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**ORIGINAL PAPER**

# MINERALS, VITAMINS, PROTEIN AND AMINO ACIDS IN WILD *CICER* SPECIES AND PURE LINE CHICKPEA GENOTYPES SELECTED FROM A LOCAL POPULATION

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**Abstract**

In this study, ten local chickpea genotypes, ILC4951, *Cicer reticulatum, C. echinospermum*, standard variety Cagatay and a population from Izmir region were investigated for their composition of vitamins, minerals, protein and amino acids. The samples were collected in 2015 from 40 different chickpea production areas of Mardin, Diyarbakir and Adiyaman provinces of Southeastern Anatolia and İzmir regions of the Aegean area of Turkey. ILC 4951, *Cicer echinospermum* and *C. reticulatum* were obtained from the Faculty of Agriculture of Dicle University in Diyarbakir. The local chickpea samples included the lines obtained by pure line selection from local chickpeas grown farmers in the chickpea production areas in southeast Anatolia region. Genotypes were separated as desi and kabuli types. Genotypes had low crude protein content, 18.71 to 22.41%. Wild species had higher calcium, phosphorus and sodium content than the local varieties genotypes. Thiamine, riboflavin and pyridoxine ranged from 0.32 to 0.70 mg 100 $g^{-1}$, 0.03 to 0.54 mg 100 $g^{-1}$ and 0.22 to 0.53 mg 100 $g^{-1}$, respectively. *C. reticulatum* had low lysine, while a local desi genotype had the highest lysine content. The research results demonstrated that varieties grown by farmers, which were a mixture of both local and wild species, were of higher quality than the standard variety.

**Keywords:** chickpea, *Cicer arietinum* L., wild species, kabuli, desi, local, thiamine, Na, Ca, P.

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# INTRODUCTION

Chickpea (*Cicer arietinum* L.) has an important place in food legumes production in the world, with the total production of 14.2 million tonnes over 14.8 million hectares of harvested area. The most important chickpea producing countries are India, Australia, Myanmar, Ethiopia, Turkey, Pakistan, Russia, Iran, Mexico, USA and Canada (FAO 2019).

The chickpea most probably originated in south-eastern Turkey and adjoining Syria. Three wild annual species of *Cicer* are found there: *C. bijugum* K.H. Rech., *C. echinospermum* P.H. Davis and *C. reticulatum* Lad. *Cicer reticulatum* can be considered as a progenitor of or having a common ancestor with chickpea (Van Der Maesen 1987). It is believed that chickpea was first cultivated and consumed 7500-6800 years ago in Southeast Turkey in Chaion (=Cayonu =Çayönü) – Zeist (1982), where the material for this study were collected.

There are two main commercial classes of chickpeas: desi (colored flower, wrinkled thick seed coat and small, dark, angular seeds) common in semi-arid tropics, and kabuli (white flower, smooth thin seed coat, and large, cream-colored seeds) types usually grown in temperate regions (Cobos et al. 2007). Another type called "pea-shaped" is distinguished by a small/medium seed size and round seeds of cream/brown color (Knights et al. 2011). Vishnyakova et al. (2017) reported that 57% of the Turkish landraces were classified as kabuli-type.

The popularity of chickpea in human nutrition is due to its balanced seed nutrient composition and low price. Those who cannot afford animal protein, vegetarians and people in semi-arid regions mostly consume chickpeas as a protein source (Muehlbauer, Rajesh 2008). Although chickpea used to be popular in developing countries, it is now accepted by developed world countries (Jukanti et al. 2012). Cereals are rich in thiol-containing amino acids (methionine and cysteine) and deficient in lysine, while legumes are rich in lysine and deficient in methionine and cysteine. Therefore, legumes are taken with the addition of seeds for proper intake of essential amino acids. Also, legumes have higher protein, folate, magnesium, potassium and zinc content that cereals (Singh 2017). Chickpea is relatively cheap, and it is a rich source of folate. It is characterized by a relatively high content of folate combined with more modest amounts of other water-soluble vitamins such as riboflavin, pantothenic acid, and pyridoxine. The amount of these vitamins is similar or higher than in other legumes.

Local crop varieties or landraces or farmers' varieties, can be essential to the food, nutrition and economic security of many people, smallholder farmers in rural and marginal areas (FAO, 2021).

The local chickpea varieties of the South-eastern Anatolia region are, mainly kabuli, a mixture of kabuli and desi types. These are medium and small, ivory white (off-white) coloured, dark yellow, brown and partially black, thistly- thick seed coat, which are close to wild forms, like *Cicer bijugum* Rech. seed coat, and black coloured desi types are common in mountainous villages.

