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Image Analysis as a Non-Destructive Approach in Selective Characterization of Promising Indian Chickpea Cultivars †

Ravneet Kaur [1], Shubhra Shekhar [2], Praveen Kumar [3] and Kamlesh Prasad [1,*]

[1] Department of Food Engineering and Technology, SLIET, Longowal, India; ravneetrke@gmail.com
[2] Department of Food Process Engineering, NIT, Raurkela, India; shekharshubhra@gmail.com
[3] Department of Mechanical Engineering, SLIET, Longowal, India; praveen_pme1802@sliet.ac.in
* Correspondence: profkprasad@gmail.com
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Abstract: Physical properties of food grains play an important role in optimizing the design parameters for machines and equipment, process automation, and determining the efficiency of the machine during various stages like harvesting, drying, storage, de-hulling, and other unit operations. Thus, the aim of the present study was to characterize the promising chickpea varieties for their physical properties and determine the image processing technique was employed to study the geometrical variations among different chickpea varieties. The digital image processing approach offers rapid computation of shape and size parameters and validation of data obtained from manual methods by using digital vernier calipers. The dimensional parameters, namely length, breadth, and thickness were examined that were further used to calculate the derived parameters as mean diameters, sphericity, surface area, volume, and aspect ratio. The length of chickpea grains of different varieties lies in the range of 7.42 ± 0.63 to 8.78 ± 0.46 mm, width varied from 5.33 ± 0.38 to 6.50 ± 0.42 mm and thickness ranged from 5.17 ± 0.46 to 6.23 ± 0.45 mm. The sphericity of the grains was found to vary from 75.84 ± 3.03% to 82.89 ± 3.92%. The 3-D imaging approach was adopted for the determination of various physical properties of grains, the results obtained are precise and thus this approach may help in the characterization of grains and in process automation. It was observed that the hilum portion of the chickpea contributes less than 5% to the total chickpea volume. Thus, if this portion is removed, it results in a significant improvement in the sphericity of the grains to behave as spheres. Therefore, calculations for physical properties may be carried out considering chickpea grains as spherical objects. During milling, the hilum portion is the first to be broken due to abrasion as it is brittle in nature, and this also results in a decrease in the coefficient of friction. Thousand kernel weight, bulk density, and true density were also examined as they are the important parameters that help in designing the storage bins. Chickpea cultivars were evaluated for the frictional properties, i.e., angle of repose and coefficient of static friction. The coefficient of static friction was determined over different common contact material surfaces and it was found that all the varieties have a maximum coefficient of friction over plyboard followed by the galvanized iron sheet and minimum on the glass surface.

Keywords: Chickpea; physical properties; image analysis; hilum; frictional properties

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1. Introduction

Chickpea (*Cicer arietinum* L.) is a widely cultivated leguminous crop, with India being its largest producer in the world. It is a drought-resistant crop; thus, it does not require excessive water for its cultivation and can be easily grown in rain-deprived regions. Depending on the shape and size of the seed, chickpea is classified into two types- Desi and Kabuli. Desi chickpea seeds are characterized by a dark seed coat, small size, and angular shaped, whereas Kabuli seeds are larger in size and have beige colored seed coat and an owl head shape. Chickpea is consumed as a whole or in the processed form [1]. Mainly desi chickpea is used for processing into products like chickpea split (commonly known as chana dhal) and chickpea flour for their use in the preparations of various processed food products [2]. Many of the processed chickpea-based products are generally employ hydration to a suitable extent to maintain the quality characteristics [3–7].

Determining the physical properties of food grains is vital in the fields like agricultural engineering. Shape and size play an important role in classification, quality inspection, and describing food grains' behavior during handling and processing. Design parameters of the equipment required for handling food grains during processing are optimized depending on the physical and engineering properties of food grains [8]. These properties play an important role in designing various machines involved in harvesting, handling, storage, and processing. For example, the designing of conveying and transporting structures required during processing depends on the grains' frictional properties [9]. Besides equipment design, the physical properties can also be used to study the differences among various cultivars of food grains. Various researchers have determined the physical properties of food grains [9–13].

