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Vegetable Food Toxicants and their Harmful Effects on Health

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A B S T R A C T

Plant toxins are substances produced as secondary metabolites that are identical to extra cellular bacterial toxins in their properties. They show both useful and harmful effects to human beings. They show a wide range of side effects from minor itching, nausea, vomiting to adverse effects like psychosis, teratogenicity, arrhythmias. Natural toxins are present in numerous types of plants. These types of compounds whenever consumed in large quantity or when they are not cooked properly may lead to food poisoning. Plant toxins are found naturally in vegetables and fruits which have been the common food sources. Natural toxins can also be found in plants because of natural choice as well as new reproduction methods which enhance these defensive mechanisms. Different kinds of natural toxins can be present in various parts of a plant like roots, tubers, stems, fruits, buds and foliage. There are many classes of toxic compounds like phenols, alkaloids, terpenoids, flavonoids, tannins, anti-vitamins, proteins, etc. plant toxins are described according to the organ system in the human body which they affect, e.g., cardiotoxins, neurotoxins, etc. The degree of toxicity also depends on the location, climatic factors, growing season, variety and age. The people are advised to be cautious in the amount of intake and are recommended to observe the effects after ingestion.

Keywords

Plant toxin, Secondary metabolites, Alkaloids, Flavonoids

Introduction

Plant toxins are substances produced as secondary metabolites that are identical to extra cellular bacterial toxins in their properties. They show both useful and harmful effects in human beings and animals. They show a wide range of side effects from minor itching, nausea, vomiting to adverse effects like psychosis, paralysis, teratogenicity, arrhythmias. They are useful in production of cosmetics, ulcers, menstrual cramping, cancer and in treatment of man ailments and diseases. Toxins may enter into the by body either by inhalation, swallowing or by contact. The action is based on their chemical constituents which are classified into alkaloids, phenols, peptides, amino acids, glycosides, proteins, oxalates, anti-vitamins, tannins, volatile ether layers etc. They act by altering specific mechanisms involving enzymes, receptors and even genetic material at particular cells and tissues. They can be modified to exemplify improved affinity and efficacy for health endorsement. Poisonous plants have a seed, root, leaf, stalk, fruit or juice where even a relatively small amount, taken either internally or eternally, can lead to injury to the human body. In some species the poisonous constituents occur throughout the whole plant. In others they are concentrated in one or more parts. Plants evolve to generate natural products as a means of defence against animals (Saravanan *et al.,* 2016)

Plants have a wide range of pharmacologically effective phytochemicals. Many of these have been discovered to be really helpful for the treatment of a variety of human as well as animal diseases (e.g. colchicines, atropine and digitoxin); although few plant phytochemicals produce harmful effects after exposure. The onset of harmful effects could be really immediate or taken a little time to develop. Fortunately, among thousands of plants present in the environment, relatively few of the plants only cause acute and life-threatening diseases when ingested. The variety of chemical components in the plants is really amazing and in most of the cases, still the function a specific phytochemical substance, i.e. the normal ecology of the plant remains unknown. The inclusion of toxic phytochemical substances in the plants is considered to confer some extent of defense against plant potential predators like ruminants and insects.

The medical diagnosis of plant poisonings is very challenging since the ingestion of several plants produces nonspecific clinical signs that could not be distinguished from other disease conditions. Additionally, death caused by toxic plant ingestion frequently does not result in characteristic post-mortem lesions, due to relatively limited numbers of tests are available to identify the plant toxic compounds in post mortem or ante-mortem samples. In many instances, the simplest way to help the diagnosis of the plant poisoning is to confirm the existence of the poisonous plant in the environment, ensure that the plant was ingested and correlate clinical findings, if it is possible, with those known to be associated with the suspect plant (Deependra singh *et al.,* 2013).

The degree of toxicity also depends on the location (including height above sea level), climatic factors including the local micro climate (light, warmth, humidity), the growing season, type of soil, fertilization, plant variety and age. The condition of the poisonous plant material is equally important (dried, chewed, cooked, as tea). The dose of course is the most important factor (Table 1–4).

