Impact of climate change over the cropping years on nutritional and phytochemical compositions in chickpeas and harnessing their potential for human utility

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Abstract

The study investigates the proximate composition, non-nutrient phenols and mineral profile of selected chickpea cultivars. Eight cultivars, comprising of four desi (BG-3062, BG-20211, BG-1053 and K-850) and four kabuli (BG-3022, BG-2024, BG-1103, BG-1108) varieties were analyzed. The data on the proximate composition of chickpeas depicted that all cultivars had appreciable amount of protein, however, a significant difference (19.13% - 25.36%) was found between cultivars. The non-nutrient analysis showed total phenolic content (TPC) ranging from 101- 276 mg GAE/100g and total flavonoid content (TFC) from 0.100-0.173 mg/g. Phytate content varied between 579-891.6 mg/100g. Phenol and phytate content were higher in desi cultivars than in kabuli. Mineral analysis done by ICP-OES showed that newer cultivars BG-20211 had ample amounts of iron and zinc. The study also compared the nutritional profile of four established cultivars of chickpea over a 10-year (2009 and 2019) cropping interval.

There were significant changes in protein and mineral content in established chickpea cultivars in both cropping years whereas TPC content was in the same order of magnitude. A significant increase in phytate content was reported in the year 2019 in three out of four established cultivars. The findings suggest that these chickpea cultivars possess diverse nutritional properties, the ability to induce biotic/abiotic stresses and to have a significant impact on climate change. This emphasizes the need for targeted breeding and agricultural practices to enhance quality and biotic/abiotic stresses in chickpeas.

Keywords: Chickpea, TPC, TFC, Nutraceuticals, Protein, Minerals.

Introduction

Chickpeas, scientifically known as *Cicer arietinum*, are one of the oldest cultivated legumes. Also called garbanzo beans, these versatile legumes belong to the Fabaceae family. Chickpeas are distinguished by their exceptionally high protein content, rendering them an exemplary plant-based protein source for individuals adhering to vegetarian and vegan diets[11]. Furthermore, chickpeas possess a rich nutritional profile characterized by an abundance of dietary fibre, complex carbohydrates, proteins, vitamins and essential minerals including iron, zinc, magnesium and potassium[17].

The synergistic combination of these nutrients confers numerous health benefits including the promotion of digestive health, regulation of blood sugar levels and potential mitigation of degenerative diseases, such as cardiovascular disease and type 2 diabetes, thereby underscoring the significance of chickpeas as a nutritionally valuable food component. Moreover, chickpeas are replete with bioactive compounds including antioxidants and minerals, which have been empirically linked to mitigating inflammation and minimizing the risk of chronic lifestyle diseases such as cardiovascular disease and certain types of cancer[20]. While pulses such as chickpeas, contain various bioactive compounds that confer health benefits, some of these compounds can also exhibit ambivalent or dual properties. They may have both positive and negative effects on human health, depending on the context and individual circumstances. For instance, certain polyphenols like phytate and saponins present in pulses can have both antioxidant and antinutrient properties, highlighting the complexity of the nutritional and biochemical effects of these compounds[27]. The dual effect of phytates emphasizes the need for further research to fully elucidate their role in human health[6]. Tannins, a class of bioactive compounds renowned for their robust antioxidant properties[24], have been found to exert a paradoxical effect on digestion. Chickpeas are also rich in minerals such as iron (important for oxygen transport in the blood), magnesium (essential for muscle function and nerve transmission) and potassium (critical for heart health and blood pressure regulation)[18].

As the global demand for nutritious and sustainable food sources grows, chickpeas stand out as a valuable crop with the potential to address both nutritional and environmental challenges. Pulses are a nutrient-rich food group that can play a crucial role in the transition towards a more sustainable food system[8,17,22]. With their low environmental footprint, pulses offer a compelling solution for those seeking to reduce their ecological impact. By incorporating pulses into our diets, we can not only improve our nutritional intake but also contribute to a more sustainable food culture, making them a key driver for a dietary shift towards a healthier and more environmentally conscious food system[3]. Their adaptability to various climates and soil conditions makes them an attractive crop for farmers worldwide, contributing to food security and agricultural sustainability.

Chickpea *(Cicer arietinum L.)* is one of the largest and most widely grown crops across the world, particularly in Afro-Asian countries. In 2022, Pakistan, Bangladesh and India emerged as the leading importer countries, driving demand for this versatile pulse crop. Conversely, Russia, Australia and Canada stood out as the top exporter countries[10]. Chickpeas can be broadly classified into two distinct categories, namely *desi* and *kabuli*, which exhibit disparate morphological characteristics. These differences in physical attributes have significant implications for the utilization of each type in various culinary and industrial contexts[5].

