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Antinutritional compounds in food and their targeting methods to ensure nutritional security

Behzad Mohammadi*
Department of Food Science and Technology, Afagh Higher Education Institute, Urmia, Iran.
Dorna Abdolkhani
Ph.D. student, Department of Food Sciences and Industries, Biotechnology Orientation, Islamic Azad University Yasouj Branch, yasouj, Iran.
Ali Asghar Fakhari
PhD student, Department of Food Science and Industry, Islamic Azad University, Varamin Pishva branch, Varamin- Iran

Abstract
Anti-nutritional factors are the compounds found in most food substances which are poisonous to humans or in some ways limit the availability of nutrient to the body. Anti-nutritional factors are present in different food substances in varying amounts, depending on the kind of food. Many anti-nutrients (oxalate, phytate, etc.) and toxic substances (cyanide, nitrate, phenols, etc.) are present in many plants and vegetables. Anti-nutrients in foods are responsible for deleterious effects related to the absorption of nutrients and micronutrients. However, some anti-nutrients may exert beneficial health effects at low concentrations. For example, phytic acid, lectins, tannins, saponins, amylase inhibitors and protease inhibitors have been shown to reduce the availability of nutrients and cause growth inhibition. However, when used at low levels phytate, lectin, tannins, amylase inhibitors and saponins have also been shown to reduce the blood glucose and insulin responses to starchy foods and/or the plasma cholesterol and triglyceride. Anti-nutrients are chemical substances which reduces the maximum utilization of nutrients especially proteins, vitamins, and minerals, thus preventing optimal exploitation of the nutrients present in a food and decreasing the nutritive value. Anti-nutrients can be divided into two groups: heat-stable group-phytic acid, tannins, alkaloids, saponins, non-protein amino acids etc. and heat labile group include lectins, cynogenic glycosides, protease inhibitors and Toxic amino acids etc. Due to the presence of several anti-nutritional factors, legumes possess low protein digestibility. Most of the toxic and antinutrient effects of these compounds in plants could be removed by several processing methods such as soaking, germination, boiling, autoclaving, fermentation, genetic manipulation and other processing methods, but extensive research is still needed to discover elimination methods for heat stable antinutrients present in various food without altering the nutritional value of food.

Keywords: Antinutrient compounds,anti nutrient elimination strategy,nutritional safety

Introduction

The Anti-nutritional factors are compounds which reduce the nutrient utilization and/or food intake of plants or plant products used as human foods. They play a vital role in determining the use of plants for humans. Plants evolved these substances to protect and prevent themselves from being eaten. However, if the diet is not varied, some of these toxins build up in the body to harmful levels. Some vitamins in food may be destroyed by anti-nutritional substances. These anti-nutritional factors must be inactivated or removed, if values of food substances are to be fully maintained. Plants which produce seeds rich in energy supplies (carbohydrates, lipids, proteins) usually accumulate potent chemical defence compounds. This also applies to grain legumes with comparably large and protein-rich seed which often contain substantial amounts of "anti-nutritive" factors (ANF), such as lectins, protease inhibitors, non-protein amino acids (NPAAs), alkaloids, cyanogenic glycosides, pyrimidine glycosides, saponins, tannins, isoflavones, oligo-saccharides, erucic acid, or phytates. Anti-nutritional factors are present in different food substances in varying amounts, depending on the kind of food, mode of its propagation, chemicals used in growing the crop as well as those chemicals used in storage and preservation of the food substances. Many anti-nutrients (oxalate, phytate, etc.) and toxic substances (cyanide, nitrate, phenols, etc.) are present in many plants and vegetables. Cassava for example is known to contain high levels of cyanide, a respiratory poison [1]. Consumption of vegetables in their fresh form which is believed to contain more micronutrients than processed vegetables becomes a major health concern because of the high levels of anti-nutrients and toxic substances that might be ingested with the associated health problems. Anti-nutrients or antinutritional factors may be defined as those substances generated in natural feedstuffs by the normal metabolism of species and by different mechanisms (for example inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed) which exerts effect contrary to optimum nutrition. Being an anti-nutritional factor is not an intrinsic characteristic of a compound but depends upon the digestive process of the ingesting animal. Trypsin inhibitors, which are anti-nutritional factors for monogastric animals, do not exert adverse effects in ruminants because they are degraded in the rumen. Legumes, including beans, occupy an important place in human nutrition as in many countries they are one of the staple food. Besides being a cheap source of valuable proteins, saccharides, and several micronutrients including minerals and vitamins, they are known as rich in dietary fibre and low in fat. The contribution of legumes in the daily diet has many beneficial physiological effects. It allows to prevent common metabolic diseases, such as diabetes mellitus, coronary heart disease (CHD) and cancer. Therefore, their consumption is supposed to have a positive correlation with reducing the CHD death [2]. Of particular interest are resistant starch, enzyme inhibitors, lectins and polyphenols, therefore their role as preventive agents in diets of persons suffering from metabolic disorders is gaining attention. The term “antinutritional compounds” (ANCs) will be used in regard to bioactive compounds of bean seeds.Some of these

