CHAPTER 2:
Animal Behavior Principles and Practices

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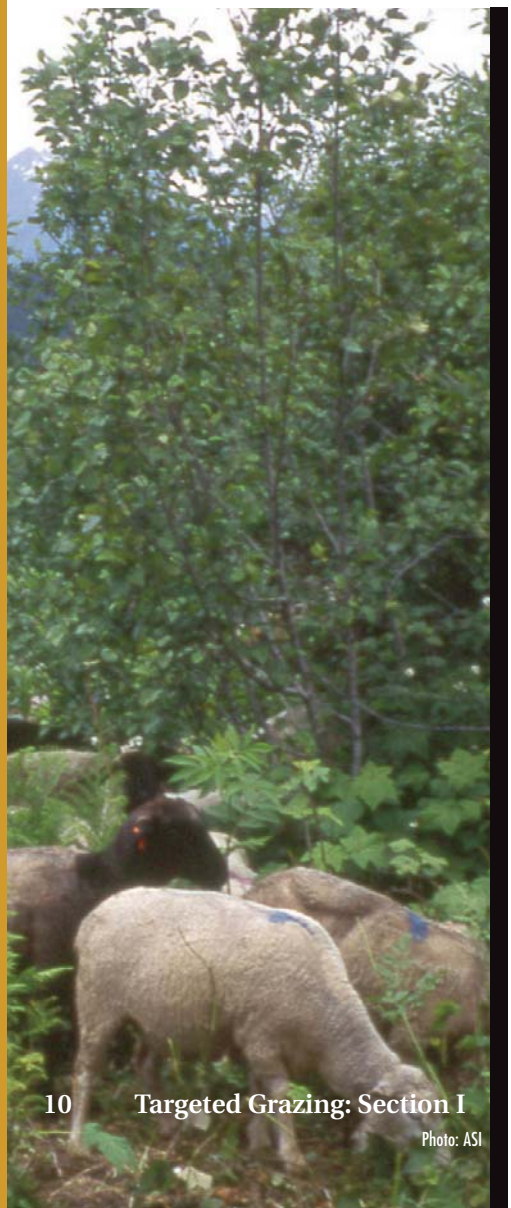
10 KEY POINTS

- Understanding animal behavior is a powerful tool that can help managers modify diets to improve targeted grazing.
- The consequences of foraging experiences – positive and negative – shape animal behavior.
- Herbivores are not created equal in foraging, digestion, and toxin-coping skills.
- Herbivores are classified as grazers, browsers, or intermediate feeders.
- Foraging behaviors differ by species, age, body condition, gender, production cycle, and heritability.
- An animal's mother lays the foundation for the foods it will prefer later in life.
- Experiences in early life can influence animal behavior.
- Animals learn automatically from feedback after eating.
- Livestock must be taught to eat new foods.
- Animals are born with constraints that can be bent but not broken.



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INTRODUCTION

Nature and nurture work in concert to influence animal behavior. Animals are born with certain physiological needs and inherited abilities. However, these needs and abilities vary greatly by species, breed, sex, age, physiological state, and experience. Understanding how these attributes influence diet selection can help in determining which species and class of animal will be effective for specific prescription grazing projects.

As animals gain foraging experience, the consequences of their actions shape future decisions. Positive consequences increase the likelihood of a behavior recurring. Negative consequences decrease it. Experiences that shape animal behaviors, including diet selection, continue throughout life. Managers who understand how animal behavior is shaped can harness and direct foraging of sheep, goats, and cattle to create powerful tools for vegetation management.

Animal Attributes that Influence Diet Selection

Selecting Species – Sheep, Goats, or Cattle?

