Chapter 1

Nutraceutical Properties of Legume Seeds and Their Impact on Human Health

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Additional information is available at the end of the chapter

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Abstract

Legume seeds known to produce richer quality of proteins than cereals provide nutritious food for people around the world. Legume seeds contain around 20–40% protein. Apart from protein, it is also composed of carbohydrates, fiber, amino acids, micronutrients including several vitamins and minerals. Legume seeds can be considered a potent nutraceutical as it provides beneficial effects on human health as well as it helps in the prevention or treatment of certain diseases such as cardiovascular diseases, diabetes, digestive tract diseases, overweight, obesity, cancer, etc. Legume seeds also contain anti-nutritional compounds which may be toxic when consumed raw, but when processed and treated may play a positive role on human health. There are many more underutilized food legume seeds that may be a potential source of nutraceutical food. The main aim of this chapter is to describe the nutraceutical properties of legume seeds and their impact on human health.

Keywords: legume, nutraceutical, anti-nutritional, underutilized legume, human health

1. Introduction

Nutraceutical can be defined as a food or part of a food that provide medical or health benefits, including the prevention or treatment of a disease [1]. It can be isolated nutrients, dietary supplements, specific diets, designer foods, herbal products, processed foods or processed beverages. Several nutraceuticals found in legumes are listed among the top 200 list of the American Nutraceutical Association [2]. Legumes are considered to produce substantial amount of proteins than cereal grains. Not only proteins but legumes also supply adequate amount of energy, carbohydrates, minerals, vitamins, and dietary fiber with low fat production [3]. The major

storage proteins of legume seeds are oligomeric globulins which are of 7S and 11S protein fractions [4]. Legumes are well known for the presence of different bioactive compounds such as saponins, tannins, flavonoids, isoflavones, lectins, phytic acid etc. which is important for its nutraceutical property [5, 6]. Highly pigmented and dark colored legume seeds have higher level of phenolic and flavonoid content which helps in its antioxidant activity [5, 7–9]. Legume seeds contain enzyme inhibitors like α-amylase, α-glucosidase and γ-aminobutyric acid (GABA) for which it can be used as a nutraceutical molecule. Green legume seeds are also a good source of nutraceuticals [10]. Legume seeds are normally consumed after processing there by increasing the bioavailability of nutrients by inactivating trypsin, growth inhibitors and hemagglutinins [11]. Different species of legumes are involved in the treatment of various diseases like coronary heart diseases, cardiovascular diseases, cancer, diabetes, etc. [5, 7–9]. Legume seeds also contain resistant proteins and carbohydrates that play an effective role in human health [12]. The importance of legumes in human diet is expected to increase in the near future in order to meet the demand for protein and other nutrients in the increasing world population and also to reduce the risk related to animal food source consumption. Molecules present in legume seeds that are considered toxic or unhealthy may also provide positive effects on human health in the prevention and treatment of certain diseases if consumed in a limited scale and proper way, and hence play an excellent role in the nutraceutical and antioxidant property of seed legume [4].

2. Different species of legumes possessing a potential nutraceutical property

2.1. Black soybean (*Glycine max* L.)

It is a variety of soybean composed of black seed coat that has been extensively used as a tonic food and material in oriental medicine for many years. The traditional Chinese medicine theory believes that black soybean is helpful in treatment of diabetes, hypertension, anti-aging, cosmetology, blood circulation, etc. due to its active peptide compounds [13].

2.2. Pegion pea (*Cajanus cajan* L. Millspaugh)

This legume food is an excellent source of protein, starch, calcium, manganese, crude fiber, fat, trace elements and minerals. Pigeon pea seeds are composed of 85% cotyledons, 14% seed coat, about 1% embryo and a variety of dietary nutrients. The embryo contains majority of the seed proteins whereas the cotyledons constitute majority of the carbohydrates. It has both the nutritional and medicinal property. Scorched seeds can relieve headache and vertigo when added to coffee while fresh seeds help urinary incontinence in males. On the other hand, immature seeds are used in the treatment of kidney ailments. Pigeon pea seed husks possess an effective anti-oxidant and anti-hyperglycemic activity which may be a potential organic resource for the development of nutraceutical for hyperglycemic individuals [14].

2.3. Mung bean (*Vigna radiata*)

It is rich in proteins, carbohydrates, amino acids and vitamins. It contains different bioactive compound which help in lowering the risk of various diseases [5].