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chemicals are known as ‘‘secondary metabolites’’ and they have been shown to be highly biologically active. They include saponins, tannins, flavonoids, alkaloids, trypsin (protease) inhibitors, oxalates, phytates, haemagluttinins (lectins), cyanogenic glycosides, cardiac glycosides, coumarins and gossypol. The list is inexhaustible. Some of these plant chemicals have been shown to be deleterious to health or evidently advantageous to human and animal health if consumed at appropriate amounts. Most of these secondary metabolites elicit very harmful biological responses, while some are widely applied in nutrition and as pharmacologically-active agents [3]. The antinutritional factors may be defined as those substances generated in natural food stuffs by the normal metabolism of species and by different mechanisms (e.g. inactivation of some nutrients, diminution of the digestive process, or metabolic utilization of feed) which exert effects contrary to optimum nutrition. While mass foodstuff production was achieved in industrialized countries during the twentieth century, the limitations of such an intensive production system have been highlighted for decades by ecologists and numerous agronomists, nutritionists and medical doctors. Briefly, great concern has been caused by high energy and chemical inputs, worldwide contamination of the food chain and water by persistent pesticide residues and nitrates, and the reduced nutrient and flavor contents through low-cost and intensive food production and extensive milling or processing. Only recently has the combined awareness for environment protection, food safety and security and well-being markedly raised public concern and demand for ecologically grown staple foods. For developing countries, concern is also focused on the appropriate way to ensure present and future food security, the number of malnourished and undernourished people approaching one billion worldwide, with no decreasing trend for the coming decade. Worldwide, emphasis is increasingly being put on the relationship between food, nutrition and health.

Classification of the Anti-Nutritional Factors

Anti-nutritional factors also known as anti-nutrients which are poisonous substances that can be found in most food and able to limit the nutrient available to the body. Basically, antinutrients can be divided into two primary groups, which are heat-stable and heat labile group [4]. Anti-nutrients with heat-stable property which resist and can be maintained at high temperature are Phytic acid, Condensed Tannins, Alkaloids, Saponins; whereas, for antinutrients that fall in heat-labile group that are sensitive to standard temperature and lost at high temperature are lectins, Cynogenic Glycosides, Protease inhibitors, and Toxic amino acids. The anti-nutritional factors in plants may be classified on the basis of their chemical structure, the specific actions they bring about or their biosynthetic origin. Although this classification does not encompass all the known groups of anti-nutritional factors, it does present the list of those frequently found in human foods and animal feedstuffs. [5], there are several antinutritional factors that are very significant in plants and are used for human foods and animal feeds. They are: (i) Enzyme inhibitors (trypsin and chymotrypsin inhibitors, plasmin inhibitors, elastase inhibitors), (ii) Haemaglutinnins, (iii) Plant enzymes (urease, lipoxygenase), (iv) Cyanogenic glycosides (phaseolunatin, dhurrin, linamarin, lutaustralin), (v) Goitrogens (pro-goitrins and glucosinolates), (vi) Oestrogens (flavones and genistein), (vii) Saponins (soya sapogenin), (viii) Gossypol from Gossypium species e.g. cotton, (ix) Tannins (condensed and hydrolysable tannins), (x) Amino acid analogues (BOAA, DAP, mimosine, N-methyl-1- alanine), (xi) Alkaloids (solanine and chaconine), (xii) Antimetals (phytates and oxalates), (xiii) Anti-vitamins (antivitamins A, D, E and B12) and (xiv) Favism factors.