Our local chickpeas are tasty, short cooking time, low yielded, sometimes sensitive to anthracnose, but more yielded than improvement varieties in dry conditions. These are cheap, and prices are remained stagnant for a long period of time, thus consumer demand is constant. Our local chickpeas are available in local markets, not in new markets. Although this situation reduces the market opportunity of our producers, their production is still continuing.

The popularity of chickpea in human nutrition is due to its balanced seed nutrient composition and low price. Those who cannot afford animal protein, vegetarians and people in semi-arid regions mostly consume chickpea as a protein source. Although chickpea used to be popular in developing countries, it is now accepted by developed world countries. The local chickpea varieties of the South-eastern Anatolia region are, mainly kabuli, a mixture of kabuli and desi types. Local crop varieties or landraces or farmers' varieties, can be essential to the food, nutrition and economic security of many people, smallholder farmers in rural and marginal areas.

We aimed to examine the nutritional characteristics of chickpea, which is preferred and consumed by the local people in our region, and which attracts a lot of attention in local markets, by collecting it from production areas. Instead of examining the populations we collected collectively, we examined these local varieties, which are in the form of mixtures or populations, individually after purifying them through selection.

## MATERIALS AND METHODS

Samples were collected from 40 different chickpea production areas, from the provinces of Mardin, Diyarbakir and Adiyaman belonging to the South-east Anatolia, and İzmir province of the Aegean regions of Turkey in 2015. ILC 4951, *Cicer echinospermum* and *C. reticulatum* were obtained from the Faculty of Agriculture of Dicle University in Diyarbakir. Seed samples were separated as desi, kabuli and pea shaped in the first year. In the 2$^{nd}$ year, seeds were sown as single row, and individual plants were selected, and in the 3$^{rd}$ and 4$^{th}$ years seeds of individual plants were sown in single rows in augmented design, and harvested at the end of the year by selecting rows. The pure line selection method was applied for three years. On the 5$^{th}$ year, the seeds was sown randomized complete block design with three replications observations were taken in amino acid profile, protein, Ca, P, K, and vitamins. Seed types of genotypes were given in Table 1.

Table 1

Seed types in local chickpea genotypes

<table>
<tr><th>Geno-types</th><th>Seed type</th><th>Geno-types</th><th>Seed type</th><th>Genotypes</th><th>Seed type</th></tr>
<tr><td>L1</td><td>desi-rough - wrin-kle- dark yellow</td><td>L6</td><td>pea shaped</td><td>Izmir</td><td>kabuli-white</td></tr>
<tr><td>L2</td><td>desi-rough - wrinkle yellow</td><td>L7</td><td rowspan="3">kabuli-wrinkle -beige</td><td>ILC 4951</td><td>ILC 4951</td></tr>
<tr><td>L3</td><td>desi-rough black</td><td>L8</td><td>standard variety</td><td>kabuli-cagatay</td></tr>
<tr><td>L4</td><td>kabuli-smooth-beige</td><td>L10</td><td>Cicer echinospermum</td><td rowspan="2">wild</td></tr>
<tr><td>L5</td><td>kabuli-smooth-white</td><td>L9</td><td>kabuli-rough -wrinkle</td><td>C. reticulatum</td></tr>
</table>

The samples were analysed in Food Industry Laboratory in Marmara Research Centre of Turkish Scientific and Technological Research Institute (TUBITAK MAM- Kocaeli, Turkey). B vitamins, thiamine, riboflavin and pyridoxine, were determined in HPLC HL detector following an enzymatic incubation (Finglas, Faulks 1984, Gauch et al. 1992). Mineral analyses were made by Mass spectrometry method. Minerals (for crushed and dried samples kept at 70-105°C) were made soluble through closed system microwave wet etching and concentrations were determined by using ICP-OES. The sample is solubilized with nitric acid or hydrochloric acid at 100-500 psi and 50-180°C. For the solubilization process, nitric acid, hydrochloric acid, hydrofluoric acid, sulfuric acid, hydrogen peroxide etc. are used. Ca, Na, K and P were determined in accordance with AOAC (2002). Samples of the experimental were analysed for proximate analysis using the procedure of AOAC.

Crude protein was estimated by Kjeldahl method based on AOAC methods. The digest contained residual $H_2SO_4$ to retain the $NH_3$. Water was added manually to the digest to avoid mixing concentrated alkali with concentrated acid and to prevent the digest from solidifying. Concentrated NaOH was added to neutralize the acid and make the digest basic, and the liberated $NH_3$ was distilled into a boric acid solution and titrated with a stronger standardized acid, HCl, to a colorimetric endpoint. The analysis was crude protein because the method determined N.

The nitrogen content determined was converted to protein content using conversion factor 5.80. For amino acid composition, proteins were hydrolysed into amino acid components by deriving with phenyl isothiocyanate in ultra-fast liquid chromatography (UFLC) and then area of peaks obtained from UFLC UV detector (The Phenomenex EZ:faast™ amino acid analysis kit, varian GC), CP-3800GC) (Badawy et al. 2008).

