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Nutritional quality and health benefits of chickpea (Cicer arietinum L.): a review

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Nutritional Quality and Health Benefits of chickpea (*Cicer arietinum* L.): A Review

Abstract Chickpea (*Cicer arietinum* L.) is an important pulse crop grown and consumed all over the world, especially in the Afro-Asian countries. It is a good source of carbohydrates and protein, and the protein quality is considered to be better than other pulses. Chickpea has significant amounts of all the essential amino acids except sulfur containing types, which can be complemented by adding cereals to daily diet. Starch is the major storage carbohydrate followed by dietary fibre, oligosaccharides and simple sugars like glucose and sucrose. Lipids are present in low amounts but chickpea is rich in nutritionally important unsaturated fatty acids like linoleic and oleic acid. β-sitosterol, campesterol and stigmasterol are important sterols present in chickpea oil. Calcium, magnesium, phosphorus and especially potassium are also present in chickpea seeds. Chickpea is a good source of important vitamins such as riboflavin, niacin, thiamin, folate and the vitamin A precursor, β-carotene. Like other pulses, chickpea seeds also contain anti-nutritional factors which can be reduced or eliminated by different cooking techniques. Chickpea has several potential health benefits and, in combination with other pulses and cereals, it could have beneficial effects on some of the important human diseases like cardiovascular disease, type 2 diabetes, digestive diseases and some cancers. Overall, chickpea is an important pulse crop with a diverse array of potential nutritional and health benefits.

Introduction

Chickpea (*Cicer arietinum* L.), also called garbanzo bean or Bengal gram, is an Old World pulse and one of the seven Neolithic founder crops in the Fertile Crescent of the Near East[1]. Currently, chickpea is grown in over 50 countries across the Indian subcontinent, North Africa, the Middle East, southern Europe, the Americas and Australia. Globally, chickpea is the third most important pulse crop in production, next to dry beans and field pea[2]. During 2006-09, the global chickpea production area was about 11.3 million ha, with production of 9.6 million metric tonnes (mmt) and average yield of 849 kg ha^{-1}[2]. India is the largest chickpea producing country with an average production of 6.38 million MT during 2006-09, accounting for 66% of global chickpea production[2]. The other major chickpea producing countries include Pakistan, Turkey, Australia, Myanmar, Ethiopia, Iran, Mexico, Canada and USA.

There are two distinct types of cultivated chickpea, Desi and Kabuli. Desi (*microsperma*) types have pink flowers, anthocyanin pigmentation on stems, and a colored and thick seed coat. The kabuli (*macrosperma*) types have white flowers, lack anthocyanin pigmentation on stem, white or beige-colored seeds with a ram's head shape, thin seed coat and smooth seed surface[3]. In addition an intermediate type with pea shaped seeds of local importance is recognized in India. The seed weight generally ranges from 0.1 to 0.3g and 0.2 to 0.6g in desi and kabuli types respectively[4]. The desi types account for about 80-85% of the total chickpea area and are mostly grown in Asia and Africa[5]. The kabuli types are largely grown in West Asia, North Africa, North America and Europe.

There is a growing demand for chickpea due to its nutritional value. In the semi-arid tropics chickpea is an important component of the diets of those individuals who cannot afford animal proteins or those who are vegetarian by choice. Chickpea is a good source of carbohydrates and protein, together constituting about 80% of the total dry seed mass[6,7] in comparison to other pulses. Chickpea is cholesterol free and is a good source of dietary fibre, vitamins and minerals[8,9].

Globally, chickpea is mostly consumed as a seed food in several different forms and preparations are determined by ethnic and regional factors[10,11]. In the Indian subcontinent, chickpea is split (cotyledons) as *dhal* and ground to make flour (*besan*) that is used to prepare different snacks[12,13]. In other parts of the world, especially in Asia and Africa chickpea is used in stews, soups/salads and consumed in roasted, boiled, salted and fermented forms[14]. These different forms of consumption provide consumers with valuable nutrition and potential health benefits.

Despite chickpea being a member of the “founder crop package”[15] with potential nutritional/medicinal qualities, it has not received due attention for research like other founder crops (e.g. wheat or barley). Chickpea has been and is being consumed by humans since ancient times owing to its good nutritional properties. Furthermore, chickpea is of interest as a functional food with potential beneficial effects on human health. Although other publications have described the physicochemical and nutritional characteristics of chickpea, there is limited information relating its nutritional components to health benefits. This review attempts to bridge this void and review the literature regarding the nutritional value of chickpeas and their potential health benefits.

Chickpea Grain Composition

Classification of Carbohydrates

Different carbohydrates are classified into (i) available (mono and disaccharides), which are enzymatically digested in the small intestine and (ii) unavailable (oligosaccharides, resistant starch, non-cellulosic polysaccharides, pectins, hemicelluloses and cellulose), which are not digested in the small intestine[16]. The total carbohydrate content in chickpea is higher than pulses (Table 2). Chickpea has: (i) monosaccharides- ribose, glucose, galactose and fructose (ii) disaccharides-sucrose, maltose and (iii) oligosaccharides- stachyose, ciceritol, raffinose and verbascose[20]. The amount of these fractions varies though not significantly, between desi and kabuli genotypes (Table 1).

Mono-, Di-, and Oligosaccharides

Sanchez-Mata *et al.*[17] reported chickpea monosaccharide concentration for galactose (0.05 g 100^{-g}), ribose (0.11 g 100^{-g}), fructose (0.25 g 100^{-g}) and glucose (0.7 g 100^{-g}). Maltose (0.6%) and sucrose (1-2%) have been reported to be the most abundant free disaccharides in chickpea[9]. Pulse seeds contain some of the highest concentrations of oligosaccharides among all the crops. Oligosaccharides are not absorbed or hydrolyzed by human digestive system but fermented by colonic bacteria to release gases or flatulence[18]. α-Galactosides are the second most abundant carbohydrates in the plant kingdom after sucrose[19,20] and in chickpea they account for ~62% of total sugar (mono-, di-, and oligosaccharides) content[17]. The two important groups of α-galactosides present in chickpea are: (i) raffinose family of oligosaccharides (RFOs) - raffinose (trisaccharide), stachyose [tetrasaccharide], and verbascose [pentasaccharide][20] and (ii) galactosyl cyclitols - including ciceritol (Table 1)[21]. Ciceritol was isolated for the first time from chickpea seeds by Quemener and Brillouet[22] and later confirmed by Bernabé *et al.*[21]. Ciceritol and stachyose, two important galactosides in chickpea constitutes 36-43% and 25% respectively of total sugars (mono-, di-, and oligosaccharides) in chickpea seed[17,23].