Dehusking, splitting, and milling yield are correlated with the seed shape and size [14]. Generally, dimensional measurements are carried out manually using Vernier calipers that are time-consuming, so the digital image processing approach was employed in present study to validate the data obtained using the manual method. This would help in process automation by applying rapid and non-destructive methods for the characterization of seeds. The present study aimed to characterize different chickpea cultivars for their physical properties, including dimensional, gravimetric, and frictional properties. The 3-D image processing approach was employed to study the geometrical variations among different cultivars and validate data obtained from manual methods.

2. Materials and Methods

Eleven promising chickpea cultivars of Desi type were procured from Punjab Agriculture University, Ludhiana (Figure 1). Cleaning of the grains was carried out manually to remove impurities, broken and damaged grains. Airtight containers were used to store the seeds under refrigerated conditions.

Figure 1. Selected Indian promising chickpea cultivars (1–11, Top left to bottom right).

2.1. Physical Properties

2.1.1. Dimensional Properties

The three major perpendicular dimensions, namely Length (L), Breadth (B), and thickness (T) of control and soaked grains, were measured using dial-type vernier caliper (Mitutoyo Corporation, Japan) with the least count of 0.02 mm. These major dimensions were used to calculate the derived parameters, namely, Arithmetic mean diameter (Da), Geometric mean diameter (Dg), Surface area (S), Sphericity (φ), and Volume (V) using the Equations (1)–(5) [15].

$$D_a = \frac{(L + B + T)}{3} \tag{1}$$

$$D_g = (L \times B \times T)^{1/3} \tag{2}$$

$$S = \pi D_g^2 \tag{3}$$

$$\varphi = \frac{(L \times B \times T)^{1/3}}{L} = \frac{D_g}{L} \tag{4}$$

$$V = \frac{\pi}{6} D_g^3 \quad (5)$$

2.1.2. Gravimetric Properties

Chickpea samples were weighed using an electronic weighing balance with milligram accuracy. The bulk volume of the weighed samples was measured using a measuring cylinder, and it was used to calculate the bulk density. The true density was measured using the liquid displacement method [16]. True density and bulk density values were used to calculate the porosity of the samples using Equation (6):

$$Porosity\ (\%) = \frac{TD - BD}{TD} \times 100 \quad (6)$$

2.1.3. Frictional Properties

Angle of repose was calculated by measuring the height and diameter of the heap formed during free fall of grains (Figure 2). The captured picture for the same and as represented are also used to verify the traditional approach.

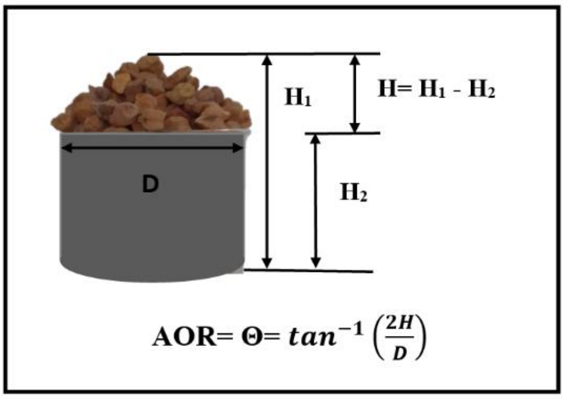

Figure 2. Setup to determine the angle of repose using image analysis.

The static coefficient of friction was measured over different surface materials, namely plyboard (parallel (COFPAR) and perpendicular (COFPER), galvanized iron sheet (COFGIS) and glass (COFG). A plastic cylinder of known diameter was placed on the tilting surface and was filled with nearly 100 gm sample. The cylinder was slightly raised to avoid touching the surface and the adjustable surface was tilted gradually until the cylinder started to slide. The angle at which cylinder containing the sample starts to slide is measured manually and optically to calculate coefficient of friction. Figure 3 illustrates the experimental setup to measure the coefficient of friction on different surface materials.

