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Influence of Varieties on the Flow Characteristics of Chickpea Flour and the Physico-Functional Properties of Seeds and Splits

Deribe Mengistu
Food Science and Nutrition, Food Engineering, Deber Zeit Agricultural Research Centre, Bishoftu, Ethiopia

ABSTRACT

Background and Objective: Chickpeas and their products are important and affordable sources of protein in Ethiopia, especially compared to animal-based proteins. This study aimed to evaluate the effect of variety on the physical and functional properties of seeds and split chickpeas, as well as on the flowability of chickpea flour from four selected varieties. **Materials and Methods:** Chickpea varieties including Arerti, Hora, Eshete and Geletu were obtained from the Debre Zeit Agricultural Research Centre. The analysis involved whole seeds, splits and flours from these varieties. Extensive cleaning removed foreign matter and sorting excluded broken or spoiled seeds. Data analysis utilized Analysis of Variance (ANOVA) with SAS software at ($p \leq 0.05$). **Results:** The study found significant variations in the physical and functional properties of chickpea seeds and splits among varieties, highlighting the need for equipment adjustments. Chickpea flour's flowability properties, such as bulk and tapped density, also differed notably ($p \leq 0.05$) among varieties, with bulk density ranging from 606.78 to 643.33 kg/m^3 and tapped density from 834.58 to 917.45 kg/m^3. Similarly, the compressibility index varied significantly ($p \leq 0.05$) across varieties, indicating poor flowability. The color variations in chickpea flour were significant ($p \leq 0.05$), with L, a* and b* values ranging from 82.77 to 86.12, -0.67 to -1.49 and 22.07 to 24.97, respectively, alongside varying chroma and hue angle values ranging from 22.06 to 25.01 and from 86.60 to 87.87°, respectively. **Conclusion:** The study's findings can inform the development of diverse processing equipment, optimizing their design by accounting for variability.

KEYWORDS

Chickpea, varietal influence, seed characteristics, physico-functional attributes, chickpea flour flowability

INTRODUCTION

Ethiopia is the largest producer of chickpeas in sub-Saharan Africa, accounting for over 90% of chickpea production in the region and ranking sixth globally[1]. Chickpeas are the most important pulse crop in the country, with the sweet desi type dominating the bulk of production and the kabuli type grown in limited areas[2]. In Ethiopia, chickpea cultivation covers 213,048.42 ha of land, with a production of about 401,238.51 metric ton[3]. Chickpeas are a vital food source in many countries and have a significant impact on the diets of malnourished communities globally[4] and provide nutritious food for a growing world population and will continue to be increasingly important. They are an excellent source of protein and

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carbohydrates, with superior protein quality compared to other legumes like pigeon peas, black gram and green gram. Additionally, they are high in fiber and low in fat[5] and contain essential minerals like calcium, magnesium, zinc, potassium, iron and phosphorus, as well as vitamins[6].

They are rich in vitamins, making them an ideal alternative to meat and an important legume crop due to their abundance of nutritional content[7]. So, nutritionists in many countries worldwide have emphasized the value of chickpeas in terms of nutrition and body health[8]. In Ethiopia, various methods for processing and using chickpeas have been developed, including split seeds, soaked and roasted seeds and boiled seeds. Pulses, including chickpeas, lentils and fava beans, are a significant part of the daily diet of most people. Traditional dishes often incorporate these pulses, such as *Shiro and* splits a popular chickpea sauce for lunch or dinner[9].

The physical properties of whole and split chickpeas have a great influence on the behavior of grains when subjected to various postharvest handling and processing processes. Knowledge of these properties is needed to adequately design appropriate equipment and conduct harvest and post-harvest operations such as cleaning, conveying, storage and processing[10]. The physical and functional properties of seeds are crucial for seed preservation. Additionally, the functional characteristics of chickpea grains, including hydration capacity, swelling capacity and cooking duration, are essential. Hydration capacity shows a positive relationship with hydration index, swelling capacity and cooking time[11]. Swelling capacity is significant characteristic for consumers, particularly when consuming whole grains post-soaking and cooking[12]. This trait correlates positively with hydration capacity, swelling index and 100-seed weight[13]. To meet the demand of the fast-growing population of the country for chickpeas, the use of mechanization systems in production, handling, storage and processing is indispensable. With the development of the food industry in the country, the potential of its processing from the field to industry is very high. In order to ensure optimal use by the agro-processing and food industries, the objective of this study is to investigate the physical and functional attributes of both whole and split chickpeas, alongside analyzing the flow characteristics of flour derived from diverse varieties developed by research institutions.

MATERIALS AND METHODS

Sample: The study was conducted from April, 2022 to February, 2023 at the Food Science and Nutrition Department of the Ethiopian Institute of Agricultural Research. Four chickpea varieties Arertin, Hora, Eshete and Geletu were obtained from the Debre Zeit Agricultural Research Centre for their high yield and disease resistance. These chickpea varieties were cultivated under uniform agro-ecological conditions and at the same location, with detailed soil characteristics provided in Table 1. The sample chickpea variety was cleaned of foreign materials like dust, stones, dirt, immature seeds, damaged seeds and other impurities through manual selection, the healthy seeds chosen for further analysis were stored at 5 in an airtight plastic bag for further analysis.