Data analyses were performed with SPSS software (version 23.0, SSPS Inc, Chicago IL, USA). A $p$ value of $<0.05$ was considered as significant.

# RESULTS AND DISCUSSIONS

Legumes are valued worldwide as a sustainable and inexpensive meat alternative and are considered the second most important food source after cereals. We evaluated desi and kabuli of local chickpea genotypes and wild species to assess differences for nutritional quality components.

Chickpea has protein quality better than other legumes and is a good source of dietary protein (Kaur, Singh 2007). The raw protein content in chickpea genotypes (Table 2) ranged from 18.71% (standard variety Cagatay) to 22.41% (L10). The raw protein content in desi genotypes was on average 21.47%, and the protein content ranged from 18.41 to 22.41% in kabuli genotypes with the mean value of 21.41%. The raw protein content in wild species was from 21.56% in *C. echinospermum* and 21.83% in *C. reticulatum* (Table 2). Singh et al. (1990) reported protein content between 18.7% and 24.0% in five improved desi chickpea cultivars. Gaur et al. (2016) reported that the protein content in desi (29.2%) was found to be higher than in kabuli

Table 2

Protein (%), calcium, phosphorus, sodium and potassium minerals of chickpea genotypes (mg 100 g$^{-1}$).

| Genotypes | Crude protein | Calcium | Phosphorus | Ca:P ratio | Sodium | Potassium | Na:K ratio |
|---|---|---|---|---|---|---|---|
| L1 | 21.21 | 127.8 *k* | 259.8 *h* | 0.5 | 4.37 *l* | 934.2 *l* | 0.017 |
| L2 | 21.52 | 117.5 *l* | 271.6 *g* | 0.4 | 4.55 ıj | 1128.0 *b* | 0.017 |
| L3 | 21.42 | 216.9 *a* | 287.4 *f* | 0.8 | 4.37 *l* | 960.0 *k* | 0.015 |
| ILC 4951 | 21.75 | 107.3 *n* | 308.1 *e* | 0.3 | 5.57 *c* | 1050.0 *g* | 0.018 |
| Standard variety | 18.71 | 199.7 *b* | 252.8 *h* | 0.8 | 5.29 *f* | 924.2 *l* | 0.021 |
| L4 | 22.00 | 85.9 *o* | 295.1 *f* | 0.3 | 6.30 *b* | 1152.7 *a* | 0.021 |
| L5 | 21.61 | 109.0 *m* | 308.4 *e* | 0.4 | 6.32 *b* | 1010.7 ı | 0.020 |
| L7 | 22.33 | 161.0 *f* | 371.8 *b* | 0.4 | 4.83 *h* | 1063.3 *ef* | 0.013 |
| L8 | 21.67 | 156.9 *g* | 387.3 *a* | 0.4 | 5.1 *g* | 1102.7 *c* | 0.013 |
| Izmir | 21.92 | 152.8 *h* | 390.9 *a* | 0.4 | 5.46 *d* | 993.4 *j* | 0.014 |
| L9 | 20.18 | 143.0 *j* | 275.2 *g* | 0.5 | 4.52 *j* | 1068.3 *e* | 0.016 |
| L10 | 22.41 | 193.6 *c* | 333.0 *d* | 0.6 | 5.35 *e* | 1082.0 *d* | 0.016 |
| L6 | 21.64 | 147.8 *i* | 385.2 *a* | 0.4 | 4.59 ı | 1054.3 *fg* | 0.012 |
| *C. echino.* | 21.83 | 176.0 *e* | 351.4 *c* | 0.5 | 4.45 *k* | 1019.3 ı | 0.013 |
| *C. reticulatum* | 21.56 | 181.7 *d* | 366.8 *b* | 0.5 | 6.43 *a* | 1037.0 *h* | 0.018 |
| LSD 0.05 | - | 0.512** | 5.213* | ns | 0.03** | 5.07* | ns |

The means in columns followed by the same letter are not significantly different from each other.
* significant at 0.05 level of significance,
** significant at 0.01 level of significance, ns – no significant.

chickpea (20.5%). Singh et al. (2010) revealed that the protein content in chickpea genotypes ranged between 15.7 and 31.5%. Differences in the protein content among chickpea cultivars may be attributed to differences in their genetic background. Wang et al. (2017) showed that desi, kabuli and pea-shaped genotypes contained on average 22.2%, 23.4%, and 22.4% of protein, respectively. The protein content of the local varieties we used in our study was low, which is similar to the findings of Ozer et al. (2010), who also demonstrated that the Diyarbakir landraces had a low protein content. Karaca et al. (2019) reported that the highest protein concentration was observed in wild genotypes (Derei_070 and TR37527), and all of these genotypes belong to the *C. reticulatum* species, collected from this study area.

