Research Article

Comparison of Physical and Physiological Properties of Specialty Maize Inbred Lines

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Abstract

The aim of this study was to acquire data on the physical properties and compression loading behaviour of seed of eight inbred lines of maize. The mean values of length, width, thickness, geometric diameter, surface area, sphericity, 1000 kernel mass and seed hardness were studied at single level of corn seed moisture content. Physiological properties of specialty maize inbred seeds were also srudied. Our result showed that seeds of double recessive corn inbreds had highest (9mm) seed length compared to others where as popcorn seeds had lowest (6mm). Width (4mm) and thickness (2mm) were observed lowest in seeds of double recessive. Surface area and seed volume of QPM seeds (192.93 mm^2 and 252.17 mm^3) were highest where as popcorn (94.97 mm^2 and 86.69 mm^3) and double recessive (127.23 mm^2 and 128.56 mm^3) inbred seeds had lowest surface area respectively. Flint seeds had highest test weight where as double recessive and shrunken maize inbred had lowest test weight. Popcorn and waxy seeds had highest toughness followed by dent, qpm and flint. Sweetcorn inbreds had lowest rupture force compared to all specialty maize groups. Among sweetcorn inbreds shrunken and double recessive showed lowest rupture force compared to sugary sweetcorn inbreds. Sweet corn group (Double recessive, Sugary and Shrunken) showed lowest germination percentage (75-85%) compared to other. Double recessive (41.52 µScm-1g-1), shrunken (40.45 µScm-1g-1) and sugary (16.08 µScm-1g-1) had highest electrical conductivity compared to all other genotype.

Keywords: Specialty maize, Physical and physiological properties, Rupture force, Germination percentage

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Introduction

Differences in kernel characteristics caused by genetic pattern, environmental conditions, or handling may influence the processing and utilization of maize. These properties include the three perpendicular dimensions, which affect cleaning and grading processing, the kernel surface, which affects drying, sphericity and thousand kernels mass, which affect packaging of seed and compression loading behaviour, which affects milling, extruding and flake preparation. Coskun *et al*. [1] determined sweet corn seed properties as a function of moisture content, while Karababa [2] reported similar results on popcorn kernels; sweet corn kernel properties were reported by Karababa and Coskuner [3] and those of dent corn by Esref and Nazmi [4]. The quality of corn kernels is not evaluated solely by the physical traits mentioned above. The behaviour of the corn kernel during compressive loading is one of its textual properties. The processing of corn for food and feed requires various types of mechanical treatment that depend on external forces. The physical properties have been studied for various agricultural products by other researchers such as locust bean seed [5], pigeon pea [6], amaranth seed [7], rape seed [8], Bambara groundnut [9], watermelon seed [10], pistachio nut and its kernel [11], coriander seed [12], barley [13], moringa seed [14]. The aim of this study was to provide new information describing the primary physical and physiological properties of the seeds of eight specialty maize inbreds. The compression loading behaviour of maize seeds at same moisture contents was also studied.

Materials and Methods

Eight Inbreds lines of major varieties that are commercially grown specifically for human consumption, including *Zea mays* var. dent (*indurate Sturt*), flint (*indurate Sturt*), popcorn (*everta Sturt*), waxy maize (*Zea mays* var. *ceratina*), quality protein maize, and sweetcorn (*saccharata Sturt*) (Sugary, Shrunken and Double recessive) were used for all experiments in this study. The seeds were collected from Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi.

Estimation of moisture content

Moisture content of seed was recorded during physiological and harvest maturity following the protocols developed by ISTA [15]. Five gram seed samples were grinded in grinding mill. The moisture content (mc) was determined by keeping the samples in oven at 130°C for 2 hrs. The seed moisture content was determined by the following formula.

$$\text{Moisture content} = \frac{M2\text{-}M3}{M2\text{-}M1} \times 100 \qquad (1)$$

Where, M1 = wt. of sample before drying, M2 = wt. of sample + container before drying, M3 = wt. of sample + container after drying

Physical properties

For obtaining length, width and thickness of about 10 randomly selected seeds of each sample, a digital caliper was used. The geometric mean (D_g) and arithmetic diameter (D_a) in mm were calculated by these equations respectively [16].

