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A REVIEW ON PLANT TOXIN

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ABSTRACT

Since ancient times, plants have been used in many areas of life due to their characteristic secondary metabolites such as alkaloids, phenols and terpenoids, especially for medical purposes. Toxins naturally occur in a variety of plants. Plants develop to produce natural products as a means of fighting animals. The alkaloids are by far the most common plant toxins. Due to their enormous structural diversity and different mechanisms of action, examples can be selected that serve as paradigms for practically every type of herbivore interaction. Plant toxins show many useful effects that can be used in the treatment of the respective diseases, and they can be modified to show better affinity and effectiveness. Most of the non-nutrient chemicals that people ingest in their normal diet are naturally occurring secondary metabolites of food crops. It has been proposed to define inherent plant toxins as plant components that can have adverse effects on human consumption of plants or plant products.

KEYWORDS: Plant toxins; Secondary metabolites; Herbivore; Inherent plant toxicants.

INTRODUCTION

Plant toxins are usually secondary metabolites that plants produce and excrete. These metabolites either accumulate in the tissue or are deposited on the plant surface. Toxins are naturally present in a variety of plants that evolve to produce a natural product as an animal defense. Some plants produce toxins that can seriously damage or destroy any herbivore. They show both beneficial and harmful effects on humans and animals. Natural toxin may also be present due to natural selection and new breeding methods that improve this protective mechanism.[1]

Toxins enter the body either through inhalation, ingestion, or through contact. The effect is based on its chemical component. These are divided into alkaloids, glycosides, proteins, oxalates, antivitamins, tannins, volatile ether layers, etc. They change certain mechanisms in which enzymes, receptors and even genetic material in certain cells and tissues are involved. Poisonous plants have seeds, roots, leaves, stems, fruits or juice, although a relatively small amount, taken either internally or externally, can cause harm to the human body. In some species, the toxic ingredient is found throughout the plant. In others, they are concentrated in one or more parts.[2]

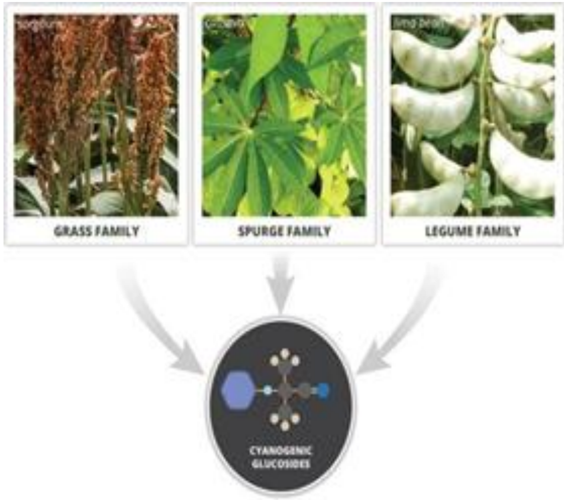
Plants are a common cause of a medical dilemma, generally due to the phytochemicals. The different flowering plant species differ not only in their profile, but also in their limitless biochemical properties. The phytochemicals were used not only to compensate pollinators and seed distributors, but also to protect against animals that pose a risk. However, some phytochemical or secondary metabolites produced by plants are toxin-like substances that are similar in properties to extracellular bacterial toxins and can cause problems in humans. These have both useful and harmful effects in humans and animals. The problems vary greatly from skin irritation to thyroid problems to neurological syndromes. Plant toxins can enter the body either through inhalation, swallowing or through contact. The effect mainly depends on their phytoconstitutes such as alkaloids, glycosides, proteins, tannins, volatile oils, terpenes, steroids etc. They act in the animal or human body through different specific mechanisms in which receptors, transporters, enzymes and even genetic material are involved in certain cells and tissues.[3]

Plants express a variety of toxic proteins, which are believed to play a role in the defense against pathogens and insects. Plant toxins include ribosome inactivating proteins (RIPs) such as ricin toxin, which have highly specific rRNA-N-glycosidase activity and may possibly be used as biothreat agents. The antiviral activity and cytotoxicity of plant toxins has been used for research purposes and in antiviral and targeted cancer therapy. So far it is not clear how structural differences between these toxins affect receptor binding, intracellular trade, ribosome interactions and toxin activity. It is important to understand how their structure-function relationships affect these processes. This special edition looks at the latest advances in various aspects of plant poison biology, from basic research to medical applications, and highlights key aspects of the field.[4]

