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Nutrient limitations of the edible sprouts: A review

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Abstract

In recent times people are quite aware of health and nutrition. Both fibers and proteins play an effective role in human nutrition. Even though animal meat contains more protein than plant protein, it is devoid of fibers'. However, plant sources found to be contain both protein and fibers in high amounts. The seeds are good reservoirs for rich proteins and fibers, especially during sprouting. During the germination process seeds release light proteins along with various vitamins i.e Vit. A, B complex vitamins, C - vitamin, E- vitamin and K- vitamin and minerals i.e Ca, Mg, Zn, Fe, Se and K. Among the seeds pulses showed significant levels of proteins, fibers, vitamins and minerals. Sprouting time and cooking showed significant variations in their nutrient contents and this review clearly emphasizes the changes in sprouts due to time and cooking.

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Introduction

A healthy, adequate, and balanced diet is only possible with a sufficient intake of proteins through diet (Can and Can, 2022). The recommended daily intake of protein for adults varies between 0.8 and 1.6% (average 1%) of body weight, depending on age, physical activity, and physiological status (FAO, 2020). Despite animal proteins being superior to plant proteins in many respects, insufficient production, high prices, and low purchasing power play an important role in animal protein deficiency (Ismail *et al.*, 2020). Hence, consumers need to choose alternative protein-rich sources based on the principle of "economic rationality". In addition, access to animal protein can be a problem not only in underdeveloped countries but also for lower socioeconomic groups and the elderly population in developed countries (Berner *et al.*, 2013).

In recent years the increasing tendency toward a protein-rich diet made nutritionists search for novel and high-quality but least expensive sources of protein (Podsedek, 2005). Further, some religious and cultural habits of the people of developing countries like India limited the consumption of animal proteins (Lahsaeizadeh, 2001; Hindu ethic of nonviolence, 1996; Devi *et al.*, 2014). Alternative sources of proteins that could alleviate this problem include proteins from different plants. In this context, legumes, particularly pulses emerged as an important and irreplaceable source of dietary proteins (Akhtar *et al.*, 2022). Sprouted seeds are ready-to-eat vegetables that have been harvested at very early stages of growth. Sprouts are shoots of germinated seeds. They are excellent sources of protein, vitamins, minerals, and key health-promoting phytonutrients (Rosaiah *et al.*, 1994). Because sprouts are harvested at such a young stage of growth days, their nutrient density remains high. The array of phytochemicals, nutrients, vitamins, minerals, enzymes, and amino acids found in sprouts is of great interest because of their potential for human health benefits (AACR, 2005; Webb, 2005). Some putative protective phytochemicals are found in higher amounts in young sprouts than in mature plants (Harrison, 1994; Fernandez-Orozco, 2006). Sprouts have been viewed as a healthy food in the Far East for more than 5,000 years. The global Bean Sprouts market size was valued at USD 5615.58 million in 2022 and is expected to expand at a compound annual growth rate (CAGR) of 6.89% during the forecast period, reaching USD 8376.7 million by 2028 (https://www.marketwatch.com). The increase in sprout consumption is partly attributed to the high nutritional value of this food (Viswanathan and Kaur 2001; Bharathi *et al.*, 2001). Moreover, the role of sprouts against certain carcinogens and reducing the risk of developing chronic diseases is not ignorable (Wu *et al.*, 2004; Marton *et al.*, 2010; Sikin *et al.*, 2013).

Pulses are the legumes harvested solely for their dried fruit. They are an important source of proteins, carbohydrates, dietary fiber, vitamins, carotenoids, and phenolic compounds (Khedidja, 2016; Saini *et al.*, 2019). Despite of high nutritional value of pulses, they contain several antinutritional compounds as well, such as trypsin and chymotrypsin inhibitors, lectins, tannins, phytic acids, and amylase inhibitors (Kumar *et al.*, 2021; Lovro *et al.*, 2023). To improve the nutritional value and to provide effective utilization of pulses to a maximal level, it is essential to remove the activity of anti-nutritional factors (Devi *et al.*, 2019; Faizal *et al.*, 2023). In this regard, many researchers have shown that these anti-nutritional factors can be eliminated by different processing methods like soaking, germination, and cooking, etc. that tend to modify the composition and availability of nutrients (Jain *et al.*, 2009; Ann *et al.*, 2016; Das *et al.*, 2022).

