

Review paper

Nutritional profile of chickpea (*Cicer arietinum* L): Breeding efforts for enhancing nutritive value

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ABSTRACT

Chickpea is the dominant rabi pulse crop in India, accounting for 50% (13.5 mt) of the nation's pulse production. This nutrient-dense and cost-effective legume provides a rich source of energy, protein, minerals, vitamins, and dietary fibre. Beyond its basic nutritional value, chickpea harbor a diverse array of non-nutritive phytochemicals, including oligosaccharides, saponins, tannins, polyphenols, flavonoids, and enzyme inhibitors, holding promising potential for antioxidant, anti-inflammatory, anti-diabetic, anti-obesity, anti-cancer, prebiotic, and cholesterol-lowering effects. Recent advancements in genome sequencing have unlocked the chickpea's complete genetic blueprint and empowered cutting-edge breeding methods like QTL analysis, GWAS, and genomic selection to effectively pinpoint and target beneficial genomic regions governing key nutritional traits. These findings help germplasm enhancement, nutritional enrichment and optimization of bioactive components to meet the food security of nations. This chapter reviews the current state of knowledge regarding chickpea's nutritional profile, highlighting past breeding achievements and future prospects for enriching its nutritive value.

Key words: Chickpea, Legume, Oligosaccharides, Phytochemicals, Genome sequencing technology, Nutritive value

INTRODUCTION

In India, pulse crops are playing a crucial role in dietary security and environmental sustainability due to their nutritional value and soil quality enhancement. Pulses are a main source of nutrition and, together with cereals, offer a balanced amino acid composition with a ratio close to the optimal for humans. They are the most preferred commodity among common man as they are available at affordable prices. Besides that, pulses have varied uses, capable of growing in marginal environments, have minimal carbon footprints and can be preserved for longer periods with smallest amount of care. During last 10 years Indian pulses production is marching towards self-sufficiency and touched 27.3 m tones during 2021-22. Rabi pulses contribute to 70% (19.1 mt) of the total pulse basket of the country. Among Rabi pulses in India, chickpea (*Cicer arietinum* L) has a lion's share of 50% (13.5 mt) and made a major role in pulse revolution of the country. Chickpea is a versatile pulse crop and globally it ranks second in terms of production, following the common

bean (*Phaseolus vulgaris* L.). Chickpea represents economical and readily available source of energy, protein, minerals, vitamins, fibre, and also contains potentially health-beneficial phyto-chemicals (Geervani, 1989). The WHO recommends a high consumption of energy-dilute foods rich in non-starch polysaccharides (NSPs) such as chickpea along with other vegetables and fruits. It has many anti nutritional factors, anti-inflammatory and hypo-cholesterolemic properties which had medicinal value and is used for the prevention of many diseases (Jukanti *et al.*, 2012). Thus chickpea has diverse culinary applications and nutritional profile, holds substantial role in emerging countries like India, where a significant portion of the population adheres to a vegetarian diet.

Chickpeas can be categorized into two main types based on their seed characteristics: *desi* and *kabuli*. *Desi* chickpeas are characterized by their colored and thick seed coat, small, angular shape, and rough surface. Their flowers are typically pink due to anthocyanin pigmentation. *Desi* chickpeas account for approximately 80-

85% of the global chickpea cultivation area and are commonly dehulled and split to produce *dal* or flour. In contrast, *kabuli* chickpeas are distinguished by their white seed coat, ram's head shape, thin seed coat, and smooth seed surface. Their flowers are white due to the absence of anthocyanin pigmentation. The name "*kabuli*" derived from "Kabul" in Hindi, and this variety is thought to have originated from Kabul, Afghanistan, when it was introduced to India in the 18th century. Compared to *desi* chickpeas, *kabuli* chickpeas have higher sucrose levels and lower fiber content, suiting them for consumption as whole grains. Additionally, *kabuli* chickpeas require shorter cooking times compared to *desi* varieties.

