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Plant Based Antinutrients: A Review

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Abstract

Plants possesses certain ability to produce chemical compounds which act as protective mechanism from being getting harm from pests, microbes or any other animals. These chemical compounds when ingested by human or any other animals produce harmful effect in the body. These chemicals compounds also termed as antinutrients. Some of the antinutrients from plant based food product are saponin, phytic acid, oxalate, alkaloids, lectins, protease inhibitor, amylase inhibitor, goitrogens and cyanogenic Glycosides. Most of these antinutrients reduced the bioavailability of nutrient in our body and can cause deficiency of certain nutrients. Processing methods like soaking, pressure cooking, sprouting, dehulling, ordinary cooking, boiling and mechanical processing can help in the reduction of these antinutrients to considerable extent.

Key Words- Antinutrients, phytic acid, saponin, nutrients, utilization, bioavailability

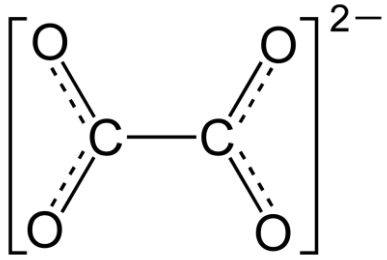
1. Introduction

Many of the species of plant kingdom have been gifted by the nature to have capability to synthesize range of chemical compounds which act as defensive mechanism against insect, microbes or animal by being eaten. Therefore numerous of these chemical compounds might employ detrimental effect in body when it is consumed by humans and these chemical compounds are frequently termed as antinutrients. However some of these chemical compounds may have valuable benefits subjected to amount of consumed like antioxidant, prebiotic or immunostimulatory. The potential harmful effect of these chemical compounds includes underutilization of nutrient, reduced palatability, growth inhibition, improper function of intestine or alteration in the balance diet. (Krogdahl, 2010).Taking cereals, fruits and vegetables in diet have lot of benefits because they are rich source of essential nutrients. But these food constituents also contain some antinutrients factor which is harmful for the body (Thompson, 1993). Antinutritional factor are compound which diminish the nutrient intake by human body. Antinutritional factor play one of the important role in decision that which plant source can be use as food or feed (Gemede, 2014). Antinutrients can also be elaborated as compound which suppress the nutrient intake, and also affect digestion, absorption and nutrient utilization or may produce poor effect on the body. Many plant sources such as seed, fruits and vegetables in the uncooked state have range of potentially noxious antinutrients (Akande, 2010). It has been observed that most of the antinutrients factor are found within raw plant material and these antinutrient substance can become inactive by simple processing like cooking, soaking, heating, germination or sprouting, autoclaving e.t.c (Novak, 2000) . Nausea, headaches, bloating, rashes, nutritional deficiencies are some of the common symptom shown by antinutrient when they are present in large amount in the body (Essack, 2017). In cereals, beans, nuts and legumes antinutrients are found in much higher concentration in comparison to leaves, roots, vegetables and fuits. Phytates, tanins, lectins, oxalate are some of the plant based antinutrients. Antinutients in plant based food such as cereals, legumes, beans and nuts are problematic only when they are unprocessed or uncooked (Popova, 2019). Presence of excess of tannins in the body can inactivate the enzyme responsible for the protein absorption. Phytates which is a antinutrient mainly found in cereals, nuts , beans are able decrease the absorption of mineral in the body thus causing the deficiency of mineral in the body (Gupta, 2013). Antinutrient such as saponins, enzyme inhibitors, tannins, phytic acid and glycosides not only decreases the availability of nutritional component but they also have adverse effect on the body. Lignans and phytoestrogens are antinutrient component that have been associated with infertility in humans (Shahidi, 1997). In most cases antinutrient affect the utilization and absorption of nutrient by the body. Most of the antinutrient form complex which can't be digested, absorbed or utilized by the body. There are many effective method by which antinutritional component of the food can be suppressed or inactivated. Processing method such as cooking or heating, sprouting or germination, fermentation and certain chemical treatments can help in the brining down the antinutritional content of food.