Germination is usually practiced as a household processing technology even in many underdeveloped regions as it is a low-cost option to improve the existing dietaries (Aloo *et al.*, 2021). Sprouts have been reported to be nutritionally superior to their respective seeds with higher levels of nutrients and lower amounts of anti-nutrients (Ebert, 2022; Zinia *et al.*, 2022). However, it was reported that the sprouting time and the quality of water in which the seeds are soaked affect the biochemical and nutritional qualities of pulses (Shah *et al.*, 2011). Similarly, many studies were conducted to determine the nutritional values of pulses in raw and cooked forms, and minor changes were noticed in the proximate composition of pulses after cooking (Zhang *et al.*, 2019; Hanif *et al.*, 2019). The present data are evidence that the impact of various factors i.e. sprouting time and cooking time on the biochemical and nutritional value of sprouted and cooked pulses is meager. The present study emphasizes the impact of sprout time and cooking time on the nutritional potentiality of sprouts.

Effect of sprouting time on proximal composition

Sprouting is a complex metabolic process during which storage proteins, carbohydrates, and lipids are broken down to provide the energy necessary for the developing plant (Ziegler, 1995). As seeds are soaked, enzyme inhibitors are disabled and the seed explodes to life. Germination unfolds, and enzymes trigger elaborate biochemical changes. Sprouting is reported to be associated with improvement in the nutritive value of seeds (Badshah *et al.*, 1991; Khattack *et al.*, 2007). At the same time, there are indications that germination is effective in reducing phytic acid and flatulence causing oligo saccharides, stachyose, and raffinose increasing protein digestibility and improving sensory properties (Lintschinger *et al.*, 1997). However, the sprouting depends on the types of pulses, conditions, and duration of the sprouting process (Savelkoul *et al.*, 1992; Ehirim *et al.*, 2018). Effects of various sprouting times on the biochemical and nutritional qualities of pulses are reviewed here.

Proximate composition

Moisture content

Estimation of moisture content is an important part of proximate composition analysis of food samples. Moisture contents of sprouts were significantly influenced by sprouting time showing an almost linear upward trend with the passage of sprouting time. Masood *et al.* (2014) reported an increase in the moisture content of chickpea and mung bean varieties with sprouting time. The mean values for moisture concentration in un-sprouted samples of mung bean and chickpea were 10.5% and 9.0%, which increased to 68.63% and 56.70% respectively after 120 h sprouting. Khalil *et al.* (2007) and Shah *et al.* (2011) also found a significant increase in the moisture level of mung bean cultivars and desi and kabuli chickpea seeds after sprouting for 96 h. As germination proceeds, seeds took up water from the surrounding for the metabolic process to start. Dry legumes absorb water rapidly, influenced by the structure of the legume. The increase in water uptake with time is due to the increasing number of cells within the seed becoming hydrated (Nonogaki *et al.*, 2010). Uwaegbute *et al.* (2000) observed that the moisture increased from 15.6 to 17.6 % after sprouting cowpea.

Protein

The effect of sprouting was highly significant on protein content, which showed an increasing trend with sprouting time. Some workers (Alexander, 1984; Sattar *et al.*, 1995), reported slight to considerable increases in the total protein content during soaking and subsequent sprouting of plant seeds. However, these trends may not be due to increases in the true protein content but the result of elevated values of non-protein nitrogen which indeed has been observed in certain studies (EI-Shimi *et al.*, 1984).

