Lima Bean (Phaseolus Lunatus L.) – A Health Perspective

Lourembam Chanu Bonita, G. A. Shantibala Devi and Ch. Brajakishor Singh

Abstract: Lima beans are underutilized crops with a good nutritional profile. They are very good sources of proteins, minerals, dietary fibres and the essential amino acid lysine which is lacking in cereals. They are also good sources of bioactive compounds. Some of these compounds can adversely affect the health of the consumers, and are known as antinutritional compounds. Compounds like phytates, saponins, and phenols reduce the bioavailability of minerals. Cyanogenic glycosides which can be hydrolyzed into the highly toxic hydrogen cyanide are also known to be present in lima beans. Its content is highly variable among the different varieties. Another reason which makes lima beans unpopular to consumers is the presence of flatulence causing oligosaccharides. Different methods have been proposed to remove the content of these undesirable components. For most of them, soaking and cooking are enough to reduce their content to a desirable level. Bioactive compounds, including those which have been traditionally designated as antinutritional factors, can also affect the health in a beneficial way. Many compounds present in lima beans such as phenolic compounds are known to be antioxidants. The health promoting effects of lima beans and its constituents reported in literature so far include hypoglycemic, anti-HIV, anticancer, antihypertensive, bile acid binding, gastroprotective, protection from cardiovascular diseases and antimicrobial properties. These nutraceutical properties of lima beans are discussed in this review.

Index Terms: Lima bean, nutritional, antinutritional, health, bioactive, anti-HIV, anticancer

1. INTRODUCTION

Pulses are important sources of dietary protein. They also help in sustainable agriculture by improving soil fertility [120]. Pulses are good complements of cereal based diets as they are rich in lysine, which the cereals are deficient in [126]. With the increasing global population, there is increasing demand for new food sources. Dietary proteins, especially those of animal source like milk, eggs, meat are very limitedly available to the poor of the population. As an alternative source, traditionally grown, underexploited legumes may provide an answer. So, researchers are giving greater attention to non-conventional legumes. Underutilized crops are localized in a restricted area in terms of production and consumption even though the crop may be distributed globally [47]. FAO estimates that a large number of varieties of pulses, including local varieties are not grown or exported globally. The genetic diversity of these crops is important for soil and pest management, especially for small scale farmers [56]. New crop varieties are one possible way for crop improvement under climate change [57]. The global reliance on only a few major crops could pose a threat to the ecology, agronomy, nutrition and economy in the long term. Crop diversification will provide a buffer against stresses like climate change [47]. Underutilized crops like landraces, crop wild relatives may be the repository of genes that impart resistance to biotic and abiotic stresses, with potential for increasing yield under climate change [101]; [122]. Lima bean has a history of confusion regarding its origin and nomenclature. This plant has been proposed to have an origin in Bengal (Linnaeus, 1753) and to have two different species – P. lunatus L. and P. limensis Macf. [10]. There has also been a proposal to differentiate between wild and cultivated types – var. silvester, var. lunatus [12], var. viridis [40]. Debouck (1991) suggested that wild and cultivated groups cannot be distinguished strictly and only the species name Phaseolus lunatus should be retained. Mackie (1943) for the first time proposed Central America to be the area of origin for lima bean. There are evidences that prove the existence of two gene pools of lima beans – an Andean genepool and a Mesoamerican genepool. Evidences come from seed characteristics like morphology, seed weight, seed protein electrophoretic analysis [95], [68], [97], genomic DNA polymorphisms [108], [55], [8], and chloroplast DNA polymorphisms [131], [55]. The Mesoamerican gene pool has two groups – MI and MII [131], [7]. An Andean origin has been proposed for wild lima beans with the other groups separating from it [97], [54], [131]. Seeds of lima beans show variation in their physical properties such as size, sphericity and volume. Accordingly, three morphotypes have been differentiated in P. lunatus. They are – Potato which have small rounded seeds, Sieva having medium flat seeds, and Big lima having big flat seeds [121].

