Nutritional compositions and functional properties of New Ethiopian chickpea varieties: Effects of variety, grown environment and season

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ABSTRACT
Chickpeas are nutritious legumes, which are a rich source of proteins, fiber, carbohydrate, vitamins and minerals. Factors affect the nutritional composition of crops including chickpeas like variety, growing environments and seasons are the most common. Studies have not yet reported on the effects of variety, grown location, and grown season on specifically for Ethiopia chickpea nutritional and functional characteristics. To address this, eleven released chickpea varieties were grown at three locations in Ethiopia, during 2018 and 2019 main cropping season, representing three different agroecological environments. Then functional properties, proximate and minerals composition and in chickpea flour were determined. Variation in most nutritional composition and functional properties of eleven chickpea varieties were observed among grown within each location in each season. Statistical analysis of combined data showed significant differences among varieties, locations, and grown season for each measured parameter. High proportion of the total variation for almost studied parameters explained by the main effects of variety indicates a significant heritability for them. Growing location was found to have a significant effect on all functional properties except OAC, total ash, crude fat, crude protein, carbohydrate, energy, calcium, magnesium, iron and zinc. Grown Season was found to affect OAC, WAC, SC, FS, EA, total ash, calcium, magnesium, iron and zinc. Rainfall is the climate characteristic that may be responsible for these year-dependent differences. HC and SC ($r = 0.902$) and energy and fat ($r = 0.800$) showed positive correlation whereas, carbohydrate and protein ($r = -0.896$) and energy and fiber ($r = -0.674$) showed negative correlation. The current study established a better understanding of the varietal effects of genotype and environment on functional and nutritional composition properties of chickpea flours.

Introduction
Chickpea (*Cicer arietinum* L.) is the world’s third most planted pulse crop.[1] Chickpea is an important pulse crop grown and consumed all over the world, especially in the Afro-Asian countries. Chickpea seed is a good source of carbohydrates (52.40 to 70.90%), protein (12.40 to 30.60%) and minerals like Ca, Fe, Mg, K, P, Zn and Cu. It also has vitamin A and B–carotene,[2] and the protein quality is considered to be better than other pulses. All of the important amino acids are present in significant quantities in chickpea. The central storage of carbohydrate is starch, which itself is followed by dietary fiber. Lipids are available in small amounts; however, chickpeas are rich in nutritionally beneficial unsaturated fatty acids, such as linoleic and oleic acid.
Chickpea is one of Ethiopia’s most vital annual crops, both in terms of overall farmed pulses area and direct human consumption. In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop.\textsuperscript{[3]} In Ethiopia, its first chickpea was recorded in 1520 BC.\textsuperscript{[4]} Ethiopia is Africa’s leading chickpea grower, accounting for over half of the continent’s production between 1994 and 2006. It’s also the world’s seventh largest producer, accounting for almost 2\% of worldwide chickpea supply.

Plant composition can be manipulated in a multitude of ways. Chemical composition of all crops including legumes grains are significantly influenced by environmental conditions and also genetic variations.\textsuperscript{[2,5]} Breeding studies are being conducted in order to find high-yielding chickpea cultivars in particular to meet the escalating demand for chickpea seeds. The functional and nutritional profiling of released and improved Ethiopian chickpea varieties are not well emphasized. It is possible by breeding and selection to develop varieties high in certain nutrients. The nutritional composition of chickpeas varies widely depending on developmental stages, growing regions, and agricultural practices, even within the same variety.\textsuperscript{[6]} The topsoil, fertilizer applications, elevation, geography, weather, length of growth period, light levels, length of day, and heat all contribute to a plant’s growing environment. An experimental showed that the nutritional quality (especially micronutrients) of different type of beans were reduced under drought stress.\textsuperscript{[7]} Shifting seasonal means and increased seasonal variability will impact food production, pests and diseases in crops and livestock.\textsuperscript{[8]} This has the potential to include impacts on the nutrient quality of foods due to accelerated development under warmer conditions.\textsuperscript{[9]} These vary the nutritional makeup of crops in a variety of ways, all of which are interconnected.\textsuperscript{[10]}

Improved chickpea variants have been introduced and circulated to farmers to improve productivity and disease resistance. The focus has been on releasing chickpea varieties with higher yields and better agronomic features, with far less priority on quality parameters. Lack of knowledge on the nutritional quality of released Ethiopian chickpea varieties in different agroecology’s and this also might have contributed to affect the functional properties (processing quality) of different chickpea-based food products. Despite the existence of published works, describing the effects of different processing methods on nutritional composition of some chickpea varieties but the nutritional profile information about Ethiopian released chickpea varieties in different agroecological environments were lacking, so in order to fill this gap this study were initiated with the objectives of, to explore the impact of variety, growth environment and grown season on the nutritional composition, mineral contents and functional properties of released Ethiopian chickpea varieties.