Developing a grazing prescription begins by selecting the right animals for the job. The species of livestock best suited for vegetation manipulation depends on the plants of concern and the production setting. All herbivores are not created equal when it comes to digestion and the ability to cope with toxins. Animals consume foods that they are physiologically adapted to digest and that meet their nutritional requirements. Because of these inherent dietary differences, herbivores are often classified into three major groups: grazers, browsers, and intermediate feeders.[18, 41]

Grazers, including **cattle** and **horses**, primarily consume grass and have the digestive capabilities to handle large quantities of forages relatively low in quality. Cattle, because of their overall size and mouth design, are better adapted to grazing than browsing.[33] Cattle have a large muzzle and lips and a tongue that is used as a prehensile foraging tool.[48] The larger muzzle limits their ability to select among plants and plant parts. They forage using their tongue to sweep vegetation into their mouth where is it pinched between an upper dental pad and lower incisors and torn off. Cattle have large rumens, giving them the ability to digest lower quality roughage. That makes them superior to goats or sheep for managing fibrous and abundant herbaceous vegetation like dormant grasses. For example, cattle and horses are being employed to control Johnsongrass in Arizona in an attempt to restore native grasses.[47]

Sheep, classified as *intermediate feeders*, possess a narrow muzzle and a large rumen relative to body mass, allowing them to graze selectively and still tolerate substantial fiber content. Sheep, like all ruminants, have incisors only on the bottom with a hard dental pad in their upper jaw. Sheep also possess a relatively small mouth allowing them to graze relatively close to the ground and take small bites to select specific parts of a plant, such as small leaves or buds.[2] These anatomical differences give them an advantage over cattle to harvest prostrate plants or strip leaves or flowers from stems.[30] These features result in diets generally dominated by forbs. (Forbs are herbaceous plants that are not grasses, usually with broad leaves and showy flowers.) Indeed, sheep have been used successfully to control several weedy forbs including leafy spurge, spotted knapweed, yellow starthistle, thistles, tansy ragwort, and others.

Sheep will readily consume grass-dominated diets when grasses are succulent or when other forages are unavailable. Sheep tend to consume more forbs as forb availability increases. Plant parts that are tender, succulent, and readily visible are usually selected over those that are coarse, dry, and obscure.[2] Compared with cattle, it is more difficult for sheep to graze tall dense stands of forage than short dense stands.

Sheep are small, sure-footed, and well suited for travel in rough topography. Sheep will graze steeper terrain than most cattle and tend to avoid marshy wet areas.[15] These attributes, coupled with their gregarious nature, make them ideal for careful and strategic application of grazing in many weed-dominated lands.

Browsers, like **goats**, have a narrow, strong mouth with a dexterous tongue well designed for chewing branches and stripping individual leaves from woody stems. For this reason, goats are used extensively throughout the United States to manage invasive woody plants like juniper, saltcedar, and oak brush. Their smaller mouths give them the ability to selectively consume the highest quality leaves and stems, generally resulting in higher quality diets than cattle when grazing on the same range. A goat's adaptation for browse often results in diets with higher crude protein but lower digestibility compared to sheep.[29, 50]

Relative to body weight, goats also have larger livers than cattle or sheep, so they can more effectively process plants that contain secondary compounds like terpenes or tannins. This could explain why goats consume a higher percentage than sheep or cattle of leafy spurge, which contains a host of plant-defensive chemicals. Browsers are equipped with salivary glands that produce saliva, which binds tannins. They also possess specialized rumen microbes to break down alkaloids and other toxins in many situations.

Goats are physically agile animals that can stand on their hind legs to reach high-growing forage or use their forefeet to pull down branches to strip leaves. Smaller goats can even climb trees to gain access to higher forage. Their athletic nature enables goats to handle rougher and steeper terrain than sheep or cattle.

Multi-species Grazing

The best way to combat invasive plants is to select the livestock species that most readily consumes the plant targeted for control. Using more than one species – multi-species grazing – can enhance the benefits. Such grazing uses two or more species to graze the same piece of ground, not necessarily at the same time. It has the potential to restore balance to ecosystems by encouraging more even utilization of all forage species, preventing an ecological advantage for one plant species or class of plants. An example of multi-species grazing is adding sheep to cattle ranches to control leafy spurge. The sheep graze through a pasture quickly while the spurge is in the yellow bract stage. After the sheep remove the flower heads, effectively eliminating seed production, the cattle are turned out for the normal grazing season.

