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Naveen Kumar
Department of Farm Machinery and Power Engineering, College of Technology and Engineering, MPUAT, Udaipur, Rajasthan, India

Ajay Kumar Sharma
Professor & Head, Department of Farm Machinery and Power Engineering, College of Technology and Engineering, MPUAT, Udaipur, Rajasthan, India

Corresponding Author:
Naveen Kumar
Department of Farm Machinery and Power Engineering, College of Technology and Engineering, MPUAT, Udaipur, Rajasthan, India

Study on engineering properties of chickpea (*Cicer arietinum*) seeds in relation to design of threshing mechanism

Naveen Kumar and Ajay Kumar Sharma

Abstract
A study was conducted to assess the engineering properties of chickpea seeds (Pratap Chana - I) as these are crucial in designing equipments/machines for handling, conveying, processing and storage units. The parameters were determined using standard methods in the laboratory. The average values of spatial dimensions viz. length, width, thickness and geometric mean diameter were 8.76, 6.08, 6.06 and 6.86 mm respectively. The average surface area, thousand seed weight and sphericity were found to be 148.08 mm^2, 182.18 gm and 0.78 respectively. The mean values of true density and bulk density were 1237.93 kg/m^3 and 881.49 kg/m^3, respectively. The frictional properties of chickpea seeds varied significantly on different surfaces and seed rupturing force varied with axial directions of seeds.

Keywords: physical properties, chickpea, density, sphericity, force

1. Introduction
Chick pea (*Cicer arietinum*) is an important pulse crop in India which belongs to the leguminous family and commonly known as gram or Bengal gram. It is an exceptionally nutritious pulse crop which is used for human consumption as well as for animal feeding. It is a vital source of protein for a large number of individuals in the developing countries, particularly in South Asia, who are predominantly vegan either by choice or because of economic reasons. Raw seeds per 100g contain: 357 calories, 4.5 – 15.69 per cent moisture, 14.9 – 24.6 g proteins, 0.8-6.4 per cent fat, 2.1-11.7 g fiber, 2-4.8 g ash, 140-440 mg Ca, 190-382 mg P, 9 mg Fe, 0.21-1.1 mg thiamin, 0.12 -0.33 mg riboflavin and 1.3 -2.9 mg niacin (Duke,1981; Huisman and Poel,1994) [4, 6].
Chickpea ranks third in the importance list of the food legumes and cultivated in more than 50 countries in the world. The global production of chickpea in 2018 was 17.2 MT over 17.8 Mha of land. India is the largest producer of chickpea with production of 11.8 MT in 2018 (Anonymous, 2020a) [2]. Figure 1 shows the share of different countries in chickpea production in 2018.

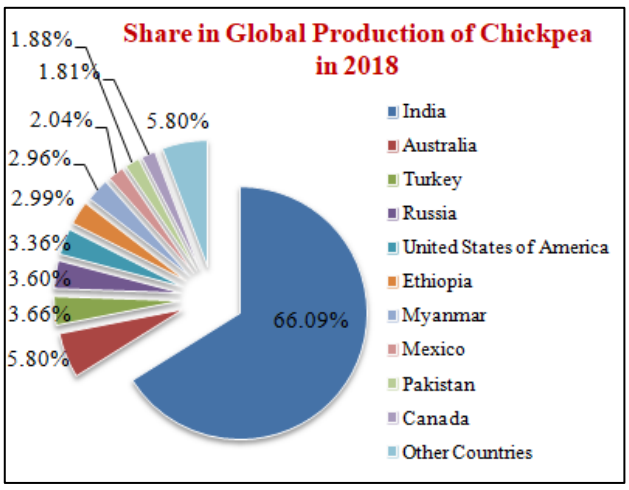

Fig 1: Share of different countries in chickpea production in 2018

Recent ascent in prices has led to a rise in demand for legumes (Merga *et al*., 2019) [10]. There is a critical call for enhancing seed production of improved varieties to ensure ample availability of superior seed to the farmers. In any seed production programme, seed processing is a basic component which targets improving the seed qualities. Engineering properties (Physical and mechanical properties) have a critical role in designing equipments and machines which reduce human drudgery, save labour and time in seed collection from fields, transportation, cleaning, grading and processing with minimum seed damage which improves its storage life and thus, diminish the cost of production. These includes physical and mechanical properties such as spatial dimensions, geometric mean diameter, surface area, density, thousand seed weight, sphericity, angle of repose, terminal velocity, coefficient of friction and seed rupturing force. Various studies have been conducted by Dutta *et al*., (1988) [5]; Konak *et al*., (2002) [9]; Ghadge *et al*., (2008); Ayman *et al*., (2010) [3] and Tikle and Mishra (2018) [14] for some physical properties of chickpea in different aspects but no detailed literature is available for Indian varieties. Therefore, a study was carried out to determine the physical and mechanical properties of chickpea seeds useful in design of threshing mechanism.

