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Chickpea (*Cicer arietinum* L.): Nutrition beyond protein, bioactives and associated health benefits

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Abstract
Chickpea (*Cicer arietinum* L.) is a major pulse crop that is cultivated and consumed all throughout the world, but it is particularly popular in Afro-Asian nations. Chickpea having protein content 18.55%, a dietary fibre content 6.49%, a fat content of 7.01% and carbohydrate content is 56.30%. Chickpea contain a large number of bioactive compounds like phytic acid, tannin, saponin, trypsin inhibitor, anthocyanin, carotenoid, isoflavones, tocopherol and phenolic acid. The chickpea bioactive compound include particularly GABA (γ-aminobutyric acid) which produced directly by L-glutamate decorboxylation or by converting alpha-ketoglutarate and semialdehyde succinate is produced by the GABA transaminase enzyme. Advantages of GABA, it is known for its capacity to lower blood pressure, relieve alcohol related chronic disorders, stop cancer cell proliferation and control cholesterol level. Chickpea provides a number of health benefits for some serious human problems such as cancer, cardiovascular diseases, diabetes and digestive disorders. The bioactive compound is affected by conventional techniques including cooking or boiling, soaking, germination, roasting and dehulling. The protein content, fatty acid profile, vitamin and mineral content of chickpea, all affected by processing methods. The information in this review presented nutritional value of chickpea as well as their contribution to better diet and health. People today suffer a lot of health issues that can be avoided or managed by increasing dietary intake of foods high in beneficial bioactive compounds.

Keywords: Chickpea, *Cicer arietinum* L, nutritional composition, bioactive compound, health benefits

Introduction
According to overall grain production, the chickpea (*Cicer arietinum* L.) ranks seventh among all important legume crops and it is a member of Fabaceae family (Aguilera *et al*., 2011) [6]. But among the pulse crop, chickpea has maintained a more important position that is coming second in term of area 15.3% and third in terms of production 15.42% (Merga & Haji., 2019) [2]. It is also known as Bengal gram as well as Garbanzo bean. The cultivated area of chickpea over the world is more than 12.5 million (Hevryk *et al*., 2020) [7]. Chickpeas are mostly grown in developing nation, where local consumption accounts for more than 90% of total production and nearly 70% of the worlds production of chickpea is produced and consumed on the Indian subcontinent, which includes India, Pakistan, Bangladesh and Nepal (Arriagada *et al*., 2022) [5]. Other nations with significant production of chickpea include Turkey, Australia, Ethiopia, Iran, Mexico, USA and Canada.

Chickpea is cool season crop and drought resistant. Desi and Kabuli are two type chickpea seeds that are distinguished by their size and color. Kabuli chickpeas are larger and have beige seed coat while Desi chickpeas are dark brown seed coat and have dark color seed coat (Kaur & Prasad., 2021) [4]. The Desi and Kabuli cultivars typical seed weight are 0.1 to 0.3 g and 0.2 to 0.6 g respectively (Jukanti *et al*., 2012) [8]. Desi cultivars have 327 Kcal/100 g energy value, while Kabuli has 365 Kcal/100 g (Rosiak *et al*., 2015) [9]

Legumes are sometime described as the "poor man's meat" because they are essential source of nutrition for millions of people in impoverished nations (Merga& Haji., 2019) [2]. With a mean annual output of more than 11.5 million tones, production comes in third after beans, with the majority of it being produced in India (Merga& Haji., 2019) [2]. Around the world, chickpeas are mostly eaten as a seed food. In addition to being chickpea eaten roasted, boiled, salted and fermented and these various eating method provides customers beneficial nutritional and possibly health advantage (Jukanti *et al*., 2012) [8].

Chickpea is a rich source of both proteins and carbohydrates. It has been discovered that chickpea consumers take more dietary fibre, polyunsaturated fatty acids, vitamin C, vitamin A, vitamin E, magnesium, potassium and iron than non-consumers of chickpea (Wallace *et al*.,

2016) [10]. Mono- and disaccharides, which are enzymatically digested in the small intestine, are categorized as available carbohydrates and unavailable carbohydrates, such as oligosaccharides, polysaccharides, pectins, celluloses and hemicelluloses are not digested in small intestine. The oligosaccharides (Ciceritol, raffinose, stachyose and verbascose) are found in chickpea together with the monosaccharides (ribose, galactose, fructose and glucose) (Jukanti *et al*., 2012) [8]. Chickpea contains minor amounts of prolamines and glutelins.

The chickpea is a rich source of many important nutrients, including proteins, carbohydrates, vitamin, minerals fibres and health promoting fatty acids. It also includes phenolic compounds such as phenolic acid and flavones, mainly isoflavones (Leon-Lopez *et al*., 2020) [11]. Antinutritional elements such as tannin, trypsin inhibitors, hemagglutinins, phytic acid and saponins are the high nutritional value of chickpea (Ferreira *et al*., 2019) [12]. Phytic acid decreases the bioavailability of some essential minerals like iron and zinc etc while tannin prevent the digestion of protein and starch (Kinfe *et al*., 2015) [13]. The bioactive compound present in chickpea including saponins, phenols and trypsin inhibitors that have variety of biological activities including antioxidant, antifungal, antibacterial, ACE-1 inhibition, hypocholesterolemic, anticancer and anti-inflammatory (Ferreira *et al*., 2019) [12]. The chickpea bioactive compound include particularly GABA (γ-aminobutyric acid) which produced directly by L- glutamate decorboxylation or by converting alpha-ketoglutarate and semialdehyde succinate is produced by the GABA transaminase enzyme (Ferreira *et al*., 2019) [12].