Classification of plant toxins

Alkaloids include indole alkaloids, pyrrolizidine alkaloids, tropane alkaloids, opium alkaloids, vicine and covicine alkaloids.

Glycosidal toxins include cardiac glycosides, goitrogenic glycosides, anthraquinonr glycosides, mustard oil glycosides, saponin glycosides, cyanogenetic glycosides.

Tannins like pyrogallol.

Proteins like lectin, abrin, ricin, cicutoxin, anisatin, gelonin, falcarinol, oenotheatoxin, etc.

Antivitamins like thiaminases.
Phytoestrogens like coumestrol.

Volatile etheric layers such as ushuriol, photo sensitizing substances including hypericin.

Enzyme inhibitors like cholinesterase inhibitors, protease inhibitors, amylase inhibitors.

Others include lathyrogens, Anti-thiamin compounds, Avidin.

Various types of toxins produced by different vegetable crops (Fig. 1–18)

Glycoalkaloids

Cyanogenic glycosides

Glucosinolates

Tomatine

Pyrrolizidine alkaloids

Zucchini and Cucurbitacins

Amylase inhibitors

Lectins

Coumarins

Furocoumarins

Safrozole

Myristicins

Toxins in food plants

Amygdalin

The seeds of apple, apricot, plum, bitter almond and peach contain small amount of a poisonous cyanogenic glycosides, called amygdalin. Amygdalin derived from aromatic amino acid phenylalanine. It is hydrolysed by β-glucosidase and amygdalase to afford L-mandelonitrile and gentiobiose. Mandelonitrile is further hydrolysed to hydrogen cyanide and benzaldehyde. Hydrogen cyanide causes cyanide poisoning. The quantities of amygdalin present in the seeds not enough to be dangerous to human health, but consumption of more quantity of seeds may lead to a fatal dose (Saravanan, 2016).

Lotaustralin

Is a cyanogenic glycoside found in austral trefoil, cassava and lima bean. It is the glycoside of methyl ethyl ketone cyanohydrins. Lotaustralin hydrolysed by the enzyme linamerase to form glucose and toxic compound hydrogen cyanide. Hydrogen cyanide causes a drop in blood pressure rapid respiration, rapid pulse, headache, dizziness, mental confusion, vomiting, stomach pains and diarrohea.

Linamarin

Is another cyanogenic glycoside present in the leaves and roots of lima beans, cassava and flax. It is decomposed by gut flora in the human intestine to form hydrogen cyanide. Consumption of food prepared from insufficiently processed plant material containing linamarin to produce dietry toxicity, called Konzo disease. Dietary exposure to linamarin was also been reported as a risk factor in developing diabetes and glucose intolerance.

Oxalyl-di-amino propionic acid (ODAP)

This is a structural analogue for the neurotransmitter glutamate found in the grass pea and Indian pea. It is the neurotoxic amino acid responsible for motor neuron degeneration syndrome, neurolathyrism, characterized by pyramidal tract neurons in the area of cortex controlling legs and in the spinal cord. As a result, lower body paralysis.

Phytohaemagglutinin

It is a lectin found in high concentration in uncooked red and white kidney beans and in low concentration in green, broad and common beans.

Phytohaemagglutinin has complex oligosaccharide conyaining mannose, galactose and N-acetylglucosamine. It is causing severe stomach ache, diarrhea, and vomiting in humans when consumed as raw or half boiled.

phytohaemagglutinin was destroying the epithelia of the GI tract that causes local haemorrhage, interfere with cell mitosis, and damage the liver, kidney and heart. The beans also contain an alpha amylase inhibitor, which affects the digestion of starch.

Glucosinolates (Goitrogens)

Are derived from glucose and amino acid. It is present in cassava, spinach, soyabeans, pears, sweet potatoes, peanuts, strawberries, peaches, broccoli, cabbage, cauliflower, Brussels sprouts, mustard greens, rapessed and radishes. Glucosinolates are sulphur containing substances which are metabolized by the enzyme thioglucosidase to produce nitriles, sulphur, isothiocyanates and thiocyanate.