Lima bean was introduced from America to other parts of the world. However, its spread to the Old World was restricted [121]. It remains neglected and underutilized in many developing countries outside their indigenous region when compared to other pulses such as the common bean, Phaseolus vulgaris. In a meeting of the Global Crop Diversity Trust (2012), it was recommended that Phaseolus lunatus may be planted instead of Phaseolus vulgaris (common bean) where the changing global climate may make planting common beans unsuitable. The report of the meeting suggested that lima bean may have good potential in South Asia. This may help in achieving the necessary yield gains under climate change to feed the increasing population [122]. The crop is getting marginalized today because of neglect of traditional diet and customs, presence of toxic compounds, and competition from other legumes like common beans, soybeans, cowpeas, lablab beans and pigeon pea [17]. Therefore, the objective of this review is to provide information on the underutilized legume, lima bean as an important crop for enhancing food and nutrition security and also as a potential functional food with good health promoting potential

2 COMPOSITION OF LIMA BEANS

The nutritional composition of lima beans shows variation within species [110], [65], [63], [51], [45]. Climatic fluctuation

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and developmental stage also affect the nutritional value of lima beans [121].

2.1 Proteins and amino acids

The protein content of P. lunatus is around 21 – 26 % [34], [149], [147]. Even the seed coat of lima bean has higher protein content than most cereals [130]. Storage proteins are one of several kinds of protein reserves of seeds. The storage protein phaseolin and legumin are two of the characteristic storage proteins of P. lunatus. Lima bean variety 'fagiolo a formella' contains 6.7 mg phaseolin g-1 of dry seed. Phaseolin of P. lunatus occurs as oligomers made of two types of subunits (32 – 38.5 kDa and 21 – 27 kDa) which are cleaved from precursors having molecular masses of 54 and 58 kDa [139]. Phaseolin extracted from the seed coat of lima bean have been shown to have insecticidal effect [105]. The amino acid content of lima bean is given in table 1. Lysine which is a limiting amino acid in cereals is present in good amount in P. lunatus. So, lima beans will make a good nutritional supplement to cereal grains. The value of lysine in lima bean is higher than the recommended amount by FAO [19].

Table 1. *Amino acid composition (g kg-1 protein) of P. lunatus*

Amino acid	FAO (1991)	P. lunatus
Lysine	58	79.7
Tryptophan	11	13.2
Phenylalanine + Tyrosine	63	106.7
Methionine + Cysteine	25	20.5
Threonine	34	48.7
Leucine	66	85.4
Isoleucine	28	42.9
Valine	35	51.2
Asparagine		144.3
Glutamic acid		148.5
Serine		79.9
Histidine		32.0
Glycine		48.7
Arginine		70.1
Alanine		50.1

(Source: [19])

2.2 Carbohydrates

Carbohydrates are the main components of lima bean seeds, comprising around 53 - 71% on a dry matter basis [63], [15], [51]. Starch is the most abundant among the bean carbohydrates. Starch content of lima beans are usually around 200-670g kg^{-1} on a dry matter basis [3], [65], [19], [18], [15], [116]. Lima bean also contains resistant starch of around 35.0 g kg^{-1} d.m. [65]. Resistant starch is resistant to digestion so they reach the large intestine where it is fermented by bacteria. They change the microbiota of gut producing a healthier gut and increase gene expression for gene products involved in apoptosis of potential cancer cells, and also reduce abdominal fat and improve insulin sensitivity [84]. Scanning Electron Micrograph revealed lima bean starch granules of oval and spherical shapes, having an average size of 23.6 µm with pores of about 2 µm near the equatorial region of the granules. Amylose level of this bean is 325 g kg^{-1}, higher than common cereals but similar to other legumes. P. lunatus starch has high temperature of gelatinization, which means it can have potential application in foods like canned goods which use high temperature in their preparation [19].

2.3 Fats and Fatty acids

Lima beans contain 0.32 – 2 % fat [149]. Ryan et al. (2007) found butter bean, a variety of lima bean to contain 0.9 % total oil with 28.7 % of it as saturated fatty acid, 10.5 % as monounsaturated fatty acid and 69.8 % as polyunsaturated fatty acid. The major components are linoleic acid, linolenic acid and palmitic acid. Marimuthu et al. (2014) detected 19 fatty acids in dry Christmas lima beans by using GC-MS which included high amounts of oleic acid which is known to have beneficial effect on cancer, autoimmune inflammatory diseases, and wound healing [128]. Table 2 shows the fatty acid composition of mature lima bean.

