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Review Article

Effects of Different Processing Methods on Anti-nutritional Attributes in Red Gram (*Cajanus cajan*), Bengal Gram (*Cicer arietinum*), Green Gram (*Vigna radiata*)

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Abstract

Pulses are crucial for impoverished countries since they are a more cost-effective source of protein than dairy products, cheese, nuts, meat, fish, etc. The nutritional value of pulses and their seeds is excellent, and they include respectable amounts of several vitamins and minerals in addition to having about the same number of calories per unit weight as cereals. When compared to most cereals, they frequently have twice as much protein. When compared to other countries where pulses are grown, India eats the most because to its low purchasing power and religious restrictions on consuming meat. Around 1 to 5% fat and 18.0 to 32.0% protein make up pulses. Pulses are substantially richer in calcium than the bulk of cereals, containing between 100 and 200 mg per 100 g of grain. They contain much more iron, thiamine, riboflavin, and nicotinic acid than grains do. In addition to lectins, polyphenols, flatulence-inducing substances, lathyrogens, saponins, antihistamines, and allergens, pulses also include a number of other anti-nutritional components. Heat treatment has been proven to eliminate protease inhibitors, lectins, and other proteinaceous anti-nutrients; however, heat treatment also destroys a number of vitamins and amino acids. A variety of techniques are used to process pulses, including grinding, dehulling, soaking, germination, fermentation, and cooking. These processing techniques provide edible products with a higher nutritional value and fewer dangerous substances while also conserving time, energy, and fuel, providing a number of nutritional advantages. Hazardous chemicals can be reduced to varied degrees depending on the type of pulses and the processing techniques. This review focuses on the effects of different processing methods on anti-nutritional attributes in Red Gram (*Cajanus cajan*), Bengal Gram (*Cicer arietinum*) and Green Gram (*Vigna radiata*).

Keywords: Pulses, conventional, protein, germination, soaking, anti-nutritional factors.

Introduction

Many flowering plants that release seeds in pods are referred to as legumes and are frequently farmed for food and feeds. The third-largest family of flowering plants by number of species and genera is the legumes, which have over 19,500 species and over 750 genera (Lewis *et al.*, 2016). Red gram (*Cajanus cajan*), Bengal gram (*Cicer arietinum*), and Green gram (*Vigna radiata*) are three plant species that belong to the family of legumes. Red gram is one of the oldest and most popular types of legume in the world, and it is a staple crop, especially in tropical and subtropical regions. Legumes' nutrient-rich, high-calorie edible seeds are a crucial component of the diet (Aykroyd and Doughty, 1982).

Although most legumes are considered low in fat and cholesterol, others, like soybeans, are high in oil (Karmas and Harris, 2012). It has structural carbohydrates and a balanced amino acid profile, which are advantageous for dietitians and other medical experts (Tharanathan and Mahadevamma, 2003; Ghadge *et al.*, 2008). Beans include a variety of nutrients that are favourable physiologically for both humans and animals (Hayat *et al.*, 2014). An essential food legume growing in tropical and subtropical regions is the green gramme, also known as the mung bean. It has a high protein content and nearly no ingredients that can cause flatulence. Green gram seeds are therefore favoured for feeding infants and individuals recovering from illness.

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More lysine than any other legume seed is present in the seeds. Pigeon peas are rich in protein and the essential amino acids tryptophan, lysine, and methionine. Chickpeas are a nutrient-rich food that contains high levels of protein, dietary fibre, folate, and several dietary minerals including iron and phosphorus (20% or more of the Daily Value, DV) of these nutrients. Pulses contain roughly 21-25% protein while having a limited number of crucial amino acids like methionine, tryptophan, and cystine. The Department of Agriculture and Farmers' Welfare (DA&FW) projects that in 2021–2022, 26.96 million tonnes of pulses would be produced. In comparison to the average production for the preceding five years, which was 23.82 million tonnes, the projected production for 2021–2022 is 26.96 million tonnes, an increase of 3.14 million tonnes. Pigeon pea production is expected to be 4.49 million tonnes worldwide. Its production is sourced to about 63% of India. An estimated 5.4 million hectares are used to raise pigeon peas worldwide. 3.9 million hectares or 72%, of the global pigeon pea production area are in India. Africa is the second-largest source of diversity, and it currently provides 1.05 million tonnes, or around 21% of global production (Devegowda *et al.,* 2018). The output of chickpeas reached 15 million tonnes in 2020, with 73% of the world's supply coming from India, Turkey, Myanmar, and Pakistan serving as secondary producers. However, inclusion of anti-nutritional components limited its use by interfering with digestion of carbohydrates and proteins. When ingested repeatedly, even in moderate amounts, they also impair the utilization of protein and carbohydrates and interfere with growth, reproduction, or health. Trypsin inhibitors, phytic acid, tannins, saponin, and haemagglutinin activity are a few of these elements that might have negative physiological effects or reduce the availability of specific nutrients.