Shah *et al.* (2011) reported that the protein content in variety Ramzan of mung bean increased from an initial value of 20.3 to 27.7% in 96 h sprouting. In the case of variety NM-98 the protein contents increased from an initial value of 19.25 to 26.8% in 96 h sprouting. Parameswaran and Sadasivan (1994), Khatoon and Prakash (2006), Urbano *et al.* (2005), Ghavidel and Prakash (2007), and Kaushik *et al.* (2010) also noted an increase in the protein content in germinated grains. Masood *et al.* (2014) observed a sharp increase in crude protein after 24 h sprouting time in mung beans and chickpeas but then it became gradual with further progress in sprouting time. An increase in protein content was also noted by Camacho *et al.* (1992) during the germination of beans, chickpeas, and pea seeds. Mehta *et al.* (2007) have found that 19.15% increase in the crude protein content of cowpea after 28 h of sprouting. Uppal and Bains (2012) observed crude protein increase from 8 to 11 % after sprouting. However, the decrease was also observed in crude protein with germination (King and Puwastien, 1987; Torres *et al.*, 2007; Veluppillai *et al.*, 2009) and given the reason that the decrease in total protein content is concurrent with the increase in amino acid content caused by high level of protease activity during germination. El-Edawy *et al.* (2003) worked on mung bean, and pea seed flours and observed a significant decrease in total protein content with increased germination time in all legume seed flours, while non-protein nitrogen content significantly increased. The decrease in proteins could be attributed to their use as energy sources to start germination. Higher sprouting temperature and longer sprouting time would mean a greater loss in dry weight and more increase in crude protein content. There is a reawakening of protein synthesis upon imbibitions (Nonogaki *et al.*, 2010), which leads to an increase in protein content in sprouted seeds.

Fat

Sprouting treatments have a significant effect on the ether extract irrespective of legume type. Sprouting caused a reduction in crude fat content. Masood *et al.* (2014) reported that the un-sprouted samples of mung bean and chickpea have the highest average value (3.79%) for ether extract which was reduced to 2.97% after 120 h sprouting time. The fat content in mung bean and chickpea seeds decreased from initial values of 1.79 and 5.80% to 1.32 and 4.62% after 120 h sprouting time. Shah *et al.* (2011) reported a total lipid loss in mung bean varieties with increased sprouting time. Shah *et al.* (2011) also reported a decrease in crude fat content in mung bean varieties with sprouting time. El-Adawy *et al.* (2003) analyzed the germinated mung bean, and pea seed flours and observed a decrease in fat content with increased germination time. The decrease in fat content could be attributed to their use as energy sources to start germination. Wang *et al.* (1997) also reported the loss of fat in cowpea flour with an increase in germination time.

Fiber content

Chavan *et al.* (1989) found that germination improves the crude fiber content in seeds due to the consumption of starch. Peer and Leeson (1985); Cuddeford (1989) assumed that the crude fiber content increases due to the synthesis of structural carbohydrates such as cellulose and hemicelluloses. Uppal and Bains, (2011) germinated mung bean seeds for 12, 16, and 20 hours and also chickpea seeds for 36, 48, and 60 hours and observed a significant increase in crude fiber content. Masood *et al.* (2014) reported higher mean values (7.41%) for crude fiber in chickpea samples than in mung bean (7.20%) over the entire period of sprouting. Shah *et al.* (2011) noted a significant reduction in mung bean sprouts at 48 h whereas further sprouting time increased the fiber content. A significant increase in fiber during the sprouting process of chickpeas was also reported by Sood *et al.* (2002). Basanti Devi *et al.* (2015) reported a significant in crude fiber content in cowpea sprouts at 24 h. Akpapunam *et al.* (1996) also observed slightly higher crude fiber content in cowpea seeds throughout the sprouting time of 24, 48, and 72 hours. Ranhotra *et al.* (1977) considered the increase in crude fiber only as apparent and attributed to the disappearance of starch.

Ash content

Most of the studies on the nutritional qualities of sprouted pulses have reported an increase in ash content with an increase in sprouting time. Although the increase was not regular during different sprouting periods and it ended in a higher mean value (3.67%) in mung bean samples sprouted for 120 h as compared to un-sprouted samples (2.75%). Chickpea sprouted samples showed a mean value of 2.59% for ash content (Masood *et al.*, 2014). El-Adawy *et al.* (2003) reported a significant increase in ash content during sprouting in mung bean, and pea seeds. They considered the apparent increase in ash content may be due to the decrease in crude fat and carbohydrate contents during sprouting. Shah *et al.* (2011) reported that ash contents calculated on a moisture-free basis increased with an increase in sprouting time in mung bean seeds. In variety Ramzan the ash content slightly decreased with 24 h germination and thereafter with 48 h and 72 h germination. It becomes at par with control after 96 h germination the ash content reaches a maximum level (Shah *et al.*, 2011). Akpapunam *et al.* (1985) and Basanti Devi *et al.* (2015) observed a slight increase in the ash content of sprouted cowpea seeds with an increase in germination time. Gujral *et al.* (2011) observed that black gram showed some decrease and green mung showed an insignificant increase in the ash content after 24 h germination.

