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Study of Physical and Engineering Properties of Corn (*Zea mays*)

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ABSTRACT
Corn (Zea mays) is an economically important cereal crop often used as a food product which contains essential vitamin and mineral which are necessary for the human health. Measurement of physical and engineering properties of corn cob and corn kernel is necessary to design processing equipment. The two popular corn varieties in Telangana state, India viz., Dent corn and Sweet corn were selected for the study. The physical properties viz., unit mass of the cob with and without husk varies from 246.92±37.49 to 371.53±68.16, linear dimension varies from 44.40±253 to 289.90, Geometric mean diameter, arithmetic mean diameter, cross sectional area of the corn cobs is in the range of 82.80 ± 4.92 mm to 86.60 ± 5.50 mm, 123.70 ± 11.47mm to 126.20 ± 13.4mm, 644.50 ± 675.20mm^{2}to 3803.4 ± 803.71mm^2 and shape index is in range of 5.61 ± 0.88 mmto 6.546 ± 0.96 mm. Based on result obtained by the experiment the shape index of both the selected varieties was found to be oval in shape for corn cobs and spherical in shape for kernels. The average husk% content on the corn cob was in the range of 19% to 32%and thousand kernel weight of the selected corn cob verities varies from, , , 80.50 ± 1.51g to 321.85 ± 17.18g, respectively. Similarly the physical properties of kernels of selected numbers from each verity were measured to know the variation with in the genotype and effect on growth parameter. The differences in the physical properties among the corn verities observed in this study are due to variations in the compositions and structures of these materials.
Key words: *Sweet corn, Dent corn and Physical properties.*

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INTRODUCTION

Corn (*Zea mays*) is a most important cereal crops plant belonging to the *Poaceae* family.Corn is also recognized by different synonyms such as zea, corn, silk corn, maize etc. In Hindi it is called Makka and Barajovar. Corn is mother grain of Americans and is considered as the earliest cultivar of the new world. Corn is a crop having short life cycle and requires warm weather, appropriate apprehension and management. Corn is not only an important human nutrient, but also a basic element of animal feed and raw material for manufacture of many industrial products. For 100 g of edible portion of dried corn contains, 0.12 mg of vitamin 'C', 10 mg of Calcium,2.3 mg of Iron, 90 µg Carotene, 66.2 g of Carbohydrates, 0.10mg of Riboflavin, 1.78 mg of Amino acids, 342 mg of Calories, 2.7 g of Fibre, 3.6 g of Fat, 11.1 g of Protein, 114 mg of Sulphur and the rest makes the dry matter (Gopalan*et al*., 2007).

Corn is grown throughout the year in India. It is predominantly a kharif crop with 85 % of the area under cultivation in the season. Corn is the third most important cereal crop in India after rice and wheat, it accounts for 9% of total food grain production in the country. In India the production rate increased from 14 MT in 2004-05 to 23 MT in 2013-14.The total area of cultivation increased from 7.5 Mha in 2004-05 to 9.4 Mha in 2013-14 (*Federation of Indian Chambers of Commerce & Industry*). Andhra Pradesh(4.97 MT), Karnataka(3.98 MT) and Maharashtra (3.08 MT) are the most important states growing corn in India, which account for more than 80% of the total corn area of the country and also account for similar share in production(*Department of Agriculture and Cooperation*).

The knowledge of engineering properties of corn is fundamental in order to optimize the design of equipment's for post-harvest handling and processing product. This information on engineering properties is useful for plant and animal breeders, engineers and food scientists. In addition, this information is helpful for data collection in the design of machines, structures, processes, controlsand in determining the efficiency of a machine or an operation (Mohsenin, 1986; Srivastava*et al*., 1990; Aviara*et*

al., 1999). The physical properties have been studied for various agricultural products by other researchers such as locust bean seed (Ogunjimi et al., 2002), pigeon pea (Baryeh and Mangope, 2003), amaranth seed (Abalone et al., 2004), rape seed (Calısır et al., 2005), Bambara groundnut (Adejumo et al., 2005), watermelon seed (Koocheki et al., 2007), pistachio nut and its kernel (Razavi et al., 2007), coriander seed (Coskuner and Karababa, 2007), tung seed (Sharma et al., 2011), carob bean (Karababa and Coşkuner, 2013), moringa seed (Aviara et al., 2013), barley (Sologubik et al., 2013). However, literatures on physical properties of selected popular verities (Sweet corn and Dent corn) of cornavailable in regional area of Sangareddy, Telanganastate were studied. Hence the objective of this study was to investigate the geometric properties such as length, width, thickness, geometric and arithmetic mean diameter, shape index, gravimetric properties like volume, 1000 kernel weight, bulk density of corn cobs and corn kernels of both selected verities (Sweet corn and Dent corn kernels) of corn.