2.4. Cowpea (*Vigna unguiculata*)

It is an important leguminous food rich in protein, carbohydrates, minerals, and water soluble vitamins like thiamine, riboflavin and niacin [5].

2.5. Rice bean (*Vigna umbellate*)

It is known as climbing mountain bean, mambi bean and oriental bean and is native to Southeast Asia. It has high nutritive value with rich source of protein and essential amino acids such as lysine, tryptophan and methionine. It also contains a number of bioactive compounds such as phytate, α-galactosides and trypsin inhibitors which can act as anti-oxidant, anti-cancer and anti-diabetic agents [14].

2.6. Black gram (*Vigna mungo*)

It is an important legume crop having high nutritional value used as a diet during fever, cooling astringent, poultice for abscesses, affection for cough and liver and also recommended for treating diabetes [8].

2.7. Lentil (*Lens culinaris*)

It is a rich source of proteins, vitamins, minerals, dietary fibers, folic acid and carbohydrates, mostly the resistant starches. It also contains different bioactive compounds such as lectins, enzyme inhibitors, phytates, oligosaccharides, and phenolic compounds. Lentil seed is composed mostly of carbohydrates. Lentil seeds play an important role in the prevention and treatment of various diseases. Due to the high content of dietary fiber and low glycemic response of lentil seeds, it is highly recommended for patients suffering from cardiovascular diseases and diabetes. Several bioactive compounds present in lentil seeds such as phytic acids, lectins, defensins, saponins, etc. show anti-carcinogenic, anti-mutagenic, anti-oxidative and anti-hyperglycemic activities [15].

2.8. Chick peas (*Cicer arietinum*)

The demand for chick pea is high due to its nutritional value. In the semi-arid tropics, chickpea is an important component of the diets of those individuals who cannot afford animal proteins. Chickpea is cholesterol free and is a good source of carbohydrates, protein, dietary fiber (DF), vitamins and minerals [16, 17]. Chickpea consumption has been reported to reduce the risk of chronic diseases and optimize health. Chickpea seed oil contains different sterols, tocopherols and tocotrienols [18]. These phytosterols have been reported to exhibit anti-ulcerative, anti-bacterial, anti-fungal, antitumor and anti-inflammatory properties coupled with a lowering effect on cholesterol levels [19].

2.9. Lupins (*Lupinus* sp)

Lupin seeds contain many bioactive components. The protein, which may correspond to 35–40% of the dry weight, is mostly composed of albumins and globulins in a ratio of 1:9 [20]. Different potential health benefits of lupin have been investigated, particularly in the area of dyslipidemia, hyperglycemia, and hypertension prevention [21].

2.10. Peanut (*Arachis hypogaea*)

Peanuts are a rich source of omega-3, fiber, vitamin E, antioxidants and "good" fats. Consumption of peanuts has been associated with a number of health benefits, particularly for the heart and to reduce the risk of blood clots, lower cholesterol and reduced the risk of arrhythmia. Now, a recent study supports that the consuming peanuts may protect against death from numerous diseases, including cancer, heart disease and diabetes [22] (**Figure 1**).

Figure 1. Species of legumes possessing potential nutraceutical property [a. Black soybean (*Glycine max* L.); b. Pegion pea (*Cajanus cajan* L. Millspaugh); c. Mung bean (*Vigna radiata*); d. Cowpea (*Vigna unguiculata*); e. Rice bean (*Vigna umbellate*); f. Black gram (*Vigna mungo*); g. Lentil (*Lens culinaris*); h. Chick peas (*Cicer arietinum*); i. Lupins (*Lupinus sp*); j. Peanut (*Arachis hypogaea*); vetch (*Vicia faba*); l. winged bean (*Psophocarpus tetragonolobus*); m. Pigeon pea (*Cajanus cajan*); n. Cluster bean (*Cyamopsis tetragonoloba);* o. Kidney bean (*Phaseolus* sp)].

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2.11. Vetch (*Vicia fava*)

Vicia is a genus of about 140 species of flowering plants that are part of the legume family (Fabaceae), and which are commonly known as vetches. The vetch or fava bean is an important food crop, and several other species of vetch are cultivated as fodder and cover crops and as green manure. It is a protein-rich legume seed and also at the same time toxic to humans if consumed in quantity. The seed composed of tannins, vicine and convicine. Beside the positive impact of tannin-free varieties, the development of faba bean cultivars with very low levels of vicine and convicine would represent a real advantage in terms of nutritional performance in poultry diets and of food safety to humans [23].