Red, Bengal, and green grams are recognized for possessing phytate, saponin, trypsin, and tannin that bind to proteins and minerals like Fe, Zn, and so forth. If suitable and inexpensive processing methods are not used, it would eventually lower the bioavailability and digestibility. Anti-nutritional issues can be minimized by using processing methods such dehulling, soaking, germination, roasting, and milling. Processed legume consumption offers customers excellent nutrition and possibly health advantages. The impact of their processing techniques on the anti-nutritional traits of the various bean species has not yet been investigated.

Red gram, Green gram and Bengal gram production in India: An annual/perennial legume from the Fabaceae family, the pigeon pea is also referred to as redgram, arhar, or tur. It is a significant source of protein for the people of the Indian subcontinent and is consumed widely throughout South Asia.

Redgram is produced on 60.96 million hectares around the world, with a production of 50.12 million tonnes and a yield of 822.2 kg/ha (FAO STAT, 2020). With 42.8 lakh tonnes grown on 48.24 lakh hectares with an 887 kg/hectare yield in 2020–2021, India leads the world in redgram output (agricoop.nic.in). Redgram production in Kharif 2021–2022 was 44.3 lakh tonnes (first advance estimates) on an area of 50.02 lakh hectares (agricoop.nic). In 2020–21, Andhra Pradesh produced 0.84 lakh tonnes, or 1.96% of all the food produced in India, on an area of 2.31 lakh hectares with a productivity of 363 kg/hectare. Redgram was produced in 2.51 lakh hectares with a yield of 1.21 lakh tonnes and a productivity of 482 kg/ha between 2021 and 2022, according to 2nd advance estimates.

India is the world's top producer of green gram, and it is grown in practically every State. It is grown on roughly 4.5 million hectares with the total production of 2.5 million tonnes with a productivity of 548 kg/ha and contributing 10% to the overall pulse production. According to third advance projections from the Indian government, 2.64 million tonnes of green gramme will be produced in 2020–21. The marketing year 2020–2021 saw consumption of green gramme rise to 22.5 lakh tonnes from 21.42 lakh tonnes of production, with the remaining demand-supply gap being filled by imports of about 1.08 lakh tonnes and opening stockpiles of 2.10 lakh tonnes. (Green gram Outlook report– January to May 2021). Bengal gram is grown on 137 lakh hectares of land worldwide, producing 142.4 lakh tonnes with a productivity of 1038 kg/ha (FAO STAT, 2019). In 2020–21, India would provide 70% of the world's total production of Bengal gram, which will be grown on 112 lakh hectares at productivity of 1036 kg/hectare (agricoop.nic.in). India leads the globe in gram output, which is then followed by Australia, Burma, and Ethiopia (FAO STAT, 2019). Bengal gram comes in top place among all types of pulses produced in India, followed by black gramme. In 2020–21, Andhra Pradesh will produce 5.66 lakh tonnes over an area of 4.65 lakh hectares at productivity of 1218 kg/hectare (Third Advance Estimates, 2020-21, DES-AP).

Nutritional value of pulses: Legume seeds are excellent sources of protein, dietary fibre, various micronutrients and phytochemicals (Sreerama *et al.,* 2012), but still some legumes have remained underutilized which are consumed merely by the rural communities and low-income groups. Legume seeds are excellent sources of protein, dietary fibre, various micronutrients and phytochemicals (Sreerama *et al.,* 2012), but still some legumes have remained underutilized which are consumed merely by the rural communities and low-income groups. 100 g (3+1⁄2-ounce) reference serving of raw millet (*Panicum miliaceum* or proso millet) provides 1,582 kJ (378 kcal) of food energy and is a

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rich source (20% or more of the DV) of protein, dietary fiber, several B vitamins and numerous dietary minerals, especially manganese at 76% DV (Table 1, Gopalan *et al.,* 1989).