Environmental conditions like season, temperature, cropping practices and varietal differences have a significant impact on the nutritional and functional properties of chickpeas. There has been continuous improvement in chickpea varieties in India and the world and the major objectives of this program include increasing production and yield, developing resistance varieties against abiotic and biotic stress, changing maturity etc.[33] Comparatively, less work has been done on the nutritional and functional quality improvement of chickpea, therefore, these new varieties are required to be studied for their dietary components before making them popular production varieties[30]. In India, in recent years, lots of varieties have been developed through breeding programs and are mostly studied for their morphological characteristics.

Hence, there is limited information available on the nutritional composition of these selected seeds. These cultivars need to be studied to assess their nutritional profile and the previously developed varieties also need to be studied to ensure their chemical composition consistency and to find the effect of environmental factors. Data on climate change and the nutritional profile of chickpeas is currently not available in India. The study evaluated the effect of a ten-year cropping period (2009-2019) on protein, minerals, total phenolic compounds and phytate content of four established cultivars of chickpeas.

The studied *desi* and *kabuli* chickpea varieties were newly developed at IARI, New Delhi. This study has evaluated four new chickpea cultivars (two *desi* varieties: BG-3062, BG-20211 and two *kabuli* varieties: BG-3022, BG-2024), along with four established cultivars (*desi* BG-1053, K850 and *kabuli* BG-1103, BG-1108).

The established cultivars were also studied for agronomic variation. The comprehensive analysis aimed to provide a detailed understanding of the varieties' nutritional benefits, functional applications and overall value, covering aspects such as protein and fibre levels and essential mineral levels. The findings of this research can be applied to enhance food processing techniques.

Material and Methods

Collection of chickpea: Chickpea (*Cicer arietinum)* seeds were collected from the Indian Agricultural Research Institute (IARI), New Delhi, India; this includes four *desi* (BG-3062, BG-1103, BG-20211, K-850) and four *kabuli* (BG-3022, BG-2024, BG-1108, BG-1053) cultivars of chickpea. Each type had two established cultivars (*desi* BG-1103, K850 and *kabuli* BG-1053, BG-1108) along with four new cultivars grown in two cropping years, 2009 and 2019.

Physical Properties: The physical properties of chickpea seeds were evaluated according to Heiras-Palazuelos et al.[14] The weight of 100 grains was measured using a Denver instrument, while the diameter of each grain was measured using a Vernier Caliper. Additionally, the number of seeds per 100 grams was manually counted. These measurements were taken in triplicate samples to ensure accuracy, providing data on the weight, size and density of the chickpea seeds.

Chickpea flour preparation: Chickpea seeds were hand-cleaned to remove impurities and then ground into flour using a Butterfly grinder. The flour was packaged in airtight bags and refrigerated at 4-5°C to preserve quality for future analysis.

Proximate analysis: Chickpea flour samples were analyzed for nutritional content using Association of Official Analytical Chemists (AOAC, 2016) standards[2], measuring moisture (952.08), fat (948.15), protein (992.23), ash (930.30) and fibre (985.29). Protein content was calculated by multiplying the nitrogen percentage by 6.25. Carbohydrate content was determined by subtracting the sum of the other components from 100, with each experiment repeated three times for accuracy and then subjected to statistical analysis.

Sample extraction: A chickpea flour extract was prepared by steeping a 1:10 flour-to-methanol mixture for 24 hours, then centrifuging and filtering the solution. The resulting extract was refrigerated and stored for antioxidant activity analysis.

Total phenolic content (TPC): The total phenolic content of the chickpea flour extract was measured using the Folin-Ciocalteu method[39]. The procedure involved mixing 1 ml of the extract with 5 ml of diluted Folin-Ciocalteu reagent and 4 ml of sodium carbonate solution, involving a 60-minute incubation and UV-VIS spectrophotometer at 765 nm. Results were expressed as gallic acid equivalent (GAE) per 100g of polyphenol, with a standard curve and a triplicate analysis for accuracy.

Total flavonoid content (TFC): The TFC activity of chickpea flour extracts was measured following the method described by Boetang et al.[4] Two milliliters of methanolic extract were mixed with 150 µl of 10% $AlCl_3$. After a 10-minute interval, 1 ml of 1M NaOH and 1.2 ml of distilled water were added to the mixture. After 10-minute incubation, the absorbance was measured at 510 nm against a blank.