2.12. Winged bean (*Psophocarpus tetragonolobus*)

It is a source of important minerals, such as iron, manganese, copper, calcium, phosphorus, magnesium. It also contains an abundance of Vitamin A, which is a powerful antioxidant that prevents DNA damage [24].

2.13. Pigeon pea (*Cajanus cajan*)

Pigeon peas are rich in proteins, minerals, vitamins and lipids. It is an excellent source of magnesium, phosphorus, calcium and potassium. It provides an adequate amount of iron and selenium. Pigeon peas contain dietary fiber, potassium and low cholesterol which help to maintain the healthy heart. Potassium lowers the strain on heart by reducing the blood pressure. Dietary fiber maintains cholesterol balance and prevents atherosclerosis [25].

2.14. Cluster bean (*Cyamopsis tetragonoloba)*

Cluster beans are rich source of soluble fiber content and are known for their cholesterol lowering effect. It is also beneficial for blood circulation, resolve anemia, make bone strong and stimulates bowel movement [26].

2.15. Kidney bean (*Phaseolus* sp)

Phaseolus is the most important food legume for human consumption in the world. Its seeds consist mainly of carbohydrates and are a good source of nitrogen and protein. It also contains calcium, magnesium, potassium, phosphorus, copper, iron, zinc, manganese and sulfur. This legume is rich in bioactive components such as enzyme inhibitors, lectins, phytates, oligosaccharides and phenolics, which exhibit metabolic roles in humans and animals. Among the observed biological activities are the antioxidant capacity, the reduction of cholesterol and reduction of low-density lipoproteins, thus Phaseolus has a protective effect against cardiovascular diseases. Also it has shown favorable effects against cancer because of the antimutagenic and antiproliferative properties of their phenolics, lectins and protease inhibitors. Additionally, it has showed effects on obesity and diabetes due to its content of resistant starch and α-amylase inhibitor [7].

3. Nutritional and anti-nutritional components found in legume seeds

There are various nutritional and anti-nutritional components present in legume seeds which plays a significant role as a nutraceutical property of legume seeds.

3.1. Phenolic compounds

In legume seeds, phenolic compounds are found as antinutritional compounds, but it also can act as antioxidants because of its ability to chelate metal ions, inhibit lipid peroxidation and scavenge free radicals. Phenolic compounds found in legume seed are mainly tannins, phenolic acids, anthocyanins and flavonoids Polyphenolic compounds such as flavonol glycoside, anthocyanins and condensed tannins provide color to the seeds of legumes. The seeds which are dark colored and highly pigmented have high phenolic content such as red kidney beans (*Phaseolus vulgaris*) and black gram (*Vigna mungo*). The phenolic content of the legume seeds is highly associated with its anti-oxidant activity [5, 15]. Phenolic compounds in legume seeds show anti-bacterial, anti-viral, anti-inflammatory and anti-allergenic activities. They are also known to lower the risk of cancer, heart diseases and diabetes [8]. It has been reported on the analysis of total phenolics against antioxidant activities that fermented legume seeds exhibit more antioxidant potential [27]. The balance between antinutrient and biological antioxidant effects present in legume seeds will help in nutrient utilization improvement thereby providing potential nutraceuticals for human health [8].

3.2. Tannins

Tannins help in removal of toxins from the intestine because of its ability to bind the proteins. Tannins also help in maintaining hygiene of the mouth by inhibiting bacterial growth that cause tooth decay [5, 27].

3.3. Flavonoids

Flavonoids contained in legume seeds act as an antioxidant and prevent many diseases such as cancer, cataract, arteriosclerosis, autoimmune diseases, inflammation and aging [4–6].

3.4. Isoflavones

Isoflavones in legume seeds act as an antioxidant and helps in lowering the risk of many diseases such as osteoporosis, cardiovascular diseases and cancer. It is also used for the treatment of menopause symptoms [5]. Isoflavones daidzein and genistein are natural phytoestrogens that are able to inhibit LDL oxidation thereby reducing the risk of atherosclerosis [28]. Genistein and Daidzein acts as an anti-cancer agent. Genistein helps in the inhibition of platelet aggregation, leukotriene production, DNA topoisomerase II, angiogenesis, reduction of bioavailability of sex hormones, induction of apoptosis, and differentiation in cancer cells. Daidzein induces differentiation in B16 melanoma, and HL-60 human leukemia cells. Daidzein also helps in the inhibition of enzyme ALDH-I, an NAD dependent aldehyde

dehydrogenase that catalyzes the oxidation of acetaldehyde, the primary product of alcohol metabolism which further helps in the treatment of alcoholism. There is epidemiological evidence regarding high legume seed diets to reduced risk of cancer [29].

