Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Bioactive Compounds, Phytochemical Composition and Health-Promoting Properties of Cicer arietinum L: A Comprehensive Review

Ramesha K. Lakshmaiah[1], Shivakumar Venkataramaiah[2], Devaraja Sannaningaiah[3].

[1]Department of Home Science, Government Home Science College for Women, Holenarasipura, Karnataka, India
[2]Department of Research, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam, Tamil Nadu, India.
[3]Department of Studies and Research in Biochemistry and Food Science and Nutrition, Jnanasiri Campus, Tumkur University, Tumakuru, Karnataka, India

Abstract
Cicer arietinum L. (chickpea) is a valuable source of nutrition comprising various bioactive compounds. The seeds of this legume plant are a rich source of protein, carbohydrates, fiber, minerals, vitamins and unsaturated fats. They also contain phenolic acids, flavonoids, saponins, tannins, carotenoids and other phytochemicals. The bioactive compounds found in chickpeas are promising due to their antioxidant, anti-inflammatory, antidiabetic, cardioprotective, anticarcinogenic and gastroprotective effects. Researchers have proved the ability of chickpeas to improve glucose and lipid metabolism, as well as intestinal function and reduce oxidative stress and inflammation. So that, this legume product can be considered a functional food with a noteworthy impact on human health, particularly in the prevention of chronic diseases. However, the processing methods, including soaking, germination, cooking, roasting, fermentation, and milling, can significantly affect the composition and content of phytochemicals. Despite the existing data on the impact of C. arietinum on human health, it is necessary to conduct further studies. In particularly, the need for deep understanding of the physiological effects. Besides, it needs to be analyzed the impact of most common processing technologies on the chemical composition of chickpeas.

Keywords:
Cicer arietinum; Phytochemicals; Bioactive compounds; Antioxidant; Anti-inflammatory; Antidiabetic.

1. Introduction

1.1 Overview of Cicer arietinum

Cicer arietinum L. (chickpea, Bengal gram, garbanzo bean, gram) is an annual diploid legume of the Fabaceae family and the genus Cicer. The species is cultivated for its high-protein seeds. Chickpea originated in the Fertile Crescent region of the Near East and naturalized in Asia, Africa, Europe, Australia and the Americas [1]. It is now one of the world’s most widely grown pulses, especially in India. Seeds of the species can be classified into two groups: desi and Kabuli. The two subspecies differ in terms of seed sizes, shapes and colors, with desi possessing small, angular and dark seeds while Kabuli have large, round and cream-colored seeds. Besides the morphological difference, the subspecies differ in their nutrient profiles and phytochemical contents [2].

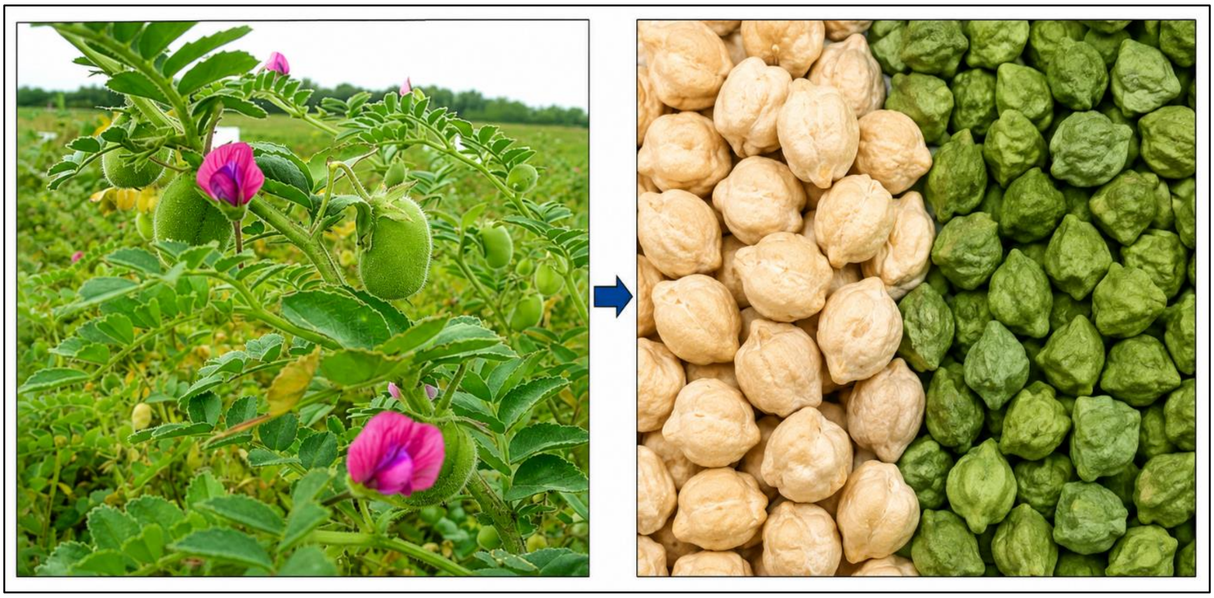

Figure 1. Cicer arietinum (chickpea) plant and its major cultivated types: Desi (smaller, darker seeds) and Kabuli (larger, cream-coloured seeds).

1.2 Nutritional importance

Chickpea is a complete food, providing the body with a balanced amount of nutrients. It contains high levels of plant protein, including essential amino acids that are lacking in cereals. The main source of energy is represented by carbohydrates, including significant amounts of dietary fibers [3]. By the composition, chickpeas contain high content of soluble and insoluble fibers also contains unsaturated fatty acids, among which linoleic and oleic, are the major ones. Moreover, chickpeas contain vitamins, mainly folate, B vitamins and minerals such as iron, magnesium, phosphorus, potassium, zinc, calcium [4].

