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Effect of Genotypes, Environment and Grown Year on Nutritional Composition and Functional Properties of Promising Ethiopian Chickpeas Varieties

Lamesgen Yegrem[1], Derbie Mengestu[1], Oli Legesse[1], Workenh Abebe[1] and Negussie Girma[2]

[1] Food Science and Process Engineering, Deber Ziet Agricultural Research Centre, Ethiopia
[2]Chickpea and Lentil Breeder, Deber Ziet Agricultural Research Centre, Ethiopia

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ABSTRACT: *Chickpea is a major source of energy and micronutrients for majority of population in Africa. However, comprehensive studies have not reported on the effects of genotype, cultivation location, and year on chickpea flour characteristics. To address this, 11 selected chickpea varieties were grown at three locations in Ethiopia, during 2010 and 2011, representing three environments, and composition of proximate, minerals and functional in chickpea flour were determined. The cultivation environment, the cultivation year and the chickpea genotypes, as well as their interactions significantly affect the functional properties and nutritional composition of chickpea. High proportion of the total variation for all 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. Year 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) shows 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.*

KEY WORDS; varieties, chickpea, functional properties and nutritional composition

INTRODUCTION

Chickpea (*Cicer arietinum L.*) is the world's third largest pulse crop based on cultivated area (Hasan et al., 2008). Chickpea (Cicerarietinum L.) 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 (USDA, 2010), and the protein quality is considered to be better than other pulses. Chickpea has significant amounts of all the essential amino acids. Starch is the major storage carbohydrate followed by dietary fibre, lipids are present in low amounts but chickpea is rich in nutritionally important unsaturated fatty acids like linoleic and oleic acid.

Chickpea is one of the main annual crops in Ethiopia both in terms of its share of the total cropped pulses area and its role in direct human consumption. In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop (Shiferaw et al., 2007). In Ethiopia, the earliest finding of chickpea is reported in 1520 BC (Joshi et al., 2001). Ethiopia is the largest producer of chickpea in Africa accounting for about 46% of the continent's production during 1994-2006. It is also the seventh largest producer worldwide and contributes about 2% to the total world chickpea production.

Environmental conditions exert significant influences on chemical composition of legumes (Al-Karaki et al., 1997). Significant genetic variations in chemical composition of legume seeds have been reported (Bajaj, 1975 and Ereifej et al., 2001). The breeding programs are carried out in search for high yielding chickpea cultivars to meet the increasing demand for chickpea seeds. The functional, chemical composition and mineral element levels in the improved or released chickpea cultivars is not emphasized. The composition of plants can be altered in many ways. It is possible by breeding and selection to develop varieties high in certain nutrients. Even within the same variety, nutritional composition of chickpea varies depending on developmental stages, growing regions, and agricultural practices (Perez-Lopez et al., 2007). The growing environment of a plant is made up of many factors. Some of these are soil, fertilizer treatments. Altitude, climate, rainfall, length of growing season, light intensity, length of day, and temperature. These operate in different, but interrelated, ways to change the composition of plants.

Improved chickpea varieties have been released and disseminated to the farmers to improve productivity. However, mainly focus to release crop varieties with better yield and good agronomic traits with little emphasis on some quality parameters. Lack of knowledge on the nutritional quality of each chickpea varieties in different agro ecologies might have contributed to affect the processing quality of different chickpea based food products. Despite the existence of published works, describing the effects of different processing methods on chemical and nutritional composition of chickpea, nutritional profile information about Ethiopian improved chickpea varieties in different environments/ agro-ecologies were lacking, so in order to fill this gap this study were initiated with the objectives of, to explore the impact of genotype and growth environment on the nutritional composition, mineral contents and functional properties of improved Ethiopian chickpea varieties.

MATERIAL AND METHODS

Genotypes

Eleven chickpeas varieties were collected from Debre Zeit Agricultural Research Centre, Ethiopia and then cultivated at three locations (Deber Ziet (DZ), Minjar (MI) and Chefe Donesa (CD)) in Ethiopia 2010 and 2011. 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 three blocks with a RCBD design. Chickpea seeds were collected randomly from each block and pooled together and after seeds were dried in sun and finally transported to laboratory.