The protein content of chickpea ranges from 18-29%, the fat content is 4-7% and the starch content in between 50-60% (Boukid., 2021) [14]. About 80% of dry seed weight is made up of chickpea, which are great source of both proteins and carbohydrates (Ali Esmail Al-Snafi., 2016) [3]. Chickpea may provide a number of health advantage and they also improve some of major human diseases including type 2 diabetes, intestinal disorder, cardiovascular diseases and some cancer (Kishor *et al*., 2017) [15].

The main oligosaccharide in chickpea is ciceritol and the bioactive compound responsible for anti-cancerous property is canthaxanthin (Kaur & Prasad., 2021) [4]. Lutein and zeaxanthin are the major carotenoids present in chickpea seed (Jukanti *et al*., 2012) [8]. All of the necessary amino acids are present in large concentration of chickpea. The primary storage carbohydrate is starch which is followed by dietary fibre. Although lipids are present in little amount, the chickpea is high in linoleic and oleic acid, two nutritionally significant unsaturated fatty acids (Hirdyani., 2014) [16].

Nutritional composition of chickpea

The carbohydrate, protein, fat, vitamin, mineral and dietary fibre are present in chickpea. The nutritional composition present in chickpea are shown in table 1.

Carbohydrate

The primary nutritional component of chickpea is carbohydrate, which ranges from 52.61% to 676.6% in the Ethiopian variety type. Legumes typically have a lower carbohydrate content (60-65%) than cereals (70-80%) and monosaccharides, disaccharides, oligosaccharides and polysaccharides are the four main classes of carbohydrates (Lamesgen yegrem., 2021) [17].

The concentration of monosaccharides in chickpea: galactose 0.05 g/100 g, fructose 0.25 g/100 g, ribose 0.11 g/100 g, glucose 0.7 g/100 g. The two most abundant free disaccharides in chickpea have been found to be maltose (0.6%) and sucrose (1-2%) (Jukanti *et al*., 2012) [8]. The primary carbon reserve in pulse seed is starch (Chibber *et al*., 2010) [18] 18v. High molecular weight polymer of monosaccharides called polysaccharides, are found as structural carbohydrate such as starch and storage carbohydrate such as cellulose and provide structural support (Jukanti *et al*., 2012) [8]. It is composed of two major glucan polymer called amylase and amylopectin, in which the glucose residue are joined by α-(1→4) bond to create a linear molecule and the linear molecule is branched by α-(1→6) linkage (Chibber *et al*., 2010) [18]. Ciceritol, raffinose, stachyose and small quantity of verbascose are the major oligosaccharides present in chickpea (Rosiak *et al*., 2015) [9]. The proportion of starch in total carbohydrate ranges from 40-50% and compare to the desi chickpea, kabuli cultivar have a higher concentration of soluble sugars (Sucrose, glucose and fructose) (Jukanti *et al*., 2012) [8].

Protein

Chickpea are good source of both proteins and carbohydrates which constitute around 80% of dry seed mass in total (Hirdyani., 2014) [16]. High protein digestibility, a high quantities of complex carbohydrate (low glycemic index), vitamin and minerals all are present in chickpea seed (Mittal *et al*., 2012) [1]. Between the two cultivar (Desi and kabuli cultivar), there is a significant difference in the content of protein and desi cultivar having the least amount (20.29%) (Ghribi *et al*., 2015) [20]. The main genetic factor causing the variation in protein content between kabuli and desi cultivar, which is 28 to 31% (Kabuli) and 18 to 23% (Desi) respectively (Kinfe *et al*., 2015) [13].

Fat and fatty acid profile

The raw chickpea seed range in total fat content from 2.70% to 6.48%. compared to the other pulses like red kidney bean (1.06 g/100 g), mung bean (1.15 g/100 g), lentil (1.06 g/100 g), pigeon pea (1.64 g/100 g) and chickpea (6.04 g/100 g), chickpea have the highest fat content (Jukanti *et al*., 2012) [8]. For consumer with limited resources, the 6% fat content of chickpea is essential to their vegetarian diet. Despite having low lipid content, chickpea are high in linoleic acid and oleic acid which are two essential unsaturated fatty acid for nutrition (Hirdyani., 2014) [16]. The kabuli cultivar have high level of oleic acid and the desi cultivar have high level of linoleic acid (Jukanti *et al*., 2012) [8].

Vitamins

Important vitamins like riboflavin, thiamin, niacin, folate and the precursor to vitamin A, β- carotene can be found in abundance in chickpea (Hirdyani., 2014) [16]. It contains low levels of water-soluble vitamins like riboflavin (B2), pantothenic acid (B5), pyridoxine (B6) and is a relatively rich source of folic acid. Compared to the pigeon pea and lentils, chickpea have a lower niacin concentration (Jukanti *et al*., 2012) [8].