Protease inhibitors

Protease inhibitors are protein-based substances widely distributed within the plant kingdom, including the seeds ofmost cultivated legumes, which have the ability to inhibit the activity of proteolytic enzymes within the gastro-intestinal tract of animals. They are readily destroyed by heat; the degree of destruction or inactivation depending upon the temperature, duration of heating, particle size and moisture conditions. These substances reduce protein digestion. They decompose with heat. Therefore, when legumes are eaten raw or without being cooked properly, they upset digestive functions and cause diarrhea or excessive gas. Autoclave treatment or boiling also reduces the quantity of these substances. About 10-20% of the total active trypsin is found in human pancreatic juice. They bind proteases, which are resistant to digestion in the small intestine, and thus ensure their removal through excretion. The presence of trypsin inhibitors in the diet leads to the formation of irreversible condition known as enzyme-trypsin inhibitor complex. This causes a drop in intestine trypsin and a decrease in protein digestibility, leading to slower animal growth. Trypsin inhibitors are a unique class of proteins found in raw soybeans that inhibit protease enzymes in the digestive tract by forming indigestible complexes with dietary protein. These complexes are indigestible even in the presence of high amounts of digestive enzymes[6].

Amylase inhibitors

Amylase inhibitors are also known as starch blockers because they contain substances that prevent dietary starches from being absorbed by the body. Starch is a complex carbohydrates that cannot be absorbed unless they are first broken down by the digestive enzyme amylase and other secondary enzymes. Pigeon peas have been reported to contain amylase inhibitors. These inhibitors have been found to be active over a pH range of 4.5-9.5 and are heat labile [7]. Amylase inhibitors inhibit bovine pancreatic amylase but fail to inhibit bacterial, fungal and endogenous amylase. Pigeon pea amylase inhibitors are synthesized during late seed development and also degraded during late germination. Amylase inhibitors are also very heat labile and have been reported as having hypoglycemic effects. However, instability of this inhibitor under the conditions of the gastrointestinal tract resulted in failure to reduce insulin responses and increase the caloric output of food by using them as starch blocker tablets [8] .

Hemagglutinins (lectin)

They are proteins or glycoproteins. Lectin activity has been determined in more than 800 varieties of the legume family. 2-10% of the total protein legume seeds are lectins. One of their most important characteristics is that they prevent absorption of digestive end products in the small intestine. They enable the coagulation of red blood cells by affecting erythrocytes. Lectins possess some other interesting chemical and biological properties, some of which are as follows: they interact with specific blood groups; they perform various functions in mitotic division, demolish cancerous cells and have toxic effects in some animals. Since they bond with different sugar groups, their bonding with intestinal wall may exhibit variation depending on the type of sugar. If some types of beans are consumed raw, they may cause shock cramps. Besides these characteristics, lectins can easily

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disintegrate. Plant hemagglutinins are referred to as phytohemagglutinins (PHA). Lectins are carbohydrate binding proteins present in most plants, especially seeds like cereals, beans, etc., in tubers like potatoes and also in animals. Lectins selectively bind carbohydrates and importantly, the carbohydrate moieties of the glycoproteins that decorate the surface of most animal cells. Dietary lectins act as protein antigens which bind to surface glycoproteins (or glycolipids) on erythrocytes or lymphocytes [9] . They function as both allergens and hemagglutinins and are present in small amounts in 30% of foods, more so in a whole-grain diet. The consumption of lectin-containing foods may lead to endogenous loss of nitrogen and protein utilization. The carbohydrates and proteins that are undigested and unabsorbed in the small intestines reach the colon where they are fermented by the bacterial flora to short-chain fatty acids and gases. These may in turn contribute to some of the gastrointestinal symptoms associated with the intake of raw beans or purified lectins. The lectin-induced disruption of the intestinal mucosa may allow entrance of the bacteria and their endotoxins to the blood stream and cause toxic response. Lectins may also be internalized directly and cause systemic effects such as increased protein catabolism and breakdown of stored fat and glycogen, and disturbance in mineral metabolism [10] .

Allergens

They are substances that are generally found in nutrients. They cause allergic reactions that are specific to certain individuals. The level of harm done depends on the sensitivity level of individual's body rather than the quantity of the substances taken with the food. Diarrhea and vomiting are symptoms of allergy. It is also argued that proteins with high molecular weight cause allergies [11] . Histamine and compounds of histamine derivatives act as antigens against allergens.