Table 2. *Fatty acid composition of lima bean, large, mature seed, raw*

Total saturated fatty acids (g $100g^{-1}$)	0.161
14:00 (myristic)	0.002
16:00 (palmitic)	0.118
18:00 (stearic)	0.032
Total monounsaturated fatty acids	0.062
16:1 undifferentiated (palmitoleic)	0.004
18:1 undifferentiated (oleic)	0.052
22:1 undifferentiated (Erucic)	0.004
Total polyunsaturated fatty acids	0.309
18:2 undifferentiated (linoleic)	0.215
18:3 undifferentiated (linolenic)	0.095

(Source: [149])

2.4 Dietary fibre

Lima beans contain around 5 – 8 % total dietary fibres [34], [5]. Insoluble and soluble dietary fibre content are 193 and 83 g kg^{-1} d.m. respectively. Amount of insoluble dietary fibre of lima beans increased on cooking [65]. This increase has been suggested to occur because of the formation of retrograded starch during the heating/cooling cycles. Retrograded starch is a type of resistant starch which is formed due to reassociation of the amylose and amylopectin. Starch retrogradation can change the texture and flavour of the food product and decrease the starch digestibility [118]. Dietary fibre seems to have some protective function against diseases like diabetes, hypertension and arteriosclerosis [20]. Lima bean fibrous residue has high insoluble dietary fibre (IDF) value, which suggests that it can be used in treating constipation. Because the lima bean fibrous residue has low oil holding capacity, it may be used in making non-greasy fried food products.

2.5 Ash and Minerals

Lima beans contain 3.4 - 6.4% ash [111]. Ash content of food and feed stuff is routinely analyzed for proximate composition as it represents the total mineral content. Unlike many cereals which are polished before eating, legumes are generally consumed with seed coat which conserves the micronutrients [28]. Raw Lima bean has high mineral content, particularly of K, P and Mg. In comparison with cereals, the Ca and Fe content are very high (table 3). The iron availability of lima bean is higher than that of many other legumes including cowpeas, mung beans, pole sitao, chickpeas, green peas, groundnuts, pigeon peas, kidney beans and soybeans [148].

Table 3. *Mineral content of lima beans in comparison with a cereal*

Minerals (mg kg^{-1} d.m.)	Raw	Cooked
Calcium	1587[a], 3500[c], 317[d],	1062[a], 317[d]
Iron	119.8[a], 169 ppm[c]	114.3[a], 86[d]
Magnesium	2668.4[a], 2600	2062.5[a]
Phosphorus	3850[b], 9800[c]	1110[b]
Potassium	18817.0[a], 6900[c]	10341.4[a]
Sodium	180[b], 4300[c]	20[b]
Zinc	41.8[a], 70[c]	39.1[a], 51[d]

Source: a: [65]; b: [149]; c: [2]; d: [148]

2.6 Lima bean Protein Fractions

Protein isolates, concentrates and hydrolysates have been produced from the flour of beans to improve the functional and physicochemical properties of protein sources [19], [34], [147]. Protein hydrolysates have bioactive peptides. Bioactive peptides of vegetable proteins exhibit many useful nutraceutical properties. Torrucco-Uco et al. (2009) were able to obtain bioactive peptides with ACE inhibitory activity from lima bean by alcalase hydrolysis. Alcalase® is an alkaline protease and it had been previously used to produce bioactive peptides with ACE – I inhibitory activity from animal sources like bovine skin gelatin [86]. Guzman-Mendez et al. (2014) showed that essential amino acid content of lima bean hydrolysate is higher than the recommended FAO/WHO/UNU (2002) amount, while the content of sulphur containing amino acids (Met, Cys) is low. Extensive hydrolysate of P. lunatus had higher DPPH free radical scavenging activity (13.22%) than that of the protein concentrate (4.56%). This increase in antioxidant activity may be due to the presence of specific peptide sequences in the hydrolysate which were released from the native protein during hydrolysis.

3 ANTINUTRITIONAL FACTORS (ANFs)

ANFs are substances that exert some kind of effect contrary to optimum nutrition. Being an ANF depends on the digestive or metabolic process of the ingesting species. It is not an intrinsic quality of the substance [90]. Many crops have ANFs but they are still consumed safely as for the most time conventional processing methods are able to remove the antinutrients [103]. Many anti-nutritional factors are present in legumes, e.g. trypsin inhibitors, lectins, phytates, etc., of which the heat labile ones get inactivated on cooking. Antinutrients reduce the bioavailability of proteins and trace elements. Although lima bean is a rich source of proteins and starch, they are not popular because of the presence of antinutritional factors and toxins. Inactivation or removal of such ANFs will improve the nutritional quality of lima beans and increase their acceptance and utilization as food. The content of these antinutritional factors are given in table 4.