Table 1. Nutritive value of pulses.

Energy (Kcals)	Moisture (g)	Protein (g)	Fat (g)	Mineral (g)	Carbohydrates (g)	Fibre (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Bengal gram, Whole	360	10	17	5	3	4	4	202	312
Bengal gram, dhal	372	10	21	6	3	1	1	56	331
Bengal gram, Roasted	369	11	22	5	2	1	1	58	340
Green gram, Whole	334	10	24	1	3	4	4	124	326
Green gram, Dhal	348	10	24	1	3	1	1	75	405
Red gram, whole	335	13	22	2	3	58	1	73	304
Red gram, Tender	116	65	10	1	1	17	6	57	164

Source: Gopalan *et al.,* 1989.

Proteins: Legumes are the barely cultivated plant which has the capacity to fix nitrogen from the environment by the action of unique bacteria which survive in nodules on their roots. This nitrogen is being utilized through the plant to compose protein which becomes available to humans. Legume seeds accumulate large amounts of proteins during their development (Duranti, 2006). Legumes have superior quantity of protein in comparison with other plant foods and have twice the dietary protein content of cereal grains (Kouris-Blazos and Belski, 2016). Legume seeds enclose numerous rather minor proteins, which includes protease and amylase inhibitors, lipoxygenase, lectins and others, which are related to the nutritional or functional quality of the seed. Pigeon pea, like other beans and peas, is a fantastic vegetarian source of protein. Dry seeds provide 343 calories and 21.70 g, or 39% of the daily recommended intake, of protein/100 g. In the legumes methionine (Met), cysteine (Cys) and lysine (Lys) are in the range of 30-90, 30-130 and 400-520 mg/ g of nitrogen (N), respectively (Gopalan *et al.,* 1989). Legume seeds are among the richest food sources of proteins and amino acids for human and animal nourishment. On the other hand, legumes are considered to be incomplete protein (except soy) because they contain relatively low quantities of the essential sulphur containing amino acids cystine, Met and Cys (which are found in higher quantity in grains). However, grains contain relatively low quantities of Lys, whereas legumes contain appreciable quantity (Curran, 2012; FAO, 2014). Sorghum contains around 8-13% proteins. Ragi provides 13g of protein per 100g. This can prove to be an excellent protein source for vegans who rely on plant-based sources for their protein intake.

Dietary fibre: Adequate dietary fibre is vital for proper working of the gut, which is related to reduce risk of a number of chronic diseases including certain cancers, heart disease and diabetes. Fibre comprises pectin, mucilage, cellulose, gum, hemicelluloses and lignin (Khogare, 2012). Most of the legume grains which are consumed as pulses by humans, their fibre content ranges from 0.9-5.3% (Gopalan *et al.,* 1989). Legumes are mainly rich in resistant starch (RS), have low glycaemic index (GI) carbohydrates (Munro, 2007). The oligosaccharides (mainly raffinose and RS) and fibre pass through the stomach and small intestine in the undigested form until they reach the colon, where they act as food (prebiotics) for the probiotic or beneficial bacteria which resides there. This bacterial fermentation leads to the development of short-chain fatty acids, such as butyrate, which possibly will improve colon health through promoting a healthier gut micro biome and reducing colon cancer risk (Bird *et al.,* 2010). They also play a positive role in weight reduction due to its satiety value (Papanikolaou and Fulgoni, 2008; Li *et al.,* 2014). In addition, they are capable to help in moderating blood sugar levels after meals and improve insulin sensitivity (Mollard *et al.,* 2011). Ragi flour provides around 15%-20% of dietary fibre per 100g of serving.

Carbohydrates: Commonly consumed legumes having carbohydrate content in the range of 20.9-60.9% (Gopalan *et al.,* 1989). Carbohydrate comprises monosaccharides, oligosaccharides, other polysaccharides and starch (Ekanayake *et al.,* 2000). In the legume seeds, starch is the main source of accessible carbohydrate and most plentiful 22-45% along with 1.8-18% oligosaccharides and 4.3-25% dietary fibre (Hoover and Zhou, 2003). Sorghum contains around 60–75% carbohydrates. The saccharose and glucose content in the stalk is 10–16% (Volker and Beyel, 2003) in comparison sugar cane has a sugar content of 10-20%. Thus *Sorghum bicolor* (Sorghum) can be used as an alternative to sugar cane.

