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Design a Seed Metering Wheel for Sowing Pigeon Pea Seeds

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A B S T R A C T

Physical properties of grains plays play important role in the design of seed hopper, conveyers and seed metering device. The physical properties of pigeon pea grains at different range of moisture content from 10.3 to 20.3 d.b. were investigated. The pigeon pea grains dimensions such as length, width thickness and diameter increase linearly with increase moisture content. An increase in bulk density and true density was observed at different moisture content 10.3, 13.6, 16.8 and 20.3 % d.b. The diameter of seed metering wheel was 10.1 cm and number of cells on periphery of seed metering wheel was 9.

Introduction

Pigeon pea (Cajanus cajan (L.) millsp.) is a multipurpose leguminous crop that can provide food fuel wood and fodder for the small-scale farmer in subsistence agriculture and is widely cultivated in Nigeria (Remanandan *et al.*,). Pulses along with cereals play a vital role in human nutrition, especially for the vegetarian population as a cheap source of protein (Mangaraj *et al.*,). Pigeon pea (Cajanus cajan) is the most commonly consumed pulse in the Indian subcontinent. These are cultivated in more than 25 tropical and subtropical countries, either as a sole crop or intermixed with cereals, such as sorghum, pearl millet or maize or with other legumes, such as peanuts. Pigeon peas are cultivated for both as food crop (dried peas, flour or green vegetable peas) and forage/cover crop. They contain high levels of protein and important amino acids like methionine, lysine, and tryptophan (Nwokolo, 1987). Sprouting enhances the digestibility of dried pigeon peas via the reduction of indigestible sugars that would otherwise remain in the cooked dried peas.

The study of physical, aerodynamic and mechanical properties of food grain is important and essential in the design of processing machines, storage structures and processes. The shape and size of grains are important in the design and development of grading and sorting machineries for the separation of foreign material as well as for the thermal processing calculations. Rupture force can be used in design of de huller. Bulk density and particle density are important factors in designing of storage structures. The angle of repose of the grains can be used for designing the bins, silos, hoppers and storage structures. The effect of moisture content on physical properties like bulk density, particle density, hardness and angle of repose of different grains such as sunflower, neem nut, pumpkin, gram, pigeon pea, soya bean, karingda, canola seed, paddy, mung bean, corn, pistachio nut (Shepherd and Bhardwaj, Dutta *et al.*, Desphande *et al.*, Gupta and Das, Chowdhury *et al.*, Reddy and Chakraverty, Unal *et al.*, Seifi and Alimardani.

Galedar *et al.*, Maghsoudi *et al.*, have been investigated. The knowledge of moisture dependence of these properties is important during equipment design in order to construct the equipment that can be used for processing pigeon pea whether seeds are dried or freshly harvested. The objective of this study was to evaluate the effect of moisture content on the physical properties of pigeon pea.

Metering mechanism is the heart of sowing machine and its function is to distribute seeds uniformly at the desired application rates. In planters it also controls seed spacing in a row. A seed planter may be required to drop the seeds at rates varying across wide range [Sowing and planting equipment].

The effect of planting speed on metering and seed accuracy was studied by (Chhinnan *et al.*, 1975). They found that higher planting speeds resulted in more skips, higher speed placement errors, and higher average spacing.

Materials and Methods

Preparation of samples

The sun dried pigeon pea grains used in the present study were purchased from Alopi Bagh Market, Allahabad (U.P.). The grains were cleaned manually foreign materials such as stone, straw and dirt were removed. All the physical properties were calculated at moisture levels (10.3, 13.6 16.8 and 20.3% d.b). 100 matured kernels were randomly picked for the experiments.

Determination of physical properties

A sample of 100 grain of pigeon pea randomly selected a variety (BAHAR) 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:

$$R_p = \frac{Ap}{Ac} \times 100$$

Where,

R_p = percent roundness
A_p = projected area, mm^2
A_c =area of smallest circumscribing circle, mm^2

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

Bulk density

A wooden box with inside dimension of $10 \times 10 \times 10$ cm 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

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.

$$\text{Truedensity} = \frac{\text{Weight of grain}\,(g)}{\text{True Volume occupied by the same grains}\,(cm)^3}$$

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:

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

Where,

Φ = angle of repose, degrees
h = height of cone, cm
d = diameter of cone, cm.

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.