Material and methods

Genotypes

Eleven chickpea varieties were collected from Debre Zeit Agricultural Research Center, Ethiopia and then cultivated at three locations (Deber Zeit (DZ), Minjar (MI) and Chefe Donesa (CD)) in Ethiopia 2018 and 2019 in main season. From eleven chickpea varieties, the three (Natoli, Dimtu and Teketaye) were desi type whereas; the other nine varieties are kabuli type. All chickpea varieties were planted in field in three blocks with a RCBD design in replication. Chickpea grain were randomly harvested from each block and mixed together, after which the seeds were dried in the sun before being transferred to the laboratory.

Field experimental trials

A total eleven varieties, nine were improve and two where candidate varieties of chickpea varieties were grown in RCBD with three replications on plot size 1.2 m × 4 m at three different agroecology’s.
Table 1. Cultivation locations soil characteristics.

| Tested Soil Parameter’s | Deber Ziet | Minjar | Chefe Donsa |
|-------------------------|------------|--------|-------------|
| pH (1:2.5 H₂O)          | 7.31       | 6.76   | 8.27        |
| Total Nitrogen (%)      | 0.08       | 0.12   | 0.07        |
| Available P (Olsen Method) | 19.52    | 12.41  | 9.91        |
| Organic matter (%)      | 1.14       | 1.83   | 1.26        |
| CEC (meq/100 g)         | 29.67      | 36.91  | 62.52       |
| Exchangeable K (cmol(+)/kg) | 0.73   | 0.97   | 1.06        |
| Texture group           | Heavy Clay | Clay   | Clay        |

CEC: cation exchangeable capacity

Testing environments

Chefe Donsa represents the high-altitude area at 2200–2750 m above mean sea level and characterized by receiving high annual rainfall and poorly drained black vertisols soils types. The second site Debre Ziet represents the mid-altitude area at 1900–2300 m above mean sea level and was characterized by moderate annual rainfall and well-drained black vertisols. The third site Minjar was representative of low altitudes at 1575 m above mean sea level and the moisture stress area with having erratic annual rainfall (500 mm) and well-drained Andosol’s soil type. As per recommendation of each site, similar agronomic practices were conducted for all varieties. All of the investigations were carried out in triplicate, utilizing three samples generated from a pool of powered samples. Weather data such as temperature, relative humidity, wind speed, and total rainfall were recorded (Table 2).

Sample preparation

At maturity stage, the grain yield was harvested and brought into the laboratory for quality parameter analysis. Chickpea grain samples were manually cleaned by sieving and sorting with hand picking to remove the stones, foreign materials (large chaff, dusts and soils) and other cereals. All the samples were ground by a laboratory mill (Cyclo sample mill model) to pass through a 75 μm sieve and were kept in moisture proof plastic bag placed in air tight tin container at 4°C. The seed flours processed samples were evaluated for nutritional composition and flour techno-functional properties.

Flour functional properties

Water and oil absorption capacity of chickpea flours were evaluated by method of Sosulski et al.,[11] they were expressed as g of water or oil, absorbed per g of the sample on a dry-weight basis. Foaming properties were determined according to the method of Okaka and Potter.[11] About 1 g of flour was

Table 2. Description of the test locations used in the study.

| Year | Aug | Sep | Oct | Nov | Dec | Jan |
|------|-----|-----|-----|-----|-----|-----|
| 2018 | 13.77 | 12.75 | 9.55 | 7.64 | 8.46 | 8.77 |
| 2019 | 25.26 | 25.26 | 27.42 | 25.98 | 26.52 | 27.11 |
| 2018 | 14.03 | 11.43 | 8.02 | 6.99 | 5.10 | 8.52 |
| 2019 | 25.32 | 25.85 | 25.82 | 25.93 | 25.32 | 27.41 |
| 2018 | 70.94 | 68.17 | 57.58 | 55.93 | 53.65 | 51.68 |
| 2019 | 69.77 | 72.07 | 48.97 | 45.60 | 43.87 | 70.58 |
taken and dispersed in 50 ml of distilled water, in a capped test tube, by shaking vigorously for 5 min followed by immediate pouring into a 250-ml graduated cylinder. The volumes of the foam formed were recorded as the foam capacity (ml/100 ml). A final observation will be made after 60 min for recording the foam stability (ml/100 ml). The volume of foam was recorded 1 hour after whipping to determine foam stability as per cent of initial foam volume.

The emulsifying properties of chickpea flours were determined by the method of Yasumatsu et al.\[12,13\] About 0.5 g samples of flour were suspended in 3 ml of distilled water contained in a graduated tube followed by the addition of 3 ml of oil. The contents were then shaken vigorously for 5 min. The resulting emulsion was centrifuged at 2000 × g for 30 min. The volume of the emulsified layer divided by that of the whole slurry multiplied by 100 were taken as the emulsifying activity of the flour (ml/100 ml). To determine the emulsion stability, the homogenized mixture of flour, water, and oil were heated at 80°C for 30 min before centrifugation at 2000 g for 30 min. The emulsifying stability was then calculated as the volume of the emulsifying layer divided by that of the heated slurry multiplied by 100, reported as ml/100 ml.