Phytate content: Phytate content in the chickpea extract was measured using the Sadasivam and Manickam method[31]. The extract was mixed with $FeCl_3$ and heated for 45 minutes, then cooled and centrifuged. The resulting precipitate was washed and treated with NaOH, TCA and HNO_3 before being transferred to a potassium thiocyanate solution, followed by spectrophotometric analysis at 480nm, allowing for accurate quantification of phytate content:

$$\text{Phytate content } (mg/100g) \text{ of sample} = \frac{\mu g Fe}{\text{weight of sample}[g]} \times 15$$

Mineral analysis: Chickpea flour's mineral content was analyzed using ICP-OES (Agilent 5800), following Gunduz et al.[13] The instrument was optimized for sensitivity and minimal interference and samples were prepared using ash solution. The ICP-OES operating conditions included a radiofrequency power of 1450 W, plasma gas flow rate of 15 L/min, auxiliary gas flow rate of 0.2 L/min, nebulizer gas flow rate of 0.8 L/min, sample flow rate of 1.5 L/min, axial view mode, peak area reading, 15 s source equilibration time, 50 s read delay and argon as the plasma gas. The analysis provided accurate measurements of mineral content, with precise operating conditions ensuring reliable results.

Statistical analysis: A comprehensive analysis was conducted to evaluate the proximate composition and mineral analysis of the chickpea flour. The data was collected in triplicate and presented as mean values. Additionally, mineral profiling was performed to provide a detailed understanding of the flour's composition.

To determine significant differences among the samples, statistical analysis was conducted using one-way ANOVA followed by the Duncan test, with a significance level set at $p<0.05$. The IBM SPSS Statistics 16 software was employed to facilitate the analysis, providing a robust and reliable evaluation of the data.

Results and Discussion

Physical Properties of selected chickpea cultivars: The physical properties of different chickpea cultivars are shown in figure 1.

BG-1103	K-850	BG-3062	BG-20211
Grain Diameter-4.67 mm	Grain Diameter-7.5 mm	Grain Diameter-4.00 mm	Grain Diameter-5.00 mm
100 grain weight-21.45g	100 grain weight-27.08g	100 grain weight-22.91g	100 grain weight-18.19g
No. of Grain/100g-473	No. of Grain/100g-372	No. of Grain/100g-442	No. of Grain/100g-571

BG-1053	BG-1108	BG-2024	BG-3022
Grain Diameter-4.67 mm	Grain Diameter-5.00 mm	Grain Diameter-4.67 mm	Grain Diameter-5.33 mm
100 grain weight-26.71g	100 grain weight-29.27g	100 grain weight-27.07g	100 grain weight-33.98g
No. of Grain-375	No. of Grain-337	No. of Grain-372	No. of Grain-294

Fig. 1: Variability in phenotypes of selected chickpea cultivars, represented along with their physical characteristics

A significant difference was seen in the 100-grain weight of *desi* and *kabuli* varieties of chickpea. *The Desi* variety shows a weight range of 18.19±0.42 to 27.08±1.03g, while *the Kabuli* variety shows a higher value (26.71±0.58 to 33.98±0.50 g) per 100-grain weight. The diameter of chickpea seeds ranged from 4±1 to 7.5±0.5mm. K-850 shows a higher seed diameter (7.5±0.5mm), while BG-3062 looks smaller (4±1mm) in all the selected cultivars. The number of grains per 100g was higher in *desi* cultivar BG-20211 (571±0.00), while the lowest was in *Kabuli* variety BG-3022 (294±0.5). These findings are consistent with earlier studies that showed notable size disparities between *desi* and *kabuli* cultivars, mostly as a result of their distinct genetic backgrounds.[43]

Proximate composition of different cultivars of Chickpea: Eight chickpea cultivars analyzed in 2019, comprising four *desi* (BG-3062, BG-20211, BG-1103, K-850) and of four *kabuli* (BG-3022, BG-2024, BG-1053, BG-1108) types, underwent proximate analysis, with the results presented in figure 2. The protein content ranged from 19.13% to 25.36%, with the highest value in cultivar K-850 (25.36% ± 1.83%) followed by BG-2024 (24.56% ± 1.88%) in the tune of earlier studies.[25]

According to Pasha et al[29], higher protein content is indicative of good quality functional food products. In this study, the ash content of chickpea flour ranged from 2.63% to 3.73%, with cultivar BG3022 exhibiting the highest ash content at 3.73% and cultivar BG-3062 showing the lowest at 2.63%. This variation in ash content may impact the overall quality and functionality of the chickpea flour. Ash is a measure of the mineral content in food, as it is what remains after water and organic acids are removed through heating. Minerals are not destroyed by heat because they have lower volatility compared to other components in food[23]. The fat content of chickpeas ranged from 2.5% to 4.24%. The cultivar BG3022 had the highest fat content at 4.24±0.32%, while the BG3062 cultivar had the least fat content at 2.5±0.22%. Previous studies have reported varying fat content in Bengal gram, ranging from 2.05% to 7.42%[19,36,42].