The calcium content in chickpea genotypes ranged from 85.9 mg 100 $g^{-1}$ to 216.9 mg 100 $g^{-1}$. Wild species had higher calcium content than the other genotypes, with the mean value of 171.6 mg 100 $g^{-1}$. Desi genotype L3 had the highest Ca content, and the Ca content in all desi genotypes varied from 107.3 to 216.9 mg 100 $g^{-1}$ with the mean value 165.5 mg 100 $g^{-1}$. In kabuli genotypes, it ranged from 85.9 to 199.7 mg 100 $g^{-1}$ with the mean value 158.8 mg 100 $g^{-1}$, and kabuli genotype L4 had the lowest calcium content. (Table 2, Figure 1). Jukanti et al. (2012) reported that were significant diffe-

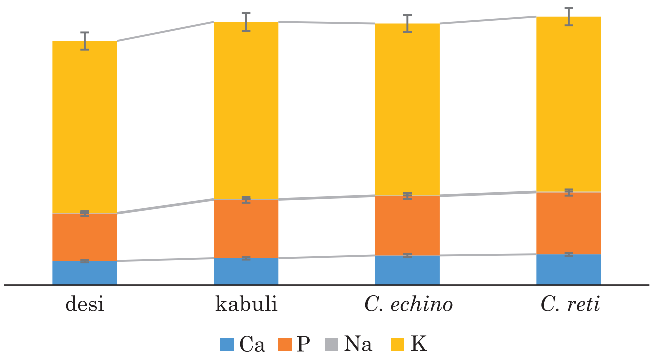


Fig. 1. Minerals in local desi, kabuli genotypes and wild species

rences between the kabuli and desi chickpeas in terms of Ca, and the desi type had more Ca than the kabuli one.

Phosphorus is found in almost all foods and therefore deficiencies are not so common. While animal origin foods provide an important source of phosphorus, one of the most important non-animal sources of phosphorus is chickpeas. The phosphorus content in chickpea genotypes ranged from 259.8 to 390.9 mg 100 $g^{-1}$. Wild species had the highest phosphorus content with the mean value of 358.1 mg 100 $g^{-1}$. In kabuli genotypes, the phosphorus content ranged from 252.8 to 390.9 mg 100 $g^{-1}$ with the mean value of 354.3 mg 100 g-1, and the total phosphorus content in desi genotypes ranged from 259.8 to 308.1 mg 100 $g^{-1}$ with the mean value of 275.9 mg 100 $g^{-1}$. L6, Izmir and L8 genotypes, all representing the kabuli type, had the highest phosphorus content. (Table 2, Figure1). Iqbal et al. (2006) and Alajaji, El-Adawy (2006) reported average P content in chickpea to be 226 mg 100 $g^{-1}$ and 251 mg 100 $g^{-1}$, respectively.

The mean Ca:P ratio in chickpea genotypes ranged from 0.3 to 0.8, indicating a high concentration of phosphorus compared to calcium. This ratio should be no less than 1.0 (Table 2).

The sodium content in chickpea genotypes ranged from 4.37 to 6.43 mg 100 $g^{-1}$ with the mean value of 5.0 mg 100 $g^{-1}$. Wild species had the highest sodium content with the mean of 5.2 mg 100 $g^{-1}$, and the highest sodium content was in *C. reticulatum*. The sodium content ranged from 4.29 to 6.32 mg 100 $g^{-1}$ with the mean value of 5.0 mg 100 $g^{-1}$ in kabuli genotypes, and from 4.37 to 5.57 mg 100 $g^{-1}$ with the mean value of 4.8 mg 100 $g^{-1}$ in desi genotypes (Table 2, Figure 1).

The potassium content in chickpea genotypes ranged from 924.2 mg 100 $g^{-1}$ to 1152.7 mg 100 $g^{-1}$. The highest content of potassium was found in L4. The standard variety had the lowest potassium content. Although the differences between kabuli, desi and wild species in terms of the mean potassium content were not high, the desi genotypes were relatively low in this element (Table 2, Fig. 1).

The mean Na:K ratio in chickpea genotypes ranged from 0.012 to 0.02, indicating a low concentration of sodium compared to potassium. This low ratio is very important for human health.

Wild species had higher calcium, phosphorus and sodium content than the local varieties (Table 2, Figure 1). Similarly, Kaur et al. (2019) reported the calcium content of wild species to be higher than in cultivated genotypes. Desi and kabuli genotypes and wild species had high amounts of potassium (69%), phosphorus (21%) and calcium (10%), but a low amount of sodium (Figure 1). Vandemark et al. (2018) reported that potassium was the most abundant mineral in chickpea seed.