α-Galactosides are neither absorbed nor hydrolyzed in the upper gastro-intestinal tract of humans, accumulating in the large intestine of the human digestive system. Humans lack α-galactosidase, the enzyme responsible for degrading these oligosaccharides[20]. Therefore, α-galactosides undergo microbial fermentation by colonic bacteria resulting in the production of hydrogen, methane and carbon dioxide, major components of flatulent gases[24]. The expulsion of these gases is responsible for abdominal discomfort. Gas production is higher in chickpea compared to other pulses, and this could be due to a higher content of oligosaccharides in chickpea[25,26]. Germination decreases raffinose, stachyose and verbascose content[27]. Chickpea has lower values for absolute flatulent α-galactosides [1.56 g 100^{-g}] compared to other pulses like white beans [2.46 g 100^{-g}], lentils [2.44 g 100^{-g}] and pinto beans [2.30 g 100^{-g}][17].

Polysaccharides

Polysaccharides are high molecular weight monosaccharide polymers present as storage carbohydrate (e.g. starch) or as structural carbohydrates (e.g. cellulose) providing structural support[9]. Among the storage polysaccharides, chickpea is reported to synthesize and store starch and not galactomannans[9]. Starch is the major storage carbon reserve in pulse seeds[6]. Starch is made up of two large glucan polymers, amylose and amylopectin, in which the glucose residues are linked by α-(1→4) bonds to form a linear molecule and the linear molecule is branched by α-(1→6) linkages[6]. The amylopectin side chains are packed into different polymorphic forms in the lamellae of the starch grains: 'A' type in cereals and 'C' type in pulses. The 'C' polymorph is considered to be of intermediate type between 'A' polymorph in cereals and 'B' polymorph in tubers in packing density and structure[6]. The content of starch varies from 41-50% of the total carbohydrates[28-30], with kabuli types having more soluble sugars (sucrose, glucose and fructose) compared to the desi types[28]. The total starch content of chickpea seeds is reported to be ~ 525 g kg^{-1} dry matter, about 35% of total starch is considered to be resistant starch (RS) and the remaining 65% as available starch[23,31]. Cereals such as wheat have higher amount of starch compared to chickpea[32], but the chickpea seeds have higher amylose content [30-40% versus 25% in wheat][33,34]. The *in vitro* starch digestibility values (ISDV) of chickpea vary from 37-60%[35,36] are higher than other pulses like black grams, lentils and kidney beans[37]. However, the ISDV of pulses in general are lower than cereals due to higher amylose content[38].

Dietary Fibre

Dietary fibre (DF) is the indigestible part of plant food in the human small intestine. DF is composed of poly/oligosaccharides, lignin and other plant-based substances[39]. The dietary fibres can be classified into soluble and insoluble. Soluble fibre, is digested slowly in the colon whereas the insoluble fibre is metabolically inert and aid in bowel movement[40]. The insoluble fibre undergoes fermentation aiding in the growth of the colonic bacteria[40]. Total dietary fibre content (DFC) in chickpea is 18-22 g 100^{-g} of raw chickpea seed[23,40] and it has higher amount of DF among pulses (Table 2). Soluble and insoluble DFC is about 4-8 and 10-18 g 100^{-g} of raw chickpea seed respectively[29,41]. The fibre content of chickpea hulls on a dry weight basis is lower [75%] compared to lentils [87%] and peas [89%][29]. The lower DFC in chickpea hulls can be attributed to difficulty in separating the hull from cotyledon during milling.

The DFC of chickpea seed is equal to or higher than other pulses like lentils [*Lens culinaris]* and dry peas [*Pisum sativum*][(40)]. The desi types have higher total DFC and insoluble DFC compared to the kabuli types. This could be due to thicker hulls and seed coat in desi (11.5 % of total seed weight) compared to the kabuli types (only 4.3-4.4 % of total seed weight)[(41)]. Further, Wood *et al.*[(42)] have reported that the thinner seed coat in kabuli types is due to thinner palisade and parenchyma layers with fewer polysaccharides. Usually no significant differences are found in soluble DFC between kabuli and desi types due to similar proportion of hemicelluloses which constitute large part (~ 55%) of the total seed dietary fibre in kabuli and desi[(43)]. The hemicellulosic sugar arabinose/rhamnose is present in appreciable amounts in hull and insoluble fibre fractions of chickpea[(29)]. Glucose is present in large amounts in hull and soluble fibre fractions of chickpea. Xylose is the major constituent of soluble fibre fractions in chickpea[(29)].

Protein Content

Protein calorie malnutrition is observed in infants and young children in developing countries and includes a range of pathological conditions arising due to lack of protein and calories in the diet[(44)]. Malnutrition affects about 170 million people especially preschool children and nursing mothers of developing countries in Asia and Africa[(45)]. Pulses provide a major share of protein and calories in Afro-Asian diet. Among the different pulses, chickpea is reported to have higher protein bioavailability[(46,47)].

The protein content in chickpea significantly varies as percentage of the total dry seed mass before (17-22%) and after (25.3-28.9%) dehulling[(13,48)]. The differences in crude protein concentration of kabuli [K] and desi [D] types are inconsistent showing significant differences at times [241 g kg^{-1} in ‘K’ vs 217 g kg^{-1} in ‘D’][(49)] and showing no differences at other times [217 g kg^{-1} in ‘K’ vs 215 g kg^{-1}in ‘D’][(41)]. The seed protein content of eight annual wild species of genus *Cicer*, ranged from 168 g kg^{-1} in *Cicer cuneatum* to 268 g kg^{-1} in *Cicer pinnatifidum* with an average of 207 g kg^{-1} over the eight wild species[(50)]. Chickpea protein quality is better than some pulse crops such as black gram [*Vigna mungo* L.], green gram [*Vigna radiata* L.] and red gram [*Cajanus cajan* L.][(51)]. Additionally, there is no significant difference in protein concentration of raw chickpea seed compared to some pulses such as black gram, lentils, red kidney bean and white kidney bean[37].

Protein Digestibility

The *in vitro* protein digestibility (IVPD) of raw chickpea seeds varies from 34-76%[36,52,53]. Chitra *et al.*[54] found higher IVPD values for chickpea genotypes [65.3-79.4%] compared to those of pigeon pea [*Cajanus cajan*; 60.4 to 74.4%], mung bean [*Vigna radiata*; 67.2 to 72.2%], urd bean [*Vigna mungo*; 55.7 to 63.3%] and soybean [*Glycine max*; 62.7 to 71.6%]. The digestibility of protein from kabuli type is higher than the protein from desi types[47,55].