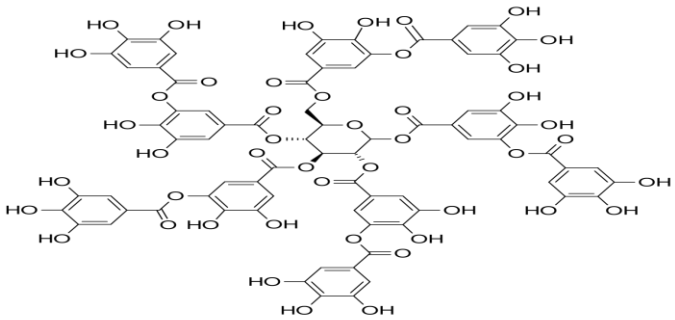
2. Antinutrient in Foods

Antinutritional are those component of food which have adverse effect in the body. Most of the antinutrient reduces the bioavailability of nutrients and this lead to deficiency of certain nutrients which may bring unfavorable effect on health condition of body. The reason for the synthesis of antinutrients by plant is that it synthesizes metabolite as defense mechanism to protect itself from herbivores, insect, pathogens or even from adverse climate effect. The effect of these antinutrients varies biologically which depends upon the chemical structure of individual compound. Some of the chemical structure of antinutrient compound has been shown in Fig. 1.

Figure 1: Structure of certain antinutrients



Oxalate



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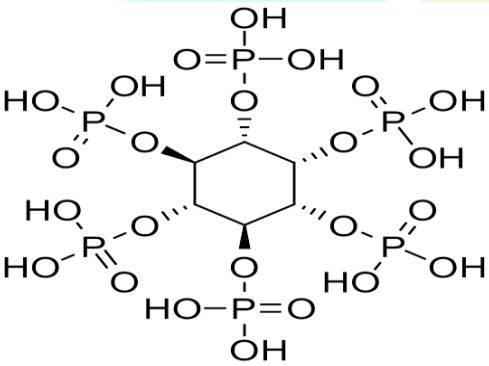
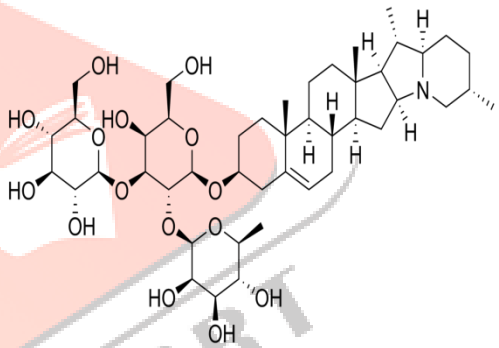


Phytic Acid



Solanin

I. Saponin

Saponins are non-volatile, secondary and surface active compounds which are extensively dispensed in the nature especially in the plant kingdom. Saponins are structurally assorted molecules which are chemically recognized as steroid glycosides and triterpene. Saponins are regarded as antinutrient because it has found that it facilitate in the reduction of nutrient bioavailability, in the reduction of enzyme activity and it also have effect in the digestion of protein by inhibiting various digestive enzymes such as chymotrypsin and trypsin. It is also considered as antinutrient because unfavorable effect on growth impairment, and decreases the intake of food due to throat irritating action and bitterness of saponin (Gemede, 2014). Apart from their toxicity, unwanted haemolytic effect and instability in aqueous phase saponin shows many different pharmacological and biological effect such as it stimulate the immune system of mammals. The exclusive capacity of saponin to activate Th1 immune response and the of cytotoxic T-lymphocytes production against foreign antigens make the saponin perfect for being utilization in vaccines against intracellular pathogens and even for cancer (Sun, 2009).