$$D_g = (LWT)^{\frac{1}{3}} \qquad (2)$$

$$D_a = \frac{(L+W+T)}{3} \qquad (3)$$

Where, L is the length, W is the width and T is the thickness in mm.
The ratio of surface area of the sphere having the same volume as that of grain to the surface area of grain, defined as sphericity (Sp), was determined using following formula [16].

$$S_p = \frac{(LWT)^{\frac{1}{3}}}{L} \qquad (4)$$

For obtaining thousand seed weight, 100 seeds were weighted in an electronic balance with an accuracy of 0.001g and then multiplied by 10 to give mass of 1000 kernels. Jain and Bal [17] have considered seed volume, V and surface area, S by:

$$V = 0.25\left[\left(\frac{\pi}{6}\right) L\,(W+T)^2\right] \qquad (5)$$

$$S = \frac{\pi B L^2}{(2L-B)} \qquad (6)$$

where:

$$B = \sqrt{WT} \qquad (7)$$

Hardness of grain

Compression tests were conducted on seed using texture analyser. Individual kernels in its natural rest position were placed between 75 mm diameter probe (P75) and the base supporting unit and were compressed at 0.5 mm/min speed. As the compression began and progressed, a force-deformation curve was plotted automatically in relation to the response of seed to compression. Highest force value was taken as hardness of seed.

Germination percentage

Initial seed germination was determined as per ISTA [15]. Four replications each of 50 seeds were placed between two layers of moist paper towel and placed in the walk-in-germinator maintained at 25°C. First and final count was taken on 4^{th} day and 7^{th} day respectively. Germination percentage was calculated based on number of normal seedlings on final count (7^{th} day).

Electrical conductivity

50 Seeds were soaked in 250 ml of distilled water with at 25°C for 24 h. The electrical conductance of the seed leachate decanted in a 50 ml of beaker was measured at room temperature [15] using a digital conductivity meter and values were expressed in µScm-1g-1 seed. The evaluations were made with four replicates, using seeds previously weighed to four decimal place imbibed in distilled water and kept at 25°C. The readings for each replication were made soon after the material was removed from the incubator and gently shaken. The conductivity of the seed leachate was measured at room temperature and calculated as:

$$\text{Electrical Conductivity } (\mu\text{S cm} - 1\text{g} - 1) = \frac{\text{Conductivity reading} - \text{Background reading}}{\text{Weight of seeds (in grams)}}$$

Results and Discussion

Moisture content

Moisture content of all the specialty maize inbred was 10±0.02. The entire seed samples were kept on silica gel in dassicator to obtain same moisture content. Same moisture content is necessary for observation of seed toughness.

Physical properties

Seeds of double recessive corn inbreds had highest (9mm) seed length compared to others where as popcorn seeds had lowest (6mm). All the maize inbred lines e.g. sugary, shrunken, dent, flint, waxy and QPM seeds were at par in terms of length, width and thickness except double recessive. Width (4mm) and thickness (2mm) were observed lowest in seeds of double recessive. Dent (6.28mm) and QPM (6.26mm) seeds had highest Geometric mean where as double recessive (4.14mm) and popcorn (4.48mm) had lowest. Arithmetic mean and sphericity were at par among all seeds. Surface area and seed volume of QPM seeds (192.93 mm^2 and 252.17 mm^3) were highest where as popcorn (94.97 mm^2 and 86.69 mm^3) and double recessive (127.23 mm^2 and 128.56 mm^3) inbred seeds had lowest surface area respectively (**Figure 1**). Our results are similar to the results of the study of sweet corn physical properties reported by Karababa and Coskuner [3] and the measured data for dent corn kernels presented by Esref and Nazmi [4]. Flint inbred seeds showed highest test weight (264.3g) followed by dent (235.2g), QPM (226.1g) and waxy (211.9g). Double recessive (59.3g) and shrunken (93.5g) had lowest test weight followed by popcorn (100.6g) and sugary (158.1g) inbred seeds. Similar data were published by Coskun *et al.* [1] for sweet corn seed. Karababa [2] results for popcorn 1000 kernel mass values are significantly lower.