Toxic Amino acids

There are certain amino acids in legume plants that are not of protein nature and reduce nutritious value and cause toxic effects. These substances are commonly found in Lathyrus and broad beans. Dihydroxyphenyl alanine (DOPA) is the most common toxic amino acid found in legumes. Although these amino acids do not display a direct toxic effect, the plant firstly takes on a black color due to these substances, and then withers. Moreover, the nutritional value of plants that contain such amino acids (broad beans, Lathyrus) decreases substantially. Toxic amino acids are believed to combine causes of metabolic favism. When it is taken into account that pulses are sources of the highest quality vegetable proteins, the importance of studies on the toxicity mechanisms of toxic amino acids that have an unfavorable effect on the quality of this protein and the degree of their potential harm become obvious. Canavanine: another toxic amino acid found in the seeds of the legume sesbania (Sesbania spp.) and jack bean (Canavalia spp.) and acts as arginine antagonist. The toxicity of the seed proteins increasing with increasing dietary inclusion level, and being reduced with water extraction (canavanine being soluble in water).

Saponins

Saponins are a heterogeneous group of naturally occurring foam-producing triterpene or steroidal glycosides that occur in a wide range of plants, including pulses and oil seeds such as kidney bean, chickpea, soybean, groundnut, lupin and sunflower. Saponins are secondary compounds that are generally known as non-volatile, surface active compounds which are widely distributed in nature, occurring primarily in the plant kingdom. The name 'saponin' is derived from the Latin word sapo which means 'soap', because saponinmolecules form soap-like foams when shaken with water. They are structurally diverse molecules that are chemically referred to as triterpene and steroid glycosides. They consist of nonpolar aglycones coupled with one or more monosaccharide moieties [12]. This combination of polar and non-polar structural elements in their molecules explains their soap-like behaviour in aqueous solutions. The structural complexity of saponins results in a number of physical, chemical, and biological properties, which include sweetness and bitterness, foaming and emulsifying properties, pharmacological and medicinal properties, haemolytic properties, as well as antimicrobial, insecticidal, and molluscicidal activities [13]. Their general characteristics can be cited as follows: they give a bitter taste, foam when they are treated with various solutions and cause haemolysis in red blood cells. Since they reduce the surface tension of blood in cold-blooded animals, they have an extremely toxic effect. Saponins, in high concentrations, impart a bitter taste and astringency in dietary plants. The bitter taste of saponin is the major factor that limits its use. saponins were recognized as anti-nutrient constituents, due to their adverse effects such as for growth impairment and reduce their food intake due to the bitterness and throat-irritating activity of saponins. In addition, saponins were found to reduce the bioavailability of nutrients and decrease enzyme activity and it affects protein digestibility by inhibit various digestive enzymes such as trypsin and chymotrypsin [14] . Saponins are attracting considerable interest as a result of their beneficial effects in humans. Recent evidence suggests that saponins possess hypocholesterolemic, immunostimulatory, and anticarcinogenic properties. In addition, they reduce the risk of heart diseases in humans consuming a diet rich in food legumes containing saponins. On the other hand, due to their cholesterol-reducing effect, legumes are the most important sources of saponins. The fact that saponins can bond with cholesterol and therefore reduce absorption and that legumes contain saponins points to their importance for health. Saponin-rich foods are important in human diets to control plasma cholesterol, preventing peptic ulcer, Osteoporosis and to reduce the risk of heart disease.

Cynogens

A number of plant species produce hydrogen cyanide (HCN) from cyanogenic glycosides when they are consumed. These cyanogens are glycosides of a sugar, often glucose, which is combined with a cyanide containing aglycone. Cyanogenic glucosides are classified as phytoanticipins. Their general function in plants is dependent on activation by bglucosidases to release toxic volatile HCN as well as a ketones or aldehydes to fend off herbivore and pathogen attack [15]. Cyanogenic glycosides or cyanoglycosides account for approximately 90% of the wider group of plant toxins known as cyanogens. The key characteristic of these toxins is cyanogenesis, the formation of free hydrogen cyanide and is associated with cyanohydrins that have been stabilised by glycosylation (attachment of sugars) to form the cyanogenic

