Ingestion of Toxic Plants by Herbivores

Toxins are everywhere in nature. They occur in virtually all grasses, forbs, shrubs, and trees throughout the world (see Table 1). Even the vegetables we grow in our gardens contain low concentrations of toxins. Tomatoes and potatoes contain alkaloids, corn contains cyanogenic glycosides, and cabbage contains glucosinolates. Eating plants means dealing with toxins.

Plants produce a variety of toxins. Chemists subdivide plant toxins into various classes based on their molecular structure. There are many of classes of toxins - alkaloids, terpenoids, tannins, cyanogenic glycosides to name a few. Within each class are thousands of compounds, each with a different molecular structure. For example, roughly 10,000 different alkaloids and 25,000 different terpenes have been identified to date.

Within a class of toxins, different plant species produce a variety of compounds with different molecular structures. Larkspur, for example, makes 23 different alkaloids, but only 2 - methyllycaconitine and 14-deacetylnudicauline - are toxic to cattle. Presumably, it costs a plant little to produce different compounds with the same basic structure, and the benefits are great. Plants that make a variety of compounds are more likely to deter feeding by a wide array of herbivores. That's because different species of herbivores differ in their ability to tolerate the effects of different toxins.

Many people assume all plants that contain toxins cause death or decrease production by impairing an animal's physiology. In reality few toxic plants eaten by herbivores cause overt signs of poisoning. Rather, toxins cause herbivores to limit their intake of plants. At high concentrations, most toxins cause plants to be unpalatable.

Table 1. Several plant species that contain toxins.

Toxin	*Plant Species*
Cyanide compounds	Arrow grass, White clover, Serviceberry, Chokecherry, Sudan grass, Johnson grass, Mountain mahogany, Velvet grass
Alkaloids	Reed canarygrass, Bindweed, Lupin, Larkspur, Jimsonweed
Fungal endophytes	Tall fescue, Perennial ryegrass
Nitrate	Oats, Wheat, Cheeseweed, Pigweed, Sweet clover, Alfalfa
Tannins and phenolic compounds	Birdsfoot trefoil, Lespedeza, Sainfoin, Crown vetch, Oak, Bitterbrush, Blackbrush, Mountain mahogany
Terpenes	Sagebrush, Juniper, Pine trees, Bitterweed, Rubberweed

Animals limit their intake of plants that contain toxins through feedback mechanisms that link the body with the palate. Toxins have aversive effects on the body that feed back via various nerves to the palate. That feedback causes animals to satiate - stop eating a particular food and begin eating another food. This limit on intake is called a toxin-satiation threshold, and it is specific to various toxins and combinations of toxins and nutrients. The ability of herbivores to pair a plant's flavor with negative post-ingestive effects is the reason well-fed animals in familiar environments rarely over-ingest toxic plants, despite their abundance.

Toxins do not necessarily render a plant unpalatable. Whether a herbivore will eat a toxic plant depends on several factors. Herbivores are least likely to eat a toxic plant if it is low in nutrients or contains high levels of acutely toxic compounds. They are more likely to eat toxic plants high in nutrients when they contain low concentrations of compounds that are not acutely toxic. For example, lambs offered unlimited access to alfalfa pellets will consume grain laced with toxins, because the grain provides needed energy and variety in their diet. However, well-fed lambs will only ingest a limited amount toxins. On the other hand, when herbivores have no other foods to eat, they may be forced to eat plants high in toxins. Hungry animals will often over-ingest toxic plants and die rather than starve.

Intake of nutritious plants high in toxins is typically cyclical. Herbivores gradually increase intake of a nutritious toxic plant over several days. When intake exceeds the toxin-satiation threshold, intake of the food declines for a few days, then gradually increases due to the positive post-ingestive consequences animals experience from nutrients in the plant.

Different species of animals vary in their susceptibility to different toxins, as do individual animals within a species. For example, sheep are more tolerant of larkspur alkaloids than cattle, but cattle are more tolerant of lupine alkaloids than sheep. The same is true within a species. Most goats prefer older to current-season's twigs of the shrub blackbrush, due to high tannin concentrations in current season's growth. However, about 10 to 20% of goats readily eat current-season's blackbrush, presumably because they can tolerate or detoxify tannins more effectively than other goats.

We often try to predict the intake of plants based on their nutritional composition using mathematical equations. However, equations based merely on nutrient concentrations do not accurately predict preference or intake of most plants or mixtures of plants. We fail to appreciate the influence of toxins on intake because most toxins are not acutely lethal nor do they cause birth defects or other health problems in animals. Toxins undoubtedly play a role in regulating the intake of many plants that are not considered toxic because they are not acutely poisonous.

Additional Readings

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