WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Plants Constituents, Alkaloids and Toxicity of Plant Toxins to Animal Health

Maria Siddika Mim [1], Bithe Saha [1], Md. Aminul Islam Ripon [1], Anupam Sarker Avi [1]

[1] Department of Pharmacy, Jahangirnagar University, Dhaka-1342, Bangladesh
Email: mariamimju2016@gmail.com

ABSTRACT:

Typically, plant toxins are the byproducts that plants create to defend themselves against various dangers such as insects, predators, and microbes. The presence of these poisons in food plants is caused by either novel or natural reproductive strategies that strengthen defenses. The parts of the plant that can be harmful are the stem, roots, fruits, buds, and leaves. Several plant species have natural poisons that can be eaten as food if they are swallowed in excessive quantities or are improperly cooked, which can result in food poisoning. When consumed, these poisonous compounds may have negative effects on one's health. Certain plants can kill or seriously injure herbivores with their phytotoxins. like harmful proteins that are involved in the body's defense against insects and infections. Alkaloids are synthesized by plants to help them survive adverse environments. Native Americans have been using plant extracts containing alkaloids for almost 2,000 years to cure a variety of illnesses, including fever, snakebite, and insanity. However, because of their immense structural variety and diverse mechanisms of action, several plant alkaloids are classified as primary plant poisons despite their substantial advantages to humans and the pharmaceutical industry. Exposure to toxic alkaloids can occur in humans and animals through inhalation, swallowing, or direct contact. This can result in a specific mechanism involving receptors, transporters, enzymes, and genetic materials at specific cells and tissues, which can cause musculoskeletal deformities and hepatotoxic effects. When these poisonous compounds are consumed in large quantities, they can be uncomfortable and hazardous to human health.

Keywords: Alkaloids; Metabolites; Neurological diseases; Glycosides; Toxicity

Introduction:

Plants that are common food sources, such fruits and vegetables, may naturally contain plant harmful substances. Typically, plants create these secondary metabolites as a defense mechanism against several types of dangers, including bacteria, fungus, insects, and predators [1]. Food plants may also naturally contain poisons due to innovative breeding techniques and natural selection that improve these defense systems. Plants frequently cause medical problems, most often because of their phytochemicals. The many flowering plant species vary not only in their profiles but also in their infinite biochemical characteristics. Phytochemical compounds were created to shield flowering plants from potentially dangerous animals as well as to recompense animal pollinators and seed distributors [2, 3]. However, some of the phytochemicals or secondary metabolites that plants generate have toxicity-like qualities and are similar to extracellular bacterial toxins in that they may harm people. These affect humans and animals in both positive and negative ways. The negative effects range greatly, from skin irritation to neurological diseases and thyroid issues.

Alkaloids are a class of chemicals that include nitrogen and are found in bacteria, fungus, plants, and mammals [4]. The alkaloid structure's nitrogen atom gives the substance its medicinal qualities. While hydrogen in primary and secondary amines can function as a proton donor, the nitrogen's lone pair electrons can take protons [5]. The majority of alkaloids are found in higher plants, particularly in the fruit, stem, and roots of such plants, where 31,000 different chemicals have been discovered [6-8]. Plant species with high alkaloid content include Amaryllidaceae (amaryllis), Papaveraceae (poppies), Ranuncalaceae (buttercups), and Solanaceae (nightshades). However, the amount of alkaloids in these plants fluctuates and is constantly dependent on certain elements including climate and geographic location [9, 10]. The first alkaloid to be identified from the Papaver somniferum L. (Opium poppy) was morphine in 1804.

