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DESIGN A SEED METERING WHEEL FOR SOWING CORN (*ZEA MAYS*) SEEDS

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Abstract

Properly designed seed metering device maintain seed to seed spacing in row and reduced breakage of seeds during operation. Before design the seed metering device physical properties of corn seeds are necessary measured. Physical properties plays major role in the design of seed box, conveyers and cell of seed metering device. The physical properties of corn seeds at different levels of moisture content from 10.45 to 20.30 d.b. were investigated. The seeds dimensions such as length, width thickness and diameter increase linearly with increase moisture content. An increase in bulk density and true density was observed whereas the porosity decreased at different moisture content 10.45, 13.50, 16.60 and 20.30% d.b. The diameter of seed metering wheel was 10.1 cm and number of cells on periphery of seed metering wheel was 9.

Key words : Seed metering device, corn seeds, moisture content, physical properties, bulk density, angle of repose.

Introduction

As our population continues to increase, it is necessary that we must produce more food, but this can only be achieved through some level of mechanization. Manual method of seed planting, results in low seed placement, spacing efficiencies and serious back ache for the farmer which limits the size of field that can be planted. However, planting machine or planter that is normally required to produce more food is beyond the buying capacity of small holder farmers (Khan *at al*., 2015).

Corn, also known as corn, belongs to the family Poaceae. Corn (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agricultural and climatic conditions. Globally, corn is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is widely cultivated throughout the world and enormous quantity of corn is produced each year than any other grain.

The knowledge of engineering properties of biomaterials is fundamental in order to optimize the design of equipment's for post-harvest handling and processing of agricultural products. 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 and controls; and 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 (Calýsýr *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). To date dry milling properties of corn seeds have been evaluated by (Mestres *et al*., 1991; Velu *et al*., 2006).

Materials and Methods

Preparation of samples

The sun dried corn grains used in the present study were purchased from Alopi Bagh Market, Allahabad (U.P.), India. The grains were cleaned manually foreign materials such as stone, straw and dirt were removed. All the physical properties were calculated at moisture levels (10.45, 13.5 16.60 and 20.30% d.b). 100 matured seeds were randomly picked for the experiments.

Determination of physical properties

A sample of 100 seeds of corn randomly selected a variety (CoH-3) were measured for size, shape, volume, bulk density, true density, porosity, angle of repose, coefficient of static friction and thousands seed weight (Mohsenin, 1986).

Size

The size of the seed was specified by length, width and thickness. The axial and lateral dimension of the seeds was measured by using vernier caliper (least count 0.01). Twenty seeds were selected randomly for the dimension.

Shape

This parameter of seed was relevant to design of seed metering wheel and hopper. The shape of the seed was expressed in term of roundness and sphericity.

Roundness : A seed was selected randomly and its dimension was taken by using image analysis method in natural rest position. The area of smallest circumscribing circle was calculated by taking the largest axial dimension of seed at natural rest position as the diameter of circle. The percent roundness was calculated as follow:

$$R_p = \frac{A_p}{A_c} \times 100$$

Where,

R_p = percent roundness

A_p = projected area, mm^2

A_c = area of smallest circumscribing circle, mm^2.

The procedure was repeated for five time and mean value was taken.

Sphericity : The sphericity is a measure of shape character compared to a sphere of the same volume. Assuming that volume of solid is equal to the volume of tri-axial ellipsoid with intercepts a, b, c and that the diameter of circumscribed sphere is a largest intercepts of the ellipsoid, the degree of sphericity was calculated as follows:

$$DS = \frac{(a \times b \times c)^{1/3}}{a}$$

Where,

DS = degree of sphericity

a = largest intercept, mm

b = largest intercept normal to a, mm

c = largest intercept normal to a and b, mm.

The procedure was repeated five times and mean value was taken.

Bulk density

A wooden box with inside dimension of 10×10×10cm was used for the measurement of bulk density of each crop seeds. The box was filled with seeds without compaction and then weighed. The bulk density was calculated as follow:

$$BD = \frac{W}{V}$$

Where,

BD = bulk density, g/cm^3

W = weight of seeds, g

V = volume of wooden box, cm^3

The procedure was repeated five times and the average bulk density of the seed was calculated.