Table 4. *Antinutritional factors of lima bean*

Antinutritional Factors	Content	References
Cyanogenic glucosides (mg kg^{-1})	0 - 4000	[91], [38], [134] [72], [141]
Lectin (mg 50g^{-1})	71.3	[160]
Trypsin inhibitors (TIU mg^{-1} protein)	29.7 – 73.7	[114], [51], [121], [2]
Flatulence causing oligosaccharides (g 100 g^{-1})	0.991 to 12.8	[45]
Oxalate (g kg^{-1} fresh weight)	0.69	[51]
Saponin (g kg^{-1} d.m.)	1	[115]
Phytate (mmol kg^{-3})	IP_3 - Not Detected, IP_4 - 0.23, IP_5 - 2.13, IP_6 - 9.96	[106]
Total phenols (mg kg^{-1} d.m.)	6,660 – 19,599.2	[65], [45]
Tannins (mg kg-1 d.m.)	5 - 7368.4	[65], [45]

3.1 **Cyanogenic Glycosides**

Phaseolus lunatus is the only Phaseolus species containing cyanogenic glycosides. The main cyanogenic glycoside present in lima bean is linamarin [58]. Another cyanogenic glycoside present in lima beans is lotaustralin [141]. It is present in vacuoles of cells. It gets released during tissue damage such as maceration or wounding of the plant and is hydrolyzed into toxic HCN by linamarase, a cell wall-associated β-glucosidase [104]. This is called cyanogenesis and it is a natural herbivore defence mechanism for many plants including lima beans [11], [156], [161], [64]. Hydrocyanic acid or prussic acid is highly toxic. It inhibits cytochrome oxidase which is the terminal oxidase of aerobic respiration resulting in death by oxygen starvation [37]. An oral dose range of 0.5 – 3.5 mg HCN kg^{-1} of body weight is estimated to cause acute lethality in humans [22]. Chronic dietary intake of cyanogenic glycosides has been associated with several diseases [141], [22]. World Health Organization gives 10 mg kg^{-1} HCN as the acceptable level which is not associated with acute toxicity [141]. Cyanogenic glycoside content is highly variable among the different lima varieties. Although some of the wild varieties have been reported to contain very high level of cyanogenic glycosides, the cultivated varieties usually have lower levels. Cressey et al. (2013) found raw lima beans to contain 32 mg kg^{-1} HCN and 6.8 mg kg^{-1} in canned butter beans and lima beans [38]. There have been reports of varieties having more than 2000mg kg^{-1} of hydrocyanic acid [118], [135]. Betancur-Ancona et al. (2004a) proposed a wet fractionation technique to remove this ANF. Ologhobo et al. (1984) reported that cooking and autoclaving can reduce the total hydrocyanic acid content of lima beans by 54-82%. Cooking for 120 min reduced hydrocyanic acid content from 420 mg kg^{-1} in the raw sample to 217 mg kg^{-1} [48].