**Proximate composition**

Nutritional compositions of the samples were done after milling the grain with laboratory miller. The moisture content of samples from several chickpea cultivars was determined using standard analysis techniques.\[14\] Official methods were used to determine protein, crude fiber, and ash.\[15\] Crude fat was done by Soxhlate apparatus method. Carbohydrate content was found by difference to 100%,\[16\]

**Mineral composition analysis**

Mineral analysis was carried out using the (AOAC, 2005) standard technique, using Atomic Absorption Spectrophotometer (Model No. AAS-700, Perkin Elmer), the tested mineral is calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn).

**Statistical analysis**

SAS software (Version 9.0) was used to perform statistical analysis. The significance probability (p-value) was assessed using one-way analysis of variance, and statistically significant differences were found at the probability threshold of p ≤ .05.

**Results and discussion**

Genetics and environmental factors like as rainfall, temperature, and soil types, as well as interactions between these elements, have a considerable impact on grain nutritional composition.\[17,18\] Statistical analysis indicated that most parameters showed significant variation among eleven chickpea varieties, indicating a clear genotypic effect. The nutritional composition of the eleven chickpea varieties across three environments are presented in Tables 3 and 4 as the mean. The main factor (environment, genotype and grown season) effects on proximate composition, functional properties and mineral contents of the eleven chickpea varieties are presented in Tables 3, 4 and 5, respectively. The impacts of variety, season, location, and the interactions of location with variety, year * variety, variety * year, and location * variety * year are all considered in determining nutritional component variation (Table 6).

**Functional properties**

Functional properties are the crucial physicochemical characteristics of foods that exemplify the various interrelationships between the structures, molecular conformation, compositions, and physicochemical properties of ingredients, as well as the nature of the environment and the conditions
### Table 3. Functional properties in the 11 chickpea varieties grown across three environments by variety, location, and year.

| Variety | WAC | OAC | HC | SC | FC | FS | EA | ES |
|---------|-----|-----|----|----|----|----|----|----|
| Natoli  | 1.25<sup>cd</sup> | 1.23<sup>d</sup> | 0.28<sup>a</sup> | 0.56<sup>c</sup> | 16.59<sup>ab</sup> | 6.63<sup>b</sup> | 53.92<sup>d</sup> | 59.54<sup>cd</sup> |
| Ejere   | 1.30<sup>bc</sup> | 1.32<sup>bcd</sup> | 0.31<sup>d</sup> | 0.64<sup>cd</sup> | 15.98<sup>bcde</sup> | 4.54<sup>a</sup> | 53.74<sup>d</sup> | 62.72<sup>bc</sup> |
| Teketaye| 1.21<sup>e</sup> | 1.43<sup>a</sup> | 0.30<sup>ab</sup> | 0.60<sup>cde</sup> | 16.34<sup>ab</sup> | 5.23<sup>c</sup> | 54.92<sup>bc</sup> | 62.07<sup>cd</sup> |
| Hora    | 1.31<sup>bc</sup> | 1.36<sup>b</sup> | 0.33<sup>c</sup> | 0.59<sup>ab</sup> | 16.85<sup>a</sup> | 5.80<sup>b</sup> | 55.82<sup>a</sup> | 63.15<sup>bc</sup> |
| Dhera   | 1.28<sup>bcd</sup> | 1.29<sup>c</sup> | 0.34<sup>cd</sup> | 0.76<sup>ce</sup> | 16.28<sup>abc</sup> | 5.87<sup>b</sup> | 54.16<sup>cd</sup> | 65.66<sup>a</sup> |
| Arerti  | 1.33<sup>b</sup> | 1.33<sup>b</sup> | 0.30<sup>de</sup> | 0.64<sup>cd</sup> | 15.60<sup>de</sup> | 6.10<sup>b</sup> | 55.07<sup>b</sup> | 62.76<sup>bc</sup> |
| Dimtu   | 1.22<sup>a</sup> | 1.24<sup>d</sup> | 0.29<sup>ab</sup> | 0.63<sup>cd</sup> | 15.99<sup>bcd</sup> | 5.50<sup>de</sup> | 54.47<sup>bcd</sup> | 62.68<sup>bc</sup> |
| Habru   | 1.24<sup>ab</sup> | 1.41<sup>ab</sup> | 0.35<sup>c</sup> | 0.74<sup>e</sup> | 14.95<sup>ef</sup> | 5.28<sup>cd</sup> | 54.01<sup>d</sup> | 65.02<sup>ab</sup> |
| DZ-2012-CK-0019 | 1.38<sup>a</sup> | 1.27<sup>cd</sup> | 0.40<sup>c</sup> | 0.92<sup>b</sup> | 15.32<sup>de</sup> | 6.71<sup>a</sup> | 54.49<sup>bcd</sup> | 62.22<sup>cd</sup> |
| Shasho  | 1.32<sup>b</sup> | 1.32<sup>b</sup> | 0.30<sup>de</sup> | 0.66<sup>f</sup> | 14.54<sup>f</sup> | 5.88<sup>bc</sup> | 54.99<sup>b</sup> | 64.39<sup>bc</sup> |
| DZ-2012-CK-0024 | 1.20<sup>a</sup> | 1.28<sup>cd</sup> | 0.35<sup>b</sup> | 0.74<sup>e</sup> | 16.96<sup>e</sup> | 5.33<sup>cd</sup> | 54.94<sup>bc</sup> | 61.84<sup>cd</sup> |
| CV      | 2.55 | 4.73 | 3.09 | 5.01 | 2.53 | 6.51 | 0.89 | 2.59 |
| LSD     | 0.0001 | 0.02 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0029 | 0.0199 |