Volume and true density

Toluene displacement method was used to determine the volume and true density of each crop seed. A sample of 100 seeds was weighed. The sample was immersed in a jar containing toluene displaced by the sample was recorded, thus volume of single seed was calculated. True density was calculated as the ratio of weight of the sample to its volume. Five set of observation were taken separately for volume and true density of seed.

True density =

$$\frac{Weight\, of\, gain(g)}{True\, volume\, occupied\, by\, the\, same\, grains(cm)^3}$$

Porosity

The porosity of the each crop seed was calculated using the following expression:

$$\text{Per cent porosity} = \left(1 - \frac{BD}{TD}\right) \times 100$$

Where,

BD = bulk density, g/cm^3

TD = true density.

Bulk and true density values obtained from previous experiments were used to calculate the per cent porosity of the seed.

Angle of repose

The angle of repose of the grains of each crop seeds was used for designing the hopper of planter. A box having circular platform fitted inside was filled with different grains. The circular platform was surrounded by a metal funnel leading to a discharge hole. The extra grains surrounding the platform were removed through discharge hole leaving a free standing cone of pigeon pea grains on the circular platform. A stainless steel scale was used to measure the height of cone and angle of repose was calculated by the following formula:

$$\Phi = tan-\left(\frac{2h}{d}\right)$$

Where,

Φ = angle of repose, degrees

h = height of cone, cm

d = diameter of cone, cm.

Five observations were taken and the mean value of angle of repose was calculated.

Coefficient of static friction

The coefficient of static friction of each crop seed was measured by using inclined plane method on mild steel surface. The seed was kept separately on a horizontal surface and the slope was increased gradually. The angle at which the materials started to slip was recorded. The coefficient of static friction was calculated by using the following formula:

Coefficient of static friction = tan Φ

Where,

Φ = angle of static friction, degrees.

Five replications were done and mean value of Φ for seed was calculated separately.

Thousand seeds weight

One thousand seed weight of each crop seed was weighing on a digital weighing balance.

Design of seed metering wheel for pigeon pea seeds

The proper design of the seed metering wheels is the most important thing is that how many cells would be develop for desired seed spacing. So, the diameter of the seed metering wheel was calculated by following equation (Sharma and Mukesh, 2010)

$$D_m = \frac{V_r}{\pi N_r}$$

Where,

D_m = diameter of seed metering wheel, cm

V_r = Peripheral velocity of seed metering wheel in m/min

N_r = rpm of seed metering wheel.

Peripheral length of seed metering wheel = 2πr

= 2×3.14×.165

=1.0362m

Forward speed of manually operated multi crop planter = 2.5 km/h

Speed of small sprocket (rpm) =

$$\frac{Forward\ speed\ in\ metre\,/\,min}{Peripheral\ length\ of\ seed\ metering\ device}$$

$$= \frac{41.67}{1.0362} = 40.21\ rpm$$

Speed of large sprocket (rpm) = Speed of small sprocket × drive ratio

= 40.21 × 0.375 = 15.08 rpm.

So minimum speed for seeds breakage 0.2892 km/h

$$\text{Diameter of seed metering wheel} = \frac{V_r}{\pi N_r} = \frac{4.91}{3.14 \times 15.08}$$

= 0.101 m

= 10.1cm

Number of cells in seed metering wheel

To maintain seed to seed spacing, increase or decrease number of cells on periphery of seed metering wheel and drive ratio. The numbers of cells on seed metering wheel was calculated by following equation (IKECHUKWU *et al*., 2014)

$$= \frac{\pi \times Diameter\ of\ drive\ wheel\,(cm)}{Drive\ ratio \times Plant\ spacing\,(cm)}$$

$$\text{No of cells in seed metering wheel} = \frac{\pi \times 33}{0.375 \times 25}$$

= 11

Fig. : A fabricated view of seed metering wheel of a manually operated multi-crop planter for showing corn seeds (Developed in SHUATS, Allahabad).