Choosing a Breed

Breeds of livestock differ in size and production characteristics, which dictate their nutrient requirements, dry matter intake, and digestive ability. These factors influence which plants, and in what proportion, an animal chooses to include in its diet.

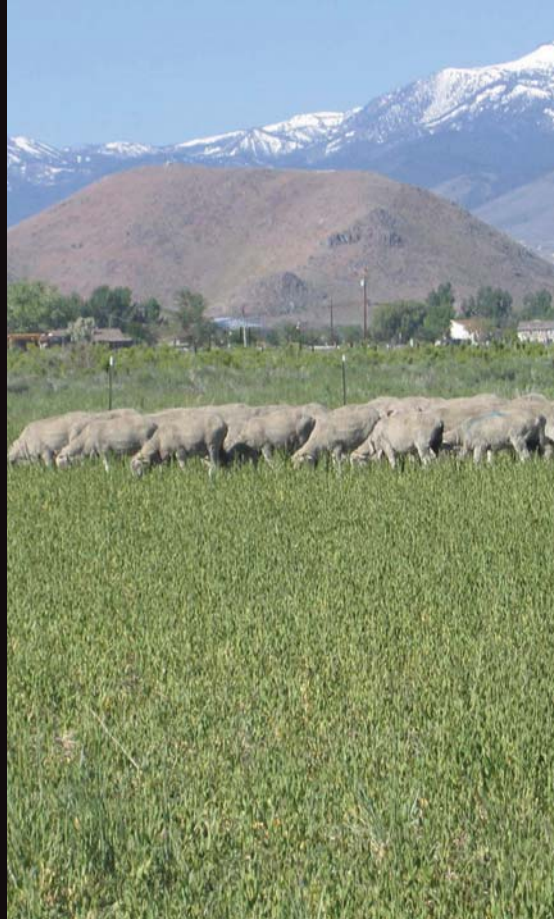
Research on redberry juniper illustrates the differences in dietary preference among breeds. Spanish goats ate juniper more readily than Angora goats, while Ibex goats (a wild breed from Europe) ate more than both domestic breeds.[23] These differences may be explained by the degree of breeding selection. Ibex goats are largely feral and have experienced virtually no selective breeding by humans. Angoras have been highly selected for hair production, and Spanish goats are raised primarily for meat production. When selecting for these performance traits, managers may have inadvertently selected physiological traits that influence diet selection, such as the ability to handle various secondary plant compounds. Livestock selection and breeding may have also affected the kind of terrain animals can effectively forage. Breeds of cattle developed in mountainous terrain may graze rugged rangeland more uniformly than breeds developed in gentler terrain.[3] An animal's ability to navigate rough terrain is an advantage of using livestock to manage vegetation compared to conventional methods.

Animal Age

Animal age can also profoundly affect diet selection and tolerance to secondary compounds. Metabolic requirements change with age, so older animals need less food and spend less time foraging. Compared with adults, young, growing animals need diets higher in crude protein and energy and lower in fiber.[17] Their search for a more nutritious diet takes more energy. This, combined with limited foraging knowledge, may lead younger animals to try novel foods and retry foods that once made them sick.[39] For example, younger animals appear more willing than older animals to consume less desirable forages like juniper. Animals just weaned are expanding their diet choices, so they are also more willing to try novel foods.

As herbivores age, their incisor teeth wear, so they are less able to graze and achieve maintenance requirements, particularly on short forage. Incisor wear also influences forage selection. Goats with worn teeth tend to avoid grasses and choose a higher proportion of tender-leaved shrubs than goats with unworn incisors.[25]

Photo: Scott Bauer, USDA/ARS



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Body Condition

How fat or thin an animal is influences its foraging behavior. Animals in low body condition or on a diet that fails to meet their maintenance requirements may have reduced tolerance for plant toxins. That's because there is a nutritional "cost" to metabolize a toxic or aversive plant compound.[12, 19] Detoxification most often occurs in the liver, so an animal that consumes chemically defended plants needs a large, healthy liver. Prolonged nutritional stress can reduce liver mass. Protein and mineral supplements can enhance rumen microbial function, liver enzymes, and compounds for conjugating toxins, all of which enhance an animal's detoxification abilities.