2. Material and methodology

In this study, Indian variety of desi chickpea 'Pratap Chana – I' introduced by ARS, Banswara, Rajasthan which is commonly used in Mewar region and produced at Instruction farm, CTAE, MPUAT, Udaipur was used. The harvesting stage of crop was taken for the experiments.

2.1 Physical properties

The moisture content of seed samples was determined by oven drying method at 105 ± 1 °C for 24 hrs (Suthar and Das, 1996; Altuntas *et. al*., 2005) [13, 1]. The seed samples were weighed by digital electronic balance of accuracy 0.01 g.

The linear dimensions as shown in figure 2 viz. length (L), width (W) and thickness (T) of 100 randomly selected seeds were measured using digital vernier caliper of accuracy 0.01 mm.

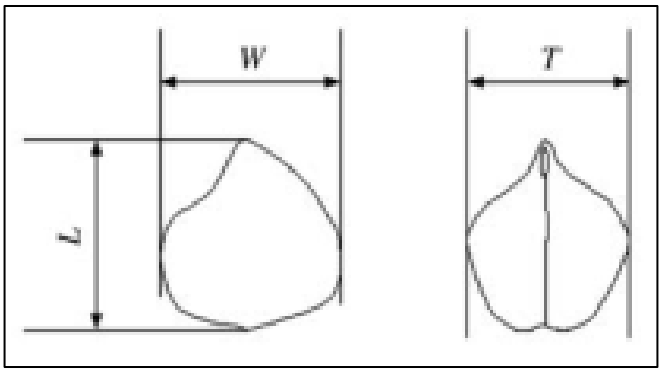

Fig 2: Dimensions of chickpea seed

The geometric mean diameter (D_g), arithmetic mean diameter (D_a), surface area (S) and sphericity (φ) of seeds were calculated respectively by using the following equations (Mohsenin, 1970):

$$D_g = (LWT)^{1/3} \quad \text{…. (1)}$$

$$D_a = \frac{L + W + T}{3} \quad \text{…. (2)}$$

$$S = \pi(D_g)^2 \quad \text{…. (3)}$$

$$\varphi = \frac{(LWT)^{1/3}}{L} \quad \text{…. (4)}$$

where L, W and T are length, width and thickness respectively.

The bulk density and true density were determined as per the method suggested by Mohsenin (1970) and porosity (∈) was calculated as following:

$$\in = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad \text{…. (5)}$$

where ρ_t and ρ_b are true density and bulk density respectively.

The terminal velocity was measured using an air column method (Kachru *et al*., 1994) [8] as shown in Figure 3. The angle of repose was determined from geometry of the cone formed by vertical free fall of chickpea seeds on horizontal surface as following:

$$\theta = \tan^{-1}\left(\frac{2h}{D}\right) \quad \text{…. (6)}$$

where h and D are height and diameter of the cone respectively.

Fig 3: Measurement of terminal velocity by air column method

2.2 Mechanical properties

Coefficients of static friction, internal seed friction and angle of friction were determined with the procedure suggested by Kachru *et al*., (1994) [8]. A HD plus Texture analyzer was used to study the rupturing force for chickpea seeds as shown in figure 4. The first rupture force and peak rupture force were observed for randomly selected seeds in different axial direction. Replicated trials were conducted for the experiments.

Fig 4: Determination of seed rupturing force by texture analyzer

3. Results and discussion

3.1 Physical properties

The mean value of moisture content of the chickpea seeds on

dry basis was found to be 10.72 per cent.
Figure 5 shows the frequency distribution curves for chickpea seed dimensions at 10.72 per cent moisture content (db). Nearly 94 per cent of chickpea seeds had a length ranged from 7.96 – 9.47 mm, about 74 per cent of seeds had width ranged from 5.76 – 6.68 mm and about 89 per cent of a seeds had a thickness ranged from 5.45 – 6.67 mm.

