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Phytotoxins - A mini review

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Abstract
A number of toxic factors occur naturally in food of plant origin. Food and fodder sources from plants of leguminosae family seem to have the greatest diversity of the toxicants. Phytotoxins are poisonous substances produced by plant or plant pathogens that have adverse effects on living organisms. Phytotoxins have great diversity in their composition, occurrence, mode of action and lethal effects. They belong to diverse classes of compounds such as peptide (amino acid derived), terpenoid, glycoside, phenolic, polyacetate and sometimes combinations of these classes. The biological activity of a phytotoxin can be measured in a number of ways depending on its chemical nature and their apparent effect. Toxic agents can be classified in variety of ways i.e. on the basis of target organ, use, source and effects on biological system. Toxins play an important role in the field of pharmacology especially in forensic medicine and clinical toxicology, veterinary medicine, agrochemicals and their application as vaccines to inactivate toxoids. Furocoumarins (found in citrus fruits, carrots), lectins (rosary peas & caster beans), aflatoxins, (groundnuts, almonds) and glycoalkaloids (potato) are some of the important plant toxins which are harmful for living organisms. Fortunately, under normal dietary conditions, the concentration of such toxicants in food is too low to cause any adverse effects however, under certain conditions, if very high concentration of these phytotoxins is consumed may lead to certain health implications.

Keywords: Phytotoxins; Furocoumarins; lectins; aflatoxins; glycoalkaloids

Introduction
Recently, public health and social agendas have become more proactive in food toxicology. For their part, the regulators can limit amounts of potentially toxic substances allowed in food and in those circumstances where setting limits is not effective and public health policy makers provide the public with sufficient information, where possible, to protect the consumer from reasonably foreseeable problems. Labeling requirements by the FDA provide the consumer with helpful information about contents of fats, carbohydrate, protein, potential allergens, caloric value, *etc.*, but do not provide valuable information about toxins that may be inherent in the foods or formed during processing. Because some food toxins cannot be removed from foods and others may be created during processing or cooking, consumption of small quantities of food toxins is unavoidable. A number of toxic factors occur naturally in food of plant origin. Food and fodder sources from plants of leguminosae family seems to have the greatest diversity of the toxicants (Torrents *et al.*, 2017) [10]. Phytotoxins are poisonous substances produced by plant or plant pathogens that have adverse effects on living organisms. Toxins can be small molecules, peptides, or proteins that are capable of causing disease on contact with or absorption by body tissues interacting with biological macromolecules such as enzymes or cellular receptors. Phytotoxins have a great diversity in their composition, occurrence, mode of action and lethal effects.

Importance of Toxins
Phytotoxins play an important role in the field of medicine, especially in forensic medicine, clinical toxicology, pharmacy, pharmacology and veterinary medicines. Botox (produced by *Clostridium botulinum*) is used in facial remodeling mainly but can also used for treatment of migraines, excessive perspiration, brain and spinal cord disorders and enlargement of prostate and bladder function. Toxins are also safe for use in agrochemicals. Selenium at right dose, is a powerful antioxidant, but at too high dose, it is a nerve toxin. The mycotoxin avermectin is currently used as insecticide and for the control of nematode parasites of domestic animals (Cope *et al.*, 2004) [3]. Inactive toxins (toxoids) are also useful for public health as vaccines.

Major Health Concerns
Phytates or phytic acid are antinutrients that block the absorption of minerals like iron, calcium and phosphorus and zinc. Furocoumarins

(found in citrus fruits, carrots) are a family of natural food constituents that can cause DNA damage. Lectins are a group of glycoproteins which can produce toxicity by facilitating bacterial growth in GI track. Aflatoxins are responsible for up to 172,000 liver cancer cases per year, most of which results in mortality within several months of diagnosis (Wu *et al*., 2014) [12].

Sources of Toxic Compounds

There are majorly two basic toxic compounds in food viz. natural toxic compound and synthetic toxic compound

Natural toxic compound

These are the compounds that are naturally produced by living organism. These toxins are not harmful to the organism themselves but they are toxic to other creatures. These chemical compounds have diverse structure and differ in biological function and toxicity. Natural plant toxins may be present inherently in plants such as fruits and vegetables which are common food sources. They are usually metabolites produced by plants to defend themselves against various threats such as bacteria, fungi, insects and predators. Natural toxins may also be present in food plants as a result of natural selection and new breeding methods that enhance these protective mechanisms. Wink, (1988) [11] (Fig 1).

