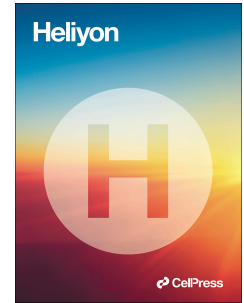


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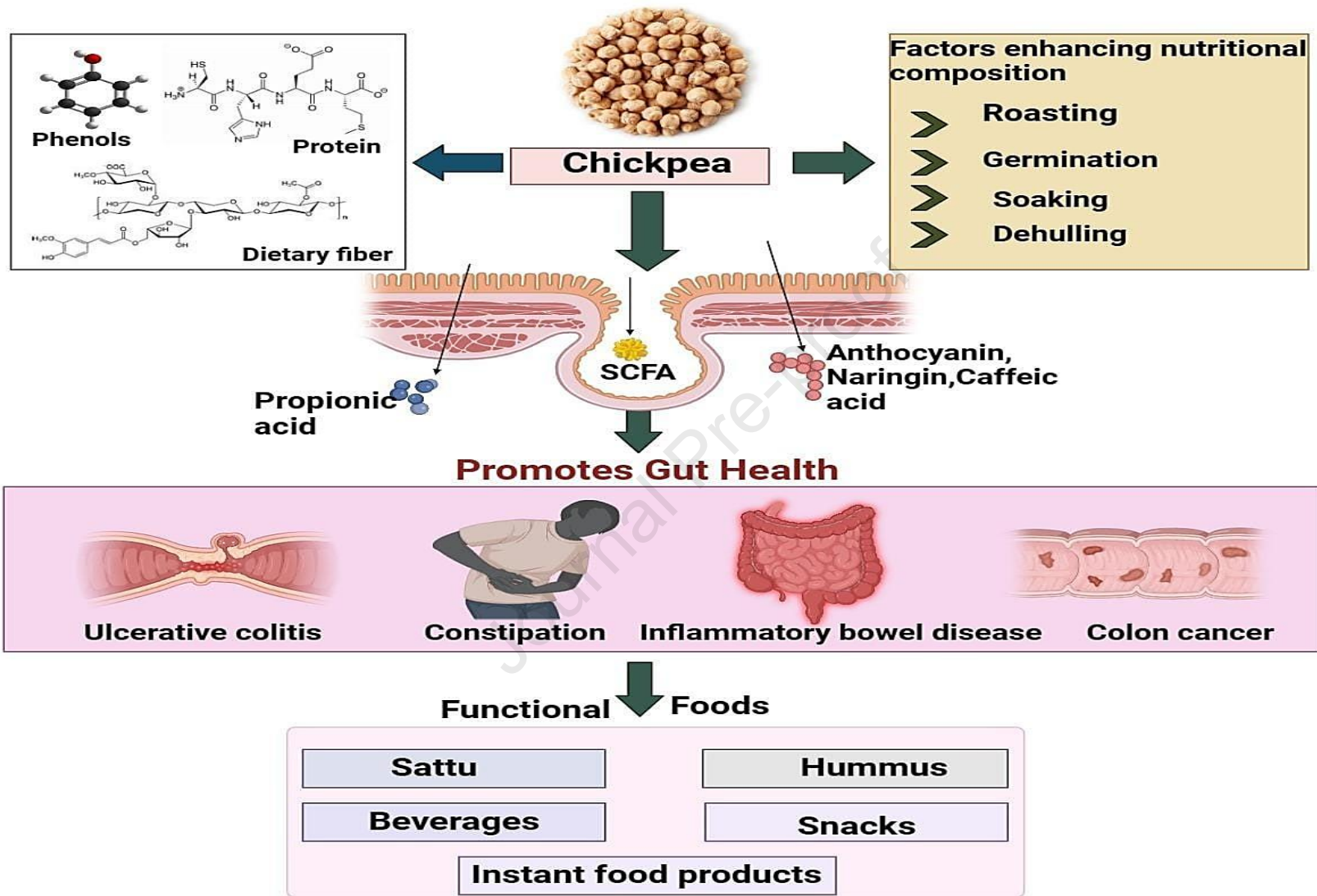
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Graphical abstract

Chickpeas and Gut Microbiome: Functional Food Implications for Health

Running Title: *Role of Chickpeas in Gut Health*

**Aswani Ajay¹, Supriya Singh Gaur^{1*}, Rafeeya Shams¹, Kshirod Kumar Dash^{2*}, Shaikh
Ayaz Mukarram³, Béla Kovács^{3*}**

¹Department of Food Technology and Nutrition, Lovely Professional University, Phagwara, Punjab, India.

²Department of Food Processing Technology, Ghani Khan Choudhury Institute of Engineering and Technology, Malda, West Bengal, India.

³Faculty of Agriculture, Food Science and Environmental Management Institute of Food Science, University of Debrecen, Debrecen 4032, Hungary

***Correspondence**

Kshirod Kumar Dash Email: kshirod@tezu.ernet.in

Supriya Singh Gaur Email: supriya.27320@lpu.co.in

Kovács Béla Email: kovacsb@agr.unideb.hu

Abstract

Chickpea is considered a rich source of nutrients, especially protein and dietary fibre. Besides, chickpea has potential benefits for the maintenance of gut health by improving intestinal integrity and serving as a source of energy for the gut microbiota. Moreover, chickpea consumption has been found to possess anti-cancer, anti-inflammatory, and antioxidant activity. On undergoing certain treatments like soaking, dehulling, roasting, and germination, the anti-nutritional profile of chickpeas can be reduced. Observing these benefits, this review explores the impact of chickpea and its components on maintaining gut health, emphasizing various benefits. Besides, the paper comprehensively covers the nutritional composition of chickpeas and factors influencing the bioavailability of its components concerning gut health. Additionally, it outlines the mechanisms through which chickpeas influence gastrointestinal health, providing valuable insights into complex processes and potential therapeutic applications. Furthermore, the review identifies contributions that can guide future research, encouraging further exploration of chickpeas' role in gut health and the development of interventions. As a result of the presented review, chickpeas can be used as an affordable source of food, which is nutritionally stable and prevents gastrointestinal diseases.

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Keywords: Chickpea; Gut health; dietary fibre; functional food; germination; anti-nutritional profile

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69 **1 Introduction**

70 Chickpea (*Cicer arietinum L.*), popularly known as garbanzo bean or Bengal gram, belongs
71 taxonomically to the Fabaceae family, specifically to the monogeneric tribe Cicereae (Sajja et
72 al.,2017). Chickpeas are one of the oldest cultivated crops and their versatility, nutritional value,
73 and adaptability have contributed to their widespread popularity, utilized in various culinary
74 forms. Though it is believed to have originated in Middle Eastern countries and spread to
75 eastern and western parts of the world, the majority of chickpea production is in Australia,
76 Eastern Africa, and South Asia, with 80-85 percent of the desi type grown worldwide.
77 Moreover, it ranks as the third most popular pulse in the world, with an annual production of
78 13.3 million tons, which is grown over 50 countries, especially in North Africa, Asia, America,
79 Southern Europe and Australia (Zhang et al.,2017). Among these, Southern and South-East
80 Asian countries dominate in chickpea production, leading to 80% of regional contribution
81 (Merga and Haji,2019). Specifically, in African Sub-Saharan regions and India, chickpeas are
82 recognized as a major source of protein and amino acids, especially for reducing the risk of
83 malnutrition and contributing to food safety worldwide (Merga and Haji, 2019). More
84 importantly, on account of all pulses cultivated in India, chickpea represents 45% of total pulse
85 production, contributing about 75 percent of global production. Similarly, India has produced
86 over 66.19 % of chickpea globally during 2018, totalling 17.20 million tonnes as well as,
87 covering about 32.51% of cultivation area (around 29.03 million ha) (Malik, 2021).
88 Furthermore, chickpea consumption in India has risen steadily and is cultivated in 25 states
89 (Sharma and Sharma, 2020). For instance, Andhra Pradesh is the highest chickpea yielding state
90 in India, averaging 1.4 metric tons per ha (Merga and Haji,2019). Indeed, chickpeas contain a
91 healthy balance of protein, carbohydrates, fats, vitamins, and minerals, making them a good
92 food component to incorporate into a daily diet for better nutritional status in developing
93 countries (Dadon et al.,2017). Besides, it holds a good amount of dietary fiber, which is
94 beneficial in reducing the chances of several serious ailments such as gastrointestinal diseases,
95 diabetes, coronary artery diseases, stroke, and even cancer (Núñez-Gómez et al.,2021).
96 Moreover, chickpea has significant probiotic effect by promoting growth of beneficial bacteria,
97 which is primarily due to their high levels of dietary fiber and resistant starch that nourishes gut
98 microbiota (Sidhu et al.,2020). Chickpea has become recognised as a functional food due to its
99 various health benefits including managing cholesterol, controlling diabetes, anti-cancerous and
100 aiding weight loss (Kaur and Prasad,2021). Functional foods can be defined as natural or
101 industrially processed foods that when consumed regularly can positively affect health beyond

102 normal nutrition (Granato et al.,2020). The consumption of functional foods can be associated
103 with benefits like disease prevention, increased nutrient intake and anti-inflammatory properties
104 (Tripathy et al.,2019).

