Why Range Forage Quality Changes

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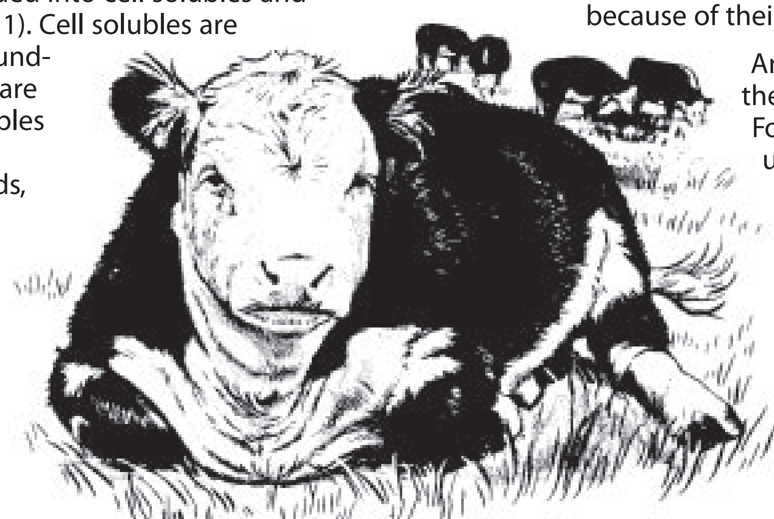
Range livestock and wildlife have access to a tremendous diversity of forage plants which vary in nutritional quality. Range animals get the nutrients (protein, energy, vitamins, and minerals) required for growth, reproduction, and milk production from these plants. Nutritional quality is affected by plant part, plant age, plant group, season of growth, weather, soils and range sites, stocking rates, and secondary compounds. Animal species (cattle, goats, deer, etc.) affects the plant group used and potential digestibility.

Plant Parts

Plant cells can be divided into cell solubles and cell wall material (Figure 1). Cell solubles are contained within the boundaries of the cell wall and are easily digested. Cell solubles include crude protein (nucleic acids, amino acids, proteins, other nitrogen-containing compounds), sugars, starch, and lipids (fats). In comparison, the cell wall contains slowly digestible material called fiber which includes hemicellulose, cellulose, and the mostly indigestible substance lignin. These fiber fractions are included in the neutral detergent fiber (NDF) and acid detergent fiber (ADF) fractions often used in forage analysis reports. Hemicellulose, cellulose, and lignin are included in NDF while cellulose and lignin are included in ADF. Because animals lack the enzymes or chemicals necessary to break down hemicellulose and cellulose, they must depend on microbial fermentation (breakdown or digestion) to reduce these substances into compounds they can use.



Generally, leaves contain more cell solubles and, therefore, more proteins, sugars, vitamins, and minerals than stems contain. Conversely, leaves have less hemicellulose, cellulose, and lignin than stems (Figure 2). Fruits and flowers generally have more cell solubles than leaves. Although grass seeds are higher in cell solubles than leaves, they are usually inferior to forb fruits and flowers as sources of protein and energy because of their size.

Animals are selective in the plant parts they eat. For example, herbivores usually prefer new leaves over old leaves and select leaves over stems. Because plant parts differ in nutritional quality and animals select certain plant parts, analysis of whole plants is not generally an accurate indicator of diet quality (Figure 2).

Plant Age

Cell solubles are highest in actively growing forage tissue and decline as plants become mature and dormant. Declines in cell solubles are due to increased fiber (cellulose, hemicellulose, and lignin), movement of nutrients from leaves to roots, and leaching of cell solubles by rain and snow during dormancy.