Malnourished and thin herbivores generally eat more than animals in good condition.[1, 42] When forage is limited, animals in low body condition may turn to poisonous or less desirable plants to maintain that higher intake. For example, cattle in low body condition began grazing the poisonous plant lupine sooner and in greater quantity than cattle in average body condition.[24] Goats in low body condition consumed nearly four times more redberry juniper than those in average body condition.[14] So, even though animals in low body condition are generally less able to metabolize plant toxins, they may be more likely to eat aversive or poisonous plants and in greater quantities.

Sex of Animal

Males and females select different diets, in part because of differences in size and overall nutrient requirements during reproduction. Morphological and physiological traits, such as growth rate and feed conversion efficiency, also contribute to differences in diets. Males generally have larger stature and muzzle size than females and may have greater energy needs.[17] Differences in foraging behavior between males and females are widely recognized but not well understood. Still, the sex of the grazing animal should be considered when selecting animals to achieve specific vegetation management goals.

Stage in Production Cycle

Animals choose their diets based on nutritional needs, which change dramatically during life stages. This knowledge can help with prescribed grazing. For example, some invasive plants with high nutrient content can meet the requirements of lactating females and growing offspring. Studies indicate that sheep grazing leafy spurge wean heavier lambs than their counterparts grazing spurge-free rangeland.[9] However, not all invasive plants are highly nutritious, and animals must have enough alternative forage to maintain body condition before breeding to meet nutrition needs during gestation and lactation.

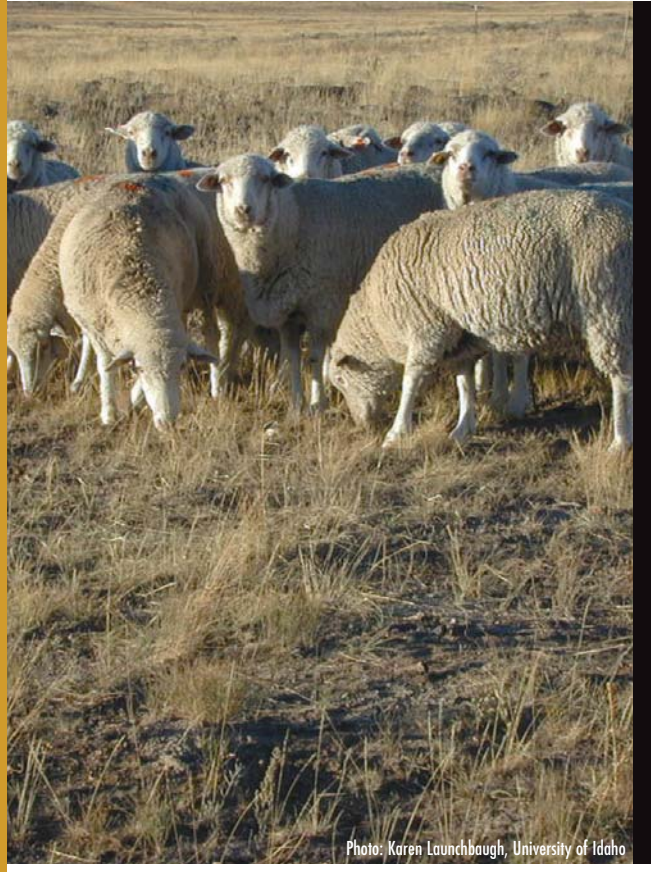
Photo: Karen Launchbaugh, University of Idaho

Castrated males can be useful for managing vegetation because they do not need to maintain body condition for breeding and can recover lost weight faster than females. Dry (non-lactating) females are also effective in managing low quality forages.