MATERIAL AND METHOD

Two varieties which are locally available in the region of Telangana like Dent corn and sweet corn were selected for experimentation (Fig.1 a & b).

Determination of physical properties of corn cobs and kernels

The techniques employed to measure various physical properties are discussed below.

Unit mass

Twenty five numbers of corn cobs and thousand numbers of kernels drawn randomly from each variety were weighed by using an electronic balance having least count of 0.01 gm. The mean mass of corn cob and 1000 kernel of each variety was computed and reported as unit mass.

Linear dimensions

From each variety, twenty five numbers of corn cobs drawn randomly and each variety consists of atleast 16 to 19 columns, from each column one number of kernel drawn spirally over the cobs (Fig. 3) and their linear dimensions were measured using a vernier calliper with an accuracy of ±0.01 mm. Linear dimensions of cob and kernel measured were: length (l), breadth(b), thickness (t), geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}) and cross sectional area (A_{cs}) . Breadth (b) is the randomly measured diameter at three sections of cob from top to bottom. Thickness (t) is the smallest intercept diameter at three sections for cobs. (Ghaffari*et al.*, 2013 and Karthik*et al*., 2016).

Geometric & Arithmetic mean diameter and Cross sectional area of corn cobs and kernels.

The geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}) and cross sectional area (A_{cs}) of corn cobs and kernel were calculated using the following equations (Mohsenin, 1986):

$$D_{gm} = (lbt)^{\frac{1}{3}} \qquad D_{am} = \frac{(l+b+t)}{3} \qquad A_{cs} = \frac{\pi}{4}\left\{\frac{(l+b+t)^2}{3}\right\}$$

Where, l – Length (mm), b– Breadth (mm), t – Thickness (mm)

Shape index

Shape index is a measure of the shape of cob and kernel. The data is computed according to the following equation (AbdAlla, 1993)

$$\text{Shape Index} = \frac{l}{\sqrt{b \times t}}$$

The cob and kernel is considered an oval if the shape index is > 1.5, on the other hand, it is considered spherical if the shape index is < 1.5 (Bahnasawy*et al.*, 2004).

Bulk density of kernel

The samples of corn kernel were filled into a 1000 ml measuring jar up to the brim level. The excess samples were removed so that the top surface was level and even. Care was taken to see that corn kernels were not compressed in any way. Then the samples in the measuring jar were weighed by using an electronic balance. The bulk density was calculated using the following Equation (Mohsenin, 1986). This procedure was replicated for five times and the mean values were reported.

$$\text{Bulk density } (kg/m^3) = \frac{\text{Weight of sample in measuring jar (kg)}}{\text{Volume of measuring jar } (m^3)}$$

Husk Percentage

The total weight of husk presented on samples collected from different varieties was expressed in percentage and the relationship given in the following equation.

$$\text{Husk } \% = \frac{\text{Weight of the husk (kg)}}{\text{Total weight of the corn cobs (kg)}} \times 100$$

Fig. 1(a) Dent corn

Fig. 1(b) Sweet corn

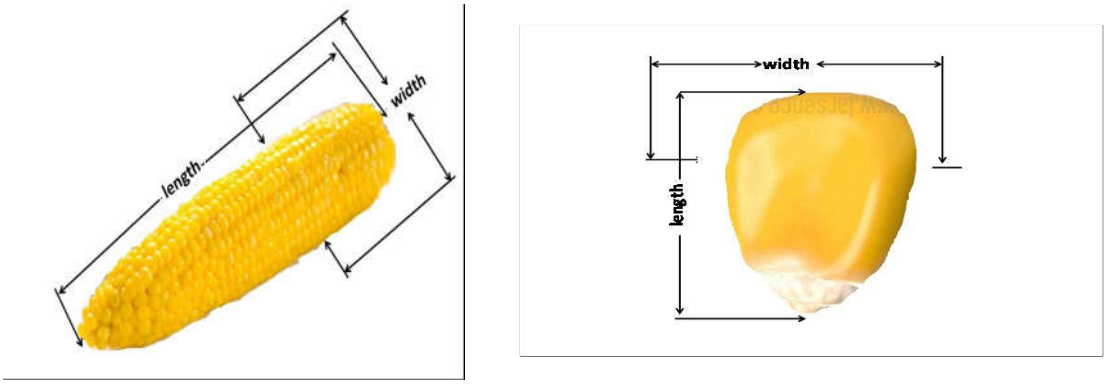

Fig. 2 Physical properties of corn cob and corn kernel

Fig. 3 Samples of kernels taken spirally over *Dent* corn and *Sweet*corn cob to measure physical properties

Thousand Kernel Weight

The kernels of each variety were taken and thousand kernel weight was recorded using electronic balance (accuracy ± 0.001 g) for five trials by counting clean and unbroken kernels. The mean kernel weight was expressed as grams per thousand kernels.