Amino Acid Profile

The amino acid profiles of chickpea seed are presented in Table 3. There are some minor variations in the quantity of a few amino acids such as lysine, tyrosine, glutamic acid, histidine and the two combined aromatic amino acids (Table 3)[45]. Generally the sulfur-rich amino acids (methionine and cystine) are limiting in pulses. Commonly consumed food pulses such as chickpea, field pea, green pea, lentil and common bean have ~ 1.10 g 16^{-g} N of methionine and cystine[56], the exceptions being cowpea which has ~ 2.20 g 16^{-g} N of methionine and green pea which has, ~1.80 g 16^{-g} N of cystine[45]. There are no significant differences in the amino acid profiles of kabuli and desi type chickpea[56,57]. The amino acid deficiencies in chickpea (or other pulses) could be complemented by consuming cereals, which are rich in sulphur-containing amino acids[35]. Pulses are usually consumed along with cereals, especially in Asian countries, thereby allowing the daily dietary amino acid requirements to be met.

Fat Content and Fatty Acid Profile

Total fat content in raw chickpea seeds varies from 2.70-6.48 %[51,58]. Shad *et al.*[59] reported lower values (~ 2.05 g 100^{-g}) for crude fat content in desi chickpea varieties. Fat content of 3.40-8.83% and 2.90-7.42% in kabuli and desi type chickpea seeds respectively was reported by Wood and Grusak[9]. Further, even higher levels (3.80-10.20%) of fat content in chickpea was reported[24]. The fat content in chickpea (6.04 g 100^{-g}) is higher than the other pulses like lentil (1.06 g 100^{-g}), red kidney bean (1.06 g

100^{-g}), mungbean (1.15 g 100^{-g}) and pigeonpea (1.64 g 100^{-g}) and also cereals like wheat (1.70 g 100^{-g}) and rice (~0.60 g 100^{-g})[32]. Chickpea is composed of polyunsaturated fatty acids (PUFA; ~ 66%), monounsaturated fatty acids (~19%) and ~ 15% saturated fatty acids (Table 4). On average oleic acid was higher in the kabuli types and linoleic acid was higher in the desi types (Table 4). Chickpea is relatively a good source of nutritionally important PUFA, linoleic acid (51.2 %; LA) and monounsaturated oleic acid (32.6%; OA). Chickpea has higher amounts of linoleic and oleic acid compared to other edible pulses like lentils (44.4% LA; 20.9 OA), pea (45.6 LA; 23.2 OA) and bean 46.7% LA; 28.1% OA)[56]. Linoleic acid is the dominant fatty acid in chickpea followed by oleic and palmitic acids (Table 4).

Oil Characteristics

Chickpea cannot be considered an oilseed crop since its oil content is relatively low [3.8-10%][24,60] in comparison to other important oilseed pulses like soybean or groundnut. However, chickpea oil has medicinal and nutritionally important tocopherols, sterols and tocotrienols[61]. The content of different sterols and tocopherols in chickpea is presented in Table 5. Sitosterol (72.52-76.10%; Table 5) was the dominant sterol in chickpea oil followed by campesterol. The α-tocopherol content reported by USDA[35] is lower than other reported values in Table 5. But, α-tocopherol content in chickpea is relatively higher (8.2 mg 100^{-g}) than other pulses like lentil (4.9 mg 100^{-g}), green pea (1.3 mg 100^{-g}), red kidney bean (2.1 mg 100^{-g}) and mungbean (5.1 mg 100^{-g})[32]. The α-tocopherol content, coupled with concentration of δ-tocopherol, which is a potent antioxidant property[62], makes chickpea oil oxidatively stable and contributes to better shelf life during storage[63]. Triacylglycerol is the predominant neutral lipid in desi chickpea oil and phospholipids are also found in oil[61].

The physicochemical characteristics of chickpea oil are summarized in Table 6. The relative index values of chickpea (1.49) are higher than those of soybean (1.46) and groundnut (1.47), the two important oil-bearing pulses[64]. The iodine values (IV) of chickpea oil (111.87-113.69, Wijs method) were also higher than the IV of groundnut (80-106, Wijs method) and *Phaseolus vulgaris* (80.5-92.3, Wijs method)[61,65]. Higher refractive index and iodine values indicate a substantial unsaturation in chickpea oil and this is demonstrated by the dominance of linoleic acid content[61] (Table 4). The lower acid values observed for chickpea (Table 6) makes its oil refining easier[66]. The peroxide value for chickpea oils (3.97-6.37 mequiv/kg; Table 6) was within the maximum limit of Codex recommendation (10 mequiv/kg) for edible oils[64].

Minerals

Chickpea, like other pulses, not only brings variety to the cereal-based daily diet of millions of people in Asia and Africa, but also provides essential vitamins and minerals[67,68]. The different minerals present in chickpea seed are presented in Table 7. Raw chickpea seed (100 g) on an average provides about 5.0 mg 100^{-g} of iron, 4.1 mg 100^{-g} of zinc, 138 mg 100^{-g} of magnesium and 160 mg 100^{-g} of calcium. About 100g of chickpea seed can meet daily dietary requirements of iron (1.05 mg/day in males and 1.46 mg/day in females) and zinc (4.2mg/day and 3.0 mg/day) and 200g can meet that of magnesium (260 mg/day and 220 mg/day)[69]. There were no significant differences between the kabuli and desi genotypes except for calcium, with desi types having a higher content than kabuli types[56,70]. The amount of total iron present in chickpea is lower (5.45 mg 100^{-g}) compared to other pulse crops like lentils (8.60 mg 100^{-g}) and beans (7.48 mg 100^{-g})[71]. The data on other minerals present in chickpea is very limited. Selenium, a nutritionally important essential trace element is also found in chickpea seed [8.2 μg 100^{-g}][32,67]. Chickpea is reported to have other trace elements including aluminum [10.2 μg /g], chromium [0.12 μg/g], nickel [0.26 μg/g], lead [0.48 μg/g], and cadmium [0.01 μg/g][32,67]. The quantities reported here for aluminum, nickel, lead and cadmium do not pose any toxicological risk.

Vitamins

Vitamins are required in tiny quantities; this requirement is met through a well-balanced daily diet of cereals, pulses, vegetable, fruits, meat and dairy products. Pulses are a good source of vitamins. As shown in Table 8, chickpea can complement the vitamin requirement of an individual when consumed with other foods. Chickpea is a relatively inexpensive and good source of folic acid and tocopherols [both γ and α; Table 8][72]. It is a relatively good source of folic acid coupled with more modest amounts of water soluble vitamins like riboflavin (B2), panthothenic acid (B5) and pyridoxine (B6), and these levels are similar or higher than that observed in other pulses [Table 9][73]. However, the niacin concentration in chickpea is lower compared to pigeonpea and lentil [Table 9][74].

