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Short Communication

Naturally Occurring Toxicants in Foods

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Food constitutes the most complex part of our chemical environment. Certain plant and animal products contain natural constituents that are toxic. When foods containing them are consumed in sufficient quantities, the toxins present may prove to be hazardous. Some investigations claim that the health risks from natural chemicals in foods are even greater than the health risks from pesticide residues. Therefore, a thorough understanding of these naturally occurring toxicants is essential to ensure proper preparation and processing of foods beneficial to the public. Each toxin is followed by a list of some possible sources of natural toxins in food plants.

ENZYME INHIBITORS

(i) Cholinesterase inhibitors/Glycoalkaloid

The Cholinesterase represents a group of enzymes that are of great significance in both the physiological and economic sense. Tomatoes contain a toxic solanum alkaloid called tomatine. The mature fruit is low in alkaloid, but green potatoes contain appreciable quantities. Tomatine is a cholinesterase inhibitor.

Poisoning of both livestock and humans from potatoes has occurred. The solanum alkaloids are in highest concentration in green sprouts and green potato skins (peels). The greening of potatoes occurs when the tubers are exposed to sunlight during growth or after harvest. The green pigment is cholorophyll, the increased concentration of solanum alkaloids in green potatoes is due to the fact that similar environmental conditions promote development of both chlorophyll and glycoalkaloids. High levels of glycoalkaloids are found in potato sprouts and potato peels that taste bitter. Cooking does not destroy these toxins. Therefore, potato sprouts should not be eaten and any green or damaged parts should be removed before cooking.

(ii) Protease (Trypsin) inhibitors

Protease inhibitors are widely distributed throughout the plant kingdom, particularly in the Leguminosae and to a lesser extent, in cereal grains and tubers. These substances inhibit the digestive enzymes trypsin and chymotrypsin. Soybeans, most other legumes seeds, and some grains (e.g. rye and triticale) contain trypsin inhibitors. These are small protein molecules which combine with and inactivate the digestive enzymes trypsin in

the small intestine. They cause reduced growth and pancreatic hypertrophy.

Protease inhibitors occur mainly in seeds, although in some cases they are also found in leaves. Becides, soybeans, other legumes seeds with trypsin inhibitors include lima, kidney beans, peanuts, cowpea, fava beans and peas. Most plant protein inhibitors are destroyed by heat, with a concomitant increase in the nutritive value of the protein. Clearly, soybeans and other related legumes should be properly cooked and processed before being eaten.

Protease inhibitors are widely distributed within the plant kingdom, including the seeds of most cultivated legumes and cereals. Protease inhibitors are the most commonly encountered class of antinutritional factors of plant origin.

(iii) Amylase inhibitors

Amylase inhibitors reduce the rate of digestion of starches in the small intestine. They are primary proteins, derived from beans or wheat that inhibits alpha- amylase, a pancreatic enzyme that hydrolyzes (digests) starch. These inhibitors have been commercialized as “starch blockers” to reduce obesity in humans.

Amylase inhibitors activity was determined in four legume seeds which are widely consumed in Egypt. The effect of dehulling, heat treatment, soaking and germination were also assessed. The results showed that faba bean contained the highest activity of amylase inhibitor followed by cow pea, lentils, and then chickpea. Dehulling resulted in raising the amylase inhibitor activities in all samples investigated, while heat treatment and cooking lowered it. Soaking for 10 hours and germination eliminated completely the inhibitor from all samples.

Protease inhibitors have the ability to inhibit the activity of proteolytic enzymes within the gastrointestinal tract of animals. Due to their particular protein nature, protease inhibitors may be easily denatured by heat processing although some residual activity may still remain in the produced products. The antinutrient activity of protease inhibitors is associated with growth inhibition and pancreatic hypertrophy. Potential beneficial effects of protease inhibitors remain unclear, although lower incidences of pancreatic cancer have been observed in populations where the intake of soybean and its products is high. While protease inhibitors have been linked with pancreatic cancer in animal studies, they may also act as ant carcinogenic agents.

The application of dry heat to sorghum seeds and meat was not effective in inactivating the amylase inhibitory activity. Overnight soaking followed by heat treatment was more effective in destroying amylase inhibitory activity. Cooking the meal, raw seeds and soaked seeds drastically reduced the levels of alpha- amylase inhibitory activity (Mulimani and Supriya, 1993).

