Legumes for food are probably as old as agriculture and civilization. Over the years, legume consumption has evolved in conjunction with cereals. They contribute relatively more of other dietary components per gram consumed.

Legumes are second only to the members of Gramineae in their importance to humans. With some 20,000 species, they are the third largest family of higher plants on the earth. Grain and forage legumes are grown in about 12-15% of the earth’s arable land surface with grain legumes alone contributing 33% of the dietary protein nitrogen needs of humans.

In rank order bean, pea, chickpea, broad bean, pigeon pea, cow pea and lentil constitute the primary dietary legumes. Beans, like other legumes, supply proteins, carbohydrates, vitamins and minerals to our body.

Leguminous plants produce the majority of protein requirements for humans. Plants are the major source of all proteins consumed by humans and livestock. Currently, the world protein supply is 150 million tons of which 65% is obtained directly from plants and the rest 35% through animal protein production. Compared to meat, plant protein is much more economical to produce, store and transport. Most plant proteins are nutritionally attached to some anti-nutrient compounds which make them least edible.

Anti-nutrients
However, grain legumes have some anti-nutrients too. Anti-nutrients are natural or synthetic compounds that interfere with the absorption of nutrients. Robin and Ross (1996) highlighted that anti-nutrients are not something to be alarmed about since most foods typically have one or more anti-nutrients and that the issue is the concentration and type of anti-nutrient and whether that specific anti-nutrient adversely affects the health.

All plants have some anti-nutrient properties. So, there is a need to be aware about the anti-nutrient level in plants in general and leguminous plants in specific and their role in human nutrition.

The anti-nutritional factors in plants may be classified into two major...
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Categories on the basis of their chemical structure and the specific mode of actions:

(i) Anti-nutrients with protein conjugates
- Lectins
- Trypsin inhibitors
- Alpha-amylase inhibitors

(ii) Temperature-resistant anti-nutrients
- Polyphenolics
- Phytates
- Raffinose oligosaccharides
- Saponins

Anti-nutrients in Grain Legumes
Lectins: Lectins are carbohydrate binding proteins present especially in bean seeds. Lectins are glycoproteins and usually bind to the intestine of humans and interfere with nutrient absorption. They also bind themselves to carbohydrate molecules. Many lectins are toxic or inflammatory in nature. They are resistant to digestive enzymes in the body. They can damage gut wall or sometimes cause allergic reactions. In blood, they can bind to cell membranes in arteries causing antigen-antibody reactions leading to autoimmune disorders.

Lectins can be blocked by simple sugars and oligosaccharides in the body. Soybean lectins have been shown to increase nitrogen excretion via urine.

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More than 70 lectins from leguminous plants have been reported till date. They have been isolated mostly from seeds. Although they differ in their carbohydrate specificities, they resemble each other in their physio-chemical properties.

Protease inhibitors: Proteases are enzymes in human gastric juices that break down protein. The examples of proteases are trypsin and chymotrypsin. Many plants, especially legumes, have protease inhibitors.

Trypsin helps to regulate secretions of the pancreas. Trypsin inhibitor inhibits the function of trypsin enzyme, causing pancreatic problem and dietary loss of cysteine from the body. Trypsin inhibitors are proteins that interfere with nutrient absorption by reducing the activity of proteolytic enzymes trypsin and chymotrypsin. The amount and activity of trypsin inhibitors in the diet has been shown to be inversely related to the availability of energy and protein.

The presence of protease inhibitors in food decreases the apparent nutritional quality of proteins in the diet by affecting the ability of body digestive enzymes to degrade dietary protein, and thus limiting the intake of amino acids needed to construct new proteins.

Alpha-amylase inhibitor: Alpha amylase is a digestive enzyme that is present in the saliva and pancreas. It helps to initiate the digestion of starches in the food. Alpha amylase inhibitors stop alpha amylase from doing its job. They survive the baking process and are found in bread and baked products. They are also reported in many legume crops.

Polyphenolics: These secondary plant metabolites are distributed ubiquitously within the plant kingdom. Environmental factors such as light, germination, degree of ripeness, variety, processing and storage can influence the levels.

Common beans contain polyphenolic compounds such as tannins that interfere with protein digestibility and protein quality. They are found primarily in the seed coat. They can bind to proteins preventing enzymatic susceptibility of the protein as well as inhibiting the proteolytic enzymes such as trypsin and chymotrypsin.

Polyphenols in legumes have been receiving considerable attention largely because of their adverse influence on colour and flavor. These are mostly located in the seed-coat and pericarp of the grains. Several factors such as plant type, age of the plant or plant parts, stage of development and environmental conditions also govern the polyphenol content of the plants.