1.3 Chickpea as a functional food

The growing interest in chickpea is justified not only because of its nutritious qualities but also because of the variety of phytochemicals that can beneficially affect the human body. The functional properties of legumes, particularly, chickpea make them an ideal product for the prevention and control of metabolic syndrome [5]. The low glycemic-load of chickpea and other legumes makes them especially valuable foods in the context of balanced diets and carbohydrate consumption. The high content of dietary fibre, resistant starch, as well as its vitamin and mineral content, offers more beneficial affects to the digestive system as well as heart. The presence of phenolic acids, flavonoids, saponins, tannins, carotenoids and other phytochemicals in chickpea make them significant food with high antioxidant potential [6]. Moreover, the clinical trials conducted so far confirm the possibility of using this product for the prevention and treatment of certain diseases, including diabetes, atherosclerosis, inflammatory processes, cancer and other pathological conditions. Thus, chickpea, like other legumes, has a significant impact on human health and is a valuable food and source of nutraceuticals.

1.4 Rationale and objective of the review

Although there is a vast amount of information regarding chickpea nutrition and health, the variations in genotype, agro-ecological conditions, processing, phytochemical content and bioavailability and experimental models may compromise the reproducibility and comparability of the data. Thus, there is a need for an integrated consideration of the nutritional, phytochemical, and bioactive properties of this legume to understand the structure–function relationships and the contribution to human health and disease prevention. The present review aims to provide an updated overview of the phytochemical composition and nutritional properties of C. arietinum, including the modes of action of specific compounds and their impact on health and physiological functions. Particular attention is paid to the effect of different processing techniques on the nutritional and phytochemical properties of chickpeas. The review also highlights the experimental evidence for the antioxidant, anti-inflammatory, antidiabetic, cardioprotective, anticancer, gastroprotective potential of chickpeas and identifies knowledge gaps and research needs for the development of functional food and nutraceutical products.

2. Nutritional and Phytochemical Composition of Cicer arietinum

The nutritional and phytochemical composition of Cicer arietinum L. makes it a valuable source of food and functional food. Chickpea is a good source of nutrients necessary for the body's energy supply and metabolic processes. Moreover, it contains minerals, vitamins, phenolic compounds, flavonoids, saponins, phytosterols, carotenoids, peptides, and other secondary metabolites. The content of individual nutrients depends on the variety, region and growing conditions of chickpea, as well as the stage of technological maturity and processing technology [7].

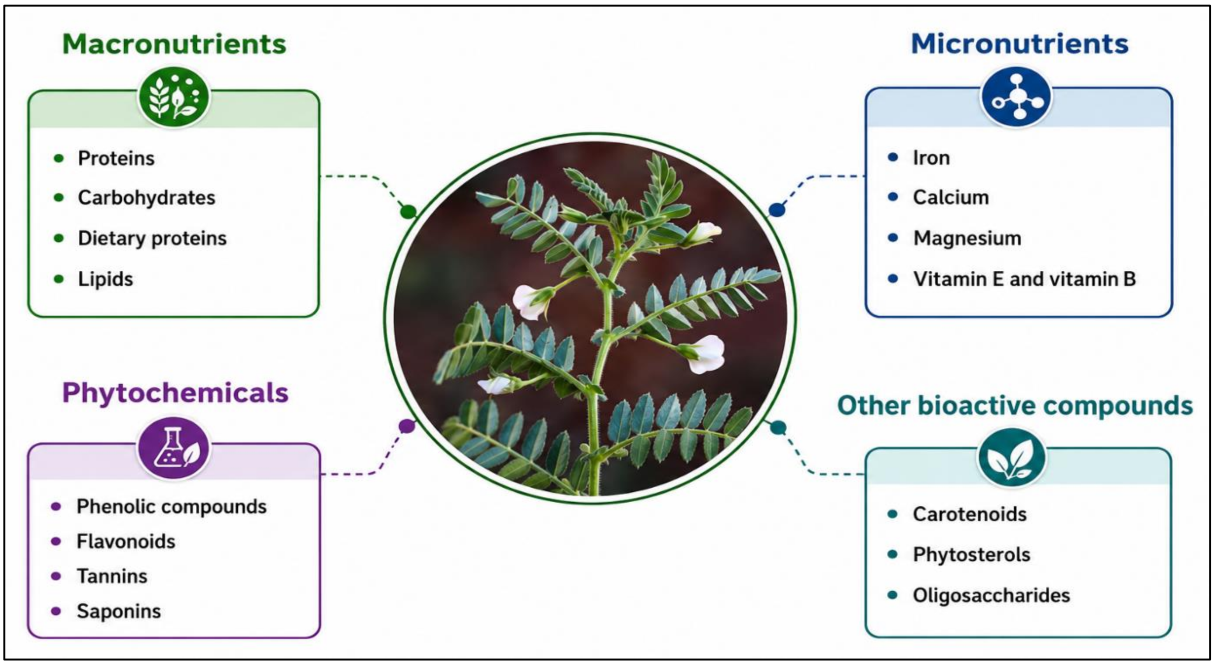

Figure 2. Phytochemical and bioactive composition of Cicer arietinum.

2.1 Macronutrient composition

Protein: Chickpea contains good amount of protein (17-24 % on average) compared to other legumes; Albumins, globulins, glutelins and prolamins are the four main classes of chickpea proteins with large proportions of storage globulins. Seeds of chickpea are a rich source of essential amino acids. Moreover, chick pea protein can complement cereal proteins to provide a balanced amino acid composition.

Carbohydrates: Carbohydrates are the main macronutrient in chickpea, with starch being the primary component, followed by soluble sugars, resistant starch and non-starch polysaccharides. In whole chickpeas, the slow digestion of carbohydrates can help control blood sugar levels after meals. Moreover, resistant starch and other indigestible carbohydrates can reach the large intestine and be fermented into short-chain fatty acids, which are beneficial for intestinal function and overall health.

Dietary fiber: Chick-pea contains significant amounts of dietary fibre, mostly insoluble cellulose and hemicellulose, but also including small amounts of soluble fibre and pectic substances. Dietary fibre increases the bulk of the stools, promotes intestinal motility, reduces the absorption of nutrients from the gut, and delays stomach emptying. In addition, a portion of fibre is fermented by intestinal bacteria, thereby altering the composition and function of the gut microbiota.

Lipids: Even though chickpea contains only a small amount of lipids compared to oilseeds, this fraction is qualitatively favourable in terms of nutrition. They contain essential unsaturated fatty acids, such as linoleic and oleic, and a relatively small amount of other fatty acids. Unsaturated acids, along with phytosterols and vitamin E, have a positive effect on the human body, improving lipid metabolism and reducing the risk of atherosclerosis.

