Plant Attributes That Affect Livestock Selection and Intake

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Abstract

Grazing animals depend on a variety of physical and chemical cues when selecting which plants they will eat. The soluble energy in the plant may serve as a primary factor for selection. Management and plant breeding strategies should use soluble carbohydrate levels as likely indicators of animal grazing responses.

Introduction

Grazing animals eat an array of plants, but often prefer some and avoid others. These preferences or aversions are responses to certain physical and chemical senses of which touch, smell and taste are of greatest importance for ruminants (Arnold and Hill 1972, Bate-Smith 1972, Krueger, et al. 1974, Bazelly 1990). Food preference is seldom a response to a single factor, but rather a combined response to several stimuli. We will share our own experiences and limited review of other published literature on each subject. Additionally, we accept the theorem that chemical and some physical effects presented in our paper affect the postingestive feedback mechanism discussed by Provenza and Launchbaugh (this volume).

The intake of food is determined by the complex interaction of pre- and post-absorptive factors. Those factors operating before the food leaves the mouth can be collectively referred to as palatability while those operating after this stage are referred to as postingestive (Grovum and Chapman 1988).

We have completed cattle preference testing of eight, endophyte-free tall fescue cultivars (Shewmaker et al. 1997) and are relating preference scores to various physical and chemical components of the tall fescue that might serve as cues to grazing animals. We hope to analyze a series of chemical components including 1) volatiles, 2) amino acids, 3) organic acids, 4) carbohydrates, 5) minerals, and 6) fiber and agronomic quality characteristics. We also hope to analyze several physical components like 1) shear strength, 2) tensile breaking strength, 3) maceration scores and relate these to animal preference scores of tall fescues used in the grazing study (Shewmaker et al. 1997).

Because of photosynthesis and respiration, total nonstructural carbohydrates (TNC) in plants increase during day and decrease during night. We have noted that cattle, sheep, and goats are able to differentiate between forages harvested in afternoon versus in morning (Fisher et al. 1999). Dairy cows produce more milk when fed a total mixed ration containing 40% alfalfa when that hay was cut at 4 in the afternoon rather than 6 in the morning (Kim 1995, Mayland et al. 1998).

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Physical Cues

Color

It is generally accepted that ruminants see varying shades of gray, but are unable to distinguish between the primary colors. This is not to say that visual cues are not important in foraging (Howery et al. this volume).

Plant texture

Grasses and especially forbs may have physical attributes that discourage grazing. Plants with pubescent leaves have greater resistance to some insect pests. These characteristics may have similar effects on ruminants. However, we (Rumbaugh et al. 1993) found that trichome density of globemallow (*Spaeralcea* spp.) leaves was positively related to accession preference by sheep. Thus other cues or factors were of greater importance in determining sheep preference.

Sward structure

Ungar et al. (1991) summarized results from several studies indicating that sward heights below 4 inches are often related to significant depressions in intake by cattle. They reported significant (99%) reduction in number of bites and total dry matter intake by steers as the sward height was reduced below 4 inches. Laca et al. (1992) and

Distel et al. (1995) showed that cattle graze most efficiently and expend more time where forage density allowed the most rapid intake rate. That was not supported by Ganskopp et al.(1997) who found that steers did not seek out the highest density forages.

Prehension

Prehension is the act of seizing or grasping forage with the tongue and then tearing it from the plant as might be done by ruminants. Energy expended in this action is quantified by measuring tensile breaking strength. Grazing behaviorists have not explored this factor as a potential grazing cue.

Prehensile strengths

Prehensile strength is the energy required to bite or tear the forage from the plant. Herbivores, like horses that have incisors on top and bottom jaw impose a cutting or shearing action on forage. Ruminants use a combination of tear and shearing action. Energy requirements are characterized as either shear or tensile breaking forces.

The intrinsic shear strength is calculated as the force required to shear a leaf, divided by the length of the cutting blade in contact with the leaf material (Henry et al. 1997). Differences in these forces among forage cultivars has not been related to grazing preferences.

Mastication

Mastication is the act of reducing particle size of ingested feed. For monogastrics there is one opportunity to do this whereas ruminants have a second chance because they regurgitate fiber boluses and chew the cud.