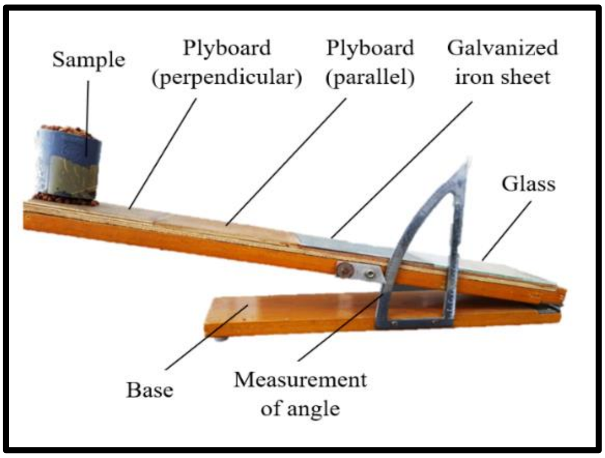

Figure 3. Setup for measurement of coefficient of friction on different surfaces.

2.1.4. 3D Scanning

A turntable and 3D Scanning system (Range Vision Spectrum, Italy) was used to reverse chickpea engineering. The structured light 3D scanner has 0.06–0.25 mm 3D resolution with 3.1 MP colour industrial camera having an accuracy of 0.04–0.12 mm. The sample chickpea placed at a permissible range of 1 mm to 1000 mm for scanning. By setting the smallest calibration field, the contour of the sample chickpea was obtained. The lines and dots fringed patterns are projected on the object using the triangulation technique. The image sensor projects the structured light on the sample chickpea and coordinates collected throughout the whole projection plane of the pattern when reflected light falls on camera. After collecting coordinates of the sample chickpea, a polygon mesh (PGM) model obtained by cross-link a group of points or a point cloud (PC) using polygon elements (PGE) in 3D measurement and modeling software. A texture applied to the PGM to allow for the reconstruction of 3D models. The representative figure for the selected chickpea cultivars has been assessed to use image analysis of 3D scanned images as an alternative precision approach to the traditional approach in dimensional characterization of biomaterials (Figure 4).