2.2 Micronutrients

Chickpeas are a good source of minerals and vitamins. They contain iron, which is necessary for the formation of hemoglobin and calcium and magnesium, which are involved in the processes of bone formation and muscle activity, as well as nerve conduction and acid-base balance [8]. In chickpeas, there is zinc, which is involved in the catalytic activity of enzymes, protein synthesis, and functioning of the immune system and defense systems against free radicals. Potassium, in turn, is responsible for the balance of water and salt in the body and the normal functioning of the heart and blood vessels. The product is a source of folate, which is involved in the synthesis of purines and pyrimidines, and the normal functioning of the human body. Besides, chickpeas contain vitamin E. This vitamin, along with B vitamins, is part of many enzymes and plays a vital role in the human body. The tocopherol component of vitamin E has an anti-aging effect, removes free radicals, and protects cell membranes from damage [9].

2.3 Phenolic compounds

Phenolic compounds are a large group of phytochemicals found in chickpeas, which play a significant role in its antioxidant activity. They can be present in a free form and bound to other compounds. Moreover, a considerable amount of them is located in the seed coat and cell walls [10]. Phenolic acids are common in chickpeas, with hydroxybenzoic and hydroxycinnamic acids being the most widespread. In addition, hydroxycinnamic acids are believed to have antioxidant and anti-inflammatory properties. Among these acids are caffeic, p-coumaric, and ferulic acids, the content of which varies depending on the variety and processing technology [11].

2.4 Flavonoids

Chickpea as well contains diverse flavonoids such as quercetin, kaempferol and catechin, among others, which also vary in different cultivars. The flavonoids in chickpeas are categorized into hydroxylated flavonoids that eliminate reactive oxygen and nitrogen species, and flavonoid derivatives that inhibit distinct cellular signalling cascades [12]. For instance, quercetin and kaempferol are flavonoids with antioxidant and anti-inflammatory effects, whereas catechin is a precursor of flavan-3-ols and serves as an antioxidant by scavenging free radicals.

2.5 Tannins and saponins

Tannins can be mainly found in the seed coat of chickpeas. These compounds may affect the color, flavour and digestibility of proteins, as well as nutrient availability. High tannin content may reduce the nutritional value of chickpeas due to their interaction with proteins and enzymes, which decreases the bioavailability of minerals and impairs digestion (….). On the other hand, they may also have positive effects, including antioxidant, antimicrobial activities, and others. Saponins are also amphiphilic phytochemicals that can bind to cell membranes and possess anti-inflammatory, antioxidant, hypocholesterolemic, and even anti-carcinogenic activities [13].

2.6 Other bioactive constituents

Chickpea contains a number of other constituents with potential physiological activity, including phytosterols, carotenoids, proteins, and oligosaccharides. Among phytosterols in chickpea, β-sitosterol and related sterols are represented in considerable amounts, potentially helpful in displacing cholesterol from the intestines to reduce its absorption. Carotenoids are present in chickpea in substantial quantities, although much lower than in some other legumes. Proteins from chickpea can produce biologically active peptides during digestion, microbial fermentation, or enzymatic hydrolysis.

Chickpea contains significant amounts of oligosaccharides, among which are raffinose-family sugars, mainly raffinose and stachyose. Due to the absence of α-galactosidase in humans, these sugars are not digested and cause gas formation in the intestine. However, they fermented by intestinal microflora to short-chain fatty acids, with beneficial effects on colon motility and immunity [14]. In addition, chickpeas contain phytic acid, which is a storage form of phosphorus and has metal-chelating properties. Thus, the various components of chickpea, in addition to macronutrients, affect the human body, particularly the gastrointestinal tract and metabolism [15]. However, these effects are determined by many factors, including the variety and geographical location of the crop, processing technology, digestion conditions, and physiological activity.

Category	**Component**	**Potential nutritional relevance**
Macronutrients	Protein	High-quality plant protein; provides essential amino acids
	Carbohydrates	Major source of dietary energy
	Dietary fibre	Supports bowel function, glycaemic control and gut health
	Resistant starch	Promotes colonic fermentation and beneficial microbiota
	Fat	Mainly unsaturated fatty acids
	Energy	Nutrient-dense energy source

Fatty acids	Linoleic acid (C18:2)	May contribute to cardiovascular health
	Oleic acid (C18:1)	Associated with favourable lipid metabolism
	Palmitic acid (C16:0)	Structural and metabolic role
Vitamins	Folate (vitamin B9)	DNA synthesis, cell division and homocysteine metabolism
	Thiamine (B1)	Carbohydrate metabolism and neuronal function
	Riboflavin (B2)	Energy metabolism and redox reactions
	Niacin (B3)	NAD/NADP-dependent metabolic reactions
	Vitamin B6	Amino-acid metabolism and neurotransmitter synthesis
Minerals	Calcium	Bone health and cellular signalling
	Iron	Haemoglobin synthesis and oxygen transport
	Magnesium	Enzyme activity, energy metabolism and cardiovascular function
	Phosphorus	Bone mineralisation and ATP metabolism
	Potassium	Fluid balance and cardiovascular function
	Zinc	Enzymatic activity and immune function
Phenolic compounds	Phenolic acids	Antioxidant and anti-inflammatory activities
	Flavonoids	Antioxidant, anti-inflammatory and metabolic effects
Other phytochemicals	Saponins	Potential hypocholesterolaemic, antioxidant and anti-inflammatory effects
	Phytosterols	May modulate intestinal cholesterol absorption
	Carotenoids	Antioxidant and cellular protective effects
	Tannins	Antioxidant and potential antimicrobial activity
	Tocopherols	Lipid-phase antioxidant activity
Bioactive proteins	Bioactive peptides	Potential antioxidant, ACE-inhibitory, antidiabetic and anti-inflammatory activities
Antinutritional factors	Phytic acid	Mineral chelation; may also exhibit antioxidant properties
	Raffinose-family oligosaccharides	Fermentable substrates for intestinal microbiota; may contribute to flatulence
	Protease inhibitors	Reduce proteolytic activity; substantially reduced by processing
	Lectins	Antinutritional at high levels; reduced by cooking

Table 1. Nutritional and phytochemical composition of C. arietinum

Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

3. Health-Promoting Properties of Cicer arietinum

The high nutritional and phytochemical value of Cicer arietinum L. provides a functional food with beneficial effects on human health and the possible prevention of chronic diseases. The consumption of chickpeas and its extracts offer a wide number of health benefits due to the content of proteins, fibers, resistant starch, unsaturated fatty acids, vitamins, minerals, polyphenols, flavonoids, saponins, phytosterols and bioactive peptides in the legume. These phytochemicals are associated with different mechanisms that can affect and reduce the development of oxidative stress, decrease chronic inflammation, modulate glucose and lipid metabolism, improve gut function, regulate cell signalling pathways and other processes. The mechanisms derived from biochemical and cell studies were identified in the literature, but there is also information from animal and human studies that demonstrate physiological effects.