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glycosides. Hydrogen cyanide inactivates the enzyme cytochrome oxidase in the mitochondria of cells by binding to the Fe3+/Fe2+ contained in the enzyme. This causes a decrease in the utilization of oxygen in the tissues. Cyanide causes an increase in blood glucose and lactic acid levels and a decrease in the ATP/ADP ratio indicating a shift from aerobic to anaerobic metabolism. Cyanogenic glucoside on hydrolysis yields toxic hydrocyanic acid (HCN). The cyanide ions inhibit several enzyme systems, depress growth through interference with certain essential amino acids and utilization of associated nutrients. They also cause acute toxicity, neuropathy and death [16] . Cyanide activates glycogenolysis and shunts glucose to the pentose phosphate pathway decreasing the rate of glycolysis and inhibiting the tricarboxylic acid cycle. Hydrogen cyanide will reduce the energy availability in all cells, but its effect will be most immediate on the respiratory system and heart. Cyanogenic glucosides are widely distributed in the plant kingdom and more than 2500 different plant species have been reported to contain cyanogenic glucosides including cassava (Manihot esculenta), linseed (Linum usitatissmium), various sorghums (Sorghum spp.) and white clover (Trifolium repens). Lesser quantities are found in the kernels of such plants as almonds (Amygdalus communis), apricots (Prunus armeniaca), peaches (Prunus persica), and apples (Malus sylvestris). As cyanide is extremely toxic, one of the most obvious symptoms is death. In the body, cyanide acts by inhibiting cytochrome oxidase, the final step in electron transport, and thus blocks ATP synthesis. Prior to death, symptoms include faster and deeper respiration, a faster irregular and weaker pulse, salivation and frothing at the mouth, muscular spasms, dilation of the pupils, and bright red mucous membranes. The toxicity of a cyanogenic plant depends primarily on the potential concentration of hydrogen cyanide that may be released upon consumption. Upon consumption of a cyanogenic plant, βglycosidase will be released during digestion and remain active until deactivated by the low pH of the stomach. This enzyme will hydrolyse the cyanogenic glycoside and release at least part of the potential hydrogen cyanide content of the plant .

Goitrogens

Goitrogens are naturally occurring substances that can interfere with the function of the thyroid gland, have been found in legumes such as soybean and groundnut. Goitrogens get their name from the term ‘goiter’ which means the enlargement of the thyroid gland. They may act directly on the gland or indirectly by altering the regulatory mechanisms of the gland and peripheral metabolism and excretion thyroid glands. If the thyroid gland has difficulty synthesizing thyroid hormone, it may enlarge to compensate for this inadequate hormone production. They have been reported to inhibit the synthesis and secretion of the thyroid hormones. Since thyroid hormones play an important part in the control of body metabolism their deficiency results in reduced growth and reproductive performance. Goitrogenic effect have been effectively counteracted by iodine supplementation rather heat treatment [17]. Soybean, a kind of oil seed and cruciferous vegetables contain glycosides called goitrogens, Consisting of sulphur, these glycosides cause the thyroid gland to grow by inhibiting the iodine intake of the thyroid gland. This toxic effect can be reduced with the addition of iodine to the diet [18].

Oligosaccharides or bloating agents

Legume contains some oligosaccharides such as raffinose, stachyose, verbascose and adjugose, which contain α-galactosidic bonds and are α-galactosyl derivatives of sucrose [19]. Due to lack of α-galactosidase enzyme in human body, which is required for hydrolysis, these carbohydrates remain undigested in the human intestine and hence constitute the indigestible fibre group. However, in the colon, anaerobic fermentation of these undigested carbohydrates by the residing microflora leads to the production of gases (H2, CO2 and traces of CH4), thus causing flatulence. These gases cause abdominal discomfort, and excessive consumption of these carbohydrates may lead to diarrhoea. Due to these effects, these oligosaccharides are known as flatus-producing carbohydrates. Oligosaccharides are dietary fibres and display physiological benefits like bowel function and immune health, reduce chances of coronary heart diseases, increase lactobacilli and bifidobacteria population and decrease enterobacteria in the intestine [20].