Many pharmacological characteristics, including antibacterial, analgesic, antidepressant, and anticancer effects, are displayed by plants high in alkaloids [11–13]. Alzheimer's disease has also been treated with some of them because it has been demonstrated that they have neuroprotective qualities. Toxins derived from plants can enter the body through touch, ingestion, or inhalation. Their phyto-constituents, such as alkaloids, glycosides, proteins, tannins, volatile oils, terpenes, and steroids, are primarily responsible for the action. Through a variety of unique processes involving receptors, transporters, enzymes, and even genetic material at particular cells and tissues, they work in the animal or human body [14-16]. Furthermore, the dose, duration of exposure, sensitivity, site of action, and stage of organism development all affect how hazardous alkaloids are. Therefore, the focus of this review is on a few alkaloids originating from plants that are harmful to both humans and animals.

Alkaloids' function in both plants and animals:

Alkaloids are nitrogen-storing substances found in plants that act as growth regulators, calcium and potassium replacements, and predator defense mechanisms [17]. The alkaloids in plants have the ability to disrupt the nervous system, membrane transport, protein synthesis, and enzyme activity of predators [18]. Alkaloids have been used as drugs throughout human history, which has demonstrated their significance to the pharmaceutical sector. An example of an alkaloid with antibacterial, anti-HIV, and anti-parasitic properties is harmine, which is generated from the beta-carboline group. Leukemias, lymphomas, testicular cancer, breast cancer, lung cancers, and Kaposi's sarcoma have all been treated with vinca alkaloids (vinblastine and vincristine) isolated from Catharanthus roseus, berberine isolated from Coptis spp., and taxol isolated from Taxus bravifolia as anticancer medications [19, 20].

Glycosides:

These compounds are made up of an aglycone, a non-sugar component, to which one or more sugar chains are attached. Prussic acid is released by cyanogenic glycosides. By attaching themselves to the mitochondrial cytochrome oxidase, the cyanide ions (CN-) prevent electron transport. Acute cyanide intoxication can include rapid breathing, a reduction in blood pressure, a fast pulse, dizziness, headaches, nausea, vomiting, diarrhea, mental disorientation, stupor, and cyanosis with twitching and convulsions that ends in a fatal coma, among other clinical signs [21]. Cardiac glycosides, like foxglove's digitoxin. Digoxin prevents Na-K-ATPase from functioning. The most common symptoms are vomiting, disorientation, alterations in color perception, and, most importantly, heart arrhythmias. Goitrogenic glycosides: excessive use combined with a concurrent iodine shortage might cause thyroid problems.