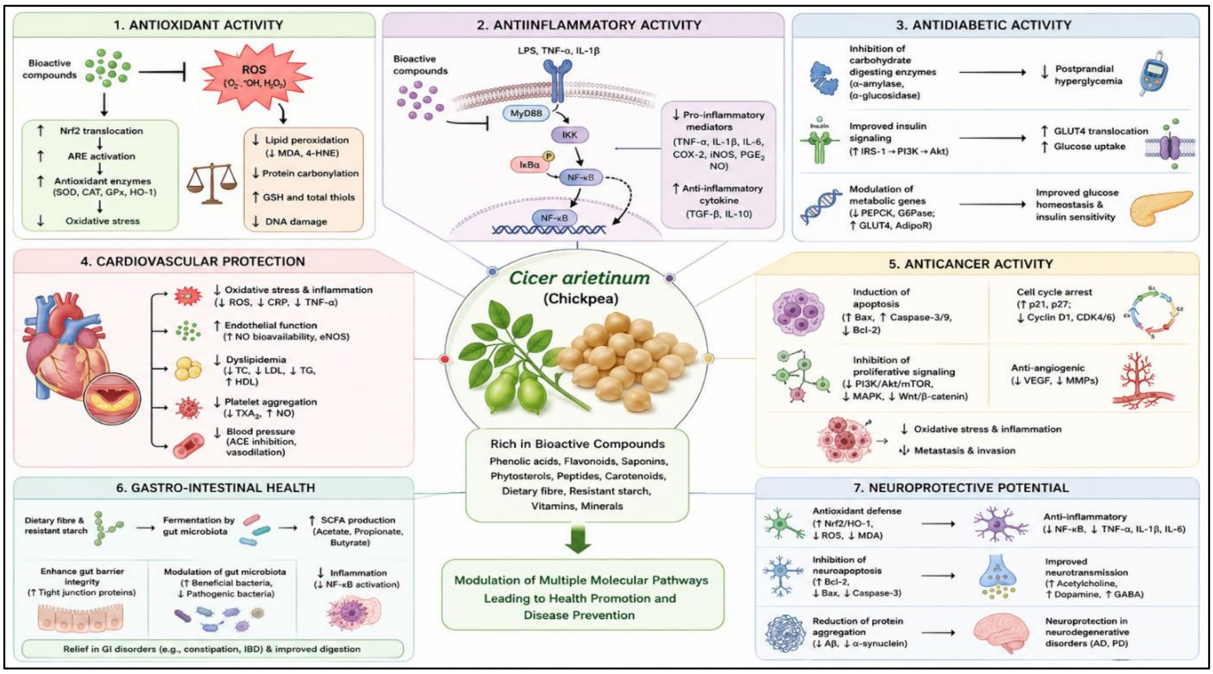

Figure 3. Health-promoting effects of Cicer arietinum.

3.1 Antioxidant activity

Chickpea shows antioxidant activity due to radical scavenging and/or modulation of antioxidant defense system. The plant contains phenolic acids, flavonoids, tocopherols, peptides, and other reducing substances that can donate electrons or hydrogen atoms to neutralize free radicals. The antioxidant potential of chickpea is often evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and ferric-reducing antioxidant power (FRAP) assays [16].

3.2 Anti-inflammatory activity

Chronic, low-grade inflammation plays a key role in the development of various diseases, such as metabolic, cardiovascular, gastrointestinal and other chronic disorders. Chickpea phytochemicals may attenuate inflammatory processes by regulating multiple pathways and targets, including transcription factors, enzymes, and inflammatory mediators. A number of chickpea flavonoids, phenolic acids, saponins, and peptides have been found to possess anti-inflammatory properties, however, the contribution of each class depends on particular structures and bioavailability [16]. Moreover, some in-vivo experiments confirm the anti-inflammatory potential of chickpeas through the downregulation of inflammatory pathways in experimental animals. Therefore, based on the available evidence, it is possible to suggest that chickpeas may help in the regulation of inflammatory processes [17].

3.3 Antidiabetic and metabolic benefits

A review shows that chickpea has the potential to improve glucose homeostasis since dietary fiber, resistant and slowly digestible starches in this legume are capable of lowering postprandial glucose peaks and decreasing overall glycemic responses [18].

3.4 Cardiovascular benefits

The regular consumption of chickpea could be beneficial for cardiovascular health due to specific mechanisms of action that could reduce cholesterol levels and blood pressure, counter inflammatory processes, and improve oxidative stress status. The dietary fibre content could reduce intestinal cholesterol absorption and increase bile-acid excretion into the intestines and their hepatic reuse. In addition, phytosterols could also lower cholesterol levels by competing with dietary cholesterol for absorption sites in the gastrointestinal tract [19]. The rich content in potassium and magnesium could also improve vascular and muscular function and reduce blood pressure. Moreover, the antioxidants and anti-inflammatory compounds could reduce oxidative modifications of low-density lipoproteins and endothelial inflammation.

3.5 Anticancer potential

Chickpea has garnered considerable interest due to its hypothesized anti-cancer properties. The phenolics, flavonoids, saponins, peptides, fibre and other bioactive constituents may modulate key cellular pathways and processes, including oxidative stress, inflammation, proliferation, and apoptosis.