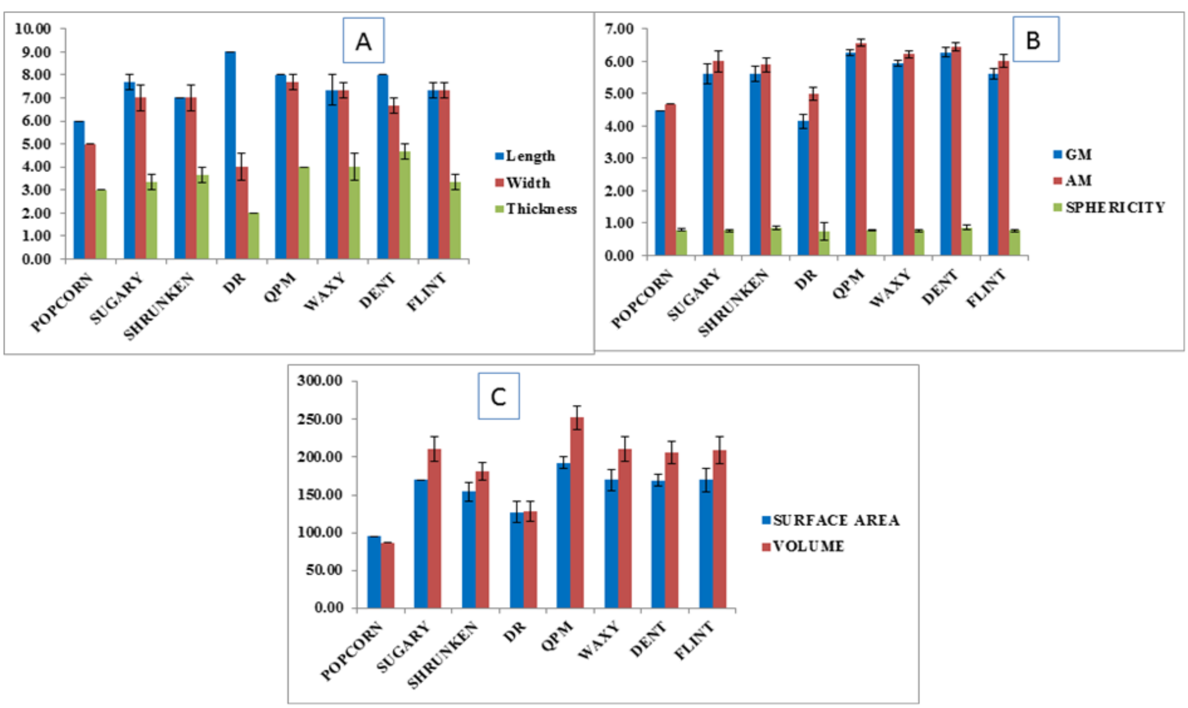

Figure 1 Physical properties of speciality maize inbred lines. (Abbreviations: DR; Double recessive)

Hardness of seed

Compressive tests were carried out on maize seeds at same moisture contents. As compression began and progressed, a force-deformation curve was plotted automatically in relation to the response of each sample of seed to compression. Rupture point was the point on the force-deformation curve at which the seed hull completely became broken and torn with the kernel exposed. The variation of compressive strength of specialty maize seeds with same moisture content when subjected to compressive loading under lateral orientation as presented in the **Figure 2**. The figure shows that the popcorn and waxy seeds had highest toughness followed by dent, qpm and flint. Sweetcorn inbreds had lowest rupture force compared to all specialty maize groups. Among sweetcorn inbreds, shrunken and double recessive showed lowest rupture force compared to sugary sweetcorn inbreds.

Both starch and protein affect hardness, with most research focusing on the storage proteins (zeins). Both the content and composition of the zein fractions affect hardness. Genotypes and growing environment influence the final protein and starch content and, to a lesser extent, composition. However, hardness is a highly heritable trait and, hence, when a desirable level of hardness is finally agreed upon, the breeders will quickly be able to produce material with the hardness levels required by the industry [18].