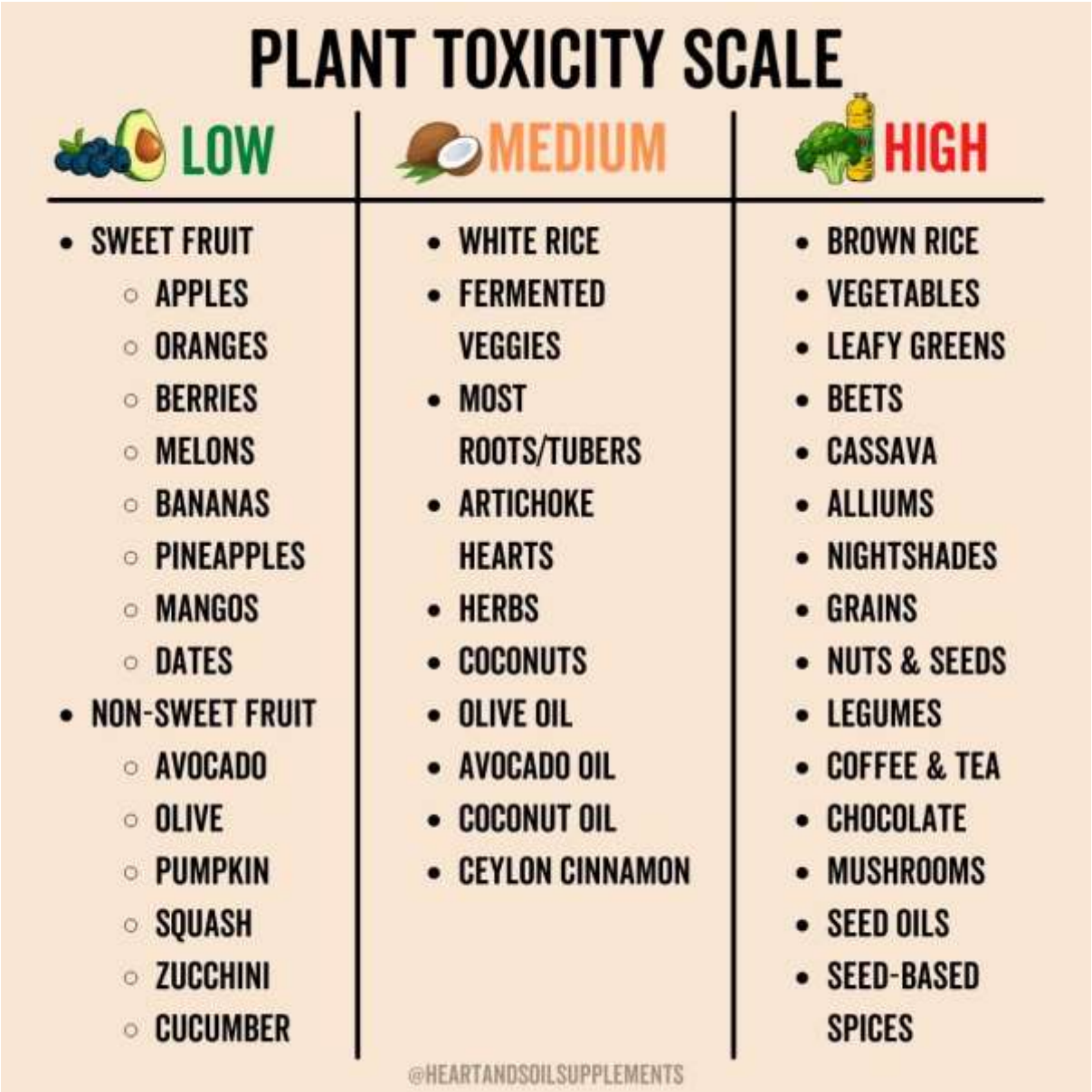

Figure 1. Commonly used plants toxicity level

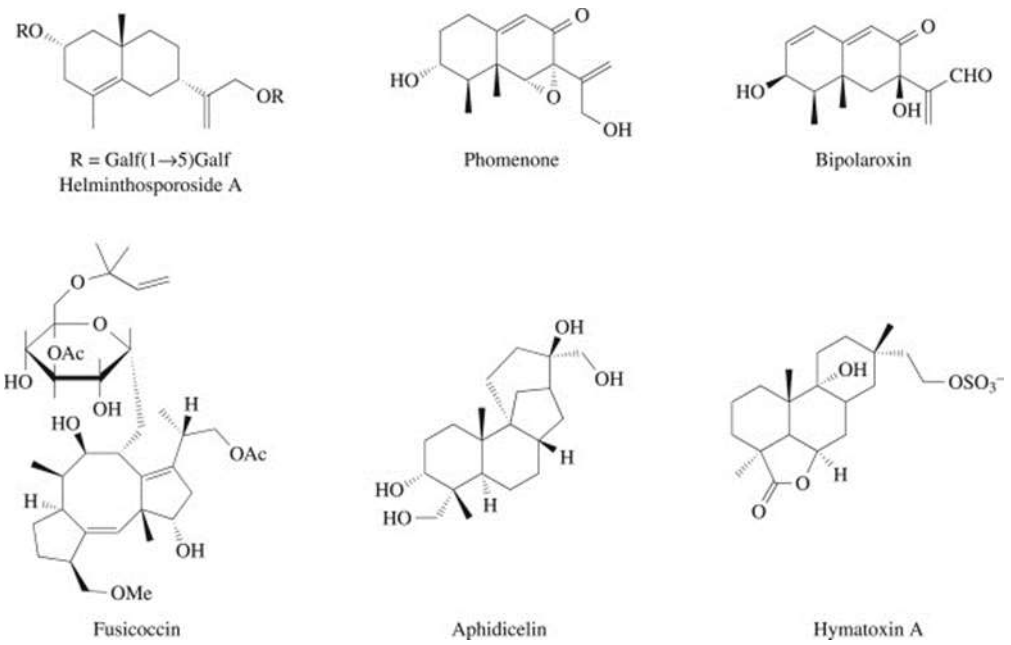

Figure 2. Common plant toxins chemicals

Toxicological Effects of Plant Toxins: Some wild plants have strong poisons that are difficult to eliminate through cooking, such wild mushrooms and enormous elephant ears. If consumed raw and in large enough quantities, cyanogenic plants like bitter apricot seeds can result in food poisoning; however, when cooked sufficiently in boiling water, as in Chinese soups, they are safe to eat. It is more efficient to soak plants like cassava and bamboo shoots in water or cut them into small pieces before boiling in order to remove harmful cyanide.

Hay fever is frequently brought on by pollen from plants such as rye grass, ragweed, birch, hazel, and timothy grass. Other known allergy diseases caused by phytoconstituents include urticarial disease, which is caused by eating strawberries, and peanut allergy. Some types of extrinsic allergic alveolitis are brought on by specific phytoconstituents [22]. Food poisonings caused by plant toxins are primarily caused by eating foods like inadequately cooked beans, some potato cultivars, and ingestion of wild herbs that are not intended for human use, like toxic mushrooms and berries.

PLANT COMPOUNDS, FOOD SOURCES, & THEIR SUGGESTED CLINICAL IMPLICATIONS

'Anti-nutrient'	Food Sources	Suggested Clinical Implications
Lectins	Legumes, cereal grains, seeds, nuts, fruits, vegetables	Altered gut function, inflammation