3.2 Hemagglutinins/ Lectins

Lima beans also contain hemagglutinins/lectins. Lectins are also a group of antinutritional factors. They have the ability to agglutinate erythrocytes and bind to glycoproteins on the epithelium cells lining the small intestine, which interferes with nutrient absorption. Lectins which are proteins or glycoproteins are not usually stable at high temperatures. So, they are generally inactivated after cooking. Although they may retain some activity if not properly cooked. 90 min of cooking can effectively remove lectins and trypsin inhibitors and also improve the protein quality [27]. Lectin content also gets reduced on germination [133]. Lectin and related proteins are seed storage proteins with defensive functions. Most of the Phaseolus species has three types of lectin and lectin-related proteins that belong to the same multigene family: the true lectins, the α-amylase inhibitors, and the arcelins. These proteins show insecticidal properties. Arcelin and α-amylase inhibitor are reported to be resistant against weevils [30], [132], [76]. Boyd was the first to find out in 1945 that extracts of P. lunatus can agglutinate RBCs of human blood group A [25]. Blood group specificity of Lima Bean Agglutinin is A1 > A2 >> B [100]. All lectins which are specific for type A blood are inhibited by N-acetyl-D-galactosamine, the carbohydrate of type A erythrocytes. The lectins also react with blood type AB and hog mucin type A substance. The lima bean lectin does not agglutinate type 0 human red blood cells or native or trypsinized rabbit erythrocytes [60]. Sparvoli et al. (1998, 2001) have characterised lectin-related proteins in lima beans of the Andean and Mesoamerican gene pool. An amylase inhibitor-like (AIL), an arcelin-like (ARL), and the lima bean lectin (LBL) proteins are present in both gene pools. P. lunatus has only one true lectin, LBL. It has three subunits (α, α', β) with monomers of 31kDa. The lectin and lectin related genes originated from a duplication event that occurred before the speciation of the common and lima beans. Through tandem duplications, the lectin gene gave rise to the other related genes [140]. It has recently been shown that lectins of different varieties of Phaseolus lunatus show differences such as in their molecular weight, carbohydrate content and bioactivity. E Lacerda et al. (2017) isolated and characterized a lectin from a Brazilian lima bean variety, P. lunatus var. cascavel with molecular weight of 128 kDa.

3.3 Trypsin Inhibitors

Trypsin inhibitors are regarded as antinutritional factors due to its ability to inactivate digestive enzymes irreversibly. Lima bean trypsin inhibitor (LBI) (1mg) inhibits both trypsin (2.5mg) and chymotrypsin (1.0-1.5mg). So, it is a double headed inhibitor like the Bowman-Birk soyabean inhibitor. LBI inhibits trypsin and chymotrypsin by binding them at different and independent sites. The trypsin inhibitory site in LBI is a lysyl-X peptide bond, while the chymotrypsin inhibitory site is leucyl-seryl peptide bond located at residue 29 from the carboxy terminus. Hydrolysis of the lys-X bond results in loss of trypsin inhibitory activity while the chymotrypsin inhibitory activity is unaffected. Similarly, hydrolysis of the leu-ser bond results in inactivity of LBI towards chymoptrypsin while it remains inhibitory towards trypsin [89]. Household processing methods like soaking and cooking are known to reduce the content of trypsin inhibitors. Overnight soaking caused 9-18% decrease in trypsin inhibitor activity in common beans [133]. Trypsin inhibitor activity can be significantly decreased by autoclaving (83.67%), boiling (82.27%), microwave cooking (80.50%) and germination (33.95%) [49]. Cooking resulted in reduction of trypsin inhibitor activity from 6.32 mg g^{-1} in raw bean to 0.59 mg g^{-1} [6].

3.4 Flatulence Causing Oligosaccharides

Lima beans contain flatulence causing oligosaccharides [45]. Oligosaccharides are carbohydrates consisting of two to nine monosaccharide units. The oligosaccharides raffinose, stachyose, and verbascose cause flatulence. Raffinose is a trisaccharide composed of fructose, glucose and galactose. Stachyose is a tetrasaccharide made of two molecules of galactose, one molecule each of fructose and glucose. Verbascose is a pentasaccharide consisting of three galactose units, one unit each of fructose and glucose [146]. They have α galactosidic bonds. The enzyme α-galactosidase which can break these bonds are absent in humans. As a result, these oligosaccharides remain undigested and are acted on by microbes in the gut. The gases produced due to the anaerobic fermentation cause flatulence. This makes beans an unpopular food choice for many people. The flatulence inducing factor of beans increases with maturity and also varies with genotype [102]. So, varieties which are low in content of these sugars would be desirable. A lima bean ecotype of Italy, Fagiolo a formella has RFO (Raffinose Family Oligosaccharides) value of 0.991 g $100g^{-1}$ [45]. Processes like soaking and discarding the water, and cooking lead to a decrease in the amount of α galactosides. For instance, raffinose decreased by 71.43% on cooking [65]. Overnight hydration of common bean seeds in water or salt media have been reported to decrease the amount of α-galactosides by 40-48%, with significant reduction in stachyose, followed by raffinose content [133]. El-Adawy (2002) reported that in Cicer arietinum germination completely removed raffinose, stachyose and verbascose. Although raffinosaccharides are unpopular because of its flatulence causing activity, it stimulates the growth and activity of beneficial bacteria [123].