Nitrogen-free extracts (NFE)

The NFE contents represent digestible carbohydrates. Harmuth-Hoene *et al.* (1987) reported losses in dry matter and carbohydrates for mung bean and chickpea seeds during sprouting. Khalil *et al.* (2017) while working on kabuli and desi-type chickpea varieties reported a decrease in NFE content. Masood *et al.* (2014) worked on the effect of germination time on the nutritional qualities of mung bean and chickpea seeds and observed a similar reduction trend in both mung bean and chickpea up to 96 h of sprouting. However, they further observed that mung bean had higher percent loss over and sprouted seeds in NFE content (21.32%) than chickpea (12.58%) after 120 h sprouting time. The decrease in NFE might be due to enhanced hydrolytic activities, particularly alpha-amylase activity (Lasekan, 1996). This alpha-amylase breaks down complex carbohydrates into simpler and more absorbable sugars which are utilized by the growing seedling during the germination time.

Vitamins

Vitamins like Ascorbic acid, Vit. E and β-Carotene were barely detectable in the dry pulses. However, a significant increase in the content of vitamins during germination was observed.

Vitamin C

Many studies indicated the increase of Vitamin C, which is practically absent in dry pulses after sprouting. Deosthale and Barai (1949) reported that germination increased the vitamin C and folic acid content of food legumes. Fernandez and Berry (1988) reported a significant increase in ascorbic acid during chickpea germination. As per the investigations of Sattar *et al.* (1988) ascorbic acid was not detectable in the un-sprouted mung bean seeds and this vitamin increased markedly during germination and the maximum values of 39.9 and 47.0mg/100g were observed after 48h of germination at ambient temperatures (20-35°C) and 20°C, respectively. Riddoch *et al.* (1998) reported that many species of pulses produced significant quantities of vitamin C up to five days after germination. A study by Masood *et al.* (2014) on Chickpea and mung bean varieties revealed a phenomenal linear increase in both seeds with progress in sprouting. Khalil *et al.* (2007) and Shah *et al.* (2011) also approved the same result through their works on chickpea and mung bean seeds respectively. Uppal and Bains (2012) reported 9.4 times increase in vitamin C content after 24 h of sprouting in cowpea seeds. They reported that longer sprouting periods significantly enhanced ascorbic acid in chickpeas, cowpea, and mung beans. Vanshika Handa *et al.* (2017) confirmed the increase of ascorbic acid in the germinated horse gram. The increase in ascorbic acid owes to the reactivation of the enzyme (L-Galactono- lactone dehydrogenase) involved in the oxidation of L-galactono- 1, 4-lactone to ascorbic acid (Smirnoff, 2000).

Vitamin B

Most of the research works reported about the ascorbic acid content in sprouted pulses and relatively less work was done on the quantity of other vitamins and their precursors. A study done by Vidal-Valverde *et al.* (2002) explained that germination did not produce any significant variation in the content of vitamin B1 in peas but in germinated beans, no significant changes were observed during the first 4 days, and a little but significant decrease was observed after 6 days (9 and 7%, respectively). Regarding vitamin B2 content, in general, it increased progressively during the germination of legumes. Urbano *et al.* (2004) investigated the nutrition of sprouted green peas and observed that germination caused a significant increase in levels of vitamin B2 in germinated pea flour with 80% and 87% increments for 72 h and 144 h of germination respectively. Vitamin B1 content was not affected by the germinating conditions and remained similar to that of raw peas. Sadawarte *et al.* (2018) recently showed that the thiamine content was reduced in both horse gram and green gram due to germination while the riboflavin content was increased over germination of horse gram and green gram. The vitamin B3 (Niacin) was found to be increased with the germination period.