Oxalates	Spinach, Swiss chard, sorrel, beet greens, beet root, rhubarb, nuts, legumes, cereal grains, sweet potatoes, potatoes	May inhibit calcium absorption; May increase calcium kidney stone formation
Phytate (IP6)	Legumes, cereal grains, pseudocereals (amaranth, quinoa, millet), nuts, cassava	May inhibit absorption of iron, zinc and calcium; Acts as an antioxidant; Antineoplastic effects
Goitrogens	Brassica vegetables (kale, Brussels sprouts, cabbage, turnip greens, Chinese cabbage, broccoli), millet, cassava	Hypothyroidism and/or goiter; Inhibit iodine uptake
Phytoestrogens	Soy and soy products, flaxseeds, nuts (negligible amounts), fruits and vegetables (negligible amounts)	Endocrine disruption; Increased risk of estrogen-sensitive cancers
Tannins	Tea, cocoa, grapes, berries, apples, stone fruits, nuts, beans, whole grains	Inhibit iron absorption; Negatively impact iron stores

Figure 3. Plant toxins from plant compound with suggested bad clinical impact on animals

SOME COMMON ALKALOIDS IN PLANTS:

Tropane alkaloid: The most abundant concentrations of tropane alkaloids (TAs), which are common alkaloids present in all plant parts, have been detected in the roots and seeds of the families Brassicaceae, Solanaceae, and Erythroxylacea. The species and growth environment of plants affect how much TAs they produce. Approximately 200 TAs have been found and then classified into subgroups based on stereochemical characteristics and the amount of carbons in the tropane skeleton. Atropine, Scopolamine, Hyoscyamine, Calystegine, Tigloidine, Secotropane are the most common TAs.