Physical dimensions of seeds and split of chickpea: Relevant physical-dimensional properties of whole and split chickpeas were measured the method of Adebowale *et al.*[10]. Hundred seeds and split of chickpea

Table 1: Soil traits of the chickpea cultivation area for this study

Evaluated soil parameter	Cultivated in the Debre Zeit location
pH (1:2.5 H_2O)	7.31
Total nitrogen (%)	0.08
Available P (Olsen method)	19.52
Organic matter (%)	1.14
Cation exchangeable (meq/100 g)	29.67
Exchangeable K (cmol+/kg)	0.73
Texture type	Heavy clay

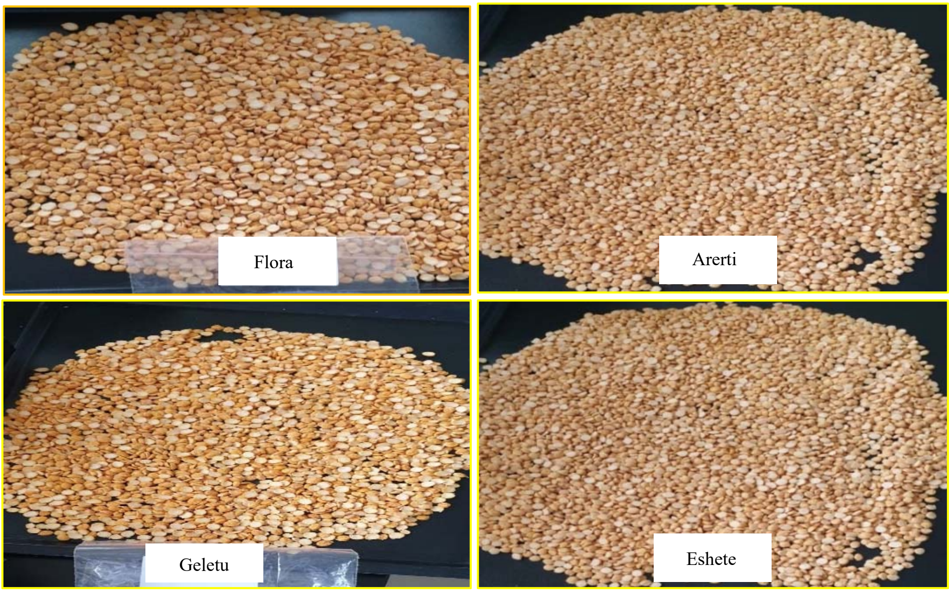

Fig. 1: Split of chickpea variety

variety were randomly selected (Fig. 1) and their three principal linear dimensions, namely length (L), width (W) and thickness (T) were measured using a digital vernier caliper (TA, M5 0-300 mm, China) with an accuracy of 0.01 mm.

Geometric and arithmetic mean diameter: The geometric and arithmetic mean diameter of seeds and split of chickpea were calculated using the Eq. (1 and 2)[14,15]:

$$Dg = (LWT)^{\frac{1}{3}} \tag{1}$$

$$Da = \frac{(L + W + T)}{3} \tag{2}$$

Volume and surface area: The volume and surface area of seeds and split of chickpea were then determined by using Eq. (3 and 4)[16-18]:

$$V = \frac{\pi B^2 L^2}{6\,(2L - B)} \tag{3}$$

$$S = \frac{\pi B L^2}{2L - B} \tag{4}$$

where, $B = \sqrt{WT}$, L, W and T are length, width and thickness of seeds/split of chickpea in mm, respectively.

Sphericity: Sphericity is defined as the ratio of the surface area of a sphere having the same volume as the seeds and split of a chickpea to the surface area of the sphere. The sphericity was determined using the Eq. 5[18]:

$$\phi = \frac{D_g}{L} \times 100 \tag{5}$$

where, ϕ is sphericity, D_g is geometric mean diameter and L is length of seeds/split of chickpea.

Mass-volume-area properties

Hundred seed weight: The hundred seeds' weight was determined using a digital electronic balance (Model Pag2102c, Ohaus Corporation, USA) having an accuracy of 0.001 g following the procedure as described by Wodajo *et al*.[18]. Hundred randomly selected seeds and split of chickpeas were counted and weighed.

Bulk density: The bulk density was determined by filling a graduated cylinder of 500 mL with the seeds and splitting of chickpeas up to their brim by pouring from a height of about 150 mm and the excess materials were removed by striking off the top with a plank of wood to make it level and weighing the contents of the cylinder. The bulk density (ρ_b) of chickpeas grains was calculated by dividing the mass (M) by the volume (V_b) of 500 mL and expressed by kg/m^3 [18]:

$$\rho_b = \frac{M}{V_b} \tag{6}$$

True density: True density of the seeds and split of chickpeas was determined by the liquid displacement method. Toluene was used because it has lower surface tension so that it fills even shallow dips in seeds and lower specific mass when compared to water[19]. The true density was determined by calculating the average ratio of their masses to the volume of toluene displaced by the seeds, achieved by immersing a measured amount of chickpea seeds in toluene. True density (ρ_t) was then calculated using Eq. 7[19]:

$$\rho_t = \frac{M}{V2 - V1} \tag{7}$$

where, M is the mass of seeds/split of chickpea (kg), V1 and V2 are the initial and final volume of toluene (m^3).

