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Note

Influence of moisture content on physical properties of maize

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Abstract. The physical properties of maize kernels have been evaluated as a function of moisture content (12.8-29.0% w.b.). The maize kernel length, width, thickness, geometric mean diameter, surface area, sphericity and kernel volume increased linearly with increase in moisture content. The bulk density and true density decreased while porosity and thousand grains mass increased with increasing moisture content. The static coefficient of friction increased for mild steel sheet, galvanized iron sheet and aluminium sheet surfaces while rupture or cutting force and energy absorbed decreased with increasing moisture content.

Keywords: maize, physical properties, moisture content, angle of repose

INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile cereal crops of the world. Also referred as corn, it is an important cereal crop, serving as staple to large population of Africa, Asia and North and South America. It can be processed into different breakfast items, food and feed ingredients and beverages for its consumption throughout the world (Chakraverty, 1988; Rajoo, 1998).

Information on physical properties of maize, like other agricultural materials, is necessary to design equipment for grading, handling, processing and storage *etc*. To design machines for cleaning, grading, sorting and packing *etc*., size and shape such as geometric mean diameter and sphericity are necessary to be known. The surface area and porosity are required to evaluate the rate of heat transfer for heating and drying and thus to design heat exchangers and driers *etc*. Bulk density, true density and porosity are required for the design of aeration, storage, transport and separation systems. True and bulk density data have also been used to determine the dielectric properties of cereal grains. Angle of repose and coefficient of frictions on various structural surfaces are required for designing bins, silos and other storage structures. It has been established that the properties of crops vary with their moisture contents (Pradhan *et al*., 2008; Sahay and Singh, 1994; Singh *et al*., 2004).

The literature on other agricultural materials was surveyed to select an appropriate method for determination of physical properties of maize. In recent years, physical properties have been studied for various crops such as arigo seeds (Davies, 2010), lentil seed (Bagherpour *et al*., 2010), bay laurel seeds (Yurtlu *et al*., 2010), rapeseed (Izli *et al*., 2009), and popcorn kernels (Karababa, 2006).

The objective of present study was to evaluate the physical properties of maize in order to facilitate the design of a machine for degerming of maize.

MATERIAL AND METHODS

A bold variety of maize (var. Jai Kisan), commonly grown in Karnataka State, India was procured from the local market of Ludhiana, India for the present study. The maize kernels were cleaned by using pedal cum power operated grain cleaner (top sieve: 8.0 mm in diameter; bottom sieve: 2.0 × 2.5 mm) to remove foreign matter such as dust, dirt, chaff, immature and broken grains. The maize, above 8.0 mm in diameter sieve, was used for determination of its moisture dependent physical properties which was used for degerming study of maize. The initial moisture content of maize was determined by hot air oven method (AOAC, 1984) and to achieve desire moisture content levels of 12, 18, 24 and 30% w.b., maize was conditioned adding desired quantity of distilled water (Chakraverty, 1988) and mixed thoroughly by hand before storing in refrigerator at 5°C for 24 h. The maize samples were allowed to equilibrate at room temperature (30±2ºC) to determine the actual moisture content present in

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the maize prior to experiments for determination of its properties in triplicate. The average values of moisture content in maize found to be 12.8, 19.5, 25.1 and 29% w.b., respectively.

One hundred maize grains were selected randomly to determine the size and shape. For each individual grain, length, width and thickness were measured by using dial vernier calliper (least count: 0.02 mm). These values were used to calculate the derived geometric properties *eg* geometric mean diameter, surface area, unit volume and sphericity using standard relationships (Mohsenin, 1980; Singh *et al.,* 2004).

Bulk density was determined by filling a 200 ml cylinder with seeds from a set height, tapping twice (to obtain uniform packing and to minimize wall effect, if any) and then weighing the contents. True density was measured using the toluene displacement method (Jha, 1999). The porosity (ε) of the conditioned maize was computed using the established formula (Mohsenin, 1980; Singh *et al.,* 2004). The 1 000 grain mass of maize was determined using standard procedure (IS: 4333, 1968).

Angle of repose (θ) of the maize grain was calculated from the height and diameter of the naturally formed heap of the grains on a circular plate (Akaaimo and Raji, 2006; Jha, 1999; Kingsley *et al.*, 2006). The static coefficient of friction (μ) on three commonly used metallic surfaces for transportation, storage and handling of grains *ie* mild steel, galvanized iron and aluminium sheet surfaces at different moisture levels of the prepared samples were determined using a laboratory set up according to Jha (1999). The experiments were replicated 3 times and the average values were reported.