NUTRITIONAL VALUE OF CHICKPEA

The nutritional significance of chickpeas in human consumption and the research efforts in improving nutritional value are briefly presented in here.

a) Energy

Chickpea is rich in non-starch polysaccharides (complex carbohydrates) that can provide long-lasting energy. The energy provided by chickpeas range from 334 to 437 kcal/100 g for *desi* types and 357 to 446 kcal/100 g for *kabuli* types (Kinfe *et al.*, 2015). Under identical growing conditions, *kabuli* seeds generally have slightly higher energy values than *desi* type. This difference is ascribed to the smaller seed coat component of *kabuli* seeds. By incorporating chickpeas into the diet, individuals can reap the benefits of their high energy content and nutritional value.

b) Protein

The protein content in chickpea seeds ranges from 16.7% to 30.6% for *desi* cultivars and 12.6% to 29.0% for *kabuli* cultivars which is 2-3 times higher than cereal grains (Badola *et al.*, 2023). Srugarapu *et al.* (2022) found substantial variation in grain protein content (16.3-26.2%) among 280 diverse chickpea accessions. The amino acid composition of chickpea is exceptional with high lysine content. Over all, its protein configuration is well composed though limited in sulfur amino acids (methionine and cysteine). On account of this, chickpea is rated as a valuable dietary component and a potential therapeutic agent for protein malnutrition. Protein digestibility of raw

chickpea seeds varies from 34 to 76% and *kabuli* types had higher digestibility than that from the *desi* types (Khalil *et al.*, 2007).

c) Lipids

Chickpea exhibits a higher lipid content compared to other pulses, and displaying wide genotypic variation. Chickpea lipid content varied from 6.35 to 9.35 g/100 g, with linoleic, oleic, and palmitic acids being the major fatty acids (Xiao *et al.*, 2023). The total lipid concentration ranges from 2.9% to 7.4% and 3.4% to 8.8% for *desi* and *kabuli* types, respectively, which is high for pulses but lower than certain grain legumes like soybeans and peanuts (Reddy and Lal, 2021). The lipid profile of chickpea is predominantly composed of polyunsaturated (62-67%), monounsaturated (19-26%), and saturated (12-14%) fatty acids (Sahu *et al.*, 2022). This favorable lipid composition indicates that chickpeas mainly contain beneficial monounsaturated and polyunsaturated fats rather than saturated fats, which have been related with cardiovascular diseases. Chickpea seeds are also a valuable source of essential fatty acids, including omega-6 linoleic acid and omega-3 linolenic acid, which play pivotal roles in normal human growth, physiological functions, and cell maintenance.

d) Minerals

Chickpea is recognized as a valuable source of essential minerals, constituting a significant contribution to the overall maintenance of human life. It plays a crucial role in enhancing iron (Fe) and zinc (Zn) intake in the human diet. In chickpea seeds, iron and zinc are available in a range of 44.1-76.7 mg/kg and 36.3-56.2 mg kg⁻¹, respectively (Srugarapu *et al.*, 2022) (Table 1). A single 100 g serving of cooked chickpea offers substantial quantities of essential nutrients, providing up to 40% of the recommended daily allowance (RDA) for certain minerals. Notably, chickpea surpasses the RDA for various micronutrient minerals, emphasizing its nutritional significance. While a single serving can potentially supply approximately 40% of the adult RDA for manganese and copper, as well as around 15% for iron and zinc, it is crucial to acknowledge the variability in seed concentrations across different genotypes. Chickpea seeds boast a commendable content of macronutrients, specifically phosphorus and magnesium. Additionally, these seeds are amusing sources of essential minerals, including manganese, copper, and selenium. Furthermore, the micronutrient profile of chickpea

seeds encompasses several other metals, such as molybdenum and cobalt.