Due to their anticholinergic qualities and hallucinogenic effects—which can lead to constipation, photophobia, pupil dilatation, visual impairment, and dryness of the upper digestive and respiratory tract mucosa—older people have employed TA-containing plants for folkloric and medical purposes. Due to the hallucinogenic qualities of Datura species, exposure to TAs can occur either directly through eating of the plant or indirectly through ingestion of TA-contaminated food. Freshly cut hay or maize with D. stramonium is typically the source of TAs that result in horse and cattle poisoning incidents [23, 24]. In experimental animals, the common toxicological effects are pupillary dilatation and neurobehavioral repercussions. TAs stop acetylcholine from interacting with its receptor in humans. The central nervous system, breathing, and heart rate may all be impacted by this response. For instance, scopolamine blocks acetylcholine at both central and peripheral muscarinic receptors in a competitive manner. Both people and animals may have toxicological effects from this interaction, and in extreme circumstances, both species may perish from respiratory failure [25, 26].

Indolizidine alkaloids: An indolizidine alkaloid known as "swainsonine" was identified from Swainsona plants [27]. Swainsonine has the ability to inhibit lysosomal hydroxylases, including Golgi α-mannosidase and α-mannosidase. This can result in cellular alterations, such as lysosomal storage disease, which is caused by an excessive build-up of carbohydrates in lysosomes [28]. The neurological disorder known as locoism can be brought on by cattle, sheep, and horses consuming locoweeds, according to Chenchen et al. [29]. In addition, proprioceptive impairments, sadness, anxiety, intention tremors, emaciation, reproductive failure, and mortality may result from swainsonine poisoning. Swainsonine poisoning has been known to cause excitation, an exaggerated fear response, trembling, and mild ataxia in several animals, including horses.

Piperidine alkaloids: Piperidine alkaloids are chemical substances that exist naturally and belong to the alkaloids category, which is formed chemically from piperidine. Alkaloids containing a piperidine building block are widely distributed and are further classified based on their biogenetic origin and mode of occurrence. The most significant piperidine alkaloids representative is piperine, which gives pepper its strong flavor. The sedum alkaloids (e.g., sedamine), pelletierine, lobelia alkaloids (e.g., lobeline), conium alkaloids (e.g., coniine), and pinus alkaloids are likewise classified as piperidine compound. Neonate animals that are exposed to piperidine alkaloids have musculoskeletal abnormalities and are acutely harmful to adult cattle species. Cleft palates and multiple congenital contracture (MCC) deformities in cattle, pigs, sheep, and goats are examples of these teratogenic effects. Tobacco (Nicotiana tabacum), lupine (Lupinus spp.), and poison hemlock (Conium maculatum) are examples of poisonous plants that contain teratogenic piperidine alkaloids.

Plant hepatotoxins: Naturally occurring phytochemicals or secondary metabolites, plant poisons serve as defense mechanisms against a range of pathogens, fungi, insects, and predators. Common human diets like fruits and vegetables can contain toxins. Plant materials utilized in the cosmetics and phytomedicine industries may also expose humans. But the most common poisoning happens to animals and grazing fauna. These poisons have the potential to be toxic and cause severe liver damage when consumed. The adverse effects on the liver depends on the phytoconstituents or metabolites formed in the liver. Plant toxins can be classified into many different genera or chemical categories. For instance, Senecio, Echium, Cynoglossum, Heliotropium, Crotalaria, and Symphytum contain hepatotoxic pyrrolizidine alkaloids. Other genera contain glycosides, proteinaceous compounds, organic acids, alcohols, photosensitizing, and contact-sensitizing substances like poison ivy and volatile oils. The alkaloids of pyrrolizidine cause hepatotoxicity. The synthesis of the poisonous pyrrole moiety in the liver is the outcome of CYP3A-mediated metabolism, which is responsible for the toxicity. It has been demonstrated that the reactive metabolite interacts with proteins and nucleic acids, depleting hepatic glutathione. The mitochondrial ATP synthase subunit beta (ATP5B), a crucial subunit that generates pyrrole-ATP5B adducts, is a target of reactive pyrrolic metabolites of pyrrolizidine alkaloids. As a result, mitochondrial function is compromised.