Porosity: Porosity is defined as the ratio of the volume of pores to the total volume. The porosity (ε) of seeds and split of chickpea were calculated from the mean values of bulk density (ρ_b) and true density (ρ_t) using Eq. 8[19]:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \tag{8}$$

Angle of repose: Angle of repose of the seeds, split and flour of chickpea were determined using a topless and bottomless cylinder of 10 cm diameter and 15 cm height. The cylinder was placed on a table and filled with grams. Then it was raised off the table slowly until the grain mass formed a conical heap on the table surface. The diameter and height of conical heap were measured. The angle of repose,   was calculated by using the Eq. 9[19]:

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right) \tag{9}$$

where, θ is angle of repose in degrees, h and d is height and the diameter of the cone, respectively.

Co-efficient of static friction: The coefficient of static friction for whole and split chickpeas against a stainless-steel surface was evaluated. A 50 mm diameter, 100 mm height polyvinylchloride cylindrical pipe was placed on an adjustable tilting plate, filled with the grain sample and oriented towards the test surface. The cylinder was slightly elevated to avoid contact. Gradually, the surface of the cylinder was lifted using a screw device until the cylinder began to slide. The angle of tilt of the surface was measured using a graduated scale placed on the side of the test surface per the method described by Wandkar *et al.*[20]. The static coefficient of friction was then calculated using Eq. 10:

$$\mu = \tan\alpha \tag{10}$$

where, μ is static coefficient of friction and α is angle of inclination.

Determination of functional properties and cooking time

Hydration and swelling capacity: The hydration and swelling capacity of the both seeds and split of the chickpea were determined using the method of Natabirwa *et al.*[21] and Seena and Sridhar[22].

Hydration and swelling index: ydration and swelling index were calculated using the method of Natabirwa *et al.* [21] and Seena and Sridhar[22].

Hydration and swelling coefficients: The hydration coefficient of both seeds and split of chickpea seeds immersed in distilled water for 24 hrs was estimated as the percentage increase in grain mass. The volume of seeds/split of chickpea before and after soaking in distilled water for 24 hrs was calculated using displaced water. The swelling coefficient was estimated as a proportion of the volume of seeds/split of chickpea after soaking divided by the before soaking[23].

Cooking time: Cooking time was determined using a Mattson cooker and has been stated in a variety of ways, including the time necessary for 50% of the seeds to be pierced. The 25 clean seeds and a split of chickpea were steeped in distilled water in triplicate at a ratio of 1:4 for 24 hrs before being drained. The grains were put on a rack of Mattson cooker with plungers on each grain and cooked on a hot plate[23]. The time was determined based on the time it took to penetrate 50% of the seeds.

Determination of flowability of chickpea flour

Bulk and tapped density: To determine the bulk density of chickpea flour, a 2 g sample was placed in a 10 mL graduated cylinder and its volume was measured. The bulk density was calculated by dividing the mass by the volume (kg/m^3). Afterward, the flour sample inside the graduated cylinder underwent 150 taps (compression) using a glass rod at a consistent speed. The tapped density was determined by dividing the mass by the sample volume after the taps[24]:

$$\text{Bulk density } (\rho_b) = \frac{M}{V_b} \tag{11}$$

$$\text{Tapped density } (\rho_t) = \frac{M}{V_t} \tag{12}$$

where, M is mass of chickpeas flour (g), V_b is volumes for bulk and V_t is volumes for tapped (mL).

Hausner ratio and Carr's index: Flow characteristics of chickpea flour were estimated using the Hausner ratio (HR) and Carr's index (CI), which is the ratio of tapped density to bulk density. The Hausner ratio and Carr's index were calculated using the following Eq. (13 and 14)[25]:

$$\text{Hausner ratio (HR)} = \frac{\rho_t}{\rho_b} \tag{13}$$

$$\text{Carr's index (CI)} = \left(\frac{\rho_t - \rho_b}{\rho_t}\right) \times 100 \tag{14}$$

Colour measurement: The colour of chickpea flour was measured using Konica Minolta equipment (CHROMA METRE CR-400, Japan). The color readings were given in L*, a* and b* format. The L* represents the lightness/darkness, positive a* values show redness and negative values show greenness, while b* indicates yellowness for positive values and blueness for negative values. The color measurement process was carried out seven times and the L*, a* and b* values were calculated using the method described by Jangchud *et al.*[26]:

$$\text{Hue angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \tag{15}$$

$$\text{Chroma} = \sqrt{(a^*)^2 + (b^*)^2} \tag{16}$$

where, Hue angle is the colour perceived by the naked eye and Chroma is the chromaticity coordinate which is perpendicular to the distance from lightness.

Statistical analysis: All data collected in the study were averaged over three replications and were analyzed by Analysis of Variance (ANOVA) using SAS (version 9.4). A statistical difference was tested at ($p \leq 0.05$) and the difference between means was compared using the least significance difference (LSD).