Minerals

Chickpea seed contain minerals such as calcium, magnesium, phosphorus and particularly potassium (Hirdyani., 2014) [16]. The most abundant element is calcium, which varied from 187.25 mg/100 g in the kabuli cultivar and 177.94 mg/100 g in the desi cultivar. Other elements like manganese, iron, zinc, sodium, magnesium and copper are found in chickpea (Ghribi *et al*., 2015) [20]. Comparing chickpea to the other pulse crop like lentils (8.60 mg/100 g) and beans (7.48 mg/100 g), the amount of total iron found in chickpea is lower (5.45 mg/100 g) (Jukanti *et al*., 2012) [8]. Lower amount of copper found in chickpea, ranging from 0.59 to 0.7 mg/100 g. For chickpea seed, the mean value of sodium, magnesium, iron, manganese, zinc, copper are 103 mg/100 g, 4.55 mg/100 g, 3.4 mg/100 g, 1,7 mg/100 g, 3.6 mg/100 g and 11.5 mg/100 g (Ghribi *et al*., 2015) [20].

Dietary fibre

The portion of plant food that cannot be digested by human is called dietary fibre. It is made up of lignin, polysaccharides/oligosaccharides and other plant based material (Jukanti *et al*., 2012) [8]. There are two types of dietary fibre; soluble and insoluble fibres. While the insoluble fibre is metabolically inactive and promotes bowel movement, the soluble fibre is slowly digested in colon (Tosh & Yada 2010) [22]. Comparing the desi cultivar to the kabuli cultivar, the desi cultivar have a greater total dietary fibre content and insoluble dietary fibre content (Jukanti *et al*., 2012) [8].

Table 1: Nutrient composition in chickpea

S. No.	Nutrients	Chickpea	References
1.	Protein (Albumins) (%)	18.55	Mittal *et al*., 2012 [1]
2.	Carbohydrate (%)	56.30	Kinfe *et al*., 2015 [13]
3.	Dietary fiber (%)	6.49	Kinfe *et al*., 2015 [13]
4.	Fat (%)	7.01	Kinfe *et al*., 2015 [13]
5.	**Fatty acid**		
	Palmitic acid (%)	9.66	Mittal *et al*., 2012 [1]
	Oleic acid (%)	15.5	Hussein *et al*., 2020 [56]
	Linoleic acid (%)	53.94	Hussein *et al*., 2020 [56]
6.	**Vitamins**		
	Riboflavin (ug/100 g)	173.33	Alajaji & Adawy (2006) [52]
	Thiamin (B1) (ug/100 g)	4.53.3	Alajaji & Adawy, 2006 [52]
	Niacin (B3) (ug/100 g)	1602.67	Alajaji & Adawy (2006) [52]
7.	**Minerals**		
	Iron (mg/100 g)	6.47	Kinfe *et al*., 2015 [13]
	Calcium (mg/100 g)	187.25	Ghribi *et al*., 2015 [20]
	Manganese (mg/100 g)	115.53	Ghribi *et al*., 2015 [20]
	Copper (mg/100 g)	1.04	Nobile *et al*., 2013 [35]
	Zinc (mg/100 g)	3.12	Kaur *et al*., 2019 [27]
	Magnesium (mg/100 g)	2.41	Kaur *et al*., 2019 [27]

Bioactive compound of chickpea

Bioactive compounds are present in the seed of chickpea. When compared to macronutrients, bioactive compounds are usually the non-nutrient food components that are present in minute quantities in cereals, legumes, fruits and vegetables (Singh *et al*., 2017) [23]. All the bioactive compound present in chickpea shown in table 2.

Phytic acid

Legumes and grains are the main source of the antinutrient phytic acid. The possibility exists of phytic acid to bind with mineral micronutrients (such as Zn, Cu and Fe) in dietary matrix, lowering their bioavailability in humans (Bueckert *et al*., 2011) [24]. Compared to the other legumes, the phytic acid level in chickpea is comparatively less (Dragicevic *et al*., 2015) [25]. ICC-7184 has the higher concentration of phytic acid that is 4.06mg/g. The main phosphorous storage form in legume is phytic acid (Bhagyawant *et al*., 2018) [26].

Tannin

Tannins are natural occurring, anti-nutritional compound with low molecular weight (0.5-3 kDa) (Kaur *et al*., 2019) [27]. Tannin acid content was often higher in Desi variety than Kabuli.

Between 0.6 to 0.9%, tannic acid was present. Tannic acid concentration were highest in Prabat and C-44 (0.9%) and lowest in Karak1 (0.6%). Tannin stop enzyme functioning, lowering the astringency of chickpea as well as their digestibility (Jukanti *et al*., 2012) [8]. Chickpea seed have a tannin concentration of 8.23mg/g. Tannins are resistant to enzymes that break down food in the digestive system, as a result they did not absorb and move to other body tissues (Bhagyawant *et al*., 2018) [26]. The tannin found in the pigmented seed coat of legumes. A minor portion of large and varied group of phenolic chemicals generated by the plant as secondary metabolites are tannins, which are polymeric flavonoids (Sharma, S *et al*., 2013) [28].