105 There is a growing demand for plant-based proteins, i.e., legumes and pulses because of its
106 nutritional benefits towards various diseases (Hamed et al.,2023). For instance, the phenolic
107 compounds and fermentable fiber present in chickpeas make it a prime substance for
108 maintaining the functioning of gut microbiota as well as preventing other gut related diseases
109 (Monk et al.,2017). Moreover, gut microbiota is crucial in regulating the metabolic responses
110 in the host physiology and is considered as a vital metabolic organ (Guo et al.,2022). Indeed,
111 effective gut health can be achieved through maintaining a well-balanced, non-dysbiotic
112 microbial community structure, along with preserving an intact colonic mucus and epithelial
113 barrier. Any disruptions in these elements are linked to the onset of various gut associated
114 diseases, such as obesity, colon cancer, and inflammatory bowel disease, among others. As a
115 solution, the consumption of chickpeas improves mucus production in the gut, inhibits cancer
116 cell proliferation, microbiome composition modulation, and attenuation of inflammation
117 (Milán-Noris et al.,2018). Furthermore, chickpea based diet helps enhance the colonic micro-
118 environment by producing short chain fatty acids and improved metagenomic function (Monk
119 et al.,2017). Apart from this, the peptides present in chickpea protein prevent colonic cancer by
120 possessing antiproliferative and antioxidant activity(Milán-Noris et al.,2017).

121 Coming to the anti-nutritional factors present in chickpeas, it include tannin, phytic acid, and
122 protease inhibitors that hinder the nutritional quality and absorption of nutrients (Gupta et
123 al.,2017). Some of the domestic processing methods utilized for reducing the effect of these
124 anti-nutritional factors include soaking, dehulling, germinating, and roasting, enhancing the
125 protein digestibility and sensory properties of chickpeas (Bulbula and Urga, 2018). Besides,
126 incorporating chickpeas into a balanced diet is part of ongoing efforts to promote not only
127 general health but also the well-being of the gastrointestinal system. These legumes serve as a
128 natural and nutritious means to support gut health, aligning with a broader initiative to
129 emphasize the connection between diet and the maintenance of a healthy digestive tract.
130 Overall, existing efforts in research and nutritional studies underscore the potential benefits of
131 incorporating chickpeas into the diet for gut health. These efforts focus on understanding the
132 specific mechanisms through which chickpeas influence the gut microbiota and exploring their
133 role in preventing or managing gut-related disorders.

134 Considering the aforementioned benefits, this review aims to summarize the impact of
135 chickpeas and its components on maintaining gut health. Moreover, the contribution of this

136 work is given in Table 1 which outlines the novelty of the study in comparison with related
137 works and are summarized as:

- 138 • This study summarizes a comprehensive knowledge about the nutritional composition of
139 chickpea and different factors affecting the nutritional bio-availability of chickpea
140 components, fostering a favorable environment for beneficial gut microbes.
- 141 • Besides, this work summarizes the mechanisms through which chickpeas influence gut
142 health and provides valuable insights into the intricate processes involved, offering
143 potential avenues for therapeutic applications.
- 144 • Building the relationship between chickpeas and gut health, the findings emphasize the
145 inclusion of chickpeas as a beneficial component in promoting and maintaining optimal
146 gut health.
- 147 • Further, the identified contributions pave the way for future research, encouraging further
148 exploration of chickpeas' role in gut health and the development of interventions.

149 **2 Nutritional Composition: Unfolding the Benefits**

150 Chickpeas is considered a good source of several nutritional components including
151 carbohydrates, protein, fat, dietary fiber, vitamins, and minerals, often preferred for maintaining
152 the gut microenvironment (Monk et al.,2017). Bringing together these benefits, this section
153 highlights key nutritional components present in chickpeas as listed in Table 2. Chickpeas
154 contain smaller amounts of digestible carbohydrates and larger amounts of unavailable
155 carbohydrates, compared to other legumes. It is worth noting that the major proportion of
156 carbohydrates present in chickpeas is starch which has slow digestibility (Ipsken et al.,2022).
157 Also, chickpeas are rich in amylose, amylopectin, and cellulose whereas sugars like
158 oligosaccharides are found in smaller proportions which ultimately benefits maintaining gut
159 health (Hamed et al.,2023). Moreover, bifidobacteria and lactobacillus comes under generally
160 recognized as safe (GRAS) (Abedinia et al.,2021). Other parallel research reveals that the
161 alpha-galactosidase present in pulses like chickpeas helps to increase bifidobacteria and
162 lactobacilli levels, improve bowel movement, and prevent the gut from carcinogenic agents
163 (Singh et al.,2017). Chickpea is also a popular source of protein and hence possesses several
164 nutritional properties including a balance of amino acids and other biological activities
165 (Boukid,2021). Moreover, Chickpea protein has the highest bioavailability in the human body
166 and its hydrolysates have properties including angiotensin-converting enzyme inhibition and
167 antioxidant activity (Kaur and Prasad,2021). Besides, recent studies confirm that chickpea
168 protein albumin, globulin, and glutelin can decrease the starch digestibility time, thus
169 preventing gut related diseases. Additionally, studies have shown that chickpea protein

170 albumin, globulin, and glutelin can decrease the starch digestibility time, thus preventing gut
171 related diseases (Tan et al.,2022). Chickpea protein is valuable in plant-based diets as it is a
172 great source of essential amino acids, and hence plays a major role in human nutrition. It is
173 found to be a rich source of non-essential amino acids such as aspartic acid and glutamic acid
174 along with modest amounts of histidine, serine, proline, alanine, glycine, and cysteine (Khan et
175 al.,2015). Researchers stated that the alpha-galactosidase present in chickpeas helps to increase
176 bifidobacteria and lactobacilli levels, improve bowel movement, and protect the gut from
177 carcinogenic agents (Singh et al.,2017). Fermented black chickpea flour is a rich source of
178 amino acid and resistant starch, significantly increased after fermenting via *Lactiplanti Bacillus*
179 *plantarum* T0A10. More importantly, the total resistant starch content of chickpeas can be
180 increased by treating it with the pullulanase enzyme (Bicak et al.,2018). In relation to gut health,
181 the resistant starch content in chickpeas gets fermented by the gut microbiota, which helps in
182 the production of short chain fatty acids (Brummer et al.,2015).

183 Chickpeas fat includes sterols, lipids, tocopherols (phytosterols), and fatty acids like
184 monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) (Madurapperumage
185 et al.,2021). The fat of chickpea seeds is characterized by the high content of essential
186 unsaturated fatty acids: linoleic acid, oleic acid, and linolenic acid, as well as saturated fatty
187 acids such as palmitic acid and stearic acid. Incorporation of chickpeas in diet could help in
188 enhancing the polyunsaturated fatty acids content in the human body (Nobile et al.,2013). As
189 per the studies done on the basis of clinical trials, essential fatty acids in chickpeas are observed
190 to maintain cellular integrity, leading to a healthy gut barrier ((Madurapperumage et al.,2021).
191 Chickpea is considered a good source of water-soluble vitamins such as B2, B5, and B6
192 (Ipekesen et al.,2022). The most important minerals contained in chickpeas are calcium,
193 phosphorus, magnesium, iron, copper, zinc, sodium, and potassium, most of the seed calcium
194 is located in the seed coat (Shabbir et al.,2020). Being a good source of zinc and iron, chickpea
195 consumption also helps in the prevention of mineral malnutrition. In a complementary study,
196 the administration of iron was observed to be effective in balancing the gut microbiota and
197 beneficial for patients with Inflammatory Bowel Disease (IBD) and colorectal cancer
198 (Kujawska et al.,2016). Moreover, an in vitro study stated that supplementing chickpeas is
199 favorable for gut health, as minerals like calcium in it have synergistic effects with specific
200 bacterial species. Vitamin B4 has a positive influence on gut related diseases including
201 constipation, ulcers, dyspepsia, and other gastrointestinal disturbances (Shabbir et al.,2020).
202 Another variety of chickpeas, known as Kabuli Chana, has various nutrients including lignin,
203 cellulose, fat, and dietary fiber (Hamid and Kalsom, 2017). The Chickpea hull comprises

204 dietary fiber and bound and free phenolics (Medina et al.,2017). Chickpea hull has a greater
205 amount of dietary fiber which is more than 70%. Recently, the two major commercial types of
206 chickpeas; Kabuli and Desi were evaluated, in which the nutritional quality of Kabuli chickpea
207 puree was compared with Apulian black chickpea puree. On one hand, black chickpea puree
208 contains a high content of fiber and bioactive compounds, while Kabuli chickpea puree contains
209 high lipid concentration. Besides, it has been exhibited dietary fiber variations in different
210 genotypes of chickpeas, under processing techniques including soaking and cooking. While
211 cooking, the cellulose as well as lignin contents accelerate while hemicellulose content
212 decreases (Vasistha and Srivastava,2013).