In-vitro experiments on cell lines of colorectal, breast, prostate, or liver cancer and in vivo experiments on animal models have shown chickpeas' extracts' ability to inhibit tumour progression and induce cancer cell death [20]. The proposed molecular mechanisms of action encompass the regulation of intracellular ROS levels and the promotion of cancer cell apoptosis via the modulation of caspase activity, the induction of the Bax/Bcl-2 ratio shift, the disruption of mitochondrial function, and cell cycle arrest. Moreover, phenolics and other bioactive constituents of chickpeas may inhibit NF-κB-driven inflammatory response and survival signalling cascades, including PI3K/Akt and MAPK pathways [21].

3.6 Gastrointestinal and gut-health benefits

Chickpea is associated with positive changes in the gastrointestinal tract due to the high content of dietary fibre, resistant starch, and fermentable oligosaccharides in it. Insoluble fibre promotes bowel movements and accelerates intestinal transit [22]. At the same time, oligosaccharides are broken down by intestinal bacteria, which creates favourable conditions for the intestinal microflora. Furthermore, resistant starch reaching the colon is actively broken down by bacteria, which breaks down into short-chain fatty acids, such as acetate, propionate, and butyrate [23].

The fermentation of chickpeas affects the composition and function of the gut microbiota, which, in turn, affects metabolic processes. The presence of raffinose oligosaccharides in the composition of chickpeas, which can ferment in the large intestine. However, this fermentation is often accompanied by excessive gas formation that can lead to uncomfortable sensations in the digestive tract. Fermentation of fibre, resistant starch, and oligosaccharides in foods improves bowel function, increases the volume of feces, and positively affects the microbiota. In addition, short-chain fatty acids, produced as a result of the breakdown of resistant starch, have numerous beneficial effects on the body [24].

3.7 Neuroprotective potential

The bioactive compounds in chickpeas may also be neuroprotective. The oxidative stress and neuroinflammation contribute to neuronal damage in the pathophysiology of many neurodegenerative diseases. The antioxidants may help reduce oxidative damage, as well as regulate inflammatory signalling pathways [25].

4. Influence of Processing on Phytochemicals and Bioavailability

Food processing greatly influences the nutritional, phytochemical, antinutritional and biological properties of Cicer arietinum. Processing of chickpeas may lead to the degradation of heat-labile materials or alternatively, to an increased release of phenolics and phytochemical components. Therefore, by modifying the composition of chickpeas, processing methods may also affect the subsequent utilization of these products by humans.

4.1 Soaking

Soaking is a common pre-treatment that facilitates the leaching of water-soluble anti-nutritional factors during the germination process of chickpea seeds. Soaking also reduces cooking time; increases the solubility of minerals thus improving their bioavailability; and also enhances the digestibility of proteins. The process can influence the levels of phenolic compounds and their extractability from the seed. Although prolonged soaking tends to lower the content of water-soluble phenolics in the leachates, the hydrolysis of cell contents and membranes [26].

4.2 Germination

Germination is the process during which enzymes inherent in seeds become active and numerous metabolic transformations occur in the seeds. As a result of these processes, the content of protein, amino acids, peptides and phenolic compounds may increase and the content of some antinutritional factors can decrease. Furthermore, germination can involve the formation of phenolic compounds through the activity of enzymes responsible for phenylpropanoid metabolism. Therefore, the level of phenolic compounds in germinated chickpeas can be significantly higher compared to non-germinated ones [27].

4.3 Cooking

Cooking makes chickpeas more palatable, improves the digestibility of their protein and starch, and makes their cell structure softer, compared to raw seeds. The application of heat inactivates some phenolic compounds and flavonoids. Cooking can decrease levels of particular phytochemicals. The thermal processing can free phenolics from the plant cell walls and protein matrix by degrading cell structure and protein, hence increasing the content of some compounds. Therefore, cooking methods should be used to optimize the nutritional and phytochemical content of chickpeas [28].

4.4 Roasting

Roasting leads to the exposure of chickpea to high temperatures, which can cause significant changes to its phytochemistry, flavor, color and antioxidant potential. Thermal processing can both decrease the content of heat-labile phenolics and flavonoids and facilitate the formation and release of bound antioxidants. The Maillard reaction between reducing sugars and amino groups can produce melanoidins, thereby contributing to the observed antioxidant activity. At the same time, roasting at too high temperatures can affect the nutritional and biochemical qualities of chickpea, decreasing the contents of vulnerable bioactive compounds [29].

4.5 Fermentation

Fermentation can be very effective in improving the functional properties of chickpea by allowing microorganisms and their enzymes to modify the characteristics of the seed. Microbial phytases can degrade phytic acid whereas microbial enzymes can modify proteins, carbohydrates and phenolic compounds, among others. In addition, fermentation can mobilize phenolics from the seed through deconjugation resulting in lower molecular weights and potentially higher bio accessibility. Fermentation can lower some oligosaccharides and other components that may cause gastrointestinal discomfort. These modifications can improve the mineral content, protein digestibility, antioxidant activity, and overall gastrointestinal comfort of the processed food [30].

Processing method	**Major phytochemical changes**	**Effect on bioavailability**	**Effect on biological activity**	**Overall effect**
Soaking	Partial reduction of soluble phenolics, tannins, phytates and raffinose-family oligosaccharides due to leaching; may promote release of some bound phenolics	Improves mineral bioavailability by reducing phytic acid; enhances protein and starch hydration and digestibility	May improve antioxidant potential and reduce antinutritional effects; decreases gastrointestinal discomfort associated with oligosaccharides	Generally beneficial, although prolonged soaking may cause loss of water-soluble compounds
Germination	Increases phenolic acids, flavonoids and other secondary metabolites through activation of endogenous enzymes; decreases phytate, tannins and some oligosaccharides	Enhances accessibility and bioavailability of phenolics, minerals and proteins; improves protein digestibility	Often increases antioxidant, antidiabetic and anti-inflammatory potential; may improve α-amylase/α-glucosidase inhibitory activity	Highly beneficial for enhancing bioactive compounds
Cooking / Boiling	Reduces heat-sensitive and water-soluble phytochemicals;	Improves protein and starch digestibility and reduces	Improves digestibility and nutritional quality; antioxidant activity	Beneficial overall, with possible losses of heat-