In contrast, the current study found that chickpea cultivars contain a moderate amount of fibre, ranging from 3.1% to 4.5%. The *desi* cultivar BG-3062 had the highest fibre content (4.5%), followed by K-850 (4.3%) and the lowest was in BG-1053 (3.1%). Additionally, the carbohydrate content of the chickpeas was substantial, ranging from 53.74% to 62.2%, making them a good source of energy. These findings highlight the nutritional value of chickpeas with variations in fibre and carbohydrate content across different cultivars. The results showed that the cultivar BG1103 had the maximum carbohydrate content i.e. 62.2±0.32% followed by BG3062 (59.87±0.13%).

A comparison of established cultivars for their proximate composition over a span of ten years showed that the values for ash content were not affected by climate change over the cropping year. However, the protein content in *desi* cultivars (BG1103 and K850) increased by 7.2% and 10.2% respectively while it decreased by 18.93% and 30.84% in *kabuli* cultivars (BG-1053 and BG-1108), after a decade gap.

The variation in protein content among chickpea cultivars may be attributed to environmental factors such as temperature, fertility and soil conditions, as suggested by Zheng and Wang[46]. This is consistent with the findings of Pace et al[28], who observed fluctuations in protein and nitrogen-free extract (NFE) content in sweet potatoes over a one-year period. These studies indicate that environmental variations can significantly impact the nutritional composition of crops, leading to variations in protein content and other nutritional components. Our study also observed similar results, noting that the location, environments and genotypes greatly influenced all chickpea cultivars. Yegrem[44] outlined the moisture levels ranging from 5.73% to 12.10%, ash levels from 2.47% to 3.87%, total lipid levels from 3.77% to 7.41% and protein content ranging from 12.02% to 24.91% in different Ethiopian chickpea varieties.

Yegrem et al[45] conducted study on same chickpea varieties and showed moisture levels ranging from 10.85% to 12.06%, protein levels roved from 16.21% to 19.28%, crude fat levels roamed from 5.24% to 6.43%, carbohydrate levels arrayed in between 59.61% to 63.34%, ash levels outlined from 3.11% to 4.19% and crude fibre levels traversed from 5.92% to 7.49%. The nutritional compositions found in this study are comparable to existing values reported in previous research.

Yegrem et al[45] also discovered significant variations in the nutritional composition of eleven chickpea varieties over a two-year period (2018-2019), suggesting that genetic factors contribute to these differences. Similar findings were reported by Yegrem[44]. Additionally, some studies have noted slightly higher fat content in chickpeas[1,15,44,45]. These results indicate that both genetic and environmental factors can influence the nutritional composition of chickpeas, leading to variations in proximate values among different cultivars and growing conditions.

Non-nutrient composition of different Chickpea Cultivars: Dry legumes, such as chickpeas, are vital food source and offer numerous health benefits due to their high content of polyphenols and flavonoids[35]. The bioactive compound content of the tested *desi* and *kabuli* chickpea genotypes is presented in table 1. Notably, the total phenolic content (TPC) of chickpea varied from 101 to 276 mg gallic acid equivalent (GAE) per 100g, highlighting the significant presence of phenolic compounds in these legumes. This range suggests that different chickpea genotypes may offer varying levels of antioxidant activity and potential health benefits. The highest TPC content was observed in BG3062 cultivars followed by K850, BG20211, BG1103, BG1108, BG3022, BG2024 and BG1053 respectively.

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TPC content in the *desi* cultivar was significantly higher than in the *kabuli* cultivars. When the established cultivars were compared over duration of 10 years, the value remained almost similar to the previous values. de Camargo et al[7] reported lower TPC content than our result (31.5-17.3 mg GAE/100g) while Johnson et al[17] reported varying TPC content in six chickpea genotypes: kernel flour (65.0-104.6 mgGAE/100g), hulls(56.4-149.9 mgGAE/100g) and husks (198.1-259.1mgGAE/100g). Ferreira et al[11] reported a free phenolic content of 369.47 mg/100g while bound phenolic content was 109.01 mg/100g in raw chickpea cultivars. Phenolic chemicals are of great importance since they contribute to seed colour, sensory features and various biological traits. In this study, *desi* cultivars with darker seed coats showed better phenolic content.

TPC depicts the presence of the total phenolic compound in the sample. Phenolic chemicals display redox properties that account for their antioxidant effects. These variations could be attributed to the grain type, being different varietals, harvest conditions and extraction procedures. The total flavonoid content (TFC) of chickpea cultivars varied from 0.100 to 0.173 mg/g, with the highest content found in cultivar BG-3062 (0.173±0.06 mg Quercetin equivalent (QE)/g), followed by BG-20211 and K-850 respectively (Table 2). These values are comparable to those reported by Saleh et al[32], who found total phenols and total flavonoids in chickpeas to be 5.68 mgGAE/g and 8.43 mg Quercetin/g respectively.