Results and Discussion

Kernel dimensions

The average axial dimensions of corn seeds such as length, width and thickness were determined. These values at different moisture contents are presented in table 1. The graph indicates that, on moisture absorption, the corn kernel expands in length, width and thickness within the moisture range of 10.45 to 20.30% d.b. The average length, width and thickness of the seeds varied from 10.40 to 11.04 mm, 8.67 to 9.21 mm and 3.10 to 3.52 mm, respectively as the moisture content increased from 10.45 to 20.30% d.b. The geometric mean diameter ranged from 8.55 to 9.15 mm as the moisture content increased from 10.45 to 20.30% d.b., respectively. The length, width, thickness, geometric mean diameter of the corn kernel was found to increase linearly with increase in the moisture content. Similar results were observed for various products such as cucurbit seeds (Milani *et al*., 2007), soybean (Kibar and Ozturk, 2008) and corn (Sangamithra, 2016).

Sphericity

The relationship between sphericity and moisture content of corn grain is shown in fig. 1. The sphericity of the corn grain samples increased with the increase in moisture content. The sphericity of corn kernel varied from 57 to 65 % as the moisture content increased from 10.45 to 20.30% d.b., respectively. A positive variation of sphericity depending on the increase of moisture content was also observed in some seeds such as sunflower seeds (Gupta and Das, 1997), almond nuts (Aydin, 2003), coriander seeds (Coskuner and Karababa, 2007) and sesame seeds (Darvishi, 2012) and corn (Sangamithra, 2016).

Seeds weight

The relationship between seeds weight and moisture content of corn grain is shown in fig. 2, it is observed that the 1000 kernel weight increased linearly from 96.4 to 102.5g as the moisture content increased from 10.45 to 20.30% d.b. Similar thing have been observed by (Tavakoli *et al*., 2009) for soybeans and (Bamgboye and Adebayo, 2012) for jatropha seeds and (Sangamithra, 2016) for corn kernel.

Bulk density and true density

Bulk density and true density of the corn seeds at different moisture content was varied from 410 to 478 kg/m^3 and 1298 to1340 kg/ m^3 with the moisture range of 10.45 to 20.30% d.b., respectively. A nonlinear increase in bulk density and true density was studied for different moisture content (figs. 3 and 7). This increase in true density may be due to the higher rate of increase in mass than the volumetric expansion of the seeds. The bulk density of the corn kernel decreases with increase in the moisture content from 10.45 to 20.30 % d.b., respectively. Similar trend was found for ground nut seeds (Firouzi *et al*., 2009). Similar trends of bulk density and true density with moisture content was also observed by (Polat *et al*., 2007) for pistachio nut and seeds, (Balasubramanian and Viswanathan, 2010) for minor millets (Sangamithra, 2016) for corn seeds.

Table 1 : Axial dimensions of corn seeds.

Moisture content (%) d.b.	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)
10.45	10.40	8.67	3.10	8.55
13.5	10.70	8.75	3.22	8.76
16.60	10.95	8.95	3.40	8.95
20.30	11.04	9.21	3.52	9.15

Porosity

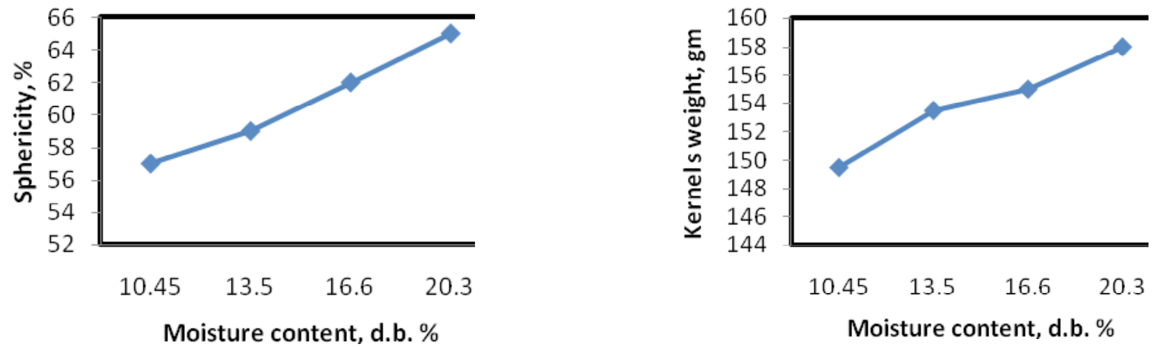
The variation of porosity depends on bulk as well as true density. The porosity of corn seeds was found to slightly decrease from 55.15 to 43.83% with increase in moisture content from 10.45 to 20.30% d.b., respectively in fig. 4. A similar relationship was observed for soybean (Deshpande *et al*., 1993), pistachio nuts and seeds (Polat *et al*., 2007) and minor millets (Balasubramanian and Viswanathan, 2010) and (Sangamithra, 2016) for corn seeds.