	decreases tannins, phytates, lectins and protease inhibitors; may release some bound phenolics	antinutritional factors; mineral bioavailability may improve	may increase or decrease depending on compound and cooking conditions	sensitive compounds
Roasting	Promotes liberation of bound phenolics and formation of Maillard reaction products; may decrease some heat-sensitive phenolics	Improves palatability and digestibility; may increase availability of certain phenolic compounds	Can enhance antioxidant capacity through increased free phenolics and Maillard-derived antioxidants; excessive roasting may degrade bioactives	Moderately beneficial, when controlled
Fermentation	Microbial enzymes hydrolyse phytate, tannins and complex carbohydrates; may increase free phenolic acids and bioactive peptides	Substantially improves mineral and protein bioavailability and reduces antinutritional factors	Can enhance antioxidant, antidiabetic, antihypertensive and anti-inflammatory activities; may generate new bioactive metabolites	Highly beneficial and potentially the most effective for improving functional properties
Soaking → Cooking	Combined reduction of phytate, tannins, oligosaccharides and protease inhibitors; some phenolics may be lost through soaking water and cooking	Improved protein, starch and mineral bioavailability	Enhanced digestibility and reduced antinutritional activity	Highly beneficial for nutritional quality
Germination → Cooking	Germination-induced increase in phenolics followed by reduction of antinutritional factors during cooking	Improved protein digestibility and mineral availability	Potentially enhanced antioxidant and metabolic health-promoting properties	Strongly beneficial
Fermentation → Cooking	Fermentation increases free bioactive compounds and peptides; subsequent cooking	High potential for improved nutrient accessibility and digestibility	May provide enhanced antioxidant, anti-inflammatory and antidiabetic effects	Highly beneficial, depending on fermentation conditions

	further reduces antinutritional factors			

Table 2. Effects of processing methods on phytochemical composition, bioavailability and biological activity

5. Antinutritional Factors, Safety and Limitations

5.1 Antinutritional factors

Although Cicer arietinum is a good source of nutrients and biologically active compounds, it contains some anti-nutritional components. The level of phytic acid in chickpeas is relatively high and decrease the bioavailability of iron, zinc and other minerals [31]. Moreover, tannins present in chickpeas may reduce the digestibility of proteins and interfere with digestive enzymes' activity. Chickpeas contain protease inhibitors that can decrease the activity of proteolytic enzymes. However, cooking destroys protease inhibitors, so properly prepared chickpeas are not harmful in this regard [32]. Lectins are another group of compounds that may be detrimental to health. These proteins may bind to specific carbohydrates on intestinal cells and cause impaired digestion and nutrient malabsorption. Luckily, legumes' lectins are heat-labile, and their intake with food does not interfere with digestion. Oxalic acid is present in chickpeas, which can decrease the bioavailability of calcium [33]. The intake of chickpeas may cause gas formation in the gastrointestinal tract due to the presence of raffinose oligosaccharides. Stachyose and raffinose can only be digested in the large intestine and undigested portions of these sugars may lead to uncomfortable sensations in the abdomen [34]. Soaking, germination and other preparation techniques can reduce anti-nutritional effects in chickpeas.

5.2 Safety

The chickpeas are generally safe to use in the diet as part of the balanced nutrition. However, chickpea allergy is possible, resulting in various digestive tract or skin adverse effects, or manifesting severe allergic reaction symptoms. Moreover, the under-digested oligosaccharides provoke gas formation, causing bloating, discomfort, diarrhea, and changes in bowel movements [35]. The overconsumption may lead to these negative consequences due to higher fiber and undigested carbs content. A sufficient preparation of chickpeas removes some anti-nutritive compounds, phytosterols and poorly digested carbs, improving tolerance to this legume [36].

5.3 Limitations of Current Evidence

Though there is evidence to support the role of Cicer arietinum in promoting health, there are still barriers to overcome before chickpeas can be officially endorsed as health benefactors. The content of phytochemical in chickpeas varies with different cultivars, genotype, geographical location, growing conditions, stage of maturity, storage and processing therefore making it hard to compare results from different studies. The phytochemicals concentration and composition differ due to variations in extraction solvents, methodology and analytical procedures used in various studies. The lack of uniformity of the compounds, their metabolites, and optimal dosage in different studies presents another challenge. Though some extracts have high concentrations of the desired compounds, these phytochemicals may not be readily available for absorption hence lower health benefits.

6. Conclusion

Cicer arietinum L. (chickpea) is a legume containing a significant amount of protein that can be considered as a functional food /nutraceutical compound. Chickpea is a good source of dietary fibre, resistant starch, unsaturated fatty acids, vitamins and minerals. Phenolic acids, flavonoids, saponins, phytosterols, carotenoids and bioactive peptides are also present in this legume. The beneficial effects of chickpea are mostly attributed to the synergistic action of its phytochemicals. The antioxidant and anti-inflammatory effect of chickpea are mostly due to the presence of phenolic acids, flavonoids, and related compounds. The anti-diabetic and cardio-protective effects are mainly attributed by the insoluble and slowly digestible starch, non-starch polysaccharides, resistant starch and dietary fibre, which are able to modulate postprandial glycaemia and lipid metabolism. The anti-cancer potential of chickpea, is mostly due to their ability to modulate various molecular targets and signalling pathways controlling the cell cycle progression, apoptosis, invasion and angiogenesis. The beneficial effects of chickpea described are mostly proven at cellular and animal levels. Moreover, the beneficial effects of chickpea may depend on genetic, agricultural, and environmental factors, as well as on the preparation or extraction procedures. Therefore, more preclinical and clinical studies are needed to elucidate the effects and mechanisms of action of chickpea phytochemicals on their therapeutic potential.

Conflict of Interest

The authors declare that they have no known financial, personal, or professional conflicts of interest that could have influenced the research, authorship, or publication of this manuscript.

Acknowledgement

The authors would like to express their sincere gratitude to their respective institutions and all individuals who provided assistance and support during the experimental work and preparation of the manuscript.

Authors' Biography

Dr. Ramesha K. Lakshmaiah is an Associate Professor in the Department of Home Science at Government Home Science College for Women, Holenarasipura, Hassan, Karnataka 573211, India. His academic and research activities are associated with the field of Home Science and related areas. He is currently engaged in teaching, academic activities, and research at the institution.