213 **3. Mechanism: Modulating Gut Microbiota Composition and Diversity**

214 Gut health refers to the mutual and beneficial relationship between the gut microbiota and the
215 immune system, which aims to diminish harmful inflammatory responses and strengthen the
216 integrity of the mucosal barrier of the gut (Núñez-Gómez et al.,2021). This section discusses
217 the mechanism by which chickpea components like dietary fiber, protein, and phenolic
218 compounds modulate colonic microbiota and gut health as illustrated in Fig 1.

219 **3.1 Dietary Fiber**

220 Chickpea contains a high content of dietary fiber, considered effective for maintaining the gut
221 microbiome, regular bowel movements, and relieving constipation (Goldstein and
222 Reifen,2022). Indeed, the gut microbiota produces metabolites like short-chain fatty acids
223 (SCFA) in order to utilize the dietary fiber as human indigenous enzymes can- not digest it
224 properly (Arroyo et al.,2023). Being a rich source of dietary fiber, chickpea helps in maintaining
225 the health of the colonic microbiome and epithelial barrier which prevents several gut-related
226 diseases (Monk et al.,2017). Researchers have shown that dietary fibers present in chickpeas
227 increase propionic acid levels and improve Lactobacillus and Bacteroides (Han et al.,2021).
228 Further, intestinal mucosa production can be effectively increased by dietary fiber and SCFA
229 from the intestinal epithelium (Arroyo et al.,2023). Another parallel work on chickpeas has
230 shown that dietary fiber can mechanically decrease the interaction time between mucosal cells
231 and carcinogens, proteolytic fermentation time due to bulky fecal, and can improve viscosity.
232 Furthermore, Bacillus and Bacteroides in the gut can be increased in abundance due to increased
233 consumption of chickpea dietary fiber, which positively affects the gut microbiota homeostasis
234 (Han et al.,2021).

235 **3.2 Protein**

236 Due to the presence of protease inhibitors in plants, majorly in pulses and legumes like
237 chickpeas, the digestibility of protein decreases, and the undigested protein gets fermented by

238 the microbiota in the colon. The substantial amount of undigested protein helps to improve the
239 number of species capable of protein fermentation which ultimately flourishes the gut
240 microbiota (Karlund et al.,2019). Precursors of SCFA such as propionate and butyrate, release
241 as an end product of amino acid and peptide fermentation, which benefit gut health (Arroyo et
242 al.,2023). Apart from this, butyrate acts as a major source of energy for colonocytes, which are
243 essential for modulating intestinal inflammation, promoting genomic stability, and maintaining
244 mucosal integrity. For instance, the ability of butyrate to assist in the removal of dysfunctional
245 cells and synchronize apoptosis and differentiation of colonocytes emphasizes its potentiality
246 in preventing colon cancer (Conlon and Bird,2014).

247 **3.3 Phenolic Compounds**

248 Studies have proved that kaempferol, a flavonoid present in pulses like chickpeas, has a positive
249 effect on reducing the chances of inflammatory bowel disease (IBD) by inhibiting the nuclear
250 factor- kappa B (NF- κ B) signaling pathway and boosting the secretion of interleukin-8 (IL-8)
251 (Hu et al.,2022). Besides, it is also evident that cooked chickpeas contain phenolic compounds
252 like formononetin, biochanin A, daidzein, quercetin, etc. These compounds mainly possess
253 anti-inflammatory and antioxidative action and lessen the membrane permeability, which
254 enhances gut health and diminishes pathologies like colitis (Monk et al.,2017). Besides,
255 Chlorogenic acid in legumes exhibits potent antimicrobial properties, permeabilizing and
256 binding bacterial cell membranes while also regulating gut microbiota by promoting the growth
257 of specific beneficial bacteria (Coman and Vodnar, 2020). Another key compound in chickpeas,
258 anthocyanins, has the ability to improve the growth of *Bifidobacterium* spp. which commits
259 mucosal layer thickening by stimulating mucosa secretion. . It also decreases the permeability
260 of the gut membrane by the distribution and localization of restored tight junction protein (ZO-
261 1 and Occludin) (Garcia et al.,2021; Huang et al.,2023). An experiment showed that Naringin,
262 another key compound of chickpeas, can improve the integrity of intestinal barriers from
263 disruption induced by TNF- α (Lin et al.,2019).). Studies have also shown that by the inhibition
264 of the NF- κ B signaling pathway, caffeic acid can decrease the production of pro-inflammatory
265 cytokines, comprising tumor necrosis factor-alpha, interleukin-6 (IL-6), and infiltration of
266 F4/80 macrophages, CD177+ neutrophils and CD3 + T cells (Coman and Vadnar,2020; Duan
267 et al.,2020).

268 **4. Health Benefits of chickpea**

269 Being an abundant source of several nutrients, chickpea is recognized as an excellent food for
270 the prevention of numerous chronic gut disorders such as Inflammatory Bowel Syndrome
271 (IBS), diabetes, colorectal cancer, etc., which majorly occur due to gut microbiota dysbiosis

272 (Monk et al.,2017). The inclusion of chickpeas into a regular diet not only helps to meet the
273 daily nutritional requirement but also fulfills several nutrients required for human gut health as
274 illustrated in Fig 2. Moreover, most of the acute and chronic intestinal disorders often disrupt
275 the natural integrity of the intestinal barrier (Huang et al.,2023). Chickpea can be used as an
276 effective alternative for carcinogenesis. For instance, sprouted chickpea is represented as
277 chemo-preventive and has a potential effect on colorectal cancer treatment due to the presence
278 of isoflavonoids and dietary selenium. This leads to apoptosis due to overexpression of cell
279 surface death receptors and thus reduces tumor cell growth (Felix et al.,2019). Besides, it is
280 found that daily consumption of chickpea (200gm/day) reduces the risk of colorectal cancer
281 due to the production of SCFA such as butyrate, which induces apoptosis and inhibits cell
282 growth (Wallace et al., 2016). Similarly, several meta-analyses have stated that daily intake of
283 $\frac{2}{3}$ cup of chickpea can effectively maintain the health of an individual (Kadyan et al.,2022).
284 Besides, the gut bacteria perform fermentation on the prebiotic carbohydrates of chickpeas,
285 which prevents the occurrence of colon cancer (Johnson et al.,2020). This might be due to the
286 ability of dietary fiber to bind with secondary bile acids (BA's), which controls the level of
287 BA's. Also, this structural connection may influence host physiology by avoiding the build-up
288 of toxic BA's responsible for polyps and colon cancer (Makki et al., 2018). Similarly, chickpea
289 protein by modulating immune response and produce butyrate that induces apoptosis in cancer
290 cells (Wang et al.,2021). Moreover, studies indicated that daily supplementation of cooked
291 chickpeas exhibited anti-inflammatory and antioxidant properties, during carcinogenesis by
292 decreasing DNA oxidation, and expression of inflammatory enzymes COX-2, iNOS, and β -
293 catenin, an oncogenic protein (Chino et al.,2017). Furthermore, raffinose oligosaccharides
294 derived from chickpeas have prebiotic that can promote probiotic strains and contribute
295 antioxidant activity which helps in managing colon cancer (Pandae et al.,2024).

296 Chickpeas, like other legumes, are rich in dietary fibre, and contribute a positive effect on
297 diseases like constipation. Besides, consuming legumes like chickpeas has a positive effect on
298 reducing constipation by regulating transit time, stool size, and microbial effects (Gill et
299 al.,2021). Studies have also shown that pulses and foods rich in pulse fibre improve laxation by
300 increasing the weight of feces, though the frequency of the stools depends on age and intake
301 (Dahl and Alvarez,2019). With a consequent release of SCFA, legumes like chickpeas, rich in
302 fermented soluble fiber, act as prebiotics, contributing to an increase in biomass and fecal mass
303 (Arroyo et al.2023). Moreover, chickpeas can be clinically utilized in the treatment of
304 constipation and other gut-related diseases due to the presence of dietary fiber in it (Rao et
305 al.,2015). Similarly, the dietary fiber content in chickpeas possesses the ability to retain water

306 which hydrates the stool and causes an irritation in intestinal mucosa, leading to the release of
307 water and mucus that improves laxation (Bellini et al.,2021).