3.5. Phytic acid

Phytic acid is present in legume seeds as antinutrients. It is stored in legume seeds in the form of phosphate in the endosperm [15] Phytic acid act as anti-HIV agent by inhibiting the transcription of the viral genome. Phytic acid prevents the formation of kidney stones. It also helps in the prevention of cavities, plaque and tartar in the teeth by reducing solubilities of calcium, fluoride and phosphate and protects it from demineralization. Phytic acid also helps in reducing risk of heart diseases and diabetes mellitus [7]. It also shows antioxidant and anti-carcinogenic properties [30].

3.6. Saponins

Saponins are secondary plant metabolites which can be either steroidal or triterpenoid. Commonly found saponins in legume seeds are triterpenoids. Saponins may play a significant role as anti-cancer agent by reducing the formation of carcinogenic substances in colon. They may also lower the risk of heart diseases. Saponins may also show immune stimulant effects by inducing the formation of cytokinins such as interleukins and interferons. Saponins may also provide several other beneficial effects such as anti-inflammatory, anti-fungal, anti-parasitic, hypercholesterolaemia, hypoglycemia, immunomodulatory, etc. [15, 30].

3.7. Oligosaccharides

Legume seeds constitute indigestible substances especially flatulence induced oligosaccharides, e.g. raffinose, stachyose and verbascose. These oligosaccharides can be used as a prebiotic agent by promoting the growth of bifido bacteria. They may show anti-carcinogenic, anti-diabetic and anti-cardiovascular effect and also a higher rate of mineral absorption that are beneficial to human health [8].

3.8. Enzyme inhibitors

Legume seeds contain enzyme inhibitors which are involved in the regulation of endogenous proteases, amylases, lipases, glycosidases and phosphatises enzyme. They provide defense mechanism against seed eating insects and microorganisms. Enzyme inhibitors of legume seeds belong to Kunitz (20–24 kDa) and Bowman-Birk (8 kDa) family [5].

3.8.1. Protease inhibitor

Seeds of legumes such as pea, chickpea and mung bean protein hydrolysates have angiotensin converting enzyme (ACE) inhibitory activity which helps in improving cardiovascular health. Inverse correlation between pulse consumption and risks of colon cancer, prostrate cancer, gastric cancer and pancreatic cancer shows that it helps in the prevention of these diseases [5, 28].

3.8.2. α-Amylase inhibitor

α-Amylase protein inhibitor present in raw legume seeds help in the prevention and therapy of obesity and diabetes [5, 28].

3.8.3. α-Glucosidase inhibitor

Legume seeds contain α-glucose inhibitor which helps in the treatment of diabetes. Postprandial hyperglycemia, the earliest metabolic abnormality of type 2 diabetes mellitus can be suppressed by inhibition of α-glucosidases delaying the digestion and absorption of carbohydrates [5, 28].

3.8.4. γ-Aminobutyric acid

γ-Aminobutyric acid (GABA), a non-protein amino acid, acts as a depressive neurotransmitter in the sympathetic nervous system. GABA is effective for the treatment of hypertension, depression, sleeplessness, autonomic disorders, and chronic alcohol related symptoms and for stimulation of immune cells [5, 28].

3.9. Polysaccharides

The presence of carbohydrate in grain legume seeds in amounts up to 60%, which include oligosaccharides, such as alpha-galactosides, and complex molecules, such as starches and fibers [31]. Starch is a storage polysaccharide made up of amylose and amylopectin in the ratio roughly of 1:3 but in wrinkled pea the ratio reach 3:1 [32]. As far as starch concerns, in lupin and soybean are found the lowest amounts (about 1–2%) whereas in pea and fababean it accounts for about 50% of the dry seed weight. From the nutritional viewpoint this polysaccharide can be classified, according to its hydrolysis degradation in animal model systems, as rapid digestion starch (RDS), slow digestion starch (SDS) and resistant starch. This later is not hydrolysed by human amylases but it can be fermented by the microorganisms present in the colon as if it is fiber [33].

3.10. Lipids

Lipids are generally present in legume seeds such as pea, common bean, lentil at low amounts (1–3%) with approximately 40–50% neutral lipids, 25–35% phospholipids and 9% glycolipids. Phospholipids have been shown to possess potent effects on serum lipoproteins and the phospholipids in pulses could contribute to the lipoprotein effects [34]. The effects on the cardiovascular system in preventing diseases are seemingly due to their capacity to lower the blood cholesterol levels by inhibiting cholesterol absorption [35].