WAC: Water absorption capacity in ml/g, OAC: Oil absorption capacity in ml/g, HC: Hydration capacity in g/seed, SC: Swelling capacity in ml/seed, FC: Foaming capacity in %, EA: Emulsifying activity in ml/100 ml, DZ-Deber Ziet, CD-Chefe Donsa and MI-Minjar

### Table 4. Proximate compositions in the 11 chickpea varieties grown across three environments by variety, location, and year.

| Variety       | Moisture | % Total Ash | % Crude Fat | % Crude Pro | % Crude Fib | % Total Carbohydrate | Gross Energy Kcal/100 g |
|---------------|----------|-------------|-------------|-------------|-------------|----------------------|-------------------------|
| Natoli        | 10.93<sup>bcd</sup> | 3.71<sup>f</sup> | 5.24<sup>g</sup> | 17.74<sup>cd</sup> | 6.72<sup>ab</sup> | 62.38<sup>bc</sup> | 368.62<sup>d</sup> |
| Ejere         | 10.85<sup>d</sup> | 3.19<sup>g</sup> | 6.28<sup>b</sup> | 17.92<sup>bcd</sup> | 6.59<sup>ab</sup> | 61.75<sup>cde</sup> | 376.54<sup>a</sup> |
| Teketaye      | 10.31<sup>b</sup> | 3.29<sup>d</sup> | 5.70<sup>f</sup> | 16.98<sup>e</sup> | 6.78<sup>ab</sup> | 62.71<sup>ab</sup> | 370.83<sup>c</sup> |
| Hora          | 10.30<sup>bc</sup> | 3.14<sup>gh</sup> | 6.08<sup>e</sup> | 17.56<sup>d</sup> | 5.92<sup>bcd</sup> | 61.91<sup>cd</sup> | 373.15<sup>b</sup> |
| Dhera         | 10.26<sup>e</sup> | 3.28<sup>de</sup> | 5.86<sup>e</sup> | 19.18<sup>e</sup> | 7.49<sup>e</sup> | 59.61<sup>f</sup> | 368.29<sup>d</sup> |
| Arerti        | 10.03<sup>bc</sup> | 3.19<sup>gh</sup> | 6.37<sup>ab</sup> | 18.33<sup>b</sup> | 5.12<sup>d</sup> | 61.81<sup>e</sup> | 376.08<sup>a</sup> |
| Dimtu         | 10.05<sup>bcd</sup> | 4.19<sup>gh</sup> | 5.29<sup>g</sup> | 16.21<sup>f</sup> | 7.33<sup>a</sup> | 63.26<sup>e</sup> | 371.47<sup>bc</sup> |
| Habru         | 10.05<sup>bc</sup> | 3.11<sup>b</sup> | 6.43<sup>c</sup> | 18.33<sup>c</sup> | 6.39<sup>bcd</sup> | 61.08<sup>b</sup> | 376.34<sup>e</sup> |
| DZ-2012-CK-0019 | 11.12<sup>bc</sup> | 3.23<sup>de</sup> | 5.86<sup>e</sup> | 16.43<sup>f</sup> | 6.51<sup>a</sup> | 63.34<sup>c</sup> | 371.56<sup>bc</sup> |
| Shasho        | 11.04<sup>bcd</sup> | 3.26<sup>de</sup> | 5.98<sup>d</sup> | 18.14<sup>bc</sup> | 5.35<sup>cd</sup> | 61.57<sup>de</sup> | 375.82<sup>a</sup> |
| DZ-2012-CK-0024 | 10.92<sup>cd</sup> | 4.43<sup>a</sup> | 6.25<sup>c</sup> | 16.34<sup>f</sup> | 6.41<sup>abc</sup> | 62.07<sup>bcd</sup> | 375.28<sup>a</sup> |
| CV            | 2.05 | 1 | 1.13 | 1.63 | 10.77 | 0.67 | 0.3 |
| LSD           | 0.0004 | 0.0001 | 0.0001 | 0.0001 | 0.0015 | 0.0001 | 0.0001 |

Location:

- DZ:
- MI:
- CD:
- CV:
- LSD:

Season:

- 2018:
- 2019:
under which these are analyzed and related.\[19\] They are also explained how components behave during preparation and cooking, as well as how they affect the appearance, texture, and taste of the final product. The constituents of the food, particularly carbohydrates, proteins, fats and oils, moisture, fiber, ash, and other substances or food additives added to the food (flour), such as sugar alcohols, affect the functional qualities of foods and flours,\[20,21\] in addition to the structures of these components. The physical behaviors of foods or food ingredients during preparation, processing, or storage is influenced by most functional qualities.\[22\]

Water absorption capacity, oil absorption capacity, hydration capacity, swelling capacity, foaming capacity, foaming stability, emulsifying activity and emulsifying were analyzed for eleven Ethiopian chickpea varieties obtained from Minjar, Chefe Donsa and Debre Ziet cultivated during 2018 and 2019. Only oil absorption capacity of Debre Ziet 2019 and emulsifying activity of Minjar 2018 did not show variance among the eleven chickpea varieties. The data showed that most of the tested varieties have significantly different at \( p < .05 \) (Table 3). The DZ-2012-CK-0019 variety which is the newly released was found to have higher water absorption capacity, Hydration capacity and swelling capacity.

High WHC flours might be useful in bakery applications, which include bread formulations because they allow bakers to add enough water to the dough, to enhance handling attributes and maintain bread freshness. Water absorption characteristics refer to a product’s ability to combine with water in scenarios where water is scarce.\[23\] The WAC findings of this study ranges in between 0.88 and 1.75 g/g which is similar to the findings of Macar, et al.\[24\] Teketaye, Hora, Arerti and Habbru scored the highest oil absorption capacity without significant difference between them. Teketaye, Hora and new candidate DZ-2012-CK-0024 varieties had the highest foaming capacity. High WAC flours may be advantageous in goods with a high viscosity need, such as soups and gravies.\[25\]

The two growing seasons differently influenced the functional properties of parameters considered. In the first growing season (2018) (Table 3), a significant difference in water absorption capacity, oil absorption capacity, and swelling capacity were observed with respect to the second season (2019). Flours’ oil absorption capacity (OAC) is also important since it increases mouth-feel and flavor retention.\[25\] According to Kaushal et al.\[25\] more hydrophobic proteins have better lipid binding, meaning that nonpolar amino acid side chains bind the fats’ paraffin chains. Fats operate as a flavor keeper and boost the mouth feel of food, hence OAC is essential.\[2\] In this study, the oil absorption capacity of chickpea varieties ranged from 1.43 to 1.20 ml/g but higher than those reported for raw chickpea flour 1.10 ml/g.\[26\] According to this finding, kabuli type chickpea flour, which possesses higher OAC, had more accessible nonpolar side chains in its protein molecules than desi-type chickpea flour.

The results for foaming capacity and foaming stability for eleven chickpea varieties are depicted in Table 3. The obtained results ranged in 16.96–14.54% for foaming capacity and 6.71–4.54 for foaming stability. Chickpeas had the capacity to make a slight foaming, but after 30 min these foams mostly disappeared as they were unstable. Previous studies have showed that foaming, emulsification and stabilizing properties of depend on different factors, such as content, molecular weight and structure of carbohydrate, protein content and additional compounds in hydrocolloids.\[27\]

On the contrary, foaming stability was higher in 2019 than in 2018. Because the efficacy of whipping agents depends on their capacity to maintain the whip for as long as possible, foam stability is critical.\[25\] Chickpea flours’ excellent foam stability suggests that the native proteins that are soluble in the continuous phase (water) are particularly surface-active. When proteins unfold, they generate an interfacial skin that keeps air bubbles suspended and keeps them from collapsing.\[28\] And there are no significant differences observed in hydration capacity, foaming capacity and emulsifying activity in between the two growing seasons. Relative to the growing locations (Table 3), significant difference was observed in different functional properties of chickpea flours. In Debre Ziet location had observed the highest in water absorption capacity, hydration capacity and swelling capacity, were as Minjar location had the highest score in emulsifying activity and in the other functional properties listed in Table 2, there were no significant difference between three locations.
Swelling power is a measurement of the water absorption index of flours when heated. The genotype did show significant effect on swelling power of chickpea flours irrespective of growth location. The variety DZ-2012-CK-0019 have the highest swelling power among eleven chickpea varieties. Varieties from Deber Ziet seem to have higher swelling power than their counterparts grown in Chefe Donsa and Minjar. The greater protein content in flour from Minjar chickpea varieties may have contributed to the lesser swelling power of chickpea flour. Proteins, according to Aprianita et al.\(^{29}\) can cause starch granules to become lodged in a rigid protein matrix, limiting starch access to water and hence limiting swelling ability. A similar observation was made in this investigation. As previously reported, chickpea flours with low protein and high carbs appeared to have a stronger swelling ability.\(^{30}\)

The location effect across eleven chickpea varieties was significant for WAC, HC, SC, FC, FS and EA, but OAC and ES were not statistically significant (Table 3). Cultivars from Deber Ziet on the other hand, have slightly greater WAC than those cultivated in Chefe Donsa and Minjar locations. Chickpea flour’s high-water absorption could be linked to the high amount of carbohydrates in these flours. The ability of chickpea flours to absorb oil was nearly identical across all kinds grown in both locations. Environment or genotype did not seem to have any influence on the OAC, although slight differences were observed. Almost all of the functional properties of selected chickpea varieties were influenced by cultivation season, except that of hydration capacity, foaming capacity and emulsifying activity.