Dr. Shivakumar Venkataramaiah is an Assistant Professor in the Department of Research at Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603103, Tamil Nadu, India. His current academic activities include teaching, research, and scientific contributions within the field of biomedical and health sciences.

Dr. Devaraja Sannaningaiah is a Professor in the Department of Studies and Research in Biochemistry and Food Science and Nutrition, Jnanasiri Campus, Tumkur University, Tumakuru, Karnataka, India. His academic and research activities are focused on biochemistry and biomedical sciences, with research interests encompassing oxidative stress, thrombosis, platelet biology, inflammation, and the evaluation of bioactive compounds for therapeutic applications. He has contributed to research publications in the fields of biochemistry, oxidative stress, platelet aggregation, anticoagulant and antiplatelet activities, and related biomedical sciences.

References

1. A. Raina, S. Khan, M.R. Wani, R.A. Laskar, W. Mushtaq, Chickpea (Cicer arietinum L.) Cytogenetics, Genetic Diversity and Breeding, in: J.M. Al-Khayri, S.M. Jain, D.V. Johnson (Eds.), Adv. Plant Breed. Strateg. Legum., Springer International Publishing, Cham, 2019: pp. 53–112. https://doi.org/10.1007/978-3-030-23400-3_3.
2. J.A. Wood, E.J. Knights, M. Choct, Morphology of Chickpea Seeds (Cicer arietinum L.): Comparison of desi and kabuli Types, Int. J. Plant Sci. 172 (2011) 632–643. https://doi.org/10.1086/659456.
3. A.K. Jukanti, P.M. Gaur, C.L.L. Gowda, R.N. Chibbar, Nutritional quality and health benefits of chickpea (Cicer arietinum L.): a review, Br. J. Nutr. 108 (2012) S11–S26. https://doi.org/10.1017/S0007114512000797.
4. N. Begum, Q.U. Khan, L.G. Liu, W. Li, D. Liu, I.U. Haq, Nutritional composition, health benefits and bio-active compounds of chickpea (Cicer arietinum L.), Front. Nutr. 10 (2023) 1218468. https://doi.org/10.3389/fnut.2023.1218468.
5. I. Fatima, M.K.I. Khan, A.A. Maan, S. Arif, An Insight into Chickpea-Derived Secondary Metabolites as Functional and Nutraceutical Agents against Diabetes, Plant Foods Hum. Nutr. 80 (2025) 162. https://doi.org/10.1007/s11130-025-01399-4.
6. A. Ajay, S.S. Gaur, R. Shams, K.K. Dash, S.A. Mukarram, B. Kovács, Chickpeas and gut microbiome: Functional food implications for health, Heliyon 10 (2024) e39314. https://doi.org/10.1016/j.heliyon.2024.e39314.
7. N. Kumar, S. Hong, Y. Zhu, A. Garay, J. Yang, D. Henderson, X. Zhang, Y. Xu, Y. Li, Comprehensive review of chickpea (Cicer arietinum): Nutritional significance, health benefits, techno-functionalities, and food applications, Compr. Rev. Food Sci. Food Saf. 24 (2025) e70152. https://doi.org/10.1111/1541-4337.70152.
8. B. Merga, J. Haji, Economic importance of chickpea: Production, value, and world trade, Cogent Food Agric. 5 (2019) 1615718. https://doi.org/10.1080/23311932.2019.1615718.
9. S. Elma Mathew, D. Shakappa, A review of the nutritional and antinutritional constituents of chickpea (Cicer arietinum) and its health benefits, Crop Pasture Sci. 73 (2022) 401–414. https://doi.org/10.1071/CP21030.
10. S. Tiwari, V.K. Sahu, N. Gupta, M.K. Tripathi, M. Yasin, Evaluation of Physiological and Biochemical Contents in Desi and Kabuli Chickpea, LEGUME Res. - Int. J. (2020). https://doi.org/10.18805/LR-4265.
11. M. Sova, L. Saso, Natural Sources, Pharmacokinetics, Biological Activities and Health Benefits of Hydroxycinnamic Acids and Their Metabolites, Nutrients 12 (2020) 2190. https://doi.org/10.3390/nu12082190.
12. P. Semwal, S. Gupta, Chahat, G. Joshi, M. Wahajuddin, B. Kumar, A Comprehensive Review on Key Chemical Constituents of Indian Pulses and Their Multifaceted Health Benefits in a Global Context, Legume Sci. 7 (2025) e70055. https://doi.org/10.1002/leg3.70055.