How Plant Make, Store And Use Plant Toxins

Plants produce an amazing number of small molecules that they use in their wars with the insects or other animals like mites or vertebrates that try to eat them. In some cases, these toxic molecules disrupt animal nervous systems. Or they can interfere with the basic cellular and biochemical functions needed for life. Some plants produce proteins that make it difficult for insects to extract important nutrients from the plant tissue they consume. Some can slow down the growth and development of the insect, reducing plant damage.[5] Plants carefully control how specialized compounds are made, stored, and released. This chemical process can be very complex. In maize, at least fourteen different enzymes compose benzoxazinoids via three different cell organelles. Once built, the plant stores the inactive toxin in its cell vacuoles. When a herbivore hits the leaf, the damage tears open the vacuole. When the inactive toxin emerges, it reacts with enzymes in the cytoplasm. The toxin is activated and the herbivore eats. Sometimes compounds that are very effective against herbivores developed independently of one another in different plant families. An example is cyanogenic glucosides. These compounds are found in unrelated plants such as sorghum, cassava and lima beans. Plant genomes usually have more genes than the animals they consume. One reason why plants have so many genes is that they produce a large number of enzymes. Plants use these enzymes to make complex chemical compounds.

Some of these relationships play a role in the development and propagation of plants. Many are also used for defense. These defense connections are often referred to as "specialized connections". One plant can make a certain specialized connection, while a closely related plant can make another. However, related plants often make similarly specialized compounds. These connections are important for the success of plant families. For example, plants from the mustard family produce glucosinolate compounds. And many plants in the grass family produce benzoxazinoid compounds.



Often, only one part of the specialized compound molecule causes the damage. This part can even hurt the plant that makes it. So, in the plant, these reactive chemical groups are bound up in large molecules. This makes them safe to store. Glucose, a common and harmless sugar, often serves this purpose. When herbivores feed on plant cells, plant enzymes remove the glucose. Or, sometimes the toxin may form later, inside the herbivore's digestive system. These processes make the toxic part of the specialized compound active. These mechanisms ensure that the toxins hurt the herbivores, while protecting the plant.

NATURAL PLANT TOXIN IN FOOD PLANTS

What are Natural Plant Toxins and Why are they Present?

Plants can contain natural toxins. They are usually metabolites produced by plants to defend themselves against various threats such as bacteria, fungi, insects and predators, which can be species-specific and give the plant its special properties, e.g. Colors and flavors. Common examples of natural toxins in food plants are lectins in beans such as green beans, red kidney beans and white kidney beans. cyanogenic glycosides in bitter apricot seeds, bamboo shoots, cassava and linseed; Glycoalkaloids in potatoes; 4'-methoxypyridoxine in ginkgo seeds; Colchicine in fresh lily flowers; and muscarin in some wild mushrooms.[7]

Poisoning from natural plant toxins

These types of poisoning mainly occur inthe following three scenarios

1. **Consumption of plants that are not intended for human consumption**

Some wild plants, such as B. wild mushrooms and giant elephant ears contain strong toxins that are not easily destroyed during cooking. These wild plants can be mistaken for edible plants. Severe symptoms can occur even when eaten in small amounts.

2. **Consumption of food plants without proper preparation or processing**

Green beans often cause poisoning if they are not cooked thoroughly before eating. Cyanogenic plants such as bitter apricot seeds can cause food poisoning if eaten raw and in sufficient quantities. However, they can be safely consumed if they are boiled thoroughly in boiling water like Chinese soups. In plants such as cassava and bamboo shoots, poisonous cyanide can be removed more effectively by soaking in water or by cutting into small pieces before cooking.

3. Consumption of plants in which the toxins cannot be destroyed by cooking or processing

Some edible plants can also cause food poisoning if consumed in excess, but the existing toxins cannot be effectively reduced by normal processing. Cases of poisoning have been reported after eating only ten gingko seeds, as not all existing toxins can be easily destroyed during cooking. In some food crops such as potatoes, there may be high levels of plant toxins if they are green or germinating. Because the toxins are heat-resistant, food poisoning can occur even if the potatoes are cooked thoroughly. Different natural toxins can cause different symptoms, ranging from mild gastrointestinal symptoms to severe central nervous system symptoms. Whether poisoning occurs generally depends on the amount of plant ingested, the level of toxins present, and the susceptibility of the individual. The level of toxins in a plant can vary widely depending on the species, growing conditions and geographic factors.