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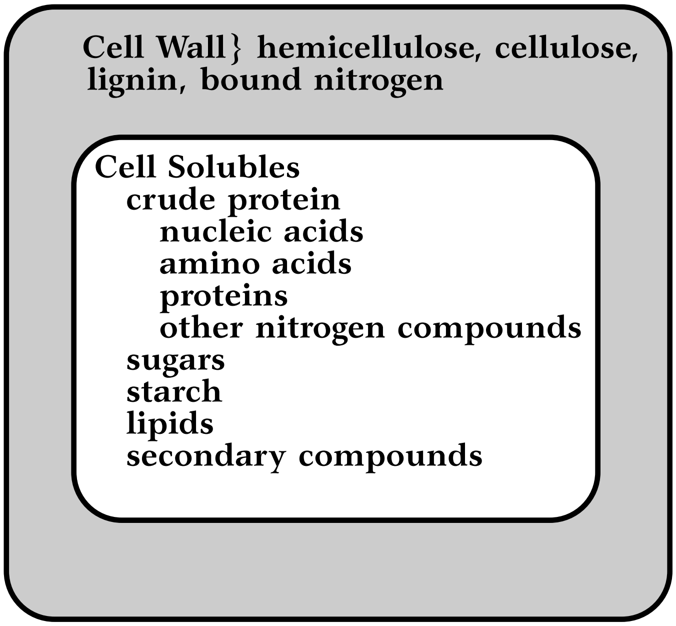

Figure 1. Plant cell structure and nutritional components found within the cell wall and cell solubles parts of the cell. Substances found in the cell solubles are generally easily digested. Substances within the cell wall are either slowly digested with the help of rumen microbes or indigestible.

As plant cells mature, cell walls increase in thickness and amount of fiber. This increase in fiber results in decreased cell wall digestibility. Because cell wall fermentation in the digestive system of a herbivore depends on the amount of time food stays in the rumen and/or hindgut and is exposed to microbes, this loss in digestibility is a result of both more fiber to ferment and changes in the nature or chemistry of the fiber.

As plants approach dormancy or maturity, nutrients are redistributed from leaves (where food is manufactured by photosynthesis) to the root system, reducing the amount of cell solubles present within individual leaf cells. This movement increases the percentage of cell wall in a leaf, even though actual cell wall quantity may not be greater. Therefore, this nutrient redistribution, in effect, decreases the nutrient quality available to the herbivore.

When plant cells freeze, they rupture, releasing the readily digestible cell solubles. Once cell solubles are exposed, rain and snow can dissolve these substances which are then leached by the precipitation.

Plant Group and Season of Growth

On a whole-plant basis, concentrations of cell solubles are highest in actively growing plant material of forbs, with shrubs intermediate, and grasses lowest, as indicated by nutritional quality data in Figures 2 and 3. In winter, evergreen shrubs are higher in cell solubles and therefore, appear to be higher in nutritional quality than grasses and forbs. However, because evergreen shrubs are usually high in secondary plant compounds (tannins, oils, toxins), their nutritional quality is often less than indicated by a forage quality analysis. At the same growth stage, cellulose is higher in grass leaves and stems than in leaves of forbs and shrubs, which makes these grass plant parts more difficult to digest.

Compared to warm-season plants, cool-season forages are generally higher in crude protein content and digestibility (Table 1). These differences

