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Review Article

Review on Nutritional Importance and Anti-nutritional Factors of Legumes

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Abstract: Legumes are important crops in human nutrition and considered as protein sources for low income populations due to the fact that they can be accessed at relatively lower price than animal products. In Ethiopia, the production of leguminous crops is increasing supported by generation of agricultural technologies by different research institutes. The improvement in the production is supported by pre-harvest information like agronomic characteristics, disease resistance, yield potentials and the like. Nutritional data are lacking in varietal selection for breeding and production and this is due to shortage of nutritional research in our country. Legumes contain sufficient amount of nutrients for both humans and animals. These crops are known for their significant source of protein, dietary fiber, carbohydrates, and dietary minerals. In addition to their proximate value, legumes also contain other very important biochemical compounds called phytochemicals which helps in either prevention or even treatments of certain chronic problems. On the other hand, legumes also contain different compounds which impair their nutritional value after consumption. These compounds are commonly called antinutritional factors and they are known to inhibit either digestion or absorption of nutrients by human body. Some of the anti nutritional factors are known to bind the different micronutrients available and reduce the bioavailability of some important minerals. Others, bind directly to the enzyme used in digestion of foods and inhibit the digestion process. This is why legumes are sometimes considered low nutritional value crops. Hence, it is mandatory for legumes to undergo certain processing like soaking, cooking, fermentation and the like before consumption so that the level of these anti nutrients will be reduced or possibly removed.

Keywords: Antinutrieints, Bind, Bioavailability, Digestibility, Legumes

1. Introduction

Legumes are important crops in human nutrition and considered as meat for low income peoples especially for developing countries due to the reason that legumes are a good source of protein and slowly digestible carbohydrates. They are very important in both human and animal nutrition. Legumes are considerable source of food components including protein, dietary fiber, carbohydrates, and dietary minerals. Ideally, the basic protein requirement is met by consuming proteins of plant and animal origin. Above all these facts, legumes contain more protein than any other plant proteins. They also have unique property of maintaining and restoring soil fertility through their ability of fixing nitrogen as an additional advantage apart from the nutritional advantages [1]. This advantageous composition of legume seeds, not solely make them a meat replacer for vegetarians but also as a component of rational nourishment. They serve as a low-cost protein source to satisfy the needs of the large section of the people more specifically in developing world.

Like other plant-based foods, pulses, a group among legumes contain no cholesterol and little fat or sodium. Legumes are also an excellent source of resistant starch (excellent source of Prebiotic carbohydrates), which is fermented by bacteria in the large intestine to produces short-chain fatty acids (such as butyrate) used by intestinal cells for food energy. Preliminary studies in humans include the potential for regular consumption of legumes in a vegetarian diet to affect metabolic syndrome [2]. There is evidence that a portion of pulses which are one family among leguminous crops, a diet may help lower blood pressure and reduce LDL cholesterol levels, though there is a concern about the quality of the supporting data [3].

The nutritional importance of legumes can be negatively affected by their anti-nutritional factor compositions such as R-galactosides, trypsin inhibitors, or phytic acid, which interfere with the ingestion, digestive, absorption and utilization of protein and minerals by monogastric animals. This is because; the presence of these antinutritional factors degrades the nutritive value of legumes, and even may lead to health problems which could eventually become fatal to humans and animals if taken in larger amount [2]. It has been reported that legumes are considered low nutritive value because of low amounts of sulfur-containing amino acids, low protein digestibility and also the presence of anti-nutritional factors.

Legumes are usually cooked prior to consumption to improve the protein quality by destruction or inactivation of the heat labile anti-nutritional factors. Authors reported in a literature that applying hydrothermal treatment can reduce levels of phytic acid by 70%, and improved the digestive utilization of protein [4]. As the authors further elaborated, the mild hydrothermal treatment increased the nutritive utilization of protein and carbohydrates, but this effect was not observed in the phytase-supplemented diet. Despite the advantages in reducing these anti nutrients, heat treatments can also have an effect on its nutritional value by causing considerable losses in soluble solids, especially vitamins. As reported in a literature, processing methods such as boiling; autoclaving; microwave has effects on nutritional composition of lentils, one example of leguminous crops [5]. Processing methods including boiling, autoclaving and microwave cooking affect the composition, antinutritional factors, flatulence factors and nutritional quality of beans. However, microwave cooking caused slight losses in minerals, while boiling and autoclaving caused significant losses. All cooking treatments improved the in-vitro protein digestibility and protein efficiency ratio of lentils. It is quite clear that cooking lentils by microwave not only saves time but also retains the most nutritive value. It is not only processing methods that are known to affect this nutritional and antinutritional availability in legumes. Other factors besides cooking such as growth conditions and variety/cultivar can also affect nutritional and antinutritional factors and sensory parameters [6].

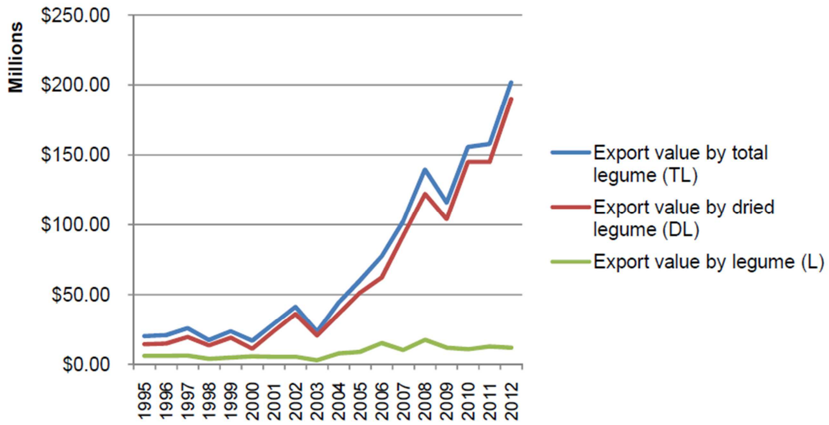
Legume crops play very important nutritional role in the Ethiopia. Information on legumes crops however is mostly limited to varietal selection which depends on adaptation, disease resistant, rate of maturation, yields, seed size, color and specific agronomic traits, but never nutritive quality [7]. Currently also, the information concerning nutritional advantages and antinutritional factors of legumes are limiting in the country and found in dispersed form, and thus, need to be complied together in the form of scientific review so that one can simply read and understand the status of nutritional research in the area and come up with possible research gap. Thus, the purpose of this current review is to review literatures related to nutritional and antinutritional composition of legumes and point possible research gap for future research.

