w.b.) by randomly selecting 100 capsules and weighing in an electronic balance of 0.01 g sensitivity. The mass was then converted into 1 000 capsule mass (W_{1000}). The bulk density (ρ_b) of cardamom capsules was determined by filling a circular container of known volume and weighing the content. During the experiment, care was taken to avoid any compaction of the material in the container. Bulk density was calculated as the ratio between the mass of cardamom and the container volume. At each moisture level, five replications were carried out and the average values were reported. The true density (ρ_t) was determined by toluene displacement method (Kingsly *et al.,* 2006; Mohsenin, 1980). The porosity (ε) was calculated from the values of true density and bulk density (Ozguven and Vursavus, 2005).

The angle of repose (θ) for the cardamom capsules was determined from the height and diameter of the naturally formed heap of seeds on a circular plate (Kingsly *et al.,* 2006). The coefficient of static friction (μ) was determined with respect to four test surfaces, namely: stainless steel (*SS*), galvanized iron (*GI*), mild steel (*MS*) and aluminium (*Al*), using the experimental setup according to Jha and Kachru (1998). The hardness (h) of cardamom capsule was measured using texture analyzer (TA-Hdi, Stable Microsystems, UK) (Sajeev *et al.,* 2004).

RESULTS AND DISCUSSION

The size of cardamom capsules (d_p) at different moisture content is presented in Fig. 1. The size increased from 8.34±0.08 to 9.78±0.10 mm with the increase in moisture content (Eq. (1)). It was due to the filling of capillaries and voids upon absorption of moisture and subsequent swelling:

$$d_p = 7.68 + 0.09MC \; (\mathrm{R}^2 = 0.98). \qquad (1)$$

The sphericity of the cardamom capsules (ϕ) increased linearly from 0.662 ± 0.006 to 0.684 ± 0.005 as the moisture content increased from 8.41 to 24.87% (w.b.) (Eq. (2)). The sphericity value of the cardamom capsule falls within the range of 0.32-1.00 reported by Mohsenin (1980) for most of the agricultural products:

$$\phi = 0.65 + 0.001MC \; (\mathrm{R}^2 = 0.98). \qquad (2)$$

The mass of 1 000 capsules (W_{1000}) increased from 115±2.61 to 146.3 ± 4.63 g with the increase of moisture content (Eq. (3)) (Fig. 2). The similar trend of increase has been reported by Visvanathan *et al.* (1996) for neem nut Kingsly *et al.* (2006) for anardana seeds and Kiani Deh Kiani *et al.* (2008) for red bean grains:

$$W_{1\,000} = 97.06 + 1.92MC \; (\mathrm{R}^2 = 0.98). \qquad (3)$$

The values of porosity (ε) were calculated by using the data of bulk and true densities of the cardamom capsules. The results obtained are presented in Fig. 2. The porosity of the cardamom capsules increased from 40 ± 0.75 to 43.40 ± 0.34% as the increasing of water content was observed (Eq. (4)). The similar results were reported by Altuntas and Yildiz (2007) for faba bean grains:

$$\varepsilon = 38.36 + 0.20MC \; (\mathrm{R}^2 = 0.99). \qquad (4)$$

The variation in bulk density (ρ_b) and true density (ρ_t) with moisture content is shown in Fig. 3. The bulk density of cardamom was found to decrease linearly whereas the true density increased with the moisture content increase (Eqs (5) and (6)).

$$\rho_b = 731.03 - 1.80MC \; (\mathrm{R}^2 = 0.99). \qquad (5)$$

$$\rho_t = 1184.80 + 1.09MC \; (\mathrm{R}^2 = 0.98). \qquad (6)$$

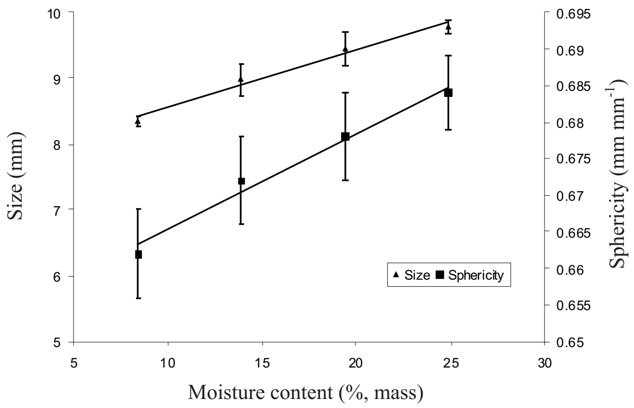

Fig. 1. Effect of moisture content on size and sphericity.