The isothiocyanates undergo cyclisation to produce goitrins which increasing the goitrogenic activity. It is suppressing the uptake of iodine that causes the thyroid gland to enlarge, forming a goiter. Upon consumption, they give pungent taste due to breakdown of glucosinolates.

Oxalic acid

Present in spinach, rhubarb (0.2-1.3%),tea (0.3-2.0%), spinach (1.7%), purslane and in parsley (1.7%). It can bind with calcium and minerals, making them insoluble and thus reducing the bioavailability. Consumption of foods containing oxalates could cause kidney stones, decreased bone growth, renal toxicity, diarrhea, convulsions and coma. Approximately 65% of kidney stones consists of Calcium oxalates.

Ipomeamarone

Is found in kumara, which is a member of the sweet potato family. It can produce harmful toxins due to insect attack, injury and some other stress. Ipomeamarone makes the kumara to taste bitter. The toxin concentrations are normally highest in the area of the damage. Make sure that the destroyed parts in kumara are removed before cooking.

Furocoumarins

Parsnips generally consist of a variety of natural toxins referred as furocoumarins such as psoralen and angelicin. They are most likely produced during the defendind of the plant with regards to happens to be pressured. The amount for the furocoumarins is generally highest during the peel or at damaged areas of the plant. Furocoumarins could cause stomach pain and may produce a painful skin reaction if exposed to sunlight. It is very important to peel the plant prior to cooking in order to eliminate all the damaged parts.

Cucurbitacins (Courgette)

Members of the cucurbitaceae family (Zucchini, cucumbers, pumpkins, squash, melons and gourds) consist of a group of naturally occurring toxins generally cucurbitacins (oxygenated tetra cyclic terpenes) that act as a movement arrestors and compulsive feeding stimulants for diabriticine beetles (corn root worms and cucumber beetles). Cucurbitacins are among the most bitter compounds known (Lawrence; 2006).

Phytic acid

Also called as phytate. It is present in the germ and bran of several plant seeds, grains, nuts and legumes. Phytic acid is a simple sugar that contains six phosphate side chains. It is a dietary source of phosphorus and a good chelator of divalent cations like copper, zinc, iron, calcium and magnesium. Investigations suggest that phytate-mineral complexes were insoluble in the intestinal tract and thus reducing mineral bioavailability and also inhibit the digestive enzymes like pepsin, trypsin, β- glucosidase and α-amylase. So, intake of foods containing high concentrations of phytic acid could decrease the starch and protein digestibility.

Thiosulphate

Onions and garlic have thiosulphate. It is harmful to horses, cats, dogs and many types of animals. Thiosulphate damage the red blood cells, haemolytic anemia by the formation of Heinz bodies in erythrocytes of horses, cats, dogs and many other animals.

Solanine and chaconine

Potatoes have poisonous glycoalkaloids such as solanine and chaconine. Solanine is also present in hyoscyamus and atropa. Glycoalkaloids are produced within the parenchyma cells for the periderm as well as the cortex of the tubers. It produces armed effects in animals and insects and help to defend from predators. The glycoalkaloids found in all potato tubers are not reduced by cooking and washing. The level of solanine and chaconine in potatoes is enough to produce harmful effects in human beings. The glycoalkaloids affects the nervous system, leading to extreme digestive disturbances, diarrhea, headaches, weakness, cramps, confusion and in severe cases coma and death. Mild gastro intestinal effects, generally begin within 8-12 hours of ingestion. Glycoalkaloid concentrations above 200 mg/kg is dangerous for humans. Prolonged exposure of potato tubers to light on the storage shelf or at home stimulate formation of green colour and glycoalkaloids. Its concentration is high in tubers, peel and sprouts (Saravanan *et al.,* 2012).