Field experimental trials
A total 11 varieties, 9 were improve and two were candidate varieties of chickpea varieties were grown in RCBD with 3 replication on plot size 1.2 m × 4 m at three different agro ecologies.

Table 1: Cultivation locations soil characteristics (analysis results provided by soil research departments in Deber Ziet Agricultural Research Centre)

Tested Soil Parameter's	**Cultivation Locations**		
	Deber Ziet	Minjar	Chefe Donsa
pH (1:2.5 H_2O)	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/100g)	29.67	36.91	62.52
Exchangeable K (cmol(+)/kg)	0.73	0.97	1.06
Texture group	Heavy Clay	Clay	Clay

Testing environments
Chefe Donsa represents the high –altitude area at 2200-2750 meters 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 meters 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 meters above mean sea level and the moisture stress area with having erratic annual rainfall (500mm) and well-drained Andosols soil type. As per recommendation of each site, similar agronomic practices were conducted for all varieties. All of experiments were conducted in triplicate by collecting three samples from pooled powered samples. Weather data such as temperature, relative humidity, wind speed, and total rainfall were recorded.

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

Year		Aug	Sep	Oct	Nov	Dec	Jan
2010	Mean T ^{0}C min	13.77	12.75	9.55	7.64	8.46	8.77
	Mean T ^{0}C max	25.26	25.26	27.42	25.98	26.52	27.11
2011	Mean T ^{0}C min	14.03	11.43	8.02	6.99	5.10	8.52
	Mean T ^{0}C max	25.32	25.85	25.82	25.93	25.32	27.41
2010	Mean RH%	70.94	68.17	57.58	55.93	53.65	51.68
2011	Mean RH%	69.77	72.07	48.97	45.60	43.87	70.58

At maturity stage, the grain yield was harvested and brought in to the laboratory for quality parameter analysis. Chickpea grain samples were manually cleaned by sieving and sorting with handing 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 75µm sieve and were kept in moisture proof plastic bag placed in air tight tin container at 4^{0}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. (1976). The water and oil absorption capacities 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 (1977). About one gram of flour was 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 one 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., (1972). About 0.5g 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 x 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 mill. Samples from different chickpea cultivars were estimated for their moisture content as per standard methods of analysis (AOAC, 1990). Protein, crude fiber and ash were determined by the official methods (AOAC, 1984). Crude fat was done by Soxhlate apparatus method. Carbohydrate content was found by difference to 100% (FAO, 2015).

Mineral Composition Analysis
Mineral analysis was done according to the standard method of analysis AOAC (2005). The mineral contents viz. Iron (Fe) and zinc (Zn) were determined using Atomic Absorption Spectrophotometer (Model No. AAS-700) (Perkin Elmer).

Statistical analysis
Statistical analysis of the data was carried out with SAS Enterprise Guide 7.0. To identify differences among chickpea varieties within each location per year and across three environments, the significance probability (p-value) was calculated by two-way analysis of variance. (ANOVA).The genotypic and environmental means were compared using least significant difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Crop nutritional composition is significantly affected by genetics and environmental conditions including rainfall, temperature, soil types, and the interactions between these factors (Eun-Ha et al., 2019 and Chen et al., 2016). To investigate variations in nutritional composition among 11 chickpea cultivars, we analysed data within each location per year to exclude the influence of the environment. This enabled us to assume the variance for components was attributed to genotypes. Statistical analysis demonstrated that most components showed significant variation among 11 chickpea cultivars, indicating a clear genotypic effect (Additional file 1). The nutritional composition of the 11 chickpea cultivars across three environments are presented in Tables 2 and 3 as the mean. Further, the nutritional compounds across the 11 cultivars were compared by location and year, respectively, in order to determine the effect of the environment on composition. The main factor (environment, genotype and year) effects on proximate composition, functional properties and mineral contents of the 11 chickpea varieties are presented in Tables 2 and 3, respectively. The variation in nutritional components is apportioned between the effects of variety, year, location, interaction of location * variety, year * variety, variety * year and location * variety * year (Table 5).