Individual Variation and Heritability

"Individuality" is a powerful force that influences dietary preference. Even animals of the same age, sex, breed, and experience will vary in their plant preferences. Some prefer plants high in energy while others prefer those with medium or low energy concentrations.[40] Just as with humans, animals have unique dental structure, physical abilities, organ size and function, and sensory abilities. Individual differences affect foraging abilities and how an animal metabolizes nutrients. Individuals also vary in responses to plant toxins. Almost every feeding trial with toxic plants has revealed individuals capable of consuming what would be a lethal dose to other animals without showing signs of toxicity. For example, some sheep fed a high dose of the alkaloid-containing plant goatsrue appeared unaffected, while others were killed by eating a small amount of this plant.[20] Physiological ability enables some animals to tolerate or metabolize plant toxins better than the average animal.

It would be helpful to identify these individuals and determine if their dietary traits can be perpetuated through breeding. There is evidence suggesting that diet selection may be somewhat heritable. For example, genetic factors significantly influenced dietary preferences of sheep browsing mountain big sagebrush[44] and goats eating juniper.[8]

Origins of Diet Selection

When selecting animals to manage plants, livestock species, breed, sex, and age are only part of the story. As an animal grows, experience shapes its body, physiology, and food preferences. Goats reared on shrub-dominated ranges of Texas perform better on blackbrush ranges in southern Utah than goats reared on grass. Sheep reared on foods containing toxins, such as tannins, terpenes and oxalates, eat these foods readily compared to sheep that have never seen the foods even when alternative foods without toxins are present.[49] Finally, some cattle eat plants they aren't expected to eat. For example, cattle on a ranch in Nebraska eat leafy spurge, cattle on another ranch in eastern Montana eat snowberry and silver sagebrush, and, recently, cattle have learned to incorporate knapweed, leafy spurge, and a variety of thistles into their diets (Kathy Voth, personal communication). Understanding that animal behavior, especially diet selection, can be shaped enables the training of animals to utilize and modify vegetation structure and abundance to meet management goals.

Social Models for Learning

When it comes to foraging, "mother knows best." An animal's mother is a good role model because she has foraged well enough to grow up and reproduce. Interacting with mother teaches young animals about the kinds and locations of both nutritious and toxic foods as well as locations of water, shade, cover, and predators.

Lambs and kids learn about foods before birth because they can taste the flavors of their mother's diet in the womb.[27] They do the same while nursing as food flavors are often transferred through milk.[28] As young ruminants begin to forage, they learn which foods to eat and which to avoid by foraging with their mother, and they remember those foods for years. Lambs fed wheat – a nutritious food – with their mothers for an hour a day for five days ate more wheat than lambs introduced to wheat without their mothers. Even three years later, with no additional exposure to wheat, lambs exposed to wheat with their mothers ate nearly 10 times more wheat than lambs exposed to wheat without their mothers.[16] Lambs of mothers trained to avoid one of

two palatable shrubs – mountain mahogany and serviceberry – avoided the shrub their mother avoided.[26] Thus, an animal's mother lays the foundation for the foods it will prefer later in life. Strong as a mother's influence can be, lambs won't eat foods that make them sick. Lambs made sick each time they eat a food, even if their mother strongly prefers it, soon refuse to eat it.[36]

While mother may be the best teacher, a young animal can learn about new foods from any member of the flock or herd. Lambs eating barley with their mothers ate 40% more barley than lambs eating barley with another adult. But lambs eating barley with any ewe ate dramatically more barley than lambs eating alone.[45] Peers also affect diet selection. In one study, mature nannies reared in different locations had distinctive dietary habits and maintained them when moved to a common pasture. Their kids preferred the diets they did, but the diets of successive generations became more alike as peers influenced each other's dietary preferences.[4]