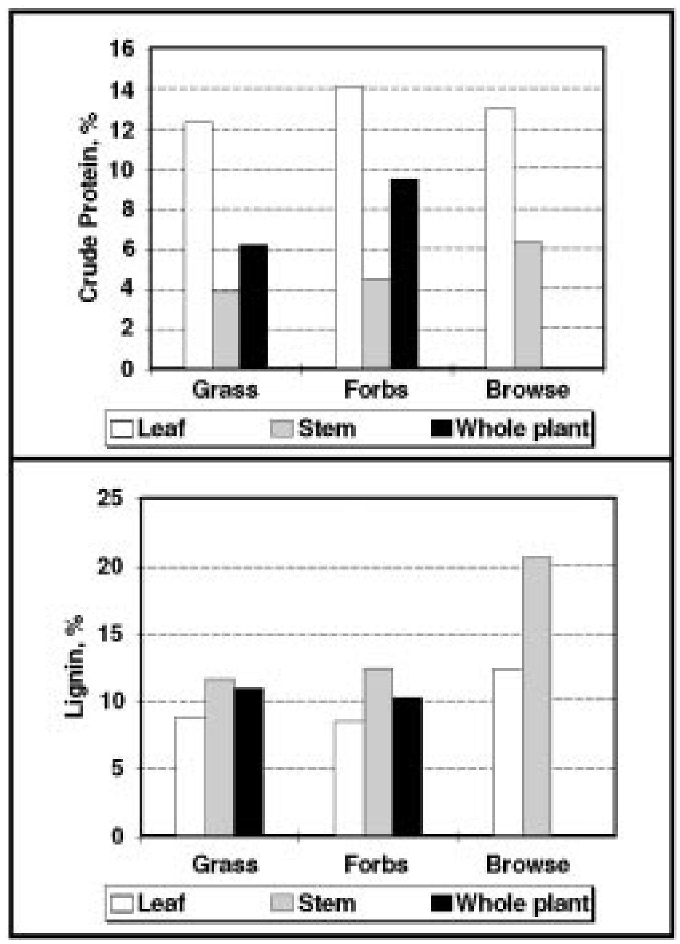

Figure 2. Crude protein and lignin content (%) of three forage groups and plant parts on Utah summer range (adapted from Cook and Harris 1950).

Table 1. Typical crude protein and digestibility in warm- and cool-season native and improved forages on a world-wide basis (adapted from Huston and Pinchak 1991).					
Forage	**Type**	**Growth Period**	**Form**	**Crude Protein, %**	**Digestibility, %**
Grass	Native	Warm	Annual	–	50-73
			Perennial	2-15	20-65
		Cool	Annual	2-25	60-95
			Perennial	3-25	42-94
	Improved	Warm	Annual	4-18	46-69
			Perennial	2-25	36-68
		Cool	Annual	3-30	50-91
			Perennial	5-30	30-76
Forbs		Cool/Warm	Annual/Perennial	4-32	42-91
Browse		Cool/Warm	Perennial	4-32	14-74

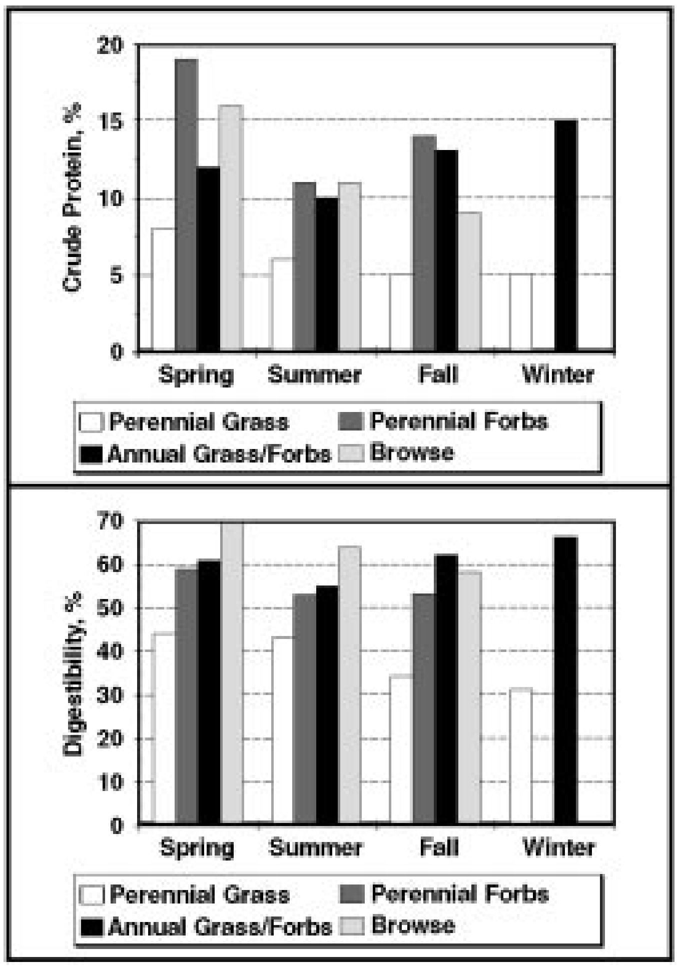

Figure 3. Average crude protein and digestibility in some range plants by season in the Edwards Plateau region of Texas (adapted from Huston et al. 1981). Grass and forb values are on a whole plant basis, while browse values are for leaves. Expected grass diet quality would be greater than shown here for whole plants because of animal selection of leaves.

are related to 1) temperature conditions under which these plants are adapted and grow and 2) plant fiber content. For example, warm-season grasses have developed a relatively high fiber content which allows these plants to resist wilting associated with high temperatures. This additional fiber tends to dilute the concentration of cell solubles in these plants and reduce their nutritional value compared to cool-season grasses.