Functional Properties

Functional properties are the essential physicochemical properties of foods that reflect the complex interactions between the structures, molecular conformation, compositions, and physicochemical properties of food components with the nature of the environment and conditions in which these are measured and associated (Suresh and Samsher, 2013). Functional properties also describes the behaviour of ingredients during preparation and cooking, as well as how they affect the finished food products in terms of how it looks, feels and tastes. The functional properties of foods and flours are influenced by the components of the food material, especially the carbohydrates, proteins, fats and oils, moisture, fibre, ash, and other ingredients or food additives added to the food (flour), such as sugar alcohols (Awuchi, 2017; Awuchi and Echeta, 2019), as well as the structures of these components. Most functional properties play a major role in the physical behaviour of foods or food ingredients during their preparation, processing, or storage (Igwe et al., 2019).

Water absorption capacity, oil absorption capacity, hydration capacity, swelling capacity, foaming capacity, foaming stability, emulsifying activity and emulsifying were measured and/ or calculated for the 11 Ethiopian chickpea varieties obtained from Minjar, Chefe Donsa and Debre Ziet cultivated during 2010 and 2011. Only oil absorption capacity of Debre ziet 2011 and emulsifying activity of minjar 2010 did not show variance among the 11 chickpea varieties (Additional file 1). Table 2 shows combined functional properties data obtained from the three environments. The data showed that the tested cultivars have significantly different. The cultivar 19 which is the newly released variety was found to have the water absorption capacity (1.38), Hydration capacity and swelling capacity.

Flours with high WHC could be good ingredients in bakery applications, such as bread formulations, since a higher WHC enables bakers to add more water to the dough, thus improving the handling characteristics and maintaining freshness in bread. Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting (Singh et al., 2016). The WAC findings of this study (0.88 to 1.75g/g) were similar with (Macar, et al., 2017). Teketaye, Hora, Arerti and Habru scored the highest oil absorption capacity without significant difference between them. Teketaye, Hora and new candidate variety-24 varieties had the highest foaming capacity.

The two growing seasons differently influenced the functional properties of parameters considered. In the first growing season (Table 3), a significant water absorption capacity, oil absorption capacity, and swelling capacity were observed with respect to the second one. The oil absorption capacity (OAC) of flours is also important as it improves the mouth feel and retains the flavour (Kaushal et al., 2012). According to Kaushal et al., (2012) more hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind the paraffin chains of fats. Our results suppose that chickpea have more nonpolar side chains and hydrophobic amino acids. OAC is important since fats act as a flavour retainer and increase the mouth feel of food (khalifa et al., 2013). Based on this suggestion, it could be inferred that kabuli type chickpea flour, which showed higher OAC, had more available non-polar side chains in its protein molecules than did desi type chickpea flours.

On the contrary, foaming stability was higher in 2011 than in 2010. Foam stability is important since the usefulness of whipping agents depends on their ability to maintain the whip as long as possible (Kaushal et al., 2012). The good foam stabilities of chickpea flours suggest that the native proteins that are soluble in the continuous phase (water) are very surface- active in chickpea flours. Foams are formed when proteins unfold to form an interfacial skin that keeps air bubbles in suspension and prevents their collapse (Bose and Shams, 2010). And there is 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 were 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.

The location effect across 11 chickpea varieties was significant for WAC, HC, SC, FC, FS and EA, but OAC and ES were not statistically significant (Table 3). Almost all of the functional properties of selected chickpea varieties were influenced by cultivation year, except that of hydration capacity, foaming capacity and emulsifying activity.

Table 3: Functional properties in the 11 chickpea varieties grown across three environments by variety, location, and year