Plant toxins and the human diet: The toxins and defensive proteins in crop plants are critical. Without these defenses, there would be much greater crop loss to herbivores. This would have profound negative consequences for farmers as well as society. Humans are impacted by the toxins that plants produce to repel herbivores. Both positive and negative effects are possible. For example, in many tropical nations, hundreds of millions of people depend on cassava as their main crop. It has a lot of hydrogen cyanide as well. Cassava must be processed by humans in order to be edible. One method to dissolve and get rid of the hydrogen cyanide is to soak cassava roots in water. Toxins in some plants can also be reduced by cooking at a high temperature. One special human invention that is utilized to remove deadly cyanide from some crops, including lima beans, is cooking. Cooking can also break down protective proteins that are bad for people. Additionally, crop varieties with lower amounts of toxins in plant sections that humans eat have been created by plant breeders. For instance, geneticists have chosen rapeseed seeds, which are the source of Canola oil, to have a low level of glucosinolate toxins. In addition, growers have chosen "sweet" almond cultivars that have lower cyanide content. Certain substances that repel insects and other herbivores can also impart powerful flavors to food that humans find palatable.

Conclusion:

Edible plants include a wide variety of plant poisons, which have both negative and positive health effects in addition to their toxic properties. These materials could be proteins, tannins, glycosides, or alkaloids. These poisons pose a risk as potential bioterror weapons and have been linked to a number

of ailments. Even yet, they are excellent instruments for researching cellular and other processes, and our growing understanding of plant poisons could lead to the development of novel pharmaceuticals.