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 = $2\pi r = 2\times3.14\times.165 = 1.0362$m

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

Speed of small sprocket (rpm)

$$= \frac{\text{Forward speed in metre/min}}{\text{peripheral length of seed metering device}}$$

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

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

Diameter of seed metering wheel = $\frac{V_r}{\pi N_r}$ = $\frac{4.81}{3.14\times15.08}$ = 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)

Number of cells in seed metering wheel

$$= \frac{\pi\times\text{diameter of drive wheel (cm)}}{\text{drive ratio}\times\text{plant spacing (cm)}}$$

No of cells in seed metering wheel = $\frac{\pi\times33}{0.375\times30}$ = 09

Results and Discussion

Kernel dimensions

The length, width, thickness and geometric diameter of the pigeon pea seeds varied from 4.9 to 6.9 mm, 4.52 to 5.40 mm, 4.10 to 4.70 mm and 4.95 to 5.45 mm respectively. As the moisture content increased from 10.30 to 20.30% d.b. The length, width, thickness, geometric mean diameter of the pigeon pea seeds were 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 maize (Sangamithra, 2016).

Sphericity

The sphericity of the pigeon pea seeds samples increased with the increase in moisture content. The sphericity of pigeon pea seeds varied from 0.83 to 0.91. As the moisture content increased from 10.30 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 maize (Sangamithra, 2016).

1000 grains weight

It is observed that the 1000 grains weight increased linearly from 96.4 to 102.5g as the moisture content increased from 10.30 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 maize kernel.

Bulk density and true density

Bulk density and true density of the pigeon pea grains at different moisture content was varied from 820 to 890 kg/m^3 and 1310 to1340 kg/ m^3 with the moisture range of 10.30 to 20.30 % d.b. respectively.

This increase in true density may be due to the higher rate of increase in mass than the volumetric expansion of the grains. The bulk density of the maize kernel decreases with increase in the moisture content from 10.45 to 20.30 % d.b. respectively.

Similar trend was found for ground nut kernels (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 kernels, (Balasubramanian and Viswanathan, 2010) for minor millets, (Sangamithra, 2016) for maize kernels.

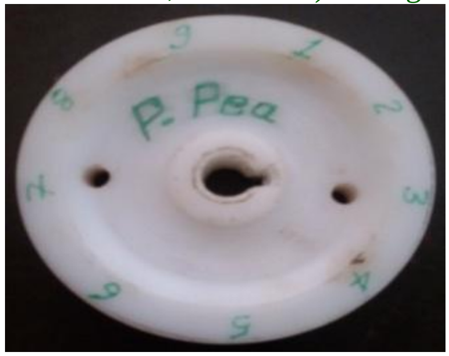
Coefficients of friction

Coefficients of friction of pigeon pea grains were determined with respect to metal sheet a surface at different moisture content ranges; coefficients of friction were varied from 0.44 to 0.50, with the moisture range of 10.30 to 20.30 % d.b. respectively.

The coefficient of static friction increased significantly as the moisture content of the grains increased.

The relationship between the coefficients of friction and moisture content of the maize kernels is studied. 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 maize kernels.

Fig.1 A fabricated view of seed metering wheel for a manually operated multi-crop planter (Developed in SHUATS, Allahabad) for Pigeon pea seeds



Angle of repose

The angle of repose for pigeon pea grains varied from 25 to 28.70^0 at different moisture content. The angle of repose for pigeon pea grains increased poly nomially with increase in moisture content from 10.30 to 20.30 % d.b. 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 kernels. 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 kernels (Galedar *et al.*, 2008) and for maize kernels (Sangamithra, 2016).

Seed metering wheel for pigeon pea seeds

This seed metering wheel for manually operated multi crop planter developed in the laboratory of FPME in SHUATS. Seed metering wheel 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 9 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 (Fig. 1).

The following conclusions are drawn on the basis on physical properties of pigeon pea grains for moisture content range of 10.3 to 20.30% d.b. The length, width, thickness and geometric diameter of the pigeon pea seeds varied from 4.9 to 6.9 mm, 4.52 to 5.40 mm, 4.10 to 4.70 mm and 4.95 to 5.45 mm respectively. As the moisture content increased from 10.30 to 20.30% d.b. As the moisture content increased from 10.3 to 20.3% d.b. The sphericity of pigeon pea seeds varied from 0.83 to 0.91. As the moisture content increased from 10.30 to 20.30 % d.b respectively. The 1000 grains weight increased linearly from 96.4 to 102.5g as the moisture content increased from 10.30 to 20.30 % d.b. Bulk density and true density of the pigeon pea grains at different moisture content was varied from 820 to 890 kg/m^3 and 1310 to1340 kg/ m^3 with the moisture range of 10.30 to 20.30 % d.b. respectively. At different moisture content ranges, coefficients of friction were varied from 0.44 to 0.50, with the moisture range of 10.30 to 20.30 % d.b. respectively. The angle of repose for pigeon pea grains varied from 25 to 28.70^0 at different moisture content. The angle of repose for pigeon pea grains increased poly nominally with increase of moisture content from 10.30 to 20.30 % d.b. All the physical properties of pigeon pea grains is necessary for designing seed metering wheel, 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 9. 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.

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