Soils/Range Sites

Range site can influence forage quality. For example, one study (Launchbaugh et al. 1990) indicated differences in forage quality between two sites. The explanation for this difference appeared to be that on the site producing less forage but higher quality forage, there was a higher proportion of green forage. Because green forage is actively growing, it would have higher levels of cell solubles and, therefore, higher nutritional quality.

Stocking Rate

Stocking rate effect on forage nutritional quality depends on grazing history (McCollum 1993). Short-term stocking rate increases on previously lightly or moderately stocked ranges may result in lower forage quality because animals are forced to consume more dead, standing forage. If a pasture has a history of heavy stocking, forage quality of grasses will generally be higher because plants will be at more immature growth stages with less dead forage present. These differences in diet quality do not mean that long-term heavy stocking is a good nutritional management technique. Long-term heavy stocking will result in a shift toward less productive and less palatable forage plants. This shift results in less total forage and less desirable forage and, therefore, reduced forage intake. In range situations, factors which reduce forage intake are as important as forage quality.

Secondary Compounds

A number of chemical compounds are produced in plants after the initial stages of photosynthesis. These secondary compounds, which are chemically complex, can serve as defense mechanisms against harsh environments and insect damage. Lignin, for example, appears to 1) provide structural strength allowing plants to resist wilting and 2) act as a defense against being eaten.

Many secondary compounds are poisonous. However, some types of tannins, a substance found mostly in forbs and leaves of some woody plants, may have some nutritional benefit. For example, low levels of tannins appear to decrease breakdown of protein by microbes in the rumen. When this protein reaches the stomach and small intestine, it can then be digested by animal enzymes. If the protein escaping rumen breakdown is a high quality protein (high in required or essential amino acids), this escape could be beneficial to the animal. Protein escaping ruminal breakdown is a benefit only if adequate soluble protein is available to support rumen microbe requirements.

Much of the protein used by ruminant animals comes from rumen microbes. These microbes break down protein and manufacture their own amino acids and protein. Proteins produced by rumen microbes may be of greater value or of lesser value than the protein in the original plant material. High levels of some tannins can make protein unavailable to microbes in the rumen and create a protein deficiency. For example, wildlife studies have demonstrated that tannins reduced forage crude protein availability by an average of 2 percentage units.

Another example of the impact of secondary compounds is with junipers (ashe and redberry cedar). Although junipers are relatively nutritious, animals do not eat much of these plants. Junipers contain volatile oils called terpenes. These oils appear to discourage animals from eating juniper through their effect on taste, possible decreased rumen microbial activity, and limited ability of the animal to detoxify these oils (Huston et al. 1994). Total volatile oil content and concentrations of specific oils differ with age, sex, and species of juniper. For example, young plants have lower concentrations of these oils and are more palatable than mature plants; female plants are more palatable than male plants; and ashe or blueberry juniper is more palatable than redberry juniper.

Livestock/Wildlife Species

The nutrient content and availability of forage is not influenced to a large extent by the species of herbivore that consumes it. However, herbivore species does influence plant groups used (Lyons et al. 1996). Ruminants can be divided into three feeding types based on the primary plant group (grass or browse) or mixture of plant groups used. These ruminant feeding types include grazers (cattle, bison), intermediate feeders (goats), and browsers (deer). These patterns are the result of anatomical differences among the feeding types. Grazers consume a relatively bulky, high-fiber diet and have a large, highly compartmentalized, and muscular rumen. This type of rumen is able to hold large amounts of fiber for long periods to allow fermentation. At the other extreme, browsers tend to have small, relatively open rumens which allow fiber to leave the rumen quickly while cell solubles, released by active chewing action, are rapidly fermented. As a result of these differences in rumen anatomy, food passage through the rumen tends to be slow in grazers and rapid in browsers.