Variety	Flour functional properties							
	WAC	OAC	HC	SC	FC	FS	EA	ES
Natoli	1.25^{cde}	1.23^{d}	0.28^{e}	0.56^{e}	16.59^{ab}	6.63^{a}	53.92^{d}	59.54^{cd}
Ejere	1.30^{bc}	1.32^{bcd}	0.31^{d}	0.64^{cd}	15.98^{bcd}	4.54^{e}	53.74^{d}	62.72^{bc}
Teketaye	1.21^{e}	1.43^{a}	0.30^{de}	0.60^{cde}	16.34^{ab}	5.23^{d}	54.92^{bc}	62.07^{cd}
Hora	1.31^{bc}	1.36^{abc}	0.33^{c}	0.59^{de}	16.85^{a}	5.80^{bc}	55.82^{a}	63.15^{abc}
Dhera	1.28^{bcd}	1.29^{cd}	0.34^{bc}	0.76^{b}	16.28^{abc}	5.87^{bc}	54.16^{cd}	65.66^{a}
Arerti	1.33^{b}	1.33^{abcd}	0.30^{de}	0.64^{cd}	15.60^{cde}	6.10^{ab}	55.07^{ab}	62.76^{bc}
Dimtu	1.22^{e}	1.24^{d}	0.29^{de}	0.63^{cd}	15.95^{bcd}	5.59^{bcd}	54.47^{bcd}	62.68^{bc}
Habru	1.24^{de}	1.41^{ab}	0.33^{c}	0.74^{b}	14.95^{ef}	5.28^{cd}	54.01^{d}	65.02^{ab}
19	1.38^{a}	1.27^{cd}	0.40^{a}	0.92^{a}	15.32^{de}	6.71^{a}	54.49^{bcd}	62.22^{cd}
Shasho	1.32^{b}	1.32^{bcd}	0.30^{de}	0.66^{c}	14.54^{f}	5.88^{bc}	54.99^{b}	64.39^{abc}
24	1.20^{e}	1.28^{cd}	0.35^{b}	0.74^{b}	16.96^{a}	5.33^{cd}	54.94^{bc}	61.84^{cd}

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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
Location								
DZ	1.34[a]	1.35[a]	0.35[a]	0.78[a]	16.51[a]	6.74[a]	54.44[b]	62.04[a]
MI	1.24[b]	1.33[a]	0.33[b]	0.67[b]	16.14[a]	5.32[b]	55.11[a]	62.59[a]
CD	1.26[b]	1.28[a]	0.28[c]	0.59[c]	15.18[b]	5.12[b]	54.24[b]	64.12[a]
CV	0.20	0.23	0.06	0.20	2.26	2.26	1.66	8.52
LSD	0.011	0.153	0.0001	0.0001	0.002	0.0001	0.007	0.35
Year								
2010	1.40[a]	1.42[a]	0.32[a]	0.76[a]	15.75[a]	4.64[b]	54.57[a]	69.22[a]
2011	1.16[b]	1.22[b]	0.32[a]	0.61[b]	16.14[a]	6.81[a]	54.62[a]	56.60[b]
CV	0.20	0.23	0.06	0.20	2.26	2.26	1.66	8.52
LSD	0.0001	0.0001	0.731	0.001	0.226	0.0001	0.855	0.0001

Note: 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/100ml, DZ-Deber Ziet, CD-Chefe Donsa and MI-minjar

Proximate Composition

Moisture, protein, crude fat, carbohydrate, ash, and crude fibre analysed for the 11 chickpea varieties obtained from Minjar, Chefe Donsa and Debre Ziet cultivated during 2010 and 2011 (Table 4). When these proximate compositions were observed among all cultivars showed high variance among all varieties (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 2010 did not show variance among the 11 chickpea varieties (Additional file 1). The varieties Dera was found to have the highest protein (19.18%) which was slight similar with values reported by (Abebe et al., 2006) and in the range from 12.4% to 30.6% reported by (Chavan et al., 1986) and Habru with the best technological quality performance showing the highest protein content. The varieties like variety-19, Dimtu and Teketay had the highest total carbohydrate content (63.34%) which was generally higher compared to previously reports data’s on chickpea flours (Olika et al., 2019 and Kinfe et al., 2015). Whereas, Shasho, variety-24, Habru, Arerti and Ejeri were the highest in gross energy content among other varieties.

Most proximate compositions in location effect across 11 promising chickpea varieties of were showed significant effect except total moisture content and crude fibre content. All proximate compositions across all 11 selected chickpea varieties were influenced by cultivation year but not total ash contents of chickpea flours. In chickpeas, year was found to affect significantly both the protein and fat contents (Al-Karaki and Ereifej, 1999). The highest protein content from the three location 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, effects of climate and weather on grain protein concentrations are more predictable 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. Increasing temperature and/or reducing water availability is, therefore, associated with increased grain protein concentration, an effect long recognised in the field (Benzian and Lane, 1986). The effects of the year to the studied parameters could be possibly related to rainfall that is the most obvious meteorological data change between 2010 and 2011 (Table 2).