Oxalates

Oxalates affects calcium and magnesium metabolism and react with proteins to form complexes which have an inhibitory effect in peptic digestion. Oxalic acid binds calcium and forms calcium oxalate which is insoluble. Calcium oxalate adversely affects the Ca absorption. Fatal human poisoning following the eating of large quantity of the leaves of certain plants i.e. rhubarb, known to contain relatively large amounts of oxalates. Cooking can reduce the soluble oxalate content of many common vegetables, but not the insoluble fraction, if the cooking water containing some of the leached soluble oxalate is discarded. A salt formed from oxalic acid is known as an Oxalate: for example, Calcium oxalate, which has been found to be widely distributed in plants. Strong bonds are formed between oxalic acid, and various other minerals, such as Calcium, Magnesium, Sodium, and Potassium. This chemical combination results in the formation of oxalate salts. Some oxalate salts, such as sodium and potassium, are soluble, whereas calcium oxalate salts are basically insoluble. The insoluble calcium oxalate has the tendency to precipitate (or solidify) in the Kidneys or in the Urinary tract, thus forming sharp-edged calcium oxalate crystals when the levels are high enough. These crystals play a role to the formation of kidney stones formation in the urinary tract when the acid is excreted in the urine [21] . Higher content of oxalate can bind to calcium present in food, thereby rendering calcium unavailable for normal physiological, and biochemical role such as the maintenance of strong bone, teeth, cofactor in enzymatic reaction, nerve impulse transmission, and as clotting factor in the blood. Though lost of calcium leads to degeneration of bones, teeth, and impairment of blood clotting process. When oxalic acid is consumed, it irritates the lining of the gut, and can prove fatal in large doses. If food with excessive amounts of oxalic acid is consumed regularly, nutritional deficiencies are likely to occur, as well as severe irritation to the lining of the gut. In ruminants oxalic acid is of only minor significance as an antinutritive factor since ruminal micro-flora can readily metabolize soluble oxalates, and to a lesser extent even insoluble Ca oxalate. The values of oxalate changes as a result of processing. Soaking and cooking of foodstuffs high in oxalate will reduce the oxalate content by leaching. Boiling may cause considerable skin rupture, and facilitate the leakage of soluble oxalate into cooking water; this may be the possible reason to observed

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high reduction in oxalate level upon boiling [22]. It is reported that boiling affects the highest reduction in oxalate. Calcium oxalate is insoluble at a neutral or alkaline pH, but freely dissolves in acid. Oxalate can be found as soluble and insoluble forms in plants. Soluble salts are formed when oxalate binds with potassium, sodium and magnesium (magnesium oxalate is less soluble than the potassium and sodium salts) while insoluble salts are produced when the oxalate binds with calcium and iron.

Phytic acid

Not getting a balanced diet is one of the factors affecting the lack of micronutrients in developing countries. Phytic acid plays a role in inhibiting the bioavailability of some micronutrients. Phytic acid has a strong affinity with minerals such as calcium, magnesium, iron, copper, zinc, manganese, as well as vitamins and proteins. This leads to a decrease in the absorption of nutrients in the intestine. Phytic acid is common in the hulls of nuts, seeds and grains. Studies show that phytic acid, although an anti-nutrient, plays a role in the prevention of a number of diseases directly and indirectly. Phytic acid can have an antioxidant function; A property that makes it have many medicinal values and has anti-diabetic, anti-cancer and anti-inflammatory effects. Because phytic acid prevents the absorption of some elements in the body; It can cause diseases such as anemia in humans. Despite the anti-nutritional effect of phytic acid, it also has beneficial effects and it is recommended to reduce the level of phytic acid in flour and other foods, but it should not be completely eliminated[23].

Protease and amylase inhibitors

Proteases are enzymes that help break down proteins into smaller pieces. Hence, protease inhibitors are compounds that prevent the digestion and absorption of proteins and amino acids in the intestine. This category of anti-nutrients can disrupt the activity of various proteolytic enzymes such as trypsin, pepsin, chymotrypsin, etc.; All three enzymes are responsible for protein digestion and absorption. This disorder can eventually lead to growth problems and malnutrition. Protease inhibitors have also found a therapeutic role in modern drugs for the treatment of HIV and respiratory diseases; But recent studies show that long-term use of this Drugs cause insulin resistance and other metabolic conditions. Soy contains the highest amount of protease inhibitors, other sources include crops such as mung beans, beans, potatoes, barley, millet, wheat, buckwheat, peanuts, peas, corn and It is pineapple[24].

Glucosinolate

Among the goitrogenic and sulfur-containing compounds found in cabbage, broccoli, rapeseed, mustard, horseradish, etc. The consumption of glucosinolate and its derived compounds is associated with changing thyroid function and increasing the risk of developing various types of thyroid diseases, because these anti-nutrient compounds can play a role as competitive inhibitors of sodium-iodide membrane transporter protein in thyroid follicular cells.reduce the release of iodine from the thyroid gland; In fact, these anti-nutritional compounds block the thyroid's ability to use iodine. Therefore, it is recommended that people with hypothyroidism eat less glucosinolate-containing foods and avoid the adverse effects of these compounds by cooking food and iodized salt. Antinutrients reduce the bioavailability of iodine. To reduce this anti-nutritional compound, its concentration can be significantly reduced by industrial processing, cooking food and microwaves. The researchers found that frozen vegetables had a greater reduction in glucosinolates after boiling than fresh vegetables[25].