II. Phytic Acid

Inositol-6-phosphate or phytate in its salt form also known as Phytic acid or myoinositol 1, 2, 3, 4, 5, 6-hexakis dihydrogen phosphate is antinutrient factor which is found mostly in the cereal and legumes at concentration of 1-3%. In some fruits and vegetables phytic acid is also found but is present in lower concentration as compared to cereals (Valencia-Chamorro, 2003 and Higuchi, 2014). In plant seed phytic acid is storage form of phosphate. On the early growth of seedling and during germination, phosphorus and myo-inositol are provided by the phytic acid. Phytic acid is less digestible in animal which have simple single chambered stomach (Shitan, 2013). There is decrease in the bioavailability and absorption of nutrient in the body due to presence of high amount of phytic acid in the body. In human gastrointestinal tract phytic acid is not digestible but by dietary plant enzyme phytase or by phytases which are originating from enteric microorganism it can be digested (Decker, 2000). Phytate have antinutritional activities in human or in animal which have single chambered stomach because of strong chelation of certain minerals like zinc and iron which makes insoluble complexes which remain unabsorbed in the body thus bringing the deficiency

of minerals (Stone, 2009). Phytic acid problematic concern is mainly with cereal grain but preprocessing can improve the absorption of mineral. There is also another fact that there can be elevated levels of toxic heavy metals in some food due to natural accumulation (Rosa, 2007).

III. Protease Inhibitors

Protease inhibitors are extensively dispersed in the kingdom of plant. These compounds have capability to restrain proteolytic enzymes activity inside the animal's gastrointestinal tract (Liener, 1980). In raw legume seeds protease inhibitors occurs such as chymotrypsin and Trypsin inhibitor. One of the most common antinutritional factor of plant origin is Protease inhibitors. It is also partially responsible for the growth retarding properties of legumes. Trypsin inhibitors have been known to reduction of protein digestibility. Trypsin inhibitors are polypeptides compound which make well distinguish stable complexes one to one molar ratio with trypsin which obstruct the enzymatic action (Akande, 2010). Protease inhibitors can be easily denatured by heat due to its particular nature of protein even though in produced product some residual activity might still remain. pancreatic hypertrophy, reduction in protein digestibility and growth inhibition are some antinutrient activity which is associated with protease inhibitors (Sinha, 2017).

IV. Tannins

One of the major group of polyphenol antioxident found in food and beverages are tannins. In the bark of tree, wood, roots, vegetables, pods, leaves and fruit, tannins are found in profusion. It is high molecular weight phenolic compound which contain enough hydroxyl or carboxyl group which under specific environment condition form strong complexes with protein and other macromolecule. They are classifies into two wide groups condensed tannins and hydrolysable tannins (Kumari, 2012). From aqueous solution tannins have capability to precipitate protein. With protein which is utilized by our body tannin make a complex which is less digestible and also hamper endogenous protein. Both hydrophobic interaction and hydrogen bond are involved in tannin protein complex. Ionic strength, pH and molecular size of tannins are some parameters for which precipitation of tannin-protein complex depends (Akande, 2010). As the molecular size of tannins increases then precipitation of protein and incorporation of tannin phenolic into precipitate also increases (Kumar, 1986). It is also found that tannin obstruct with digestion because it shows anti-amylase and antitrypsin activity. Some of the other antinutrient activities of tannin are that it interfere with iron absorption, intestinal damage and also there are also possibility that it also produces carcinogenic effect (Butler, 1989).

V. Amylase inhibitors

In buckwheat the first amylase inhibitor was informed. Amylase inhibitor is found in beans, mangoes, taro root, acorns, legumes, potatoes, sorghum, oats and rye. It has been found out that most of the plant's amylase inhibitors are active against amylase of animal but they are inactive against plant, bacterial and fungal enzymes. Amylase inhibitor make a complex with amylase and the degree of which governed by several factor such as ionic strength, temperature, pH, inhibitor concentration and time of interaction. As the amylase inhibitor form complex with amylase enzyme which lead into inactivation of enzyme and result in the decrease in the digestion of starch (Thompson, 1993). It has been suggested that the role of enzyme inhibitors physiologically is to act as storage for protein, as endogenous enzyme regulator or act as protective or defensive mediator against the predator animals, insects, microbes or pests attack (Heidari, 2005). Plant enzyme inhibitor (alpha-amylase inhibitors) demonstrate effective agent to make crop resistance against pests (Octavio, 2002). As amylase inhibitor causes reduction in digestion of carbohydrate which results in malabsorption of nutrient in the body which ultimately leads in decrease of pancreatic enzymes inside the intestinal lumen to less than or equal to 10% (Boivin, 1998).