Pulses are a good source of vitamins. Chickpea can complement the vitamin requirement of an individual when consumed with other foods. It is a relatively inexpensive and good source of folic acid and tocopherols. It is also a relatively good source of folic acid coupled with more modest amounts of water-soluble vitamins such as B2, B5 and B6, and these levels are similar to or higher than those observed in other pulses (Jukanti et al. 2012).

Thiamine, riboflavin and pyridoxine ranged from 0.32 to 0.5 mg 100 $g^{-1}$, 0.03 to 0.54 mg 100 $g^{-1}$ and 0.22 to 0.53 mg 100 $g^{-1}$, respectively. The highest thiamin value was recorded in L10, a kabuli genotype, riboflavin was the highest in *C. reticulatum*, and prydoxine was the most abundant in ILC 4951, a desi genotype (Table 3).

Riboflavin in the wild species was higher (with a mean 0.34 mg 100 $g^{-1}$) than in the kabuli (0.18 mg 100 $g^{-1}$) and desi genotypes (mg 100 $g^{-1}$). Thiamin was higher in the kabuli genotypes (with a mean 0.51 mg 100 $g^{-1}$) than in both desi and wild species. Thiamin (46%) was higher than pyridoxine (37%)

Table 3

Thiamin, riboflavin and pyridoxine vitamins of chickpea genotypes (mg 100 g$^{-1}$)

| Genotypes | Thiamine (B1) | Riboflavin (B2) | Pyridoxine (B6) |
|---|---|---|---|
| L1 | 0.38 *g* | 0.08 *i* | 0.23 *h* |
| L2 | 0.51 *e* | 0.11 *h* | 0.49 *ab* |
| L3 | 0.32 *i* | 0.03 *k* | 0.22 *h* |
| ILC 4951 | 0.56 *d* | 0.24 *d* | 0.53 *a* |
| Standard variety | 0.33 *hi* | 0.09 *i* | 0.43 *cde* |
| L4 | 0.36 *gh* | 0.07 *j* | 0.42 *def* |
| L5 | 0.45 *f* | 0.12 *gh* | 0.45 *b-e* |
| L6 | 0.62 *b* | 0.12 *g* | 0.40 *ef* |
| L7 | 0.61 *bc* | 0.15 *f* | 0.37 *fg* |
| L8 | 0.37 *g* | 0.16 *e* | 0.40 *ef* |
| İzmir | 0.59 *bc* | 0.38 *b* | 0.43 *de* |
| L9 | 0.58 *cd* | 0.14 *f* | 0.48 *abc* |
| L10 | 0.70 *a* | 0.35 *c* | 0.37 *fg* |
| *Cicer echino.* | 0.51 *e* | 0.14 *f* | 0.34 *g* |
| *C.reticulatum* | 0.43 *f* | 0.54 *a* | 0.46 *bcd* |
| LSD | 0.08** | 0.005** | 0.03** |

The means in columns followed by the same letter are not significantly different from each other.
** significant at 0.01 level of significance.

and riboflavin (17%) in the all genotypes. *C. reticulatum* had the highest overall B vitamins compared to the other genotypes (Figure 2). Similarly, Alajaji, El-Adawy (2006) reported average B1 453.3 μg 100 g$^{-1}$, B2 173.3 μg 100 g$^{-1}$ and B6 466.3 μg 100 g$^{-1}$. Patil et al. (2020) reported that thiamin, pyridoxine and riboflavin were 0.33-0.61 mg 100 g$^{-1}$, 0.39-0.71 mg 100 g$^{-1}$ and 0.16 0.33 mg 100 g$^{-1}$, respectively.

The amino acid profile in chickpea seeds shows that there were eight types of essential amino acids (Table 4). Leucine, phenylalanine and lysine were the highest constituents, whereas histidine and methionine, and even sltighly threonine, were the lowest in concentration. Also, histidine and methionine did not markedly differ. Leucine, phenylalanine and lysine ranged from 7.15 to 10.83 g 100 g$^{-1}$, 5.18 to 9.15 g 100 g$^{-1}$ and 5.53 to 9.92 g 100 g$^{-1}$, respectively. The highest leucine, phenylalanine and valine were recorded in *C. reticulatum,* wild species. *C. reticulatum* had low lysine (Table 4, Figure 3). The highest lysine was recorded in the desi genotype L2. Also, the differences in the lysine content between the cultivated and wild species were not as large as reported by Singh, Pundir (1991).