308 Inflammatory Bowel Syndrome (IBS) is a common gastrointestinal disorder that is caused by
309 abdominal pain and a disruption in the rhythm of bowel movements, usually lasting three
310 months.It is found that IBS is caused due to stress, imbalance between microbiota and
311 neurotransmitters, infection, inflammation, etc., and the treatment includes dietary supplements
312 like foods rich in dietary fiber (Zhang et al.,2023). Studies found that the phenolic compounds
313 present in chickpeas possess anti-inflammatory properties that can reduce the symptoms of
314 several gastrointestinal diseases including IBS mediated through functional gut microbiota
315 (Garcia et al.,2021). Similarly, studies have stated that dietary fiber content in chickpeas has a
316 potential effect on bowel regulation, changing intestinal permeability and managing microbiota
317 composition, which in total positively manages the etiology of IBS (Liu et al.,2015).

318 Ulcerative colitis occurs typically in the colon and rectum and mainly manifests as abdominal
319 pain, bloody diarrhea with or without mucus, and weight loss (Kim et al.,2020). Studies
320 reported a strong protective effect of chickpeas on colitis owing to their ability to regulate
321 inflammation-mediated cytokines and signaling pathways (Chen et al.,2015). Research has
322 shown that chickpea has a potential effect on colitis induced by DSS, related to their ability to
323 deactivate STAT3 and NK- κ β pathways. This leads to the inhibition of inflammatory
324 mediators, contributing to positive effects on colitis treatment (Kim et al.,2020). Also, in a
325 model for colon cancer associated with colitis, it has been observed that the intake of chickpeas
326 can impede the development of colon cancer. Notably, among the ways in which chickpea
327 consumption offers protection, includes the suppression of nitric oxide synthase and COX-2,
328 both of which play a role in inflammatory processes (Chino et al.,2017).

329 **5. Key factors influencing functionality of chickpea on gut health**

330 Chickpea contains various bioactive compounds and dietary fibers which play beneficial
331 roles in human health. Processing techniques like soaking, roasting, germination, etc., improve
332 the nutritional profile and quality of chickpeas. Mainly, this section discusses the impact of
333 different processing techniques on the bioavailability of chickpea components illustrated in Fig.
334 3. Soaking chickpeas before consumption is considered beneficial due to the lack of the
335 essential alpha-galactosidase enzyme in the gut. Inadequate hydrolysis of alpha galacto-
336 oligosaccharides in chickpeas, such as verbascose, raffinose, and stachyose, can lead to
337 gastrointestinal issues (Njoudi et al.,2019). Soaking serves as a remedy for these problems and
338 a pre-treatment, facilitating starch gelatinization and protein denaturation, resulting in a softer
339 texture for the legumes (Makki et al.,2018). Moreover, soaking the chickpeas decreases trypsin

340 inhibitors and tannins because of the water-soluble phenolic compounds (Singh et al.,2015). It
341 leaches out phytates and significantly reduces oxalates and lectins (Shi et al.,2018)
342 (Yegrem,2021). These can be attributed to the increased activity of endogenous enzymes in
343 chickpeas during soaking (Desalegn,2015). Similarly, soaked chickpeas have decreased levels
344 of alpha-galactosidase, proteolytic enzyme inhibitors, and total sugars (Vasishtha and
345 Srivastava,2013). In addition, soaking causes increased water absorption and starch
346 gelatinization in chickpeas, altering them for safe consumption (Costa et al.,2018). Dehulling,
347 a process of removing the seed husk of the grains, helps to eliminate the bitter taste of legumes,
348 reducing the tannin content of grain (Pal et al.,2017) (Patterson et al., 2017). Besides, it
349 influences the total composition of chickpeas, particularly affecting the fiber and increasing the
350 protein content (Vasistha et al.,2014). In addition, dehulling also improves the color, texture,
351 and aroma of legumes, and reduces excess fiber content responsible for bloating (Yegrem et
352 al.,2021). Moreover, dehulling enhances starch and protein digestibility as well as zinc and
353 calcium bioavailability (Oghabaei and Prakash,2020). Similarly, researchers observed that
354 chickpeas, when properly dehulled, can be digested easily and utilized potentially by the gut
355 (Ghermezgoli et al.,2017).

356 Chickpea quality can be improved by germination, owing to the improvement in bioavailability
357 of nutrients and phytochemicals, and the degradation of antinutrients (Oghbaei and
358 Prakash,2020). During the germination process, the synthesis of absorbable polypeptides and
359 essential amino acids is increased due to enzymatic activity (Yegrem,2021). Similarly,
360 proteolysis during germination leads to an increase in free amino acids and non-protein nitrogen
361 (Bulbula and Urga,2018). The rise in amino acid profile during germination can be due to the
362 breakdown of 'globulin', an abundant chickpea protein. Besides, a reduction in the fat content
363 of chickpeas during germination can be attributed to their utilization as a source of energy for
364 initiating the sprouting process (Desalgen,2015). Studies conducted on germinated chickpeas
365 showed that protein content in treated samples is higher than that of untreated samples. This
366 can be due to the enhancement of protein quality during germination by enzymatic breakdown
367 of it into simpler compounds through protease activity (Devisetti and Prakash, 2020).
368 According to research, germination results in increased levels of phytochemicals, thus
369 improving the antioxidant capacity (Pal et al.,2017). Similarly, the increase in antioxidant
370 activity in germinated chickpeas can also be due to enhanced vitamin C content during
371 sprouting (Masood et al.,2014). Also, germination leads to the modification of antioxidant
372 activity in chickpeas, due to the degeneration of carbohydrates in the seed (Arispuro et al.,
373 2018). Similarly, germination transforms chickpeas into a source of bioactive compounds, by

374 increasing antioxidant activity, and elevating phenolic compounds and gamma-aminobutyric
375 acid (GABA) levels (Idate et al.,2021). This increase in antioxidant activity during germination
376 is associated with the rise in free phenolic compounds, resulting in the reduction of the bound
377 form (Ferreira et al.,2019). Moreover, germination elevated the dietary fiber content in
378 chickpeas, transforming it into a functional food that can help maintain gut microbiota and
379 decrease transit time (Sofi et al., 2023). Antinutritional factors in chickpeas like phytates and
380 saponins are reduced by the germination process (Yegrem,2017). Activation of phytase
381 enzymes during sprouting is reported as the major cause of the reduction of phytic acid in
382 legumes (Singh et al.,2015). Similarly, chickpeas utilize phytic acid as a source of phosphorus
383 and cations for germination, which also leads to diminished levels of phytic acid (Bulbula and
384 Urga,2018). Moreover, the decrease in phytic acid during germination increases the
385 bioavailability of other minerals whereas, diminished saponin content reduces hemolytic
386 properties and off-flavor of chickpea when consumed (Devisetti and Prakash, 2020).
387 Furthermore, germination leads to reduction in alpha-amylase inhibitors, chymotrypsin
388 inhibitors, and trypsin inhibitors (TI) (Patterson et al.,2017).

389 Roasting helps improve the color, flavor, and shelf life of legumes as well as enhances protein
390 digestibility and denaturation (Kumar et al.,2020). Moreover, it leads to the transformation of
391 both macronutrients and micronutrients into a more palatable form and improves its overall
392 acceptability by improving flavor, texture, and taste (Qureshi et al., 2023). Similarly roasting
393 chickpeas helps in eliminating volatiles and other compounds like pyrazines and alkylated
394 pyrazines, which impart pleasant flavor as well as mask's off flavors (Saeed et al., 2023).
395 Furthermore, heat treatments like roasting increased protein digestibility through protein
396 denaturation, and deactivation of anti-digestive factors can be achieved (Yadav et al.,2017).
397 Similarly, roasted chickpeas also possessed high antioxidant activity, improved levels of
398 essential amino acids, reduced water activity, and hence increased shelf life (Jogihalli et
399 al.,2017). Besides, due to increased starch gelatinization, roasting leads to an increase in
400 carbohydrate levels in chickpeas (Raza et al.,2019). Additionally, roasting inactivates the
401 enzymes responsible for deterioration during the storage period, thus making chickpeas more
402 suitable for consumption (Zaaboul et al.,2019). Unlike other processing techniques, roasting is
403 considered the most effective method since it causes less contamination and consumes less time
404 in chickpea processing (Jogihalli et al.,2017). Moreover, anti-nutritional factors, e.g.tannin and
405 phytate content of chickpeas have a significant decrease. Studies have shown that roasted
406 chickpeas possess less glycemic index and high resistant starch content (Simsek et al.,2016).