RESULTS AND DISCUSSION

Physical dimension properties of seeds and split of chickpea: The effect of variety on the dimensional properties of seeds and split of chickpeas are shown in Table 2. The dimensional properties of seeds and split of chickpeas were significant ($p \leq 0.05$) among the varieties, indicating that these should be taken into account when designing processing equipment. Length, width and thickness of seeds and split of chickpea variety ranged from 7.77 to 9.62, 5.70 to 7.60, 5.94 to 7.64 and 5.80 to 8.25, 4.78 to 7.15 and 2.87 to 3.37 mm, respectively. The length, width and thickness of Geletu were significantly ($p \leq 0.05$) higher than Eshete, Arerti and Hora for seeds and split of chickpea. Comparisons in terms of length, width and thickness indicate that Geletu variety is longer, wider and thicker than Arerti, Hora and Eshete varieties. The result of this study was higher than 6.25, 5.31 and 2.91 mm in length, width and thickness of split of chickpea reported by Adegunwa *et al.*[27] and higher than the values 6.42 to 6.70,5.20 to 5.38 and 2.50 to 2.72 mm of chickpea splits of variety PBG-1 that reported by Jangchud *et al.*[26] The geometric and arithmetic mean diameters of seeds and split of chickpea were ranged from 6.40 to 8.23, 6.47 to 8.29, 4.30 to 5.83 and 4.48 to 6.25 mm, respectively, being this value lower than the length and width and higher than thickness. Geletu reported the highest geometric and arithmetic values and the lowest values were recorded for Eshete for seeds and split of chickpeas, respectively. This is due to the size of the chickpea seed having the largest and smallest sizes contributed to the highest and lowest geometric and arithmetic mean diameters. This result of geometric mean diameters is higher than the value 4.40 to 4.59 mm of chickpea splits of variety PBG-1 reported by Prasad *et al.*[28]. The geometric mean diameter is helpful for estimating the projected area of a particle traveling in a turbulent or near-turbulent area of an air stream, which is a valuable parameter in the design of separation systems for seeds and extraneous materials[18].

The results of the volume and surface area of both seeds and split of chickpea are presented in Table 2. Varieties showed significant differences ($p \leq 0.05$) in the volume and surface area of seeds and split of chickpeas. The results showed that the volume and surface area of split of chickpea ranged from 30.62 to 73.92 mm^3 and 49.56 to 90.39 mm^2, respectively. The highest mean values were observed for Geletu variety (242.43 mm^3 and 190 mm^2), while the lowest values were recorded for Eshete variety (110.14 mm^3 and 113.46 mm^2). The surface area plays a crucial role in determining the shape of both seeds and split of chickpea, providing valuable insights into their behavior on oscillating surfaces during processing[28].

Table 3 presents the sphericity values for seeds and split of chickpeas. The sphericity of seeds and split of chickpeas exhibited a significant ($p \leq 0.05$) difference among varieties. For seeds, the sphericity ranged

Table 2: Effect of variety on physical dimensions of seeds and split of chickpea

	Seeds (*)				Split (**)			
Parameter	Arerti	Hora	Eshete	Geletu	Arerti	Hora	Eshete	Geletu
Length (mm)	8.89 ± 0.23^{b}	8.89 ± 0.23^{b}	7.77 ± 0.27^{c}	9.62 ± 0.42^{a}	7.48 ± 0.25^{b}	7.45 ± 0.13^{b}	5.80 ± 0.16^{c}	8.25 ± 0.09^{a}
Width (mm)	6.88 ± 0.25^{b}	7.26 ± 0.00^{a}	5.70 ± 0.20^{c}	7.60 ± 0.23^{a}	6.28 ± 0.21^{c}	6.74 ± 0.31^{b}	4.78 ± 0.16^{d}	7.15 ± 0.14^{a}
Thickness (mm)	6.77 ± 0.08^{c}	7.29 ± 0.14^{b}	5.94 ± 0.20^{d}	7.64 ± 0.23^{a}	3.14 ± 0.05^{b}	3.50 ± 0.04^{a}	2.87 ± 0.12^{c}	3.37 ± 0.15^{a}
Geometric mean dia. (mm)	7.45 ± 0.15^{c}	7.83 ± 0.05^{b}	6.40 ± 0.21^{d}	8.23 ± 0.27^{a}	5.28 ± 0.11^{c}	5.60 ± 0.07^{b}	4.30 ± 0.13^{d}	5.83 ± 0.08^{a}
Arithmetic mean dia. (mm)	7.51 ± 0.15^{c}	7.87 ± 0.05^{b}	6.47 ± 0.21^{d}	8.29 ± 0.27^{a}	5.63 ± 0.13^{c}	5.90 ± 0.08^{b}	4.48 ± 0.14^{d}	6.25 ± 0.04^{a}
Volume (mm^3)	175.90 ± 9.58^{c}	209.71 ± 5.06^{b}	110.14 ± 10.90^{d}	242.43 ± 20.84^{a}	54.94 ± 3.25^{b}	68.35 ± 3.68^{a}	30.62 ± 2.97^{c}	73.92 ± 3.95^{a}
Surface area (mm^2)	154.59 ± 5.76^{c}	172.96 ± 2.59^{b}	113.46 ± 7.470^{d}	190.68 ± 11.27^{a}	74.20 ± 3.08^{c}	84.36 ± 2.48^{b}	49.56 ± 3.14^{d}	90.39 ± 2.73^{a}

Values are Means±SD and values in the same row with different superscript letters were significantly different from each other ($p<0.05$) for seeds (*) and split chickpeas (**)

Table 3: Effect of variety on mass-volume-area properties of seeds and split of chickpea