Number of kernels

The total number of kernels on the cobs will vary within a variety. The average number of kernels presented in each cob variety is calculated and presented manually

RESULTS AND DISCUSSION

Physical properties of corn cobs and kernels

The physical and engineering characteristics of randomly selected corn cobs from each selected variety are presented in Table 1 and Table 2.

Unit mass of the corn cobs and corn kernel

The corn of selected varieties was collected from different regions of Sangareddy. The maximum mean unit mass of corns with husk was observed with Sweet corn (371.53 ± 68.16 g) followed by Dent corn (360.80 ± 76.69 g). The maximum mean unit mass of corns without husk was observed with Dent corn (290.40 ± 56.30 g) followed by Sweet corn (246.92 ± 37.49 g).

Linear dimensions

The length was measured from the stalk to the apex of corn cobs and it was found to be 273.30± 34.05 mm for Dent corns and 289.90 ± 40 mm for Sweet corn. The maximum diameter was observed with Dent corn (48.9±3.73 mm) followed by Sweet corn (44.4 ± 2.53 mm).

The mean length, breadth and thickness of corn kernels was found as 0.87±0.06 mm, 1.06±0.10 mm, 4.29±0.30 mm for Dent corn and 7.36±0.46 mm, 6.29±0.57 mm, 3.24±0.30 mm for Sweet corn, respectively.

Geometric and Arithmetic mean diameter and Cross sectional area of corn cobs and kernels.

The maximum geometric mean diameter of corn cobs was observed in Dent corn (86.66 ± 5.50 mm) followed by Sweet corn (82.81 ± 4.92 cm). The arithmetic mean diameter was observed with Sweet corn as (126.20 ± 13.40 mm) followed by Dent corn as (123.70 ± 11.47 mm). The cross sectional area was observed maximum with Sweet corn (3803.41 ± 803.70 mm^2) and minimum in Dent corn (3644.50 ± 675.40 mm^2).

The maximum geometric mean diameter of corn kernels was observed for Sweet corn (5.304 ± 0.265 mm) followed by Dent corn (1.553 ± 0.104 mm). The arithmetic mean diameter was observed with Dent corn (1.899 ± 0.66 mm) followed by Sweet corn as (5.116 ± 1.762 mm). The cross sectional area was observed maximum with Sweet corn (69.08± 0.382 mm^2) and minimum in Dent corn (8.968 ± 4.176 mm^2).

Shape index

The average value of shape index of corn cobs was found to in the range of 5.61 ± 0.88 to 6.546 ± 0.96 with the maximum value in Sweet corn and minimum in Dent corn. Based on result obtained by the experiment the shape index of both the selected varieties was found to be oval in shape.

The average value of shape index of corn kernels was found to in the range of 0.291±0.382 to 0.485 ± 0.445 with the maximum value in Sweet corn and minimum in Dent corn. Based on result obtained by the experiment the shape index of both the selected varieties was found to be spherical in shape.

Bulk density of kernel

The bulk density of selected variety of corn kernels was ranged between 663.98± 9.89 to 139.48±34.76 g/ml. The maximum bulk density was observed in Dent corn followed by Sweet corn.

Husk Percentage

The mean percentage of husk covered the entire cobs was found to be 32.75 ± 8.58 % for Sweet corn and followed by 19.05 ± 5.23 % for Dent corn

Table 1 Physical Characteristics of corn cobs

Property	Dent corn	Sweet corn
Unit mass, g		
a) With husk	360.80 ± 76.69	371.53 ± 68.16
b) Without husk	290.40 ± 56.3	246.92 ± 37.49
Linear Dimensions		
a) Length, mm	273.30 ± 34.05	289.90 ± 40
b) Diameter, mm	48.90 ± 3.73	44.40 ± 2.53
Geometric mean diameter, mm	86.60 ± 5.50	82.80 ± 4.92
Arithmetic mean diameter, mm	123.70 ± 11.47	126.20 ± 13.4
Cross Sectional area, mm^2	3644.50 ± 675.20	3803.4 ± 803.71
Shape index	5.61 ± 0.88	6.546 ± 0.96
Husk, %	19.05 ± 5.23	32.75 ± 8.58
Thousand kernel weight, g	321.85 ± 17.18	80.50 ± 1.513