3.11. L-DOPA

Seeds of wild legume *Mucuna pruriens* and seeds of *C. cathartica* are excellent natural source of the neurotransmitter L-DOPA. Consumption of food possessing L-DOPA is toxic only to those individuals having deficiency of glucose-6-phosphate dehydrogenase (G-6-PD) in their erythrocytes. Although L-DOPA is neurotoxic, it is highly effective to treat the Parkinson's disease [36–39]. L-DOPA is responsible for the release of human growth hormone (HGH) from

pituitary gland and it can be effectively used in the treatment of restless leg syndrome (http://www.ihealthdirectory.com/l-dopa/). Administration of L-DOPA for a long duration to the patients suffering from Parkinson's disease, there were no adverse effects to prove its toxicity.

3.12. L-Canavanine

L-canavanine is a suitable inhibitor of cancer-inducing nitric oxide [40]. It can prevent the anti-tumor activity of Walker carcinoma, human melanoma, pancreatic cancer [41, 42], plant sources containing L-canavanine in therapy of colon cancer through diet management. L-canavanine is highly suitable for pancreatic cancer studies due to lack of considerable amount of arginase in the pancreas [41].

3.13. Lectins

The lectin con C of *C. cathartica* has a number of applications such as a blood grouping substance [43], immunomodulator [44] and tissue marker [45]. Con A induces immune cell responses in liver, which leads to destruction of tumor cell, after binding to mannose moiety, con A exerts both autophagic and anti-hepatomic (immunomodulation) properties. Adeno virus microbeads bound to con A is an effective agent in delivering therapeutic transgenes for inflammatory bowel disease [46]. It has also been found that con A stimulates mitosis and inhibits the lymphocyte cap formation and patch formation due to anti-immunoglobulin. In isolated fat cells, con A shows similar activity to that of insulin [47].

3.14. Proteins

Mature seeds of pea, faba bean and beans contain 18–20% protein and lupin and soybean contains 35–45% protein. Most of the proteins found in legume seeds are storage proteins which are of 7S and 11S globulins based on their sedimentation coefficient [4]. Some proteins in legume seeds show antifungal and anti-viral activity and hence act as anti-HIV and anti-diabetic agent [5]. These proteins contain several essential amino acids which are beneficial to human health.

The proteins present in *Vigna species*, show antifungal and antiviral activity. Ground bean lectin inhibits the hemagglutinating activity by polygalacturonic acid but not galacturonic acid and simple monosaccharides [31]. It decreases the viability of hepatoma (HepG2), leukemia (L1210) and leukemia (M1) cell and also elected a mitogenic response from mouse splenocytes. Due to presence of all these properties, these proteins act as an excellent drug for the treatment of AIDS patients with no adverse effects as compare to synthetic drugs [44].

3.15. Minerals and vitamins

Minerals act as a cofactor for many enzymatic reaction e.g. copper, zinc, and magnesium and manganese. Vitamin E and C are known to play a role as an antioxidant and inhibiting the oxidation of vitamin A in the gastric intestinal tract [39]. Vitamin E also prevents cancer by inhibiting carcinogens from precursor substances. Whereas, vitamin K play functional role by act as blood clotting factor in liver. The B vitamin folic acid significantly also reduces the risk of neural tube defects (NTDs) like spina bifida in new born babies.

3.16. Fiber

Legumes are good source of fiber. Dietary fiber comes from the portion of plants that is not digested by enzymes in the intestinal tract. Bacteria present in lower gut may metabolize this and produce short chain fatty acid. Fiber also reduces body cholesterol level by binding with cholesterol in human gut. High fiber foods can improve serum lipoprotein values, lowers blood pressure and improves blood glucose level for diabetic individuals [35]. Insoluble fiber increases the rate of transient time of wastes material from the gastrointestinal tract.

3.17. Oligosaccharides

Indigestible substances especially flatulence induced oligosaccharides (α-galactosides) e.g. raffinose, stachyose and verbascose, occur mainly in legume seeds. Oligosaccharides show wide range of physiological properties like anticarcinogenic effect, antidiabetic, anti-cardiovascular and higher rate of mineral absorption that are beneficial to human health [43]. Prebiotic such as Bifidobacteria prevent colon cancer.

