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Antinutritional factors in foods

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Abstract

Antinutritional factors are the inhibitory compound present in most of the food stuffs. These antinutritional factors are poisonous to human when eaten in uncontrolled manner. Antinutritional factors are present in variety of food ranging from cereals, legumes, oilseeds, green leafy vegetables etc. Absorption of anti-nutrients may have deleterious effect on human body. Besides deleterious effects antinutrients may have some benefits for example phytic acid, lectin, tanins, amylase inhibitor and protease inhibitor when used at low level have shown to reduce the blood glucose and insulin response to carbohydrate foods. This antinutrients reduces the bioavailability of food nutrients e.g. vitamins, Mineral's, carbohydrates and proteins etc. A significant part of the population relies on food for to get nourishment. Along with nutritional significance of food stuffs one must to know what are antinutritional factors and how they can be effectively removed from food stuffs by means of effective processing technology.

Keywords: Antinutritional factors, anti-nutrients, bioavailability

Introduction

Anti-nutritional factors are a chemical compounds synthesized in natural food and / or 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 food/feed) which exerts effect contrary to optimum nutrition (Soetan and Oyewo, 2009) [17].

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 (Thakur A. et al., 2019) [18].

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 preventing 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 (Krupa, 2008) [8].

Methods for reducing antinutrients in food are presented according to their physical (dehulling/cooking; autoclaving/pressure cooking; dry roasting; soaking; milling/ ultrafiltration) or biochemical (enzyme processing; fermentation; germination) character. 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 (Khokar S. et al., 2016) [7].

According to Aletor (1993) [1], there are several antinutritional factors that are very significant in plants and are used for human foods and animal feeds. They are:

1. Enzyme inhibitors (trypsin and chymotrypsin inhibitors, plasmin inhibitors, elastase

- inhibitors),
2. Haemagglutinins,
 3. Plant enzymes (urease, lipoxygenase)
 4. Cyanogenic glycosides (phaseolunatin, dhurrin, linamarin, luteostralin)
 5. Goitrogens (pro-goitrins and glucosinolates),
 6. Oestrogens (flavones and genistein)
 7. Saponins (soya saponin)
 8. Gossypol from *Gossypium* species e.g. cotton
 9. Tannins (condensed and hydrolysable tannins)
 10. Amino acid analogues (BOAA, DAP, mimosine, N-methyl-1- alanine)
 11. Alkaloids (solanine and chaconine)
 12. Antimetals (phytates and oxalates)
 13. Anti-vitamins (antivitamins A, D, E and B12) and
 14. Favism factors.

Table 1: Classification of anti- nutritional factors

Proteins	Protease inhibitor Hemagglutinin
Glycosides	Goitrogenes Cyanogenes Saponins Estrogens
Phenols	Gossypol Tannins
Miscellaneous	Antiminerals Anti- Vitamins Anti- Enzymes Food – Allergens Microbial/ Plant Carcinogenic Toxic amino acid

Protease Inhibitor

Protease inhibitors are widely distributed within plant kingdom, including the seeds of most cultivated legumes and cereals. Protease inhibitors are the most commonly encountered class. 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 (Thakur A. *et al.*, 2018) [18].

The protein protease inhibitors found in plants generally contain little or no carbohydrate and have a molecular weight ranging from 4,000 to 80,000. The widely studied Bowman-Birk protease inhibitor from soybeans contains 71 amino acids with a molecular weight of 8,000, and the Kunitz inhibitor from soybeans contains 198 amino acids with a molecular weight of 23,000. Many of the larger protease inhibitors are polymeric containing up to four subunits. The amino acid sequences of many protease inhibitors have been determined and a characteristic feature is a large degree of sequence homology both within the same inhibitor and between inhibitors from different plants (Richardson M. 1997).

Hemagglutinin

Hemagglutinin refers to a substance that causes red blood cells to agglutinate. This process is called hemagglutination. Antibodies and lectins are commonly known hemagglutinins (Dorland's Medical Dictionary, 2001) [3]. Types of hemagglutinin include: - Influenza hemagglutinin - Measles hemagglutinin - Parainfluenza hemagglutinin – neuraminidase.

- Mumps hemagglutinin – neuraminidase. - The PH-E form of phytohemagglutinin. The terms phytohemagglutinins, phytagglutinins and lectins are used interchangeably to refer to most purified plant hemagglutinin are carbohydrate – containing proteins. Hemagglutinins may be pure proteins or glycoproteins.

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 (Sauvion *et al.*, 2004). 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 (Fereidoon, 2014).

Saponins

The presence of saponins has been reported in more than 100 families of plants, and in a few marine sources such as star fish and sea cucumber (Hoestetmann and Marston, 1995).

The name 'saponin' is derived from the Latin word *sapo* which means 'soap', because saponins molecules 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 (Oleszek, 2002).

Saponins are natural triterpenes that have the ability to form stable, soaplike foams in aqueous solutions and are widely distributed in all cells of legume plants. Clinical studies suggest health-promoting effects as saponins decrease blood lipids, lower cancer risks, lower blood glucose response (Shi *et al.*, 2004) [15], and may stimulate the immune system (Shahidi, 1997) [14]. A subject of discussions within the scientific community is their haemolytic activity (Podolak *et al.*, 2010) [12]. Furthermore, at excessive concentrations saponins affect negatively the absorption of nutrients, either by enzyme inhibition during digestion or by an interaction with zinc, while they are the main cause of undesirable flavors that occur after their consumption by humans (Shahidi *et al.*, 1997) [14]. Therefore, despite their beneficial actions to human health, saponins are considered unwanted components in foods.

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 β -glucosidases to release toxic volatile HCN as well as a ketones or aldehydes to fend off herbivore and pathogen attack (Zagrobelny *et al.*, 2004) [19].