Saponin

A wide class of glycosides of sapogenol A and B frequently present in plants are called saponin. It has been noted that the saponin rich chickpea, protein isolates lower plasma cholesterol in both people and animals (Serventi *et al*., 2013) [29]. It composed of triterpenoid or steroids skeleton with one or more covalently bonded sugar chains at the core structure (Serventi *et al*., 2018) [30]. The content of sapogenol A 211.9 to 352.2 mg/100 g observed in seed whereas the content of sapogenol B 413.5 to 568.8 mg/100 g observed in the grain of chickpea. KAK2 and BG256 genotypes of chickpea have the highest level of sapogenol A and JKG 1 genotypes of chickpea have the highest level of sapogenol B (Srivastava and Vasishtha., 2012) [31]. The range of total sapogenol in chickpea grain is 651.0 mg/100 g to 860.2 mg/100 g (Srivastava and Vasishtha., 2012) [31].

Trypsin inhibitor

One of the most important anti nutritional factor is trypsin inhibitor, which slow down the digestion and absorption of dietary proteins. The trypsin inhibitor activity of *Cicer arietinum* ranges from 8.10 to12.1; 9.90 to 15.7 U/mg (Aviles-Gaxiola *et al*., 2018) [32]. In Desi cultivar, the concentration of trypsin inhibitor from 17 to 31 mg/g, while in Kabuli cultivar, it ranged from 9 to 16 mg/g. (Sharma, S *et al*., 2012) [19].

Isoflavones

Various phenolic chemicals can be found in chickpea seeds. There are two significant phenolic compound among them. The isoflavones biochanin A (5,7-dihydroxy-4-methoxyisoflavones) and formononetin (7-hydroxy-4-methoxyisoflavones) found in chickpea (Jukanti *et al*., 2012) [8]. The other isoflavones are biochanin glucoside, daidzein and genistein found in chickpea (Camargo *et al*., 2019) [33]. A variety of factors including as agricultural techniques, weather, genotype and processing conditions affect the profile and amount of isoflavones in plants (Dulce-Maria *et al*., 2020) [34]. In comparion to Desi type seeds (838 mg/100 g), Kabuli type seed (1420-3080 mg/100 g) had a higher concentration of biochanin A (Jukanti *et al*., 2012) [8]. Formonnnetin content in Kabuli type seed is 215mg/100 g and Desi type seed is 94- 126 mg/100 g (Jukanti *et al*., 2012) [8].

Tocopherol

The tocopherol often known as vitamin E, are present in nature in a variety of four types (α, β, γ and δ) (Ferreira *et al*; 2019) [12]. High lightened among the bioactive substances found in chickpea is γ-aminobutyric acid (GABA), a four carbon amino acid with a non-protein origin that can produced either by the decorboxylation of L-glutamate or by the conversion of α- ketoglutarate and semi-aldehyde succinate under the influence of the enzyme GABA transaminase (Ferreira *et al*; 2019) [12]. Advantages of GABA, it is known for its capacity to lower blood pressure, relieve alcohol related chronic disorders, stop cancer cell proliferation and control cholesterol level. Tocopherol are abundant in chickpea oil which also have high level of alpha tocopherol among pulses (upto13.7 mg/100 g) and gamma tocopherol a natural seed antioxidant, is the main tocopherol found in chickpea (Nobile *et al*., 2013) [35].

Carotenoid

The bright colors of various plant tissues (such as red, yellow and orange) due to lipid soluble antioxidants/pigments called plant carotenoids. α-carotene, β-carotene, lutein, zeaxanthin, lycopene and β-cryptoxanthin are some of the significant carotenoids found in chickpea (Jukanti *et al*., 2012) [8]. Due to the greater grain weight of the Kabuli cultivar of chickpea, Desi chickpea often has a higher lutein concentration than the Kabuli chickpea. Compared to the red colored wheat (1.8-5.8 ug g^{-1}) and genetically modified "golden rice" endosperm (1.6 ug g^{-1}), chickpea dry seed had a greater carotenoid concentration is 9.08 ug g^{-1} (Rezaei *et al*., 2016) [36]. According to Ashok kumar *et al*., 2014, the main carotenoid in chickpea is lutein.

Phenolic acid

Sinapic acid hexoside, dihydroxybenoic acid, gallic acid, ferulic acid hexoside, p- hydroxybenzoic acid and p-coumaric acid are some of phenolic acid which are present in chickpea (Quintero-Soto *et al*.; 2018) [39]. Compared to the kabuli chickpea (1.24mg ferulic acid/g d.m.), Desi chickpea have higher amount of phenolic compound (1.29 mg ferulic acid/g d.m.) (Pasqualone *et al*., 2021) [38]. The greatest concentration of sinapic acid hexoside has been found in both Kabuli (199.8 ug/g) and Desi (137.9 ug/g) cultivar and the second most common phenolic acid is gallic acid which has been found in Kabuli (44.5-225.7 ug/g) and Desi chickpea (37.3- 183.9 ug/g) (Quintero-Soto *et al*. 2018) [39].

Flavonoids

The most abundant compound found in both Desi and Kabuli cultivar is flavonoids. Catechin, Catechin pentoside, myricetin, rutin, genisteinhexoside, quercetin, kaempferol and myricetin-O-methyl ether hexoside deoxy hexoside are some of flavonoids found in chickpea (Quintero-Soto *et al*; 2018) [39]. The most common flavoniods are catechin and Catechin pentoside which are present mainly in colored desi chickpea.