Table 1. Availability of various minerals in chickpea

Nutrient	Kabuli (mg/100g)	Desi (mg/100g)
Iron (Fe)	4.3-7.6	4.6-7
Calcium (Ca)	80.5-187.25	115.0-226.5
Manganese (Mg)	122-212.8	128-188.6
Zinc (Zn)	3.6-5.6	2.8-5.1
Copper (Cu)	0.7-1.4	0.5-1.4
Manganese (Mn)	1.65-4.8	1.72-4.1
Potassium (K)	816.1-1580.1	878-1479.1
Phosphorus (P)	294.1-828.8	276.2-518.6
Sodium (Na)	11.23-21.07	7.35-22.9

Source: Begum *et al.* (2023); Gaur *et al.* (2015)

e) Vitamins

Chickpea is a reservoir of various water-soluble and lipid-soluble vitamins essential for human nutrition. Water-soluble vitamins include the B-complex vitamins (folate, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, and cobalamin) and vitamin C. Chickpeas contain a significant amount of folate, ranging from 42–537 µg/100g (Begum *et al.*, 2023), and vitamin C, with 12.48 mg/100g (Karaca *et al.*, 2019). Among the lipid-soluble vitamins, chickpeas contain vitamin A, vitamin E, and vitamin K. Vitamin A, primarily found as provitamin A carotenoids (β -carotene), is present in both the cotyledon and seed coat, with concentrations ranges from 0.4–2.6 mg g⁻¹ (Ashokkumar *et al.*, 2015). Chickpea is a reasonable source of vitamin E, as the seed contains ~3-9% lipids and up to 13.7 mg/100g vitamin E (13.7mg/100g). While chickpea's vitamin K content is lesser than that of leafy vegetables, it surpasses levels found in fruits and most animal products, as reported by the Nutrient Data Laboratory, USDA Agricultural Research Service in 2005. The presence of vitamin K (phylloquinone) in chickpea is noteworthy for its role in modifying proteins crucial for blood coagulation, bone metabolism, and vascular health.

f) Dietary fibre

Dietary fibre is a component of plants that human gastrointestinal enzymes cannot digest. Chickpea dietary fibre consists of polysaccharides such as lignin, cellulose, hemicellulose and pectin (Attia *et al.*, 1994). Dietary fibre acts as a polymer matrix with different physicochemical properties and undergoes several compositional changes due to bacterial activity in the large intestine. The volume of dietary fibre varies, with lignin 18.6-21.7

g, cellulose 29.6-40.4 g, hemicellulose 26.9-77.6 g and pectin 42.1 g per kg of chickpea seeds (Mathew *et al.*, 2022). It has clinical importance in treating disorders of colonic function and lipid metabolism.

NON-NUTRITIVE HEALTH-BENEFICIAL COMPONENTS

Plant-based foods, including pulses, contain a wealth of non-nutritive elements that have been shown to promote good health. These include oligosaccharides (raffinose, stachyose and verbascose), saponins, tannins, polyphenols, flavonoids and enzyme inhibitors. Experimental evidence has demonstrated the beneficial activity of these pulse components modulate different physiological and metabolic processes in the human body, such as antioxidants (Fares and Menga, 2012), anti-inflammatory (Masroor *et al.*, 2018), anti-diabetic, anti-obesity, anti-cancer, prebiotic (Monk *et al.*, 2017) and cholesterol-lowering effects there by prompting a reappraisal of pulses as a cornerstone of a healthy diet. These studies strongly support the notion that regular consumption of pulses, including chickpeas, is an effective strategy for maintaining and enhancing overall health.