2. History of Legumes

Legumes are believed to be the earliest human-domesticated plants [8]. According to these authors, legumes have been an important part of the social evolution over the past 10 000 years, and grain legumes have carbonized seeds of pea, lentils and vetches have been found in fireplaces of the Neolithic age (7000 to 8000 years B.C.) in Turkey. These seeds formed the basis of food in this region and spread to the north-west and south-west (into Africa) and towards India [8]. Legumes include peas, beans, lentils, peanuts, and other podded plants that are used as food for human and for animals specifically in developed countries. Legumes have been cultivated for thousands of years, although many of the varieties of beans and peas that are commonplace today were unknown until relatively recent times. Legumes have played an important role in the traditional diets of many regions throughout the world. It is difficult to think of the cuisines of Asia, India, South America, Middle East and Mexico without picturing soybeans, lentils, black beans, chickpeas, and pinto beans, respectively. In contrast, in many Western countries, beans play a less significant dietary role.

Legumes represent a vital element of agricultural system in Ethiopia, and nearly twelve legume crops are cultivated in the country. Among the highland legumes are faba bean (Vicia faba L.), field pea (Pisum sativum L.), chickpea (Cicer arietinum L.), lentil (Lens cultinaris Medik.), grass pea (Lathyrus sativus L.), fenugreek (Trigonella foenum-graecum L.) and lupine (Lupinus albus L.) where as haricot bean (Phaseolus vulgaris L.), soya bean (Glycine max L.), cowpea (Vigna unguiculata L.), pigeon pea (Cajanus cajan L.) and mung beans (Vigna radiata L.) are categorized as lowland legumes [1, 9, 10].

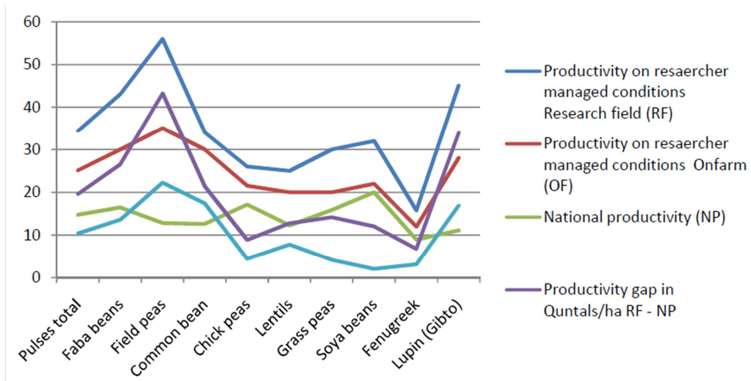
The production of leguminous crops therefore is very indigenous and is increasing these days. The production pulse by volume has been increased by 71.92% for the duration of nearly 20 years and with a growth rate of 3.78% per annum in this country, Ethiopia [11]. As per the authors, legume comprise different important commodities such as haricot bean, chick pea, faba bean etc both in domestic and export markets, in the Ethiopian trade balance. It is further stated by the authors that the export value of legumes in the Ethiopian economy has been increased by 89.92% over the last 18 years with 5% annual growth rate. For example, the actual export value by legumes in 1995 was 20.34 million USD and 201.86 million USD in the year 2012 in reported by the authors above.



Source: [11]

Figure 1. *Export value trend of legumes in the Ethiopian export market over the last 18 years.*

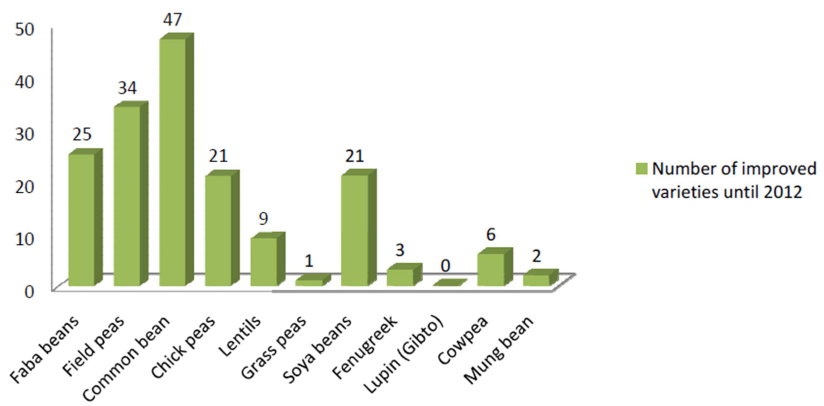
The national agricultural research system managed the development and release of 169 improved varieties of different food legumes in the country during the periods 1973 to 2012.



Source: [11]

Figure 2. *Productivity gap between researches demonstrated potential and national average of food legumes.*

By taking into consideration the different potential benefits that could be obtained from legumes such as human food, animal feed, improves soil and environmental health, and as a human nutrition and medicine, it is needed to give sufficient attention to the sub-sector of changing the perception of the farmers to produce up to the demonstrated potential by using all the production packages in Ethiopia. This is because; apart from economic use, leguminous crops are also good and cheap source of dietary protein and fetch reasonable cash for the Ethiopian poor farmers. The research system should proactively deliver productive and up to standard technologies for the different legume crops that potentially be produced in the country to make the country competitive in potential global market.