VI. Oxalates

Oxalate is salt form of oxalic acid such as calcium oxalate which is broadly distributed within the plant kingdom. Between oxalic acid and several other minerals strong bonds forms and this chemical combination leads in the development of oxalate salt (Gemede, 2014). Oxalate act as antinutrient. Under normal condition do not possess adverse effect but when it is processed or digested then in gastrointestinal tract in come in contact with the other nutrients (Noonan, 1999). Some oxalate salts like potassium oxalate and sodium oxalate are soluble while calcium oxalate is insoluble. In the urinary tract or in the kidney the insoluble calcium oxalate salt has propensity to solidify and this lead to formation of sharp edge crystals of calcium oxalate and in the urinary tract these crystals of calcium oxalate helps in the formation of kidney stone when in urine acid is excreted (Gemede, 2014). When Oxalic acid is released in the body it binds with other nutrient making them reduction in bioavailability in the body. This is the reason that nutrition deficiency occur if there is too much amount of oxalic acid in the food. Irritation occurs in the lining of gut due to high amount of consumption of oxalic acid in the diet (Oladimeji, 2000 and Liebman, 2011). Oxalates are present in high amount in some of the commodities such as radishes, cauliflower, broccoli, spinach, beets, black peeper, berries, nuts e.t.c. (Mamboleo, 2015). If the oxalate is present in normal amount in the diet then most people can take it although oxalate intake should be lowered for those people who have ailment like enteric and primary hyperoxaluria. In sensitive people consequences like burning or irritation in the ears, mouth, throat and eyes can happen even by small amount of oxalate intake and if the large amount is taken then consequences such as muscle weakness, abdominal pain, nausea and diarrhea may happen (Natesh, 2018).

VII. Alkaloids

One of the largest groups of chemical compounds that are synthesized by plant kingdom is alkaloids which are usually found as salt of organic acid of plant origin such as tartaric acid, malic acid, citric acid or oxalic acid. Even in the presence of higher number of digestive enzymes these complexes are indigestible (Gemede, 2014). Some alkaloid act as antnutrients. Solanine which is an alkaloid found in potato leads to cause neurological disorder and problem in the gastrointestinal tract if it is taken in the excess amount 20mg/100g (Fowomola, 2010). The antinutrient effect of alkaloid act on nervous system which result in disruption or improperly transmission of electrochemical. If the tropane alkaloid is consumed in high amount will lead to paralysis, fast heart beat or even lead to death. Upon intake of excessive amount of tryptamine alkaloids will cause staggering gate or even death. A symptom of neurological disorders is cause due to glycoalkaloids because it greatly inhibit the Cholinesterase (Thakur, 2019).

VIII. Lectins

Lectin or Phytohaemagglutinins are kind of glycoprotein which is broadly distributed in in some oil seeds or legumes. Lectins have capability to combine with carbohydrate and they also have properties to affinity with some particular molecule of sugar (Pusztai, 1989). When the particular sugar is unknown the term hemagglutinins is used. Lectin or hemagglutinins shows a reversible binding to particular oligosaccharides or monosaccharides that have at least one non- vatalytic domain. By without altering the properties of carbohydrate lectins can bind to the moieties of carbohydrate on the erythrocytes surface and amalgamate the erythrocytes (Gemede, 2014). Lectins have ability to interacting with enterocytes, can directly bind with the mucosa of intestine, within some lowgossypol cotton nutrients they interfere with the transportation and absorption of 0.01% free gossypol during digestion and in instestine, causing epithelial lesions. By dry heat most of the lectins are resistant to get inactive and for additional inactivation they required presence of moisture (Oliveira, 1989 and Santiago, 1993).