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 Crbohydra	G.Enrgy Kcal/100g
Natoli	10.93^{bcd}	3.71^{c}	5.24^{g}	17.74^{cd}	6.72^{ab}	62.38^{bc}	368.62^{d}
Ejere	10.85^{d}	3.19^{fg}	6.28^{bc}	17.92^{bcd}	6.59^{ab}	61.75^{cde}	376.54^{a}
Teketaye	11.31^{b}	3.29^{d}	5.70^{f}	16.98^{e}	6.78^{ab}	62.71^{ab}	370.83^{c}
Hora	11.30^{bc}	3.14^{gh}	6.08^{d}	17.56^{d}	5.92^{bcd}	61.91^{cd}	373.15^{b}
Dhera	12.06^{a}	3.28^{de}	5.86^{e}	19.18^{a}	7.49^{a}	59.61^{f}	368.29^{d}
Arerti	11.03^{bcd}	3.19^{fg}	6.37^{ab}	18.33^{b}	5.12^{d}	61.18^{e}	376.08^{a}
Dimtu	11.05^{bcd}	4.19^{b}	5.29^{g}	16.21^{f}	7.33^{a}	63.26^{a}	371.47^{bc}
Habru	11.05^{bcd}	3.11^{h}	6.43^{a}	18.33^{b}	6.39^{abc}	61.08^{e}	376.34^{a}
19	11.12^{bcd}	3.23^{ef}	5.86^{e}	16.43^{f}	6.51^{abc}	63.34^{a}	371.56^{bc}
Shasho	11.04^{bcd}	3.26^{de}	5.98^{d}	18.14^{bc}	5.35^{cd}	61.57^{de}	375.82^{a}
24	10.92^{cd}	4.43^{a}	6.25^{c}	16.34^{f}	6.41^{abc}	62.07^{bcd}	375.28^{a}
CV	2.05	1	1.13	1.63	10.77	0.67	0.3
LSD	0.0004	0.0001	0.0001	0.0001	0.0151	0.0001	0.0001
Location							
DZ	11.30^{a}	3.27^{a}	5.83^{b}	16.86^{b}	6.74^{a}	62.74^{a}	370.89^{a}
MI	11.18^{ab}	2.80^{b}	5.29^{c}	19.09^{a}	6.37^{a}	52.56^{b}	319.15^{b}
CD	11.17^{ab}	3.14^{a}	6.70^{a}	16.70^{b}	6.16^{a}	62.29^{a}	376.25^{a}
CV	0.76	0.34	0.76	1.82	1.88	1.76	5.91
LSD	0.06	0.01	0.0001	0.0001	0.206	0.0001	0.0001
Year							
2010	11.10^{a}	3.07^{b}	5.92^{a}	17.76^{a}	6.33^{a}	62.16^{a}	372.91^{a}
2011	11.20^{a}	3.38^{a}	5.97^{a}	17.34^{a}	6.51^{a}	62.41^{a}	372.73^{a}
CV	0.76	0.21	0.76	1.82	1.88	2.19	5.65
LSD	0.355	0.002	0.636	0.113	0.51	0.422	8.23

Mineral content

The chickpea seed is a good source of carbohydrates, dietary fiber, protein, niacin, folate and minerals like Ca, Fe, Mg, K, P, Zn and Cu (USDA, 2010). Calcium, magnesium, iron and zinc were measured and/ or calculated for the 11 chickpea varieties obtained from Minjar, Chefe Donsa and Debre Ziet cultivated during 2010 and 2011 (Table 5). All varieties in each locations and growing year were shows significant difference (Additional file 1). The concentration of minerals in seed flour of all genotypes showed significant variation and the same is true for the growing season (Table 5). Teketay in both calcium and iron content and Natoli in magnisum content showed the highest values among varieties. In Ejeri, Hora, Dear and Arerti varieties observed the highest zinc contents.

The levels of each mineral across three environments showed a high variation, indicating these compounds are strongly influenced by environmental factors. Previous studies have shown that amounts of minerals in chickpea depend on the agricultural practices, genotype, and environments (Guil-Guerrero et al., 2006; Sarpras et al., 2016 and Esayas et al., 2011). The location effects across 11 chickpea varieties were significant for all tested mineral contents (calcium, magnesium, iron and zinc) (Table 5). All compounds across all 11 chickpea varieties were influenced by cultivation year except iron contents of chickpea flour.