Carotenoids

Plant carotenoids are lipid soluble antioxidants/pigments responsible for bright colors (usually red, yellow and orange) of different plant tissues[75]. Carotenoids are classified into (i) oxygenated – referred to as xanthophylls, which-includes lutein, violaxanthin, and neoxanthin and (ii) non-oxygenated – referred to as carotenes which-includes β-carotene and lycopene[76]. The important carotenoids present in chickpea include β-carotene (Table 8), lutein, zeaxanthin, β-cryptoxanthin, lycopene and α-carotene. The average concentration of carotenoids (except lycopene) is higher in wild accessions of chickpea than in cultivated varieties or landraces [cv. *Hadas*][77]. β-carotene is the most important and widely distributed carotenoid in plants and is converted to vitamin A more efficiently than the other carotenoids[77]. On a dry seed weight basis chickpea has higher amount of β-carotene than “golden rice” endosperm[77,78] or red colored wheats[32].

Isoflavones

Chickpea contains several phenolic compounds in the seed[9]. Two important phenolic compounds found in the chickpea are the isoflavones, biochanin A [5, 7-dihydroxy-4'-methoxyisoflavone] and formononetin [7-hydroxy-4'-methoxyisoflavone][9]. The other phenolics detected in chickpea oil are daidzein, genistein, matairesinol, and secoisolariciresinol[79,80]. The concentration of biochanin A is higher in kabuli seeds [1420-3080 μg/100g] compared to the desi type seeds [838μg/100g][81]. The amount of formononetin in kabuli and desi seeds is 215μg/100g and 94-126 μg/100g respectively[81].

Anti-nutritional Factors (ANFs)

Despite the potential nutritional and health-promoting value of ANFs, their presence in chickpea limits its biological value and usage as food. Anti-nutritional factors interfere with digestion and also make the seed unpalatable when consumed in raw form by monogastric animal species[82]. ANFs can be divided into protein and non-protein ANFs[83]. Non-protein ANFs include alkaloids, tannins, phytic acid, saponins, and phenolics while protein ANFs include trypsin inhibitors, chymotrypsin inhibitors, lectins and antifungal peptides [Table 10][84,85]. Chickpea protease inhibitors are of two types: (i) Kunitz type – single chain polypeptides of about 20 kDa with two disulphide bridges which inhibit the enzyme activity of only trypsin but not chymotrypsin[86]; and (ii) Bowman-Birk Inhibitors (BBI) – which are also single chain polypeptides of about 8 kDa in size with seven disulphide bridges which inhibit the enzyme activity of both trypsin and chymotrypsin[87,88]. Protease inhibitors interfere with digestion by irreversibly binding with trypsin and chymotrypsin in the human digestive tract. They are resistant to the digestive enzyme pepsin and the stomach's acidic pH[84]. They negatively affect certain necessary enzymatic modifications required during food processing like water retaining capacity, gel-forming and foaming ability of different products[89].

Phytic acid can bind to several important divalent cations (e.g. iron, zinc, calcium and magnesium) forming insoluble complexes and making them unavailable for absorption and utilization in the small intestine[90-92]. Tannins inhibit enzymes, reducing the digestibility and making chickpea astringent. Saponins are commonly found in several pulses including chickpea [Table 10][93] giving the pulses a bitter taste and making them less preferable for consumption by humans and animals[94]. Saponin content in chickpea (56 g kg^{-1}) is higher than other pulses like green gram (16 g kg^{-1}), lentil (3.7-4.6 g kg^{-1}), fababean (4.3 g kg^{-1}) and broadbean (3.5 g kg^{-1})[95].

Though the ANFs act as limiting factors in chickpea consumption, they can be reduced or eliminated by soaking, cooking, boiling and autoclaving[58]. ANFs also have beneficial effects and these are discussed below.

Health Benefits

Although pulses have been consumed for thousands of years for their nutritional qualities[96], it is only during the past two to three decades that the interest in pulses as food and their potential impact on human health been revived. Chickpea consumption is reported to have some physiologic benefits that may reduce the risk of chronic diseases and optimize health (discussed in detail in the following paragraphs). Therefore, chickpeas could potentially be considered as a 'functional food' in addition to their accepted role of providing proteins and fibre. Different definitions are proposed describing the functional foods: (i) "one encompassing healthful products including, modified food or ingredient that may provide health benefits beyond traditional ingredients"[97] (ii) "foods that, by virtue of the presence of physiologically-active components, provide a health benefit beyond basic nutrition"[98]. As discussed above, chickpea is a relatively inexpensive source of different vitamins, minerals[9,99,100] and several bioactive compounds (phytates, phenolic compounds, oligosaccharides, enzyme inhibitors etc.) that could aid in potentially lowering the risk of chronic diseases. Due to its potential nutritional value chickpea is gaining consumer acceptance as a functional food. Recent reports of the importance of chickpea consumption in relation to health are discussed below.

Cardiovascular Disease (CVD), Coronary Heart Disease (CHD) and Cholesterol Control

In general, increased consumption of soluble fibre from foods results in reduced serum total cholesterol and low density lipoprotein-cholesterol (LDL-C) and has an inverse correlation with coronary heart disease mortality[101-106]. Usually pulses and cereals have a comparable ratio of soluble to insoluble fibres per 100g serving [~ 1:3][107]. Chickpea seeds are a relatively cheap source of dietary fibre and bioactive compounds (e.g. phytosterols, saponins and oligosaccharides); coupled with its low glycemic index, chickpea may be useful for lowering the risk of CVD[108]. Chickpea has higher total dietary fibre content [~18-22g][40] compared to wheat [~ 12.7g][109] and higher amount of fat compared to most other pulses or cereals[33,110]. However, two polyunsaturated fatty acids [PUFAs], linoleic and oleic constitute almost ~ 50-60% of chickpea fat. Intake of PUFAs such as linoleic acid (the dominant fatty acid in chickpea; Table 4) has been shown to have a beneficial effect on serum lipids, insulin sensitivity and hemostatic factors, thereby it could be helpful in lowering the risk of coronary heart disease[111,112].

Isoflavones are diphenolic secondary metabolites that may lower the incidence of heart disease due to (i) inhibition of LDL-C oxidation[113,114] (ii) inhibition of proliferation of aortic smooth muscle cells[115] (iii) maintenance of physical properties of arterial walls[116]. Ferulic and p-coumaric acids are polyphenols that are found in chickpea seeds at low concentrations and these have been shown to reduce blood lipid levels in rats[117,118]. β-carotene, the most studied carotenoid, is also present in chickpea seeds. Some cross-sectional and prospective studies have shown an inverse relation between the incidence of CVD and plasma levels of antioxidants like β-carotene and vitamin E[119]. However, a large scale randomized controlled trial (RCT) involving 22,071 healthy individuals demonstrated no benefit or harm of β-carotene supplementation (50 mg on alternate days) on CVD, although this study concluded that β-carotene supplementation could have some apparent benefits on subsequent vascular events[120]. These neutral results have also been supported by several other intervention and prevention trials as reviewed by Stanner *et al.*[121]. Therefore, despite the evidence supporting increased occurrence of CVD with low intake of antioxidants or low levels of antioxidants in plasma there is at present no evidence from intervention trials to support the beneficial effect of β-carotene on CVD or CHD. The role of β-carotene, along with other vitamins or nutrients in helping to reduce the incidence of CVD needs to be further investigated.