It is theorized that rate of mastication and particle size reduction by ruminants may affect consumption of forage. Troelsen and Bigsby (1964) reported that 88% of variability in hay intake by sheep was explained by similar variability in particle size indexes determined by combination of maceration and sieving. This idea has been pursued by others (Balch 1971, Chenost 1966) using more automated and quantitative methods. A proposed index of ‘fibrousness’ in ruminant diets would have units of minutes/pound of food. Values for the index increases as water content decreases and plant maturity increases.

Water content

Some have speculated that livestock preferences are positively associated with moisture content of forages (Gesshe and Walton 1980). However, Ganskopp et al. (1997) did not support this hypothesis.

Sight

Observation. Range-conditioned ewe sheep were used to evaluate palatability of various globemallow (Sphaeralcea) taxa (Rumbaugh et al. 1993) in a spaced-plant nursery. The plots in each of 4 pastures, contained 2400 spaced plants of which 85% were ‘Hycrest’ crested wheatgrass (Agropyron cristatum), 14% mallow, and 4% ‘Spredor 2’ alfalfa (Medicago sativa). Upon introduction to the test pasture, ewes would roam the area, investigating, and sampling available herbage. Within hours, ewes recognized the presence of highly sought alfalfa plants randomly scattered across a pasture area (44 x 44 yards). The sheep relished the alfalfa, and within hours, several of the lead ewes were observed stretching their necks and scanning for other alfalfa plants. Once sighted, the sheep walked and sometimes ran to eagerly graze the alfalfa plants.

Chemical Cues

Aroma

Observation. On 24 occasions of a grazing preference study, cattle were moved from one to another small pasture containing replicated plots (3x7m) of eight tall fescue (*Festuca arundinacea*) varieties (Shewmaker et al. 1997). Upon exploring the new pasture, animals would wander across different plots with their muzzles in the forage canopy, occasionally taking a bite. They were undoubtedly detecting various volatiles and sensing the forage canopy texture.

Aroma integrates the impact of volatile compounds released by plants upon the foraging animal’s organoleptic sensory system. Scehovic (1985) and Scehovic et al. (1985) noted enhanced acceptability by cattle of a low-preference tall fescue when sprayed with juice expressed from a highly preferred Italian ryegrass (*Lolium multiflorum*). However, palatability of Italian ryegrass was reduced when it was sprayed with fescue juice. Individual compounds were not identified. Later, Tava et al. (1993) associated volatile constituents of tall fescue with suggested palatability groupings. There is little doubt that aromas were related to animal preference or palatability, but in neither study were specific aeromatic compounds quantitatively associated with palatability or preference.

In a much more detailed study, Mayland et al. (1997) identified 50 of 54 compounds emitted from fresh tall fescue cultivars representing a range in grazing preference. Preference scores were significantly (R^2 = 0.97) correlated with emissions of 6-methy-5-hepten-2-one, (Z)-3-hexenyl propionate, and acetic acid. These are simply correlations and their affect on grazing animals needs to be tested. This could be accomplished by spraying combinations of these three volatiles on a given forage and evaluating animal preference for the variously treated diets.

It is important to recognize that none of the five researchers involved in the preference study (Shewmaker et al. 1997) could detect any difference in aroma among the eight varieties. Humans have hundreds of different olfactory receptor genes that may be responsible for our ability to detect odorants. Yet, 72% of these genes may be dysfunctional (Rouquier et al. 1998) and we may be olfactory disadvantaged compared with ruminants.

Flavor

Flavor or olfaction is a combination of taste and aroma. The stimulus for olfaction is chemical. For a compound to have olfactory characteristics the chemistry of the compound must be such that it will chemically bind to the organoleptic receptors on papillae of taste buds located front, back, and edge of tongue. Receptors or nerve endings are also located in nasal passage and phalanxes.