The textural/mechanical properties such as energy absorbed, rupture or cutting force in transverse and longitudinal directions of maize were determined by using Texture Analyser (TA-Hdi, Stable Microsystem, UK) (15 N, 1-3 mm, 10-15 mm travel distance, HDP/BSK blade set with knife). The individual seed was loaded between probe and base plate and compressed at preset conditions until cutting of maize occurred as is denoted by bio-yield point in the force-deformation curve. The energy absorbed was calculated by determining the area under the force-deformation curve up to the seed rupture point (Kingsley *et al.,* 2006). The probe and operating conditions were kept same as during experiments in transverse as well as longitudinal directions. Twenty replicates were run and average values were reported.

Data were analyzed as per one factor analysis of variance (ANOVA) using LSD of AgRes software statistical package. Regression analysis was carried out using Microsoft Excel 2003 software to determine the relationship between moisture content and the physical properties.

RESULTS AND DISCUSSIONS

All geometric properties such as length, width, thickness, geometric mean diameter, surface area, sphericity and kernel volume increased with increase in moisture content within the moisture range of 12.8-29.0% w.b. (Table 1). The length, width, thickness of maize increased from 12.53-12.85, 9.12-9.23, and 4.50-4.74 mm, respectively with increase in moisture content. The values of geometric diameter, surface area, sphericity and kernel volume increased from 7.97-8.21 mm (R^2=0.953), 199.87-212.14 mm^2 (R^2=0.957), 64.0-64.37% (R^2=0.973) and 268.25-293.73 mm^3 (R^2= 0.959), respectively for increase of moisture content from 12.8-29.0% w.b. Similar trend for geometric properties such as axial dimensions, geometric mean diameter, surface area, sphericity and kernel volume were reported for rapeseed (Izli *et al*., 2009).

Bulk density as well as true density decreased with increase in moisture content within the moisture range of 12.8-29.0% w.b. However, reverse trend were found for porosity and thousand grain mass. Bulk density and true density decreased from 768.7-665.1 kg m^{-3} (R^2=0.995) and 1321.7-1231.5 kg m^{-3} (R^2=0.984), respectively with increase in the moisture content of maize (Table 2). Similar

T a b l e 1. Geometric properties of maize

Moisture content (% w.b.)	Length	Width	Thickness	Geometric mean diameter	Surface area	Sphericity	Volume
	(mm)				(mm^2)	(%)	(mm^3)
12.8	12.53	9.12	4.50	7.97c	199.87c	64.00	268.25c
19.5	12.62	9.15	4.58	8.02bc	202.99bc	64.17	275.25bc
25.1	12.73	9.19	4.65	8.11ab	207.06ab	64.34	283.00ab
29.0	12.85	9.23	4.74	8.21a	212.14a	64.37	293.73a
SD	0.18	0.10	0.09	0.06	3.16	0.94	6.53
CD0.05	0.35	0.20	0.18	0.12	6.22	1.84	12.83
CD0.01	0.46	0.26	0.24	0.16	8.19	2.42	16.90
CV(%)	9.89	7.79	14.24	5.41	10.89	10.31	16.48

Mean values with the same superscript are not significantly different and mean values without any superscript are non-significant.

decreasing trend for bulk and true densities were reported by Bagherpour *et al*. (2010) and Kiani Deh Kiani *et al*. (2008), for lentil seed and red bean grains, respectively. 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 weight of material to occupy more volume of the cylinder thus decreasing the bulk density. Porosity and thousand grains mass were increased from 41.8-46.0% (R^2=0.980) and 351.9-381.5 g (R^2=0.955), respectively with increase in the moisture content (Fig. 1). The similar trend of increase of porosity and thousand grain mass were reported by Bagherpour *et al*. (2010) and Coskun *et al.* (2006) for lentil and sweet corn seeds, respectively.

Angle of repose was increased in quadratic manner from 29.4°-39.8° (R^2=0.989) with increase in moisture content (Fig. 2). The increasing trends were reported by Mohsenin (1980) for the most of biological materials. The increase in angle of repose with moisture content may be due to an increase in the internal friction with the moisture content.

The coefficient of friction is highest against mild steel surface and lowest against aluminium surface (Table 2). The static coefficient of friction of maize on mild steel sheet, galvanized iron sheet and aluminium sheet surfaces increased from 0.322-0.798 (R^2=0.981), 0.306-0.776 (R^2=0.961) and 0.285-0.731 (R^2=0.969), respectively for the moisture range of 12.8-29.0% w.b. This is so because increased moisture content may result in an increase in adhesion characteristics and roughness of the surface of maize. The similar increasing trend for static coefficients of friction were reported by Bagherpour *et al*. (2010), Coskun *et al.* (2006), Coşkuner and Karababa (2007), Kingsley *et al.* (2006), Tabatabaeefar (2003), for lentil seed, sweet corn seed, flaxseed, anardana seeds, and wheat, respectively.