407 **6. Value-added products of Chickpeas for promoting gut health**

408 Chickpeas are considered a potential functional food for gut health due to its enrichment in
409 various nutrients and bioactive compounds. Several studies have been carried out for the
410 incorporation of chickpeas in the development of beverages, instant food products, snacks, etc,
411 either by substituting any other grain or as the base ingredient as illustrated in Fig. 4. Similarly,
412 Table.3, explains the effect of chickpea based functional foods on gut health.

413 **6.1 Chickpea Based Beverages**

414 Fermentation improves nutritional profile and bioactive compounds in food while also
415 preserving it by using microorganisms as well as enzymes to break down complex substances
416 (Johnson et al.2023). It is suggested that microbial fermentation can be an effective method to
417 improve the nutritional profile of chickpea by enhancing the bioavailability of its nutrients (Zhu
418 et al.2023). Moreover, the microbial variant also plays a critical role in framing the nutritional
419 potentiality of the fermented product (Wu et al.,2024). Importance of fermented probiotic rich
420 beverages demonstrates the fact that fermentation is accepted worldwide, as it is a cost effective
421 and easy method for improving nutritional and sensory qualities of food products (Johnson et
422 al.,2023). Fermented chickpea slurries are used to develop different types of beverages which
423 can be used as an alternative for many other industrial beverages. In a study, three strains
424 including *Streptococcus thermophilus* (ST), a co-culture of ST with *Lactobacillus plantarum*
425 (STLP), and *Lactococcus lactis* (STLL) were used to prepare the fermented chickpea-based
426 beverage. The product possesses excellent sensory properties, functional properties, and high
427 protein content and can be consumed as a nutrient-rich, plant-based beverage (Mefleh et
428 al.,2022). Moreover, chickpea-based beverages produced using lactic acid bacteria (LAB)
429 fermentation have shown potential improvement in aroma, vitamin B6 (Pyridoxine) content,
430 total flavonoids, antioxidant, and lactic acid content (Zhang et al.,2022). These changes not
431 only lead to an enhanced organoleptic property but also suggest potential gut health benefits,
432 as LAB in fermented products are known to promote a healthy gut microbiota. Furthermore,
433 researchers have developed a potential alternative for dairy milk, from chickpea and coconut,
434 which is nutritionally stable with a good amount of carbohydrates, protein, fat, and calcium,
435 compared to cow's milk. Chickpea-based beverages are considered better than peanuts and soya
436 drinks as there are no officially recognized allergens in chickpeas, making it a favorable choice
437 for gut health-conscious consumers (Cabanillas et al.,2018). Similarly, chickpea based
438 beverages are developed as an effective alternative to soy based beverages, as it is
439 comparatively less in fat and highly fermentable (Wang et al.,2018).

440 **6.2 Sattu or Roasted Chickpea Flour**

441 Sattu is a traditional Indian food product, made of roasted and powdered chickpeas, consumed

442 in the form of drink, laddoo and litti chokha (Nath et al.,2017). Due to its shelf stability, high
443 protein content, taste, and easy availability, sattu is considered a supplement in rural India
444 (Sharma et al.,2020). Additionally, the low glycemic index of sattu allows it to be preferred by
445 diabetic individuals. Moreover, in order to prevent malnutrition, it is served as a nutrient rich
446 drink to infants during their translational age (Kaur and Prasad, 2021). It is generally consumed
447 in the form of a slurry with milk, which has shown beneficial effects on gastrointestinal
448 discomfort (Arooj et al.,2021). Similarly, sattu is chosen for its low glycemic index and high
449 fiber, which aids in regulated bowel movement (Shakeb et al.,2022). Due to its cooling effect
450 on the body, sattu is mainly consumed as a drink during the summer season in the Northern
451 parts of India (Munir et al.,2020). According to Ayurveda, sattu is recommended to be
452 consumed with sugar and ghee for better results during summer (Singh et al., 2023). It is also
453 used in developing stirred bio yogurt, as a prebiotic which is observed to be beneficial for gut
454 health (Arooj et al.,2021). Besides, sattu can be used in the form of Mantha, a traditional instant
455 energy drink, which relieves fatigue and thirst (Singh et al.,2021).

456 **6.3 Chickpea Based Snacks**

457 In the global food sector, snack industries are the fastest growing sector and people nowadays
458 are consuming snacks regularly. Chickpeas, in roasted form, coated with jaggery or spices are
459 largely consumed as a healthier snack in India (Kaur and Prasad,2023). In reference to gut
460 health, chickpeas could be an effective alternative to commercially available snacks due to its
461 high nutrient content, source of prebiotics, gluten free alternative, low cost, and environment-
462 friendly approach (Escobedo and Mojica,2021). Generally, snacks contain an anti-nutritional
463 factor called ‘acrylamide’, which can be reduced by incorporating chickpea flour into it (Rosiak
464 et al.,2015). Nevertheless, chickpea based extruded product is considered crispy and dense in
465 nutrients with low lipid levels, and high protein and mineral content, making it an acceptable
466 ready to eat snack in the market (Kaur and Prasad,2023). Crackers developed with chickpea
467 flour are also observed to be a rich source of protein, dietary fiber, and minerals. Moreover,
468 they exhibit good starch digestibility, making them a nutritious choice for promoting gut health
469 (Sun et al., 2023). Besides, germinated chickpeas are utilized as fat replacers along with wheat
470 flour in biscuits with nutraceutical properties (Saeed et al.,2023). Similarly, chickpea-based
471 high protein bars are also developed by researchers, with good overall nutrition and palatability
472 (Gupta et al.,2019). Moreover, cracker-type, gluten-free snacks for children, made using
473 chickpea flour possessed a balanced amino acid content with low glycemic index (Esparza et
474 al.,2023).

475 **6.4 Chickpea based instant food products**

476 Wheat flour is replaced with chickpea flour, in gluten free pasta, which is more acceptable in
477 terms of taste, texture, high protein and fiber content along with less fat profile (Cristina et
478 al.,2019). Instant soup mix formulated from chickpeas can be consumed as a functional food
479 by the elderly, which can be palatable and will meet the nutritional requirements (Mohammed
480 et al.,2020). Researchers have developed instant beverage powder by sequential alcalase and
481 alpha-amylase catalysis of chickpeas, which can be beneficial for vegan consumers, due to the
482 solubility and nutritional quality (Leon et al.,2021). Furthermore, studies have partially replaced
483 conventional wheat flour with fermented chickpea flour, aiming to develop a functional bread
484 (Shrivastava and Chakraborty,2018). Moreover, gluten-free bread developed using roasted
485 chickpea flour possessed soft crumbs, and improved nutritional and technological
486 characteristics (Kahraman et al.,2022). Similarly, the incorporation of chickpea flour into bread
487 resulted in appetite suppression, reduced diastolic blood pressure, and improvements in
488 glycaemia, insulinaemia, and antioxidant status of blood (Amoah et al.,2022). Gluten free
489 instant sweet pancake mixes are developed successfully by replacing cereal flours with
490 chickpea flour, which can be accepted by a broad range of customers. The product possessed
491 high protein content, low carbohydrate and salt levels, in comparison to the conventional cereal-
492 based pancake mix (Santos and Vasconcelos,2023).

493 **6.5 Hummus**

494 Hummus is a product made out of chickpea paste along with the addition of spices and oil and
495 is usually used as a dip or a spread (Wallace et al.,2016). It is a traditional dish originating from
496 Middle East and Mediterranean countries. The overall chickpea consumption in the world is
497 clearly associated with hummus, which is made by blending cooked and mashed chickpeas with
498 lime juice, tahini, spices, and olive oil (Olaimet et al.,2018). Due to its good nutritional profile,
499 including high amounts of protein, dietary fiber, folate, and unsaturated fats, hummus has been
500 seen as a healthier food in recent years (Alvarez et al.,2014). Similarly, the store bought
501 hummus is also a source of unsaturated oils, dietary fiber, folate, calcium, and magnesium
502 (Muñoz et al.,2021). Studies showed that the moderate consumption of hummus is exhibited
503 to maintain gastrointestinal health by slowing down carbohydrate absorption and delayed
504 gastric emptying (Wallace et al.,2016). Moreover, even a short term consumption of a
505 mediterranean diet including hummus exhibited good glycemic control (Reister et al.,2020).
506 However, the formulation of commercial hummus is constantly altered and tailored aiming to
507 develop a tastier and healthier functional food (Alvarez et al.,2017). Furthermore, probiotic
508 hummus is also available in the market, developed by the addition of selected probiotic culture
509 to freshly prepared conventional hummus (Al-Awwad et al.,2014).