	Seeds (*)				Split (**)			
Parameter	Arerti	Hora	Eshete	Geletu	Arerti	Hora	Eshete	Geletu
Sphericity (%)	83.85 ± 0.56^{bc}	86.33 ± 1.02^{a}	82.45 ± 1.09^{c}	85.66 ± 1.08^{ba}	70.63 ± 1.16^{b}	75.23 ± 2.07^{a}	74.12 ± 0.86^{a}	70.73 ± 1.48^{b}
Hundred seed weight(g)	27.03 ± 0.33^{c}	31.58 ± 1.05^{b}	17.35 ± 0.05^{d}	34.06 ± 0.09^{a}	12.73 ± 0.38^{c}	15.65 ± 0.08^{b}	7.37 ± 0.24^{d}	16.50 ± 0.46^{a}
Bulk density (kg/m^3)	792.26 ± 1.33^{b}	784.32 ± 0.14^{b}	834.12 ± 7.82^{a}	798.01 ± 26.22^{b}	723.00 ± 9.63^{c}	713.74 ± 4.79^{c}	774.63 ± 10.61^{b}	851.44 ± 7.96^{a}
True density (kg/m^3)	1339.52 ± 3.11^{b}	1314.86 ± 2.57^{c}	1354.77 ± 0.35^{a}	1323.17 ± 8.27^{c}	1304.92 ± 22.90^{a}	1307.20 ± 22.16^{a}	1285.68 ± 9.74^{a}	1302.76 ± 5.07^{a}
Porosity (%)	40.85 ± 0.04^{ba}	40.35 ± 0.13^{b}	38.43 ± 0.59^{c}	41.37 ± 0.31^{a}	44.59 ± 0.23^{a}	45.38 ± 1.29^{a}	39.75 ± 0.37^{b}	34.64 ± 0.36^{c}
Angle of repose (°)	40.85 ± 0.04^{ba}	40.35 ± 0.13^{b}	38.43 ± 0.59^{c}	41.37 ± 0.31^{a}	30.96 ± 1.91^{ba}	31.90 ± 0.95^{a}	29.50 ± 0.96^{b}	31.82 ± 1.00^{ba}
Coefficient of static friction on stainless steel	0.28 ± 0.01^{b}	0.24 ± 0.00^{c}	0.32 ± 0.00^{a}	0.33 ± 0.01^{a}	0.45 ± 0.00^{b}	0.36 ± 0.00^{d}	0.46 ± 0.01^{a}	0.40 ± 0.00^{c}

Values are Means±SD and values in the same row with different superscript letters were significantly different from each other ($p<0.05$) for seeds (*) and split chickpeas (**)

from 82.45 to 86.33%, while for a split of chickpeas, it ranged from 70.63 to 75.23%. The highest sphericity value was observed for the Hora variety for seeds and split of chickpeas respectively, whereas the lowest value of sphericity for seeds and split of chickpea was found for Eshete and Arertin varieties, respectively. Notably, these values are higher than the reported sphericity range of 68.28 to 69.21% for chickpea splits of the PBG-1 variety, as reported by Prasad *et al.*[28]. The higher sphericity values indicate that the split of chickpea tend to have a more spherical shape, approaching a semi-spherical form.

Mass-volume-area properties of seeds and split of chickpea: The mass-volume-area properties of seeds and split of chickpeas are presented in Table 3. The hundred seed weight for chickpea seed varieties ranged from 17.35 to 34.06 g, while for split of chickpea varieties, it ranged from 7.37 to 16.50 g. Geletu exhibited a significantly higher hundred seed weight than Arertin, Hora and Eshete for both seeds and split of chickpea. On the other hand, Eshete had the lowest values among the varieties for both seeds and split of chickpea. The findings of this study indicate that the reported values (28.11 to 39.72 g) by Legesse *et al.*[29] for another chickpea variety were lower than the values obtained in this study. A previous study on chickpea seeds reported higher values, which could be attributed to differences in the variety and environmental factors. When comparing seeds with a split of chickpeas, the weight of a hundred split of chickpeas is less than that of seeds. This is because a split of chickpeas only has a single cotyledon and the dehulling process also reduces the weight by removing the seed coat. The weight of one hundred seeds of seeds and the split of chickpeas a crucial factors in designing equipment for cleaning, separating, conveying and elevating operations. It can also be used to estimate the total bulk mass of seeds and split of chickpeas during bulk processing.

Density data for foods is necessary for the pneumatic and hydraulic transport of seeds[29]. There were significant differences ($p \leq 0.05$) observed in the bulk density values of seeds and split of chickpeas among varieties. The bulk density of the seeds and split of chickpea varieties ranged from 784.32 to 834.12 kg/m^3 and 713.74 to 851.44 kg/m^3, respectively. The bulk density of agricultural products such as seeds and split of chickpeas is a vital factor in determining packaging and storage needs. It is also used to address heat transfer problems involving thermal properties, determine Reynold's number of materials and estimate the pressures of storage structures and chemical composition[18]. There is a significant ($p \leq 0.05$) difference in the true density between the chickpea seed varieties. The true density of the chickpea seeds varieties had ranged from 1314.74 to 1354.44 kg/m^3, while the varieties did not show any significant variations in their true density of split of chickpea. The true density observed was higher than those reported by Prasad *et al.*[28] for split of chickpea variety PBG-1 that ranged from 1110 to 1250 kg/m^3. Data on the true density of split of chickpeas is used to develop separation or cleaning process equipment for split of chickpeas.