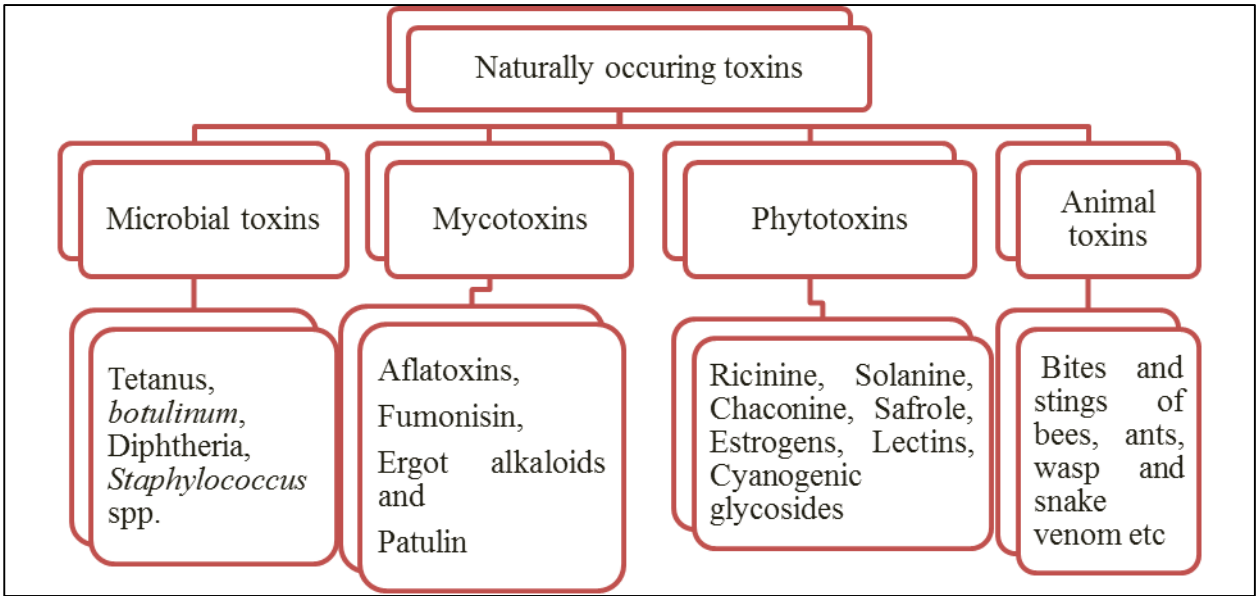

Fig 1: Sources and examples of naturally occurring toxic compounds

Mycotoxins

These are the secondary metabolites of fungi that cause toxic and carcinogenic outcomes in humans and animals. 25 per cent of the cereals produced in the world are contaminated by mycotoxins. Humans consume food containing 1.7 ppm toxin for short time experienced liver damage. Sources of mycotoxins are Cereals (aflatoxins, ochratoxin A, sterigmatocystin, alimentary toxic aleukia (ATA), Bakery products (aflatoxins, ochratoxins, luteoskyrin, sterigmatocystin), Nuts (dried), Herbs, Spices (aflatoxins, ochratoxins A), Fruits (patulin) and Vegetables (Penicillic acid, aflatoxin) (Table 1).

Table 1: Mycotoxins of Major Health Concerns

Mycotoxins	Producing fungi	Associated food
Aflatoxins	*Aspergillus flavus, A. parasiticus*	Maize, peanuts, tree nuts, copra, spices, cottonseed
Fumonisins	*Fusarium verticillioides, F. proliferatum, A. niger*	Maize
Trichothecene mycotoxins	*F. graminearum, F. culmorum*	Maize, wheat, barley, oats
Ochratoxin A	*Penicillium verrucosum, A. ochraceus, A. carbonarius, A. Niger*	Maize, wheat, barley, oats, dried meat, coffee, beans

Source: Kiessling (1986) [7]; Dutton (1996) [4]

Phytotoxins

Plant toxins are substances produced as secondary metabolites which are identical to extra cellular bacterial toxins in their properties, showing both useful and harmful effects in human beings and animals. Poisonous plants affect nearly all living creatures from insects to humans. Their effects on humans vary from causing individual poisoning to mass outbreaks and from having relatively minor to rare fatal consequences. Poisoning can be caused by accidental overdose, over-consumption, or disbelief of the toxicity. Poisons can be transferred from plants to human food through animal products such as milk, bird's eggs, and honey produced by bees foraging on toxic plants. Toxins can be present in some or all parts of plants including the roots, leaves, fruits, and seeds; and the toxin can be effective when taken internally or through skin contact. Poisonous plants are consumed as food or processed by drying or cooking. Many toxins can be deactivated by cooking, but others are concentrated by drying or by extraction into a tea-like beverage. Some people, such as children and the infants, are more at risk due to less effective immune systems and form the most important risk group. Very young children are at the highest risk from plant toxins as they regularly put almost anything of suitable size within reach into their mouths, and might find berries and leaves attractive. Poisons affect children more rapidly and severely because of the low bodyweight, thereby increasing the concentration of the toxins. Some highly toxic plants including water hemlock (Cicuta sp.), poison hemlock (*Conium maculatum*) and hemlock water dropwort (*Oenanthe crocata*) contain highly dangerous toxins (Table 2).