Source: *Source:* [11]

Figure 3. *Number of improved varieties of food legumes released by national agricultural research system of Ethiopia during the periods of 1973-2012.*

Legumes have traditionally been an important part of the diets of many cultures throughout the world. In contrast, in developed countries beans currently have only a minor dietary role. The nutritional profile of beans shows that they have much to offer; beans are high in protein, low in saturated fat, and high in complex carbohydrates and fiber. Beans are also a good source of several micronutrients and phytochemicals. Soybeans for example are unique among the legumes because they are a concentrated source of isoflavones. It has been hypothesized that isoflavones reduce the risk of cancer, heart disease, and osteoporosis, and also help relieve menopausal symptoms. Although there is much to learn about the effects of isoflavones on chronic disease risk, this area of research holds considerable potential. Taking the nutrient profile and phytochemical contribution of legumes into account, nutritionists should make a concerted effort to encourage the public to consume more beans in general and more soybean foods in particular.

Mostly, the term legumes and pulses are used interchangeably. But, there are little distinctions between the two terms. Pulses can be defined as dried edible seeds of certain plants in the legume family. The United Nations Food and Agriculture Organization (FAO) recognize 11 types of pulses grown worldwide. Pulses are legumes which are very high in protein and fibre, and are low in fat. Pulses are also known for their nitrogen-fixing properties and play important role in improvement of the environmental sustainability of annual cropping systems. Pulses come in a variety of shapes, sizes and colors and can be consumed in many forms including whole or split, ground in to flours or separated into fractions such as protein, fibre and starch (www.pulsecanada.com 2016). Other foods in the legume family like fresh beans and peas are not considered pulses as the term "pulse" only refers to the dried seed. The soybeans and peanuts are also not considered pulses because they have a much higher fat content, whereas pulses contain virtually no fat.

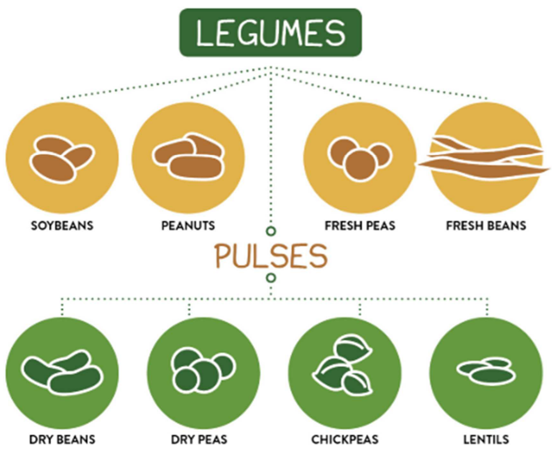


Figure 4. *Legumes and pulse distinction Source: www.pulsecanada.com 2016.*

3. Nutritional Quality of Legumes

Legumes are the most important crops cultivated for human and animal nutrition in different countries like Asia, Africa and Caribbean regions. They are a rich source of protein and dietary fiber in our daily foods, which contributes to lowering the energy density and reducing the glycaemic response, but they are also a good source of protein. A serving of legumes (1⁄2 cup cooked dried legumes) contains 2–4 g of fibre and 7–8 g of protein [12]. Most beans are very low in fat, generally containing <5% of energy as fat, with the exception of chickpeas, lupin seeds and soy beans, which contain <15–47% fat [13]. Legumes contain substantial amounts of the B-vitamins as well as the nutritionally important minerals, such as iron, calcium and potassium. It is the relative proportions of these nutrients, especially protein and fibre, and the composition of the individual components, which for the most part determines the nutritional value of legumes.

The nutritional key role of grain legumes is due to the presence in abundance of the macro and micronutrients. Among these nutrients, proteins play a relevant role in consideration of their amino acid composition which can easily be balanced in the diet. In the frame of a reappraisal of the effects that grain legume components may have on human well-being, widely accepted claims on their beneficial activity in the prevention and treatment of various diseases has been put forward. Altogether, these claims strongly support the regular dietary intake of grain legumes as one of the ways to a healthy life [14].

Table 1. *Nutrient composition of dry beans and soybeans.*

Nutrients	Dry beans	Soybeans
Total fat(g)	1	19
Saturated fats(g)	0.3	2.8
Monounsaturated fat(g)	0.11	4.4
Polyunsaturated fat(g)	0.55	11.2
Ratio of α linolenic acids to linoleic acid(mg)	0.252:0.301	1.3:9.9
Protein(g)	22	36
Carbohydrates(g)	60	30
Stachyose (mg)	1.848	3.300
Raffinose (mg)	336	1600
Insoluble fiber (g)	11	10
Soluble fiber(g)	6	7
Calcium (mg)	154	276
Magnesium (mg)	172	280
Potassium (mg)	1140	1797
Iron(mg)	6.4	16
Zink (mg)	2.5	4.8
Thiamin (mg)	0.45	0.89
Riboflavin (mg)	0.13	0.87
Niacin (mg)	2.5	1.6
Folate (μg)	370	375

Source: [14].