Tannins are phenolic compounds that react with proteins. They are astringent and adversely affect feed intake. Oligomers of flavan-3-ols and flavan-3, 4-diols, called condensed tannins, occur widely in cereals and legumes (Haard and Chism, 1996). The presence of tannins in food can therefore lower feed efficiency, depress growth, decrease iron absorption, damage the mucosal lining of the gastrointestinal tract, after, excretion of cations, and increase excretion of proteins and essential amino acids. Dehulling,

cooking and fermentation reduce the tannin content of cereals and other foods.

Table 1 Hydrogen cyanide contents of some food stuffs

Food	HCN (mg/100g)
Lima beans	250-310 (*Phaseolus lunatus*)
Almonds	250
Sorghum sp. (fodder)	250
Cassava	110 (*Manihot utilissina*)
Cassava roots (whole roots)	113
Cassava roots (without skin)	10-15
Cassava leaves	500-900
Peas	2.3
Beans	2.0
Chick peas	0.8
Linseed meal	53

Source: Swaminathan, 2000 and Janseen et al., 1996

Table 2 Glucosinolate content in edible parts of plants

Plants	Glucosinolate (µg/g vegetable)	
	Range	Mean
Cabbage	260-1060	530
Cauliflower	270-830	480
Turnip	210-600	420
Redish	70-210	140
Mustard	32800-59800	46300

2. CYANOGENIC GLYCOSIDES/ CYANOGENS

Cyanogenic glycosides are glycosides from which cyanide is formed by the activity of hydrolytic enzymes. These are known to be present in several plant species used for food. They are found in-

(a) Seeds of bitter almond, apricot and peach
(b) Green leaves of sorghum, and
(c) Cassava and lima bean (Swaminathan, 2000)

Some legumes like kidney bean, red gram and linseed cassava, and many fruit pits contain cyanogenic glycosides from which hydrogencyanide (HCN) may be released by hydrolysis[1].

Cyanogenic glucosides are classified as phytoanticipins. Their general function in plants is dependent on activation by b-glucosidases to toxic volatile HCN as well as a ketones or aldehydes to fend off herbivore and pathogen attack[3]. When plant material containing the glycoside is consumed, it is broken down by a b-glucosidase to produce a sugar and an aglycone. The aglycone is then acted upon by a hydroxynitrilelyase to produce cyanide and an aldehyde or a ketone. 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.

Cyanide doses that are lethal to humans can easily be reduces or even exceeded after the intake of a variety of cyanogenic foodstuffs. Glycosidases and hydroxynitrile lyase are present in plant cells. They become available when plant tissue is damaged. This inevitably occurs when food is prepared for consumption.

Cyanogens/ Cyanogenic glycosides can be hydrolyzed by enzymatic action with the release of HCN (hydrogen cyanide, prussic inhibiting the terminal respiratory enzyme cytochrome oxidase. If deficiency of vitamin B12 is there and higher doses of cynogenetic glycosides are taken, it causes death by inhibiting the activity of cytochrome oxidase[2]. Table 1 shows the hydrogen cyanide contents of some food stuffs.

The bitter variety of cassava is more toxic than sweet one[2]. Because of their cyanide content, ingestion of large amounts of cassava and, to a lesser extent, lima beans can be fatal if these foods are eaten raw or are not prepared correctly.

Cassava toxicity is much more reduced by peeling, washing in running water to remove the cyanogens, and then cooking and/or fermenting to inactivate the enzymes and to volatilize the cyanide. In regions like Africa, where cassava is a staple food, care is taken in its preparation for human consumption. Acute poisoning due to consumption of cassava roots have been reported occasionally from Africa. Serious outbreaks of poisoning due to consumption of lima beans have been reported in Burma, Puerto Rico, India and even in Europe. Poisoning in cattle due to consumption of fodder sorghum, cassava leaves ad linseed meals has been reported.

Consumption of cassava may lead to goiter, as the cyanide formed can be metabolized to thiocyanate by the enzyme rhodanase. High consumption of dry, unfermented cassava, containing high levels of cyanogens, accounts for the widespread incidence of goiter in parts of Africa. Sorghum can be consumed safely, as it is free from or very poor in cyanogens. On germination the sorghum seedling may reach a concentration of 0.3 to 0.5% HCN (dry weight). The young green leaves, however, are rich in cyanogens. This is why cattle are not allowed to graze on young sorghum plants. If sorghum is packed in a silo, cellular degradation and fermentation may lead to the release and elimination of cyanide.