a) Carbohydrates

Carbohydrates vary significantly in their glycemic index (GI), influencing their impact on blood glucose levels. Certain carbohydrates in white bread and potatoes, rapidly break down during digestion, causing a rapid spike in blood glucose. In contrast, legumes generally exhibit a lower GI, with chickpea possessing the lowest GI among common foodgrains. The FAO/WHO classifies chickpea as having a GI of 44 for raw chickpeas and 47 for canned chickpeas, compared to a GI of 100 for white bread. Mendosa (2005) reported a GI of 7-11 for raw chickpea, while Nalwade *et al.* (2003) demonstrated a GI of 21.45 for boiled chickpea, significantly lower than boiled lentils (27.63), boiled rice (61.18), and bread (76.55). This low GI characteristic makes chickpea a suitable dietary component for individuals with diabetes. Additionally, chickpeas contain oligosaccharides (raffinose family oligosaccharides), which act as potential prebiotics, promoting the growth of beneficial microorganisms in the colon. Therefore, incorporating chickpeas into the diet offers multiple health benefits, including improved blood glucose control and enhanced gut health.

The World Health Organization (WHO) has

recognized a high dietary intake of non-starch polysaccharides (NSP) or dietary fiber as a protective factor against obesity (WHO/FAO, 2003). They recommend a minimum daily intake of 20 g NSP. Notably, chickpeas are a rich source of NSP with a low glycemic index (GI). Consuming approximately 40 g of chickpea can meet the daily NSP requirement recommended by the WHO, potentially aiding in blood sugar control and offering protection against diabetes.

b) Polyphenols

Polyphenolic compounds, prevalent in a diverse array of plant foods including vegetables, cereals, legumes, fruits, and nuts, exhibit significant variability in content influenced by genetic and environmental factors, agronomic practices, and storage conditions. Recently, there has been a heightened interest in polyphenolics, particularly flavonoids, attributable to their recognized antioxidant capacity and potential contributions to human health. These potential health benefits encompass the treatment and prevention of various conditions such as cancer, cardiovascular disease, hypertension, hypercholesterolemia, atherosclerosis, bacterial and viral infections, diarrhea, ulcers, inflammation, and allergies (Bravo, 1998; Martens and Mithofer, 2005). Legumes generally exhibit higher polyphenolic content compared to cereals, which typically contain less than 1% polyphenolic compounds. *Desi* chickpeas, with their larger seed coats, tend to have higher polyphenolic concentrations than *kabuli* chickpeas. Singh and Jambunathan (1981) reported that approximately 75% of the polyphenolic content in *desi* chickpeas is concentrated in the seed coat. The total phenol content in chickpea genotypes lied in the range of 27.48 mg/100 g to 113.30 mg/100 g (Kaur *et al.*, 2019). *Desi* chickpeas typically have higher polyphenolic contents than *kabuli* chickpeas ranging from 0.84 to 6.00 mg/g polyphenols and in *kabuli* chickpeas ranging from 0.02 to 2.20 mg/g (Summon *et al.*, 2019).

Chickpea seeds harbor a diverse array of polyphenolic compounds, including anthocyanins, isoflavonoids (isoflavones, pterocarpan), flavones, flavandiols, and tannins (Harborne, 1994; Bravo, 1998). The presence of the flavone 3,7,4-trihydroxyflavanone in chickpea led to its designation as "garbanzol" (Kuhnau, 1976). Additionally, chickpea seeds may also contain flavonols, as they serve as precursors to anthocyanins. Most flavonoids exhibit relatively

low molecular weights and varying degrees of solubility. However, some types may be difficult to extract due to their intricate linkages with cell wall components like polysaccharides and lignin.

c) Flavonoids

Despite the remarkable diversity of flavonoids, research specifically focused on the polyphenolic composition of chickpea remains limited. Flavonoids, a diverse and widespread class of plant phenolics, encompass over 9,000 described compounds, making them one of the most extensive assemblies of plant metabolites (Martens and Mithofer, 2005). This diverse family encompasses 13 distinct subclasses, including chalcones, dihydrochalcones, aurones, flavones, flavonols, dihydroflavonols, flavanones, flavanols, flavandiols (leucoanthocyanidin), anthocyanidins, isoflavonoids, bisflavonoids, and proanthocyanidins (condensed tannins) (Bravo, 1998). Kaur *et al.* (2019) reported that flavonol content in chickpea varied from 0.80 mg/100 g to 24.20 mg/100 g. *Kabuli* genotypes possessed lower flavonol content (0.08 mg/100 g to 0.55 mg/100 g.) than *desi* genotypes (5.04 mg/100 g to 13.18 mg/100 g).