tannin

This anti-nutrient compound is abundantly found in tea, cocoa, grapes, berries, apples, stone fruits, nuts, beans and whole grains. Tannins belong to polyphenolic compounds; Due to its phenolic nature, this anti-nutrient compound is chemically reactive and can form intra- and intermolecular hydrogen bonds with macromolecules such as proteins and carbohydrates. Tannins play a role in the defense of plants and can also have beneficial effects in the human body such as antioxidant, anticarcinogenic, immune modulator, detoxification and heart protection. Researches show that tannins can easily form a bond with the iron found in vegetable foods (non-heme iron) and interfere with the absorption of this mineral. This can be problematic for people who are iron deficient, so as mentioned before, completely eliminating antinutrients is not recommended, but reducing them can improve the health benefits of food[26].

Strategies used to reduce levels of antinutrient compounds

Mill

Milling is considered the most traditional method to separate the bran layer from the seeds. This is the way in which the seeds are turned into flour. grinding technique; It removes anti-nutritional substances (such as phytic acid, lectins, tannins) that are present in cereal bran, but this technique has a major weakness and it also removes important minerals (Gupta et al, 2002). However, the contents of phytate and oxalate in semi-refined flour compared to whole flour; Due to the removal of bran fraction, it is less and more useful[27].

Heat and cooking

Studies show that calcium oxalate in boiled green leafy vegetables is reduced by 19 to 87%. Steaming and cooking are not effective for some anti-nutrient compounds; For example, phytate is resistant to heat and is not easily decomposed by boiling. Food grains are usually cooked by boiling or using a pressure cooker before consumption. Researchers found that boiling and cooking increase the nutritional value of foods. Reducing their anti-nutritional contents (such as tannins and trypsin inhibitors) greatly improves. Protease and oxalate are effective[28].

soaking

Beans and other legumes improve their nutritional value if they are soaked in water for a while. Most of the anti-nutrients in these foods are found in the skin. Since many anti-nutrients are water-soluble, the anti-nutrient compounds are easily dissolved in water by soaking. In fact, soaking is the initial stage of processing beans; To improve grain texture, reduce cooking time and more importantly to reduce anti-nutrients. During soaking, water-soluble molecules such as tannins, saponins and other anti-nutritive compounds are broken down and reduce possible adverse effects on health[29].One of the reasons that food science health experts consider it necessary to soak beans is that by doing this, anti-nutritional compounds and in some cases toxins in beans are removed. During a research, researchers found that by soaking peas for 12 hours, its phytate content decreased by about 9%. The same research showed that soaking; The levels of protease inhibitors decreased by 30%, lectins by 50% and tannin by 25%. Leafy vegetables can also be soaked to reduce

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some of their oxalates.Soaking is usually used in combination with other methods such as sprouting, fermentation and cooking.

fermentation

Fermentation is a useful strategy to reduce bacterial contamination of food. For the treatment of diarrhea in children, fermented millet products are recommended as probiotics. Fermentation is a metabolic process where sugars are oxidized to produce energy, it also improves the absorption of minerals from plant foods. Fermentation is one of the processing methods that is used in Africa to make cereal products edible, to increase the nutritional quality and also the safety aspects of cereals .In cereals, phytic acid usually interacts with metal cations such as iron, It forms a complex with zinc, calcium and proteins. These complexes are generally broken down by enzymes that require the optimal pH maintained by fermentation. Degradation of this complex reduces the content of phytic acid and releases soluble iron, zinc and calcium, which increases the nutritional level of food grains. [30]Fermentation of grains by lactic acid bacteria (LAB) has been reported to release amino acids. and increases their derivatives by proteolysis and metabolic synthesis. Fermentation improves the nutritional value of grains by increasing the content of essential amino acids such as lysine, methionine and tryptophan[31].Sourdough effectively destroys anti-nutrients in grains and leads to increased availability of nutrients. Fermentation of grains and legumes leads to significant reduction of phytate and lectin.