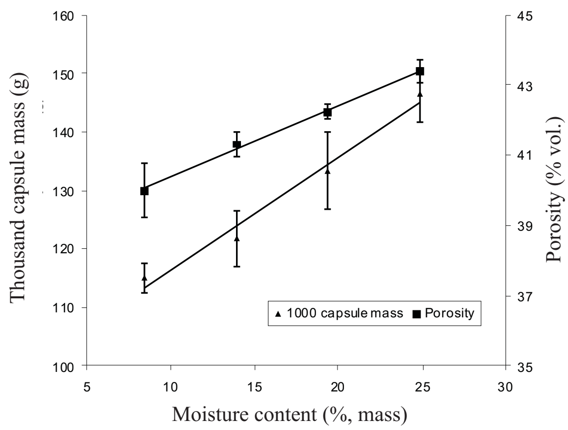

Fig. 2. Effect of moisture content on thousand capsule mass and porosity.

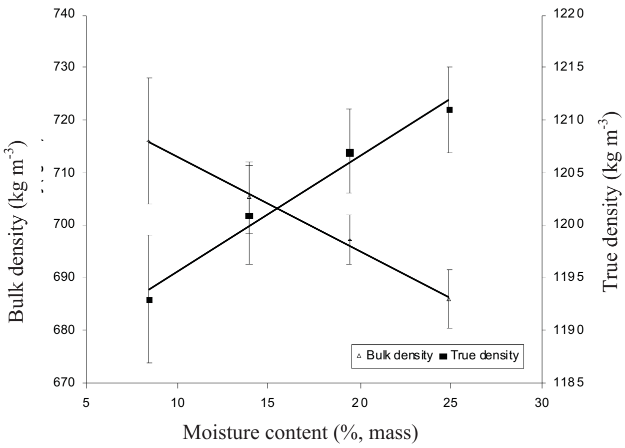

Fig. 3. Effect of moisture content on bulk and true density.

The bulk density was found to be varied from 716.08 ± 12.13 to 685.93 ± 5.63 kg m^{-3}. The decrease in bulk density with an increase in moisture content is mainly due to the increase in volume than the corresponding increase in mass of the material. It facilitates the same mass of material to occupy more volume of the cylinder thus decreasing the bulk density. The similar decreasing trend in bulk density has been reported by Tabatabaeefar (2003) for wheat grain. The true density increased from 1193 ± 6.12 to 1211± 4.06 kg m^{-3} as the moisture content increased. This increase may be due to the increase in volume due to absorption of moisture. The same trend has also been reported by Tabatabaeefar (2003) and Kingsly *et al.* (2006) for wheat and anardana seeds, respectively.

The experimental results for angle of repose (θ) with respect to moisture content are shown in Fig. 4. It was observed that the angle of repose increased linearly from 20.39 ± 0.42° to 26.63 ± 0.34° in relation to increase in moisture content (Eq. (7)). Most of the biological materials appear to exhibit an increase in angle of repose with higher moisture content (Mohsenin, 1980), and the present study also follows a similar pattern. The similar variation has been observed by Visvanathan *et al.* (1996) and Kingsly *et al.* (2006) for neem nuts and anardana seeds respectively:

$$\theta = 17.79 + 0.37MC \ (R^2 = 0.95). \qquad (7)$$

The hardness (h) as affected by the moisture content is presented in Fig. 4. The hardness decreased linearly from 19.62 ± 0.40 to 17.17 ± 0.13 N with the increase in moisture content (Eq. (8)). The decrease in hardness can be attributed to the capsules becoming softer at increased moisture levels. The similar observation was reported by Kingsly *et al.* (2006) for anardana seeds.