3.1. Proteins

During the course of their developments, legume seeds accumulate large amounts of proteins. Most of them are not devoid of any catalytic activity nor do they play any structural role in the cotyledonary tissue. They are stored in membrane-bound organelles, the storage vacuoles or protein bodies, in the cotyledonary parenchyma cells, survive desiccation in seed maturation and undergo proteolysis at germination, thus providing free amino acids, as well as ammonia and carbon skeletons to the developing seedlings [14]. Legumes are relatively rich sources of protein as the seeds contain 200-250 g protein/kg than the other plant foods. The protein content of cooked legume seed (70-100 g/kg cooked food) is similar to that of bread (80-90 g/kg), but still much higher than for potato (15-22 g/kg) [8]. Legume seeds are rich in lysine and poorer in sulfur-containing amino acids (methionine and cysteine) compared to cereals. Lysine is the first limiting amino acid in cereals so it is important that legumes complement cereals in lysine balance. Legume proteins are composed of several thousand specific proteins. About 70 to 80 % of the crude protein in legume seeds is storage protein. The non-storage proteins are enzymes, enzyme inhibitors, hormones, transporting, structural and recognition proteins. The protein contents of legume seed can be fractioned into two as vicilin and legumin. As indicated in a literature, the relative proportion of these proteins is dependent on genotype, but vicilin is the major protein fraction in all legumes except Vicia faba [8], Authors in their research on three different types of legumes concluded the result that, crude protein of the three seed flours was within the range 24.13- 26.30% [15]. In general, the above reviewed literatures are indicating that legumes of relevant protein sources specially incase the consumers are vegetarian or else low income societies. The protein content of beans is generally between 20% and 30% of energy.

Table 2. *Protein content of raw legumes (as % of dry matter).*

Legumes	Protein content, %
Chickpea	15.5 to 28.2
Lens	24.7
Lupin	34.8 to 62.5
Beans(Vicia, phaseolus)	19.4 to 24.8
Peas	23.9 to 25.1

Source: [8].

3.2. Fats

Most beans are very low in fat, generally containing <5% of energy as fat. The primary exceptions are chickpeas and soybeans, which contain <15% and 47% fat, respectively [16] USDA (1988) reported the predominant fatty acid in beans to be linoleic acid and a-linolenic acid contained in beans. However, because the overall fat content of most beans is so low, the dietary contribution of beans to a-linolenic acid intake is generally minor. As noted from the above journal, soybeans are quite high in fat, and the consumption of full-fat soyfoods contributes significantly to a-linolenic acid intake. The ratio of linoleic to a-linolenic acid in soybeans is <7.5:1 (a-linolenic acid makes up <7–8% of the total fat) (US DA 1988**)**. One of the research report from Nigeria on three legume states that the crude fat of the three seed flours (Jack bean, Pigeon pea and Cowpea) ranged between 1.95-4.78% [15]. According to these authors, jack bean seed flour had the lowest value of crude fat (1.95±0.04%) while that of Pigeon pea had the highest value (4.78±0.22%). Soy foods however are, lower in saturated fat and cholesterol, and hence have advantages as compared to animal products. In addition to the lower in saturated and cholesterol levels, soy products also contain sterols, a compound which inhibits cholesterol absorption in the small intestine, thereby decreasing serum cholesterol levels [16].

3.3. Carbohydrate and Fiber

The seeds of three different legumes tasted by researchers in a literature have high value of carbohydrate content ranging between 56.60-57.83%, and found no significant difference in carbohydrate content of the seed flours at (P<0.05) [15],. Authors however generalized the total carbohydrate composition of soybeans and dry beans to be ranges from 30-60% and these carbohydrates are primarily structural and storage polysaccharides [16]. The main storage carbohydrate is starch with small amounts of monosaccharides and disaccharides such as sucrose. The oligosaccharides compositions raffinose, stachyose and verbascose are not hydrolyzed in the small intestine because there is no α-galactosidase enzyme in the human intestinal mucosa [16]. These carboydrates are fermented to short-chain fatty acids (SCFAs), and lead to gas production in the colon which in turn brings about flatulence [17]. Because of the discomfort and social embarrassment associated with flatulence, some people avoid beans entirely [16]. But, as it is stated by this author, commercial products such as Beano (AkPharma Inc, Pleasontville, NJ), which have a digestive aid that contains α-galactosidase, are available so that individuals can eat beans without discomfort.

With respect to fiber content, the three legume seed flours tasted and reported showed no significant difference (P<0.05) with their fiber composition [15]. The authors elaborated that crude fibre of Pigeon pea (1.10±0.10%) was the highest while that of Cowpea (0.97±0.09%) was the lowest.

3.4. Micronutrients

A literature also explored that higher ash content in Jack bean seed flour (6.51±0.28%) than that of Pigeon pea (4.58±0.40%) and Cowpea (4.73±0.30%) seed flours and the difference was significant at (P<0.05) [13]. This ash composition on the other hand is an indication for the mineral contents of the legumes. Dry beans and soybeans are low in sodium but are excellent sources of minerals, including calcium, copper, iron, magnesium, phosphorus, potassium and zinc [17, 18]. However, the content and bioavailability of minerals vary depends on the processing methods applied and phytate content. Beans are a good source of iron; one serving (100 g or half a cup cooked) provides 2 mg, this compares favorably with the iron RDAs reported by national research council recommended daily allowance in 1989 which is 10 mg and 15 mg for adult men and premenopausal women, respectively. On the opposite hand, as it was reported in a literature iron bioavailability from legumes is poor, and thus their value as a source of iron is limited [19]. However, other authors differently reported that the bioavailability of zinc and calcium is relatively good and is reported to be about 25% and 20%, respectively [13]. Moreover, the authors elaborated that the calcium bioavailability from soybeans and soy foods is quite good despite the presence of phytate and oxalate.

Dry beans and soybeans among legumes are good sources of water-soluble vitamins, especially thiamin, riboflavin, niacin and folate, but poor sources of fat-soluble vitamins and vitamin C [17]. Furthermore, in terms of meeting the RDAs for adults, a one-cup serving of cooked dry beans can provide 30% of the required folate, 25% of thiamin, 10 - 15% of vitamin B6 and < 10% of niacin and riboflavin. The legumes crops can provide precious micronutrients, such as tocopherols, i.e. vitamin E [20]. Since the composition of tocopherols in food is complex and the biological activity of each congener depends on its specific structure, the most useful parameter to compare different food items is the vitamin E activity. Only some legumes, such as chickpea and, to a lesser extent, soybean and broad bean, provide relevant levels of the major contributor to vitamin E activity, i.e. alpha-T.