Anthocyanin

Anthocyanin and minerals (particularly Mn, Mg and Ca) were significantly greater in black and brown desi type chickpeas and they also have favourable correlation with antioxidant activity. In kabuli, total anthocyanin varied from 12.11 to13.28mg cyanidin 3-O-glucoside/kg d.m., whereas in Desi chickpeas they ranged from70.87-89.28mg cyanidin 3-O-glucoside/kgd.m. (Pasqualone *et al*., 2021) [38].

Table 2: Bioactive compound present in chickpea

S. No.	Bioactive compounds	Desi cultivar	Kabuli cultivar	References
1	Tannin (g/100kg)	0.18-0.22	0.07-0.13	Sharma, S *et al*., 2012 [19]
2	Saponin (sapogenol form)	413.5 (KWR-108)	40.8 (KAK-2)	Srivastava and Vasishtha (2012) [31]
3	Trypsin inhibitor	24	12	Sharma, S *et al*., 2012 [19]
	(mg/g)	(K 850)	(Pusa 1105)	
4	**Phenolic acid**			
	Sinapic acid hexoside (ug/g)	402.6 (Bco. Sin.92)	243.8 (ICC 3421)	Quintero-Soto *et al*; 2018 [39]
	Gallic acid (GAE g-1)	18.72	6.82	Rani and Khabiruddin (2016) [58]
	Vanillin (ug/g)	0.63 (Hoga 021)	0.78 (ICC 3761)	Quintero-Soto *et al*; 2018 [39]
	Ferulic acid (mg)	1.28	1.24	Pasqualone *et al*., 2021 [38]
5.	Phytic acid (mg/g)	8.48 (GL 12021)	12.73 (L522)	Kaur *et al*., 2019
6.	**Isoflavones**			
	Biochanin A (BA eq/mg e)	4.36	-	Dulce-Maria *et al*., 2020 [34]
	Formononetin (ug BA eq/mg e)	4.07	-	Dulce-Maria *et al*., 2020 [34]
	Isoformononetin glycoside (ug BA eq/100 g)	6.18	-	Dulce-Maria *et al*., 2020 [34]
7.	**Anthocyanin**			
	Cyanidine 3-O-glucoside (mg/g d.m)	76.85	12.6	Pasqualone *et al*., 2021 [38]
8.	**Tocopherol**			
	α-Tocopherol (vitamin E) (mg/100 g)	33.81 (Punjab 91)	-	Zia-ul-HAQ *et al*., 2007 [49]
	β-Tocopherol (mg/100 g)	-	11.89 (G112)	Nobile *et al*., 2013 [35]
	γ-Tocopherol (mg/100 g)	185.97 (Punjab 91)	-	Zia-ul-HAQ *et al*., 2007 [49]
9.	Carotenoid (ug g-1)	44	22	Rezaei *et al*., 2016 [36]
	Lutein (ug g-1)	8.52	7.13	Ashokkumar *et al*., 2014 [37]
	Zeaxanthin (ug g-1)	-	18.25	Rezaei *et al*., 2016 [36]
	β-carotene (ug g-1)	0.57	0.24	Ashokkumar *et al*., 2014 [37]
10.	**Flavonoids**			
	Quercetin (ug/g)	0.05 (Hoga 340)	14.5 (ICC 4418)	Quintero-Soto *et al*. 2018) [39]
	Catechin (ug/g)	4.7 (Hoga 340)	41.4 (ICC 4418)	Quintero-Soto 2018) *et al*. [39]

Health benefits of chickpea

Due to the health promoting components such as carbohydrate, dietary fibre, minerals, vitamins, oligosaccharides, isoflavones and antioxidant, chickpeas are good food choice. They are regarded as a necessary part of a healthy diet because regular consumption has been shown to have protective effects against a number of diseases (Gupta *et al*., 2016) [59].

Cardiovascular diseases (CVD)

As a relatively inexpensive source of dietary fibre and bioactive substances such as phytosterols, saponins and oligosaccharides, chickpea seed have low glycemic index and it may be helpful for reducing the risk of CVD (Jukanti *et al*., 2012) [8]. An Australian-style wheat-based diet supplemented with isoenergetic chickpea has been found to significantly lower serum total cholesterol (TC) and low density lipoprotein cholesterol (LDL-C), according to a controlled dietary invention study (Wallace *et al*., 2016) [10]. A 20-week crossover study of people with elevated CVD risk factors found that eating chickpea improved TC and LDL-C reduction (Pittaway *et al*., 2008) [41]. Isoflavones are diphenolic secondary metabolites that may reduce the risk of heart diseases because they prevent the LDL-C oxidation, maintain the structural integrity of artery wall and prevent the proliferation of aortic smooth muscle cells (Jukanti *et al*., 2012) [8]. Rat fed a high fat with chickpea di*et al*so displayed decreased visceral adiposity and improved lipid profiles after eight month in a mechanistic animal research when compared to rat fed a high fat di*et al*one (Yang *et al*., 2007) [44]. As a result, dietary chickpea may help to reduce the risk of CVD (Gupta *et al*., 2016) [59].