The correlation between total phenolic content and seed colour in chickpeas has been observed in numerous studies, suggesting that seed colour may be an indicator of the antioxidant potential of chickpea grains. A slight decline in TFC content was recorded in 2019.

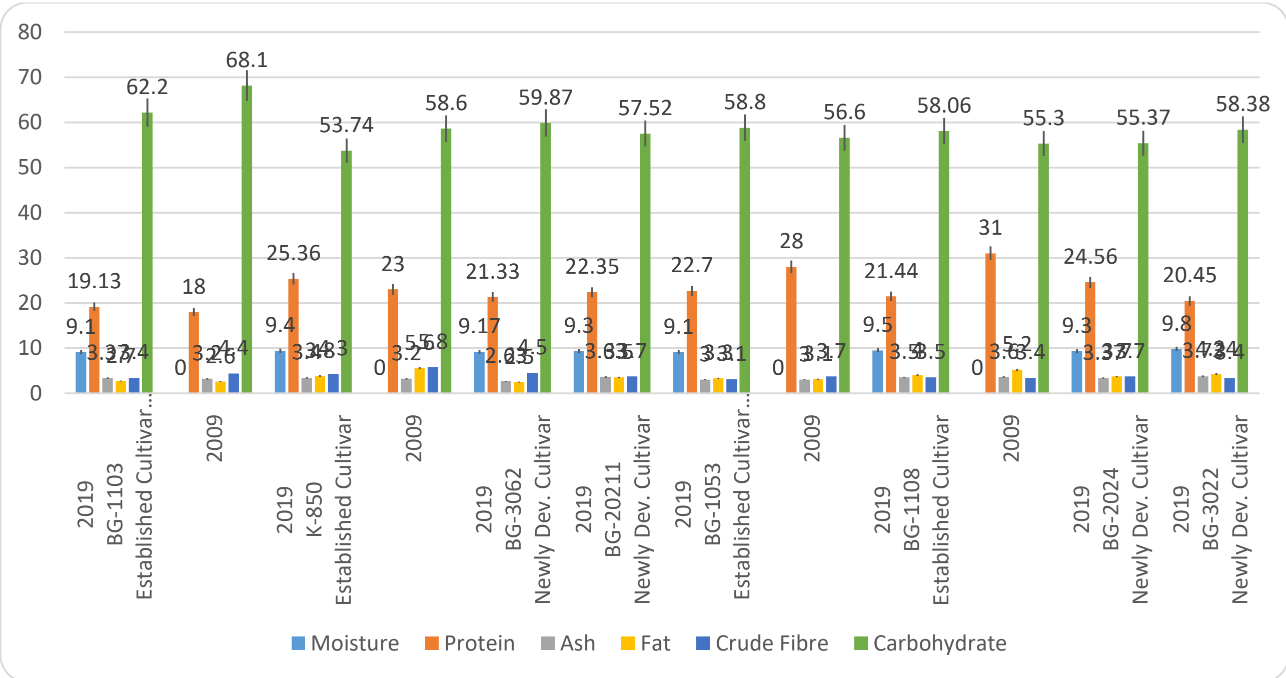

Fig. 2: Comparative representation of nutrition profiling of selected chickpea cultivars with their cropping year

Table 1
Non-nutrient composition of different Chickpea cultivars

Parameters	**Desi Chickpea**						**Kabuli Chickpea**					
	BG-1103		K-850		BG-3062	BG-20211	BG-1053		BG-1108		BG-2024	BG-3022
Cropping year	2009	2019	2009	2019	2019	2019	2009	2019	2009	2019	2019	2019
TPC (mg/100g)	203± 3.0^{ab}	203 ±9.3^{ab}	255± 1.60^{ab}	255 ±4.7^{ab}	276 ±11.3^{ab}	232 ±7.36^{ab}	101± 1.60^{a}	101 ±2.6 ^{a}	178± 1.00^{ab}	178 ±4.3^{ab}	137.14 ±6.1^{a}	147.68 ±5.4^{b}
TFC (mgQE/g)	0.34± 0.10^{bc}	0.100± 0.04^{a}	0.36± 0.15^{c}	0.136± 0.06^{a}	0.173 ±0.06^{ab}	0.158 ±0.06^{a}	0.18± 0.10^{ab}	0.104± 0.10^{a}	0.25± 0.34^{abc}	0.102 ±0.10^{a}	0.119 ±0.12^{a}	0.115 ±0.05^{a}
Phytate (mg/100g)	767± 1.00^{g}	891.6± 6.54^{k}	804± 2.00^{h}	891.6 ±8.54^{k}	579 ±4.15^{a}	863.7 ±3.04^{j}	598± 1.00^{b}	632.1± 7.35^{c}	750± 1.00^{f}	653 ±3.30^{d}	685.5 ±5.09^{e}	820.9 ±5.50^{i}

All values are means ± standard deviations of data from three independent experiments.
Different superscripts in the same row indicate significant differences ($p<0.05$)
Abbreviation: TPC, total phenolic content; TFC, total favanoid content.