Mineral content: Legumes are excellent source of iron, calcium, zinc, selenium, magnesium, phosphorus, copper and potassium. In whole or dehulled legumes, while mineral content in the range of 2.1-4.6 mg/100 g of seeds (Gopalan *et al.,* 1989). Cereals grains generally supply the higher energy and make up the volume of diets. As sources of micronutrients legumes are much superior to cereals because legumes have higher initial minerals content. Many cereals are polished before eating for production of white rice or wheat flour for white bread (Welch *et al.,* 2000). The minerals are found in the seed coat (bran) in major proportions which are discarded during processing in case of cereals. Most legumes, including common beans are consumed whole, resulting in conserving their mineral contents.

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Sorghum bicolor (Jowar) is rich in minerals like phosphorus, potassium and zinc (Cardoso, 2016). Ragi nutritional value per 100g provides 137mg of Magnesium that fulfill 50% of your body's RDA.

Vitamins: Micronutrient deficiencies have become more common, even in developed countries. Legumes are superior source of vitamin B-complex, but are a poor source of vitamin C and fat soluble vitamins. Vitamins such as pyridoxine, niacin, riboflavin, folic acid and thiamine are under the group of B-complex. These vitamins are essential because body requires them from external sources to replenish (Dias, 2012). Vitamins and co-enzyme play important role in metabolism of carbohydrates and branched chain amino acids, numerous oxidation and reduction reactions, hydrogen transfer with numerous dehydrogenases, glycogen, and sphingoid bases. Recent reports have also implicated that the low B-complex content of diets is a major factor in the outbreak of peripheral neuropathy and visual loss observed in the adult population (Abbas and Ahmad, 2018). Jowar is the finest substitute for wheat and rice when it comes to nutrition because it has high levels of thiamine, niacin, riboflavin, and folate (Volker and Beyel 2003).

Fatty acids: Legumes are normally low in fat and have no cholesterol. Soybeans and peanuts are the exception, which have major levels of mostly monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), including ω-linolenic acid (Mudryj *et al.,* 2014). They are a superior source of linoleic and ω -linolenic acid in the range of 21-53% and 4-22%, respectively. Chickpeas have the highest MUFA content (34 g/100 g), kidney beans (Rajma) have the highest PUFA content (71.1 g/100 g) and butter beans have the highest saturated fat content (28.7 g/100 g). Lupins contain a higher monounsaturated fat and lower saturated fat content (Bouchenak and Lamri-Senhadji, 2013). Saturated fatty acids are essential to keep reserved the fat soluble vitamins like vitamin A. MUFA and PUFA decrease the possibility of CHD (German and Dillard, 2004). Sorghum contains around 4-6% fat (Volker and Beyel 2003). The starches in sorghum are difficult for the human body to digest, compared to other grains. As a result, sorghum is an excellent addition to any meal, helping to feel full without contributing too many calories to the diet.

