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Proceeding Paper

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

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Abstract: The 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 such as harvesting, drying, storage, dehulling, and other unit operations. Thus, the present study aimed to characterize the promising chickpea varieties for their physical properties, and the 3D scanned image 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 and 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 lay in the range of 7.42 ± 0.63 to 8.78 ± 0.46 mm, the width varied from 5.33 ± 0.38 to 6.50 ± 0.42 mm, and the 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 3D imaging approach was adopted for the determination of the various physical properties of grains, and the results obtained are precise; thus, this approach may help in the characterization of grains and process automation. It was observed that the hilum portion of the chickpea contributes to less than 5% of 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 their storage bins. Chickpea cultivars were evaluated for their frictional properties, i.e., the angle of repose and the 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 a minimum coefficient of friction on the glass surface.

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

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1. Introduction

Chickpeas (*Cicer arietinum* L.) are a widely cultivated leguminous crop with India being the 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, chickpeas are classified into two types: desi and kabuli. Desi chickpea seeds are characterized by a dark seed coat, small size, and angular shape, whereas kabuli seeds are larger and have a beige colored seed coat and an owl head shape. Chickpeas are consumed as a whole or in processed forms [1]. Desi chickpeas are mainly used for processing into products such as 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 generally employ hydration to a suitable extent to maintain their quality characteristics [3–7].

Determining the physical properties of food grains is vital in the fields of 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 design 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 which are time-consuming, so the digital image processing approach was employed in the 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 3D image processing approach was employed to study the geometrical variations among different cultivars and validate the data obtained from manual methods.

2. Materials and Methods

Eleven promising chickpea cultivars of the desi type were procured from Punjab Agriculture University, Ludhiana (Figure 1). The cleaning of the grains was carried out manually to remove impurities and broken and damaged grains. Airtight containers were used to store the seeds under refrigerated conditions. The initial moisture content of the seeds was measured using the hot air oven method, and it varied in the range of $7.54 \pm 0.54\%$ to $9.31 \pm 0.37\%$ for all the chickpea varieties.

2.1. Physical Properties

2.1.1. Dimensional Properties

The three major perpendicular dimensions, namely length (L), breadth (B), and thickness (T) of all the cultivars, were measured using a dial-type vernier caliper (Mitutoyo Corporation, Kawasaki, Japan) with the least count of 0.02 mm. These major dimensions were used to calculate the derived parameters, namely, the arithmetic mean diameter (D_a), geometric mean diameter (D_g), surface area (S), sphericity (φ), and volume (V) using the Equations (1)–(5) [15].

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

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

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

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

$$V = \frac{\pi}{6} D_g^3 \tag{5}$$

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

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

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

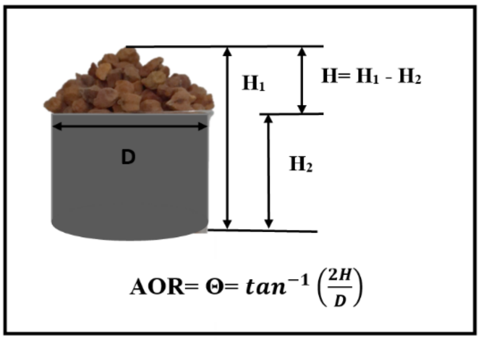

Figure 2. Setup to determine the angle of repose using image analysis.

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 a 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 the cylinder containing the sample starts to slide was measured manually and optically to calculate the coefficient of friction. Figure 3 illustrates the experimental setup to measure the coefficient of friction on the different surface materials.

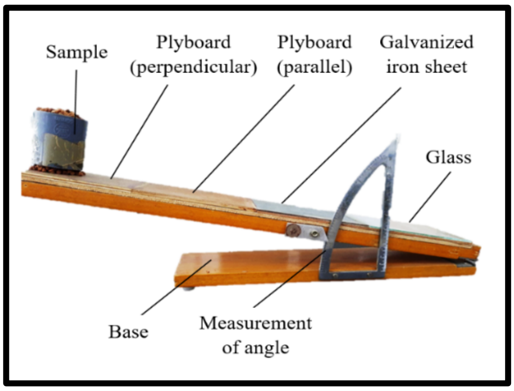

Figure 3. Setup for measurement of coefficient of friction on different surfaces.

2.1.4. Scanning

A turntable and scanning system (Range Vision Spectrum, Moscow, Russia) was used for reverse chickpea engineering. The structured light scanner had 0.06–0.25 mm resolution with a color 3.1 MP industrial camera having an accuracy of 0.04 to 0.12 mm. The sample chickpea was 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 were projected onto the object using the triangulation technique. The image sensor projected the structured light onto the sample chickpea and coordinates were collected throughout the whole projection plane of the pattern when reflected light fell on the camera. After collecting the coordinates of the sample chickpea, a polygon mesh (PGM) model has been obtained by cross-linking a group of points or a point cloud (PC) using polygon elements (PGE) in measurement and modeling software. A texture was applied to the PGM to allow for the reconstruction of models. The representative respective images for the selected chickpea cultivars were assessed as an alternative precision approach to the traditional approach used in dimensional characterization of biomaterials (Figure 4).