Learning How to Eat

In addition to learning *what* to eat, animals need to learn *how* to eat. With just 30 hours experience browsing serviceberry, lambs had bite rates and intake rates 27% higher than lambs with no experience.[10] Young animals learn foraging skills more quickly than older ones. After 30 days exposure to blackbrush, six-month-old goats had faster bite rates than 18-month-old goats.[31] And the bite rates for the younger goats were still increasing after 30 days, while those for older goats had leveled off. Foraging skills acquired on one type of plant – grass or shrub – carry forward. Lambs experienced at browsing shrubs are more efficient at harvesting shrubs than lambs experienced at grazing grass, and vice versa.[11] Skills may transfer from one shrub species to another. Goats with experience browsing blackbrush were more efficient at harvesting oak leaves than goats with no experience.[32]

Experience Early in Life

Animal experiences, especially those early in life, are so influential that they can even change body structure and physiology. For example, the size of the rumen papillae, the structures that absorb nutrients from the rumen, increases in animals fed grain early in life. Later in life, young animals raised on poor quality forages have larger rumens, recycle urea nitrogen more efficiently, and eat more poor quality forages than those raised on high quality diets. Exposing animals to toxins early in life has variable results. In some cases, early exposure may increase the liver's ability to detoxify toxins.[7] But it can also cause liver damage, depending on the toxin and its dose.[34] Experiences early in life can even change connections within the brain and how well animals cope with changes in their environment.[13]

Learning from Feedback

Whether animals continue to eat or avoid a specific food depends on how they feel after they eat it. As a food is eaten, digestion releases nutrients and toxins, making the animal feel better or worse. Animals form preferences for the flavor of foods that are satisfying and aversions to foods that are not satisfying or that make them ill. Once the consequences of a particular food are learned, flavor helps animals identify which foods are good and nutritious and which are toxic or low in quality.

Animals determine which foods made them feel better or worse in a variety of ways. If the flavor suddenly changes, animals may eat less of a plant. In a diet of familiar and unfamiliar foods, animals associate changes in feedback, positive or negative, with new foods. They associate feedback with the plant they ate the most during a meal or the plant eaten last.

People often assume that animals lack the intelligence to learn about foods through feedback, but it's not a matter of intelligence. Learning from feedback happens automatically. Even when animals are anesthetized or tranquilized, post-ingestive feedback can change food preferences. When sheep eat a nutritious food and then receive a toxin dose during deep anesthesia, they become averted to the food because the negative feedback of the toxin still occurs even though they are deeply asleep.[37]

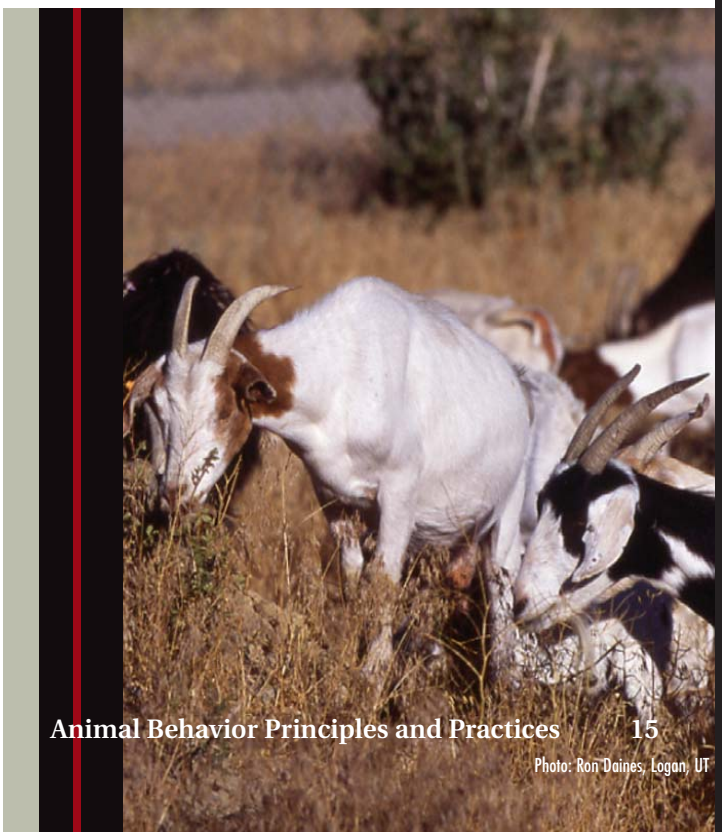

Photo: Ron Daines, Logan, UT

What Is Palatability and How Is It Created?