**Proximate composition**

Moisture, protein, crude fat, carbohydrate, ash, and crude fiber analysis for the eleven chickpea varieties obtained from Minjar, Chefe Donsa and Debre Ziet cultivated during 2018 and 2019 main rain season (Table 4). When these proximate compositions were observed among all varieties showed high variability in almost all factors (Table 4). Statistical significance was observed in all proximate compositions among all varieties across three environments, indicating a genetic contribution to the variation in these compounds. Only total ash of Chefe Donsa 2018 did not show variation among the eleven chickpea varieties. The varieties Dhera was found to have the highest protein (19.18%) which was slight similar with values reported by Abebe et al.\(^{31}\) and in the range from 12.4% to 30.6% reported by Chavan et al.\(^{32}\) and Dhera with the best technological quality performance showing the highest protein content. The varieties like DZ-2012-CK-0019, Dimtu and Teketay had the highest total carbohydrate content (63.34%) which was generally higher compared to previously reports data on chickpea flours.\(^{33,34}\) Whereas, Shasho, variety-DZ-2012-CK-0024, Habru, Arerti and Ejeri were the highest in gross energy content among other varieties.

Most proximate compositions in location effect across eleven released chickpea varieties were showed significant effect except total moisture content and crude fiber content. All proximate compositions across all eleven selected chickpea varieties were not influenced by cultivation season except that of total ash contents of chickpea flours. In chickpeas, season was found to affect significantly both the protein and fat contents.\(^{5,35}\) The highest protein content from the three locations were observed in Minjar location 19.09 which is may be from the soil characteristics that means as indicated in Table 1 the soil tested Minjar location soil type shows relatively the highest total nitrogen content than the two locations (Debre Ziet and Chefe Donsa) (Table 1) or from the weather conditions since, climate and weather effects on grain protein content are easier to quantify than those on grain-specific weight. Increased temperature and reduced water availability have a less damaging effect on nitrogen accumulation compared to that on dry matter. As a result, increased grain protein content is linked to increased temperature and/or decreased water availability, an effect that has been seen in the field.\(^{36}\) Seasonal effects on the analyzed parameters could be linked to rainfall, which is the most noteworthy climatic data that changes between 2018 and 2019 (Table 2).
The total carbohydrate content shows significant difference between minjar and the other two Deber Ziet and Chefe Donsa, but between the two (Deber Ziet and Chefe Donsa) there is no statistical difference were observed (Table 4). Chickpea flours from varieties grown in both locations (Deber Ziet and Chefe Donsa) showed high carbohydrate content ranging between 62.29% and 62.74%. Because Minjar is located at a low altitude and in a moisture-stressed area, it has been reported that a lack of water in the soil causes reduced enzymatic activity, leading to lower carbohydrate content due to less starch granule accumulation. The other reason may be higher annual rainfall may have caused higher carbohydrate content due to increased enzymatic activities in starch biosynthesis resulting in accumulation of starch granules compared to lower rainfall which could have resulted in lower carbohydrate content.\(^{32,37}\)

**Mineral content**

Trace minerals like zinc and iron, as well as other minerals like calcium, potassium, phosphorus, and magnesium, are accumulated by plants in edible parts like leaves and seeds.\(^{38}\) Calcium, magnesium, iron and zinc were analyzed for the eleven chickpea varieties obtained from Minjar, Chefe Donsa and Debre Ziet cultivated during 2018 and 2019 (Table 5). The mineral content of chickpea grains flour varied significantly across varieties, and the same was true for the growing season (Table 5). The concentration of minerals in chickpea seed flour of all genotypes showed significant variation and the same is true for the growing season. Hora in calcium, Dimtu iron content and Natoli in magnesium content showed the highest values among eleven chickpea varieties. The Ejeri, Hora, Dear and Arerti varieties observed the highest amounts of zinc concentration.

The levels of each mineral varied significantly across three environments, indicating that these compounds are strongly influenced by environmental factors. Mineral content in chickpea varies depending on agricultural practices, genotype, and environment, according to previous

| Variety   | Ca (mg/100 g) | Mg (mg/100 g) | Fe mg/100 g | Zn (mg/100 g) |
|-----------|---------------|---------------|-------------|---------------|
| Natoli    | 196.11        | 123.90        | 6.17        | 2.34          |
| Ejere     | 193.68        | 115.45        | 6.47        | 2.56          |
| Teketaye  | 202.08        | 121.40        | 6.68        | 2.23          |
| Hora      | 211.67        | 117.58        | 6.17        | 2.59          |
| Dhera     | 186.43        | 116.62        | 6.41        | 2.57          |
| Arerti    | 199.67        | 117.81        | 6.33        | 2.54          |
| Dimtu     | 188.69        | 117.99        | 6.73        | 2.17          |
| Habru     | 181.99        | 112.60        | 6.27        | 2.29          |
| DZ-2012-CK-0019 | 201.09 | 107.61  | 5.86 | 2.23 |
| Shasho    | 175.86        | 114.17        | 6.25        | 2.35          |
| DZ-2012-CK-0024 | 164.31 | 107.54  | 6.28        | 2.17          |
| CV        | 0.68          | 0.54          | 1.92        | 1.61          |
| LSD       | 0.0001        | 0.0001        | 0.0001      | 0.0001        |