3.18. Phytic acid

Phytic acid of legumes reduces colon cancer via chelation of iron and suppression of iron-related initiation and promotion of carcinogenesis. Further, it may have potential therapeutic use in cancer due to its property of increasing the activity of natural killer cells associated with suppressed tumor incidence [48, 49].

3.19. Vitamins and minerals

Soybean is a better source of vitamins B compared to cereals, although it lacks B12 and vitamin C [50]. Soybean oil also contains tocopherols which are tremendous natural antioxidants. Soybean also contains 5% minerals. It is relatively rich in K, P, Ca, Mg and Fe. Soy ferritin can be extra reasonable quantities of iron [51].

3.20. Phytosterols

Phytosterols are natural compounds structurally similar to mammalian cell-derived cholesterol. The best dietary sources of phytosterols are unrefined vegetable oils, seeds, cereals, nuts, and legumes. Phytosterols with potential effects on obesity are diosgenin, campesterol, brassicasterol, sitosterol, stigmasterol, and guggulsterone [52]. High intakes of these compounds can also protect against atherosclerosis and decrease serum TC and LDL-C levels [53]. Their influence on intestinal genes and transcription factors makes phytosterols key regulators in metabolism and cholesterol transport in the expression of liver genes.

3.21. Phytoestrogens

Phytoestrogens in food legumes are nonsteroidal phytochemicals quite similar in structure and function to gonadal estrogen hormone. They have antioxidant effects due to their polyphenolic nature, including modulation of steroid metabolism or of enzymes detoxification, interference

with calcium transport, and positive effects on lipid and lipoprotein profiles [52]. They offer an alternative therapy for hormone replacement therapy with beneficial effects on the cardiovascular system, and may even improve menopausal symptoms.

3.22. Phytochemicals in legumes

Legumes contain, in addition to the health-promoting components (fibers, proteins, resistant starch, and minerals), numerous phytochemicals endowed with useful biological activities [53]. Various studies reveal that selected polyphenols exhibit strong protective actions on many pathological conditions, particularly those triggered by oxidative stress, such as CVD and metabolic disorders [54]. The major sources of dietary polyphenols are cereals, legumes (beans and pulses), oilseeds, fruits, vegetables, and some beverages.

3.23. Legume fibers

Legumes are a very good source of dietary fibers. Dietary fibers include resistant starch, non-starch polysaccharides (cellulose, hemicellulose, pectin, gums, and b-glucans), nondigestible oligosaccharides, and lignin. High consumption of soluble fibers is associated with a decrease in serum total cholesterol (TC), in LDL-C, and is inversely correlated with CHD mortality rates [53, 54]. Dietary fibers may also be beneficial against obesity.

3.24. Antioxidant activity

The antioxidant properties of food have been studied since reactive oxygen species are widely believed to be involved in many diseases such as cancer, diabetes, autoimmune conditions, various respiratory diseases, eye diseases, and schizophrenia [55, 56]. The antioxidant activity of different dry beans has been assessed by several workers [8–12, 51–57].

3.25. Anti-nutritional components (ANC)

Despite the potential nutritional and health-promoting values of legume seeds the presence of anti-nutritional components (ANC) in it, limits its biological value and usage as food. Bean seeds like chick pea, grain beans, lupin, peanut etc. contain a number of antinutritional compounds which can be of proteinous or non-proteinous nature [58]. ANCs found in legume seeds are mainly ubiquitarian, like proteinase inhibitors, lectins, phytates, polyphenols, other are more specific, as some complex glycosides [59]. Legume seeds antinutrients are considered to limit protein and carbohydrate utilization. The negative effects of legume seeds are only observed after the consumption of raw and unprocessed seeds or flour, as normally high temperature during processing inactivates the ANCs [60]. Most of the bean ANCs have an impact on the digestive system, like the inhibition of digestive enzymes (*e.g.* protease inhibitors), impairment of hydrolytic functions and of transport at the enterocyte site (lectins), formation of insoluble complexes (phytates, polyphenols), and the increase of the production of gases in the colon (α-galactosides) [58]. The most characterized and commonly found protein inhibitors of legume seeds are trypsin inhibitor of both, Bowman-Birk type and Kunitz type, and α-amylase inhibitors like in chickpea [61]. Most of legume species like kidney bean, grain beans, etc. are also a

good source of lectins [62]. Legume seeds are also contains a number of non-protein ANCs, like phenolic compounds, saponins, alkaloids, phytates etc. that impair the biological utilization of their nutrients [63].