Differences in the content of histidine, methionine and threonine among the genotypes were statistically significant and ranged from 0.32 to 1.41 g

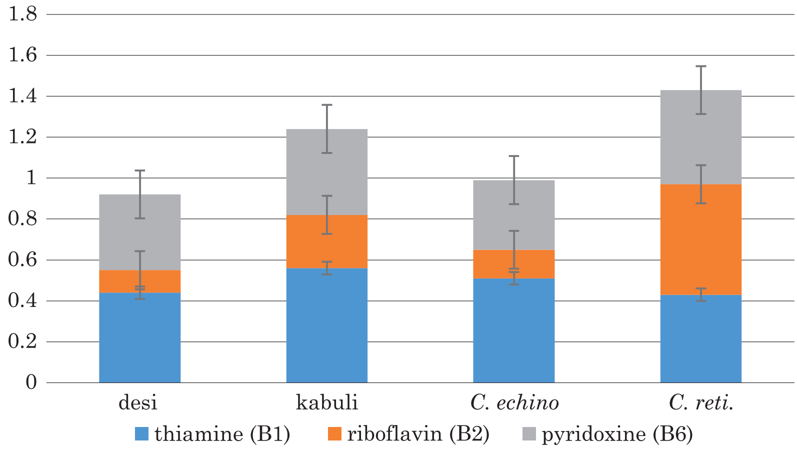


Fig. 2. B1, B2 and B6 vitamins in local desi, kabuli genotypes and wild species

Table 4

Essential amino acid content of chickpea genotypes (g 100 $g^{-1}$)

| Genotypes | Leucine | Phenyl-alanine | Lysine | Valine | Isoleu-cine | Thre-onine | Histi-dine | Methi-onine |
|---|---|---|---|---|---|---|---|---|
| L1 | 7.37 *fg* | 5.60 *gh* | 5.53 *h* | 5.01 *cd* | 4.88 *cde* | 3.90 *cd* | 1.06 *c* | 0.57 *d* |
| L2 | 7.15 *h* | 5.65 *gh* | 9.92 *a* | 4.49 *g* | 4.83 *de* | 3.69 *def* | 1.28 *b* | 1.10 *b* |
| L3 | 7.52 *f* | 5.52 *h* | 7.97 *b* | 4.89 *de* | 4.61 *f* | 4.44 *ab* | 0.90 *de* | 0.39 *e* |
| ILC 4951 | 7.37 *fg* | 6.30 *cd* | 6.64 *d* | 5.28 *b* | 5.82 *a* | 4.34 *ab* | 0.81 *fg* | 0.84 *c* |
| Standard variety | 8.62 *b* | 6.58 *b* | 6.98 *c* | 4.74 *ef* | 5.44 *b* | 4.50 *a* | 0.92 *d* | 1.26 *a* |
| L4 | 7.99 *de* | 6.26 *cd* | 6.51 *d* | 5.14 *bc* | 5.54 *b* | 4.09 *bc* | 1.25 *b* | 0.86 *c* |
| L5 | 7.89 *e* | 6.23 *d* | 6.54 *d* | 4.57 *fg* | 4.88 *cde* | 3.51 *ef* | 0.84 *ef* | 1.15 *b* |
| L6 | 8.19 *cd* | 5.92 *ef* | 6.12 *e* | 4.18 *hi* | 4.81 *e* | 3.91 *cd* | 0.84 *efg* | 1.30 *a* |
| L7 | 7.16 *h* | 5.18 *i* | 6.60 *d* | 4.02 *i* | 4.31 *g* | 3.58 *def* | 0.36 *j* | 0.39 *e* |
| L8 | 8.43 *b* | 6.12 *de* | 5.60 *gh* | 4.37 *gh* | 5.02 *c* | 3.78 *cde* | 0.32 *j* | 0.43 *e* |
| Izmir | 8.20 *c* | 6.50 *bc* | 5.74 *fg* | 4.16 *hi* | 4.96 *cd* | 3.42 *f* | 0.45 *i* | 1.14 *b* |
| L9 | 7.18 *gh* | 5.84 *fg* | 5.90 *f* | 4.82 *de* | 5.45 *b* | 3.54 *ef* | 0.78 *g* | 1.13 *b* |
| L10 | 7.05 *h* | 6.08 *def* | 6.97 *c* | 4.00 *i* | 4.33 *g* | 3.38 *f* | 1.41 *a* | 1.14 *b* |
| *C. echinospermum* | 7.23 *gh* | 5.96 *ef* | 6.89 *c* | 3.97 *i* | 4.04 *h* | 3.64 *def* | 0.94 *d* | 0.27 *f* |
| *C. reticulatum* | 10.83 *a* | 9.15 *a* | 6.27 *e* | 7.98 *a* | 5.44 *b* | 3.67 *def* | 0.63 *h* | 1.11 *b* |
| LSD | 0.10** | 0.12** | 0.09** | 0.11** | 0.07** | 0.017** | 0.03** | 0.02** |

The means in columns followed by the same letter are not significantly different from each other.
** significant at 0.01 level of significance.