d) Tannins

Tannins, once considered antinutritional factors due to their ability to form complexes with minerals and hinder intestinal absorption, have recently gained recognition for their potential health-promoting properties. Studies have demonstrated the chemoprotective, antiviral, and antibacterial activities of certain tannins, suggesting their potential applications in preventive healthcare. In chickpea seeds, the condensed tannin content is modest, measuring less than 0.04% in *kabuli* types and 0.09% in *desi* types, as reported by Peterson *et al.* (1997) and Salgado *et al.* (2001). *Desi* and *kabuli* and wild species had an average tannin content of 11.93, 10.63 and 16.38 mg/g, respectively (Kaur *et al.*, 2019).

e) Plant sterols or phytosterols

Plant sterols exhibit the capacity to impede the absorption of dietary cholesterol in the small intestine, thereby contributing to the reduction of LDL (low-density lipoprotein) blood cholesterol levels in humans and potentially mitigating the risk of coronary heart disease. Beyond their cholesterol-lowering effects, plant sterols have demonstrated anticancer properties, as highlighted by Champ (2002) and Mathers (2002). These compounds are

present in relatively low quantities in legumes, including chickpea. The Nutrient Data Laboratory, USDA Agricultural Research Service (2005) reported that chickpea seeds and flour (besan) contain approximately 35 and 39 mg/100g of sterols, respectively. Additionally, Sanchez-Vioque *et al.* (1998) determined that defatted chickpea flour contains 0.04% total sterols, with β -sitosterol as the predominant sterol at 83%, followed by campesterol (9%), stigmasterol (6%), and 8-5 avenasterol (2%).

f) Saponins

Saponins are commonly identified in the seeds of edible legumes and are characterized by molecular structures consisting of sugars linked to triterpenes. Saponins possess several potential health benefits. They play a protective role in plants against infections and microbial invasions. Mounting evidence suggests that saponins may exhibit hypocholesteremic and anticancer properties, stimulate the immune system, protect against microbial and fungal infections, and even act as a spermicide. Chickpea exhibits notably higher saponin content, ranging from 25 to 56 mg/g, when compared to soybeans and other pulses (Fenwick and Oakenfull, 1983; Kerem *et al.*, 2005). From the finding of Choudhary *et al.* (2015), the saponin content of different *kabuli* chickpea genotypes ranged from 4.98 to 12.23 mg/g.

g) Enzyme inhibitors

Chickpeas harbor two primary enzyme inhibitors: protease and α -amylase. Both categories of inhibitors have been classified as antinutritional factors due to their ability to impede protein and starch digestion. However, current research advocates that these inhibitors may also possess beneficial properties. Protease inhibitors in chickpea typically range from 1-16 mg/g trypsin inhibitor to 2-13 mg/g chymotrypsin inhibitor. Kaur *et al.* (2019) reported significant variation in trypsin inhibitor content across chickpea genotypes, ranging from 8.23 to 150.18 IU/g. *Desi* genotypes specifically showed higher levels (32.91-112.32 IU/g, mean 80.08 IU/g) compared to *kabuli* genotypes (38.53-64.47 IU/g, mean 47.83 IU/g). These protease inhibitors exhibit anticarcinogenic properties (Champ, 2002; Mathers, 2002). Additionally, α -amylase inhibitors found in chickpea, with a typical content of 5-11 units/g, have the ability to decrease starch digestion, leading to the reduction of blood glucose levels (Sievenpiper *et al.*, 2009). This property suggests potential applications

in the management and prevention of obesity and diabetes mellitus.