Table 2
Mineral analysis of different chickpea cultivars

S.N.	Cultivar	Cropping Year	Ca (mg/100g)	Cr (mg/100g)	Cu (mg/100g)	Fe (mg/100g)	K (mg/100g)	Mg (mg/100g)	Mn (mg/100g)	P (mg/100g)	S (mg/100g)	Zn (mg/100g)	B (mg/100g)
Chickpea (*desi*)													
1	BG-1103	2009	-	-	-	7.4±0.20^{de}	-	-	-	-	-	5.8±0.20^{d}	-
		2019	84.74±0.06^{a}	0.10±0.0^{ab}	0.84±0.03^{ab}	6.15±0.12^{a}	1157.29±1.32^{a}	109.82±0.31^{a}	2.54±0.11^{bc}	420.54±1.15^{b}	118.02±2.36^{ab}	5.78±0.01^{d}	2.03±0.01^{c}
2	K-850	2009	-	-	-	8.6±0.20	-	-	-	-	-	5.3±0.10^{c}	-
		2019	112.35±0.02^{c}	0.09±0.0^{a}	0.92±0.01^{b}	6.45±0.09^{g}	1167.30±1.79^{a}	105.67±0.11^{b}	2.24±0.03^{b}	725.45±1.08^{e}	110.88±1.48^{ab}	3.72±0.00^{a}	1.83±0.01^{b}
3	BG-3062	2019	102.55±0.03^{bc}	0.15±0.001^{c}	0.97±0.02^{c}	7.09±0.11^{cd}	1231.36±1.14^{c}	116.45±0.24^{c}	2.30±0.01^{b}	377.51±1.41^{a}	141.13±2.14^{c}	5.25±0.02^{c}	1.38±0.01^{ab}
4	BG-20211	2019	142.13±0.13^{d}	0.09±0.00^{a}	0.95±0.01^{bc}	8.11±0.11^{f}	1152.02±1.09^{a}	106.16±0.30^{b}	2.07±0.02^{a}	502.7±1.30^{bc}	128.59±1.89^{b}	5.05±0.01^{c}	2.40±0.00^{d}
Chickpea (*kabuli*)													
5	BG-1053	2009	-	-	-	10.5±0.10^{g}	-	-	-	-	-	6.2±0.20^{e}	-
		2019	96.25±0.09^{b}	0.10±0.001^{ab}	1.10±0.02^{d}	6.80±0.02^{bc}	1373.13±1.45^{b}	113.97±0.18^{c}	2.46±0.01^{bc}	522.82±1.37^{bc}	177.95±2.16^{d}	5.62±0.00^{d}	1.65±0.00^{b}
6	BG-1108	2009	-	-	-	6.1±0.10^{a}	-	-	-	-	-	4.5±0.10^{b}	-
		2019	103.27±0.21^{bc}	0.23±0.002^{d}	1.17±0.02^{d}	7.55±0.04^{e}	1150.06±1.37^{a}	105.01±0.29^{b}	2.70±0.03^{c}	510.2±1.11^{bc}	129.39±2.11^{b}	5.30±0.01^{c}	1.18±0.01^{a}
7	BG-2024	2019	99.25±0.10^{b}	0.15±0.001^{c}	0.95±0.02^{b}	6.48±0.07^{ab}	1335.86±1.85^{b}	109.64±0.16^{a}	2.21±0.12^{b}	544.76±1.09^{c}	104.64±2.74^{a}	8.58±0.02^{g}	1.94±0.01^{c}
8	BG-3022	2019	114.66±0.14^{c}	0.10±0.00^{ab}	0.76±0.01^{a}	6.62±0.11^{b}	1177.95±1.11^{a}	107.62±0.38^{bc}	2.54±0.03^{bc}	827.99±1.15^{d}	116.04±2.10^{ab}	7.75±0.01^{f}	2.01±0.01^{c}

All values are means ± standard deviations of data from three independent experiments. Different superscripts in the same column indicate significant differences ($p<0.05$), - values not detected

The variation in TFC among cultivars may be attributed to genetic factors, environmental influences, or a combination of both. Analyzed chickpea genotypes are therapeutic functional foods since they have an abundance of bioactive chemicals including phenolics and flavonoids and high protein content. Chickpea seed flour can supplement a balanced diet and can enhance functional foods.