Table 3. *Nutrient content of selected beans (serving size is <90 g or 1/2 c boiled).*

Bean	Fiber	Riboflavin	Folate	Ca	Zn	Fe
Black	3.6	50	128	24	0.96	1.8
Baby lima	3.9	50	137	26	0.94	1.18
Chick pea	2.9	50	141	40	1.26	2.37
Kidney	3.2	50	115	25	0.95	2.6
Lentil	4.0	75	179	19	1.25	2.3
Navy bean	2.3	55	128	64	0.97	2.26
Soybean	0.9	25	47	138	0.99	4.42
Pinto	3.4	80	147	41	0.93	2.24
Great Northern	3.0	50	91	61	0.78	1.89
Lima	2.8	50	78	16	0.80	2.25

Sources: [13].

4. Anti-nutritional Constituents in Legumes

Anti-nutritional factors are chemical constituents which impair the digestion and absorption of some interesting components (e.g. proteins, vitamins), or, in some cases, they are simply toxic or cause undesirable physiological side effects (e.g. flatulence). Leguminous plants are the most important plant food material, for they are the concentrated cheap sources of protein for the vegetarian population and low income societies. However, they are under-utilized in various countries because of antinutrient factors, such as enzyme (trypsin, chymotrypsin, -amylase) inhibitors, phytic acid, polyphenols, flatulence factors like oligosaccharides, etc [21]. Protein indigestibility is a common drawback to all legumes, due to the presence of these antinutritional factors, some of which might also diminish the bioavailability of trace elements and proteins [7]. Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients. Grain legumes are known to be composed of different antinutritional factors. The presence of these antinutritional compounds in grain legumes is therefore considered one of the limitations to an increased utilization of the grain as food as well as feed sources. This is because, if these compounds are found consumed with foods, they can decrease the nutritional value of the grain legumes and if concentration consumed is of large amount, they can cause health problems that can lead to fatal for humans or animals as well.

Antinutritional factors (ANFs) in legumes can be divided into several groups based on their chemical and physical properties such as nonprotein amino acids, alkaloids, cyanogenic glycosides, pyrimidine glycosides, isoflavones, tannins, oligosaccharides, saponins, phytates, lectins or protease inhibitors and non-protein compounds [22]. A number of anti-nutritional compounds (ANCs) in legumes can be of proteinous, i.e., hydrolase inhibitors and lectins, and they can also non-proteinous in nature. The presence of these antinutritional factors in plant is due to an evolutionary adaptation which enables the plant to survive and complete its life cycle under certain conditions. Since many of the ANFs are toxic, unpalatable or indigestible, they are needed to be eliminated from the food staff either by selection of plant genotypes or through post-harvest processing (germination, boiling, leaching, fermentation, extraction) before consumption.

4.1. Proteinaceous Anti-nutritional Factors

Legume seeds, in addition to nutritional proteins, contain a number of other abundant proteins some of which are biologically active proteins, which for years have been referred to as anti-nutritional compounds. These groups of proteins include lectins, proteases and amylase inhibitors. The proteinase and α- amylase inhibitors are monomeric seed proteins [23] and lectins are proteins that bind to carbohydrates or to molecules containing carbohydrates. These non-nutritional proteins contained in legume seeds may vary in types and amounts among the legume seeds. Some of these non-nutritional proteins are biologically active proteins, which have been referred to as anti-nutritional compounds for years. Among the protein ANCs, seed hydrolase inhibitors play a major role, due to their spread diffusion in many legume grains, including pea, lentil, bean as well as soybean, and the seed lectins are another family of protein ANCs in grain legumes [14].

4.1.1. Lectins

As opposed to its antinutritional effect, lectins have also advantages. For example, pulse lectins are used for clinical and immunological studies and used for various other purposes. In pulses, lectins ranges from 0.6% in garden pea, 2.4 to 5% in kidney bean, and 0.8% in lima and soya bean with respective to total protein content [24]. Apart from other uses, higher consumption of lectins from the above mentioned pulses results in nutritional deficiencies, and immune (allergic) reactions. Possibly, most effects of lectins are due to gastrointestinal distress through its interaction with the gut epithelial cells [25].

4.1.2. Amylase Inhibitors

Amylase inhibitors are found in pigeon pea, and showed decreased broken down of the digestive enzyme. These inhibitors have been found to be active within a pH range of 4.5-9.5 and heat labile. This inhibitors form complex with amylase that depends on ionic strength, pH, temperature, time and concentration of the inhibitors. These complexes inhibit bovine pancreatic amylase but fail to inhibit fungal and bacterial amylase. This enzyme is synthesized during late seed development and degraded during late germination in pigeon pea [26]. Among the pulses, field bean and chickpea contain very low concentrations of amylase inhibitors. Winged bean, adzuki bean, soybean, lima bean, lentil and pea showed no amylase activity [27]. This enzyme plays a vital role in the breakdown of starch to release energy in the form of glucose and maltose. Presence of this inhibitors leads to reduced hydrolysis of polysaccharides such as starch and glycogen. A reduction in growth in chickens was observed due to reduced hydrolysis of polysaccharides [26]. The authors also further elaborated that in human consumption of these inhibitors as starch blockers reported to cause symptoms like diarrhoea, nausea and vomiting because of reduced or no digestion.

4.1.3. Goitrogenic Factor

As cited by literature, it is reported that the goiterogenic effect of soy beans and further confirmed by other researchers in both rats and chickens. Furthermore, several researchers have reported the effect of soy milk on goiter [28]. This can be alleviated by increasing iodine intake. Pea interferes with the absorption of iodine through the mechanism on the intestinal mucosa. Presence of arachidoside in the outer skin of the peanuts showed goitrogenic effect. Among the entire pulses, pea, common bean, soybean, and peanut inhibited the absorption of radioactive iodine by thyroid in human subjects. These factors are present in soybean and groundnut.