Useful and Harmful Effect of Plant Toxin

Plant toxins are substances that are produced as secondary metabolites and are identical in their properties to cellular bacterial toxins. They show both useful and harmful effects in humans and animals. They show a wide range of side effects from mild itching, nausea, vomiting to side effects such as psychosis, paralysis, teratogenicity and cardiac arrhythmia. They are useful in the manufacture of cosmetics, ulcers, menstrual cramps, cancer, and in the treatment of human diseases and ailments. Toxins can enter the body either through inhalation, swallowing, or through contact. The effect is based on their chemical components, which are divided into alkaloids, glycosides, proteins, oxalates, antivitamins, tannins, volatile ether layers, etc. They work by changing specific mechanisms in which enzymes, receptors and even genetic material in certain cells and tissues are involved. Poisonous plants have seeds, roots, leaves, stems, fruits or juice, although even a relatively small amount, taken either internally or forever, can cause harm to the human body. In some species, the toxic components are found throughout the plant. Others are concentrated in one or more parts.[9]

The degree of toxicity also depends on the location (including the height above sea level), climatic factors such as the local microclimate (light, heat, humidity), the growing season, the type of soil, the fertilization, the type of plant and the age. The condition of the toxic plant material is just as important (dried, chewed, boiled, like tea). The dose is of course the most important factor.
Plants contain a variety of toxic compounds, commonly referred to as "secondary compounds" that affect the behavior and productivity of wild and domestic animals. There are many classes of these toxic compounds; However, the most common are soluble phenols, alkaloids and terpenoids. Soluble phenols include flavonoids, isoflavonoids, and hydrolyzable and condensed tannins. There are a variety of plant toxins and it is difficult to organize the myriad of plant toxins in an understandable way. Plant toxins are described according to the organ system in the human body that affect them, e.g. Cardiotoxins, neurotoxins, etc. The difference between the terms "medical" and "toxic" is sometimes less than one might think.[10]

Classification of Plant Toxins

Classification of plant toxins Plant toxins are food components of plant origin, which can be endogenous toxins with low molecular weight or products of secondary metabolism. Secondary metabolism products are species-specific and responsible for the special properties of the plant. This includes plant pigments, flavors and compounds that serve to protect the plants. Some of these secondary metabolites cause oral toxicity to the individual. These substances can be growth inhibitors, neurotoxins, carcinogens and teratogens4. These are classified based on their structural and chemical properties. Plant toxins can be classified as follows[11]

a) Alkaloids

These are organic compounds that contain nitrogen in the heterocyclic ring, are basic in nature and are derived from amino acids, most of which have strong physiological activity. For example colchicine, nicotine, aconitine, taxin, cocaine and many others: Some common toxins in this class include

- **Indole alkaloids:** beta-carbolines like harmines, which act on the central nervous system[5]
- **Pyrrolizidine:** venous occlusive disease of the liver
- **Tropans:** atropine, scopolamine, hyoscyamine, which act on the autonomic nervous system
- **Glycoalkaloid:** The main concern about glycoalkaloid toxicity is acute toxicity. Many cases of poisoning in humans have been reported (sometimes fatal) due to the ingestion of green, damaged or sprouted potatoes as a result of high glyco-alkaloid levels, i.e. H. Solanin
- **Vicine / Covicine:** important for G-6PD deficiency and fauvism (hemolytic anemia)

b) Glycosides

These substances consist of a non-sugar unit, i.e. H. Aglycon, to which one or more sugar chains are attached.

- Cyanogenic glycosides release hydrocyanic acid. The cyanide ions (CN-) bind to the mitochondrial cytochrome oxidase and thus block electron transport. The clinical symptoms of acute cyanide poisoning can be: rapid breathing, drop in blood pressure, rapid pulse, dizziness, headache, stomach pain, vomiting, diarrhea, mental confusion, stupor, cyanosis with twitching and convulsions, followed by terminal coma.