T a b l e 2. Some gravimetric and frictional properties of maize

Moisture content (% w.b.)	Bulk density	True density	Static coefficient of friction (μ)		
	(kg m^{-3})		Mild steel	Galvanized iron	Aluminium
12.8	768.7a	1321.7a	0.322d	0.306d	0.285d
19.5	722.2b	1274.8b	0.549c	0.418c	0.410c
25.1	683.5c	1253.1c	0.745b	0.685b	0.658b
29.0	665.1c	1231.5d	0.798a	0.776a	0.731a
SD	8.14	4.85	0.01	0.02	0.02
CD0.05	18.77	11.18	0.01	0.04	0.04
CD0.01	27.32	16.27	0.02	0.06	0.54
CV(%)	1.40	0.47	1.17	3.92	3.78

Explanations as in Table 1.

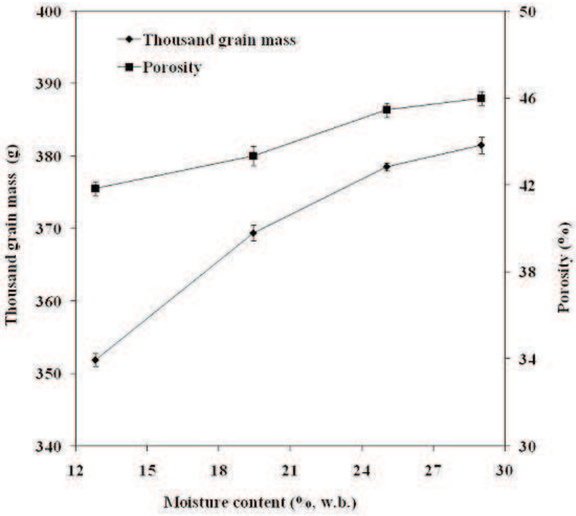

Fig. 1. Influence of moisture content on thousand grain mass and porosity of maize.

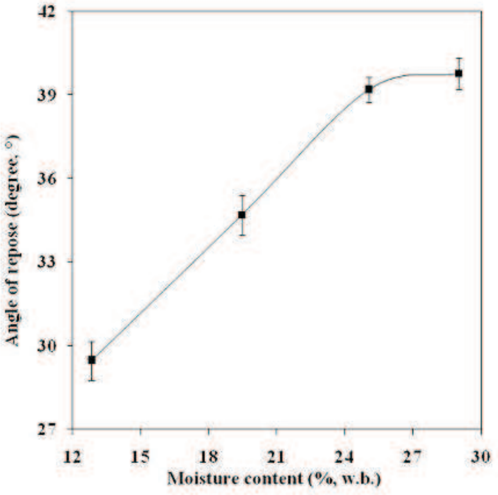

Fig. 2. Influence of moisture content on angle of repose of maize.

Table 3. Textural/mechanical properties of maize

Moisture content (% w.b.)	Peak force/cutting force/ rupture force (N)		Energy absorbed (N mm)	
	Length	Width	Length	Width
12.8	69.3a	162.6a	12.1bc	43.8a
19.5	68.6a	110.1b	18.8a	29.9b
25.1	42.8b	76.8c	14.3ab	27.5b
29.0	32.1b	48.3d	9.1c	16.3c
SD	5.34	9.57	2.62	4.11
CD0.05	10.64	19.07	5.21	8.19
CD0.01	14.12	25.29	6.91	10.87
CV(%)	31.77	30.45	60.86	44.27

Explanations as in Table 1.

The various textural/mechanical properties of maize are shown in Table 3. From this table, it is clear that rupture or cutting force and energy absorbed (length-wise as well as width-wise) decreased with increase in moisture content within the moisture range of 12.8-29.0% w.b. It is also clear from the table that rupture or cutting force as well as energy absorbed is more when maize is exposed to texture analyzer width-wise in comparison to length-wise. The similar observation was reported by Kingsley *et al.* (2006) for dried pomegranate seeds (*Anardana*).

CONCLUSIONS

1. For maize, the kernel length, width, thickness, and geometric mean diameter increased linearly from 12.53-12.85, 9.12-9.23, 4.50-4.74, and 7.97-8.21 mm, respectively with the increase of moisture content from 12.8-29.0% w.b.

2. The kernel surface area, sphericity and kernel volume increased linearly from 199.87-212.14 mm^2, 64.00-64.37% and 268.25-293.73 mm^3, respectively with the increase of the moisture content.

3. The bulk density and true density decreased linearly from 768.7-665.1 and 1321.7-1231.5 kg m^{-3}, respectively while porosity and thousand grains mass increased linearly from 41.8-46.0% and 351.9-381.5 g, respectively with increase of the moisture content.

4. The static coefficient of friction increased linearly from 0.322-0.798, 0.306-0.776 and 0.285-0.731 for mild steel sheet, galvanized iron sheet and aluminium sheet surfaces, respectively with increase in moisture. The highest value for the static coefficient of friction was observed for mild steel sheet surface.

5. Within the moisture range of 12.8-29.0% w.b., the rupture or cutting force and energy absorbed (length-wise as well as width-wise) decreased with increase in moisture content.

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