510 **6.6 Chickpea based prebiotic products**

511 Chickpea, with its significant level of prebiotics, serves as an ideal food for enhancing prebiotic
512 consumption in individuals, due to its numerous physiological benefits in gut health (Siva et
513 al.,2018). Studies conducted on the effect of chickpeas as a prebiotic source concluded that the
514 levels of *Bacteroidetes* and *Actinobacteria* were higher whereas the level of pathogenic
515 bacteria '*Firmicutes*' was lower in the host (Johnson et al.,2020). On the increasing demand for
516 plant based prebiotics, chickpea based prebiotic food products are available in the market.
517 Besides, commercial prebiotic products like Bimuno and Benefiber, derived from
518 fructooligosaccharides and inulin promote only gut bacteria, whereas chickpea based prebiotics
519 offer additional benefits like high protein and fiber content (Siva, 2019). Indeed, commercial
520 prebiotic products are less shelf stable due to presence of live cultures whereas chickpea based
521 prebiotics have longer shelf life when dried or canned (Sidhu et al.,2020). Bio-yoghurt
522 developed by utilizing yoghurt starter with other probiotic strains exhibited prebiotic
523 characteristics due to the incorporation of chickpea as a prebiotic (Hussein et al.,2020).
524 Similarly, yoghurt integrated with chickpea flour is a promised source of prebiotics, protein and
525 fiber (Patil et al.,2024). Tempeh is a fermented food product from chickpeas, which has
526 prebiotic and probiotic properties (Teoh et al., 2024). Moreover, among non-dairy matrices,
527 chickpea is the most prominently used legume, for the preparation of fermented drinks as it is
528 prebiotic in nature (Chaturvedi and Chakraborty,2021). Furthermore, researchers have also
529 developed prebiotic snack bars using chickpeas rather than conventional dairy based bars or
530 supplements (Rajagukguk et al.,2021). Beside, the addition of chickpea mucilage to kefir
531 improves its prebiotic quality, potentially enriching its beneficial effects on gut health (Saadi et
532 al.,2020). Similarly, researchers have developed prebiotic gluten-free cookies by incorporating
533 chickpea flour (Gök and Çelik,2021).

534 **7. Conclusion**

535 Chickpea, which can be easily included in the daily diet, is considered a good source of all the
536 nutrients for preventing malnutrition and promoting health. As pulses are rich in protein, they
537 are seen as a staple food in the vegetarian diet. Besides, the bioactive compounds present in
538 chickpeas have potential benefits for gut health. It is also evident that dietary fiber and protein
539 content in chickpeas will prevent the occurrence of cancer, reduce inflammation, and improve
540 digestion. Furthermore, the application of different processing techniques like soaking,
541 dehulling, roasting, and germination improves the nutritional profile of chickpeas along with
542 the significant reduction in anti-nutritional factors like tannin, phytic acid, and protease
543 inhibitors. The incorporation of chickpea-based functional foods in daily diet will reduce the

544 risk of digestive tract diseases like IBS, colon cancer, and ulcerative colitis as well as nourish
 545 the beneficial gut microbiota. Besides, the review identifies contributions that can guide future
 546 research, encouraging further exploration of chickpeas' role in gut health and the development
 547 of interventions. Moreover, future studies should focus more on clinical and subclinical trials
 548 to confirm the mechanism in which chickpea constituents influence gut health. Indeed, there is
 549 a need to explore the synergistic effect of chickpea with other other components and prebiotics
 550 to identify its effective combination for gut health.

551

552

553

554 **Abbreviations**

BA	Bile Acid
CD3+	Cluster of Differentiation 3
COX-2	Cyclooxygenase-2
DSS	Dextran Sodium Sulphate
IBD	Inflammatory Bowel Disease
IBS	Inflammatory Bowel Syndrome
IL-6	Interleukin-6
IL-8	Interleukin-8
LAB	Lactic Acid Bacteria
MUFA	Mono Unsaturated Fatty Acid
NK- κ B	Nuclear Factor Kappa-B
NK- $\kappa\beta$	Nuclear Factor- Kappa Beta
PUFA	Polyunsaturated Fatty Acid
RTCPM	Ready To Cook Porridge Mix
SCFA	Short Chain Fatty Acid
ST	Streptococcus Thermophilus
STAT3	Signal Transducer and Activation Transcription 3
STLL	Streptococcus Thermophilus with Lactobacillus Lactis
STLP	Streptococcus Thermophilus with Lactobacillus Plantarum
TI	Trypsin Inhibitors
TNF- α	Tumor Necrosis Factor- α
ZO-1	Zonula Occluden-1

555

556

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Table 1: Comparison of our Proposed Work with State of the Arts

Reference	Importance of gut health	Mechanism of nutrients on gut health	Functional foods for gut health	Chickpea and gut health	Future Direction	Objectives
(Yang et al.,2020), (Beam et al.,2021)	✓	✓				To obtain relative information regarding the importance of gut health and effect of diet on the host gut.
(Gallauziaux et al.,2021), (Makki et al.,2018).		✓				To explore the mechanism of nutrients on maintaining gut health.
(Gomez et al.,2021), (Ashaolu,2020)			✓			To compare the effect of different functional foods on gut health.
Garcia et al.,2021)		✓		✓		To investigate the effect of chickpea consumption on gut microbiota and its mechanism.
(Vinod et al.,2023)		✓				To provide insights of the essential nutrients and its futuristic

						perspective s on modulating gut microbiom e.
Proposed work	✓	✓	✓	✓	✓	Added below

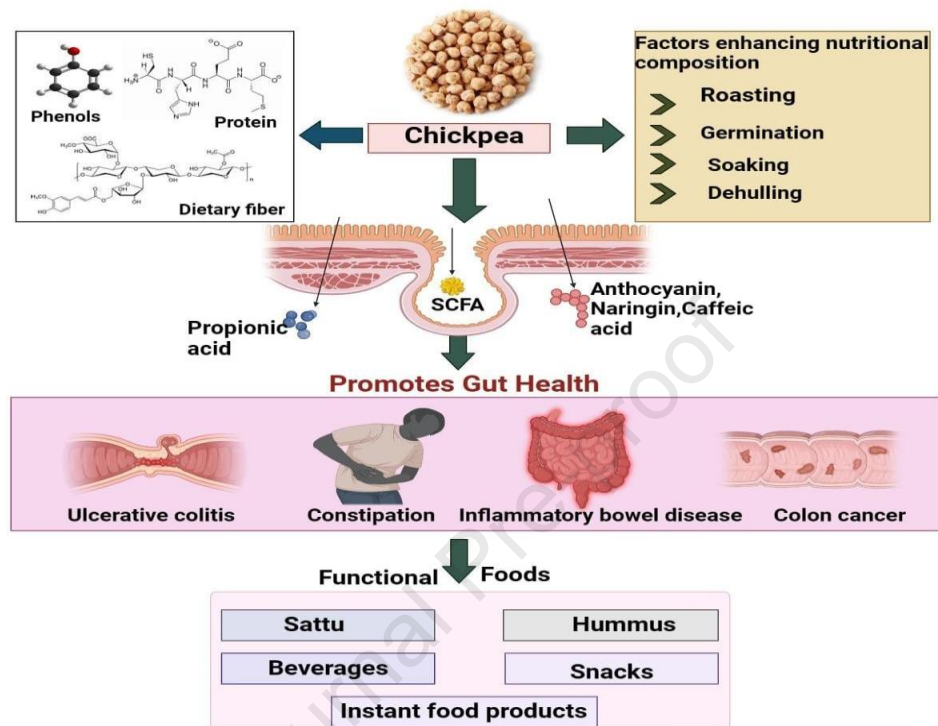
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Table 2: Nutritional composition of *Desi* and *Kabuli* type of Chickpea

Nutrients	Desi Type	Kabuli type	Reference
Carbohydrate (%)	51.74-70.17	61.70-72.8	(Singh et al.,2018),(Ghribi et al.,2015)
Protein (%)	20.29-22.37	23.68-24.51	(Singh et al.,2018),(Ghribi et al.,2015)
Amino Acids (mg/100g)			
Total essential amino acid	33.59	32.63	(Xiao et al.,2023),(Ghribi et al.,2015)
Total essential amino acid	51.57	54.55	
Fat (%)	3.62-4.62	4.12-5.03	(Singh et al.,2018)
Dietary Fibre (%)	18.73-23.8	21.86	(Ghribi et al.,2015)
Vitamin (mg/100g)			
Thiamine	0.33-0.36	0.31-0.33	(Xiao et al.,2023)
Riboflavin	0.21	0.26	
Niacin	1.72	1.22	
Pantothenic acid	1.09	1.02	
Minerals (mg/100g)			
Calcium	148-178	145-189	(Nobile et al.,2013), (Khetarpaul et al.,2018),(Ghribi et al.,2015)
Phosphorus	355	35	
Manganese	1.15-1.32	1.39-1.42	
Iron	5.2-5.3	4.6-6.4	
Copper	1.16-1.30	1.20-1.30	
Zinc	3.32-6.17	2.53-4.18	

Table.3: The effect of chickpea based functional foods on gut health.