Diabetes

Diabetic patients need to manage their glycemic conditions or blood glucose levels (Gupta *et al*., 2016) [59]. A higher concentration of resistant starch and amylase has been found in pulses like chickpea. Because glucose enter into bloodstream more slowly due to its lower bioavailability, there is less need for insulin, which lowers the glycemic index and insulinaemic postprandial response (Jukanti *et al*., 2012) [8]. The incidence and severity of type 2 diabetes can be decreased by lowering the glycemic index (Regina *et al*., 2006) [42]. Rat with hypolipidemia and insulin sensitization as a result of chickpea inclusion in a high fat rodent diet. Rat with reduced visceral and ecotopic fat deposition (Yang *et al*., 2007) [44]. In the case of diabetic rat this has been proven that where feeding of aqueous and methanolic extract of chickpea seeds at dose of 400mg/kg resultant in significant reduction in blood glucose and triglyceride level respectively. Antinutritional substances can be hazardous, some of them found in chickpea like phytic acid, lectins and amylase inhibitors, can also interfere with the digestion of starches, resulting in reduced glycemic index in the small intestine (Gupta *et al*., 2016) [59]. The ability of sprouted chickpeas with high phenolic content to inhibit two major type-2 diabetes-related enzymes,α-glucosidase and α-amylase suggest that novel health promoting substances may be produced during seed digestion (Prathapan *et al*., 2011) [45]. Due to their anti-diabetic properties, chickpea can be a valuable and risk free source of energy for diabetics (Gupta *et al*., 2016) [59].

Cancer

When healthy adult consume 200 g of chickpea per day, a major short chain fatty acid called butyrate is created. Butyrate inhibits the cell growth and induce apoptosis, both may lower the risk of colorectal cancer (Wallace *et al*., 2016) [10]. Chickpea contain bioactive substances like Biochanin A and saponins, which have been found to lower the risk of a certain cancer types (Jukanti *et al*., 2012) [8]. A potent anti-mycotic and anti-proliferative agent against a human oral cancer cell line has been recently proven by the C-25 (antifungal protein of chickpea) at the concentration of 37.5 g/mL by targeting p38 MAP kinase (Gupta *et al*., 2016) [59]. Incorporating β- sitosterol, the major phytosterol found in chickpea into rat diet decreased colonic tumor caused by the carcinogen (N-methyl-N-nitrosourea) (Jukanti *et al*., 2012) [8]. In mice, administration of chickpea albumin hydrolysate (CAH) by gavage every day for 12 days at various doses of 50, 100 and 200 mg/kg resulted in a significant reduction in tumor volume after the 10th day of CAH treatment because the chickpea albumin hydrolysate exhibit potent anti-tumor activity even after tumor reduction (Xue *et al*., 2012) [46]. Chickpea may be used as a functional food to reduce the chance of different types of cancer and its bioactive compound also help to prevent cancer during physiological conditions following chickpea consumption (Gupta *et al*., 2016) [59].

Obesity

For the majority of people worldwide, obesity is a serious health issue and it increases the risk of developing a number of diseases and health issues (Gupta *et al*., 2016) [59]. Compared to diet using higher glycemic index foods, low glycemic index diet resultant in lower insulin levels and higher weight loss. Being a low GI food, chickpea may aid in weight loss and reduction of obesity (Jukanti *et al*., 2012) [8]. In a study on animals, adding chickpea to the rat diet helped to successfully stop their body weight from rising. Rats were divided into 3 groups at random and diet having low fat, moderate fat and high fat with chickpea supplements were administrated for 8 months. The high fat diet 10% (w/w) chickpea addition slowed the weight growth from six month to the experiment conclusion. Additionally compared to the group that consumed high fat diet, the chickpea treatment caused the low density lipoprotein (LDL) to drop by 23%, high density lipoprotein (HDL) to rise by 35% and the ratio of LDL to HDL to decrease by 30% (Yang *et al*., 2007) [44]. Therefore, chickpea help in reduction of obesity.

Hypertension

The hallmark of stroke and other cardiovascular disorder is hypertension and Angiotensin I- converting enzyme (ACE) inhibitors are among the method considered to be used to avoid hypertension (Gupta *et al*., 2016) [59]. The transformation of biologically inactive angiotensin I to the activated vasoconstrictor angiotensin II, which is the cause of high blood pressure and the inhibition of vasodilator bradykinin by ACE make the ACE inhibitor peptides anti-hpertensive in nature (Fahmy *et al*., 2015) [47]. Chickpea proteins are a good source of bioactive peptides with ACE inhibitory capability, chickpea may play a vital role in regulating hypertension.

Gastrointestinal tract health

Dietary fibre which contain lignin, poly/oligosaccharides and other plant substances, is the portion of plant diets that cannot be digested. Soluble and insoluble fibres are two categories for dietary fibre. While insoluble fibres are `indigestible and encourage bowel motions, soluble fibres are slowly absorbed in the colon (Wallace *et al.*, 2016) [10]. When 19 healthy people consumed 140 g/d of chickpea and chickpea flour for 6 weeks, a significant increase (18%) in dietary fibre intake was observed (Nestel *et al.*, 2004) [48].

Other health benefits

Different sterols, tocopherol and tocotrienols are present in chickpea seed oil. In addition to decreasing cholesterol levels, these phytosterols have been shown to have anti-ulcerative, anti- bacterial, anti-fungal, anti-tumor and anti-inflammatory activities (Jukanti *et al.*, 2012) [8]. Lutein and zeaxanthin, the two main carotenoid found in chickpea seed, are thought to be involved in senile or age related macular degeneration (Mozaffarieh *et al.*, 2003) [50]. Traditional medicine has utilized chickpea seeds as stimulants, tonics and aphrodisiacs (Jukanti *et al.*, 2012) [8]. Additionally, they are used as appetizer, to quench thirst, reduce stomach burning, to expel parasitic worms from the body (anthelmintic property) (Zia-UI-Haq *et al.*, 2007) [49].