4.1.4. Saponins

Saponins are a diverse group of chemicals and they derive their name from their ability to form soap like foams in aqueous solutions. Saponins occur in a considerable number of plant species ranging from asparagus (*Asparagus officinalis*) to cucumber (*Cucumis sativus*) [29]. They are also found in legumes and are triterpene glycosides, which are very poorly absorbed by humans [17]. Most saponins form insoluble complexes with 3-β-hydroxysteroids and are known to form large, mixed micelles with bile acids and cholesterol [13]. Although saponins were shown to lower cholesterol in some animal species, the hypocholesterolaemic effects of saponins in humans are more speculative [30]. Saponins may have anticancer properties, as suggested by a study in mice [31]. Soybean, navy beans, haricot beans, kidney beans and etc are known to be composed of saponins as antinutritional factor.

4.2. Non-proteinaceous Anti-nutritional Factors

4.2.1. Phytate/Phytic Acid

Phytic acid, which is abundantly present in seeds, also exists in roots, tubers, pollens and spores of many plant species. Grain crops typically contain about 10mg phytic acid per gram seed dry weight, representing about 65% to 85% of seed total P [32]. In legumes, phytic acid is present in chick pea, pea, lentil, kidney beans, and soybean. Total P concentration typically ranges from 3.0 to 4.0 mg per gram in seed produced by grain crops, with phytic acid P ranging from 2.0 to 3.0 mg per gram. In dry pea, 99% of phytic acid is present in cotyledons and 1% is present in embryo axis. 65% of the total phosphorus in pea cotyledons and 10% of total phosphorus in embryo axis arise from phytic acid phosphorus [28]. More than 88% of phytic acid is present in pea cotyledon and seed coats contained almost no phytic acid. In peas, the phytic acid content increased from 0.16 to 1.23% during maturation. According to the finding in this literature, the phytic acid content in soybean during maturation increased from 0.87 to 1.26%. Farthermore, in winged beans, there was a proportional increase in phytic acid at four developmental stages of seed maturity. It is a strong chelator of mineral cations such as calcium, iron and zinc forming mixed salts that are largely excreted by humans and other non-ruminant animals such as poultry, swine and fish. Phosphorous and inositol in phytate are not available to non-ruminant animals, since they lack the enzyme phytase to remove the phosphate from inositol in phytate. On the other hand ruminants readily digest phytates because of the presence of microorganism in rumen. Low absorption of minerals ultimately results in reduced weight gain in livestock. Bioavailability of minerals can be increased by phytase enzyme supplementation or reduction of phytate through breeding of legumes with reduced phytic acid content.

Phytate is largely responsible for the poor iron bioavailability from soybeans. On average, the phytate content in beans is 1-2 % [13]. However, phytate has antioxidant effects, and may lower the risk of colon and breast cancer. Phytic acid and/or its salt, is inositol combined with six phosphate groups and is a common constituent of most plants and legumes. As stated before, its antinutritional effect is due to the fact that it forms a chelate with metal ions such as calcium, magnesium, zinc, and iron to form poorly soluble compounds (or even insoluble) that are not readily absorbed from the intestine, thus interfering with the bioavailability of these essential minerals constituents [34]. This makes plant based micronutrients especially minerals unavailable for absorption in the body.

4.2.2. Tannins

Many plant species are known for their tannin compositions. Legumes are among these plant species and even contain an appreciable amount of this compound [29]. Tannins are complex group of phenolic compounds which are astringent in taste that precipitate proteins and they are present in almost all legumes predominantly. They have an ability to form complexes with molecules like carbohydrates, proteins, polysaccharides; enzymes involved in protein and carbohydrate digestion and then have major impact on both human and animal nutrition [35]. Though not fully understood, the major antinutritional effect of tannins is that it interferes with the digestibility of dietary protein [36]. This effect may be due to the binding of the tannins to the protein to form substrates that are resistant to digestive enzymes (indigestible complexes) or a direct binding to these enzymes themselves[29, 36]. Tannins can irritate the gut lining and stimulate the secretion of mucus which increases endogenous protein secretion and therefore increases protein demand. They also form complexes with divalent metals and reduce mineral absorption [34]. A common feature of diets high in tannin is weight loss [29].

4.2.3. Cynogenic Glycosides

Legumes are also exhibit toxicity because of their cyanide producing potentials, compound which produce HCN upon hydrolysis. Cassava and lima beans are known plants for containing these cynogenic glycosides. High level of this glycosides is causative agent for human food poisoning. Grain legumes (pluses) contain relatively high level of cynogenic glycosides. Cyanide in trace amounts is fairly wide spread in the form of glycosides (cyanogens) which are non-toxic in the intact tissue but when later up on tissue damage or begin of decay, a hydrolytic enzyme is released liberating hydrogen cyanide [34].

4.2.4. Toxic Non-protein Amino Acids

There are two toxic non-protein amino acids in grain legumes that have a major negative effect on animals or humans consuming them. Mimosine and 3-*N*-oxalyl-L-2, 3-diaminopropanoic acid (ODPA) are the two amino acids [29, 36] which are often highly toxic, and are responsible for several serious human toxicoses, among the best known of which is lathyrism, a non-progressive motor neuron disease associated with high consumption of grass peas (*Lathyrus sativus*) [36]. Consumption of large amounts of *Lathyrus* seed in the diet often occurs at times of food shortages as a result of drought. Grass peas, grown arid regions like Ethiopia and the Indian subcontinent, contain high levels of ODPA in their seeds, and this compound is responsible for the neurological symptoms and also for deleterious effects on bone formation, particularly in children [34]. The consumption of diet sources rich in this compound is not recommended for children. One of major effects of mimosine is to stop hair growth; and it has an adverse effect on the growth of ruminants because bacteria can convert mimosine to 3, 4- dihydroxypyridine which acts as a goitrogenic agent [29, 36].