Polyphenols are known to interact with proteins and form tannin-protein complexes leading to either inactivation of enzymes or making proteins insoluble. The anti-nutritional activity of polyphenols can be reduced by removing polyphenols from the grains by chemical treatments or removing pericarp and tests by pearling. Treatment of alkaline reagents and ammonia can remove 90% of the polyphenols. Supplementation of polyphenol-rich diet with protein can alleviate the growth-depressing effect of polyphenols.

Phytates/Phytic acid: Phytic acid is a major metabolite in all mature seeds and is the primary storage form of phosphorus in the plants. Phytic acid, phytate and phytin refer to free acid, salt and calcium/magnesium ion salts respectively. This is present in legumes in significant amounts as phytin. Among the various legume crops, soybean is particularly rich in this anti-nutrient.

Phytate works in the gastrointestinal tract and tightly binds to minerals such as copper, iron, magnesium, and calcium. It has particularly strong affinity for zinc. Phytates bind proteins causing reduced protein solubility, inhibit the action of enzymes especially pepsin, trypsin, alpha-amylase and also reduce
absorption of minerals such as zinc, calcium, magnesium, and iron, because they form insoluble complexes with these minerals.

**Raffinose Oligosaccharides:** Oligosaccharides of the raffinose-series (namely raffinose, verbascose and stachyose) are major components in many food legumes. The anti-nutritional activity of grain legumes is frequently associated with the presence of these oligosaccharides.

These oligosaccharides are not hydrolyzed in the upper gut due to the absence of β-galactosidase. In the lower intestine they are metabolized by bacterial action, producing methane, hydrogen and carbon dioxide, which lead to flatulence and diarrhea. They are thus a factor limiting the use of grain legumes in monogastric diets. Flatulence is a complaint even among healthy individuals and is one of the common causes of abdominal discomfort. It is also associated with dyspepsia, constipation and diarrhea.

**Saponins:** Saponins are a heterogeneous group of naturally occurring foam-producing triterpene or steroidal glycosides that occur in pulses such as kidney beans, chickpea and soybean. Saponins are generally characterized by their bitter taste, their ability to foam in aqueous solutions and their ability to hemolyse red blood cells. Ingestion of saponin-containing foods by humans and animals has been associated with reduced weight in animals and hypocholesterolemic effects in man. Saponins are poorly absorbed and are either excreted unchanged or metabolized in the gut.

### Removing Anti-nutrients

Anti-nutritional compounds can be removed from legume crops by employing physical and chemical methods such as soaking, cooking, germination, fermentation, enzymatic removal and irradiation of the plant parts. Attempts like post-transcriptional gene silencing through RNAi technology, pathway engineering and molecular breeding techniques are also in the process to eliminate these undesirable compounds from the legume crops.

However, the basic physical and chemical techniques followed for removal or elimination of these compounds are as follows:

**a. Soaking:** Soaking beans and then discarding the soak medium removes some of the unwanted components such as enzyme inhibitors and raffinose oligosaccharides. Soak temperature, medium, bean type, length of soaking and solubility of the components are factors affecting the extent of the removal. Salts and alkali in the solution increase the permeability of cell membrane and increase the amount of anti-nutrient leaching as well as some loss of desirable nutrients such as soluble vitamins and proteins from the bean.

**b. Cooking:** Cooking inactivates heat sensitive trypsin and chymotrypsin inhibitors incompletely. Other factors such as saponins and phytates usually do not get affected by cooking. Generally, soaking and cooking to some extent removes some heat stable anti-nutrient compounds.

**c. Germination:** When the bean seeds get germinated, reserve nutrients are released. Available vitamins and mineral contents increase while the phytate content and raffinose oligosaccharide content decrease. The activities of trypsin, chymotrypsin and alpha-amylase are also reduced by germination depending on the bean type and germination conditions.

**d. Fermentation:** Fermentation helps reduce raffinose oligosaccharides due to the alpha-galactosidase found in the bean seeds. Fermentation of foods can result in significant reduction in the quantity of certain antinutrients. It reduces the phytate content. The consumption of fermented food has been shown to improve the intestinal balance of beneficial lactic acid bacteria.

**e. Enzymatic Methods:** Enzymatic removal of certain compounds such as raffinose oligosaccharides depends on the level of alpha-galactosidase which may be different in different beans.

**f. Irradiation and ultra-filtration:** Gamma irradiation results in the destruction of trypsin and chymotrypsin inhibitors in certain bean types. Ultra-filtration could help to remove the low molecular weight compounds in the bean.

**g. Heat treatment:** Heat processing is widely accepted as an effective means of inactivating the thermo-labile anti-nutritional factors of legume grains. The nutritive quality of most tropical legume grains, particularly cowpea, soybean, pigeon pea, lima bean and winged bean is notably improved by heat treatment.

**h. Chemical treatment:** Various chemical treatments have been employed in an attempt to improve the nutritional value of legumes. Alkali treatment is found to be better than by using acid, ether or alcohol.

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