The niacin content in horse gram and green gram was found to contain 3.65 and 2.05 mg/100 g. The increase in a water-soluble vitamin such as thiamine and niacin were also reported by Nnanna and Phillips (1989) in cowpea. With the available literature, we can say that germination showed no significant effect on vit B1 whereas Vit B2 and Vit B3 shows a significant increase in almost all pulses.

Vitamin E

Chattopadhyay *et al.* (1950) reported increases of about 25% in the tocopherol content of 7 pulses. Yang *et al.* (2001) reported that upon germination, the concentration of vitamin E and β-Carotene increases with increasing germination time. It is further supported by Khattak *et al.* (2008) who worked on chickpea seed sprouts. There is a need for research in the estimation of β-Carotene during different germination periods in all other pulses.

Antinutrients

The nutritional quality of pulses is often compromised by the presence of anti-nutritional factors such as oligosaccharides, enzyme inhibitors, saponins, polyphenols, phytates, etc. Sprouting reduces the amounts of different anti-nutrients in the seeds. However, reduction in phytic acid has been found more profound than other compounds (El-Adawy, 2002). The relatively high content of phytate in pulses is important in human and animal nutrition since phytate has long been known to interfere with the metabolism and absorption of certain minerals, notably Fe, Zn, and Ca (Graf and Eaton, 1984). In many food grains, 65 to 80% of the total phosphorus occurs as phytin phosphate. Reductions in phytic acid contents of pulses with sprouting have been frequently reported making all the associated minerals available. Borade *et al.* (1984); Khokhar and Chauhan, (1986) reported a decrease in phytic acid content in horse gram and moth bean. Chopra and Sankhalla (2004) observed a 24% decrease in phytic acid in horse gram. Uppal and Bains (2012) observed a 43.19% decrease in phytic acid in cowpea after sprouting for 24 h. Akpapunam (1985) also revealed similar results of lowering phytate levels in cowpea with the increase in germination time through 24 h, 48h, and 72h previously. As per the studies of Kataria *et al.* (1989) germination of soaked seeds of black gram for 24h reduced the contents of phytic acid, saponins, and polyphenols significantly. The same results were obtained in the sprouts of chickpeas by Chitra *et al.* 1996; Korant *et al.*, 2023). As the germination period was raised the concentration of these anti-nutrients decreased further. This reduction in phytic acid levels has been attributed to an increase in phytase activity which makes a solubilization of phytates and would release soluble proteins and minerals.

Loss of saponin from moth beans and chickpeas during germination has been observed by Khokhar and Chauhan, 1986; Jood *et al.*, 1988) respectively. Enzyme degradation could be a possible explanation for the saponin laws during germination. Sprouting has been shown to decrease the polyphenol contents of chickpeas and green grams (Rao and Deosthale, 1982; Barroga *et al.*, 1986). Wang *et al.*, 1997 reported that trypsin inhibitors decreased during germination and increased slightly as the length of the germination increased. Sangronis and Machado (2007) found a significant decrease in trypsin inhibitor activity (TIA) in white beans and black beans after 5 days of germination. Hence it can be concluded that germination shows a profound effect in lowering the anti-nutrients from pulses.

Effect of cooking on nutritional composition

The role of pulses as an excellent source of proteins appears to be limited by several factors (Elfas *et al.*, 1969) including low protein digestibility and flatulence. Although numerous toxic constituents are found in raw pulses (Gurusamy *et al.*, 2022), many of them are destroyed by adequate heat treatment, such as common cooking procedures. Pulses have been recognized as "hard to cook" and this could be a particular factor that discourages the use of pulses. Appreciable research efforts have been devoted to optimizing soaking and cooking treatments of legumes and it has been noted that excessive cooking, however, can result in decreasing nutritive value. Here is a review of the nutrients of different pulses after cooking.