4.2.5. Oligosaccharides

RFOs (Raffinose Family Oligosaccharides) of legumes are synthesized by sequential addition of galactose units to sucrose [37] and are α-galactosyl derivates of sucrose [38]. Furthermore, oligosaccharides, including raffinose, stachyose, ciceritol, and verbascose, are commonly found in legumes and often result in flatulence in humans. The antinutritional influence of these oligosaccharides lies in the fact that, these oligosaccharides accumulate in the large intestine where the α-galactosidase containing intestinal bacteria degrade them and subsequent anaerobic fermentation results in production of H_2, CO_2 and traces of CH_4 and hence flatulence [34]. According to a literature, the total oligosaccharide content of raw legumes ranged from 70.7 mg/g in yellow peas to 144.9 mg/g in chickpeas [38]. The oligosaccharides contents of some legumes analyzed by the previous studies are presented in the table below.

Table 4. *Oligosaccharides contents of some legumes.*

Legumes		Oligosaccharide content				
		Raffinose	Ciceritol	Stachyose	Verbascose	Total
Lentils	Cv. Pardina	28.6c	38.6b	24.6c	3.9c	95.5bc
	Cv.Crimson	37.0bc	50.0ab	28.8abc	7.2b	122.9ab
Chickpeas		50.2ab	67.7a	27.0bc	Nd	144.9a
Yellow peas		34.0c	Nd	31.7ab	4.9c	70.7c
Green peas		30.1c	Nd	35.4a	15.0a	80.4c
Soybeans		60.1a	Nd	35.0a	Nd	95.1bc

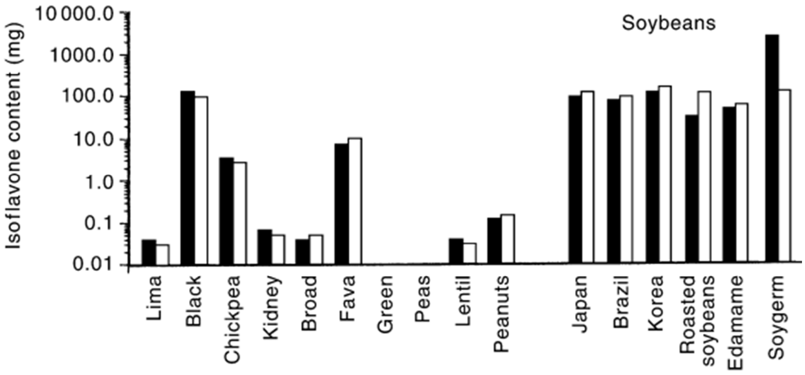
Values within a column followed by the same letter are not significantly different at $P < 0.05$.
nd Not detected.
Source: [34].

Thus from the results in the above table; it is possible to conclude that oligosaccharide content differed largely among different legumes. Raffinose, ciceritol, and stachyose were the major oligosaccharides of lentils and chickpeas while that of soybeans and peas are mainly raffinose and stachyose.

Genally, antinutritional factors are chemical substances which can decrease palatability, diminish protein digestibility and mineral bioavailability [39]; and hence limit the biological value and acceptance of legumes or pulses as a regular food item [38]. Appropriate processing is therefore important prior to consumption. This is why legumes are not eaten raw, but processed in a way that inactivates or reduces these anti-nutritional factors. Hence the aim of processing food is not limited to flavor and palatability improvement but, extend to increases the bioavailability of nutrients, by inactivating antinutritional factors [40].

5. Health Implications with Legumes

As it has been discussed a lot about the nutritional and other compositions of legumes, these crops are sources of macronutrients, micronutrients and other phytochmicals. Isoflavones as example make up one group of phytochemicals found in bean of which soybeans is are unique sources because they contain isoflavones in concentrated amount. Different literature hypothesized that this isoflavones are good for reducing the risk of cancer, heart disease, and osteoporosis, and also help relieve menopausal symptoms [13]. Given that the nutritional advantages and phytochemicals contained in legumes in general and soybean in particular, food scientists and nutritionists should encourage the public to consume these crops in sufficient amount. According to the findings in a literature, dietary pulse intake resulted in a modest reduction in LDL cholesterol of 0.17 m mol/L (equivalent to a reduction of about 5% from baseline) [41].



Source: [42]

Figure 5. *Isoflavone content of selected legumes expressed per 100 g and per serving-size.*

Furthermore, legumes play a role in prevention and even improvement and/or treatment of disease conditions such as, diabetes mellitus, cardiovascular diseases, cancer diseases (e.g. breast and prostate cancers) and lowers blood cholesterol level [33]. Most of these disease conditions are associated with over-nutrition and obesity and are considered as diseases of the rich. It is, therefore, claimed that including legumes in a health-promoting diet is important in meeting the major dietary recommendations to improve the nutritional status of undernourished as well as over-nourished individuals, and to reduce risk of chronic diseases such as cardiovascular disease, diabetes mellitus and cancer [34].

As legumes are potential sources for soluble fiber and oligosaccharides they can be recognized as a source of prebiotics, which have been described as „colonic foods that selectively stimulate the growth of beneficial intestinal microflora [16, 42]. Fibers in legumes keep human intestinal system healthy. They keep the bowels healthy and move regularly, improve constipation, and combat against colon cancer and intestinal disorders [34].

6. Factors Affecting Nutritional Composition of Beans

The different types and varieties of legume differ in their nutritional and anti nutritional composition [43]. Previous research result reported by researchers revealed higher nutrient content in black gram bean cultivar than in green gram cultivar to show that cultivar types can affect the composition of legumes [44]. Authors reported in literature that antinutritional factors and nutritional concentrations were highly influenced ($P<0.01$) by locality and combination of variety and locality [45].

Moreover, results obtained in the study by different authors permitted them to observe [43-45]:

1) The influence of variety and locality on composition, protein quality, and antinutritional factor concentrations in dry beans;
2) Relationships between some dry bean nutrients or between antinutritional factors and protein digestibility.