Porosity refers to the percentage of space in bulk seeds and split of chickpeas that is not filled by seeds and split of chickpea. The effect of variety on the porosity of seeds and the split of chickpeas is shown in Table 2. The values show a significant ($p \leq 0.05$) difference due to variety. The values range from 38.43 to 41.37 and 34.64 to 45.38% for seeds and split chickpeas, respectively. Arerti and Hora split of chickpea showed no significant differences in their porosity. These values are higher than those reported for chickpea split of Indian variety PBG-1[26]. Low porosity seeds dry slowly, while seeds with larger porosity have more aeration and water vapor diffusion during the drying process.

The angle of repose is significant for constructing hopper openings, storage bin sidewall slopes and bulk seed transfer chutes for seeds and split chickpeas. The effect variety on the angle of repose of seeds and split of chickpea were shown in Table 2. The values were significant ($p \leq 0.05$) differences due to variety of seeds and split of chickpeas. The angle of repose for chickpea seed varieties ranged from 38.43 to 41.37°, while for split of chickpea varieties, it ranged from 29.50 to 31.90°. This falls within the range of values (27.3 to 31.81°) reported by Prasad *et al.*[28] for split of chickpea of other varieties.

Table 3 presents the determined coefficient of static friction for seeds and split of chickpeas in relation to stainless steel. Among the varieties, there were significant differences ($p \leq 0.05$) in the values of the coefficient of static friction for seeds and split of chickpeas. The range of the coefficient of static friction for chickpea seed varieties varied from 0.24 to 0.33, while for split of chickpea varieties; it ranged from 0.36 to 0.46. Frictional properties such as the coefficient of static friction play a crucial role in grain processing, particularly when designing hoppers for milling machinery.

Functional properties and cooking time: The functional properties and cooking time of seeds and split of chickpea varieties were analyzed, as shown in Table 4. The hydration capacity of seeds and split of chickpea varied significantly ($p \leq 0.05$) among varieties, with values ranging from 0.14 to 0.38 g/seed for seeds and 0.07 to 0.16 g/cotyledon for split of chickpea. The Geletu variety had the highest hydration capacity of seeds, whereas Eshete had the lowest. According to Özer *et al.*[6] and Sastry *et al.*[12] this result is between 0.28 to 0.4 and 0.96 to 0.485 g/seed for Tunisian and Indian chickpea seed varieties, respectively. On the other hand, the Eshete variety had the highest hydration capacity for split chickpeas, whereas Geletu had the lowest. The hydration index and hydration coefficient of chickpea seeds ranged from 0.77 to 1.04% and 1.77 to 2.04%, respectively. The highest was recorded for Hora and the lowest was for Eshete for both parameters. However, there were no significant differences among the Arertin, Hora and Geletu varieties in terms of both parameters. This result of the hydration index was found to be lower than the range of 0.98 to 1.08 recorded for Kabuli type chickpeas by Khattak *et al.*[32] While the hydration index and hydration coefficient values of the split of chickpea varied from 0.93 to 1.06% and 1.93 to 2.06%, respectively. Eshete had the highest hydration index and hydration coefficient for a split of chickpeas, whereas Geletu had the lowest. However, there was no significant difference between the Hora, Arerti and Gelatu varieties, but these three were significantly ($p \leq 0.05$) different from the Eshete variety.

A significant difference was observed in swelling capacity among varieties, which varied from 0.13 to 0.37 mL/seed for seeds and 0.03 to 0.96 mL/cotyledon for a split of chickpeas, respectively. Geletu and Hora varieties had the highest values for seeds (0.37 and 0.35 mL/seed, respectively), while Eshete recorded the highest swelling capacity for a split of chickpea (0.96 mL/cotyledon). This result was found to be within the range of 0.082 to 0.463 mL/seed recorded for the India chickpea variety that is reported by Sastry *et al.*[12]. The swelling index and swelling coefficient of chickpea seeds of the variety Eshete were found to be statistically lower ($p \leq 0.05$) than the values that varied from 1.20 to 1.33 and 2.20 to 2.33% for the Arerti, Hora and Geletu varieties, which were not significantly different among themselves ($p > 0.05$). These results were found to be within the range of 0.88 to 1.6 of the recorded values for the India chickpea variety[13]. Whereas, there was a significant difference ($p \leq 0.05$) in the swelling index and swelling coefficient values among the split of chickpea varieties. The highest swelling index value (1.23) was of Eshete variety and the lowest (0.36) was of Gelatu variety. A significant difference was observed in the swelling coefficient among the split of chickpea varieties was varied from 1.38 to 2.23. Eshete variety seeds have a low hydration capacity, hydration index, swelling capacity and swelling index indicating the hardness and permeability of the seed coat than the split of chickpea Eshete variety.