Table 2 Physical characteristics of corn kernels

Property	Dent corn	Sweet corn
Linear Dimensions		
a) Length, mm	0.87 ± 0.06	7.36 ± 0.46
b) Breadth, mm	1.00 ± 0.10	6.29 ± 0.57
c) Thickness, mm	4.29 ± 0.30	3.24 ± 0.30
Geometric mean diameter, cm	1.55 ± 0.10	5.30 ± 0.26
Arithmetic mean diameter, cm	1.89 ± 0.66	5.11 ± 1.76
Cross Sectional area, mm^2	8.96 ± 4.176	69.08 ± 0.38
Shape index	0.29 ± 0.38	0.48 ± 0.44
Bulk density, Kg/m^3	663.98 ± 9.89	139.48 ± 34.76
Number of kernels on ear	593 ± 83	562 ± 76

Thousand kernel weight

The mean thousand kernel weight of selected corn varieties ranged between 80.50 ± 1.513 to 321.85 ± 17.18 g. The maximum thousand kernel weight was observed in Dent corn (321.85 ± 17.18 g) and minimum in Sweet corn (80.50 ± 1.513 g).

Number of kernels

The average number of kernels on selected variety of corn cobs was found to be 593 ± 83 for Dent corn and 562 ± 76 for Sweet corn.

Vengaiah*et al.* (2015) studied the physical properties of major cereals. He reported that physical properties of maize viz., length, width, thickness, geometric mean diameter, sphericity, surface area, bulk density and thousand kernel weight were found to be in the range of 9.87mm, 7.41 mm, 3.25 mm, 6.19 mm, 62.76%, 120.02 mm^2, 765 kg/m^3, 220. The results obtained by the work indicate, due to the genetic variability the properties of the corn or maize varies with in a variety only.

CONCLUSION

The results showed that the different physical and other engineering properties of selected verities of corn cobs and corn kernels. Two different sized corn genotypes namely, Dent corn and sweet corn that are available during season in Telangana were selected for experiment. For the tested two corn varieties, the unit mass (with husk), mean length, mean diameter, geometric mean diameter, arithmetic mean diameter, mean cross sectional area, shape index, sphericity, mean percentage of husk and mean number of kernels of corn cobs of the Dent corns was observed as 360.8 ± 76.69 g, 273.3 ± 34.05 mm, 48.9 ± 3.73 mm, 86.66 ± 5.5 mm, 126.2 ± 13.4 mm, 3644.5 ± 675.4 mm^2, 5.616 ± 0.88, 0.320 ± 0.0313, 19.05 ± 5.23 % and 593 ± 83 respectively. Similarly for the Sweet corns it was observed that371.53±68.16 g, 289.9 ± 40 mm, 44.4 ± 2.53 mm, 82.81 ± 4.92 mm, 123.7 ± 11.47 mm, 3803.41 ± 803.7 mm^2, 6.546 ± 0.963, 0.289 ±0.029, 32.75 ± 8.58 % and 562 ± 76 respectively.

The physical properties of corn kernal like unit mass(without husk), mean length, mean breadth, mean thickness, geometric mean diameter, arithmetic mean diameter, mean cross sectional area, shape index, sphericity, bulk density and number of kernel on ear of corn cobs of the Dent corn kernels was observed as 290.4 ± 56.3 g, 0.871 ± 0.06 mm, 1.006 ± 0.10 mm, 4.29±0.301 mm, 1.553 ± 0.104 mm, 1.899 ± 0.66 mm, 8.968 ± 4.176 mm^2, 0.291 ± 0.382, 0.362 ± 0.018, 0.664 ± 0.009 g/ml and 321.85 ± 17.18 g respectively. Similarly for the sweet corn it as observed that 246.92 ± 37.49 g, 0.36±0.464 mm, 6.29 ± 0.57 mm, 3.24 ± 0.301 mm, 5.304 ± 0.265 mm, 5.116 ± 1.762 mm, 69.08± 0.382 mm^2, 0.485 ±0.445, 0.721 ±0.035, 0.139 ± 0.034 g/ml and 80.50 ± 1.513 g respectively.The differences in the physical properties among the corn verities observed in this study are due to variations in the compositions and structuresof these materials.

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