It is fact that bean undergoes different processing methods before consumption. These processing methods may be designed for improving sensory quality, or else to reduce antinutitional factors. But, these processing methods are not only serving these factions but also affect the nutritional qualities of beans. As it is reported by authors in an article boiling, autoclaving and microwave cooking affect the composition, antinutritional factors, flatulence factors and nutritional quality of chickpeas [45]. Authors further elaborated that microwave cooking caused slight losses in minerals, while boiling and autoclaving caused significant losses. All cooking treatments improved the in-vitro protein digestibility and protein efficiency ratio of lentils. It is quite clear that cooking lentils by microwave not only saves time but also retains the most nutritivee value. Literature also reported that, amongst the various processing treatments; pressure cooking was found to be most effective in retention of the nutrients in cultivars of legumes [44]. According to the authors, for the removal of the antinutritional factors, both pressure cooking and germination were found to be most effective among all the processing treatments. Thus, from these literatures, it can be understood that processing methods are also among the different factors affecting nutritional composition and availability of nutrients in grain legumes.

7. Methods to Reduce Anti Nutritional Factors in Legumes

Processing methods are effective in reducing the antinutritional factors in different legumes. According to finding of researchers, processing of the newly developed bambara groundnut seeds with malting shows the greatest reduction effect [44, 45]. The different physical and chemical methods employed to reduce or remove antinutritional factors include soaking, cooking, germination, fermentation, selective extraction, irradiation, and enzymic treatments [44, 45]. But, the application of a single technique is frequently insufficient for effective treatment and so combinations of two or more methods are commonly employed; thus the most effective methods for reducing saponin contents have been reported to be soaking and cooking [45]. Authors further stated that using a combination of abrasion and soaking, the amount of quinoa saponins was reduced by up to 100%.

Table 5. *Some physical processes for removing antinutrients from legume seeds.*

physical processing	Comments
Autoclaving, pressure cooking, steaming	Heating at ultrahigh temperatures (>100°C). Performance dependent on temperature, moisture, pressure relations
Blanching	Mild boiling (75°C − 95°C) to inactivate endogenous enzymes and avoid cooking
Ordinary cooking	Usually preceded by soaking or another domestic processing, de-hulling, germination fermentation, and so on
Extrusion	A form of high temperature short time (HTST) processing involving a combination of high temperature, pressure, and shear processing
Roasting	Dry heating at 120°C-250°C
Soaking	Exposure to water and salt solutions with or without additive to encourage ANF loss
Processing chemical and chemical modification	Treatment with thiols, sulphite, Cu-salts (± ascorbic acid). Chemical modification via acylation, succinylation

Source: [45].

Apart from traditional processing that can reduce these antinutritional components, industrial processes, including canning, toasting, fractionation, and isolation of protein concentrates have also been shown to be effective in reducing or removing antinutritional factors [45]. As it is explained farther in this article, it should be borne in mind that processing can also introduce undesirable compounds, for example volatile aldehydes and ketones and peroxides, as a direct result of lipid oxidation, or reduce levels of desirable compounds, e.g., protein and essential minerals. The antinutritional factors can also be reduced or removed through plant breeding (biotechnology) programs. But, given the importance of antinutrients to the developing plant, the complete removal of these compounds by breeding or biotechnological programs, even if possible, may produce plants with poorer growth and lower yield characteristics [6].

8. Summary

Reports by several authors supported that the legumes are nutritious crop which even can be considered meat replacer because of the fact that legumes are a significant source of very important nutrients like protein. Legumes are also excellent sources of other nutrients including dietary fiber, carbohydrates, and dietary minerals. Legumes are commonly known as meat for low income families because it could make proteins available at relatively lower price which is hardly to obtain otherwise. Protein sources from animal products are containing cholesterol which is the base for obesity and different chronic disease. Plant protein in general and legumes in particular are not containing cholesterol and are healthy sources of protein. Legumes are also source of resistant starch which is broken down by bacteria in the large intestine to produces short-chain fatty acids (such as butyrate) used by intestinal cells for food energy. But, the issue is the nutrititional advantages of legumes can be negatively affected by their antinutritional factors, such as R-galactosides, trypsin inhibitors, cynogenic glycosides, or phytic acid, which interfere with the ingestion and digestive utilization of protein and minerals by monogastric animals. These anti-nutritional factors are chemical constituents which impair the digestion and absorption of some interesting components (e.g. proteins, vitamins), or, in some cases, they are simply toxic or cause undesirable physiological side effects (e.g. flatulence caused by raffinose family oligosaccharides). The presence of these anti nutritional compounds in grain legumes is therefore considered one of the limiting factors to an increased utilization of the grain as food as well as feed sources. That is why legumes need to be processed in one or the other way before being consumed. This is because, processing methods like boiling, soaking, fermentation, cooking, autoclaving, extrusion and the like can reduce or even remove the antinutritional constituents in legumes. Thus, it is good to encourage large scale production of legumes in order to combat the problem of proteineous food shortage or protein energy malnutrition in developing countries where animal protein is relatively costly [15].

9. Prospect

Different authors across the world have reported on the nutritional value of leguminous crops. But in our country, the breeding and variety selection programs are going on without taking the nutritional data into criteria. This may be due to lack of such information to include into the programs. This is because, if a crop is found to be disease resistant, high yielding and good performing in general and not good in its nutrient compositions or high in antinutritional factors, this is not a good package to take to the production. So, much work will be expected with respect to nutritional value of these crops. Nutritional characterization of the different varieties of legumes in our country is mandatory. The determination of different anti nutritional components of the legumes also need to be undertaken. This is because; these informations are better if included in criterion for varietal selection for either breeding programs or production. The optimization of different processing methods for nutrient retention and anti nutrient reduction should also be done. It is also important to research on different product development from legumes so that malnutrition problems in our country may be reduced or eliminated.

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