| Location  |                |               |             |               |
|-----------|----------------|---------------|-------------|---------------|
| DZ        | 171.72         | 120.10        | 7.10        | 2.55          |
| MI        | 172.06         | 116.85        | 6.19        | 2.34          |
| CD        | 229.39         | 110.14        | 5.70        | 2.23          |
| CV        | 40.72          | 11.34         | 0.97        | 0.38          |
| LSD       | 0.0001         | 0.0001        | 0.001       | 0.0001        |

| Season    |                |               |             |               |
|-----------|----------------|---------------|-------------|---------------|
| 2018      | 182.83         | 120.31        | 6.47        | 2.49          |
| 2019      | 199.28         | 111.09        | 6.19        | 2.26          |
| CV        | 40.72          | 11.34         | 0.97        | 0.38          |
| LSD       | 0.004          | 0.0001        | 0.05        | 0.0001        |
research.[1,39,40] The location effects across eleven chickpea varieties were significant for all tested mineral contents (calcium, magnesium, iron and zinc) (Table 5). All compounds across all eleven chickpea varieties were influenced by cultivation season except iron contents of chickpea flour. Across all the study environments, the mean Zn concentration ranged from 2.23 to 2.55 mg/100 g, with varieties grown at location Deber Zeit contain the highest Zn content, while varieties harvested from Minjar and Chefe Donsa location had the lowest Zn content (Table 5). Varieties collected from Deber Zeit location contain the higher Fe content of 7.10 mg/100 g, varieties produced at Chefe Donsa locations contain the least amount of Fe 5.70 mg/100 g (Table 5). Variations in soil nutritional composition can be causes for the differences in these mineral elements.

**Origin of variability**

Significantly genotype, environment, growing year, and interactions of (genotype × environment, genotype × season, environment × season and genotype × season × environment) effects were detected for proximate compositions, functional properties and mineral contents of chickpeas varieties (Table 6). The ANOVA analysis showed that most parameters were significantly affected by both variety and the interaction of variety × location (Table 6). The influence of varieties causing the higher variations for different chickpeas in chemical composition parameters is higher than the reported in other chickpeas studied researchers.[41]

All functional properties are affected by all interactions except that of foaming capacity in location and year interactions and all mineral contents of selected chickpea varieties are affected by all interactions. The result of variability for proximate from the statistical analysis showed that the quantity of moisture and carbohydrate were significantly affected by variety whereas gross energy, crude protein and fat were highly affected by locations and crude fiber was greatly affected by the interaction between variety and location (V and L). Protein did not show significantly affected by all interactions except variety and locations and this is similar finding were in the cases of protein where

### Table 6. For proximate composition, functional properties, and mineral content of chickpea flours, variability was expressed as a percentage of the total sum of squares.

| Parameters | Variety | Location | Season | V^L | V^S | L^S | V^L^S |
|------------|---------|----------|--------|-----|-----|-----|--------|
| Moisture   | 27.46** | 4.64**   | 0.67   | 22.53** | 9.44* | 11.32** | 23.13** |
| Ash        | 12.43** | 8.63**   | 10.17** | 24.83** | 12.30** | 6.91** | 24.74** |
| Fat        | 26.67** | 60.03**  | 0.12** | 12.62** | 0.08  | 0.34** | 0.14   |
| Fiber      | 17.87** | 2.08**   | 0.29** | 66.22** | 1.71** | 2.14** | 9.69** |
| Protein    | 28.10** | 40.19*   | 0.75   | 20.55** | 3.77  | 0.12  | 5.83   |
| Carbohydrate | 31.21** | 23.53**  | 2.05** | 19.57** | 6.76** | 2.51** | 14.37** |
| Energy     | 20.02** | 29.97**  | 5.24** | 16.18** | 6.97** | 7.24** | 14.38** |
| WAC        | 9.16**  | 5.05**   | 41.56** | 12.60** | 11.64** | 7.77** | 12.20** |
| OAC        | 10.36** | 2.69**   | 27.57** | 19.71** | 7.11** | 6.97** | 25.60** |
| HC         | 33.28** | 29.92**  | 0.15   | 10.53** | 11.76** | 4.89** | 9.47** |
| SC         | 26.17** | 16.70**  | 14.73** | 12.28** | 9.74** | 9.58** | 10.79** |
| FC         | 13.78** | 7.92**   | 0.96** | 51.04** | 6.02** | 0.38  | 19.90** |
| EA         | 17.07** | 6.71**   | 0.02   | 22.12** | 33.85** | 2.28* | 17.94** |
| Ca         | 10.00** | 44.64**  | 4.11** | 10.48** | 10.37** | 11.07** | 9.34** |
| Mg         | 18.63** | 13.65**  | 16.87** | 10.20** | 3.72** | 28.07** | 8.86** |
| Fe         | 6.09**  | 38.22**  | 2.07** | 34.34** | 9.38** | 0.92** | 8.98** |
| Zn         | 19.81** | 13.36**  | 10.23** | 20.38** | 6.64** | 18.02** | 11.56** |