Feed tables often show digestibility differences among animal species. Because digestibility is dependent on microbes, one might assume these differences are due to the presence of more or less efficient microbes among herbivore species. However, among range herbivores, microorganisms and fermentation are broadly similar. Digestibility differences among herbivores are primarily due to the amount of time forages spend in fermentation chambers (rumen, hindgut, cecum). For example, cattle, sheep, and goats grazing forages with similar potential digestibility in the Edwards Plateau of Texas differed in average time forages remained in the digestive tract (Figure 4). Cattle (33 to 40 hours) and sheep (26 to 40 hours) were similar in average digestive tract retention time and similar in actual forage digestibility, 48 to 58 and 44 to 59 percent, respectively. In contrast, goats had digestive tract retention times from 26 to 29 hours and correspondingly lower actual digestibility (36 to 52

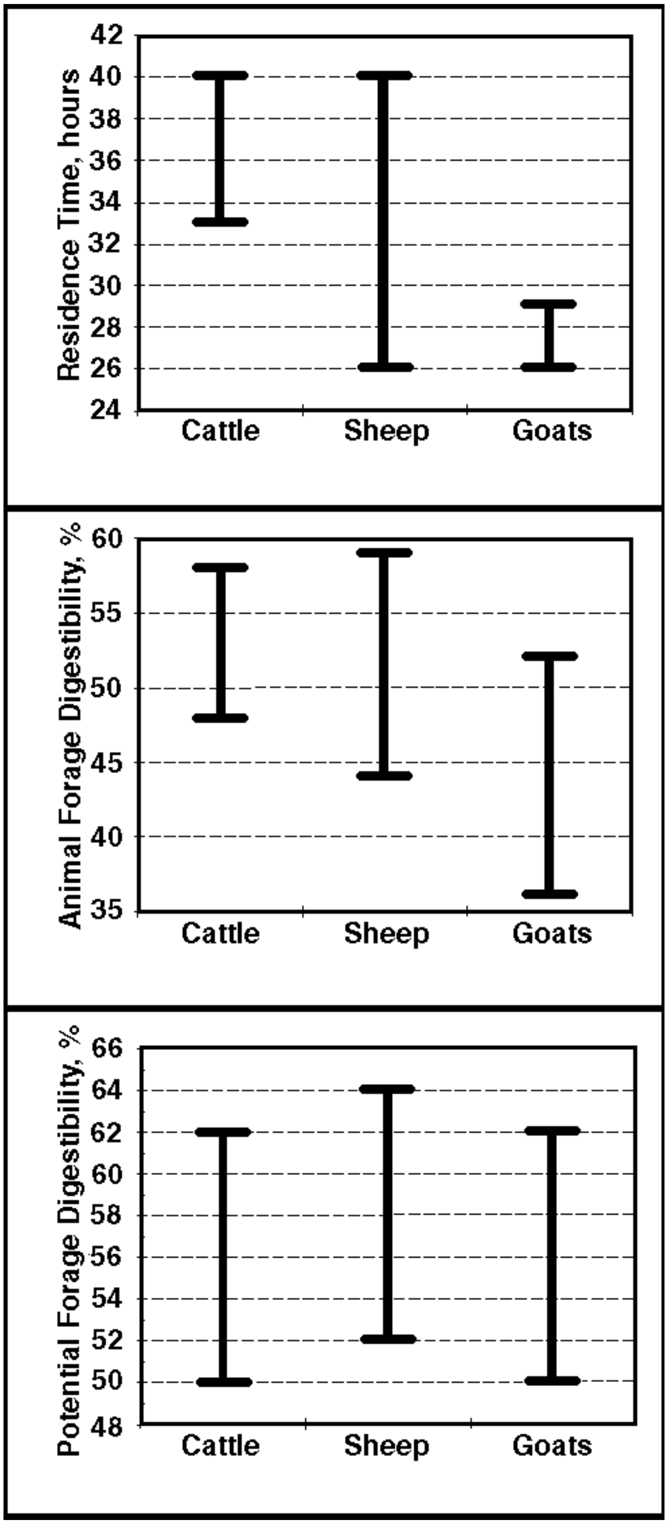

Figure 4. Comparison of residence time of forages in the digestive tract of different livestock species, forage digestibility for specific livestock species, and potential forage digestibility. Lower forage digestibility in goats corresponds to lower residence time in the digestive tract (adapted from Huston and Pinchak 1991).

percent). In another example, estimated retention time in horses was 8.5 hours with a digestibility of 54.8 percent compared to 61.5 percent in cattle (Johnson et al. 1982).

Management Implications

An understanding of forage quality dynamics can provide a basis for improved livestock management through coordination of forage quality and animal nutritional needs. An illustration of that potential is presented here.