Chickpea based functional foods	Description	Major nutrients	Effects on gut health	References
Chickpea beverages	Fermented beverages and milk	Protein, Carbohydrates, B complex vitamin, Probiotics.	Supports digestion and gut microbiome balance.	(Zhang et al.,2020), (Cabanillas et al.,2018).
Chickpea based instant food products	Bread, pasta, soup mix, pancake mix	Protein, Fiber	Provides protein and prebiotic fiber for flourishing gut microbiota.	(Karlund et al.,2019), (Gupta et al.,2019), (Mohammed et al.,2020).
Chickpea based snacks	Protein bars, crackers, biscuits.	Protein, essential amino acids, dietary fiber	Propionate and butyrate production balances colonocytes and maintains mucosal integrity.	(Arroyo et al.,2023), (Sun et al.,2023), (Esparza et al.,2023).
Chickpea based dips	Hummus	Protein, fiber	SCFA decreases carcinogenesis in the gut as well as increases the abundance of Bacillus and Bacteroids.	(Muñoz et al.,2021), (Han et al.,2021).
Chickpea based prebiotic foods	Yoghurt, Tempeh.	Prebiotics, protein, dietary fiber.	Promotes gut bacterial growth and aids digestion.	(Patil et al.,2024) , (Teoh et al.,2024) .



Graphical abstract

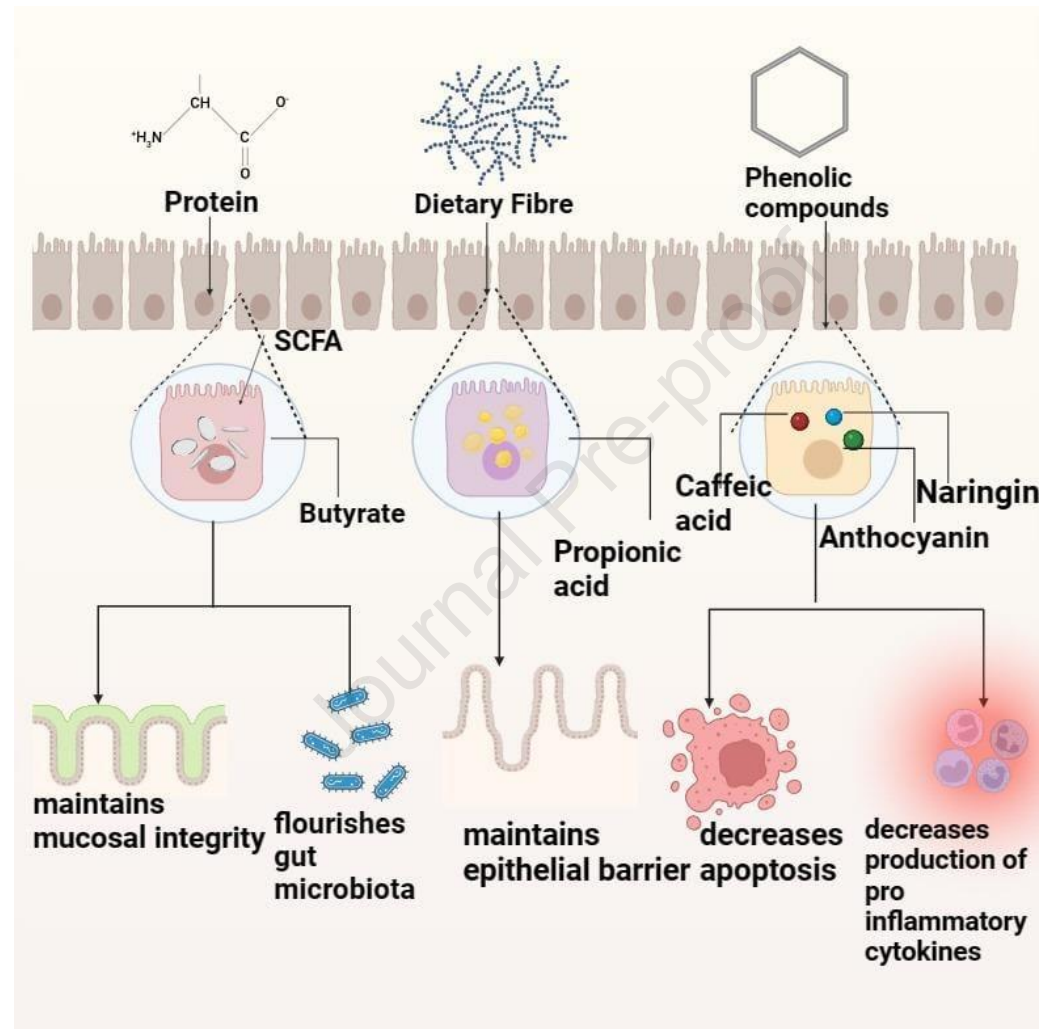


Figure 1: Chickpeas mechanism of action by promoting digestion, diversifying gut bacteria, and providing anti-inflammatory and antioxidative benefits through fiber, protein, and phenolic compounds.

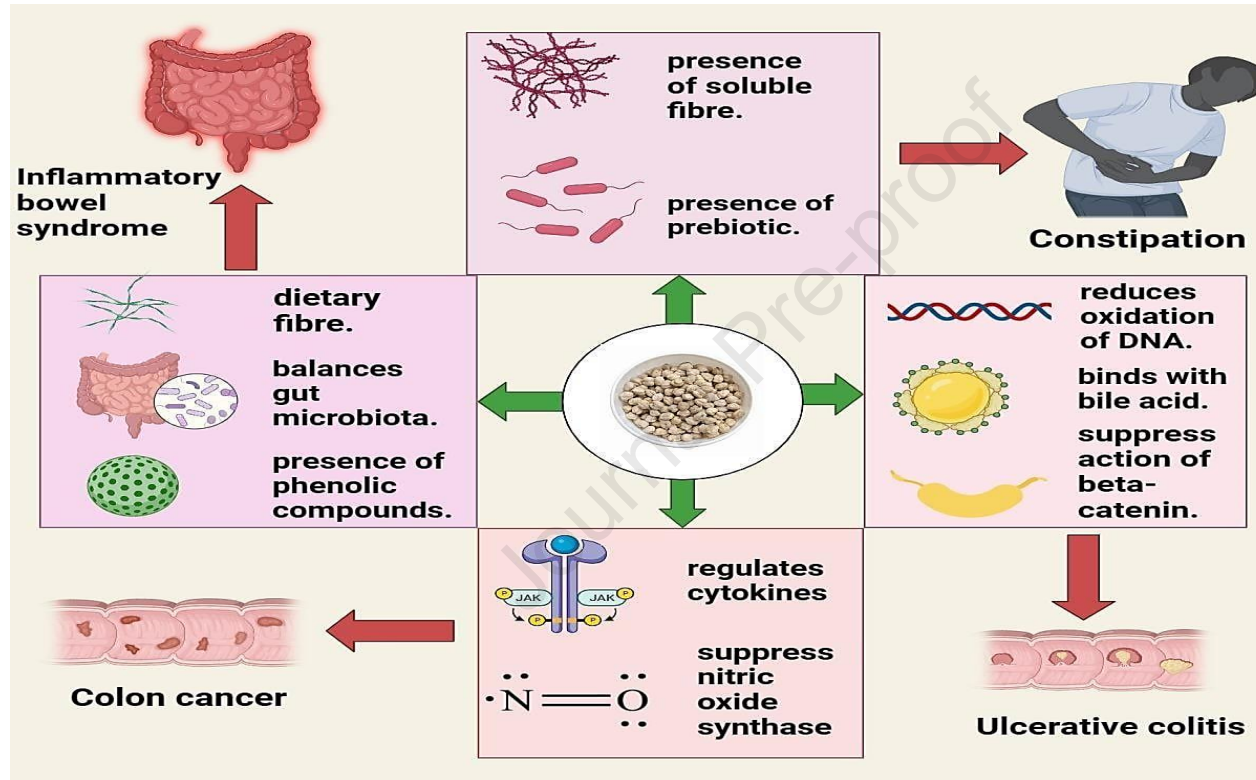


Figure 2: Potential health benefits of chickpea on gut health (Chickpeas promote gut health, guarding against colon cancer through isoflavonoids and selenium. Dietary fiber prevents constipation, acts as a prebiotic, and eases IBS and ulcerative colitis symptoms by reducing inflammation.)