Cooking time is a crucial factor in determining the quality of pulses. Longer cooking durations require more energy and can lead to nutritional loss, which may limit the final product[33]. The cooking times of different chickpea seed varieties are presented in Table 4. The values were significantly ($p \leq 0.05$) different among varieties and ranged from 25.66 to 88.93 min for seeds. The longest cooking time (88.93 min) was observed for the Eshete variety, while the shortest (25.66 and 32.31 min) were for the Geletu and Hora varieties, respectively. Due to their greater hydration and swelling capabilities, Hora and Gelatu require a shorter cooking time. The range of cooking times found in this study is lower than the 33-92 min recorded for 91 chickpea varieties from Turkey's[6]. The differences could be due to genetic makeup. In the case of split chickpea varieties, there was a significant ($p \leq 0.05$) difference. The highest value (4.91 min) was recorded for the Arerti variety and the lowest (1.27 min) for the Eshete variety. Therefore, the Eshete

Table 4: Effect of variety on functional and cooking characteristics of seeds and split of chickpeas

	Seeds (*)				Split (**)			
Parameter	Arerti	Hora	Eshete	Geletu	Arerti	Hora	Eshete	Geletu
HC (g/seed or cotyledon)	0.29 ± 0.01^{c}	0.36 ± 0.01^{b}	0.14 ± 0.01^{d}	0.38 ± 0.00^{a}	0.12 ± 0.00^{c}	0.15 ± 0.00^{b}	0.16 ± 0.01^{a}	0.07 ± 0.00^{d}
HI	1.00 ± 0.01^{a}	1.04 ± 0.01^{a}	0.77 ± 0.07^{b}	1.00 ± 0.03^{a}	0.94 ± 0.00^{b}	0.96 ± 0.05^{b}	1.06 ± 0.05^{a}	0.93 ± 0.04^{b}
Hydration coefficient (%)	2.00 ± 0.01^{a}	2.04 ± 0.01^{a}	1.77 ± 0.07^{b}	2.00 ± 0.03^{a}	1.94 ± 0.00^{b}	1.96 ± 0.00^{b}	2.06 ± 0.05^{a}	1.93 ± 0.04^{b}
SC (mL/seed or cotyledon)	0.30 ± 0.00^{b}	0.35 ± 0.00^{a}	0.13 ± 0.01^{c}	0.37 ± 0.03^{a}	0.10 ± 0.00^{c}	0.14 ± 0.00^{b}	0.96 ± 0.02^{a}	0.03 ± 0.02^{d}
SI	1.33 ± 0.03^{a}	1.21 ± 0.00^{a}	0.89 ± 0.04^{b}	1.20 ± 0.14^{a}	0.80 ± 0.03^{b}	1.00 ± 0.00^{ba}	1.23 ± 0.08^{a}	0.36 ± 0.25^{c}
Swelling coefficient (%)	2.33 ± 0.03^{a}	2.21 ± 0.00^{a}	1.89 ± 0.04^{b}	2.20 ± 0.14^{a}	1.80 ± 0.03^{b}	2.00 ± 0.00^{ba}	2.23 ± 0.08^{a}	1.38 ± 0.25^{c}
Cooking time (min)	46.07 ± 2.18^{b}	32.31 ± 2.68^{c}	88.93 ± 9.24^{a}	25.66 ± 0.77^{c}	4.91 ± 0.32^{a}	4.09 ± 0.04^{b}	1.27 ± 0.02^{c}	4.44 ± 0.30^{b}

Values are expressed in Means±SD. Means across the columns with different letters are significantly different ($p<0.05$) between varieties for seeds (*) and split chickpeas (**)

Table 5: Effect of variety on flowability properties of chickpea flour

Parameter	Arerti	Hora	Eshete	Geletu
ρ_b (kg/m^3)	606.78±0.72^c	626.77±0.52^b	643.33±4.67^a	623.73±3.14^b
ρ_T (kg/m^3)	838.88±2.21^b	834.58±0.42^b	913.05±1.23^a	917.45±4.72^a
Carr index (%)	27.67±0.28^c	24.90±0.10^d	29.54±0.42^b	32.01±0.01^a
Hausner ratio	1.42±0.08^a	1.39±0.05^a	1.40±0.03^a	1.47±0.08^a
Angle of repose (°)	52.38±1.23^a	47.78±0.14^b	51.29±0.15^a	44.53±1.38^c
L*	86.12±0.47^a	85.83±0.25^a	83.65±0.25^b	82.77±0.50^c
a*	-0.82±0.18^b	-0.67±0.05^b	-0.89±0.20^b	-1.49±0.16^a
b*	22.07±0.33^c	23.46±0.23^b	22.04±0.87^c	24.97±0.55^a
Chroma	22.08±0.32^c	23.47±0.23^b	22.06±0.86^c	25.01±0.55^a
Hue angle (°)	87.87±0.50^a	88.36±0.13^a	87.68±0.58^a	86.60±0.30^b

Values are Means±SD and values in the same row with different superscript letters were significantly ($p<0.05$) different from each other

variety of split required the least cooking time, likely due to its high hydration capacity, hydration index, swelling capacity and swelling index, indicating that it easily absorbs water during soaking because it does not have a seed coat. In general, it can be concluded that the differences between varieties significantly affect the water-related properties and cooking time.

Flowability and colour of chickpea flour

Bulk and tapped density: Bulk and tapped density are affected by the particle size and density of the flour and it's very important in determining the packaging requirement, material handling and application in the wet processing food industry[34] Table 5, presents bulk density data of chickpea flour affected by variety. The values showed significant ($p\leq 0.05$) differences among variety. The bulk density of chickpea flour varied from 606.78 to 643.33 kg/m^3 with the highest value (643.33 kg/m^3) being recorded for Eshete variety and lowest (606.78 kg/m^3) for Arerti. These results are higher than the range 536 to 571 kg/m^3 that were reported by Kaur and Singh[35]. Bulk density values of flours of Hora and Geletu chickpea varieties are not a significant difference. Tapped density data of chickpea flour affected by variety. The values showed significant ($p\leq 0.05$) differences among varieties with values varying from 834.58 to 917.45 kg/m^3.