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 glycosides. Hydrogen cyanide inactivates the enzyme cytochrome oxidase in the mitochondria of cells by binding to the Fe^{3+}/Fe^{2+} 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 (Osuntokun, 1972).

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 (Marshall and Lauda, 2007) [9]. 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 (Giri and Kachole, 2004) [4].

Phytic acid

Phytate (also known as Inositol hexakisphosphate (InsP6) is the salt form of phytic acid, are found in plants. Phytic acid causes the bioavailability of essential minerals to decrease and turn into insoluble compounds whose absorption and digestion is less in the small intestine (Desphande and Cheryan, 1984) [2]. Pulses are sources of dietary phytoid. When phytoid phosphor is not made use of, it is discharged with excretion. A way of preventing this is through the hydrolysis of phytoid phosphor; for this purpose, besides methods such as soaking, germinating, using food rich in vegetable endogen phytosis enzyme and storing, methods like cooking and performing autoclave where phytoid phosphor is demolished in the presence of heat can also be used. The studies that have been conducted demonstrated that phytoids reduce cholesterol level and protect against intestinal cancer of iron origin. Besides, phytoids exhibit characteristics of natural antioxidants also their benefits such as reducing lipid peroxidation. 62-73% and 46-73% of the total phosphorus within cereal grains and legume seeds being in form of

organically bound phytin phosphorus, respectively (Matyka *et al.*, 1993) [10]. Apart from the major part of the phosphorus contained within phytic acid being largely unavailable to animals (due to the absence of the enzyme phytase within the digestive tract of monogastric animals), phytic acid acts as a strong chelator, forming protein and mineral-phytic acid complexes; the net result being reduced protein and mineral bioavailability.

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 (Noonan and Savage, 1999) [11].

Anti-vitamin factors

Anti-vitamin factors are a wide variety of compounds exhibiting anti-vitamin activity have been isolated from plants, including 1) anti-vitamin A factor present in soybeans, which destroys carotene and is not readily destroyed by heat, 2) anti-vitamin D factor present in soybeans, which interferes with calcium and phosphorus absorption in chicks, and is destroyed by autoclaving, 3) anti-vitamin E factor present in kidney beans, soybeans, alfalfa and field pea, causing liver necrosis and muscular dystrophy in chicks and lambs, and is destroyed by autoclaving, 4) anti-vitamin K factor present in sweet clover, 5) anti-thiamine factor called thiaminase present in cottonseed, linseed, mung bean, and mustard seed, 6) anti-niacin factor present in sorghum, 7) anti-pyridoxine factor present in linseed, which is destroyed by water extraction and autoclaving, and 8) anti-vitamin B 12 factor present in raw soybeans (Hill, 2003) [5].

Alkaloids

Alkaloids are one of the largest groups of chemical compounds synthesised by plants and generally found as salts of plant acids such as oxalic, malic, tartaric or citric acid. Alkaloids are small organic molecules, common to about 15 to 20 per cent of all vascular plants, usually comprising several carbon rings with side chains, one or more of the carbon atoms being replaced by nitrogen. They are synthesized by plants from amino acids. Decarboxylation of amino acids produces amines which react with amine oxides

to form aldehydes. The characteristic heterocyclic ring in alkaloids is formed from Mannich-type condensation from aldehyde and amine groups. Tubers of the common potato (*Solanum tuberosum*) have a natural content of the two toxic and bitter glycoalkaloids (GA) α -solanine and α -chaconine. The levels are normally low and without adverse effects on food safety and culinary quality. However, consumption of potato tubers with unusually high GA contents (300-800 mg kg⁻¹) has occasionally been associated with acute poisoning, including gastro-intestinal and neurological disturbances, in man. Tuber GA levels are inheritable and can vary considerably between different species. Environmental factors experienced by tubers during germination, growth, harvest and storage may affect GA levels further (Jadhav *et al.*, 2009) [6]. Alkaloids are considered to be anti-nutrients because of their action on the nervous system, disrupting or inappropriately augmenting electrochemical transmission. For instance, consumption of high tropane alkaloids will cause rapid heartbeat, paralysis and in fatal case, lead to death. Uptake of high dose of tryptamine alkaloids will lead to staggering gait and death. Indeed, the physiological effects of alkaloids have on humans are very evident. Cholinesterase is greatly inhibited by glycoalkaloids, which also cause symptoms of neurological disorder.

Alkaloids cause gastrointestinal and neurological disorders (Aletor, 1993) [1]. The glycoalkaloids, solanine and chaconine present in potato and *Solanum* spp. are haemolytically active and toxic to fungi and humans. Some of the toxicological manifestations of potato glycoalkaloids involve gastro-intestinal upsets and neurological disorders, especially in doses in excess of 20 mg/100 g sample. Coumarins, which are constituents of forage, have been associated with the so-called bleeding disease in cattle consuming spoiled or putrid sweet clover. Alkaline pH conditions generally enhance absorption of glycoalkaloids, where binding with sterols in cell membranes causes extra disruption. Nicotine, caffeine, quinine and strychnine are well-known examples of alkaloids. As an illustration, lower dose of alkaloids mediate important pharmacological activities, such as analgesic, reducing blood pressure, killing tumour cells, stimulating circulation and respiration (Simee, 2011) [16]. Some of the more well-known.

Conclusion

From present review it was evident that besides nutritional benefits of different food crop some antinutritional factors are present which lowers the nutritional quality of food. These anti-nutrients can be effectively reduced with adoption of different processing technology. Most of the toxic and anti-nutrient effects of these compounds in food 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 anti-nutrients present in various food without altering the nutritional value of food.

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