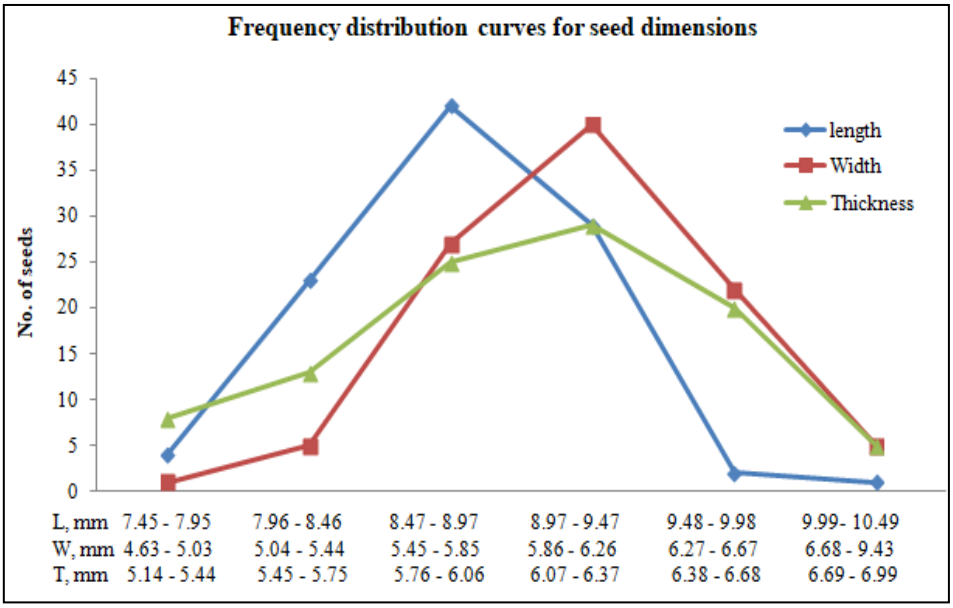

Fig 5: Frequency distribution curves for chickpea seed dimensions at 10.72 per cent moisture content (db).

The obtained mean values for chickpea seeds with its standard deviation for length, width, thickness, AMD, GMD and area were 8.76 ± 0.46 mm, 6.08 ± 0.40 mm, 6.06 ± 0.52 mm, 6.97 ± 0.41 mm, 6.86 ± 0.41 mm and 148.08 ± 17.92 mm^2, respectively. The sphericity ranged from 0.71 to 0.90. The average value of sphericity with its standard deviation was 0.78 ± 0.03. The thousand seed weight for chickpea seeds was 182.18 ± 1.78 gm. The bulk density and true density with standard deviation were found to be 881.49 ± 4.14 kg/m^3 and 1237.93 ± 11.33 kg/m^3, respectively. The angle of repose was 23.09 ± 0.66 degrees and the terminal velocity was found to be 6.28 ± 0.66 m/s. Similar observations for physical properties of chickpea seeds were reported by Sinha *et al.* (2019) [11] and Sushilendra *et al.* (2020) [12] for chickpea seeds of different varieties and moisture levels.

3.2 Mechanical Properties

For chickpea, the internal seed friction coefficient was found to be 0.63 ± 0.01. The coefficient of static friction for M.S. sheet, G. I. sheet, plywood, acrylic and painted M.S. sheet were found to be 0.49 ± 0.01, 0.42 ± 0.01, 0.55 ± 0.01, 0.36 ± 0.01 and 0.30 ± 0.01, respectively. The angle of friction for chickpea seeds on MS sheet, GI sheet, plywood, acrylic and painted surface was found to be 25.18°, 22.87°, 29.14°, 19.65 and 16.47°, respectively.
The rupturing forces were analyzed using texture analyzer. At 10.72 percent moisture content (db), the first and peak rupture forces along different axial directions for chickpea seeds were ranged from 70 to 260 N and 238 to 440 N, respectively. Figure 5 shows the graph for rupturing forces of chickpea seeds. Isik abs Isik (2008) [7] and Ayman *et al.* (2010) [3] reported similar results for mechanical properties of chickpea seeds.

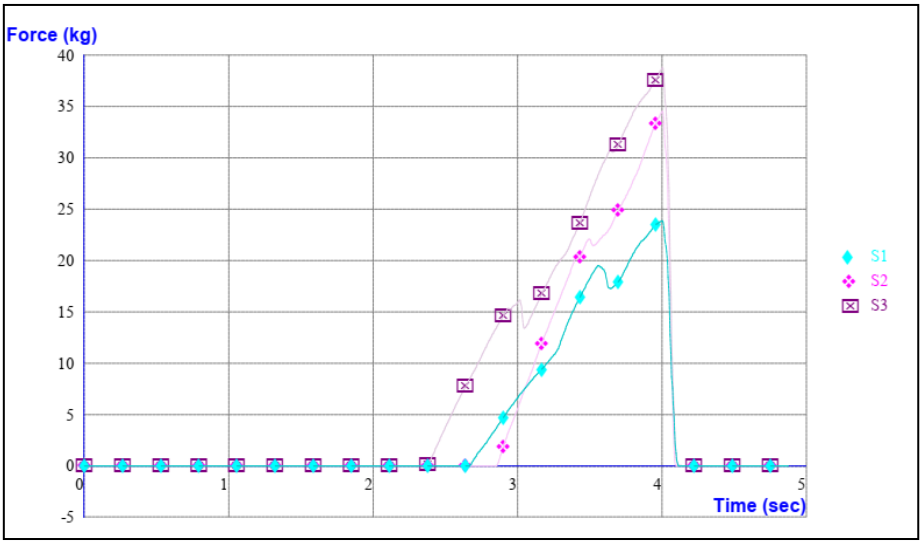

Fig 5: Seed rupturing force for chickpea seeds

4. Conclusions

The linear dimensions for chickpea seeds varied from 4.63 to 10.16 mm. The average values of sphericity, thousand seed weight bulk density and true density were 0.78, 182.18 g, 881.49 and 1237.93 kg/m^3, respectively. The coefficients of friction were varied on different surfaces and the seed rupturing force varied along the axial dimensions of the chickpea seed in the range from 70 to 440 N. The results obtained from the study will be helpful in design and development of threshing mechanism for chickpea crop.

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