IX. Cyanogenic Glycosides

There are so many number of plant based food product that contain Cyanogenic Glycosides such as cassava, almonds, stone fruits, spinach, pome fruits e.t.c. Twenty five Cyanogenic Glycosides are knowm and the basic structure of this compound –CN moiety attached to a core carbon and two R1 and R2 substituent groups attached to sugar by a glycoside bond (Cressey, 2019). This chemical compound is related to secondary metabolites of the natural product of the plant. Cyanogenic glycosides are composed of a sugar moiety and a-hydroxynitrile type aglycone (Gemede, 2014). Cyanogenic glycosides act as antinutrient because when the plant material is macerated or ingested then by enzymatic hydrolysis by β-glycosidase of cyanogenic glycosides there is release of hydrogen cyanide which is potentially toxic to the body system (Cressey, 2019). Some of the symptoms include by acute poisoning by cyanide are drop in blood pressure, headache, diarrhea, fast pulse, pale blue coloration of skin due low supply of oxygen and vomiting (FSANZ, 2004 and Speijers, 1993). It is classified as phytoanticipins. The common function of cyanogenic glycosides in plants depends upon b-glucosidases for release of aldehydes or ketones and toxic volatile compound hydrogen cyanide to defend the plant against pathogens or herbivore attack (Golden, 2009).

X. Goitrogens

Goitrogens are chemical compound that are found in plant based food such as groundnuts and soyabean. It is responsible for the expansion of thyroid gland. It has been found that goitrogens is responsible for the reduction of secretion and synthesis of thyroid hormones (Akande, 2010). As thyroid hormone is one of the important hormones that our body generate, it helps in regulating broad range of genes which play important role in our body (Brent, 2012). The deficiency of thyroid hormone leads to decrease in growth and reproductive performance (Olomu, 1995). The effect of goitrigens cannot be overwhelmed by the treatment of heat but supplementation of iodine can play a prominent role (Liener, 1975). The reason for which goitrogens are considered as antinutrient is that it suppresses the activity of thyroid hormone.

3. Efffect of antinutrient in the body

Antinutrients are those compounds which limit the utilization of nutrients in the body (Gemede, 2014). And if nutrient will not utilized by our body or there will be reduction in the utilization of nutrient by our body then that will lead to deficiency of nutrient in our body and may cause several negative effects in the body regulation system. For example phytic acid is one of the antinutritional components which is mostly found in cereals grains and legumes and when its intake exceed then phytic acid suppresses the utilization of minerals like calcium and iron (Kumar, 2021). And if there will be reduction in utilization of minerals like calcium and iron then there will deficiency of these mineral will occur which ultimately will lead into abnormal problems in the regular function of the body (Ringstead, 1990). Antinutrient like oxalate is also potential source of health hazard (Libert, 1987). The potential health hazard related to oxalate is because insoluble calcium oxalate forms sharp edge crystal in the urinary tract which ultimately leads to formation of kidney stone (Holmes, 2001). Many antinutrient act as inhibitor as their role is to inhibit or suppress the other enzymatic or nutrient activity. For example protease inhibitor inhibits the digestion of protein and amylase inhibitor hinders the absorption of carbohydrate in the body (Leung, 2000 and Sales, 2012). So basically most of the antinutrients act as either toxic or inhibitor. The presence of antinutrient in the diet may cause underutilization of nutrient which ultimately will lead abnormal condition of the body.