Foods rich in saponins are reported to reduce plasma cholesterol by 16-24 %[122]. The mechanism of cholesterol reduction is by binding to dietary cholesterol[123] or bile acids, thereby increasing their excretion through faeces[124,125]. β-sitosterol (dominant phytosterol in chickpea) is helpful in decreasing serum cholesterol levels and incidence of coronary heart disease[126-128]. Higher intake of folic acid helps in reducing the serum homocysteine concentrations, a risk factor for CHD[129]. Folic acid supplementation was shown to reduce the homocysteine levels by 13.4-51.7%[130-132]. However, although a meta-analysis has shown an association between elevated levels of homocysteine and risk of CHD and stroke[133], there are no RCTs that indicate a benefit of folic acid supplementation on the risk of CVD, CHD or stroke.

Fibre-rich chickpea-based pulse (non-soybean) diet has been shown to reduce the total plasma cholesterol levels in obese subjects[134]. The study was conducted on thirty obese subjects (body mass index [BMI] of 32.0 ± 5.3 kg/m^2) with mean age group of 36 ± 8 yrs. The subjects were divided into two groups of fifteen each and fed with hypocaloric diet consisting of chickpea-based pulse diet (LD) and a control diet (CD; no pulses) for a period of eight weeks (4 days/week). After eight weeks the total cholesterol levels in the LD fed group decreased from 215 mg/dl to 182 mg/dl whereas a smaller decrease (181 mg/dl to 173mg/dl) was observed for CD fed group[134]. The proposed mechanism for this hypocholesterolemic effect is the inhibition of fatty acid synthesis in the liver by fibre fermentation products like propionate, butyrate and acetate[134]. Short-chain fatty acids (ex. propionate) were shown to inhibit both cholesterol and fatty acid biosynthesis by inhibiting the acetate (provides acetyl co-A) utilization[135]. Feeding a chickpea diet to rats also resulted in a favorable plasma lipid profile[136]. Thirty healthy male 'Sprague-Dawley' rats were fed three different diets for eight months: normal fat diet (NFD; 5 g fat, 22 g protein and 1381 kJ/100 g), high fat diet (HFD; lard, 20 % w/w; sugar, 4 %, w/w; milk powder 2 %, w/w; and cholesterol [1 %, w/w] into the standard laboratory chow, which contained 25·71 g fat, 19·54 g protein and and 1987 kJ/100 g diet) and high fat plus chickpea diet (HFD+CP; same as HFD, but 10% crushed chickpea seed replaced the standard chow; it contained 25·11 g fat, 19·36 g protein and 1965 kJ/100 g). Several pro-atherogenic factors, including triacylglycerol (TAG), LDL-C, and LDL-C:HDL-C, decreased with consuming chickpea based diet[136]. Eighty four healthy 'Sprague-Dawley' rats divided into fourteen groups of six each fed diets containing chickpea (49-65.4% of diet) and peas (46-62% of diet) for thirty five days recorded lower levels of plasma cholesterol[137]. The decrease in cholesterol levels varied with the processing method used; extrusion and boiling had similar effects for chickpeas whereas extrusion was most effective in peas. Phytosterols present in chickpea along with other factors (e.g. isoflavones, oligosaccharides) reduces the LDL-C levels in blood by inhibiting the intestinal absorption of cholesterol due to the similarity in their chemical structure with cholesterol thereby potentially reducing the risk of CHD[9,109].

Diabetes and Blood Pressure

Pulses like chickpea has a higher amount of resistant starch and amylose[109]. Amylose has a higher degree of polymerization (1667 glucose vs 540) rendering the starch in chickpea more resistant to digestion in the small intestine ultimately resulting in lower availability of glucose [109,138]. The lower bioavailability of glucose results in slower entry of glucose into the blood stream thus reducing the demand for insulin, resulting in lowering the glycemic index (GI) and insulinemic postprandial response[139,140]. Lowering GI is an important aspect in reducing both the incidence and severity of type II diabetes[141]. Further, increased consumption of resistant starch is related to improved glucose tolerance and insulin sensitivity(102,142,143). Linoleic acid, a PUFA is biologically important due to its involvement in production of prostaglandins. Prostaglandins are involved in lowering of blood pressure and smooth muscle constriction(144). Also, linoleic and linolenic acids are required for growth and performing different physiological functions(145). Additionally, phytosterols like β-sitosterol, is helpful in reducing blood pressure(126-128). Linoleic acid and β-sitosterol are the major PUFA and phytosterol in chickpea seeds respectively, therefore chickpea seeds could be incorporated as a part of regular diet that may help to reduce blood pressure.

Inclusion of chickpea in high-fat rodent feed reduced the deposition of visceral and ecotopic fats resulting in hypolipidaemia and insulin-sensitizing effects in the rats(136). Incorporation of chickpeas in a human study also led to improvements in fasting insulin and total cholesterol content(146). Total cholesterol and fasting insulin were reduced by 7.7mg/dL and 0.75 µIU/mL respectively. In this study forty five healthy individuals were fed with a minimum of 104 g of chickpeas per day for twelve weeks as a part of their regular diet.

Cancer

Butyrate is a principal SCFA (~ 18% of total volatile fatty acids) produced from consumption of chickpea diet (200g day^{-1}) in healthy adults(147). Butyrate is reported to suppress cell proliferation(148) and induce apoptosis(149), which may reduce the risk of colorectal cancer. Butyrate inhibits histone deacetylase, which prevents DNA compaction and induces gene expression. It is also suggested that butyrate shunts the cells along the irreversible pathway of maturation leading to cell death(149). Inclusion of β-sitosterol (the major phytosterol in chickpea; Table 7) in rat diet reduced N-methyl-N-nitrosourea (carcinogen)-induced colonic tumors(150). Saponin-rich food have been shown to inhibit pre-neoplastic lesions caused by azoxymethane in the rat colon(151). Protease inhibitors are also known to suppress carcinogenesis by different mechanisms, but their precise targets are still unknown(83,152,153).

Lycopene, an oxygenated carotenoid present in chickpea seeds, may reduce the risk of prostate cancer(154). Though there are association studies suggesting a role for lycopene in protection against prostate cancer, the results from very few RCTs conducted are not sufficient either to support or refute the role of lycopene in cancer prevention[155,156]. Ziegler[157] reported that lower levels of carotenoids either in the diet or body can enhance the risk of certain types of cancers. Studies have shown a direct positive correlation between carotenoid-rich diet and decreased incidence of lung and other forms of cancer[158]. The cancer prevention ability of carotenoids could be due to their antioxidant properties[159], but the exact mode of action needs to be identified.