Angle of repose

The angle of repose for corn grains varied from 18 to 22.59^0 at different moisture content. The angle of repose for corn seeds increased polynomially with increase of moisture content from 10.45 to 20.30% d.b. (fig. 5). The increase in angle of repose with different moisture content may be due to the surface tension, which holds the surface layer of moisture surrounding the particle together with the aggregate of seeds. A similar data observed of nonlinear increased angle of repose with increasing kernel moisture content has also been noted by for gram (Chowdhury *et al*., 2001), coriander seeds (Coskuner and Karababa, 2007) and for pistachio nuts and seeds (Galedar *et al*., 2008) and for corn seeds (Sangamithra, 2016).

Coefficients of friction

Coefficients of friction of corn seeds were determined with respect to metal sheet a surface is presented in fig. 6. At different moisture content ranges, coefficients of friction were varied from 0.40 to 0.68 with the moisture range of 10.45 to 20.30% d.b., respectively. The



Figs. 1 & 2 : Effect of moisture content on (a) Sphericity, (b) Kernel weight of corn seeds.

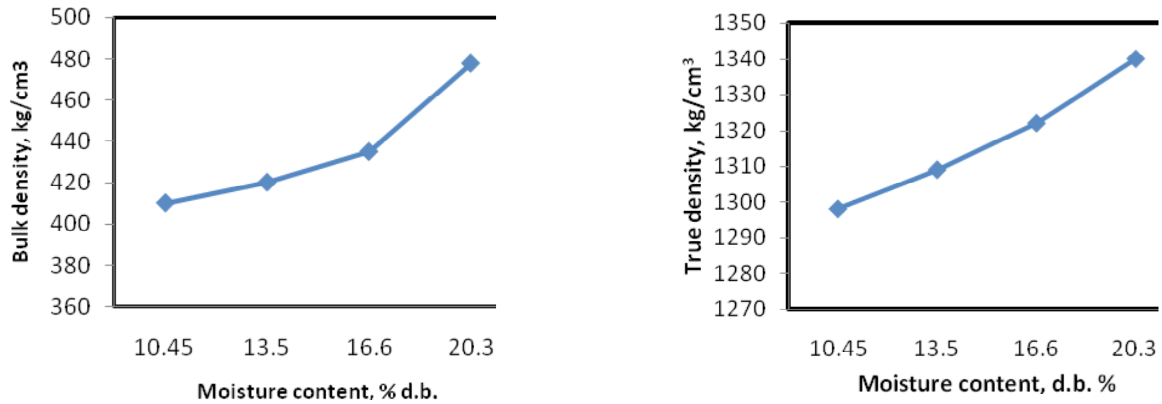


Fig. 3 & 4 : Effect of moisture content on (a) Bulk density (b) True density of corn seeds.

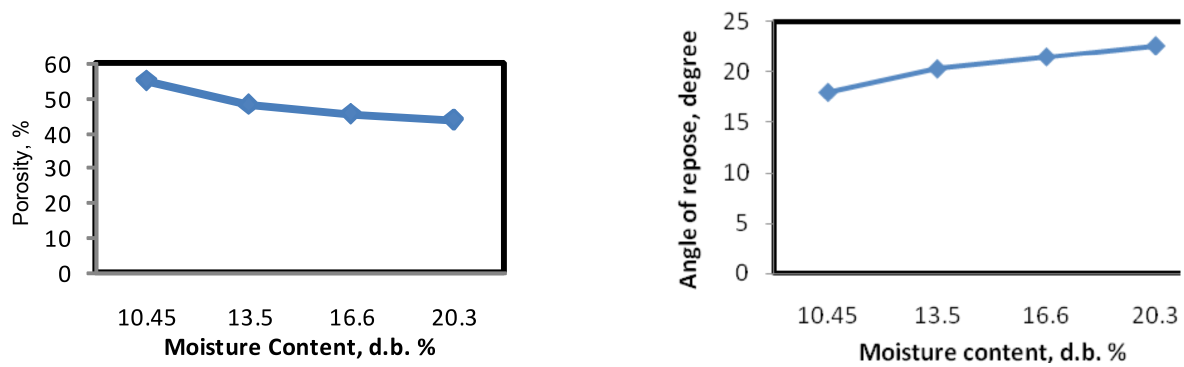


Fig. 5 & 6 : Effect of moisture content on (a) Porosity (b) Angle of repose of corn seeds.