Table 3: Health benefits of chickpea

S. No.	Bioactive compound	Health benefit	References
1.	Phenolic compound	Anticarcinogenic, anti-ulcer, anti-allergenic, anti-inflammatory, anti-artherogenic and anti-thrombotic	Kaur *et al.*, 2019 [27]
2.	Saponin	Hypocholesterolemic, Anticarcinogenic, anti-tumor, anti- diabetic	Srivastava and Vasishtha (2012) [31]
3.	GABA	Prevent cancer cell proliferation, reduce hypertension and regulate blood cholesterol	Ferreira *et al.*, 2019 [12]
4.	Isoflavones	Anticancer	Dulce-Maria *et al.*, 2020 [34]
5.	Carotenoid	Prevent the development of coronary and carcinogenic diseases	Ferreira *et al.*, 2019 [12]
6.	Phytic acid	Anticarcinogenic/antineoplastic property and reduce kidney stone formation	Bueckert *et al.*, 2011 [24]
7.	Anthocyanin	Anti-diabetic, anti-inflammatory and anticancer	Pasqualone *et al.*, 2021 [38]

Effects of food processing methods on antinutritional factors and nutritional composition of chickpea

Cooking/boiling, soaking, dehulling, milling, roasting, germination and fermentation are the main traditional methods used to process chickpea. These methods can increase the bioavailability of micronutrients in plant based diet by reducing phytate content and enhancing overall digestibility and nutrient absorption (Lamesgen yegrem., 2021) [17].

Trypsin inhibitor

Virat had the lowest content of trypsin inhibitor (11.82mg/g) whereas annigeri had the greatest value (13.08mg/g) (Roy *et al.*, 2019) [57]. The treatment of soaking in plain water resulted in a considerable reduction of several antinutritional components, ranging from 6.57% to 8.17%, depending on the germplasm (Roy *et al.*, 2019) [57]. Pressure cooked chickpea had a 50% decrease in trypsin inhibitor activity concentration (Mittal *et al.*, 2012). Autoclaving of chickpea results in an 82.27% reduction of trypsin inhibitor (Alajaji & Eldawy., 2006) [52]. Germination has a lesser impact on trypsin inhibitor activity in chickpea than other cooking techniques. Trypsin inhibitors heat labile nature may be to responsible for the decrease in trypsin inhibitor activity during heat treatment (EL-Adawy., 2002) [51].

Phytic acid

The phytate concentration of chickpea is 13.28 µmole/g and the amount of phytic acid was lowered by all processing method (Mittal *et al.*, 2012) [1]. Between 15.19% and 17.78% of phytic acid content was reduced by soaking. Under the effect of a concentration gradient, soaking induce the leaching of phytate ion into the soaking water and decreased the amount of phytic acid in chickpea germplasms (Roy *et al.*, 2019) [57]. Leaching of phytic acid is a result of soaking, which increased phytic acid losses. Chickpea lost 12.34%, 13.7% and 3.46% of their phytic acid content after they were boiled, pressure-cooked and roasted respectively (Mittal *et al.*, 2012) [1]. By dry roasting, soaking, germination, dehulling and boiling, the phytic acid concentration was decreased by 5.89%, 15.20%, 31.00%, 36.42% and 57.35% respectively. Leached into soaking water was responsible for greatest phytic acid reduction that resulted from the boiling process (Olika *et al.*, 2019) [53].

Tannin

Tannin is a phenolic compound that is water soluble and mostly present in seed coat (Olika *et al.*, 2019) [53]. The taste of chickpea slightly bitter due to the tannin, which ranged from 4.94mg to 5.30mg/g. Germination decreased the amount of tannin (22.66%-35.22%) (Roy *et al.*, 2019) [57].

Germination, boiling and pressure cooking procedures were comparable to one another in their ability to reduce tannin by up to 93% (Mittal *et al.*, 2012) [1]. Tannin are reduced while cooking legumes in the microwave, autoclave and boiling (Khattab & Arntfield., 2009) [54]. The tannin concentration were significantly reduced by roasting (50.94%-61.01%) and the activation of tannase, which caused the tannin content in chickpea germplasm to be degraded, may have been cause of the tannin content decrease during roasting (Roy *et al.*, 2019) [57].

Saponin and chymotrypsin inhibitor

Chickpea have a 0.44% saponin concentration. Chickpea that have been boiled showed the greatest reduction, which may be accounted by saponins leaching into the water (Mittal *et al.*, 2012) [1]. Cooking decrease saponin (43.96-51.65%) in chickpea (Alajaji & Eldawy., 2006) [52]. The chymotrypsin inhibitor content in raw chickpea germplasms ranged from 13.03 to 13.10 CIU/mg and chymotrypsin inhibitor content reduced during soaking in a range of 3.13 to 3.90%. Roasting (47.25%-56.02%) is the most efficient processing method and the heat sensitive nature of chymotrypsin inhibitor leads to a decrease in its activity during roasting (Roy *et al.*, 2019) [57].