Anti-nutritional and phytonutrients factors: Legumes have anti-nutritional factors (ANF) which affect its nutritional quality. ANF is able to decrease palatability and diminish protein digestibility and bioavailability of nutrients (Jain *et al.,* 2009). A number of the usually considered antinutritional compounds like phytic acid, phenols and tannins are currently considered as potential antioxidants containing health promoting effects. The phytic acid has now been revealed to have rich antioxidant, hypoglycaemic activities and also possess anti-carcinogenic properties, thus retention or elimination of these compounds depends upon consumer's preferences (Bhatt and Karim, 2009). Conventional food preparation techniques such as soaking, sprouting, boiling and fermentation, improve flavour and palatability of legumes as well as increase the bioavailability of nutrients, by deactivating ANF and also allows the digestion and assimilation of starch and protein (Xu and Chang, 2008). Therefore legumes except sweet lupin should not be consumed raw. Phytochemicals reduce the digestion and absorption of nutrients or interfere with their action. The bioactive phytochemicals including enzyme inhibitors are mainly represented as phytoestrogens, oligosaccharides, phytosterols, phytates, saponins, flavonoids and phenolic acids. The proteinaceous ANF includes lectins, protease (trypsin, chymotrypsin), amylase inhibitors and lipoxygenase (Kouris-Blazos and Belski, 2016). Saponins are gastric irritants but may also show anti-carcinogenic and hypocholesterolaemic activity (Bouchenak and Lamri-Senhadji, 2011). Saponins are found in chickpeas, lentils, soy, various beans and peas. Soy beans are predominantly high in saponins even after general baking and processing. In addition to tocopherols and glutathione, legumes contain several phenolic compounds which may protect against some cancers (Mo'ez Al-Islam *et al.,* 2009). Isoflavonoids, a subclass of polyphenols, act as phytoestrogens. Research has linked soy foods and/or phytoestrogens to a reduced risk of certain cancers including prostate and breast cancer, osteoporosis, problems associated with menopause and heart disease (Yan and Spitznagel, 2009). Phytosterols are structurally analogous to mammalian cholesterol, with 50-85% being β-sitosterol. These can obstruct the absorption of cholesterol from the food. Chickpeas (38.5 mg/100 g) are high in β-sitosterol (Bouchenak and Lamri-Senhadji, 2011). All edible plant seeds, together with legumes contain phytic acid. Phytate chelate minerals (especially calcium and zinc) form poorly soluble compounds which are not voluntarily absorbed from the intestine, thus interfering with the bioavailability of these essential minerals as well as inhibit enzymatic digestion of both starch and proteins (Pugalenthi *et al.,* 2005; Gibson *et al.,* 2014). Phytates can enhance the risk of mineral deficiencies sooner or later if animal food intake is low. Phytates do not show the influence on absorption of minerals from meat (Uzel and Conrad, 1998). Phytates are an alarm in developing countries where regular diets are based on legumes and grains as in case of vegetarians (Hunt, 2003). However dehulling, soaking, boiling or steaming, roasting, sprouting, sun drying and fermentation of legumes trigger an enzyme (phytase) which helps their breakdown (Lopez *et al.,* 2001; FAO, 2014; Gibson *et al.,* 2014). On the other hand phytates show useful health effects, having positive role as an antioxidant and are

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in protection against a variety of cancer and CHD, renal stones and diabetes mellitus(DM), thus total removal of phytates is not desirable (Kumar *et al.,* 2010). Due to presence of high fibre it also helps in reduction of cholesterols and other lipids (Midorikawa *et al.,* 2001).

Processing of pulses

Soaking and Dehulling: After cleaning and grading, most pulses undergo some degree of conditioning to facilitate the removal of the hull and increase ease of milling. Commercial conditioning methods include dry or wet pre-treatments, although chemical, thermal and enzymatic treatments have also been explored (Tiwari and Singh, 2012). In dry pre-treatments, pulses are sun-dried and/or mixed with water or oil before dehulling. Dry milling produces dehulled whole seeds and/or dehulled and split pulse products while wet milling produces only dehulled and split products (Wood and Malcolmson, 2011).

Soaking is a key step in the preparation of pulses with soaking temperature, time period, composition of soaking solution (water, acidic or basic) and pulse type affecting the anti-nutrient content of pulses. In most cases, soaking of pulses results in a reduction of phytate, primarily due to its water solubility and leaching into the soaking water and activation of endogenous phytase (Fredrikson *et al.,* 2001). Vidal-Verde *et al.* (1994) demonstrated that soaking lentils in a 0.1% citric acid solution resulted in a 32% reduction in phytate compared to soaking in water (27% loss) or 0.07% sodium bicarbonate solution (23% loss) while soaking in water for 12 hrs at 30°C resulted in a 4.5% to 11.2% reduction in phytate content of three pea varieties (Alonso *et al.,* 1998). Luo and Xie (2013) observed a 26% reduction in phytate in a white faba bean variety and 32% in a green colored faba bean. The total phenolic content (TPC) in lentils was reduced by 25-30% depending upon time and solution composition (Vidal-Verde *et al.,* 1994). Desi chickpeas appear to experience a greater loss in TPC (30-70%) than Kabuli (no loss to 45% loss) (Han and Baik, 2008; Khandelwal *et al.,* 2007; Segev *et al.,* 2010). Total tannins in chickpeas were reduced by 22% (Khandelwhal *et al.,* 2007) with a 3.7% to 22% reduction noted in peas depending upon soaking time and cultivar (Alonso *et al.,* 1998; Khattab and Arntfield, 2009); while others have observed a 17% to 30% reduction in tannins in various bean varieties (Alonso *et al.,* 2000; Barampama and Simard, 1994; Martin-Cabrejas *et al.,* 2008; Shimelis and Rakshit, 2007). Chickpeas soaked in water had a 12% reduction in trypsin inhibitor (TI) activity but no change when soaked in the 0.1% citric acid solution or 0.07% bicarbonate solution (Frias *et al.,* 2000). This was attributed to the trypsin inhibitor being more stable in acidic pH (Fernandez *et al.,* 1993). Soaking in water for 24 hrs increased the TI content in 6 varieties of peas by 3.2% to 19.3% (Wang *et al*., 2008). With the exception of the phenolic compounds, most pulse anti-nutrients are present in the cotyledon and dehulling of pulses generally results in an increase in the concentration of the anti-nutrient within the cotyledon fraction, rather than in the seed coats (hulls). The increase in phytic acid content in the cotyledons of ten cultivars of dehulled dry beans ranged from 6.9% in Sanilac beans to 59.8%. The extent of the dehulling effect on TI activity appears to be variety dependent. No significant effect was observed on TI in two Egyptian varieties of chickpeas (Attia *et al.,* 1994) while Marquez and Alonzo (1999) noted a 22% reduction upon dehulling Spanish chickpea cultivars.