h) Oligosaccharides

Chickpea seeds harbor a diverse array of oligosaccharides, including raffinose (2.3-14.5 g/kg), stachyose (5.8-25.6 g/kg), and verbascose (1.9-7.2 g/kg) (El-Adawy, 2002; Sreerama *et al.*, 2012; Longvah *et al.*, 2017). Stachyose occupies the dominant position as the primary oligosaccharide (Sreerama *et al.*, 2012). Human intestinal mucosa lacks the α -1,6-galactosidase enzyme necessary for their digestion, leading to fermentation by colonic microbiota and causes flatulence. However, recent research has revealed the benefit of these undigested oligosaccharides. They act as prebiotics, selectively enhancing the growth of beneficial bacteria like Bifidobacteria and Lactobacilli, while simultaneously suppressing the proliferation of harmful bacterial populations within the colon.

BREEDING EFFORTS FOR ENHANCING NUTRITIONAL VALUE OF CHICKPEAS

The rich nutritional and medicinal properties of chickpea have garnered significant attention among emerging plant breeders. Recent advancements in sequencing technologies have facilitated the unveiling of the entire chickpea genome, providing a comprehensive blueprint for understanding and manipulating its genetic makeup. Advanced breeding methodologies, such as quantitative trait locus (QTL) analysis, genome-wide association studies (GWAS), and genomic selection, are effectively harnessing molecular tools to identify genomic regions governing beneficial traits in chickpea. In recent years, substantial research efforts have been directed towards elucidating the genetic basis of nutritional traits in chickpea, paving the way for the development of improved chickpea varieties with enhanced nutritional profiles.

Researchers have employed various approaches to identify genetic factors influencing seed protein content (SPC) in chickpea. Srugarapu *et al.* (2022) found substantial variation in grain protein content (16.3-26.2%) among 280 diverse chickpea accessions. Chakraborty *et al.* (2023) utilized QTL-Seq and association mapping to uncover two QTLs on chromosomes 5 and 6, each associated with three SNPs. These SNPs were validated and linked to the CaREN1 gene, explaining up to 23% of SPC variation. Wang *et al.* (2019) identified a major QTL, q-3.2, on chromosome 3, significantly influencing

SPC, accounting for 44.3% of SPC variation, while Upadhyaya *et al.* (2016a) identified allelic variants in six potential genes regulating SPC. These findings provide valuable insights for marker-assisted breeding and targeted gene manipulation to enhance SPC in chickpea.

Recent studies identified chickpeas as a solution to micronutrient deficiencies, particularly iron and zinc, which can lead to health problems. Genetic variations in nutrient concentrations of chickpea seeds have been investigated using genetic markers. In a study by Srungarapu *et al.* (2022) identified genetic markers associated with grain protein, Fe, and Zn content, located on chromosomes 1, 4, 6, and 7. These markers hold the potential to be used in breeding for nutrient-rich chickpea cultivars. Additionally, Diapari *et al.* (2014) identified 9 SNPs significantly associated with Fe and/or Zn concentrations in chickpea seeds. Upadhyaya *et al.* (2016) identified genetic markers explaining 29% of the variation in seed Fe and Zn concentrations. They further validated eleven trait-associated SNPs using SNP-based high-resolution quantitative trait locus (QTL) maps, revealing robust QTLs for seed Fe and Zn concentrations in eight major genomic regions of the *kabuli* chickpea genome. Moreover, Tan *et al.* (2018) proposed a genetic engineering (GE) strategy to enhance the Fe content of chickpea by employing a combination of the chickpea nicotinamide synthase 2 (CaNAS2) and soybean (Glycine max) ferritin (GmFER) genes, which play crucial roles in Fe transport and storage, respectively. Karaca *et al.* (2019) identified 29, 10, 14, and 4 SNPs associated with protein, lutein, vitamin C, and fructose, respectively, in 180 chickpea varieties, elucidating the genetic basis of nutrient variation in chickpea seeds. Roorkiwal *et al.* (2022) analyzed 258 chickpea varieties for 12 nutritional traits and discovered genetic markers associated with these traits on chromosomes Ca1, Ca3, Ca4, and Ca6, explaining up to 28.63% of the trait variation.