$$h = 20.68 - 0.14MC \ (R^2 = 0.97). \qquad (8)$$

The coefficient of static friction (μ) of cardamom with respect to moisture content on four metallic surfaces is presented in Fig. 5. The coefficient of friction increased

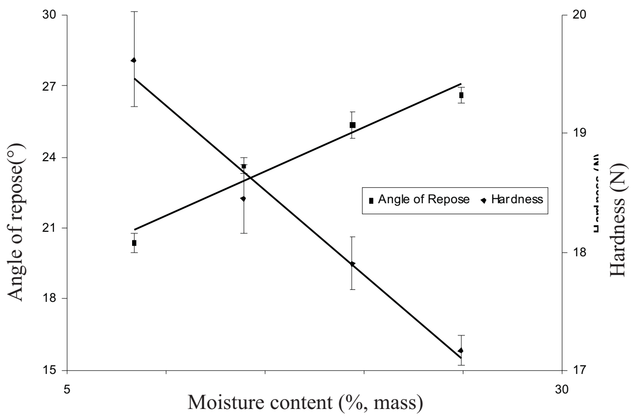

Fig. 4. Effect of moisture content on angle of repose and hardness.

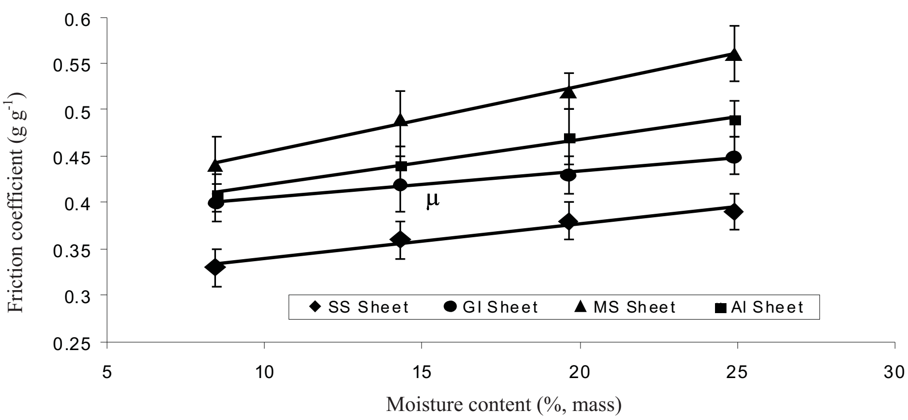

Fig. 5. Effect of moisture content on coefficient of static friction.

linearly with moisture content for all contact surfaces. It was found that, the coefficient of static friction on *MS* sheet was higher than *Al* sheet, *GI* sheet and *SS* sheet (Eqs (9), (10), (11) and (12)):

$$\mu_{SS} = 0.30 + 0.004MC \ (R^2 = 0.96)\ . \quad (9)$$

$$\mu_{GI} = 0.38 + 0.003MC \ (R^2 = 0.99)\ . \quad (10)$$

$$\mu_{MS} = 0.38 + 0.007MC \ (R^2 = 0.99)\ . \quad (11)$$

$$\mu_{Al} = 0.37 + 0.005MC \ (R^2 = 0.99)\ . \quad (12)$$

The lower value of static coefficient of friction in the case of stainless steel was due to the smooth and polished surface of the stainless steel sheet compared with other surfaces used. From the results, it was also observed that the moisture had more pronounced effect than the material surface due to the increase of adhesion of higher moisture values. The similar trend has been observed by Tabatabaeefar (2003) and Kingsly *et al.* (2006) for wheat and anardana seeds respectively.

CONCLUSIONS

1. The increase of moisture content from 8.41 to 24.87% (w.b.) causes:

- the increase of size and 1 000 capsule mass of the cardamom capsules from 8.34 ± 0.08 to 9.78 ± 0.10 mm and 115 ± 2.61 to 146.3 ± 4.63 g, respectively;
- the increase of sphericity, true density and porosity;
- the decrease of bulk density;
- the increase of angle of repose from 20.39 to 26.63°;
- the decrease of hardness from 19.62 ± 0.40 to 17.17 ± 0.13 N.

2. The highest coefficient of static friction was noted on mild steel followed by aluminium sheet, galvanized iron and stainless steel sheet.

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