- Cardiac glycoside such as digitoxin from foxglove. Digoxin inhibits the enzyme Na-K- ATPase. Vomiting, confusion, changes in color perception and especially cardiac arrhythmias are dominant symptoms
- Goitrogenic glycosides: Too much intake and simultaneous iodine deficiency can lead to thyroid disorders
- Mustard seed oil glycosides: After breaking down the sugar, irritating mustard oils were released.

c) Tannins

These substances have the ability to precipitate proteins. They make the skin hard by deceiving the proteins in the skin.

d) Proteins

A number of protein toxins produced by plants enter eukaryotic cells and enzymatically inhibit protein synthesis. Examples of toxic proteins are ricin (castor bean plant), abrin (rosary pea) and white acacia. Lathyrism occurs due to a toxic amino acid that mimics glutamate.

e) Oxalic acid

These substances can be found in trichomes or in raphids (needle-like structures). They can cause mechanical irritation. Ingested oxalate is absorbed. Oxalate in the blood binds calcium to form the insoluble calcium oxalate. Severe hypocalcaemia with tetany may occur.

f) Anti-vitamins

Some substances act against the vitamins, e.g. Thiaminases in horsetail and bracken (breakdown of thiamine) and anti- vitamin K such as coumarins.

g) Photosensitizing and contact- sensitizing substances

St. John's wort with hypericin and spurge causes photo allergy. Poison Ivy is known in North America. Many of the active ingredients are phenols, furanocoumarins or derivatives thereof that cause an allergy to sunlight.

h) Volatile oils

Volatile oils are liquid substances that are formed in special oil cells, glands, hair or channels. They are all soluble in alcohol. At certain concentrations, some are irritating (blistering) and emetic. Some volatile oils are nephrotoxic.

MECHANISM OF ACTION OF PLANT TOXIN

Neurotoxins

The neuroactive alkaloids can function either as agonists which excite a neuroreceptor or as antagonists which would block a certain neuroreceptor. Receptors on neuron cells are another major target for many of alkaloids, which structurally resemble the endogenous neurotransmitters such as glutamate, acetylcholine, dopamine, noradrenalin, and adrenaline. Some alkaloids inhibit the enzymes that break down neurotransmitters, such as cholinesterase and monoamine oxidase. Neurotoxins also have an effect on significant ion channels of neuronal cells, such as Na+, K+ and Ca2+ channels, whichever by activating or inactivating them eternally. This activities stop neuronal signal transduction and block the activity of the central nervous system and neuromuscular. The sodium, potassium ion ATPase that is an important ion pump in neuronal and other cells to maintain an ion gradient important for action potentials and transport mechanisms.[12]

Many phyto components are considered cytotoxins because they interfere with important cell functions. Biomembranes are the main target of such compounds that are involved in the import and export of metabolites and ions in cells. The fluidity and integrity of the membrane can be severely disrupted by both steroid and triterpenoid saponins. Saponins are usually stored as inactive bidesmosidic saponins in plant vacuoles; When injured and destroyed, they transform into active monodesmosidic saponins that are amphiphilic with cleansing activities. Multiple enzymes, proteins, DNA/ RNA and related processes are other important targets of such compounds. A number of potent plant toxins inhibit the biosynthesis of ribosomal proteins, such as the alkaloid emetin, amanitine and lectins. These toxins can bind to cells via their B chain, the haptomer, while the A chain is absorbed into the cytosol by endocytosis, where it blocks protein biosynthesis. The elements of the cytoskeleton, especially microtubules and actin filaments, are also vulnerable targets in animal cells. A number of plant toxins are known as microtubule poisons, such as colchicine, podophyllotoxin, vinblastine, chelidonine, noscapine, cucurbitacine and taxol. These poisons are known to block cell division, vesicle transport and microtubules. Several secondary compounds can covalently bind to proteins, such as Aldehydes, epoxides, secondary compounds with exocyclic methylene groups, with SH groups or reactive double or triple bonds. These protein modifications influence the three-dimensional structure of proteins and can inhibit their function. Therefore, many poisons with such properties have neurotoxic and cytotoxic properties or are irritating to skin and mucosal tissue.

Inhibitors of cellular respiration

Cell respiration, which occurs in mitochondria and produces ATP, is another susceptible target in animals, since ATP is essential for all cell and organ functions. Many plant toxins can attack this target with HCN, which binds to iron ions of the terminal cytochrome oxidase in the mitochondrial respiratory chain. HCN does not occur in free form, but is stored as cyanogenic glucoside in plant cell vacuoles. If plants are injured, the contents of the vacuoles come into contact with enzymes such as β-glucosidase and nitrilase due to a broken cell matrix. These enzymes hydrolyze and cyanogenic glucoside releases extremely toxic HCN. The diterpene fractyloside is a strong inhibitor of the mitochondrial ADP / ATP transporter and thus inhibits the ATP supply to a cell.[13]