Table 1: Antinutrient and their effect

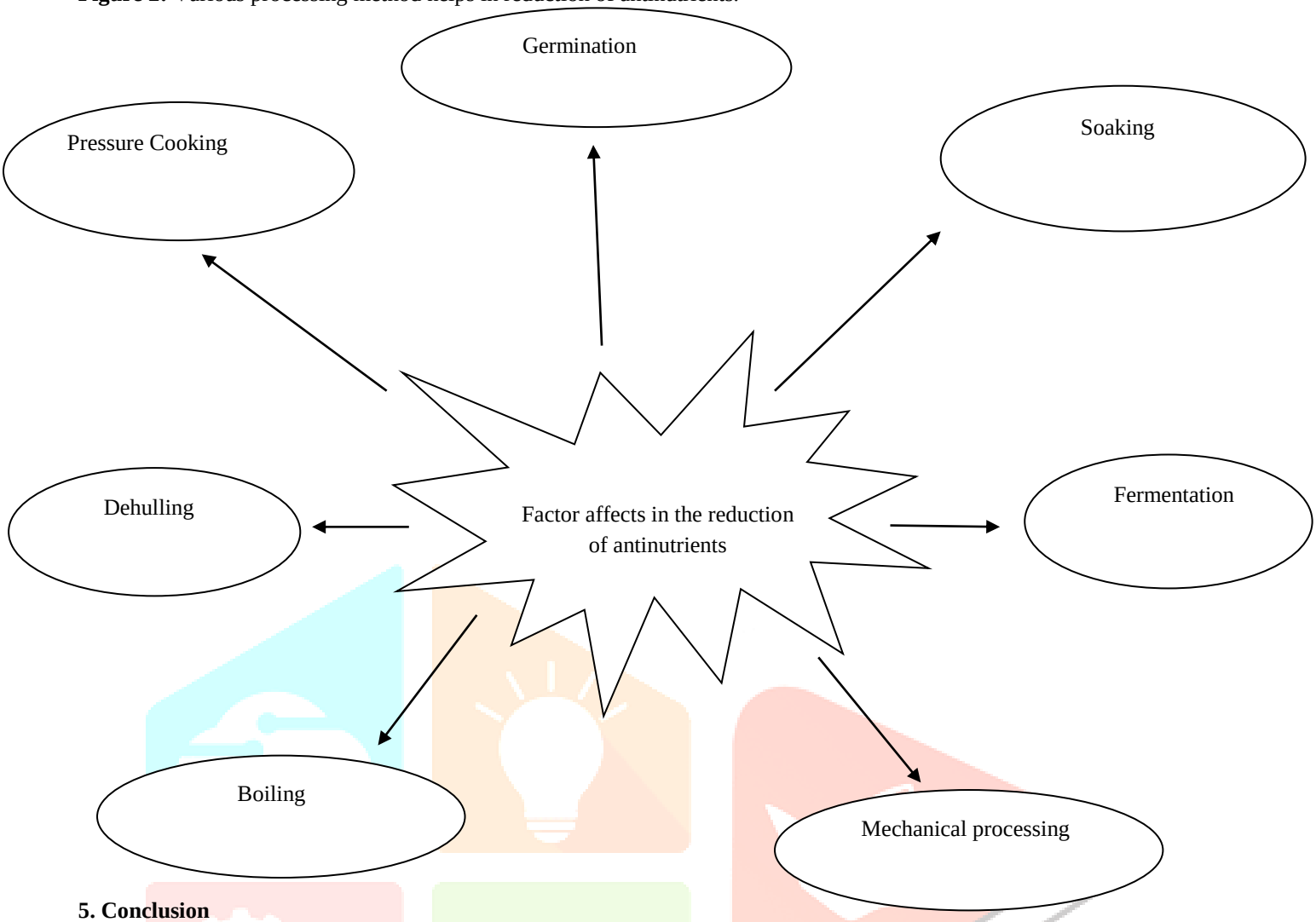
Antinutrient	Effect	Source
Phytic acid	Reduces the absorption of mineral like calcium and iron.	Seeds, cereals grains, nuts and some fruit and vegetables.