Biochanin A, a chickpea isoflavone, inhibits the growth of stomach cancer cells *in vitro* and reduced tumor growth when the same cells were transferred to mice[79,160]. Further, chickpea isoflavone extract specifically inhibited epithelial tumour growth and had no effect on healthy cells[161]. Murillo *et al.*[162] have shown a 64% suppression of azoxymethane-induced aberrant cryptic foci in rats fed with 10% chickpea flour and indicated that saponins could be one of the factors for the reduction of lesions. N-nitrosodiethylamine (NDEA), a nitrosoamine, is reported to cause carcinogenesis through DNA mutation[163]. Inclusion of chickpea seed-coat fibre in the diet was shown to reduce the toxic effects of NDEA on lipid peroxidation (LPO) and anti-oxidant potential[163]. The average percentage decrease in LPO in: liver and lungs was ~21%, spleen and kidney was ~ 15.50% and heart ~12.46%. Eighteen rats divided into three groups of six each were fed hypercholesterolemic diet for four weeks; group I was fed the control hypercholesterolemic diet (starch [63%], oil [10%], casein [15%], cellulose [5%], salt mixture [5%], yeast powder [1%] and cholesterol [1%]), group II (hypercholesterolemic diet plus NDEA [100mg/kg] and group III (group II diet + 5% chickpea seed coat fibre).

Weight Loss / Obesity

Intake of foods which are rich in dietary fibre is associated with lower body mass index [BMI][164,165]. Eating of foods with high fibre content helps in reaching satiety faster (fullness post-meal) and this satiating effect lasts longer since fibre-rich foods require longer time to chew and digest in the intestinal system[103,166]. Additionally, consumption of low GI foods results in increase of cholecystokinin (a gastrointestinal peptide and hunger suppressant) and increased satiety[167-169]. Diets with low GI foods resulted in reduced insulin levels and higher weight loss compared to those with higher GI[170]. Since chickpea is considered to be a low GI food, it may help in weight loss and obesity reduction.

Chickpea supplementation in the diet prevented increased body weight and weight of epididymal adipose tissues in rats[136]. At the end of the eight month experimental period the rats fed on high fat diet (HFD) weighed 654 g versus those fed with HFD plus chickpea (HFD+CP; 562 g). The epididymal fat pad weight to total body weight ratio was higher in rats fed on HFD (0·032 g/g) compared to those fed on HFD+CP (0·023 g/g; details of this experiment are explained under CVD)[136]. Therefore, chickpea being a low GI food could be an effective choice in weight loss programs. Chickpea is reported to decrease fat accumulation in obese subjects. This aids in improving fat metabolism and could be helpful in correcting obesity-related disorders[136]. Chickpea supplementation in the diet resulted in increased satiation and fullness[171]. Forty two participants consumed chickpea supplemented diet (average 104g/day) for twelve weeks; this was preceded and succeeded by their habitual diet for 4 weeks each.

Gut Health and Laxation

A significant increase (18%) in DF intake was recorded when 140g/day chickpea and chickpea flour were consumed by nineteen healthy individuals for six weeks[172]. Similarly, Murty *et al.*[171] reported a 15% increase in DF intake in forty two volunteers (were 52.17± 6.30 years old). These studies revealed an overall improvement in bowel health accompanied by increased frequency of defecation, ease of defecation and softer stool consistency while on chickpea diet compared to the habitual diet. The DF fibres promote laxation/bowel function by aiding in the movement of material through the digestive system.

Other Health Benefits

Chickpea seed oil contains different sterols, tocopherols and tocotrienols[173-175]. These phytosterols are reported to exhibit anti-ulcerative, anti-bacterial, anti-fungal, anti-tumoric and anti-inflammatory properties coupled with a lowering effect on cholesterol levels[171,176]. Δ^7-Avenasterol and Δ^5-avenasterol, phytosterols present in chickpea oil have antioxidant properties even at frying temperatures[177]. Carotenoids like lutein and zeaxanthin, the major carotenoids in chickpea seeds, are speculated to play a role in senile or age-related macular degeneration (AMD). Though there are some epidemiological and association studies suggesting a beneficial effect of lutein and zeaxanthin on AMD, evidence from RCTs on the effect of carotenoids on AMD is not presently available[(178).] Carotenoids are reported to increase natural killer cell activity[(179)]. Vitamin A, a derivative of β-carotene is important in several developmental processes in humans like bone growth, cell division/differentiation and most importantly vision. It is reported that at least three million children develop xerophthalmia (damage to cornea) and about 250,000-500,000 children become blind due to Vitamin A deficiency[(180)]. Chickpea is reported to have higher levels of carotenoids (explained above) than “golden rice” and it could be potentially be used as a source of dietary carotenoids.

Chickpea seeds have been used in traditional medicine as tonics, stimulants and aphrodisiacs[(181)]. Further, they are used to expel parasitic worms from the body (anthelmintic property), as appetizers, for thirst quenching and reducing burning sensation in the stomach[(35)]. In the Ayurvedic system of medicine chickpea preparations are used to treat a variety of ailments like throat problems, blood disorders, bronchitis, skin diseases and liver or gall bladder related problems [biliousness][(182)]. In addition to these applications, the chickpea seeds are also used for blood enrichment, treating skin ailments, ear infections, and liver and spleen disorders[(183)]. Uygur people of China have used chickpea in herbal medicine for treating hypertension and diabetes for over 2500 yrs[(184-186)].

Conclusions

The information presented here shows the potential nutritional importance of chickpea and its role in improved nutrition and health. It is an affordable source of protein, carbohydrates, minerals and vitamins, dietary fibre, folate, β-carotene and health promoting fatty acids. Scientific studies provide some evidence to support the potential beneficial effects of chickpea components in lowering the risk for various chronic diseases, although information pertaining to the role of individual chickpea components in disease prevention and the mechanisms of action are limited to date. This is due to the complex nature of disease etiology and various factors impacting their occurrence. It is imperative the scientific community continues to unravel the mechanisms involved in disease prevention and determine how food bio-actives from such foods as chickpea can influence human health. Further research, especially well conducted RCTs, needs to be performed to provide compelling evidence for the direct health benefits of chickpea consumption.