The presence of protein, carbohydrates, and vitamins, particularly provitamin A carotenoids found in chickpea seeds, renders chickpeas a significant dietary component, especially in numerous developing nations (Abu-Salem and Abou-Arab, 2011). Varieties with green cotyledons exhibit higher concentrations of provitamin A compared to those with yellow cotyledons. In a study by Rezaei *et al.* (2016) investigated the expression of carotenoid biosynthesis genes in chickpea and found that gene expression was highest at 8 and/or 16 days after flowering, corresponding to the peak

accumulation of carotenoids. Furthermore, Rezaei *et al.* (2019) identified eight quantitative trait loci (QTLs) associated with carotenoid components in chickpea seeds using three F₂ populations derived from crosses between green- and yellow-cotyledon chickpea cultivars. These QTLs provide valuable genetic markers for marker-assisted breeding aimed at improving carotenoid content and provitamin-A content in chickpea.

Chickpea harbors bioactive and functional compounds, notably phenolics and flavonoids, which confer significant health benefits. Despite these nutritional merits, chickpeas contain certain antinutritional factors, such as phytic acid, tannins, enzyme inhibitors, and oligosaccharides, which impede the bioavailability of these bioactive nutrients. However, there is limited scientific exploration into these factors. Notably, phytic acid, a phosphorus storage form in plants, exerts a negative influence on mineral bioavailability due to its chelating properties. Studies have revealed the polygenic nature of phytic acid content in chickpea and identified transgressive segregants with extreme phenotypes (Misra *et al.*, 2017). A SSR marker located in the promoter region of the IMP gene has been associated with phytic acid content in chickpea (Dwivedi *et al.*, 2017). Raffinose family oligosaccharides (RFOs) is another major anti nutritional factor found in chickpea seeds. Substantial genetic variation exists in RFO content, as demonstrated by Raja *et al.* (2015), who reported wide ranges for raffinose (0.16-15.13 mg/g) and stachyose (2.77-59.43 mg/g) across 213 accessions. Among RFOs ciceritol exhibited the most significant variation (4.36-90.65 mg/g). Elango *et al.* (2022) further explored this diversity within the chickpea mini-core collection, revealing distinct differences between *kabuli* and *desi* biotypes. *Kabuli* chickpeas were characterized by high sucrose content, while *desi* types possessed elevated levels of raffinose and stachyose. Genome-wide association studies (GWAS) identified 48 SNPs associated with sugar types, coupled with the identification of nine candidate genes potentially involved in sugar metabolism and transport (Elango *et al.*, 2022). These findings provide valuable insights into the genetic architecture of RFO accumulation in chickpea and lay the groundwork for breeding programs aiming to develop cultivars with reduced anti-nutritional factors and enhanced nutritional value.

CONCLUSION

Chickpea stands out as a prominent pulse

globally, following dry beans in consumption. Its nutritional richness and diverse health-promoting components position it as a valuable dietary resource. Packed with protein, fibre, vitamins, and minerals, chickpeas present a sustainable and versatile source of nutrition, making them an invaluable component of balanced diets across diverse cultures. The disclosure of chickpea's antioxidant and prebiotic potential, particularly through the presence of oligosaccharides, adds another layer of significance to its nutritional profile. Over the years, scientists have conventionally developed cultivars that not only meet basic nutritional requirements but also go beyond in providing additional health-promoting components and increase the richness of germplasm. The vast genetic variability within chickpea germplasm, coupled with advancements in genome sequencing and editing technologies, offers exciting prospects for further enhancing and optimizing nutritional traits.

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