Oxalates	Form sharp edge crystal in urinary tract responsible for the formation of kidney stone.	Radishes, cauliflower, broccoli, spinach, beets, black peeper, berries and nuts.
Protease Inhibitors	Inhibit the digestion and utilization of protein in the body.	Cereal, potato, mustard and legumes.
Tannins	Affect the utilization and digestion of protein.	Bark of tree, wood, roots, vegetables, pods, leaves and fruit
Amylase inhibitors	Reduction in the digestion of carbohydrate.	beans, mangoes, taro root, acorns, legumes, potatoes, sorghum, oats and rye
Alkaloids	Antinutrient effect of alkaloid acts on nervous system which results in disruption or improperly transmission of electrochemical.	Coffee seeds, tea leaves, cacao seeds, tomato and potato.
Lectins	Capability to combine with carbohydrate	Oil seeds and legumes.
Cyanogenic Glycosides	Formation of hydrogen cyanide in the gut.	Cassava, almonds, stone fruits, spinach and pome fruits
Goitrogens	Responsible for the reduction of secretion and synthesis of thyroid hormone	Groundnuts and soya bean
Saponin	Facilitate in the reduction of nutrient bioavailability, in the reduction of enzyme activity and it also have effect in the digestion of protein by inhibiting various digestive enzymes such as chymotrypsin and trypsin.	Banana peel, beans, kidney beans and lentils.

4. Effect of processing on antinutrient

Processing play one of the vital role in the reduction of antinutrients factor in foods. Traditional processing method like pressure cooking, boiling, soaking, germination, dehulling, and fermentation helps in the reduction of certain antinutrients of foods such as phytic acid, protein inhibitor, phenolics, condensed tannins, saponins and lectins. There also has been recent research which indicates the effectiveness of some innovative process such as microwave heating, irradiation and extrusion in the reduction of antinutrient. Germination is one of the most traditional method of processing and play one of the important role in the reduction of antinutrient especially phytate levels of pulses and cereals (Patterson, 2017). Vidal-Valverde et al. (1994) studies the effect of processing on antinutritional components of lentins. In the study it was found that soaking helped in the reduction of phytic acid and increment in the catechins and tannins content, and do not affected the activity of trypsin inhibitor. There was also reduction in the content of phytic acid and fully removal of trypsin inhibitor by cooking of the presoaked seed. It was observed that upon six days of germination there was decrease in the content of phytic acid and trypsin inhibitor. It has been found that in some beans protein inhibitor are inactivated by heat treatment. The heat treatment basically denatures the structure of these protein inhibitor enzymes (Van Der Poel, 1990). In another study effect of processing on nutritional and antinutritional component of green gram was studied. In the study it was observed that there was significant decrease in the level of antinutrient by the aid of processing method like soaking, pressure cooking, sprouting, dehulling and ordinary cooking and these processing method also improved the in vitro protein digestibility and availability of certain minerals like calcium, zinc and iron (Grewal, 2006). In many of the study it has been seen that the processing method which gave more beneficial effect was pressure cooking, sprouting, ordinary cooking, and then dehulling.

Figure 2: Various processing method helps in reduction of antinutrients.



5. Conclusion

Antinutrients are one of the major concerns when the selection of plant based food products for consumption. Antinutrients are basically defensive mechanism shown by plant for their protection from pests, microbes, rodents, herbivores and even human. In most cases when the plant based food product containing antinutrients are consumed it hinder the utilization of nutrients in the body which ultimately lead to deficiency of certain nutrients. For example phytate have strong chelation effect on minerals like iron and zinc which forms insoluble complex making it unabsorbed in the body thus leading to deficiency of those minerals. Some antinutrients may also produce harsh effect on the body such as oxalate which forms sharp edge crystal in the urinary tract leading to formation of kidney stone. Some antinutrients also act as toxicant. For example when food product containing cyanogenic glycosides is ingested it produces hydrogen cyanide by enzymatic hydrolysis and this toxic compound hydrogen cyanide is harmful for the body system. There are various processing method that can help in the reduction of antinutritional components such as germination or sprouting, pressure cooking, boiling, fermentation, mechanical processing, and ordinary cooking. Those plant based food products which contain antinutritional factor can be utilized for the consumption if the proper processing methods have utilized for the processing of food products and reduction of antinutrients.

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