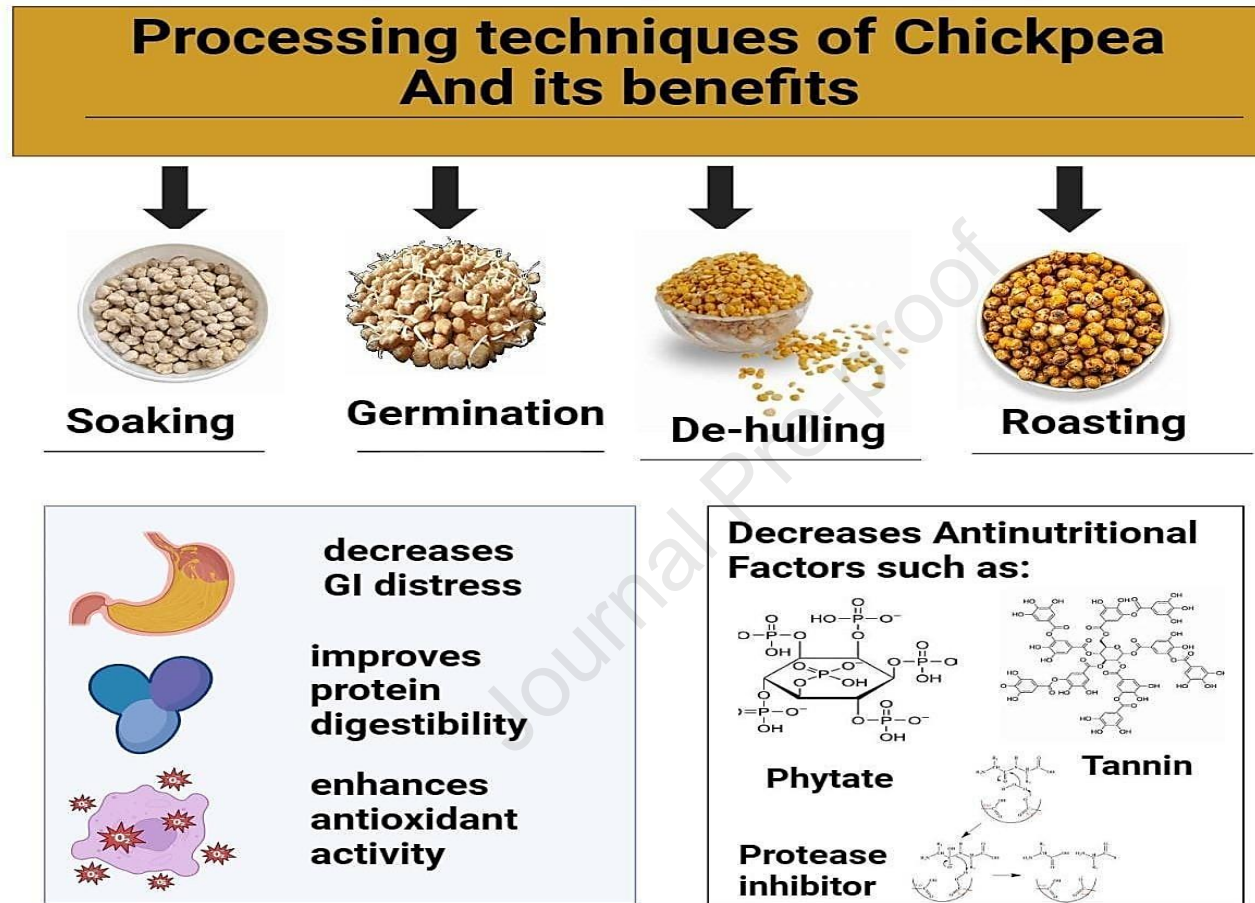


Figure 3: Processing techniques like soaking, dehulling, germination, and roasting enhance chickpea bioavailability, digestibility, and overall appeal by reducing anti-nutritional factors, improving palatability, and boosting nutrient content.

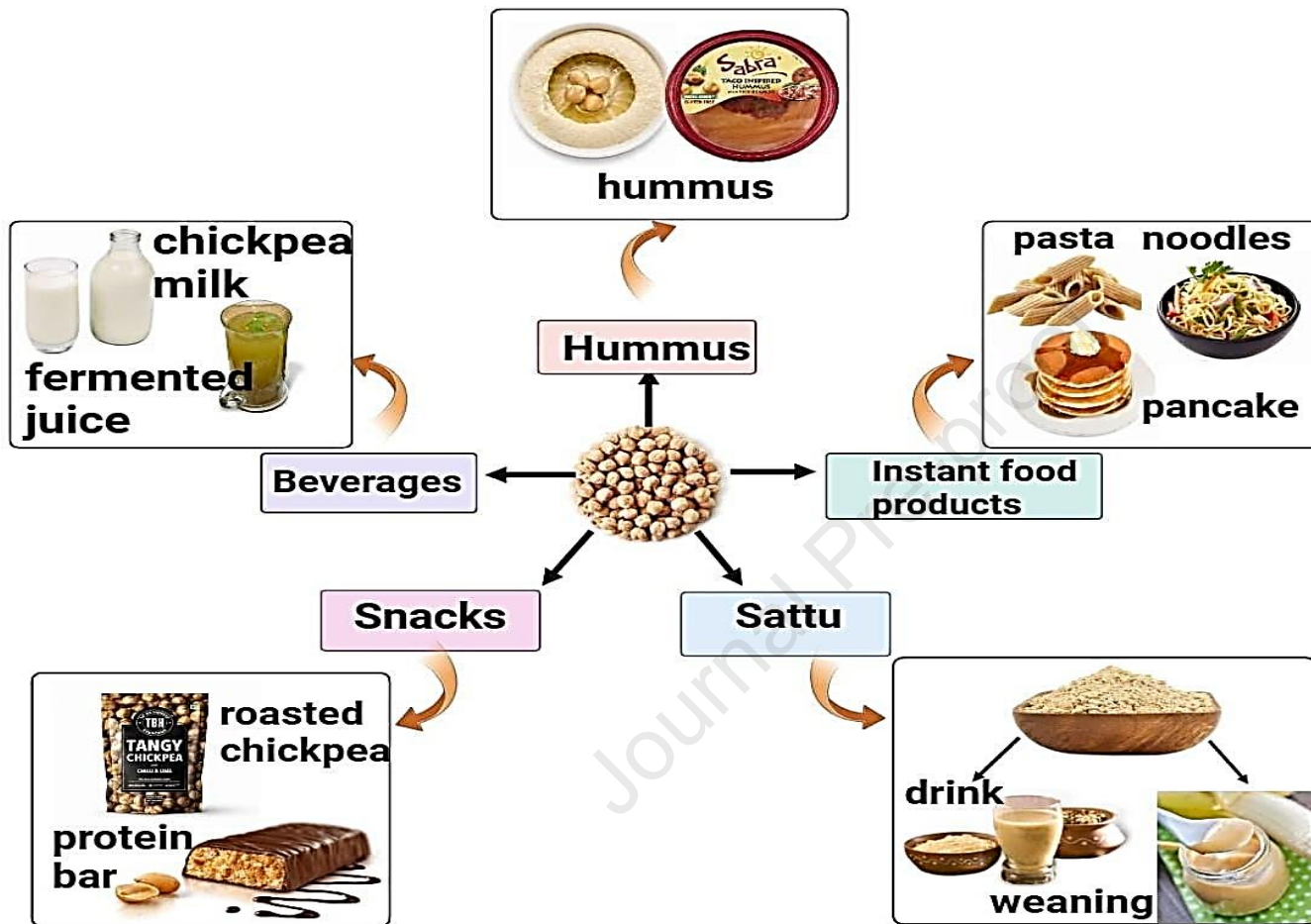


Figure 4: Chickpea based functional foods like hummus, sattu, snacks, beverages, and instant items offer affordable and nutritious choices for gut health. Being a rich source of protein, fiber, and essential nutrients, they are suitable for different diets and health needs.

There is no conflict of interest between the authors.

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