Germination: Germination improves palatability, digestibility and availability of some nutrients (Bains *et al.,* 2014). The pulse type, germination conditions (growing under light or dark conditions, timing and amount of water addition) and duration of germination (1-10 d) affect anti-nutrient content; thus creating difficulty when comparing reported anti-nutrient values. Systematic studies were conducted by Ayet *et al.* (1997) on lentils and Vidal-Verde and coworkers (2002) on peas, lentils and edible beans with contrasting results. Optimal conditions to reduce tannins and phytic acid in lentils were found to be 6 days of germination in dark with alternate watering by Ayet's laboratory while Vidal-Verde's team found the maximum reduction for total inositol phosphates (IP), and particularly degradation of IP6 to the lower inositol phosphates, occurred after 6 days in the presence of light for beans and lentils, and in the dark for beans. Compared to thermal treatments, germination is the more effective process for reducing phytic acid in pulses and has been frequently reported for lentils (Vidal-Verde *et al.,* 1994, Kyriakidis *et al.,* 1998); chickpeas (Alajaji and El, Adawy, 2006; Bains *et al.,* 2014; Bilgicli *et al.,* 2008; Rehman and Shaw, 2005), peas (Alonso *et al.,* 1998; Bishnoi *et al.,* 1994); faba beans (Khalil and Mansour, 1995; Alonso *et al.,* 2000; Khalil, 2001) and dry beans (Sathe *et al.,* 1983; Griener and Konietzny, 1999; Alonso *et al.,* 2000; Shimelis and Rakshit, 2007). Processing after germination (e.g. microwaving or pressure cooking) further reduces the level of anti-nutrients and potential for microbial contamination (El- Adawy, 2002). Germination reduces enzyme inhibitor activities but not to the same extent as thermal treatments. Reports for trypsin inhibitory activity indicate a 25% reduction in TIA for faba beans at three days germination in light (Alonso *et al.,* 2000) and a 31.8% reduction when germinated for 3 days in the dark (Khalil and Mansour, 1995). Mixed reports for the effect of germination on total phenolic content (TPC) and tannin content are noted in the literature. In chickpeas, an 83% and 156% increase in TPC was observed after 2 days and 3 days germination, respectively (Orozco *et al.,* 2009) while a 51.5% loss in TPC and 43% loss in tannins after 24hrs at room temperature was reported (Khandelwal *et al.,* 2010).

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Studies conducted by Vidal-Valverde *et al.* (1984) confirmed that soaking lentils for 9 hours at room temperature in basic soaking solutions containing 0.1% citric acid solution, or 0.07% sodium bicarbonate solution caused a greater loss of the trypsin inhibitor activity compared to acid soaking solution (4% loss). After soaking the seeds in water for 18 hours, Deshpande and Cheryan (1983) found that many cultivars of *P. vulgaris* retained 98–99% of the TIA. However, a 24-hour soak in distilled water of lentil seeds led to a 58–66% reduction in TIA (Batra *et al.*, 1986). Lentil seeds that had been presoaked in distilled water, 0.1% citric acid, or 0.07% sodium bicarbonate solutions lost all of their trypsin inhibitory power when they were cooked for 35 minutes in distilled water (Vidal-Valverde *et al.*, 1984).