The phytate content of the studied chickpea cultivars ranged from 579-891.6 mg/100g. Higher phytate content was found in BG-1103, K850 and BG-20211, followed by BG-3022 while a lower amount of phytate was reported in BG-3062 and BG-1053. Sinkovic et al[38] reported higher phytate content in chickpea 1116 mg/100g DW; this outlined the comparatively lower phytate content in our experimented cultivars. Comparatively, *desi* cultivars of chickpea except BG3022 exhibited more phytate content than *kabuli*. The cropping year showed considerable variation in the amount of phytate content in all four selected established cultivars. BG1103 (13.98%), K850 (9.83%) and BG1053 (5.4%) cultivars showed an increase in phytate content, whereas BG1108 showed a decline (14.85%) in phytate content in the year 2019 compared to 2009[37]. Phytic acid, a non-protein antinutrient, has the ability to form complexes with micro- and macro-elements, as well as to reduce mineral and protein bio-functioning.

Recent studies by Sinkovic et al[38] and Upadhyay et al[40] have highlighted the potential health benefits of small amounts of phytic acid, a compound often considered an antinutrient. Research has shown that moderate levels of phytic acid may offer several nutritional advantages including lowering blood glucose levels, preventing dental cavities, reducing the risk of colon cancer and exhibiting antioxidant activity. These findings suggest that phytic acid, in small quantities, may have beneficial effects on human health, challenging its traditional classification as a solely negative compound. This new understanding of phytic acid's role in nutrition highlights the importance of reevaluating its impact on human health and potentially harnessing its benefits. It is advised to consume 25 mg or less of phytate per 100 g of diet to minimize the loss of micronutrients through digestion.

However, the pulses examined in this study exhibited significantly higher levels of phytic acid which can be reduced by soaking and boiling. The impact of climate change was observed to be highest on phytate content. The established cultivars grown in the year 2019 had a significantly high content of phytate. In contrast, TPC content was not changed in all established cultivars. When we compared the important meteorological data of climate change for the years 2009 and 2019, we found important changes: maximum temperature increased from 29.5 to 37. 4 in the year 2019 and increase of about 8 degrees during the months of 1 November to 31 March.

A maximum rainfall of 55.8 mm was recorded in the month of Jan 2019, in contrast to the negligible rainfall in the year 2009. Similarly, relative humidity was also lower in 2019 than in 2009. The impact of specific environmental conditions on phytate content is not available. However, it is known that phytate is the major storage of phosphorus in plants, which deposits in the aleurone layer of seeds during maturity. It also participates in the metabolic pathways of plants and acts as an antioxidant. Hence, it is assumed that climate change, particularly extreme temperatures (max and min) and untimely rainfall may be responsible for high phytate formation in chickpeas grown in 2019.

Mineral Analysis of different chickpea cultivars: Chickpeas, like other plants, are a rich source of essential minerals such as iron, zinc, calcium, potassium, phosphorus and magnesium, which are present in their edible parts like leaves and seeds[41]. However, the mineral content in chickpeas can vary significantly depending on factors like agricultural practices, genotype and environmental conditions, as highlighted in previous studies[9,12,34]. This variability emphasizes the importance of considering these factors to optimize mineral content in chickpeas. Table 2 represents the mineral profiling of selected varieties of different chickpea cultivars. Calcium content was found to be the highest in BG20211 whereas phosphorus content was highest in BG3022. The mean value of calcium (Ca) in BG-20211**(**142.13±0.13mg/100g**)** was the highest, followed by BG-3022 and K850.

The chromium content in the chickpea cultivars varied, with the highest value of 0.23 mg/100g found in BG-1108, followed closely by BG-3062 and BG-2024, which had similar values. In contrast, the lowest chromium content of 0.09 mg/100g was observed in the K-850 cultivar. This variation in chromium content highlights the differences in mineral composition among the chickpea cultivars. Copper content in chickpea was highest in BG-1108, followed by BG-1053. BG-1108 and BG-20211 are outstanding iron varieties showing higher iron content. Iron and copper are important in plant metabolism and nitrogen fixation. Potassium was highest observed in BG-1053 (1373.13±1.45 mg/100g).

The magnesium content in the chickpea cultivars was found to be highest in BG-3062, with a mean value of 116.45 ± 0.24 mg/100g, followed closely by BG-1053. This indicates that BG-3062 is a rich source of magnesium, an essential mineral that plays a crucial role in various bodily functions including good heart health. The presence of magnesium in significant amounts in these chickpea cultivars makes them a nutritious addition to a healthy diet. Magnesium plays a crucial role in resistance to biotic and abiotic stress, contributing to the plant's adaptation strategies to the environment[16], especially in the context of climate change. The mean value of manganese (Mn) in BG-1108 was highest, followed by BG-3022 and BG-1103.