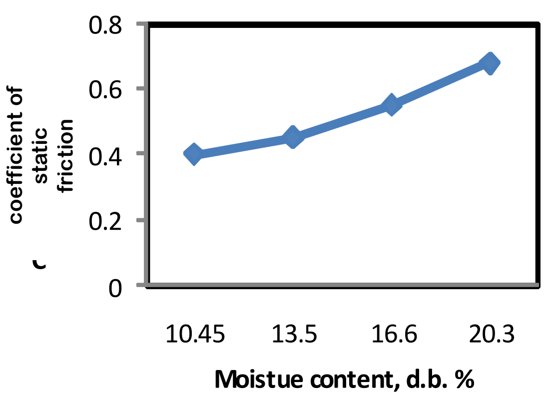


Fig. 7 : Effect of moisture content on coefficient of static friction of corn seeds.

coefficient of static friction increased significantly as the moisture content of the kernel increased. The relationship between the coefficients of friction and moisture content of the corn seeds is presented in fig. 6. Similar trend was observed by (Aydin, 2003) for almonds, (Altuntaş *et al.*, 2005) for fenugreek, (Milani *et al.*, 2007) for cucurbit seeds (Bamgboye and Adebayo, 2012) for jatropha (Sangamithra, 2016) for corn seeds.

Seed metering wheel for corn seeds

This seed metering wheel for manually operated multi crop planter developed in the laboratory of FPME in SHUATS. Seed metering wheel was made by nylon material, which is corrosion resistance and not affected by climatic factor. The diameter of seed metering wheel was 10.1 cm and number of cells on periphery of seed metering wheel was 11 which was maintained seed to seed spacing according to recommended spacing of pigeon pea. The shape and size of cell on periphery of seed metering wheel was more to grain dimensions because grain easily filled and released in cells.

Conclusion

The following conclusions are drawn on the basis on physical properties of corn seeds for moisture content range of 10.45 to 20.30% d.b. The length, width, thickness and geometric diameter of the seeds varied from 10.40 to 11.04 mm, 8.67 to 9.21 mm, 3.10 to 3.52 mm and 8.55 to 9.15 mm, respectively. As the moisture content increased from 10.45 to 20.30% d.b. The sphericity of corn kernel varied from 57 to 65% as the moisture content increased from 10.45 to 20.30% d.b., respectively. The 1000 kernel weight increased linearly from 149.5 to 158 g as the moisture content increased from 10.45 to 20.30% d.b. Bulk density and true density of the corn seeds at different moisture content was varied from 410 to 478 kg/m^3 and 1298 to1340 kg/m^3 with the moisture range of 10.45 to 20.30% d.b., respectively. The porosity of corn seeds was found to slightly decrease from 55.15 to 43.83% with increase in moisture content from 10.45 to 20.30% d.b., respectively. The angle of repose for corn grains varied from 18 to 22.59^0 at different moisture content. The angle of repose for corn seeds increased polynomially with increase of moisture content from 10.45 to 20.30% d.b. At different moisture content ranges, coefficients of friction were varied from 0.40 to 0.68 with the moisture range of 10.45 to 20.30% d.b., respectively. The coefficient of static friction increased significantly as the moisture content of the seeds increased. All the physical properties of corn seeds is necessary for designing of belt conveyors, seed box, seed metering device, conveyors, screw conveyors chutes, pneumatic etc. The diameter of seed metering wheel was 10.1 cm and number of cells on periphery of seed metering wheel was 11. The shape and size of cell on periphery of seed metering wheel should be more to grain dimensions because grain easily filled and released in cells at the time operation.

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