Tomatine

Leaves, stems and green unripe fruit of tomato contain steroidal alkaloid tomatine. It's containing two molecules of D-glucose and one molecule of each D-xylose and D-galactose.

When consumes, tomatine lead to nervous excitement and digestive upset. The usage of tomato leaves for herbal tea has been responsible certain death. Mature tomatoes don't have any detectable quantity of tomatine. Tomato plants are harmful to dogs when they consume huge amount for the fruits (Pittenger, 2002; Barceloux, 2009).

Myristicin

Myristicin is naturally occurring acaracide (2.7%) and insecticide (1.3%), present in mace and nutmeg. It is also found in carrot, black pepper, dill and celery parsley. It is structurally related to mescaline and a weak inhibitor of monoamine oxidase. Myristicin produce unpleasant symptoms like anxiety, tachycardia, nausea, fear and tremor. It also produces toxicological symptoms in humans, which are similar to alcohol intoxication. At the dose level of 6-7mg/kg it may cause psychotropic effects in man and a feeling of irresponsibility (Hallstrom, 1997).

Safrole

1-allyl-3,4-methylenedioxybenzene (safrole) is present in aromatic oils of cinnamon, nutmeg and camphor and is the main constituent of oil of sassafras. It produces testicular atrophy, weight loss, malignant liver tumors and bone marrow depletion.

The mechanism of carcinogenicity is assumed to involve cytochrome P-450 catalysed hydroxylation of safrole to 1-hydroxy safrole which upon subsequent metabolism produces extremely reactive electrophiles that bound to DNA (Wislocki *et al.*, 1977).

Lathyrogens

Lathyrogens such as $^{\beta}$-aminopropionitrile (BAPN), aminoacetonitrile (AAN) and aminoethanethiol present in legumes like vetch and chick peas. They are the analogues of amino acids and can act as antagonists of glutamic acid. Glutamic acid is a neurotransmitter present in the brain. When lathyrogens are consumed in huge amount by a human being, they produce a crippling paralysis of the lower limbs and could lead to death (Shibamoto, 1993).

Anti- thiamin compounds

Anti-thiamin compounds such as cholrogenic acid, caffeic acid and tannins found in beets, mung beans, Brussels sprouts, rice bran, some berries and buckwheat seeds. Some of the bioflavonoids like rutin and qucertin in-actives the thiamin. Vitamin B1 involved in energy production through the metabolism of carbohydrates, which is important for the normal working of heart, muscles and nervous system. Lack of thiamine produces a disease referred to as beriberi. Signs include poor arm and leg coordination, weakness, muscle pain, loss of appetite, nervous tingling throughout the body and irritability (Deshpande, 2002).

Biogenic amines

These are low molecular weight organic bases, which pose biological activity. The source of biogenic amines is eggplant (0.3mg/100g), tomato (1.2mg/100g), potato (0.1mg/100g), fermented foods and meat. 100mg/kg amine concentration in food is dangerous for health.

Most common amines found in vegetables are Dopamine, serotonin and tyramine. Harmful effects of biogenic amines are nausea, respiratory distress, heart palpitation, head ache and hypertension. The toxicity dose of biogenic amines depends on the individual sensitivity.

Mycotoxin

Have been defined as “fungal metabolites which when ingested, inhaled or absorbed through the skin cause lowered performance, sickness or death in man or animals, including birds”.

The source of mycotoxin are sorghum, nutmeg, rice, chilli, pepper and turmeric. One of the most potent mycotoxins are aflatoxin and ochratoxin.

It causes serious damage to liver, kidneys and nervous system. They are often carcinogenic and mutagenic. Today, 300-400 mycotoxins are known. Aflatoxin B1 has been classified by the IARC to be a class 1 human carcinogen (Berthiller *et al.*, 2013).