Because grazing animals select their diet from a variety of plants and plant parts which are constantly changing, estimating forage diet quality of these animals is difficult. Grazing animal feces contains undigested and partially digested portions of forages actually consumed by the animal. These forage residues and other byproducts of digestion contained in the feces are potential indicators of forage diet quality. Recent research at Texas A&M University indicates that near infrared reflectance spectroscopy (NIRS) fecal analysis has the potential to estimate the quality of forage consumed by grazing cattle.

An estimated annual forage quality profile for cattle grazing near College Station was obtained using NIRS fecal analysis (Figure 5). Forage quality information was combined in the Nutritional Balance Analyzer (NUTBAL) computer program (Ranching Systems Group 1993) with monthly descriptions of cattle production stages (lactating, pregnancy stage), cattle size, environmental conditions, and forage availability to estimate cattle nutritional status for spring- and fall-calving cows. Crude protein and energy intake and maintenance protein and energy requirements for these groups of cows are shown in Figure 6. Comparing protein intake and maintenance requirements for these two groups of cows shows an apparent protein deficiency in spring-calving cows for 3 months (December-February) and for 6 months (September-February) for the fall-calving cows. Energy intake and maintenance energy requirements show an apparent 2-month (January-February) energy deficiency for spring-calving cows, while fall-calving cows appear to be deficient for 5 months (September-January). Under the conditions in these examples, fall-calving cows would need both more supplemental protein and energy than spring-calving cows on the same forage to maintain body weight. If these cows needed to improve body condition, the fall-calving cows would be at an even greater nutritional and economic disadvantage. If fall calving