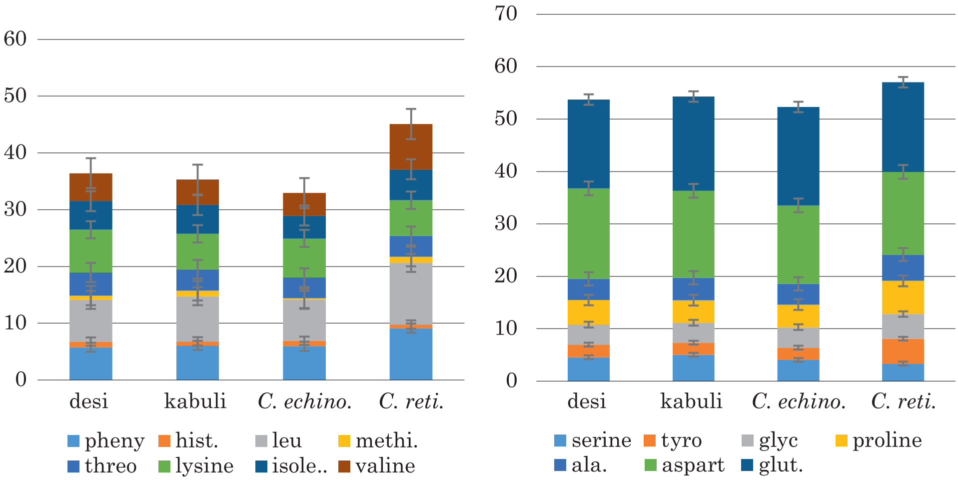


Fig. 3. Amino acid composition in local desi, kabuli genotypes and wild species

100 g$^{-1}$ and 0.27 to 1.30 g 100 g$^{-1}$, and 3.38 to 4.50 g 100 g$^{-1}$, respectively (Table 4). Singh, Pundir (1991) and Jukanti et al. (2012) reported that food legumes such as chickpea had limited concentrations of sulfur-rich amino acids (methionine and cystine). Iqbal et al. (2006) reported that histidine (8.3-13.6 g 100 g$^{-1}$), methionine (1.1-2.12 g 100 g$^{-1}$) and threonine (3.3-5.1 g 100 g$^{-1}$) of chickpea were low in quantity.

The differences in the amino acid profiles of kabuli and desi genotypes were no significant (Figure 3). Also, the highest lysine (9.92 g 100 g$^{-1}$) and isoleucine (5.82 g 100 g$^{-1}$) and threonine (4.44 g 100 g$^{-1}$) were record on desi genotypes. Similarly, Wang et al. (2010) reported that no significant differences in the amino acid profiles of kabuli and desi type chickpea. Singh, Pundir (1991) reported that methionine and histidine varied from 1.2 to 2.9 protein for all wild species accessions. They indicated that sulfur-containing amino acids were higher in the cultivated species than in the wild species.

Chickpea genotypes had a good amount of non-essential amino acids, and significant differences in both non-essential and conditionally non-essential amino acids was found among the chickpea genotypes. Aspartic acid and glutamic acid were the predominant amino acids of protein in chickpea genotypes, as reported by Singh, Jambunathan (1982). Aspartic acid, glutamic acid and alanine ranged from 12.67 to 28.05 g 100 g$^{-1}$ and 14.44 to 18.95 g 100 g$^{-1}$, and 3.78 to 5.02 g 100 g$^{-1}$, respectively. The highest glutamic acid was recorded in the kabuli L5 (18.95 g 100 g$^{-1}$) and L10 genotypes (18.94 g 100 g$^{-1}$), followed by L9 (18.85 g 100 g$^{-1}$) and wild species, *C. echinospermum* (18.80 g 100 g$^{-1}$), while the lowest amount was in the desi genotype L1 (14.44 g 100 g$^{-1}$). The highest alanine was recorded in *C. reticulatum,* a wild species, while the lowest was recorded in *C. echinospermum*. Conditionally non--essential tyrosine (1.87 - 4.75 g 100 g$^{-1}$) and proline (2.41 - 6.33 g 100 g$^{-1}$) values showed large variation among the genotypes. The highest tyrosine

(4.75 g 100 g$^{-1}$), proline (6.33 g 100 g$^{-1}$) and glycine (4.70 g 100 g$^{-1}$) values were recorded in *C. reticulatum*, while serine was the highest in kabuli L7 (5.63 g 100 g$^{-1}$) – Table 5, Figure 3. Non-essential and conditionally non-essential amino acid mean values did not show large variation among the desi and kabuli of chickpea genotypes. In contrast, the mean values of alanine, tyrosine and proline in wild species were a little higher than in the desi and kabuli genotypes (Table 5, Figure 3). Singh, Jambunathan (1982) reported that differences between wild species and cultivated genotypes were significant for the amino acid composition. The total concentrations of essential and non-essential amino acids reached 40.0% to 60.0% of protein. Shah et al. (2021) reported the total concentration of essential and non-essential amino acid were 40.81 to 59.18343 g 100 g$^{-1}$ protein in their cultivars.