References

1. Wink M (1988) Plant breeding: importance of secondary metabolites for protection against pathogens and herbivores. Theor Appl Genet 75:225-233
2. Tamanna, A. J et al., (2024). Evaluation of Phytochemical Screening, Antioxidant, and Thrombolytic Activity of Methanolic Extract of *Phlogacanthus thyrsiflorus.* South Asian Res J Pharm Sci, 6(1): 5-11. DOI: 10.36346/sarjps.2024.v06i01.002
3. Iftear Kazim Rafi et al (2023). The Impact of Banana Consumption on Bangladeshi Rickshaw Pullers' Assessing Cholesterol, Liver and Blood Pressure Functions. Middle East Res J Biological Sci, 3(2): 24-28. Doi: 10.36348/merjbs.2023.v03i02.001
4. Cushnie TT, Cushnie B and Lamb AJ. (2014). Alkaloids: an overview of their antibacterial, antibiotic-enhancing and antivirulence activities. International Journal of Antimicrobial Agents, 44(5), 377-386.
5. Kittakoop P, Mahidol C and Ruchirawat, S. (2014). Alkaloids as important scaffolds in therapeutic drugs for the treatments of cancer, tuberculosis, and smoking cessation. Current Topics in Medicinal Chemistry, 14(2), 239-252.
6. Shi QIU, Hui SUN, Zhang AH, Hong-Ying XU, Guang-Li YAN, Ying HAN and Xi-Jun WANG. (2014). Natural alkaloids: basic aspects, biological roles, and future perspectives. Chinese Journal of Natural Medicines, 12(6), 401-406.
7. Hoque, M et al., Centella asiatica: A mini review of its medicinal properties and different uses. World Journal of Advanced Research and Reviews, 2023, 19(02), 1185–1191. https://doi.org/10.30574/wjarr.2023.19.2.1699
8. Vanderplanck M and Glauser G. (2018). Integration of non-targeted metabolomics and automated determination of elemental compositions for comprehensive alkaloid profiling in plants. Phytochemistry, 154, 1-9.
9. Robertson LP, Hall CR, Forster PI and Carroll AR. (2018). Alkaloid diversity in the leaves of Australian Flindersia (Rutaceae) species driven by adaptation to aridity. Phytochemistry, 152, 71-81.
10. Ng YP, Or TCT and Ip NY. (2015). Plant alkaloids as drug leads for Alzheimer's disease. Neurochemistry International, 89, 260-270
11. Hamid HA, Ramli ANM and Yusoff MM. (2017). Indole alkaloids from plants as potential leads for antidepressant drugs: a mini review. Frontiers in Pharmacology, 8, 1-7.
12. Wadood A, Ghufran M, Jamal SB, Naeem M, Khan A and Ghaffar R. (2013). Phytochemical analysis of medicinal plants occurring in local area of Mardan. Biochemistry and Analytical Biochemistry, 2(4), 1-4.
13. Lu JJ, Bao JL, Chen XP, Huang M and Wang YT. (2012). Alkaloids isolated from natural herbs as the anticancer agents. Evidence-based Complementary and Alternative Medicine, 2012, 1-12
14. Chandra Sekhar J, Sandhya S, Vinod KR, David B, Sudhakar K, et al. (2012) Plant toxins-useful and harmful effects. Hygeia JD Med 4: 79-90
15. Burke WA (1997) Skin diseases in farmers. In: Langley, editors Safety and Health in Agriculture, Forestry, and Fisheries. Government Institutes, Rockville, MD.
16. Hoque, M et al., (2023). Heavy Metals in Poultry Chicken and Human Health Threat: A Mini Review. Middle East Res J. Humanities Soc. Sci, 3(4): 101-106. DOI: 10.36348/merjhss.2023.v03i04.006
17. Waller GR and Nowacki EK. (1978). The role of alkaloids in plants. In: Alkaloid biology and metabolism in plants. Springer: Boston, 143-181
18. Mazid M, Khan TA, and Mohammad F. (2011). Role of secondary metabolites in defense mechanisms of plants. Biology and Medicine, 3, 232-249.
19. Mohan K, Jeyachandran R and Deepa (2012). Alkaloids as anticancer agents. Annals of Phytomedicine, 1, 46 -53.
20. Isah T. (2016). Anticancer alkaloids from trees: Development into drugs. Pharmacognosy Reviews, 10(20), 90-99.
21. WHO (1993) Toxicological evaluation of certain food additives and naturally occurring toxicants. WHO Food Additive Series 30, Geneva.
22. Jadhaw SJ, Sharma RP, Salunke DK (1981) Naturally occurring toxic alkaloids in foods. Crit Rev Toxicol 13: 21-103.
23. Binev R, Valchev I and Nikolov J. (2006). Clinical and pathological studies on intoxication in horses from freshly cut Jimson weed (Datura stramonium)-contaminated maize intended for ensiling: clinical communication. Journal of the South African Veterinary Association, 77(4), 215-219

24. Bofill FX, Bofill J, Such G, Piqué E and Guitart R. (2007). Two cases of corn contamination poisoning with Datura stramonium in cattle. Toxicology Journal, 24(1), 56-58.

25. Koleva II, van Beek TA, Soffers AE, Dusemund B and Rietjens IM. (2012). Alkaloids in the human food chain–natural occurrence and possible adverse effects. Molecular Nutrition and Food Research, 56(1), 30-52.

26. Mulder PP, Nijs M, Castellari M, Hortos M, MacDonald S, Crews C, Hajslova J and Stranska M. (2016). Occurrence of tropane alkaloids in food. EFSA Supporting Publications, 13(12), 1140-1340

27. Diaz GJ. (2015). Toxicosis by plant alkaloids in humans and animals in Colombia. Toxins, 7(12), 5408-5416

28. Wu C, Feng K, Lu D, Yan D, Han T and Zhao B. (2016). Reproductive Toxicities Caused by Swainsonine from Locoweed in Mice. BioMed Research International, 2016, 1-9.

29. Chenchen W, Wenlong W, Xiaoxue L, Feng M, Dandan C, Xiaowen Y and Baoyu Z. (2014). Pathogenesis and preventive treatment for animal disease due to locoweed poisoning. Environmental toxicology and pharmacology, 37(1), 336-347.