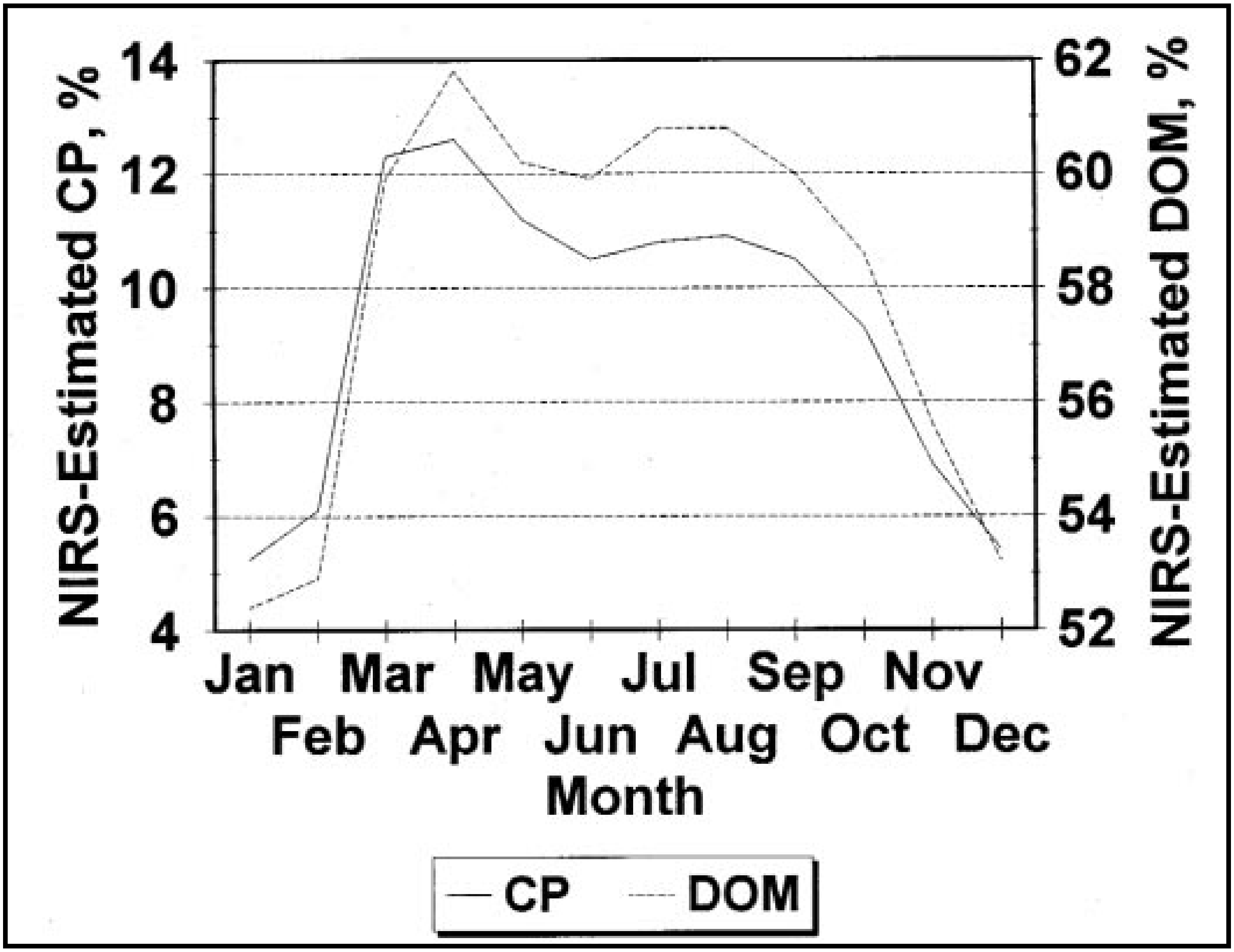

Figure 5. Estimated monthly forage quality for cattle grazing near College Station in terms of crude protein (CP) and digestible organic matter (DOM) from near infrared reflectance spectroscopy (NIRS) fecal analysis.

is necessary for marketing or other reasons, cows with a lower production potential might be used to reduce nutritional nutrient demands. Cool-season annual pastures might be used as a supplement to provide required nutrients.

Conclusions

The quality of forage available to range livestock and wildlife changes because of plant parts eaten, plant age, plant group, soils and range sites, stocking rates, and presence of secondary compounds. Forage digestibility is also influenced by the type of animal eating the forage. Differences in forage quality among range plants provide both benefits and challenges. The benefit of this diversity is that forage quality can potentially be maintained for longer periods than with a single forage species. From a livestock management perspective, one of the challenges is to match periods of high animal nutritional demand to periods of high forage quality and supply. Managing grasses for leaf production clearly provides a higher quality diet than management for consumption of the whole plant. From a wildlife perspective, the challenge is to maintain a habitat that provides food requirements and, in the case of exotic species, to match forage resources with specific species.

For More Information

Some of the information in this publication is taken from these sources:

Cook, C.W., and L.E. Harris. 1950. The nutritive content of the grazing sheep's diet on the summer and winter ranges of Utah. Utah Agric. Ex. Stn. Bull. 342.