Table.1 Mechanism of action of different plant toxins

S.no	Chemical constituent	Mechanism of action
1.	Alkaloids	
	Glycoalkaloids	Interacts with mitochondrial membranes. Increase concentration of ca++ in the cell that triggers cell damage and apoptosis.
	Indole alkaloids	Increases serotonin action.
	Pyrazzolidine alkaloids	Anti-mitotic action.
2.	Cyanogenic glycosides	Release HCN, inhibit oxidative process of cells.
	Saponin glycosides	Interact with LC cells. T cell mediated contact dermatitis.
	Goitrogenic glycosides	Inhibition of both thyroid peroxidase (TPO), inhbits both TPO-catalyzed iodination.
3.	Oxalates	Form salts with '+' charged ions. Form Ca^{++} oxalate, ferric oxalate. Form stones in kidney.
4.	Tannins	Precipitate proteins.
5.	Proteins	
	Abrin	Inhibit protein synthesis.
	Thionins	Attacks membrane, make it permeable, decrease sugar uptake, K+ ions.
	Epi podophyllotoxin	Inhibit topoisomerase II
6.	Anti vitamins	
	Thiaminases	Aids carbohydrate metabolism for CNS muscles, heart.
	Hypericin	Non specific kinase inhibitor inhibits dopamine beta dehydrogenase, increase dopamine.
7.	Volatile etheric layers	
	Ushuriol	T-cell mediated dermatitis, changes shape of integral membrane proteins.
8.	Enzyme inhibitors	
	Cholinesterase inhibitors	Cholinesterase inhibitors ultimately modify cholinergic signaling through disruption of acetylcholine degradation.
	Protease inhibitors	The protease inhibitors can slow virus production.
		Non-toxic reversible metallo-protease inhibitor. Inhibits many membrane bound peptidase which are critical regulators of peptide hormones.
	Amylase inhibitors	Inhibiting membrane bound alpha glucosidases.

Table.2 Harmful effects of plant toxins

S.no	Body system	Harmful effects
1.	Nervous system	Cause convulsions
		Depression
		Nervousness
2.	Cardiovascular system	Tachycardia
		Bradycardia
		Fluid accumulates around hears
		Shock & death
3.	Digestive system	Diarrhea, vomiting
		Colic pain
		Abdomen pain paralysed tongue
		Apetite loss
4.	Respiratory system	Pneumonia
		Respiratory paralysis
5.	Reproductory system	Abortion
		Teratogenic
		Cramps, foetal mummification
6.	Muscular system	Tremor weakness
7.	Urinary system	Haematurea
		Liver necrosis
		Liver degeneration
8.	Circulatory system & tissues	Thrombocytopenia
		Bone marrow depression
		Anaemia
9.	Integumentary system	Photosensitivity
		Conjunctivitis
		Dermatitis

Table.3 Pharmacological actions(Chandra *et al.*, 2012)

S.no	Body system	Pharmacological use
1.	Nervous system	Provide strength to nerves
		Used to treat anxiety
		Treat depression as herbal medicine
		Used to treat insomnia
		Used as brain tonic
		Tranquilizer, antidepressant
2.	Cardiovascular system	Tone cardiac muscles
		Effects include weal pulse
3.	Digestive system	Used for ulcers
		Treat tonsillitis
		Used as laxative
4.	Respiratory system	Treat bronchitis
		Treat asthma
		Tone respiratory system
5.	Reproductory system	Treat menstrual cramping
6.	Urinary system	Treat infections
		Diuretic system
7.	Circulatory system & tissues	Treat cancer
		Decrease bad cholesterol
		Relieve pain
		Blood purifier
8.	Integumentary system	treat leprosy

Table.4 Hydrogen cyanide contents of some food plants

Food	HCN (mg/1oog)
Lima beans	210-310
Almonds	250
Sorghum	250
Cassava	110
Peas	2.3
Beans	2.0
Chick peas	0.8