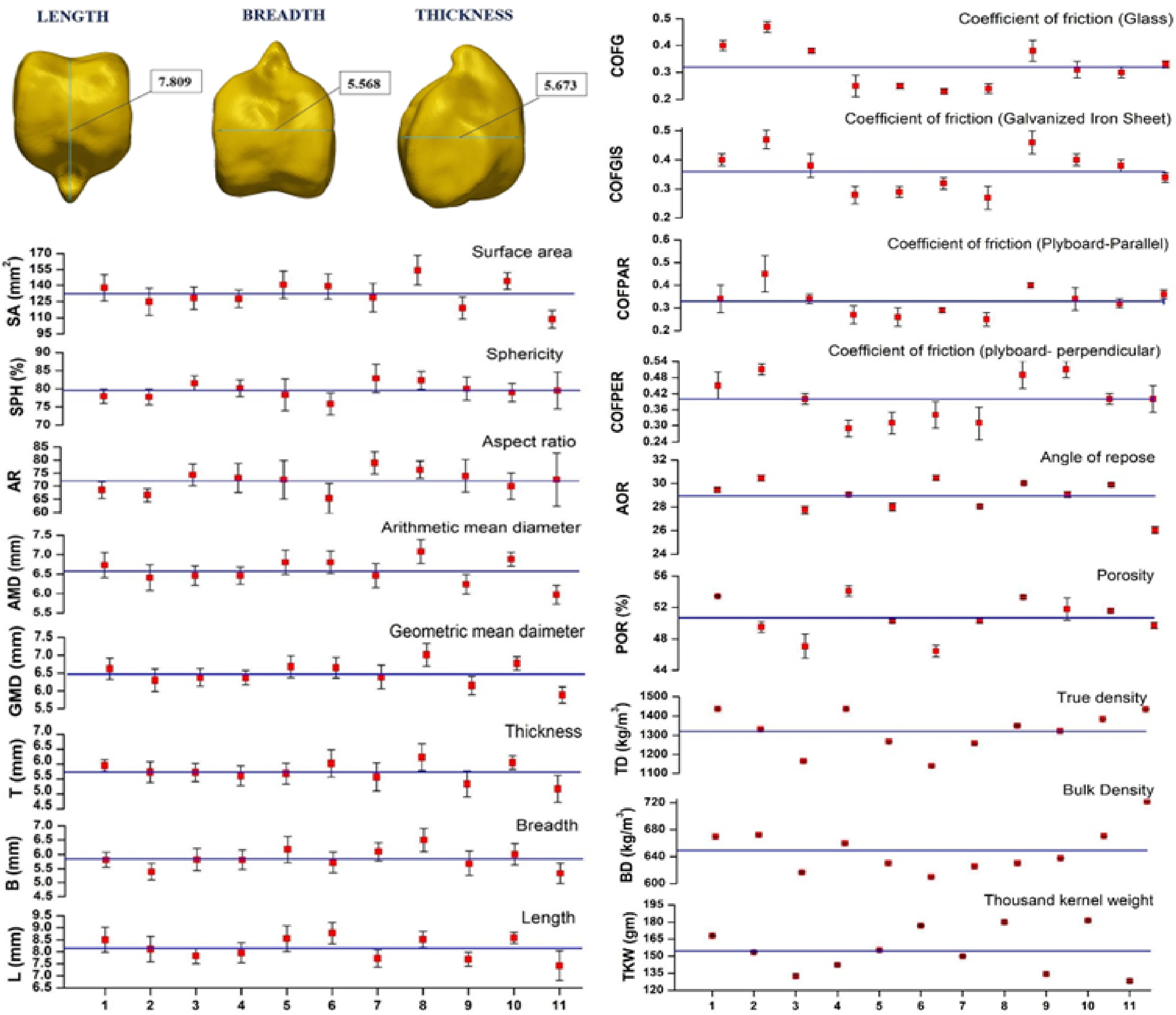

Figure 4. Three-dimensional image of representative chickpea cultivars and cultivar-dependent selected physical properties.

3. Results and Discussion

The comparative physical characteristics of the selected chickpea cultivars with respect to their mean are presented in Figure 4. The lengths of the chickpea cultivars varied from 7.42 ± 0.63 to 8.78 ± 0.46mm with an average of 8.15 ± 0.45 mm. The RSG963 variety was found to have the maximum value, whereas PBG-7 had the least value. The average breadth and thickness of the chickpea cultivars were 5.85 ± 0.34 and 5.73 ± 0.32, respectively. PBG-7 had the minimum value, and the variety PDG-4 had the maximum value for both breadth and thickness. A similar trend was observed for derived parameters, namely the 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 the shape of the seed tends to be more spherical. PBG-7 showed minimum values for surface area, and the largest surface area was that of PDG-4. Variations in principle dimensional parameters are related to the changes in sphericity, surface area, and other derived parameters, as indicated in the above equations. Less than 2% deviation was noticed among the techniques using 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 their dimensional characteristics.

The gravimetric and frictional properties of the chickpea cultivars are presented in Figure 4. It was observed that a thousand kernel weight was maximum for GNG-2171, whereas PBG-7 had a 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 $\pm$ 1.36 degrees. The angle of repose is affected by the moisture content and shape of the seeds. Average values of coefficient of friction on the 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 design of hoppers for the processing of food grains.

4. Conclusions

The physical properties of selected Indian chickpea cultivars were evaluated by using traditional and optical approaches. The size, shape, and different characteristics varied and were cultivar dependent. Lesser differences in principle dimensional parameters using 3D image analysis is more precise and could be applied as an alternative to the manual method. Moreover, the image analysis approach is less time-consuming and reliable and may find a role in process automation. Chickpea seeds are irregular in shape, and thus it becomes difficult to characterize them geometrically using manual methods. Three-dimensional scanners can simplify this problem. This technique can also be employed in quality control steps to speed up the process with fewer chances of error. Three-dimensional scanning can be effectively used to generate data that can be used in computational domains to carry out simulation studies.

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