3.26. Legume allergies

The use of legume seeds is being expanded in the food industry due to their excellent nutritional and technological properties. However, legumes have been considered causative agents of allergic reactions through ingestion. Allergy due to consumption of legume seeds for primary sensitization or cross-reactions with other legumes is also a major concern due to the presence of anti-nutritional components. In 2006, Lupin allergy was reported in the literature and there after the European Union included lupin among the allergens that must mandatorily be declared on the foodstuff labels [64]. The main allergens that have been associated with the sensitization to lupin are α- and ß-conglutins and, to a lesser extent, γ- and δ-conglutin [65, 66]. Peanut allergy is one of the most common and severe IgE-mediated reactions to food and is typically lifelong [67]. Lentils and chickpeas have also been reported to cause IgE-mediated hypersensitivity reactions, particularly in pediatric patients [68]. The major lentil allergen was identified as Len c 1 (as a 48-kDa vicilin) [69]. So far, no chickpea allergen has been identified but several IgE-binding bands (10–70 kDa) have been detected by immunoblotting [68]. Total 33 soybean proteins have been identified as allergens (from 7 to 71 kDa) to date [69]. There is need of research to investigate the impact of various treatments in raw legume seeds like roasted peanuts, lentils, chickpeas and soybeans etc. using a serum pool from sensitized patients to find out the possible allergy reaction and its possible overcome.

4. Impact of bioactive compounds present in legume seeds on human health

Several bioactive compounds may exhibit a wide range of beneficial effect on human health which may contribute to its nutraceutical property.

4.1. Cardiovascular diseases

Legumes help immensely in cholesterol lowering mechanism. There is 22–11% lowering risk of coronary heart disease and cardiovascular disease associated with legume consumption [5]. It has been reported that legume seed consumption lowers LDL cholesterol by partially interrupting the enterohepatic circulation of the bile acids and increasing the cholesterol saturation by increasing the hepatic secretion of cholesterol [15]. Different types of bioactive compounds found in legume seeds such as fibers, oligosaccharides, angiotensin converting enzyme (ACE), vitamins and minerals help in the protection against cardiovascular diseases. It has been examined that 30% neutral detergent fiber of black gram in diet can reduce cholesterol level compared to cellulose on binding with bile acids [31].

4.2. Diabetes

Legume seeds play a significant role in the treatment of diabetes. They have high content of fiber and oligosaccharide which help in maintaining the glycemic level in blood. Low glycemic

index corresponds to reduce lipid level, insulin and epididymal adipocyte volume in plasma. Hence legume seeds can be used as an anti-diabetic agent [51, 58].

4.3. Cancer

Legume seeds contain several nutrients and bioactive compounds like fibers, oligosaccharides, phenolic compounds and antioxidants that show anti-carcinogenic activity. It has been found that adzuki bean (*Vigna angularis*) has differentiation/maturation inducing activity for dendritic cells and apoptosis inducing activity for human leukemia U937 cell. Hence legume seeds help in the treatment of different types of cancer [41]. There is a reduced risk of prostrate cancer, breast cancer, colon cancer and pancreatic cancer on consumption of legume seeds [41, 57].

4.4. Hepatotoxicity

Legume seeds are healthy food for liver. γ-aminobutyric acid (GABA) present in legume seeds is a potent hepatoprotective agent [5].

4.5. Osteoporosis

Legume seeds being a good source of calcium and protein help to build strong bone and hence reduces the risk of osteoporosis. Isoflavones daidzein and genistein prevents breakdown of bones [51].

4.6. Postprandial hyperglycemia

Legume seed husks possess potent anti-oxidant and anti-hyperglycemic activity. It may become an economical natural organic resource for development of functional food/nutraceuticals meant for hyperglycemic individuals. Methanolic extract of seed husk potentially mitigated development of postprandial hyperglycemic spikes and glycemic load close to clinically used drug acarbose [52].

4.7. Anti-carcinogenic effects

Various studies have reported results for intakes of pulses and cancer risk; it will be very difficult, using conventional epidemiological tools, to ascertain the quantitative contribution made by pulses to cancer risk however the beneficial effects against cancer of specific and isolated legume components have been carried out since long. Among the potential protective components against cancer which can be present in pulses are included protease inhibitors, saponins, phytosterols, isoflavones and phytates [41, 70].