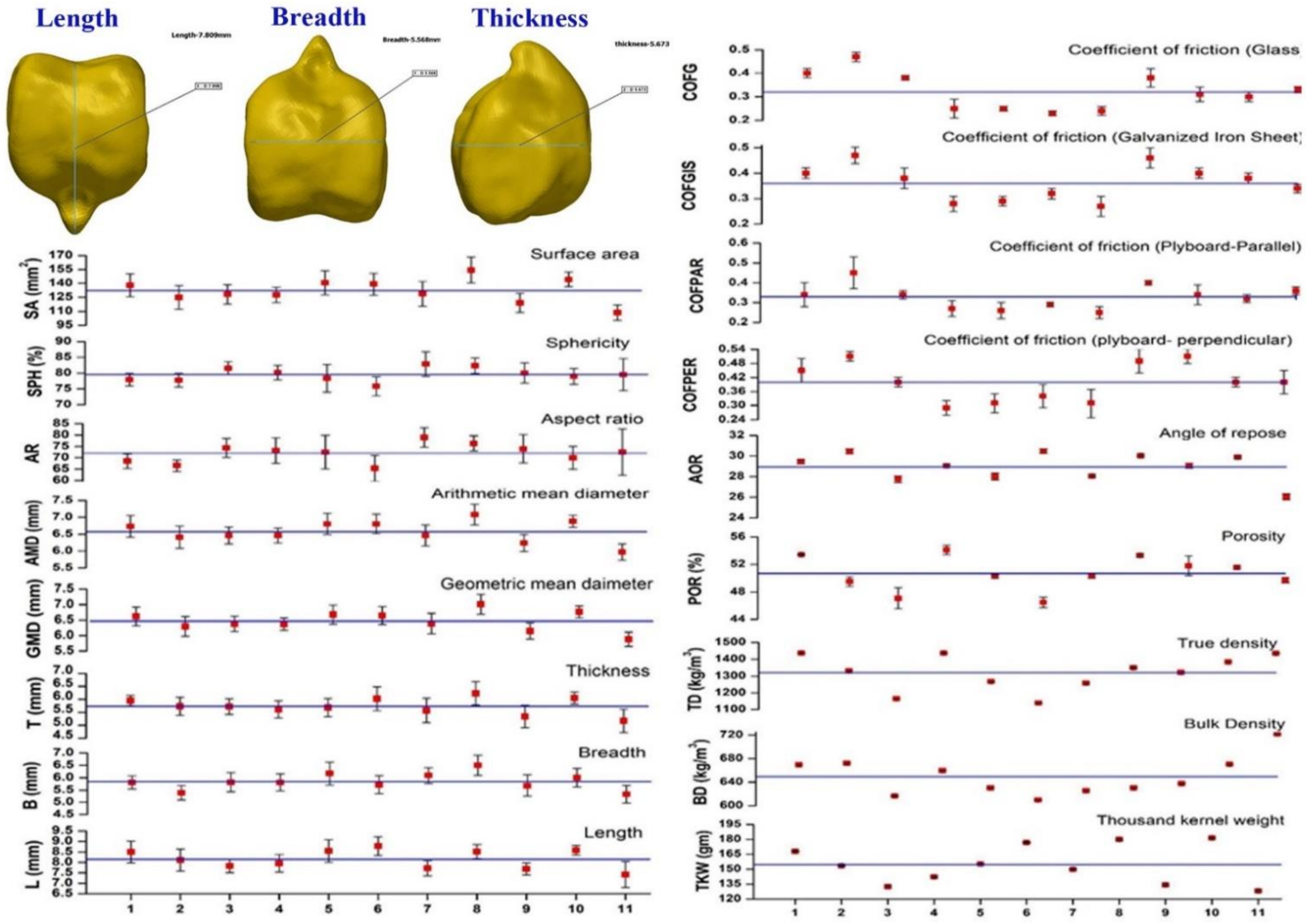

Figure 4. 3-D image of representative chickpea cultivar and cultivar dependent selected physical properties.

3. Results and Discussion

Comparative physical characteristics of selected chickpea cultivars with respect to their mean are presented in Figure 4. Length of chickpea cultivars varied form 7.42 ± 0.63 to 8.78 ± 0.46mm with an average of 8.15 ± 0.45 mm. RSG963 variety was found to have maximum value, whereas PBG-7 was having least value. Average breadth and thickness of chickpea cultivars was 5.85 ± 0.34 and 5.73 ± 0.32, respectively. PBG-7 had minimum value, and variety PDG-4 had maximum value for both breadth and thickness. A similar trend was observed for derived parameters, namely geometric mean diameter and arithmetic mean diameter. The aspect ratio varied from 65.34 ± 5.67 to 78.97 ± 4.22, with a minimum value for RSG-963 and a maximum for GPF-2. Similar results were obtained for sphericity, with an average value of 79.59 ± 2.12%. Higher sphericity values indicate that shape of the seed tends to be more towards spherical. PBG-7 showed minimum values for surface area, and the largest surface area was that of PDG-4. Less than 2% deviation was noticed among the techniques if on one-to-one measurements. However, these deviations were higher in the larger lots due to the existing variability among the internal variations associated with the cultivars having more standard deviations in the dimensional characteristics.

The gravimetric and frictional properties of chickpea cultivars are presented in Figure 4. It was observed that thousand kernel weight was maximum for GNG-2171 whereas PBG-7 had minimum value. The cultivar RSG-963 showed minimum values for bulk density, true density, and porosity. Bulk density was maximum for PBG-7, whereas true density and porosity were found to be maximum in the case of PBG-8. The porosity of the samples is dependent on bulk and true density. It is an important parameter that affects the water absorption characteristics of the seeds. The angle of repose had an average value of 28.94 ± 1.36 degrees. Average values of coefficient of friction on different surface materials indicated maximum values on plyboard (in the perpendicular direction), while it was least on the glass surface for all the cultivars. Cultivar GNG-2144 showed a maximum coefficient of friction on all the surfaces. Frictional properties play an important role in the designing of hoppers for the processing of food grains.

4. Conclusions

The physical properties of selected Indian chickpea cultivars were evaluated by using the traditional and optical approaches. The size, shape, and different characteristics varied and were cultivar dependent. Lesser differences in principal dimensional parameters using 3-D image analysis are more precise and could be applied as an alternative to the manual method. Moreover, the image analysis approach is less time-consuming, reliable and may find a role in process automation.

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

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