3.5 Phenolic compounds

Phenols are regarded as antinutritional factors as their presence in high amounts causes reduction in zinc and iron bioavailability with particularly adverse effects in undernourished populations [59], [69], [41]. Condensed tannins are isomeric flavonoids which also interferes with iron bioavailability. Amount of phenols and tannins in lima beans are variable (Table 5). Doria et al. (2012) reported an Italian variety of lima bean to contain 14.1 µg quercetin per g of flour. Phenolic compounds like quercetin and condensed tannins have been reported to have antioxidant [59], [119], anticarcinogenic [36] and antimutagenic [29] properties. As phenols have hydroxyl functional group, plant extracts with higher phenolic content will have more –OH and hydrogen atoms and therefore, have more antioxidant activity [163].

3.6 Phytic acid

Lima beans like many other legumes contain phytic acid. Plants commonly store phosphorus in the form of phytic acid. Humans and other monogastric animals cannot metabolize phytic acid because of insufficient level of phytate degrading enzymes in their digestive tract [136], [23]. Phytates have the ability to bind with divalent minerals like iron, zinc and calcium forming insoluble complexes that interfere with mineral absorption [163], [150]. Soaking and cooking has been found to be quite effective in removing phytic acid [152]. Other than being an antinutritional factor, phytic acid has been suggested to decrease the risk of iron-mediated colon cancer, reducing lipid peroxidation and lowering serum cholesterol and triglycerides [163].

3.7 Saponins

Saponins act as antinutritional factors by reducing nutrient absorption and utilization, binding with minerals like Zn, its ability to lyse erythrocytes and its bitter taste [145]. This ANF has also been detected in lima beans (table 4). Soaking, sprouting and cooking are known to lower the level of saponin in food [133], [79]. However, saponins have been found to have beneficial functions like antifungal and antibacterial activities, lowering cholesterol level, anti-mutagenic [81] and anticancer activity [112], [16].

3.8 Oxalate

Oxalate in the diet may potentially lead to kidney stone development as they chelate with minerals and precipitate as insoluble salts in kidney [109], [80]. Chai and Liebman (2005) reported oxalate content of 8 mg 100 g^{-1} wet weight for cooked large lima beans which is a much lower value than the 0.69 g kg^{-1} on a fresh weight basis reported by Ezeagu and Ibegbu (2010) for raw lima beans. The amount of oxalate in lima bean is comparatively low when compared with vegetables like red beetroot and spinach which contain 121 – 450 and 320 – 1260 mg oxalate per 100 g fresh weight respectively [109]. Cooking is an effective method in reducing the oxalate content of beans by 40 – 77% [4].

4. NUTRACEUTICAL PROPERTIES

4.1 Antioxidant

Lima beans have antioxidant properties, reported in unprocessed beans [45], protein hydrolysate [147], dietary fibre [20], and lectin [46]. Many phytochemical compounds present in lima beans have been reported to have antioxidant properties such as bioactive peptides [50], [31] and phenolic compounds [3] including quercetin [45], gallic acid, catechin, rutin [127]. DPPH radical scavenging activity of the fresh seed ranged from around 2.6 to 94.4 % [3]. The ·OH scavenging activity of baby lima bean was found to be as high as 74.97 % [162]. The lectin, PLUN of a Brazilian lima bean variety (P. lunatus var. cascavel) showed antioxidant activity [46] which may be attributed to the structure of the lectin and its constituent amino acids [98], [35]. Dietary fibre is another constituent of lima bean that has antioxidant properties. It works by trapping free metals and forming metal complexes that act as reducing agents. The antioxidant activity of P. lunatus fibrous residue was found to be 35.6% at 72 h. This is comparable to the 35% antioxidant activity of vitamin E [20].

4.2 Hypoglycemic

Lima beans have a significant hypoglycaemic effect which makes it a good choice of food for the management of diabetes. When fed with lima beans, diabetic rats showed reduction in cholesterol, bilirubin, creatinine and urea. Lima beans may reduce the cholesterol and bilirubin because of the presence of saponins which complex with cholesterol and bile making them unavailable for absorption [78]. The high dietary fibre content of lima bean may also be a reason for their hypoglycaemic effect. Dietary fibres and starch structure are some of the factors that may cause slow nutrient absorption and delayed transit time which give a hypoglycaemic effect [148]. Linoleic acid which is a fatty acid present in lima bean is reported to lower the risk of type 2 diabetes mellitus [129].