Trugo *et al.* (1990) found that about 90% of TIA in *P. vulgaris* may be inactivated by cooking for 60 minutes at 100°C. Mulimani and Paramjyothi (1993) discovered that cooking soaked red gram seeds in boiling water for five minutes totally removed TIA. Whereas Nestares *et al.* (1993) discovered a total elimination of TI after cooking presoaked chickpeas for 35 min., Savage and Thompson (1993) reported the same behaviour after chickpea seeds were cooked for 40 min. Weder and Link (1993) found that boiling whole seeds for two hours after soaking them for an overnight period nearly totally eliminated TIA in beans, chickpeas, lentils, and peas. Although trypsin inhibitor activity was not completely eliminated by germination, it was discovered that soaking treatment was less efficient at reducing it (23% and 28% decreases were seen for *L. culinaris var. vulgaris* and *Variabilis*, respectively). The impact of germination on the trypsin inhibitory action of legumes has yielded a variety of outcomes that have been published. As a result, the impact of germination on TIA is still debatable because different findings were seen depending on the species of legume and the germination circumstances. The impact of germination on lentil TIA is not well understood. El-Mahdy *et al*. (1985) noted a significant decrease in TIA after 24 hours of germination, followed by a fall in the rate, which may suggest that these chemicals are used as an energy source during the early stages of germination. Nevertheless, Batra *et al.* (1986) discovered that whereas germination for 6 days reduced TIA significantly (21-54%), germination for 3 days reduced TIA just marginally. More recently, Weder and Link (1993) discovered that sprouting lentils for 72 hours did not change their overall inhibitor level. Although citric acid solution was more effective than water alone (37% vs. 23%), soaking the seeds in sodium bicarbonate did not appear to be as effective as water in lowering the phytic acid level (27% vs. 23%). These outcomes are consistent with those of Ford et al. (1981), who examined the removal of phytic acid from soybean concentrates using changes in pH level and found that a pH level of 5.5 resulted in the greatest reduction.

Although the findings differ from those of Deshpande and Cheryan (19831), who found that soaking beans in 2% sodium bicarbonate for 12 hours was more effective at reducing phytic acid content than soaking them in distilled water, the difference could be attributed to the different sodium bicarbonate concentrations. The most efficient method for lowering the amount of phytic acid in legumes is germination. The phytase enzyme's activity may be to blame for these losses. For the growing seedling, phytic acid acts as a crucial store of phosphate produced by the activity of phytase during seed germination. According to Reddy *et al*. (1978), phytic acid was hydrolyzed during germination, increasing the amount of inorganic phosphorus that was readily available. After acid soaking, the amount of tannin increased the most. The stability of these compounds is greatly influenced by pH, with increased stability at a basic pH (Ya *et al.*, 1989; Haslam, 1993). Compared to soaking lentil seeds, cooking them for 35 minutes in distilled water with solutions of 0.1% citric acid and 0.07% sodium bicarbonate resulted in 100% retention of the phenolic component under study (Vidal-Valverde *et al.*, 1984). Because tannins are thermo- and photochemically labile, germination may cause them to move similarly to how soaking and cooking do. This makes them easier to analyze. In conclusion, cooking and germination are advised treatments at both residential and industrial scales to prepare good quality lentil flour for use in human nutrition, despite the fact that the impact of processing on lentils has been seen to vary greatly.

Conclusion

This review describes the varied and sometimes conflicting results of conventional and innovative processing methods on the anti-nutrient content in pulses. It is apparent that not every process reduces the anti-nutrient content and that processing efficacy is dependent upon pulse genotype, cultivar and growing environment. It will most likely require combinations of thermal and non-thermal processes (e.g. dehulling + soaking + cooking or microwaving + soaking + dehulling) to significantly reduce or eliminate specific antinutrients. In general, thermal treatments (~100°C or greater) are most effective at reducing the activity of enzyme inhibitors and haemagglutinating (lectin) activity while germination and fermentation can effectively reduce phytate content, and dehulling reduce phenolics and tannins. To mitigate the processing challenge, it may be that pulse processors will search out those pulse varieties with lower anti-nutrient content and then optimize processing conditions to develop pulse ingredients with defined anti-nutritional profiles. As more pulse ingredients are incorporated into food products, the effects of further processing of the food on pulse anti-nutrients will also need to be evaluated.

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