Fig.1 Amygdalin

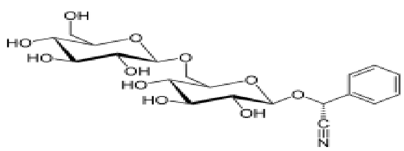


Fig.2 Lotaustralin

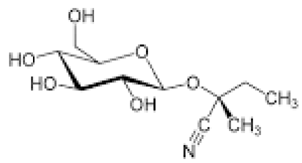


Fig.3 Linamarin

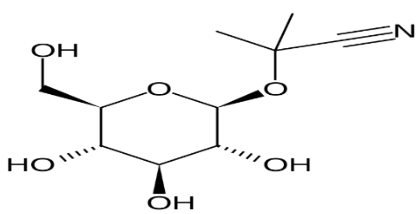


Fig.4 Oxalyldiaminopropionic acid (ODAP)

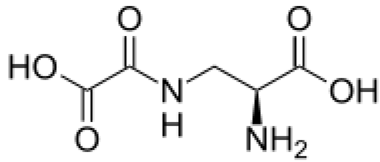


Fig.5 Glucosinolates (Goitrogens)

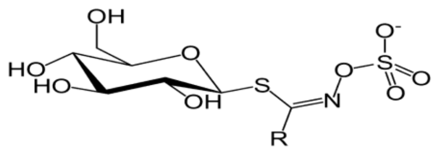


Fig.6 Oxalic acid

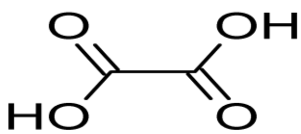


Fig.7 Ipomeamarone

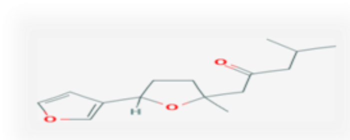


Fig.8 Furocoumarins

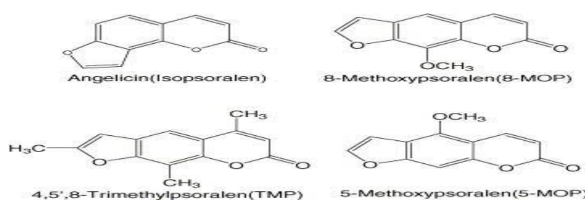


Fig.9 Cucurbitacins (Courgette)