13. Y. Kumar, S. Basu, D. Goswami, M. Devi, U.S. Shivhare, R.K. Vishwakarma, Anti-nutritional compounds in pulses: Implications and alleviation methods, Legume Sci. 4 (2022) e111. https://doi.org/10.1002/leg3.111.
14. V. Galli, M. Venturi, N. Pini, S. Guerrini, L. Granchi, Exploitation of sourdough lactic acid bacteria to reduce raffinose family oligosaccharides (RFOs) content in breads enriched with chickpea flour, Eur. Food Res. Technol. 245 (2019) 2353–2363. https://doi.org/10.1007/s00217-019-03353-6.
15. T. Luo, T. Wu, K. Liu, Y. Li, J. Li, W. Wang, Chickpea (Cicer arietinum L.): Integrating Nutritional Excellence, Health Benefits, and Abiotic Stress Resilience for Sustainable Food Systems, Foods 15 (2026) 1982. https://doi.org/10.3390/foods15111982.
16. R.K. Lakshmaiah, M.M. Venkatappa, S. Venkataramaiah, R. Rangappa, D. Sannaningaiah, Aqueous extract of Cicer arietinum leaves mitigates the oxidative stress induced RBC and vital organ damage via antioxidant and anti-inflammatory properties, Int. J. Pharm. Pharm. Sci. 7 (2025) 777–790. https://doi.org/10.33545/26647222.2025.v7.i2i.276.
17. M. Kim, K.-S. Chung, S.-J. Hwang, Y.S. Yoon, Y.P. Jang, J.K. Lee, K.-T. Lee, Protective Effect of Cicer arietinum L. (Chickpea) Ethanol Extract in the Dextran Sulfate Sodium-Induced Mouse Model of Ulcerative Colitis, Nutrients 12 (2020) 456. https://doi.org/10.3390/nu12020456.
18. M. Ghare, K. Vishwakarma, S. Tripathi, G.P. Dixit, K.R. Soren, Unveiling the Benefits of Resistant Starch in Legumes: Overview of Current and Future Prospective, Starch - Stärke 76 (2024) 2300212. https://doi.org/10.1002/star.202300212.
19. M. Bouchenak, M. Lamri-Senhadji, Nutritional Quality of Legumes, and Their Role in Cardiometabolic Risk Prevention: A Review, J. Med. Food 16 (2013) 185–198. https://doi.org/10.1089/jmf.2011.0238.
20. L. Serventi, X. Cai, R. Chen, N. Dilrukshi, J. Su, R.P.N. Tuange, E.E. Ham, Anticancer Properties of Aqueous Extracts from Leguminosae, Nutraceuticals 2 (2022) 323–334. https://doi.org/10.3390/nutraceuticals2040025.
21. P. Chaudhary, Babita, A.K. Mavi, S. Adhana, Anti-inflammatory Bioactive Compounds for Cancer Therapy, in: Md.M. Ansari, N. Akhtar (Eds.), Bioact. Food Ingred. Manag. Inflamm. Dis., Springer Nature Switzerland, Cham, 2026: pp. 213–240. https://doi.org/10.1007/978-3-032-23814-6_10.
22. S. Kadyan, A. Sharma, B.H. Arjmandi, P. Singh, R. Nagpal, Prebiotic Potential of Dietary Beans and Pulses and Their Resistant Starch for Aging-Associated Gut and Metabolic Health, Nutrients 14 (2022) 1726. https://doi.org/10.3390/nu14091726.
23. P. DeMartino, D.W. Cockburn, Resistant starch: impact on the gut microbiome and health, Curr. Opin. Biotechnol. 61 (2020) 66–71. https://doi.org/10.1016/j.copbio.2019.10.008.
24. M. Roberfroid, Dietary fiber, inulin, and oligofructose: A review comparing their physiological effects, Crit. Rev. Food Sci. Nutr. 33 (1993) 103–148. https://doi.org/10.1080/10408399309527616.
25. M.M. Wahby, D.S. Mohammed, A.A. Newairy, H.M. Abdou, A. Zaky, Aluminum-induced molecular neurodegeneration: The protective role of genistein and chickpea extract, Food Chem. Toxicol. 107 (2017) 57–67. https://doi.org/10.1016/j.fct.2017.05.044.

26. A. Fuso, M. Donna, P. Varetto, G. Pigna, F. Bonzanini, A. Caligiani, M. Blandino, Effect of soaking and roasting on antinutritional factors content in different genotypes of soybean and chickpea, J. Food Compos. Anal. 147 (2025) 108003. https://doi.org/10.1016/j.jfca.2025.108003.
27. L. Rosental, H. Nonogaki, A. Fait, Activation and regulation of primary metabolism during seed germination, Seed Sci. Res. 24 (2014) 1–15. https://doi.org/10.1017/S0960258513000391.
28. N.D. Patil, A. Bains, K. Sridhar, S. Rashid, S. Kaur, N. Ali, P. Chawla, M. Sharma, Effect of Sustainable Pretreatments on the Nutritional and Functionality of Chickpea Protein: Implication for Innovative Food Product Development, J. Food Biochem. 2024 (2024) 1–29. https://doi.org/10.1155/2024/5173736.
29. F. AlJuhaimi, M.M. Özcan, N. Uslu, E. E. Babiker, N. Walayat, I.A.M. Ahmed, Influence of Roasting on Biochemical Components and Mineral Contents of Chickpea (Cicer arietinum L.) Seeds, J. Food Qual. 2026 (2026) 6652408. https://doi.org/10.1155/jfq/6652408.
30. R. Fernandez-Orozco, J. Frias, H. Zielinski, R. Muñoz, M.K. Piskula, H. Kozlowska, C. Vidal-Valverde, Evaluation of bioprocesses to improve the antioxidant properties of chickpeas, LWT - Food Sci. Technol. 42 (2009) 885–892. https://doi.org/10.1016/j.lwt.2008.10.013.
31. T.A. El-Adawy, Nutritional composition and antinutritional factors of chickpeas (Cicer arietinum L.) undergoing different cooking methods and germination, Plant Foods Hum. Nutr. 57 (2002) 83–97. https://doi.org/10.1023/A:1013189620528.
32. A.P. Giri, A.M. Harsulkar, V.V. Deshpande, M.N. Sainani, V.S. Gupta, P.K. Ranjekar, Chickpea Defensive Proteinase Inhibitors Can Be Inactivated by Podborer Gut Proteinases1, Plant Physiol. 116 (1998) 393–401. https://doi.org/10.1104/pp.116.1.393.
33. A. Ali, S. Devarajan, A. Manickavasagan, A. Ata, Antinutritional Factors and Biological Constraints in the Utilization of Plant Protein Foods, in: A. Manickavasagan, L.-T. Lim, A. Ali (Eds.), Plant Protein Foods, Springer International Publishing, Cham, 2022: pp. 407–438. https://doi.org/10.1007/978-3-030-91206-2_14.
34. D. Urminská, N. Haring, V. Fábry, J. Urminská, FERMENTABLE OLIGOSACCHARIDES, DISACCHARIDES, MONOSACCHARIDES AND POLYOLS AND THEIR ROLE IN FOOD DIGESTION, J. Microbiol. Biotechnol. Food Sci. 11 (2022) e5521. https://doi.org/10.55251/jmbfs.5521.
35. S.P. Patil, P.V. Niphadkar, M.M. Bapat, Chickpea: a major food allergen in the Indian subcontinent and its clinical and immunochemical correlation, Ann. Allergy. Asthma. Immunol. 87 (2001) 140–145. https://doi.org/10.1016/S1081-1206(10)62209-0.
36. Z. Ahmad, A. Ahmad, M. Subtain, M. Naeem, Antinutritional characterization in plant foods; health consequences and reduction strategies, J. Food Meas. Charact. 19 (2025) 6264–6283. https://doi.org/10.1007/s11694-025-03432-1.