Moisture content

The moisture content of pulses increased significantly by cooking in pulses like Bengal gram, horse gram, cowpea, green pea, etc according to Khatoon and Prakash (2004). The moisture content of microwave legumes was lower than pressure-cooked ones due to lower water imbibement during microwave cooking. The increased moisture loss in microwaving was reported to be low due to a greater rise in post-oven temperature, which causes more dehydration through evaporation and increased shrinkage (Cross and Fung, 1982). However, Bhatty *et al.* (2000) observed a decrease in moisture content from 8.75% to 8.00% when chickpea seeds were cooked at 100 °C for 30-40 minutes. Marconi *et al.* (2000) observed an increase in the moisture content of cooked chickpea and kidney bean seeds in both normal and microwave cooking. Further, it was also observed that conventionally cooked pulses have more moisture content than microwave methods of cooking.

Proteins

Reduction in the crude protein content of pulses during cooking was reported earlier. Taiwo (1997) reported that cooking whole dry seeds of chickpeas caused significant decreases in protein content. Bhatty *et al.* (2000) also observed a decrease from 23.01% to 21.88% in the crude protein content of cooked chickpeas. Habiba (2002) also observed a slight decrease in the crude proteins in the cooked peas. The raw seeds contained 27.2% of crude protein, while the crude protein content of cooked peas varied from 25.6 to 26.3% (dry weight basis) according to the time and method of cooking. This decrease was probably due to the leaching of water-soluble proteins into cooking water or may be due to the destruction of proteins. The slight losses in crude protein with increasing cooking time in all methods of cooking viz. normal cooking, pressure cooking, and microwave cooking was observed by Amarakoon *et al.* (2009) and he explained it as the result of partial removal of certain amino acids along with other nitrogenous compounds on increasing cooking time. However, as per the reports of Khatoon and Prakash (2006) cooking methods did not alter the protein contents of chickpeas, green gram, cowpea, and horse gram, etc. Wang *et al.* (2010) observed an increase in the protein content of cooked beans and chickpeas, but this increase is attributed to the loss of soluble solids during cooking which would increase the concentration of protein and starch in cooked seeds.

Fat

In most legumes, fat content is relatively small (<1% of their dry matter). As per the observations of Wang *et al.* (2010), crude fat content improved significantly (on a dry weight basis) in all most all the beans and peas by cooking for an optimum time which is different for each pulse. Khatoon *et al.* (2011) also showed an increase in the fat content of cooked seeds of Bengal gram, kidney beans, horse gram, etc., whereas cooked methods did not alter the fat content of green gram seeds. However, a decrease in the fat content of chickpea seeds from 3.56% to 3.50% after cooking is reported by Bhatty *et al.* (2000), and this reduction in fat content may be due to the leaching effect.

Fiber content

Thermal treatments are known to cause slight alterations in dietary fibre contents of foods. Aguilera *et al.* (2009) reported an increase in insoluble and soluble dietary fibre contents in chickpeas. Khatoon and Prakash (2006) reported an increase in dietary fibre content in dehulled seeds of cowpea, green gram, and horse gram subjected to microwave cooking. Wang *et al.* (2010) also reported an increase in soluble dietary fiber (on a dry weight basis) in cooked beans and chickpeas compared to raw samples. An increase in the SDF content of cooked peas, chickpea seeds, and kidney beans was also reported by Costa *et al.* (2006). However, Vidal-Valverde and Frias (1991) and Wang *et al.* (2008) reported a reduction in SDF due to cooking. Wang *et al.* (2010) observed that cooking significantly increased insoluble dietary fiber content for most all pulses. The increase may be due to protein fiber complexes formed after possible chemical modification induced by the cooking of dry seeds (Bressani, 1993). As per the study of Morteza Oghbaei and Jamuna Prakash (2016), dietary fibre was higher in microwave-cooked products than in pressure-cooked samples in green gram. Cooking may modify the structure of both cell wall and storage polysaccharides of pulses possibly by affecting the intactness of tissue histology and disrupting protein-carbohydrate integration, thus reducing the solubility of dietary fiber (Siljestrom *et al.*, 1986).

Ash content

A reduction in the ash content of cooked pulses was reported by various researchers. Marconi *et al.* (2000) noted that both the traditional and microwave methods of cooking resulted in the reduction of ash content in chickpeas and kidney beans. The amount of ash lost in the traditional method of cooking is considerably high when compared to the loss of ash during microwave cooking. High ash loss was also found in cooked chickpeas by Attia *et al.* (1994) and Bhatty *et al.* (2000) this decrease in ash content could be attributed to leaching in water. Wang *et al.* (2008) and Khatoon *et al.* (2011) also reported a decrease in the ash content of chickpeas, peas, kidney beans, etc. The decrease in ash content would result from the diffusion of certain minerals into the cooking water.