4.3 Anti-HIV

The bioactive peptide, lunatusin from Chinese lima bean inhibits activity of HIV-1 reverse transcriptase [157]. Wong et al. (2006) also isolated a defensin-like peptide called limenin with inhibitory activity against HIV-1 reverse transcriptase from Phaseolus limensis syn. Phaseolus lunatus [144]. The anti-HIV activity of lunatusin and limenin is fairly high with IC50 values of 120 µM and 106 µM respectively when compared with other natural products with anti-HIV activity [107].

4.4 Anti-Cancer

Lunatusin which is a 7 kDa peptide of P. lunatus has shown inhibitory activity towards breast cancer cells MCF-7 with IC50 of 5.71 µM [157]. The peptide, limenin [158] shows antiproliferative activity towards L1210 leukemia cells and myeloma cells M1. Wang et al. (2009) isolated a 6.8 kDa peptide designated Limyin from P. limensis (syn. P. lunatus). It has antiproliferative activity towards tumor cells including human liver hepatoma cells Bel-7402 and neuroblastoma cells SHSY5Y. Lectins of lima beans have been reported to have anticancer activities. Lunatin, a lectin with a molecular mass of 24.3kDa isolated from P. lunatus showed antiproliferative activity towards K562 leukemia cells with an IC50 of 13.7µM [159]. E Lacerda et al. (2017) found that the lectin of P. lunatus var. cascavel show cytotoxic activity against A375 melanoma cells. This anticancer action of the lima bean lectin may be because of specific recognition and activity towards carbohydrates and glycosidic components present or exposed on the surface of cancer cells but which are absent in normal cells. It has been suggested that lectins can be useful tools in targeted drug delivery for treating cancer. To counteract the possible antibody reaction, the lectins may be “humanized” by protein engineering [92], [138], [24]. As lectins bind to very specific substances, they are expected to not affect the normal cells significantly when compared to the cancer treatment drugs being used in traditional medicine. Lima beans contain tocopherols, phytosterols and squalene [125] which are known to have cancer preventative activities [67], [9], [21], [154], [83], [143], [1], [85].

4.5 Antihypertensive

Angiotensin converting enzyme (ACE) catalyzes the conversion of angiotensin I to angiotensin II. Angiotensin II constricts blood vessels, which causes hypertension and heart disease. ACE converting enzyme inhibitors are used to prevent conversion of ACE-I to ACE-II. Protein hydrolysates and peptides from both animal and plant sources are being used to produce angiotensin I converting enzyme inhibitors. Natural ACE inhibitors have minimum side effects while synthetic ACE inhibitors have many side effects such as cough, taste alterations and skin rashes. P. lunatus protein hydrolysates and protein concentrates from germinated and ungerminated seeds respectively have been reported to show ACE inhibitory activity with IC50 values of 0.0069 - 0.056 mg mL^{-1} [147] and 0.56 – 2.40 mg mL^{-1} [33]. Lima bean hydrolysates can be processed to obtain natural antihypertensive drugs.

4.6 Bile Acid Binding

Bile acids are synthesized from cholesterol in liver. The bile acid pool of human beings is maintained by its enterohepatic circulation, with intestinal reabsorption in the ileum and jejunum [88]. Bile acid binding substances like cholestyramine bind bile acids in the intestine reducing their circulation. This leads to an enhanced conversion of cholesterol to bile acids [61]. Studies show that dietary fibres bind to bile acid and salts with the implication that the extent of binding depends on the composition or source of the fibre [151], [142], [44]. This has been suggested to be a means by which dietary fibre lowers cholesterol [26], [62]. In vitro bile acid binding percentage of lima bean relative to 100% binding by cholestyramine is 4% on a dry matter basis [82].

4.7 Gastroprotective Activity

The lectin of P. lunatus var. cascavel has been reported to reduce stomach injury induced by ethanol [46]. Intravenous administration of 1000 µg kg^{-1} concentration of the lectin reduced 63% of stomach ulcer area in mice. As increased free radical production is one of the factors involved in gastric ulcer formation induced by ethanol, the high antioxidant activity of P. lunatus var. cascavel lectin may be a reason for its gastroprotective activity.