Geletu and Eshete varieties had significantly ($p\leq 0.05$) higher values of 917.45 and 913.05 kg/m^3, respectively, than those 834.58 and 838.88 kg/m^3 which were recorded for Hora and Arertin varieties, respectively. The tapped density of chickpea flour indicated the flowability of flour with bulk density to calculate.

Carr index, Hausner ratio and angle of repose: The Carr index and Hausner ratio of the chickpea flours are presented in Table 5. Carr's index showed a significant ($p\leq 0.05$) difference among varieties with values varying from 27.67 to 32.01%. The highest value was recorded for Geletu variety and lowest for Arerti. Similarly, Hausner ratio of chickpea flour didn't show a significant ($p>0.05$) difference among varieties. The Hausner ratios of chickpea flours were found to be between 1.39 and 1.47. Based on the scale of flow ability, the flour of Arerti, Hora and Eshete varieties had almost similar flow properties which are poor flowability and Geletu had a flow property that is very poor flowability. The same conditions are verified by the data of the angle of repose, which are all 45° and above which indicated poor flow ability according to the scale defined by Gani *et al.*[36].

Colour of chickpea flour: The color is a quality attribute that consumers prefer, as it is seen as an indicator of quality. According to Table 5, the L* value, which represents the lightness of chickpea flour, ranged from 82.77 to 86.12. The highest L* values, 85.83 and 86.12, were recorded for Arerti and Hora flour, respectively. These values suggest that these flours had a lighter color compared to the other two chickpea flours. The findings of this study align with the range of 81.64 to 86.41 reported by Kaur and Singh[37] for chickpea flour from different cultivars.

The a* and b* values represent the red or green colour of chickpea flour and showed significant ($p \leq 0.05$) differences due to variety. However, Arerti, Hora and Eshete varieties were not significantly different in their a* values from each other. The a* values varied from -0.67 to -1.49 with value -1.49 being recorded for Geletu variety. The findings of this study revealed higher results than the range of -0.72 to -1.10 for chickpea flour from various chickpea cultivars, as reported by Kaur and Singh[37]. The b* value was varied from 22.07 to 24.97. The highest was recorded for flour of Gelatu variety and the lowest values (22.04 and 22.07) were recorded for Eshete and Arerti varieties, respectively. These values were higher than the range 14.12 to 20.75 for chickpea flours of different cultivars reported by Kaur and Singh[35].

The chroma of chickpea flour represents the perpendicular distance from its lightness and indicates the depth of its color. The recorded chroma values for chickpea flour ranged from 22.06 to 25.01. These values were similar to the range of 20.37 to 22.89 recorded for soybean flour by Paucar-Menacho *et al.*[38]. The Hue angle of chickpea flour varied from 86.60 to 87.87°, but the Arerti, Hora and Eshete varieties did not significantly differ from each other in terms of Hue angle. These results were consistent with the findings of Paucar-Menacho *et al.*[38] for soybean flour, which ranged from 87.49 to 89.41°. Overall, the flours of all varieties were relatively bright and light yellow.

The study highlights the crucial need to consider chickpea variety in equipment design for processing, as it reveals significant variations in physical and functional properties among varieties. Additionally, the observed variability in flowability properties of chickpea flour emphasizes the necessity for tailored processing methods to ensure consistent quality. Furthermore, the findings offer valuable insights for developing processing equipment customized to different chickpea varieties, thereby enhancing efficiency and product quality, while also aiding in product development and quality control processes in the food industry by understanding color variations in chickpea flour. Recommendations include urging manufacturers of chickpea processing equipment to accommodate variability in physical and functional properties across different chickpea varieties to optimize equipment design and advocating for further research to explore additional factors influencing chickpea flour properties and develop more comprehensive processing guidelines. However, it is important to acknowledge limitations, such as the study's focus on a limited number of chickpea varieties, which may not fully represent the diversity present in chickpea crops and the unexplored influence of environmental conditions and processing methods on chickpea flour properties, potentially impacting the generalizability of the findings.

CONCLUSION

This study extensively examined the impact of variety on the physical and functional characteristics of chickpea seeds and splits, as well as the flowability and color attributes of chickpea flour from four different varieties. The results showed significant differences in the physical properties of seeds and splits among the varieties, emphasizing the need for customized processing equipment. Moreover, there were notable variations in the functional properties across the varieties. The analysis of chickpea flour revealed diverse flowability and color properties among the different varieties. This research enhances our knowledge of chickpea varieties, providing valuable insights for post-harvest management and industrial processing. Further research is recommended to thoroughly explore the optical and thermal properties of chickpea varieties.

SIGNIFICANCE STATEMENT

This study aimed to evaluate the impact of different chickpea varieties on the physical and functional characteristics of seeds and splits as well as on the flowability of chickpea flour. Significant variations in these properties were observed among the varieties, emphasizing the necessity for customized processing equipment designs. The study also emphasized the importance of considering variety-specific processing methods due to differences in functional properties. In particular, it was noted that the flowability characteristics, comprising bulk and tapped density, as well as the compressibility index, exhibited variations, which could suggest potential challenges in attaining desirable flow behavior. These findings are crucial for developing adaptable processing equipment to enhance efficiency and quality across various chickpea varieties.

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