The phosphorus content ranged from 377.51 to 827.99 mg/100g. BG-3022 cultivar appeared to have the highest phosphorus followed by K-850 while the lowest phosphorus content was determined in BG-3062. The BG-1053 contained the highest value of sulphur, followed by BG-3062. Zn content was higher in the *kabuli* type than in the *desi* type. Zinc had a maximum value in BG-2024 (8.58±0.02mg/100g), while K-850 contained the lowest zinc content among the studied cultivars. Yegrem et al[44] reported Ca (164.31-211.67 mg/100g), Fe (5.86-6.73 mg/100g), Mg (107.54-123.90 mg/100g) and Zn (1.61-2.59 mg/100g) content in 11 chickpea varieties. This shows that Fe, Mg and Zn were comparatively higher in the current study.

Table 5 also shows that boron (B) content was highest in BG-20211 (2.40±0.00 mg/100g), followed by BG-1103, where it was recorded as 2.03±0.01mg/100g. BG-1108 cultivar appeared to have the lowest boron content (1.18±0.01 mg/g). Sharma et al[37] performed the mineral analysis of four established cultivars in 2009 and reported that iron and zinc content was high in BG1103, K850 and BG1053; these values were decreased while iron and zinc were increased in BG1108 from previous values (2009); this was also validated by Mittal et al[26]. Zinc content in *kabuli* cultivars was higher than *desi* types. New chickpea cultivars BG2024 and BG3022 are identified as outstanding varieties with the highest zinc content and an appreciable amount of iron. The variations in the mineral profile of seeds can be attributed to diverse agricultural practices, soil types, the use of different fertilizers or pesticides/herbicides and genetic factors.

Pulses are thought to be high in micronutrients. In India, there has been a progressive drop in pulse consumption along with per capita availability of pulses in the financial year 2023 (47.1g/day) from previous years against the recommended value of 60g/day (per capita requirement) [21]. Chickpea is a major legume consumed in India; hence, it contributes to the protein micro-mineral requirement of the maximum vegetarian population; this emphasizes the need for a judicious selection of variety. The new chickpea varieties were found to be rich in essential minerals such as calcium, iron and zinc which play vital roles in the body. This is particularly significant for populations in developing countries in North America, Europe and South Asia where deficiencies in these minerals are highly prevalent.

The increased mineral content in these new varieties can help to address these deficiencies, providing a nutritious solution for vulnerable populations. The enhanced levels of calcium, iron and zinc can contribute to improved overall health, making these chickpea varieties a valuable resource for combating mineral deficiencies. A newly developed chickpea that is high in minerals shows great potential for helping populations with mineral deficiencies. By adding important minerals like iron, zinc and calcium through pulses that are commonly eaten, it directly addresses nutritional gaps. This is especially important in areas where diets usually lack these nutrients, which can lead to many people having deficiencies and health problems related to them.

For instance, iron is needed to make haemoglobin and to prevent anaemia. Zinc is important for immune function and healing wounds and calcium is essential for keeping bones healthy and preventing osteoporosis. Hence, newly developed varieties should be introduced for cultivation and consumption among the population to address the deficiencies.

Conclusion

This study explores the nutritional properties of eight chickpea cultivars, emphasizing their significance in the food and health industries. Chickpeas come in two main varieties, *desi* and *kabuli*, which differ significantly in their nutritional profiles. Notably, *desi* chickpeas tend to have higher protein content than their *kabuli* counterparts, making them a potentially more protein-rich option. Furthermore, *desi* chickpeas are richer in phenolic and flavonoid compounds, which are powerful antioxidants that offer various health benefits. These differences in nutritional profiles make desi chickpeas a valuable choice for those seeking a more protein-rich and antioxidant-dense food option. These compounds are crucial for their antioxidant properties, which help to prevent chronic diseases and promote overall health.

The *Kabuli* cultivars, while varying in protein content, also displayed unique nutritional profiles including essential minerals like iron, zinc and magnesium, highlighting chickpeas as a valuable source of micronutrients. The study represents comprehensive data on the effect of climate change on phenolic compounds present in *desi* and *kabuli* types. Total phenolic content remained consistent in established cultivars after 10-year gap.

New *kabuli* cultivar BG2024 is rich in nutritional parameters like protein, zinc and iron and BG1108 in magnesium, whereas *desi* cultivar BG3062 is copious in terms of phenolic compounds. Hence, these varieties have promising options for expanding their consumption, cultivation and utilization in chickpea breeding for nutrition and biotic/abiotic stresses. Thus, these findings offer practical implications for breeders, food scientists and consumers. Breeders can develop improved varieties with enhanced properties; food scientists can optimize chickpea use in products and consumers can make informed choices based on nutritional content. This comprehensive analysis highlights chickpeas' role in promoting health and enhancing food quality.

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