Germination

Germination is a period in the life cycle of plants that begins with the seed. This natural process is also known as germination. Germination is considered as a very suitable method to reduce the anti-nutritive compounds of plant foods. Germination of seeds generally activates the enzyme phytase, which breaks down phytate and leads to the reduction of The concentration of phytic acid in the samples. Germination usually changes the nutritional level, biochemical properties and physical characteristics of foods. To reduce the anti-nutritional content of grains, this method is mostly used. This process in Increases the availability of nutrients in seeds, grains and legumes. Germination takes a few days and may begin with a few simple steps: 1- Start by washing the seeds to remove waste and dirt. 2- Soak the seeds in cold water for 2 to 12 hours. The soaking time depends on the type of seed. 3- Drain as much water as possible and place the seeds in the germination container and be sure to place it away from direct sunlight. 4- Repeat washing and draining 2-4 times. This should be done regularly or every 8-12 hours. During germination, changes occur in the seed that lead to the degradation of anti-nutrients such as phytate and protease inhibitors. Research shows that germination reduces phytate by 37-81% in various types of grains and legumes[32].

DEHULLING

Removal of seed coat of pulses is termed as dehulling, and it is one of the post-harvest primary processes of food grains to improve palatability. However, it also causes loss of minerals and dietary fibre (Goyal et al., 2009). This process however reduce/remove some ANCs such as tannins, saponins and total phenolics but is liable to increase the level of phytic acid, trypsin inhibitor, chymotrypsin inhibitor and α-amylase inhibitor. This may be due to higher concentration of these ANCs in pulse cotyledon as compared with the hull . Further, dehulling removes embryo and gummy layer present between hull and cotyledons, which may also be responsible for changes in ANC concentration. The wet dehulling method involves soaking of pulses in water for 6–8 h during which some water-soluble ANCs may leach out, though it is not quantified. As phytates are mainly located in the cotyledons, the physical removal of testa by dehulling is reported to increase the phytic acid content of pulses, namely, lentil, faba bean and kidney bean However, a contrasting effect of dehulling on phytic acid content was also obser.

Conclusion

Pulses are very good source of protein, energy, fibre and many essential vitamins and minerals. Besides these nutrients, pulses also contain a number of organic compounds produced through secondary metabolism, which have a wide range of biological activities and aid in different biological or ecological functions in plants. However, some of these compounds act as anti-nutrients for human consumption because of their adverse effect on palatability, digestibility and bioavailability of nutrients. In pulses, enzyme inhibitors such as trypsin inhibitor, chymotrypsin inhibitor and α-amylase inhibitor, lectins, tannins, phytic acid, oxalates, phenolic compounds, saponins and oligosaccharides are the common ANCs. Thus, pulses need to be processed appropriately prior to consumption in order to reduce or eliminate the harmful metabolic impediments caused by ANCs. However, selection of the appropriate processing techniques for removal/ reduction of these ANCs in pulses requires the understanding of the chemical structure, distribution in seed fractions, biological effects, heat sensitivity and solubility in water. From the reported literature, it can be concluded that processing methods such as dehulling, soaking, cooking, extrusion, germination and fermentation are among the promising techniques for reduction/removal of these ANCs.Antinutrients can significantly reduce the nutritional value of many plant foods. Fortunately, they can be destroyed with a few simple methods such as heating, boiling, soaking, sprouting, and fermentation. It's worth noting that antinutrients may also have health benefits. For example, phytates reduce cholesterol and prevent high blood sugar levels. Many anti-nutrients also have antioxidant and anti-cancer effects, so avoiding them completely is not recommended. to reduce the levels of antinutrients in foods. The anti-nutrient is only a concern if taken in very high amounts.

- Below is an overview of the main anti-nutrients and effective ways to reduce them:
- Phytate (phytic acid:) Soaking, germination and fermentation
- Lectins: soaking, boiling, heating and fermentation
- Tannin: soaking and boiling
- Protease inhibitors: soaking, sprouting and boiling
- Oxalate: soaking and boiling
- Goiter: steaming and boiling

Research shows that people who follow plant-based diets rich in foods containing antinutrients are not necessarily deficient in zinc or iron—the two minerals most susceptible to reduced absorption by antinutrients—indicating that people who Those following plant-based diets may adapt to the presence of anti-nutrients. It should also be noted that many foods contain high amounts of anti-nutritional compounds; Like grains and legumes, they should be soaked and boiled so that they are suitable for consumption anyway. It is also recommended to soak leafy greens in water for disinfection

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to reduce their anti-nutrients. The only population that should have special considerations for anti-nutrients are those at risk for nutrient deficiency diseases such as Anemia is caused by iron deficiency, osteoporosis and other diseases

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