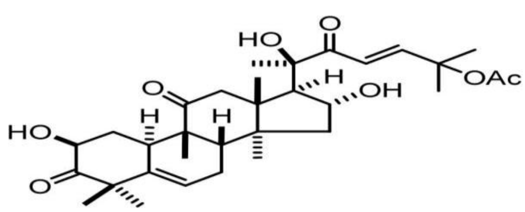


Fig.10 Phytic acid

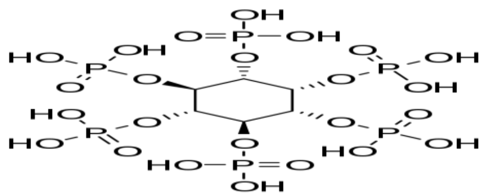


Fig.11 Thiosulphate

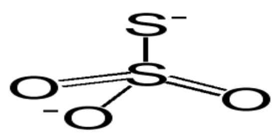


Fig.12 Solanine and Chaconine

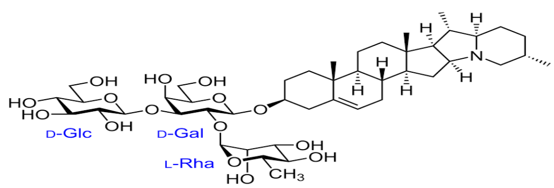


Fig.13 Tomatine

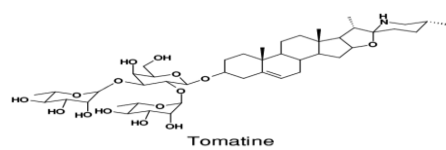


Fig.14 Myristicin

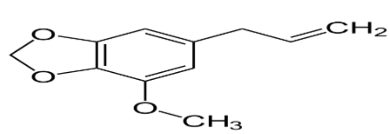


Fig.15 Safrole

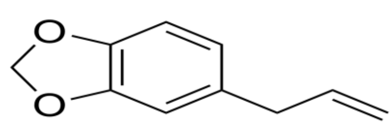


Fig.16 Anti- thiamin compounds

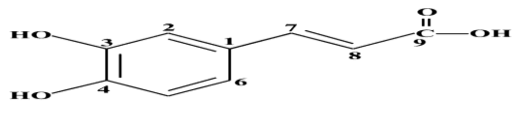


Fig.17 Biogenic amines

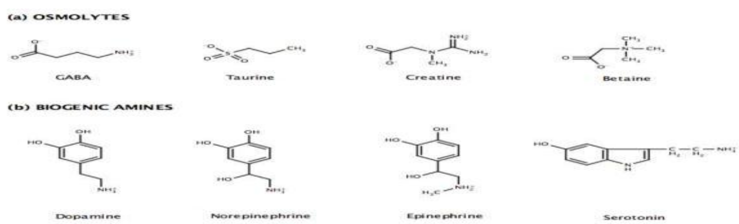
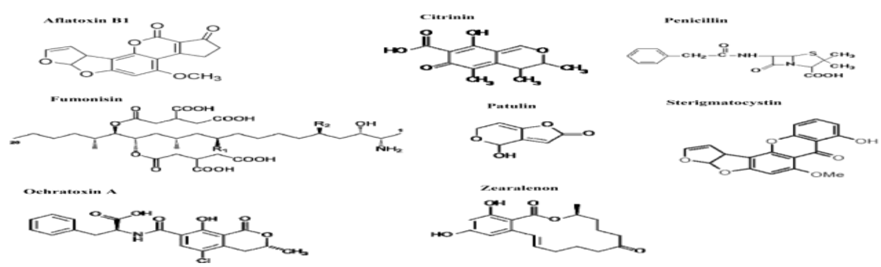


Fig.18 Mycotoxin



Mushroom toxins

These are caused by high content of Amatoxins in mushrooms. Mushrooms which have been identified containing amatoxins are Amantia bisporigera and Galenina autumnals. There are different types of mushroom toxins like Alpha amanitin (it causes fatal liver damage after 1-3 days of ingestion and the principle toxin is present in the death cap), Phallotoxin (it causes extreme gastrointestinal upset), Orellaine (it causes kidney failure within 3 weeks after ingestion) and Muscarine (causes sludge syndrome).

Methods of reduction of plant toxins

For some types of natural toxins, post-harvest processing treatments and cooking of the plant result in destroying the endogenous toxic substances or reduction of its toxicity. Toxin reduction may be made more effective by certain preparation or processing methods such as cutting into smaller pieces prior to cooking.

In case of beans, the lectin toxin can be reduced by soaking and boiling thoroughly in fresh water. In cassava, toxins can be reduced by peeling and cutting before cooking which disrupts the cell structure and releases the hydrogen cyanide.

Some breeding procedures like selection, domestication, development of transgenic lines also helps in reducing the toxicant level in food plants. Other natural toxins, however, remain unchanged after usual preparation and cooking. In these cases, special care has to be exercised in selecting the food plants and in limiting the amount of intake. Natural toxins are found widely in edible plants which are otherwise nutritious and beneficial to health.

These food plants can be safely consumed if suitable measures are taken, such as careful selection, adequate processing and cooking, and limitation of intake.

The level of toxins in the food plants vary according to geographical, environment and species differences.

The people are advised to be cautious in the amount of intake and are recommended to observe the effects after ingestion, particularly for elderly people and children.

Advice to trade

Store potatoes in a cool, dry and dark environment. Avoid keeping stocks for prolonged periods.

Display a smaller stock at any one time.

Discard stocks that show signs of sprouting, greening, physical damage or rotting.

Do not use sprouting, greened or damaged potatoes for making food products.

Advice to public

Purchase

Avoid buying potatoes that show signs of sprouting, greening, physical damage or rotting.

Storage

Remove potatoes from plastic bags and place them in a cool, dry, and dark place at home. Store only small amounts of potatoes at home.

Discard potatoes that show signs of sprouting, greening, physical damage or rotting.

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