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Table 1. Different carbohydrate fractions in chickpea seeds

Carbohydrate	Åman[27] (*)	Wang & Daun[56] (†) K	Wang & Daun[56] (†) D	Han and Baik[20] (‡) K	Aguilera *et al.*[23] (§)
Starch	-	41.1 (38.2-43.9)	36.4 (33.1-40.4)	-	51.9

Sucrose	4.3	3.8 (3.10-4.41)	2.0 (1.56-2.85)	-	15.2
Raffinose	1.0	0.6 (0.48-0.73)	0.5 (0.46-0.77)	50.2	3.2
Stachyose	2.8	2.2 (1.76-2.72)	1.6 (1.25-1.98)	27.0	17.7
Verbascose	Traces	-	-	ND	-
Ciceritol	-	-	-	67.7	27.6
Fructose	0.1	-	-	-	3.1
Galactose	-	-	-	-	0.1
Galactinol	0.5	-	-	-	-
Glucose	0.1	-	-	-	0.5
Maltose	-	-	-	-	3.3
Manninotriose	3.4	-	-	-	-
Pinitol	0.2	-	-	-	-

K-Kabuli; D-Desi; *- in percentage of the dry weight of raw seed; †-in g 100^{-g} dry weight; ‡-in mg g^{-1}; **§**-in g kg^{-1}; -not measured; *and **§**-the type of chickpea is not specified.

Table 2. Nutrient composition of different legumes in g 100^{-g}[32]

Crop	Carbohydrate	Fat	TDF	Total Sugars
Chickpea (*Cicer arietinum* L.)	60.7	6.0	17.4	10.7
Pigeonpea (*Cajanus cajan* L.)	23.8	1.6	5.1	3.0
Bean (*Phaseolus vulgaris* L.)	7.0	0.2	2.7	3.3
Mung bean (*Vigna radiata* L.)	62.6	1.2	16.3	6.6
Peas (*Pisum sativum* L.)	14.5	0.4	5.1	5.7

Faba bean (*Vicia faba* L.)	58.3	1.5	25.0	5.7

Table 3. Amino acid content in chickpea seeds

Amino Acid	Rao & Subramanian[187](*)	Wang & Daun[56] (†)		Alajaji & El-Adawy[58](†)	Wang *et al.*[57](‡)	
		K	D		K	D
Lysine	45-79	5.80	5.90	7.70	5.47	5.55
		(4.9-6.70)	(5.2-6.90)			
Methionine	7-31	1.50	1.50	1.60	1.92	2.05
		(1.1-2.10)	(1.1-1.70)			
Cystine	7-18	1.30	1.40	1.30	0.19	0.15

		(0.8-2.00)	(1.1-1.60)			
Phenylalanine	30-68	5.20	5.30	5.90	5.81	5.42
		(4.5-6.20)	(4.5-5.90)			
Tyrosine	20-35	2.80	2.30	3.70	2.63	2.55
		(2.2-3.30)	(1.4-3.10)			
Isoleucine	44-60	3.10	3.60	4.10	3.90	3.70
		(2.6-3.90)	(2.5-4.40)			
Leucine	49-80	6.40	7.00	7.00	6.69	6.30
		(5.6-7.20)	(5.6-7.70)			
Threonine	28-48	4.20	4.30	3.60	3.13	3.23
		(3.3-5.10)	(3.7-4.70)			
Valine	38-63	3.70	4.00	3.60	3.83	3.60
		(2.9-4.60)	(2.8-4.70)			
Arginine	-	10.50	9.80	10.30	8.07	8.11
		(8.3-13.7)	(8.3-13.6)			
Histidine	-	2.10	2.20	3.40	2.00	2.66
		(1.7-2.40)	(1.7-2.70)			
Alanine	-	3.90	4.10	4.40	3.44	3.40
		(3.5-4.70)	(3.6-4.53)			
Aspartic acid	-	12.10	12.80	11.40	11.66	10.59
		(11.2-12.9)	(11.1-15.9)			
Glutamic acid	-	15.2	16.00	17.30	20.24	16.70
		(13.1-17.5)	(13.4-19)			
Glycine	-	3.80	3.90	4.10	2.54	3.12
		(3.2-4.50)	(3.3-4.20)			
Proline	-	4.90	4.80	4.60	4.04	3.95
		(3.8-6.50)	(4.0-6.30)			
Serine	-	5.90	6.00	1.10	3.39	4.96
		(5.2-6.70)	(5.5-6.90)			
Tryptophan	2-12	1.0	0.90	4.90	N/D	N/D
		(0.7-1.60)	(0.8-1.10)			

K-Kabuli; D-Desi; N/D not determined; *-in mg g^{-1} protein; †-in g 16^{-g} N; ‡-in g 100^{-g} ; * & †- chickpea type is not specified.

Table 4. Fatty acid profiles of chickpea seeds

Fatty Acid	Baker *et al.*[188] (*)	Wang & Daun [56](†) K	D	USDA[32](‡) K
Lauric	ND	ND	0.02	0.00
(C12:0)		-	(0.0-0.10)	
Myristic	0.3	0.21	0.22	0.009
(C14:0)		(0.19-0.26)	(0.17-0.32)	
Palmitic	12.7	9.41	9.09	0.501
(C16:0)		(8.52-10.3)	(8.56-11.0)	
Palmitoleic	0.1	0.30	0.26	0.012

(C16:1)		(0.27-0.34)	(0.23-0.30)	
Stearic	1.5	1.42	1.16	0.085
(C18:0)		(1.21-1.68)	(1.04-1.60)	
Oleic	19.3	32.56	22.31	1.346
(C18:1)		(27.7-42.46)	(18.44-28.5)	
Linoleic	62.9	51.20	61.62	2.593
(C18:2)		(42.25-56.59)	(53.10-65.25)	
Linolenic	3.3	2.69	3.15	0.101
(C18:3)		(2.23-3.91)	(2.54-3.65)	
Arachidic	Traces	0.66	0.51	-
(C20:0)		(0.59-0.76)	(0.45-0.74)	
Gadoleic	ND	0.57	0.50	0.00
(C20:1)		(0.48-0.70)	(0.41-0.59)	
Eicosadienoic	ND	0.06	0.12	-
(C20:2)		(0.00-0.09)	(0.08-0.15)	
Behenic	ND	0.42	0.37	0.00
(C22:0)		(0.29-0.48)	(0.30-0.42)	
Erucic	-	0.07	0.13	-
(C22:1)		(0.00-0.16)	(0.00-0.21)	
Lignoceric	ND	0.17	ND	-
(C24:0)		(0.00-0.29)	-	
Nervonic	-	ND	ND	0.00
(C24:1)				

K-Kabuli; D-Desi; *-data in wt-% of total elute; †-in % oil; ‡-in g 100^{-g}; numbers in paranthesis indicate range; ND-measured but not detected; -not measured; *- chickpea type is not specified.

Table 5. Important sterols and tocopherols in oil from chickpea seeds

Sterols (%)	Gopala Krishna *et al.*[174] (*)	Zia-Ul-Haq *et al.*[63] D
Campesterol	-	12.06-13.67
Δ^7- avenasterol	-	0.79-1.21
Stigmasterol	-	4.92-5.38
β-sitosterol	-	73.12-76.10
Clerosterol	-	1.94-4.01
Δ^5-avenasterol	-	3.12-5.72
Tocopherols (mg/100g of oil)		

α	33.94 ± 1.43	32.99-34.82
β	1.87 ± 0.17	1.67-1.89
γ	186.17 ± 11.80	185.08-186.02
δ	8.36 ± 1.40	7.93-8.88
Tocotrienols		
γ	3.67 ± 0.19	-

D-desi chickpea; *- the chickpea type is not specified.