Table 2: Plant families abundant of plant toxins present

Family	Toxin	Crop plants
Leguminosae	Protease inhibitors	Pigeon pea, chickpea, lentils, lima beans, peas, cowpea
Solanaceae	Glycoalkaloids	Potato, eggplant, apples, bell peppers, cherries, sugar beets and tomatoes.
Rosaceae	Cynogenic glycosides	Almond, cherry, peach, apple, plum

Sources: Torrents *et al.* (2017) [10]

Glycoalkaloids

Cyanogenic glycosides are found in many organisms (plants, insects, fungi and some micro-organisms). Cyanide is highly toxic to all aerobic organisms, because it binds to the haem group of the cytochrome oxidase located in the mitochondria, the final step in oxidative respiration. Organisms avoid autotoxicity by the spatial separation of the stable cyanogenic glycoside and the specific degradative β-glucosidases, either at tissue or organelle level. The glycoalkaloids α-solanine and α-chaconine are natural pesticides that are produced in potatoes. α-Solanine is also found in eggplant, apples, bell peppers, cherries, sugar beets and tomatoes. The only difference between α-solanine and α-chaconine is the sugars in the trisaccharide portion of the molecule, *i.e.*, glucose with two rhamnoses for α-solanine and a glucose, galactose and a rhamnose for α-chaconine. Although glycoalkaloids are found throughout the potato tuber, the greatest concentrations are in the sprouts, peels and sun-greened areas. Synthesis of α-chaconine and α-solanine is stimulated by light, mechanical injury, aging and potato beetle infestation. Exposure of potatoes to light in the field or marketplace can lead to glycoalkaloid concentrations that are unsafe for human consumption. Concentrations of solanine in green or blighted potatoes have been shown to increase by seven fold. The symptoms of acute toxicity to α-solanine and α-chaconine are due to their ability to act as inhibitors of acetylcholinesterase and disruptors of cell membranes.

Synthetic toxic compound

Synthetic chemicals are made by humans using different methods than those by natural uses, and these chemical structures may or may not be found in nature. Table 3 showing the sources and examples of synthetic organic compounds.

Table 3: Sources and examples of synthetic toxic compounds

Sources	Examples
Air	Transportation, industrial processes, electric power generation, carbon monoxide, Oxides of nitrogen and sulphur, hydrocarbons
Water	Sewage, runoffs, waste products discharged from refineries or chemical plants, agrochemicals, detergents, heavy metals
Food contaminants	Bacterial, fungal and animal toxins, pesticide residues, plant alkaloids, residues of animal feed additives
Food additives	Nitrates, nitrites
Drugs of abuse	Cocaine, lysergic acid diethylamide, morphine, nicotine
Therapeutic drugs	All drugs beyond LD_{50} can be toxic
Agrochemicals	Pesticides, herbicides, nematicides, rodenticides
Cosmetics	Thioglycolates, thioglycerol

Sources: Alamgir (2017) [1]; Egmond (2004) [5]

Methods and strategies to eliminate or avoid toxins

Prevention of toxic exposure is concerned with preventing chemicals of synthetic or natural origin from reaching people in amounts or at rates that exceed human tolerance to them. It includes identifying and evaluating the cause of poisoning, making predictions about their frequency, and putting into practice the measures intended to mitigate or eliminate future exposures or to reduce the severity of health effects after an exposure. There are many different methods and their working principles for removal of toxicants in different types of food (Table 4 and Table 5).

Table 4: Methods and strategies to eliminate or avoid toxins

Toxicant	Method of removal
Lectins	Thermal processing
Cyanogen glycosides	Processing, Traditional household method
Potato glycoalkaloids	Autoclave, heating
Gossypols	Use of glandless cottonseed varieties, controlled moist heat processing, treatment with organic solvents
Safroles	Thermal processing
Racins and Abrins	Autoclaving

Source: AOAC (2005) [2], Gross and Bunting (1982) [6]

Table 5: Method and working principle for the elimination of toxin

Physical Processing	Working
Autoclaving, pressure cooking, steaming	Heating at ultrahigh temperatures (>100 °C).
Blanching	Mild boiling (75 °C-95 °C) to inactivate endogenous enzymes
Ordinary cooking	Usually preceded by soaking, de-hulling, germination and fermentation
Extrusion	High temperature short time (HTST) processing
Roasting	Dry heating at 120 °C − 250 °C
Soaking	Exposure to water and salt solutions
Processing chemical	Treatment with thiols, sulphite, Cu-salts (± ascorbic acid)

Source: Price *et al.* (1987) [8]; Shahidi (1997) [9]

Conclusion

The growing concerns about healthy lifestyle have forced the researchers to find out the possible relationship between diet and diseases. Further, they are constantly challenged to explore the possible adverse effects of food toxicants and at the same time to evaluate the potential of these plant secondary metabolites on our body system for safe use to overcome different ailments.

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