4.8 Reduction of Risk of Cardiovascular Diseases

Consumption of legumes has been associated with reduced risk of cardiovascular diseases [14]. Lima beans contain various bioactive compounds having diverse effects on human health such as linoleic acid, linolenic acid, palmitic acid, stearic acid, tocopherols, sitosterol, stigmasterol, campesterol, squalene, etc (Ryan et al., 2007). Some of these are compounds which have been reported to reduce the risk of cardiovascular diseases such as linoleic acid [71], [124], [135], [43], linolenic acid [13], [42], [43], [74], vitamin E (tocopherols) [77], stigmasterol [53], regulate or lower cholesterol like linoleic acid [157], palmitic acid [87], stearic acid [75].

4.9 Antimicrobial

Various components of lima beans have been shown to have antimicrobial activities. Usually wild species have more defensive chemicals than their cultivated counterparts. This is because wild species face more pressure from predators than the cultivated varieties. Isoflavonoids phytoalexins are a group of antipathogenic compounds effective against fungi [93]. Bioactive peptides are one such group of compounds. Wong et al. (2005) isolated an antifungal peptide, named lunatusin. Lunatusin showed anti-fungal activity against Botrytis cinerea (IC50 of 2.6 µM), Fusarium oxysporum (IC50 of 1.9 µM) and Mycosphaerella arachidicola (IC50 of 0.32 µM). Lunatusin also has antibacterial properties towards Mycobacterium phlei, Bacillus megaterium, Bacillus subtilis and Proteus vulgaris. Marimuthu et al. (2014) found ethanolic extract of Christmas lima beans to be effective against the fungus Aspergillus flavus. Limenin, the bioactive peptide from Phaseolus limensis (syn. Phaseolus lunatus) has antifungal and antibacterial activities. Limyin which is a peptide isolated from large lima bean also shows antifungal activity [155]. The P. lunatus lectin, Lunatin has potent antifungal activity toward a variety of fungal species, including Sclerotium rolfsii, Physalospora piricola, Fusarium oxysporum, and Botrytis cinereal [160].

Table 5. *Health benefits of lima beans*

Health benefits	Component of lima bean showing the bioactivity	References
Antioxidant	Unprocessed beans, protein hydrolysate, dietary fibre, lectin, bioactive peptides, and phenolic compounds	[45], [147], [20], [46], [50], [31], [3]
Hypoglycemic	Heat-treated beans	[78]
Anti-HIV	Peptides	[158], [159]
Anti-cancer	Peptides, and lectins	[158], [159], [155], [160], [46]
Antihypertensive	Protein fractions	[147], [33]
Bile Acid Binding	Ground beans	[82]
Gastroprotective Activity	Lectin	[46]
Reduction of Risk of Cardiovascular Diseases	Fatty acids, tocopherol, and phytosterol	[135], [124], [71], [74], [77], [42], [43], [13], [157], [75], [87], [53]
Antimicrobial	Isoflavonoids, peptides, lectin, and ethanolic extracts of whole beans	[93], [158], [159], [155], [99], [160]

5 CONCLUSION

Lima beans are nutritionally rich and a good source of proteins and essential amino acids. They are also rich in bioactive compounds which have health promoting effects. It may be useful to develop food products and nutraceuticals to increase the consumption of lima beans. Although lima beans contain antinutritional factors, most of them can be completely removed or reduced to a minimal level by common household cooking methods. Moreover, phytochemicals which have been traditionally regarded as antinutritional have recently been reported to have useful applications or previously unknown health benefits. For instance, phytates are now known to have anticancer properties [154], [137] and to prevent kidney stone formation [66]. However, the bioactivity of some of these compounds has in the most part been studied from some of the major legumes like soybeans and common beans. Investigations on the effects of these phytochemicals isolated from lima beans are lacking. Further research may also be done to determine whether the ‘antinutritional factors’ ought to be preserved or eliminated. There are widely accepted claims that legume consumption can reduce many health – risks and in view of the available literature, it is possible to say that regular dietary intake of lima beans may contribute in leading a healthy life. Research on the dose and functionality of the bioactive compounds after cooking can be an area of further studies.

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7 CONFLICT OF INTEREST

Authors declare no conflict of interest.

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