Table 6. Chickpea seed oil: physical and chemical characteristics

Characteristics	Zai-Ul-Haq *et al.*[61] D	Shad *et al.*[59] D
Total oil (%)	5.88-6.87	-
Acid values (mg KOH/g)	2.55-2.67	2.40-2.50
Iodine values (Wijs method)	111.87-113.69	112.56-113.87
Saponification values(mg KOH/g)	183.98-185.64	178.90-180.64
Unsaponifiable matter (% w/w)	2.99-3.71	3.42-3.47
Specific gravity	-	0.9339-0.9346
Relative density (40^0C; g/cm^3)	0.96	-
Refractive index (40^0C)	1.48	-
Color	Brown-Yellow	-
Peroxide value(mequiv/kg)	3.97-6.37	-

p-Anisidine value	5.39-8.74	-
Oxidation value	13.09-22.34	-
Flavor score	-	-
Monoacylglycerols (MAG; %)	2.2-2.7	-
Diacylglycerols (DAG; %)	0.7-1.6	-
Triacylglycerols (TAG; %)	55.7-63.2	-
Calorific value (kca/100g sample)	-0.92-3.11	368-373

D-desi chickpea

Table 7. Mineral constituents of chickpea seed in mg 100^{-g}

Minerals	Rao & Deosthale (†)[189]	Ibáñez *et al.*[70]		Wang & Daun[56]		USDA[32]
		D	K	D	K	K
Copper	1.18	1.25	1.20	1.00 (0.5-1.40)	1.00 (0.7-1.40)	0.847
Iron	4.60	4.51	4.46	5.90 (4.6-7.00)	5.50 (4.3-7.60)	6.24
Zinc	6.11	3.57	3.50	3.60 (2.8-5.10)	4.40 (3.6-5.60)	3.43
Manganese	1.21	1.72	1.65	3.40 (2.8-4.10)	3.90 (2.3-4.80)	2.20
Calcium	220.0	210.0	154.0	161.70 (115-226.5)	106.60 (80.5-144.3)	105.0

Magnesium	119.0	128.0	122.0	169.10 (143.7-188.6)	177.80 (153-212.8)	115.0
Sodium	-	22.9	21.07	-	-	24.0
Potassium	-	878.0	926.0	1215.70 (1027.6-1479)	1127.20 (816-1580)	875.0
Phosphorus	398.0	-	-	377.30 (276.2-518.6)	505.1 (294-828.8)	366.0
Chromium	0.08 *	-	-	-	-	-

*-in μg g^{-1}; †-chickpea type is not specified.

Table 8. Vitamins in chickpea seed

Vitamins	Chavan *et al.* [12] (*)	Wang & Daun[56] (*) K	D	Ciftci *et al.* [72] (‡)	USDA [32] K (*)
Retinol (A)	-	ND	ND	-	ND
Vitamin C	2.15-6.00	1.34	1.65	-	4.0
Vitamin (D2+D3)	-	ND	ND	115.4	ND
Thiamin (B1)	0.028-0.40	0.4	0.29	-	0.477
Riboflavin (B2)	0.15-0.30	0.26	0.21	-	0.212
Niacin (B3)	1.6-2.90	1.22	1.72	-	1.541
Panthothenic acid (B5)	-	1.02	1.09	-	1.588
Pyridoxine (B6)	0.55	0.38	0.30	-	ND
Cyanocobalamin (B12)	-	ND	ND	-	0.535
Biotin	-	ND	ND	-	-
γ-tocopherol	-	10.68	9.33	6.9	-
α-tocopherol (Vit E)	-	2.24	1.91	22.0	0.820

Choline, total	-	-	-	-	95.20
(In µg 100^{-g})					
Folic acid	150.0	299.21	206.48	-	557.00
Vitamin A, RAE	-	-	-	-	3.00
β-carotene	-	-	-	46.3	40.00
Vitamin K (Phylloquinone)	120.0	-	-	23.2	9.00

K-Kabuli; D-Desi; *- in mg 100^{-g}; ‡-in µg 100^{-g} ; *&‡-chickpea type is not specified.

Table 9. Vitamin content in different legumes in mg 100^{-g} [56]

Crop	Folic acid	Vit C	Vit B1	Vit B2	Vit B3	Vit B5	Vit B6	Tocopherol (γ + α)
Chickpea (Kabuli)	299.0	1.34	0.49	0.26	1.22	1.02	0.38	12.9
Chickpea (Desi)	206.5	1.65	0.29	0.21	1.72	1.09	0.30	11.2
Bean	107.9	3.85	0.58	0.16	1.31	0.31	0.21	3.85
Red kidney beans	34.5	0.09	0.99	0.23	0.33	0.31	0.21	3.15
Lentils	138.1	0.71	0.29	0.33	2.57	1.32	0.23	5.64
White kidney beans	22.0	0.09	0.73	0.11	1.12	0.35	0.16	2.96
Pigeonpea*	173†	NA	0.4	0.17	2.20	0.68	0.07	0.39

Vit -Vitamin; Vitamin A & B12 not detected in these legumes; *- adopted from[32]; †- in µg 100^{-g}.

Table 10. Anti-nutritional factors in chickpea

Constituent	Gupta[95]	Singh[190]	Champ[80]	Alajaji & El-Adawy[58]
Trypsin Inhibitor *	8.57	10.9 (6.7-14.6)	1.0-15.0	11.9
Chymotrypsin Inhibitor *	2.79	7.1 (5.7-9.4)	-	-
Amylase Inhibitor †	-	8.7 (0-15.0)	-	-
Haemagglutinin activity ‡	0.0	-	-	6.22
Tanins	-	Traces	-	4.85
Total Phenols	-	3.03 (1.55-6.10) ¶	-	-
Polyphenols	-	-	0.1-0.60	-
Phytolectins	-	400 **	-	-
Cyanogens	0.8 ††	Traces	-	-
Mycotoxins (ppb)	-	18 (Traces-35)	-	-
Phytic Acid	-	-	-	1.21
Saponins	5.6	-	0.40	0.91
Oxalate	-		0.07	-
Genistein §	-	-	0.07-0.21	-
Daidzein §	-	-	0.01-0.19	-

Secoisolariciresinol **§**	-	-	0.01	-

*-Units mg^{-1} protein; †-in units g^{-1}; ‡-in units mg^{-1} sample; **§**-in mg 100^{-g}; ¶-in mg g^{-1}; **- in units g^{-1}; ††- in mg 100^{-g}; others in g 100^{-g} dry weight of sample; **Note:** chickpea type is not specified in any of the citations used.