There are different methods of processing of cassava tubers like boiling, roasting, frying, sun drying. The cassava tubers are sliced, ground and then soaked in water. When the sliced cassava tubers are ground, the cyanogenic glycosides become free and after soaking, it will get reduce. Sun drying is commonly used for detoxification[2].

3. GOITROGENS/ GLUCOSINOLATES

The goitrogenic substances are classified as glucosinolates, which contains sulphur group[2]. More than 80 different glucosinolates have been found in higher dicotyledonous plants including Cruciferare, Capparidaceae, Moringaceae, etc. Glucosinolates are a particular group of substances, occurring in cruciferous plants (genus Brassica). Hydrolysis of glucosinolates results in the formation of isothiocyanates and nitriles. The enzyme

becomes available for catalysis when cells are damaged on cutting or chewing.

Glucosinolates are hydrolyzed by myrosinase present in the plant to D-glucose and an aglycone that is spontaneously rearranged to form thiocyanate and isothiocyanates derivatives.

Cabbage, cauliflower, Brussels sprouts, broccoli, turnips, radish, mustard and oil seed meals from rape and turnip all possess some goitrogenic activity. Soybean also contains goitrogenic substances. The red skin of the peanut contains the phenolic derivative which is an active goitrogenic compound[2]. The concentration of glucosinolates found in some common vegetables is presented in Table 2.

Goitrogens (glucosinolates) are estimated to contribute approximately 4 percent of the worldwide incidence of goiters in humans. Natural goitrogens are probably dominant sources of goiter in some cases where intake is abundant. They block the iodization of thyroxin by competing for the same reactive site on the molecule of thyroxin as iodine[2].

There is considerable evidence showing that glucosinolates rich plant components have adverse effects on the health and growth of animals. In several species, rape seed meal decreases feed intake and growth while enlarging the liver, kidney, thyroid and adrenal glands. For humans, the principal concern is possible depression of thyroid function associated with glucosinolate derivatives. Thiocyanate and certain isothiocyanates are goitrogenic in states of iodine deficiency. Other metabolites, notably S-5-vinyl-oxazolidine-2-thione (goitrin) from rapeseed, interfere promote goiter irrespective of iodine status. The antithyroid substances, present in different foods, can be destroyed by cooking and by action of intestinal bacteria. In cabbage, rape seed and mustard seeds, the toxic effect of goitrogen are removed by prepress heating[2].

4. LECTIN PROTEINS

Lectins are a group of glycoproteins that are present in high levels in legumes and grain products. The ability of lectins to bind to and agglutinate red blood cells is well known and used for blood typing-hence the lectins are commonly called hemagglutinins. Lectins also can bind avidly to mucosal cells and interfere with nutrient absorption from the intestine. Lectins are heat and protease resistant carbohydrate binding proteins that bind to red blood cells and cause haemagglutination. Lectin proteins (phytohemagglutinins) are present in verifying amounts in legumes and cereals, and in very small amounts in tomatoes, raw vegetables, fruits and nuts. Since lectins are widely distributed in the seeds and vegetative parts of plants, especially *Leguminosae* and *Graminaceae*, the human gut is regularly exposed to dietary lectins.

Lectins may bind to mannose/ galactose (concanavalin A from jackbean), N-acetylglucosaminae (potato and wheat germ lectins) or N-acetylgalactosamine/ galactose (ricin and kidney bean lectin). It has been stated that ‘lectins constitute one of the major antinutritive factors of foods of plant origin and their presence in food may have very serious consequences for growth and health. When untreated lectins are eaten, they agglutinate red blood cells and bind to the epithelial cells of the intestinal tract, impairing nutrient adsorption. The best method of

detoxification of Hemagglutinins is heat treatment. Heat denatures the protein as phytogglutininsa are protein in nature. Autoclaving in the presence of NaOH can inactivate the hemaggltinins. Another method of detoxification is moist cooking with NaOH and formaldehyde. The nutritive value of the legumes is enhanced by autoclaving if moist cooking is done with NaOH, phenol, instead of NaOH formaldehyde, the activity of hemagglutinins gets reduced more rapidly[2]. They cause reduced growth, diarrhea, and interfere with nutrient absorption.