WAC-water absorption capacity, OAC-oil absorption capacity, HC-hydration capacity, SC-swelling capacity, FC-foaming capacity, EA-emulsifying activity. * P < 0.05, ** P < 0.01, Values without asterisks are not significant at P < 0.05.
**Table 7.** Correlation coefficient between the selected functional and chemical composition quality parameters of chickpea genotypes grown in three different environments (Deber Ziet, Chefe Donsa and Minjar).

|       | Moisture | Total ash | Crude Fat | Crude Protein | Crude fiber | Carbohydrate | Energy | OAC | WAC | HC | SC |
|-------|----------|-----------|-----------|---------------|-------------|---------------|--------|-----|-----|----|----|
| T. ash| -0.272   |           |           |               |             |               |        |     |     |    |    |
| C. Fat | -0.109   | -0.385    |           |               |             |               |        |     |     |    |    |
| C. Protein | 0.452 | -0.630*   | 0.341     |               |             |               |        |     |     |    |    |
| C. fiber | 0.421   | 0.346     | -0.546    | -0.189        |             |               |        |     |     |    |    |
| Carb   | -0.568   | 0.372     | -0.478    | -0.896**      | 0.081       |               |        |     |     |    |    |
| Energy | -0.583   | -0.143    | 0.800**   | -0.674*       | -0.098      |               |        |     |     |    |    |
| WAC    | 0.047    | -0.627    | 0.253     | 0.253         | -0.473      | -0.068        | 0.147  |     |     |    |    |
| OAC    | 0.115    | -0.578    | 0.525     | 0.262         | -0.282      | -0.224        | 0.371  | -0.11|     |    |    |
| HC     | 0.224    | -0.103    | 0.34      | -0.221        | 0.089       | 0.035         | 0.004  | -0.039| 0.406|    |    |
| SC     | 0.203    | -0.066    | 0.273     | -0.134        | 0.141       | -0.024        | 0.017  | -0.142| 0.385| 0.902**|    |
| FC     | 0.167    | 0.452     | -0.244    | -0.261        | 0.384       | 0.081         | -0.421 | -0.183| -0.445| -0.049| -0.341|

*, ** = Significant at \( P < 0.05 \) and \( P < 0.01 \), respectively.
the combined effect of year and variety was not significant. The results of % variability for minerals showed that two minerals exhibited high percentages of variance by location and Mg showed the highest variability by L and S interaction.

**Selected trait correlation**

Data on the association between the functional and chemical traits are shown in Table 7. Specially energy and crude fat shows significant relationship (r = 0.800**). These results are consistent with those reported on chickpeas. Swelling capacity and hydration capacity of chickpea flours shows significant positive correlation an r = 0.902. Chickpea flours significant negative relationship were observed between crude protein and total ash (r = −0.630), carbohydrate and crude protein (r = −0.896) and gross energy and crude fiber (r = −0.674). It’s possible that the small magnitude of the correlation between traits was due to the small sample size and/or the genotypes’ genetic base.

**Conclusion**

Chickpea flour is a good source of protein, carbohydrates, and minerals. Determination of flour functional and nutritional characteristics of diverse released Ethiopian chickpea varieties are very important for chickpea breeding programs. The grown location, grown season and the chickpea variety, as well as the interactions of these factors strongly affect the functional properties and nutritional composition of chickpeas. All functional properties are affected by all interactions except that of foaming capacity in location and year interactions (L × Y) and all mineral contents of selected chickpea varieties are affected by all interactions. The result of variability for proximate from the statistical analysis showed that the quantity of moisture and carbohydrate were significantly affected by variety whereas gross energy, crude protein and fat were highly affected by locations and crude fiber was greatly affected by the interaction between variety and location (V × L). The positive and significant relationships between gross energy and crude fiber and swelling capacity and hydration capacity in chickpea flour offer varieties. The negative relationship between crude protein and total ash, carbohydrate and crude protein and gross energy and crude fiber across chickpea market classes will require a compromise during selection. The small magnitude of the correlation between traits and repeatability values may be due to the small sample size used and the experimental materials’ genetic base being relatively narrow. The information provided in the present study is an important first step for chickpea breeding programs in Ethiopia and in other countries interested in using Ethiopia genetic resources and finally for different local or international chickpea-based food processors. This study gives insight of the selection of chickpea varieties and can be used for different chickpea-based protein-enriched complementary food products and other food products.

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**Disclosure statement**

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