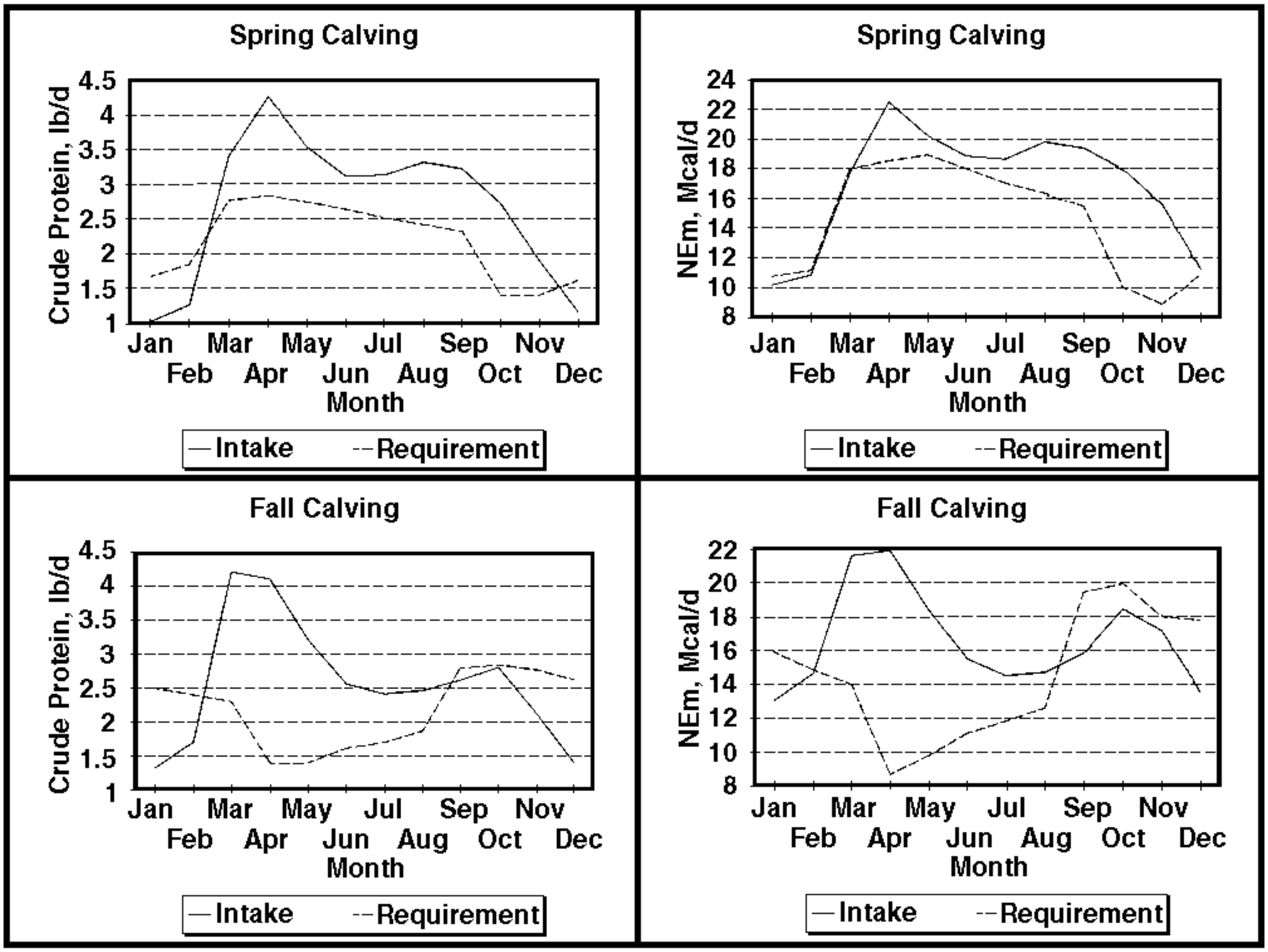

Figure 6. Computer estimated crude protein and net energy for maintenance (NEm) intake and requirements for spring- and fall-calving cows grazing the same forage. These comparisons illustrate the management potential of forage quality information. The graphs indicate periods of nutrient surplus and deficiency. Fall-calving cows appear to be at a disadvantage under the conditions in these examples with regard to protein and energy for a period about twice as long as for spring-calving cows.

Huston, J.E., B.S. Rector, L.B. Merrill, and B.S. Ingdall. 1981. Nutritive value of range plants in the Edwards Plateau region of Texas. Tex. Agric. Exp. Stn. Bull. 1357.

Huston, J.E., and W.E. Pinchak. 1991. Range animal nutrition. In: R.K. Heitschmidt and J.W. Stuth (eds.), Grazing management: an ecological perspective. Timber Press, Portland, OR.

Huston, J.E., C.A. Taylor, and E. Straka. 1994. Effects of juniper on livestock. In: Juniper symposium 1994 proceedings. Technical Report 94-2. Texas A&M University Research Station, Sonora.

Johnson, D.E., M.M. Borman, and L.R. Rittenhouse. 1982. Intake, apparent utilization and rate of digestion in mares and cows. Proc. West. Sec. Am. Soc. Anim. Sci. 33:294-298.

Launchbaugh, K.L., J.W. Stuth, and J.W. Holloway. 1990. Influence of range site on diet selection and nutrient intake of cattle. J. Range Manage. 43:109-116.

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McCollum, T. 1993. Managing Stocking Rates to Achieve Livestock Production Goals in North Texas and Oklahoma IN: J.R. Cox and J.F. Cadenhead, eds., Proceedings of Managing Livestock Rates on Rangeland Symposium, Texas Agricultural Extension Service.

Ranching Systems Group. 1993. Nutritional Balance Analyzer User's Guide. Dept. of Rangeland Ecology and Management, Texas A&M University, College Station, 148 pp.