Table 5

Conditionally non-essential and non-essential amino acid composition of chickpea genotypes

| Genotypes | Non-essential | | | Conditionally non-essential | | | |
|---|---|---|---|---|---|---|---|
| | alanine | aspartic acid | glutamic acid | tyrosine | proline | glycine | serine |
| L1 | 3.78 *i* | 25.81 *b* | 14.44 *i* | 2.11 *g* | 4.76 *fg* | 3.68 *f* | 4.64 *ef* |
| L2 | 3.95 *gh* | 12.67 *i* | 18.58 *bc* | 2.35 *ef* | 5.69 *b* | 3.69 *def* | 4.99 *d* |
| L3 | 3.94 *gh* | 15.57 *cd* | 16.30 *h* | 2.46 *cd* | 4.31 *h* | 3.66 *f* | 3.91 *h* |
| ILC 4951 | 4.49 *c* | 15.01 *e* | 18.38 *cd* | 2.70 *b* | 3.98 *i* | 4.16 *b* | 4.77 *e* |
| Standard variety | 4.01 *fg* | 14.38 *g* | 16.76 *g* | 2.42 *def* | 4.93 *de* | 3.73 *c-f* | 5.00 *d* |
| L4 | 4.28 *d* | 28.05 *a* | 16.73 *g* | 2.53 *c* | 5.04 *d* | 3.81 *c-f* | 4.56 *f* |
| L5 | 4.82 *b* | 14.61 *fg* | 18.95 *a* | 2.48 *cd* | 5.17 *c* | 3.68 *ef* | 4.65 *ef* |
| L6 | 4.01 *fg* | 15.38 *d* | 18.40 *cd* | 2.46 *cd* | 2.41 *k* | 3.73 *c-f* | 5.39 *b* |
| L7 | 4.70 *b* | 15.71 *c* | 18.03 *e* | 1.87 *h* | 3.16 *j* | 3.87 *c-f* | 5.63 *a* |
| L8 | 4.21 *de* | 14.59 *g* | 17.93 *e* | 2.19 *g* | 4.87 *ef* | 3.90 *cd* | 5.19 *c* |
| Izmir | 4.06 *fg* | 14.46 *g* | 18.15 *de* | 2.43 *de* | 4.75 *fg* | 3.89 *cde* | 5.35 *bc* |
| L9 | 4.12 *ef* | 15.37 *d* | 18.85 *ab* | 2.19 *g* | 3.95 *i* | 3.81 *c-f* | 4.56 *f* |
| L10 | 3.82 *hi* | 13.82 *h* | 18.94 *a* | 2.43 *de* | 4.64 *g* | 3.79 *c-f* | 4.15 *g* |
| *Cicer echino.* | 3.97 *g* | 14.92 *ef* | 18.80 *ab* | 2.34 *f* | 4.30 *h* | 3.91 *c* | 4.06 *gh* |
| *C. reticulatum* | 5.02 *a* | 15.74 *c* | 17.15 *f* | 4.75 *a* | 6.33 *a* | 4.70 *a* | 3.36 *i* |
| LSD 0.05 | 0.06* | 0.15* | 0.138* | 0.044* | 0.33* | 0.11* | 0.09* |

The means in columns followed by the same letter are not significantly different from each other.
* significant at 0.05 level of significance.

# CONCLUSION

The local chickpea varieties are mixed seeds of desi, kabuli and occasionally wild species, *C. reticulatum* and *C. echinospermum*. It is widely accepted that the nutritional values of local or farmer' mixed chickpea varieties are high, and therefore they are highly preferred by consumers. In this study, we aimed to identify the species and types that increased the value of the mixed local varieties. *Cicer reticulatum* showed higher values for minerals, vitamins and amino acid composition than both local genotypes and *C. echinospermum*. Also, the nutrient content of the local genotypes was higher than in the standard variety, regardless of the genotype: desi and kabuli. Therefore, it was clear that chickpea varieties grown by farmers, which were a mixture of both local and wild species, were of higher quality than the standard variety. After *C. reticulatum, C. echinospermum* is the next closest relative of the cultivated chickpea. *C. reticulatum* and *C. echinospermum* have been reported to be resistant to several biotic and abiotic stresses (Von Wettberg et al. 2018). Also, *C. reticulatum* especially has high quality. Crosses between *C. arietinum* × *C. reticulatum* have full fertile hybrids, while crosses between *C. arietinum* × *C. echinospermum* have partially fertile hybrids. Due to this fertility aspect, it is important to use wild species, especially *C. reticulatum*, in breeding programs in order to increase the low nutrition quality of new developed varieties.

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