Table 5: mineral compositions in the 11 chickpea varieties grown across three environments by variety, location, and year

Variety	Ca (mg/100g)	Mg (mg/100g)	Fe mg/100g	Zn (mg/100g)
Natoli	196.11[d]	123.90[a]	6.17[e]	2.34[b]
Ejere	193.68[e]	115.45[e]	6.47[bc]	2.56[a]
Teketaye	202.08[b]	121.40[b]	6.68[ab]	2.23[cd]
Hora	211.67[a]	117.58[cd]	6.17[e]	2.59[a]
Dhera	186.43[g]	116.62[d]	6.41[cd]	2.57[a]
Arerti	199.67[c]	117.81[c]	6.33[cde]	2.54[a]
Dimtu	188.69[f]	117.99[c]	6.73[a]	2.17[d]
Habru	181.99[h]	112.60[g]	6.27[cde]	2.29[bc]
19	201.09[bc]	107.61[h]	5.86[f]	2.23[cd]
Shasho	175.86[i]	114.17[f]	6.25[de]	2.35[b]
24	164.31[j]	107.54[h]	6.28[cde]	2.17[d]
CV	0.68	0.54	1.92	1.61
LSD	0.0001	0.0001	0.0001	0.0001
Location				
DZ	171.72[b]	120.10[a]	7.10[a]	2.55[a]
MI	172.06[b]	116.85[a]	6.19[b]	2.34[b]
CD	229.39[a]	110.14[b]	5.70[c]	2.23[b]
CV	40.72	11.34	0.97	0.38
LSD	0.0001	0.0001	0.001	0.0001
Year				
2010	182.83[b]	120.31[a]	6.47[a]	2.49[a]
2011	199.28[a]	111.09[b]	6.19[a]	2.26[b]
CV	40.72	11.34	0.97	0.38
LSD	0.004	0.0001	0.05	0.0001

Origin of Variability

Significant genotype, environment, growing year, and interactions of (genotype × environment, genotype × year, environment × year and genotype × year × environment) effects were detected

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for proximate compositions, functional properties and mineral contents of chickpeas (Table 6). The two-way ANOVA showed that most parameters were significantly affected by the variety and the interaction of both (variety x location) (Table 6). The influence of genotypes of different chickpeas in chemical parameters is higher than the reported in other chickpeas (Berhane and Berhanu, 2020).

Table 6: Variability expressed as percentage of the total sum of squares for proximate composition, functional properties and mineral content of chickpea flours.

Parameters	Variety	Location	Year	V*L	V*Y	L*Y	V*L*Y
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
Fibre	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**

Notes: 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 $P < 0.05$.