Toxins of the skin and mucous membranes

Animal skin and mucosal tissues are also affected by several toxins. Diterpene, which is similar to the endogenous signal compounds diacylglycerol (DAG), an activator of the key enzyme protein kinase. These diterpenes are classified as phorbol esters and stimulate protein kinase. If they come into contact with skin, mucous membranes or eyes, they cause severe painful inflammation with ulcers and blistering. Furanocoumarins can penetrate the skin and store the skin cells. When the skin is exposed to sunlight, the furanocoumarin alkylates the DNA, killing the cells and causing severe blistering and necrosis. Many types of ranunculaceae accumulate the glycoside ranunculin in the vacuole. It splits into the active protoanemonin, which can alkylate proteins and DNA, causing skin and mucosal irritation, followed by severe inflammation. The proteases or other harmful proteins of plants further deteriorate the condition due to their harmful activity.[14]

Plants carefully control how specialized compounds are built, stored, and released. This chemical process can be very complex. In maize, at least fourteen different enzymes compose benzoxazinoids via three different cell organelles. Once built, the plant stores the inactive toxin in its cell vacuoles. If a herbivore chews on the leaf, the damage breaks the vacuole. When the inactive toxin emerges, it reacts with enzymes in the cytoplasm. The toxin is activated and the herbivore eats it.[15]

TOXICOLOGICAL EFFECTS OF PLANT TOXINS

Phyto-dermatitis and Phyto- photodermatitis

Some substances secreted by plants have, after irradiation with UV light, e.g. Hogweed (Heracleum sphondylium), giant hogweed (Heracleum mantegazzianum) and Rue (Ruta graveolens). Figs, mango, and many other trees that are known to cause skin irritation on contact. Phytophotodermatitis, also known as dermatitis pratensis, is clinically identified by strange red streaks at the point of contact (forearms, hands, legs, face) exposed to the sun. The skin lesions resemble burns. There is a delay between skin contact and the first signs of irritation. Phytophotodermatitis should not be confused with contact allergies or photoallergic reactions such as polymorphic light outbursts, persistent light reactions or sun urticaria. The treatment consists of a thorough cleaning of the skin and the use of a steroid cream. Celery, parsnips, figs and parsley should be used by people with light dermatitis, e.g. with SLE because it contains large amounts of psoralens.[16]

Berloque dermatitis, caused by perfumes that contain bergamot oil, is a well-known condition in dermatology. There is generally residual pigmentation. Phytocomponents such as 8-methoxypsoralen and similar furano-coumarins from Ammi majus, so- called psoralens, are photodynamic substances. They absorb UV light, are activated and then cause cell damage by inhibiting DNA synthesis. These are used in the PUVA therapy of psoriasis as psoralens with ultraviolet A.[17]

Phytoallergy

Hay fever caused by pollen from spurge, birch, hazel, liechgrass and rye grass is a common case of phytoallergy. Urticaria caused by strawberry consumption and peanut allergy are some other recognized allergy conditions due to phytocomponents. Some phytoconstitutes cause certain forms of extrinsic allergic alveolitis. Allergy to pyrethrum is a well-known problem in the plantations of Chrysanthemum cineriaefolium. Japanese cedar (Cryptomeria japonica) is a source of annual misery because of the massive amounts of highly allergenic pollen every spring. A phytoallergic problem has increased significantly in recent decades.[18]

Another allergic mechanism occurs in regions with poison ivy (Rhus toxicodendron, T. rydbergii), poison oak (Rhus juglandifolia) and poison oak (Rhus vernix). The active substance is urushiol. The first contact of juice with the skin has no discernible clinical effect. However, urushiol acts as a hapten. It binds to proteins in the skin and creates new epitopes. With subsequent contact, a pronounced itchy dermatitis develops.[19]

Food poisoning

Food poisoning caused by plant toxins, mainly from eating foods such as partially cooked beans, some types of potatoes, and ingesting wild herbs that are undesirable for human consumption, such as poisonous berries and mushrooms. Acute cases of intoxication caused by plant toxins are occasionally ignored because the symptoms of toxicity can be rather non-specific. Previously, acute poisoning from high consumption of glycoalkaloids such as solanine from potatoes was misdiagnosed as microbial food poisoning60. The amount of food crops that contain toxins that are responsible for food poisoning depends on many factors, such as individual susceptibility, cooking methods, and toxin levels in the plant, which may vary depending on the species and geographic environment.[20]

Plant Toxin and The Human Diet

The toxins and defense proteins in crops are critical. Without these defenses, herbivores would lose much more crop. This would have serious negative consequences for farmers and society.[21]