Most people assume that plant palatability depends on flavors that are inherently good or bad. That may be true in some cases, but an animal's response to a flavor depends primarily on feedback. Flavor only allows animals to distinguish among plants. Whether a flavor is preferred or disliked depends on the nutrient and toxin content of the plant, the nutritional needs of the animal, the animal's experiences with the food, and its ability to digest the plant. When nutrients are eaten in correct amounts, animals experience comfort or "satiety" and a liking for the flavor of the plant, so palatability increases. Conversely, when animals over-ingest nutritious or toxic plants, or plants containing inadequate nutrients, they experience discomfort and form a disliking for the flavor of the plant, so palatability decreases.

Many weedy species contain moderate to high levels of potentially toxic plant compounds. Over-ingesting toxins like terpenes, tannins, nitrates, alkaloids, and cyanogenic glycosides decreases palatability. However, ruminants rarely over-ingest toxins; rapid post-ingestive feedback causes nausea and limits the amount they can eat. If toxin concentrations decline, intake of the plant increases. Still, an animal's ability to distinguish between safe and harmful plants sometimes fails, leading to deaths from toxic plants.

Managing Diet Selection

What does all this mean for targeted grazing? Where possible, select animals that have experience eating the target plants. If such animals are not available, choosing animals with experience eating a wide variety of forages will increase the chances they will eat a new plant. Remember, animals are most likely to eat weeds that are high in nutrients and low in toxins. Plant nutrients are highest early in the growing season, but peak toxin levels can occur at any time and vary from plant to plant or species to species.

Encouraging Animals to Eat New Foods

Grazing animals are more likely to consume plant species with which they are familiar. Using animals unaccustomed to an area often results in diet selection patterns that differ from those of animals more familiar with the vegetation and terrain. Encouraging animals, especially older ones, to try new foods requires more effort than simply starving the animals until they eat the new plant. While animals are reluctant to try new foods, especially those with strong flavors, they will acquire preferences for new foods that contain needed nutrients. Several tactics can encourage animals to eat new foods:

- Introduce young animals with their mothers to the plants or feeds they will need to eat later in life. Young animals are more likely than older animals to eat new plants.
- Take it slow. Animals should not be forced to eat a diet consisting of a single new plant species for an extended time, especially if the new plant is high in nutrients or toxins. Immature plants high in nutrients can cause acidosis or ammonia toxicity, and the rumen needs time to adapt to them. Foods high in toxins can cause numerous health problems. The liver and the rumen need time to gear up to process and ameliorate toxins.
- First impressions matter. If animals get really sick the first few times they eat a plant, either from excessive nutrients or toxins, they will be unlikely to eat much of that plant again.
- Another tactic is gentle persuasion or encouragement, like offering new plants early in the morning for a short time followed by access to familiar plants or feeds.
- Peer pressure works. A few animals familiar with the plant targeted for consumption may nudge other animals unfamiliar with the plant to give it a try.
- Animals are more likely to eat a new plant if they are in a familiar location.
- Make new plants familiar. Spraying a familiar flavor, like molasses, on unfamiliar plants sometimes increases acceptance.

Diet Mixing

Livestock can be trained to eat foods considered unpalatable even when nutritious foods are available. The key is to provide a balance. To encourage animals to eat lower quality plants targeted for control, access to nutritious foods may need to be limited. As other plants become scarce, animals are more likely to eat plants high in toxins. At the same time, nutrients must be available to help detoxify any chemically defended plants the animals may consume. Consumption of forbs or browse containing toxins, for example, is usually greater after herbivores have been eating grass-dominated diets for two to three days. It is believed that grass may help buffer the toxins and enable livestock to consume more of these plants.