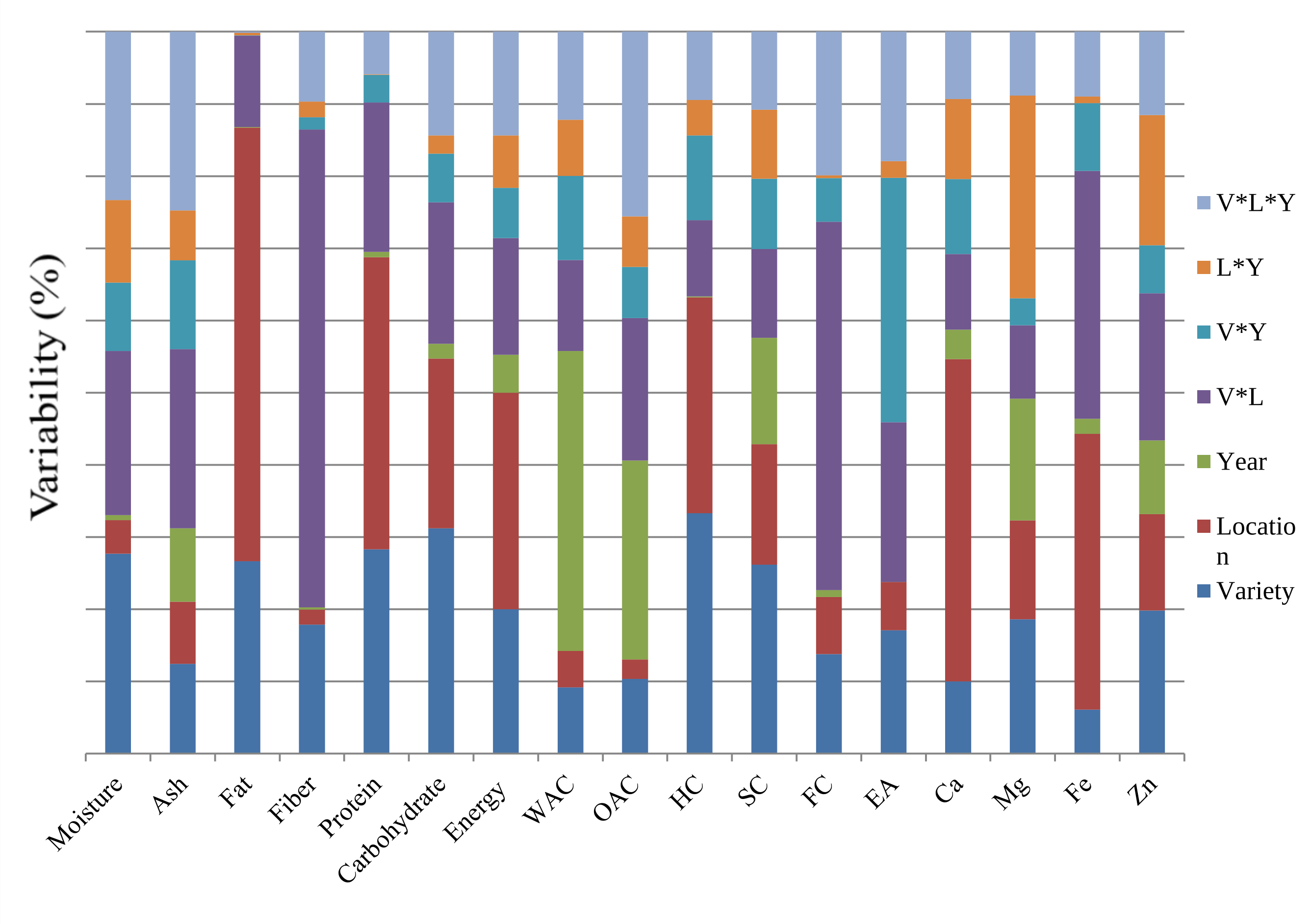

Figure 1: Variability proportion affecting on natural variation in parameters. Variability of each parameters explained by the location effect was used to order parameters on the X-axis (from the highest to the lowest)

Our results show that the main sources of variability in the proximate composition profile of chickpea are the variety and locations. Both parameters moisture and protein content were not significant (Table 3). Protein did not showed significantly affected by all interactions except variety * locations and this is similar finding were in the cases of protein where the combined effect of year and variety was not significant (Demetra et al., 2006). All functional properties are affected by all interactions except that of foaming capacity in location * 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 (fig.1) showed that the quantity of moisture and carbohydrate were significantly affected by variety, 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) (fig.1). 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 * Y interaction. The results of % variability for functional properties like water absorption capacity highly affected by year and

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 (Ereifej et al., 2001 and Gil et al., 1996). And also 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 fibre (r = -0.674). The generally small magnitude of the correlation between traits may have been due to the relatively small sample size used and/or the relatively narrow genetic base of the genotypes.

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 fibre	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	-.896**	0.081						
Energy	-0.583	-0.143	0.800**	0.054	-.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

Note:- *, ** = Significant at P<0.05 and 0.01, respectively.

CONCLUSION

Determination of flour functional and nutritional characteristics of diverse selected Ethiopian chickpea variety is very important for chickpea breeding programs. The cultivation location, the cultivation year and the chickpea variety, as well as the interactions of these factors strongly affect the functional properties and nutritional composition of chickpeas. The positive and significant relationships between gross energy and crude fibre 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 fibre across chickpea market classes will require a compromise during selection. However, like heritability, repeatability was genotype and environment specific and may be improved with additional testing to reduce error. However, the small magnitude of the correlation between traits and repeatability values may be due to the relatively small sample size utilised and the relatively narrow genetic base of the experimental materials. 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. This study will give insight for selection of chickpea varieties for the local consumption and can be used for different chickpea based protein-enriched complementary food products and other food products.

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Competing interests
The authors declare that they have no competing interests.

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