4.8. Weight control and obesity

Dry legumes are claimed to help maintaining a regular body weight, thanks to their great satiety effect, thus limiting the overall food daily intake. Various seed components have been claimed to bring about this effect. According to studies, performed with healthy subjects, showed an increase of the stool weight when they included soybean or pea fibers in the diet [31, 34]. A specific direct action of grain legume alpha-amylase protein inhibitors has been considered for its potential use in the prevention and therapy of obesity and diabetes [34].

4.9. Cryptic activity

The bioactivity of peptides which are latent until released from a protein by enzymatic proteolysis, are called cryptic activities [71]. Many kinds of bioactive peptides which might prevent lifestyle-related diseases are released from food proteins after enzymatic digestion. This can occurs during gastrointestinal digestion, germination, fermentation (the proteolytic systems of bacteria can contribute to the liberation of bioactive peptides) or food processing. In this latter case, the wise use of different proteases may bring to the release of different peptides from the same protein source.

It has often been shown that peptides originating from enzymatic hydrolysis of food proteins demonstrate biological effects in various test systems, their activity being due to the ability of inhibiting endogenous enzyme activities or binding to peptide hormone receptors. An immunostimulating peptide isolated from an enzymatic digest of soybean protein prevented alopecia induced by cancer chemotherapy [72].

4.10. Hypolipidemic effect

Dyslipidemias are an important risk factor for coronary artery disease. Insulin resistance, a consequence of increased triglyceride and low-density lipoprotein cholesterol (LDL-C) in plasma and decreased high-density lipoprotein cholesterol (HDL-C), is an important risk factor for peripheral vascular disease, stroke and coronary artery disease [73]. It has been shown that long-term feeding with beans decreases cholesterol and low-density lipoprotein (LDL) serum levels in humans, so it seems likely that it can offer protection against cardiovascular diseases [74]. The fiber isolated from *Phaseolus mungo* showed a neutral detergent residue (NDR). It has significant cholesterol lowering activity and increased bile acid excretion in feces [75].

4.11. Chronic degenerative diseases

Chronic diseases can be defined as disorders which last for a long time and progress slowly such as heart disease, infarcts, cancer, pulmonary diseases and diabetes. These diseases are the main causes of mortality in the world, accountable for 63% of deaths [76]. Bean consumption has been related to numerous health benefits, such as a decrease in cholesterol levels and cardiac diseases. Beans also offer some protection against cancer, diabetes and obesity, because of their antioxidant, antimutagenic and antiproliferative properties.

4.12. Anti-inflammatory agent

BBI proteases from legume crops achieved investigational new drug status by the FDA due to their health-promoting benefits in a denatured form [77]. Since then numerous reports have been published on the potential health-promoting benefits of protease inhibitors, such as their potential use as an anti-inflammatory agent.

4.13. Hypertension

ACE causes high blood pressure by converting the biologically inactive angiotensin I to the potent vasoconstrictor angiotensin II, and also inactivates the vasodilator bradykinin [78].

Angiotensin I-converting enzyme (ACE) inhibitor peptides have been isolated from various legumes and has proven to be effective in the prevention and treatment of hypertension.

4.14. Glycemic control and diabetes

Clinical studies consistently show that when replacing other carbohydrate-rich foods, bean reduces postprandial glucose elevations in both diabetic and nondiabetic participants [34]. When comparing extreme quintiles, bean (a category that excludes peanuts and soy products) intake was associated with a significant decreased risk of developing diabetes and bean consumption may decrease CVD as well as other diseases by reducing inflammation.

4.15. Mortality

Bean consumption has been associated with reduced risk of mortality. Legume intake ranged from 85 g/d in Japan and Greece to a low of only 14 g/d in some segments of the Australian population, legumes were the only foods associated with a reduced risk of mortality [79].

5. Conclusions

Legume seeds are nutritious food for the people around the world as it is known to produce richer quality of proteins (around 20–40% protein) than cereals. Apart from protein, it is also composed of carbohydrates, fiber, amino acids, micronutrients including several vitamins and minerals. Legumes are also well known for the presence of different bioactive compounds such as saponins, tannins, flavonoids, isoflavones, lectins, phytic acid etc. which is important for its nutraceutical property and provides beneficial effects on human health as well as helps in the prevention or treatment of certain diseases such as cardiovascular diseases, diabetes, digestive tract diseases, overweight, obesity, cancer, etc. There are many more underutilized food legume seeds that may be a potential source of nutraceutical food. The importance of legumes in human diet is expected to increase in the near future in order to meet the demand for protein and other nutrients in the increasing world population and also to reduce the risk related to animal food source consumption.

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Conflict of interest

There is no conflict of interest among the authors.

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