The toxins that plants produce to prevent herbivores also affect humans. These effects can be both negative and positive. For example, cassava is a staple food for hundreds of millions of people in many tropical countries. It is also rich in hydrogen cyanide. Humans have to process cassava to make it edible. Soaking cassava roots in water is one way to dissolve and remove the hydrogen cyanide. Cooking at high temperature also reduces the toxins in some plants. Cooking is a unique human innovation used to eliminate toxic cyanide in some crops like lima beans. Cooking can also break down defense proteins that are harmful to humans.[22]

Plant breeders have also developed varieties of plants that contain fewer toxins in parts of plants that humans consume. For example, geneticists have selected rape seeds (the source of canola oil) that are low in glucosinolate toxins. In addition, farmers have selected “sweet” almond varieties with a low cyanide content. In some cases, compounds that deter insects and other herbivores also give foods strong flavors that people enjoy.[23]

Plant Poison and Safety

In order to assess / regulate compounds that could be responsible for food poisoning, complex information on all related aspects (toxicity, exposure) must be available. In contrast to mycotoxins and some phycotoxins, very limited data are available. In the comprehensive review on this. It was concluded that the concept of estimating the ADI (Acceptable Daily Intake) for pesticide residues and food additives is not suitable for risk management and regulation of food plant toxins. Typically, a narrow spread between actual intake and potentially toxic levels would prohibit the use of certain foods, provided standard uncertainty factors are used to determine ADI. As highlighted by the expert group, the presence of plant toxins, their bioavailability from the matrix and their interaction with other inherent plant components must be assessed along with possible health benefits of the whole food (antioxidants and other natural preservatives may be present). Given the severity, incidence, and occurrence of biological symptoms associated with the health risk of various food hazards, the following six main categories, from largest to lowest, are typically classified by scientists:[24]

1. Microbial contaminants
2. Nutritional imbalance (over and under supply)
3. Environmental pollutants
4. Natural toxins
5. Pesticide residues
6. Food additives

It should be noted that the ranking of these hazards is not linear, as that of environmental conta minants and natural toxins is approximately 1/1000 of that of nutrient imbalances and pesticide residues and food additives is approximately 1/100 of the natural toxins.[25]

With regard to the regulatory aspects of the inherent plant toxins, the main problem in this area, as already mentioned, is that essential data on toxicological properties and information on the presence of these substances in human nutrition are missing. In general, the setting of ceilings must be based on both the size of the potential public health and safety risk and the ability of a legally enforceable standard to perform an effective risk management function. Various criteria are taken into account when setting priorities for research and further evaluation. In addition to the acute risk, the (experimental and epidemiological) data on chronic toxicity are important for this purpose. Connections that are thought to be associated with high consumer exposure in certain regions are cause for concern. Specific risk groups should also be considered.[26]

SCOPE OF PLANT TOXINS

In terms of chemical composition, plant- based foods can be considered as mixtures of chemicals, which can be divided into two broad categories: intrinsic components, which are inherent components of plants, and extrinsic components, which are chemicals of natural or industrial origin, either through food direct addition (food additives), through contamination (e.g. pollutants, mycotoxins, packaging migrants) or indirectly through agricultural practices (e.g. pesticide residues). The intrinsic components include a wide range of chemicals with various possible health effects.[27]

- Macro (proteins, lipids, sugar) and micro (e.g. vitamins) nutrients that determine the nutritional value of plant food.
- Antinutrients that can reduce the nutritional value of plant food (eg protease inhibitors that block protein digestion, phytates that inhibit the absorption of minerals such as iron).
- Inherent plant toxins, which are non- nutrient secondary plant metabolites that have been identified for their potential for humantoxicity.

CONCLUSION

Plants grow up in an extremely competitive environment. Insects, microbes and herbivores constantly intimidate plants. To exist, every plant has to produce secondary metabolites to protect it. Plant toxins are common in edible plants; These are not only harmful, but also nutritious and health-promoting. These substances can be alkaloid, glycoside, proteins, tannins, etc. These toxins are a problem in correlation with various diseases and can pose a risk as bio-terror weapons. Still, it serves as an excellent tool for studying cellular and other mechanisms, and better knowledge of plant toxins can provide us with new products for use in medicine. Every plant has to resort to a complex of defense mechanisms, which can be physical, such as spines or leathery leaves or chemical. These connections are of the greatest interest, since they are often specific to a particular species or genus and therefore have to be designed for the service and have a special protective function. The most common include numerous classes of phenols, terpenes and steroids, cyanogenic compounds and alkaloids.

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