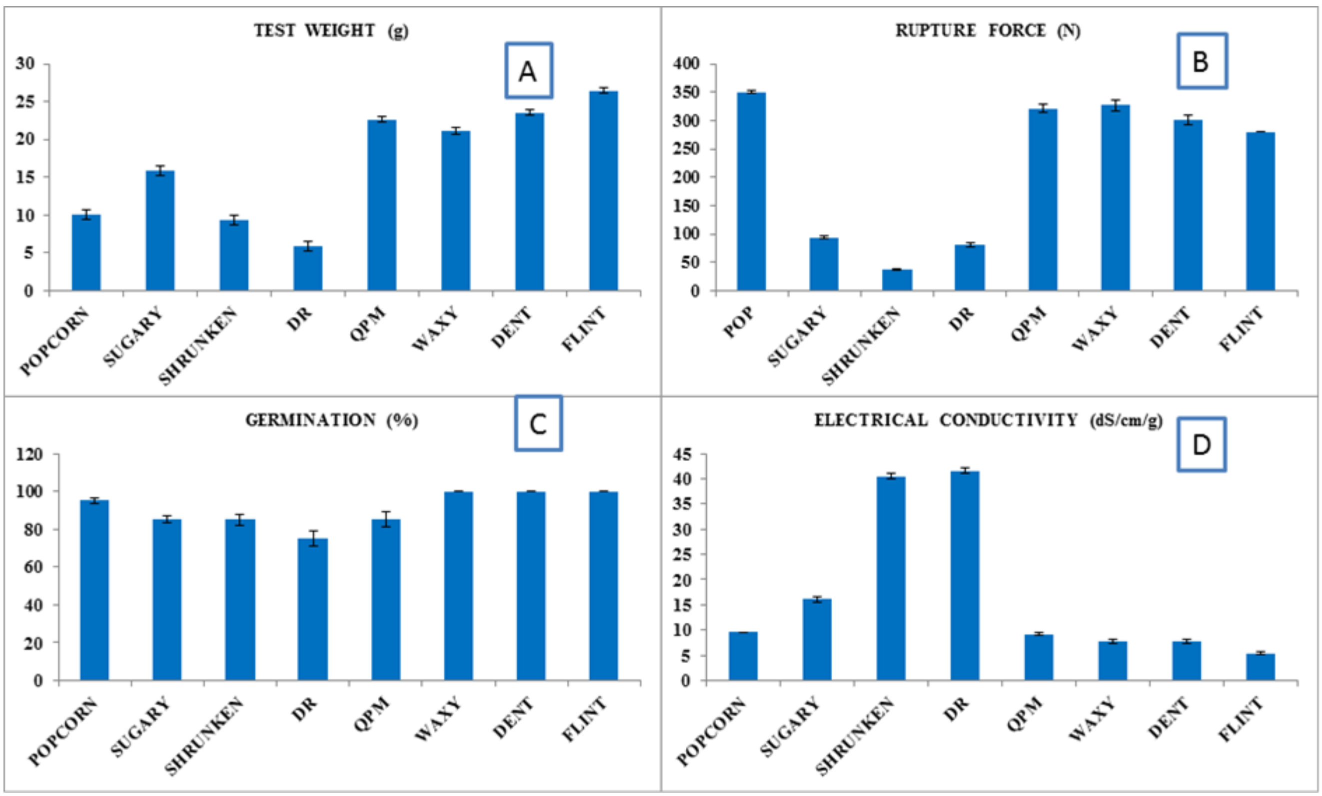

Figure 2 Comparison between physical and physiological properties of specialty maize inbreds lines. (Abbreviations: DR; Double recessive)

Physiological properties

Sweet corn group (Double recessive, Sugary and Shrunken) showed lowest germination percentage (75-85%) compared to other specialty genotype e.g. dent, flint and waxy. The reason behind less germination in sweet corn group seeds is having. By its nature, sweet corn has lower stored food reserves compared to other specialty and field corn seeds. With the advent of different endosperm types than the traditional sugary (su), such as double recessive and shrunken (sh2) types, vigour became even more of an issue. Low starch content in endosperm of sweet corn caused low seed vigor, which induced low germination rate and poor emergence [19]. Double recessive (41.52 µScm-1g-1), shrunken (40.45 µScm-1g-1) and sugary (16.08 µScm-1g-1) had highest electrical conductivity compared to all other genotype. This showed that sweet corn seeds have highest membrane permeability among the all specialty corn seeds. In this study, the results showed that an increase in leachate electrical conductivity occurs as seed viability decreases, and the seeds with low viability show high electrical conductivity compared with high viability. Increase in electrical conductivity with decrease in seed germination potential has been observed in other studies [20, 21].

Conclusion

The chemical composition of the endosperm determines different seed shapes and its physical characteristics define commercial types. Kernel hardness is an intrinsic property of the maize, with a commercial value that is expressed in its resistance to mechanical action and is related to the presence of corneal endosperm, thus presenting higher density. 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.

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