5. LATHYROGENS

Lathyrogens, found in legumes such as chick peas, are derivatives of amino acids that act as metabolic antagonists of glutamic acid, a neurotransmitter in the brain. When lathyrogens are ingested in large amounts by human or animals, they cause a crippling paralysis of the lower limbs and may result in death. Lathyrism only occurs on a impoverished diet of sweet pea, or grass pea and is characterized by bone thinning and leg paralysis.

Lathrrogens decreae collagen and elastin cross-linking by inhibiting lysine oxidase. The lathyrogens isoniazid and semicarbazide decrease liver pyridoxal phosphate and are teratogenic; all their effects are reversed by pyridoxal beta-aminopropionitrile, another lathyrogen, does not affect liver pyridoxal phosphate and its lathyrogenic and teratogenic effects are not reversed by pyridoxal. Time courses of these effects differ greatly, suggesting enzyme inhibition by different mechanism.

There are different methods of to reduce the harmful effects of lathyrogens. One method is steeping of pulse in hot water for a short period of time than repeated washing remove 70-90% of toxin. But there is loss of water soluble vitamins due to repeated washing. The detoxification of lathyrogenic factors can also be done by cooking pulse in excess amount of water and draining off the excess water. The detoxification can also be done by overnight soaking of seeds in cold water or it may be done by steeping the dehusked seed in water.

But in all these methods free amino acid and water soluble vitamins especially B vitamins are lost. Slight modification can be done in these methods. Seeds should be sun dried after steaming for 30 minutes. By this, 80% of toxin is removed and loss of B vitamins is not appreciable. There is another method suggested for the removal of toxin is roasting off seeds at 150ºC for 20 minutes results 80-90% destruction of neurotoxin.

6. PYRROLIZIDINE ALKALOIDS (PAs)

The toxic effects of PAs are due to their bioactivation in the liver to toxic metabolites called pyrroles, or dihydropyrrolizine derivatives. PAs are important causes of human illness and a significant threat to human health, especially in less developed countries subject to drought and famie. Ingested PAs are bioactivated in the liver to form highly reactive dehydroalkaloid pyrroles that alkylate DNA, RNA and proteins. The principal outcome is liver damage in the form of veno-occlusive disease, hepatic venous thrombosis, ascites, jaundice and probably an elevated risk of liver cancer. Secondary targets of pyrroles derived from PAs include the lungs, hearts, kidney, stomach, reproductive system and brain.

7. ANTIVITAMINS

Although not toxic per se, the anti-vitamins can cause problems as a result of their interference with the function or absorption of essential nutrients.

(i) Anti-thiamine compounds

Anti- thiamine compounds are found in mung beans, rice bran, beets, Brussels sprouts. Raw carp flesh contains an enzyme, thiaminase which destroys thiamine. Cooking of carp destroys thiamibne. Cooking of carp destroys the thiaminase activity. Bracken is also reported to contain thiaminase.

(ii) ***Avidin - in raw egg white***

Avidin is a glycoprotein with a molecular weight of about 43,500. It is secreted by the oviduct of birds into the egg white, and binds with the B vitamins biotin in a tight complex, resisting digestion and absorption. Avidin is denatured by moist heat and is inactivated when eggs are cooked.

An antivitamin is simply 'a substance that makes a vitamin ineffective'. A vitamin antagonist is essentially the same thing as an antivitamin. It is a substance that lessens or negates the chemical action of a vitamin in the body**.** Anti-vitamin factors raw kidney beans contain anti-vitamin E that produces necrosis of liver and muscular dystrophy. Antivitamin B1 is found in bracker fern. Antivitamin E has also been noted in isolated soya protein, which is suspected to betocopherol oxidase. Linseed contains an anti-pyridoxine factor that depresses growth. The factor responsible is L-amino acids, Dproline that occurs as peptide linatine in combination with glutamic acid. L-amino-D-proline is about 4 times as active as linatine.

References

1. Akande, K.E., Doma, U.D., Agu, H.O. and Adamu, H.M. (2010). Major anti nutrients found in plant protein sources: Their effect on nutrition. *Pakistan Journal of Nutrition*, **9**(8):827-832.
2. Pant, Suneeta, Mishra and Manoj Kumar (2007). Plant food toxicants and their harmful effect on health. *Agrobios Newsletter*, **6**(5): 11-12.
3. Zagrobelny, M., Bak, S., Rasmussen, A.V., Jorgensen, B., Naumann, C.M. and Moller, B.L. (2004). Cyanogenic glucosides and plant insect interactions. *Phytochemistry*, 65:293-306.