Carbohydrate and protein

The carbohydrate and protein content of raw and processed chickpea are shown in table4. After cooking methods, the sucrose, reducing sugar, raffinose and stachyose were all significantly ($p<0.05$) decreased, whereas verbascose was totally removed and these decrease are result of their diffusion into cooking water (Alajaji & Eldawy., 2006) [52]. Albumin made up of the total protein, which was lesser than the estimated albumin (18.55%) and the protein content of chickpea reduced during processing. Roasting had a significant impact on vicilins, which were reduced by 83.68% (Mittal *et al*., 2012) [1].

Minerals

The mineral content of raw and processed chickpea shown in table4. During the cooking processes, the minerals from leached into the water, the potassium (K) and phosphorus (P) content of roasted chickpea increased by 5.27% and 2.88% respectively, however roasting had no effect on magnesium (Mg) content of legume study (Mittal *et al*., 2012) [1]. With the processing techniques of germination, boiling, roasting and pressure cooking, the iron (Fe) content of Indian chickpea was decreased. The dehulling method resulted in the greatest reduction of calciumcontent (536.56 mg/kg) (Olika *et al*., 2019) [53]. Significant losses of potassium (24%), copper (15%) and iron (8%), when cooked in boiling water (Alajaji & Eldawy., 2006) [52].

Vitamins

Cooking method significantly (P<0.05) decreased the amount of thiamin, riboflavin, niacin and pyridoxine in chickpea seed and leaching and chemical oxidation probably played a role in these losses. The losses from cooking in microwave were lower than those from boiling and autoclaving (Alajaji & Eldawy., 2006) [52]. The thiamin content of eight legumes was lowered by pressure cooking and microwave heating (Khatoon and Prakash 2004) [55]. Cooking methods including traditional and microwave produced a significant loss in all vegetables include thiamin, riboflavin and ascorbic acid. Autoclaving and microwave cooking improved when compared to the boiling, these vitamins are retained better (Alajaji & Eldawy., 2006) [52].

Table 4: Effects of food processing methods on antinutritional factors and nutritional composition of chickpea:

S. No.	Bioactive compound/n utrients	Raw	Soaking	Boiling/cooking	roasting	Pressure cooking	References
1.	Trypsin inhibitor (mg/g)	11.82	10.88	-	3.00	-	Roy *et al*., 2019 [57]
2.	Alpha amylase inhibitor (U/g)	51.50	46.32	-	38.32	-	Roy *et al*., 2019 [57]
3.	Chymotrypsi ninhibitor (CIU/mg)	13.05	12.64	-	6.75	-	Roy *et al*., 2019 [57]
4.	Phytic acid (µmole/g)	13.28	-	11.64	11.46	12.82	Mittal *et al*., 2012 [1]
5.	Tannin (mg/g)	4.85	-	2.52	-	-	Alajaji & Eldawy., 2006 [52]
6.	Condensed tannin (µgCAE/g)	1504.33	1408.52	-	803.11	-	Roy *et al*., 2019 [27]
7.	Haemaggluti nnin(HU/mg)	6.22	-	0.00	-	-	Alajaji & Eldawy., 2006 [52]
8.	Saponin (mg/g)	0.91	-	0.44-0.48	-	-	Alajaji & Eldawy., 2006 [52]
9.	**Carbohydrates**						
	Sucrose (g/100 g)	1.89	-	1.23	-	-	Alajaji & Eldawy., 2006 [52]
	Raffinose (g/100 g)	1.45	-	0.76	-	-	Alajaji& Eldawy., 2006 [52]
	Verbascose (g/100 g)	0.19	-	0.00	-	-	Alajaji & Eldawy., 2006 [52]
10.	**Protein**						
	Albumins (%)	18.55	-	19.44	18.57	19.44	Mittal *et al*., 2012 [1]
	Legumins (%)	66.50	-	66.48	66.43	66.24	Mittal *et al*., 2012 [1]
	Vicillins (%)	12.20	-	10.36	1.99	6.08	Mittal *et al*., 2012 [1]
11.	**Vitamin**						
	Riboflavin (µg/100 g)	173.33	-	84.00	-	-	Alajaji & Eldawy., 2006 [52]
	Thiamin (µg/100 g)	453.33	-	153.33	-	-	Alajaji & Eldawy., 2006 [52]
	Niacin (µg/100 g)	1602.67	-	69.33	-	-	Alajaji & Eldawy., 2006 [52]
12.	**Minerals**						
	Potassium (mg/g)	6.64	-	8.54	6.99	3.51	Mittal *et al*., 2012 [1]
	Iron (mg/g)	0.058	-	0.091	0.045	0.048	Mittal *et al*., 2012 [1]
	Magnesium (mg/g)	0.78	-	0.67	0.76	0.64	Mittal *et al*., 2012 [1]

Conclusion

Chickpea is cost effective source of carbohydrate, dietary fibre, fat, protein, vitamins and minerals, all are good for human health. Chickpea can help to prevent or treat diabetes, heart diseases, obesity and cancer. The regular consumption of chickpea help to improve heart health. The bioactive compound, chemical composition like carbohydrate, protein, vitamin and minerals of chickpea are greatly affected by the processing methods.

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