Goatcher and Church (1970) have made an extensive comparison between ruminant species. Sensitivity to chemical solutions based on the lowest concentration to be discriminated, was as follows:

Sweet: Cattle > Normal Goats > Pygmy Goats > Sheep
Salty: Cattle > Pygmy Goats > Normal Goats > Sheep
Sour: Cattle > Pygmy Goats = Sheep > Normal Goats
Bitter: Pygmy = Normal Goats > Sheep > Cattle

If some other threshold is taken, the results are different. For example, the molarities at which solutions are rejected (<40% total fluid intake) rank, over animal species, as follows:

Salty: Cattle > Sheep > Normal Goats > Pygmy Goats
Sour: Cattle > Sheep > Normal and Pygmy Goats
Bitter: Sheep = Cattle > Normal = Pygmy Goats
Sweet:: No rejection thresholds found

Assessing nerve responses to various chemical compounds dissolved in water have shown that chemoreceptors in the sheep's tongue are sensitive to salt, sweet, sour and bitter (Grovum and Chapman 1988). Krueger et al. (1974) had earlier reported that taste was the special sense most influential in directing forage preference of sheep grazing a mountain tall-forb community. The other senses appeared to supplement taste. Sheep preferred sour and sweet plants and generally rejected bitter plants. They reported that smell or odor was of minor importance in selection.

Carbohydrates

We (Mayland et al. 1998), and others (Fisher et al. 1999), have observed a diurnal cycling of sucrose and other nonstructural carbohydrates (TNC) in forages (Orr et al. 1997). This class of compounds provides energy for animal metabolism. It contains very soluble and easily digestible to insoluble and very slowly or even indigestible compounds. Ruminants use the readily fermentable carbohydrates and may be able to cue on some of these compounds. Water soluble carbohydrates (WSC) have been high in cultivars considered highly palatable and WSC have been low in cultivars considered to have low palatability (Orr et al. 1997).

We have found that total nonstructural carbohydrates (TNC) are related (r^2 = 0.45) positively to animal preference for tall fescue (Mayland et al. Unpublished 1999).

Organic acids

Differences in organic acids might affect animal preference and overall forage palatability (Mayland et al. 1999). Both malate and citrate increase salivary flow and intensify sweet flavors in diets of monogastric animals. Similar effects may occur in ruminants (Martin 1998). Malate content of the diet stimulates lactate utilization and propionate production by ruminal bacterium, *Selenomonas ruminantium* (Martin 1998). Mayland et al. (1999) found only weak correlations of grazing preference to concentrations of malate (r = 0.28), citrate (r = 0.35), or their sum (r = 0.44, P = 0.11).

Amino acids

Provenza (1995) noted that deficits or imbalances of amino acids decrease intake and cause feed aversions in lambs. However, dietary amino acids, when consumed by the ruminant animal, are first metabolized by the rumen microflora, forming another set of amino acids whose profile may not resemble that of the diet. Such outcomes are difficult to predict. It is possible that amino acids in the forage eaten by animals or some metabolic product might have an immediate flavor effect. However, grazing preferences were not related to concentrations of any essential or non-essential amino acid quantified in these tall fescue cultivars representing the full range in preference (Mayland et al. 1999).

Alkaloids

Alkaloids in grasses and legumes are sometimes of plant origin and sometimes produced by parasitic fungal endophytes growing in the plant stem and transmitted in the seed.

Marten et al. (1973) identified three alkaloids; gamine (3-dimethylaminomethyl-in-dole), N,N-dimethyl-tryptamine, and 5-methoxy-N,N-dimethyltryptaine in Reed canarygrass (Phalaris arundinacea L.). Total basic alkaloid concentrations of clones were highly correlated (r = 0.90)with each environments. Palatability ratings of clones grazed by sheep were highly correlated. Total alkaloid concentrations and palatability rating of clones were also highly correlated (r = 0.87 to 0.94).

Summary

The reviewer may readily see the complex set of signals that plants may present to grazing animals. Knowing our responses to the odor of lilacs, the taste of ice cream, the texture of chopped nuts, and the flavor of cappuchino, we soon appreciate the potential array of cues awaiting the grazing herbivore. Nevertheless, they must and do make choices. These choices may be made on basis of odor, taste, feel, flavor etc., but these are ultimately linked to the post ingestive feedback mechanism built into the animals' system (Early and Provenza 1998). As we learn more about these relationships, we will be able to do a better job of forage and animal management.

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