Consider Supplements

Supplementing ruminants with moderate amounts of protein and energy can increase intake of foods like juniper or oakbrush that contain toxins like terpenes or tannins. In a grazing study, sheep fed supplemental protein and energy for 15 minutes a day spent 12% more time feeding on sagebrush (which contains terpenes or essential oils) than sheep without supplements.[38] Supplemented sheep continued to increase intake of sagebrush throughout the study, while sheep without supplements decreased intake near the end of the study. In Montana, a rancher's hungry sheep balked at eating spotted knapweed but grazed it readily after eating nutritious forages low in toxins. In New Mexico, hungry goats that refused to browse sagebrush for several days ate it readily after grazing alfalfa-grass pasture. The consumption of tannin-containing shrubs can sometimes be increased by supplementing animals with polyethylene glycol, a compound that binds to tannins and disarms their protein-binding characteristics.[43, 46]

Why do supplements help? When animals eat plants low in nutrients or high in toxins, they need more nutrients. Most toxins are lipophilic or fat-soluble compounds. They must be converted into hydrophilic or water-soluble substances before they can be eliminated from the body. This conversion requires additional energy and protein. In short, as toxin ingestion increases, an animal's nutritional requirements also increase, and supplements can provide these necessary nutrients and energy.

Potential Plant Toxicity

Animals typically avoid plants that are novel, low in nutrients, or high in toxins. Not all plants targeted for control under grazing prescriptions are toxic. But, caution is required. While some toxins may simply cause aversions to a plant, others have the potential to cause production loss, illness, or even death. Animals can learn to avoid a plant only if the toxin causes nausea. They cannot easily learn to avoid plants that cause neurological problems, respiratory failure, birth defects, or chronic liver disease.[35]

It is a good idea to research the nutritional and toxic properties of plants that animals will graze, although information on the chemical content of many weed species is limited. Some excellent references are: 1) *Natural Toxicants in Feeds, Forages and Poisonous Plants*, by Peter Cheeke,[6] 2) *Toxic Plants of North America*, by George Burrows and Ronald Tyrl,[5] and 3) *A Guide to Plant Poisoning of Animals in North America,* by Anthony Knight and Richard Walter.[21]

Photo: ASI

CONCLUSION AND POINTS TO PONDER

Understanding animal behavior is a powerful tool that can help managers modify diet selection to increase the effectiveness of animals used to manage vegetation. Animals learn from feedback and social models like mother and peers. Their behavior, especially when it comes to diet selection, is incredibly flexible. For targeted grazing programs to be sustainable, managers should remember that animals are born with constraints that can be bent but not broken. A sound knowledge of how animal behavior, morphology, and physiology influence diet selection can greatly increase the effectiveness of grazing prescriptions while maintaining animal health and productivity. Keep these points in mind:

1) Even if animals are familiar with toxic or detrimental plants, if they are hungry, they may eat too much of the plant before feedback mechanisms signal them to stop.

2) Introduce animals to new foods slowly. Their rumen and liver often need time to gear up to effectively digest or detoxify compounds in plants.

3) Do not starve animals to get them to eat weeds or force them to eat a single species. They need other forages to balance nutrients and toxins.

4) Provide supplements when appropriate. Many plants targeted for control contain potentially toxic compounds that may be detoxified more quickly if animals have supplemental nutrients.

5) Get the timing right. Plant nutrients and toxin levels change over the growing season. Animal health and production depend on grazing at times of maximum nutritional benefit and minimum potential toxicity.

6) Provide adequate water. Thirsty animals may lose their appetite. High quality water can maximize plant intake.

7) Manage stress. Moving animals to an unfamiliar place can add stress and limit intake for a few days. A dose of plant toxins can be much more deadly if animals are stressed. However, animals routinely moved to new locations, such as occurs during contract grazing, may suffer less stress because they're used to being moved.

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