Nitrogen-free extracts (NFE)

Carbohydrate is the largest component of pulses (24 - 61.2%). Of this starch is the major entity ranging from 27% to 56.5% (Reddy *et al.*, 1982). There was a slight reduction in the total starch content of cooked pulses. Jood *et al.* (1988); Khatoon and Prakash, (2006) observed that cooking through autoclaving decreased the starch content and increased total soluble sugars as well as starch digestibility. Wang *et al.* (2010) also observed decreased levels of resistant starch content in cooked seeds of kidney beans, peas, chickpeas, etc. A decrease in the level of resistant starch and an increase in soluble sugars was also confirmed by the investigations of Macroni *et al.* (2000) in chickpeas and kidney beans. The reduction in the resistant starch in cooked beans may be due to the destruction of amylase inhibitors during cooking. Cooking significantly reduced the amounts of sucrose, raffinose, stachyose, and verbascose (on a dry weight basis) in both beans and chickpeas (Wang *et al.*, 2010). This reduction in these sugars may be due to the thermal hydrolysis of disaccharides to monosaccharides or to form other complexes.

Vitamins

When considering vitamins, it has been investigated by El-Adawy *et al.* (2003) that riboflavin, thiamin, niacin, and pyridoxine in chickpea seeds were significantly reduced by cooking treatments. These losses were probably due to a combination of leaching and chemical destruction. The losses by microwave cooking were smaller than those obtained with boiling and autoclaving. The improvement in vitamin retention by microwave cooking may have been due to the shorter cooking time compared to boiling and autoclaving. The sensitivity of vitamins to loss from cooking was in descending order: pyridoxine, riboflavin, thiamine, and niacin. Boiling resulted in a greater loss for each vitamin compared to the other cooking treatments. Conventional cooking caused a high loss of thiamine, riboflavin, and ascorbic acid in vegetables, but microwave cooking and autoclaving improved the retention of these vitamins compared to boiling. Thiamine losses were extremely significant in cooking ranging from 40% to 70% in comparison with raw pulses as per the investigations of Khatoon and Prakash (2004)

Anti-nutritional factors

Cooking significantly reduced the level of tannins, phytic acid, and trypsin inhibitors in cowpea seeds. The levels of reduction were about 40, 6.8-11.9, and 86.98-90.46%, respectively. The reduction is probably due to the formation of insoluble tannin-protein or phytate-protein complexes not extractable from cooked seeds (Ibrahim *et al.*, 2002). Rocha - guzman *et al.* (2007) studied three kidney bean cultivars for phenolic content and reported that the phenolic content of kidney beans after pressure cooking was reduced by 90%. Barroga *et al.* (1985) found that boiling and cooking reduced the amount of phenols in pulses by 73%. As per the study by Gujral *et al.* (2011), the phenolic content of green grams decreased significantly by 28.52% after cooking. According to the study of Kataria *et al.* (1988), cooking lowered the phytic acid, saponins, and polyphenols contents of the seeds significantly in black gram. Pressure cooking for 15 min had a greater reducing effect for all the anti-nutrients cooking after soaking seemed to be more advantageous than cooking unsoaked seeds. Phytic acid was reduced by 33% when soaked seeds were pressure cooked whereas pressure cooking of unsoaked seeds could lower phytic acid by 8% only. Levels of all antinutrients decreased further when the period of pressure cooking was raised from 5 to 15 min. When soaked seeds were normally cooked, phytic acid was reduced by 29%, saponin by 18%, and polyphenols by 14%. Similar findings were also reported by Tabekhia and Luh (1980). Reduction in the levels of saponin during the cooking of chickpeas and black gram was observed by Jood *et al.* (1988). Thermo-liable nature of saponins and the formation of a poorly extractable complex may account for the loss of saponin during cooking. A decreased amount of polyphenols in cooked seeds is also may be due to their reduced extractability or change in chemical reactivity (Satwadhar *et al.*, 1981).

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