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Supplementation of Grazing Beef Cattle

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Contents

Foreword

Nutrient requirements of cattle vary widely, depending on their age, physiological function, genetic potential, and previous level of nutrition. Grazing beef cattle are expected to obtain most of their nutrients from forages, but pasture and range forages vary widely in availability and quality due to genetic, environmental, seasonal, and management differences. When forage is the only source of digestible energy and protein, nutrient intake by grazing cattle may often be less than that required to reach management targets for daily gain, body condition, reproduction rate, or milk production. In such cases, managers consider supplementation in order to increase performance, but supplements vary widely in type, nutrient concentration, and delivery system. Therefore, managers are faced with an infinite number of combinations of cattle nutrient requirements, forage availabilities, forage qualities, and supplementation programs.

Supplementation, as taught to undergraduate students, certainly appears to be simple enough: (1) determine nutrient requirements of the animal being fed, (2) determine nutrient intake for forage, and (3) if intake is less than requirement, formulate a supplement to make up the difference. It is assumed that forage intake and digestion do not change, and the supplement intake can be added to the forage intake to determine total diet intake (Fig. 1a). In many cases, however, animal responses to supplements are either less than or greater than expected. Discrepancies between observed and expected results occur when estimates of forage intake are inaccurate (due to either inadequate available forage or errors in estimating voluntary intake) or when there are "associative effects" between forage and supplements that change voluntary forage intake and nutrient digestion.

There are two simple associative effects on voluntary forage intake: decreased forage intake (substitution; Fig. 1b) and increased forage intake (Fig. 1c). In practice, it is unlikely that simple associative effects occur. Substitution may be only "partial" such that total intake increases even though forage intake decreases (Fig. 1d). Complex associative effects combine two or more of the simple effects (Fig. 1e) so that forage intake may be either increased or decreased depending on the amount of supplement consumed. Associative effects also occur with respect to digestion of energy and protein.

By recognizing the associative effect that is likely to occur in a particular situation, managers can take advantage of it in developing an appropriate supplementation program. Biological explanations are not well known in all cases, however, and the responses to supplement are often difficult to predict. Actual data and experience provide the best source of information needed by grazing managers to develop supplementation programs that are feasible and economically profitable.

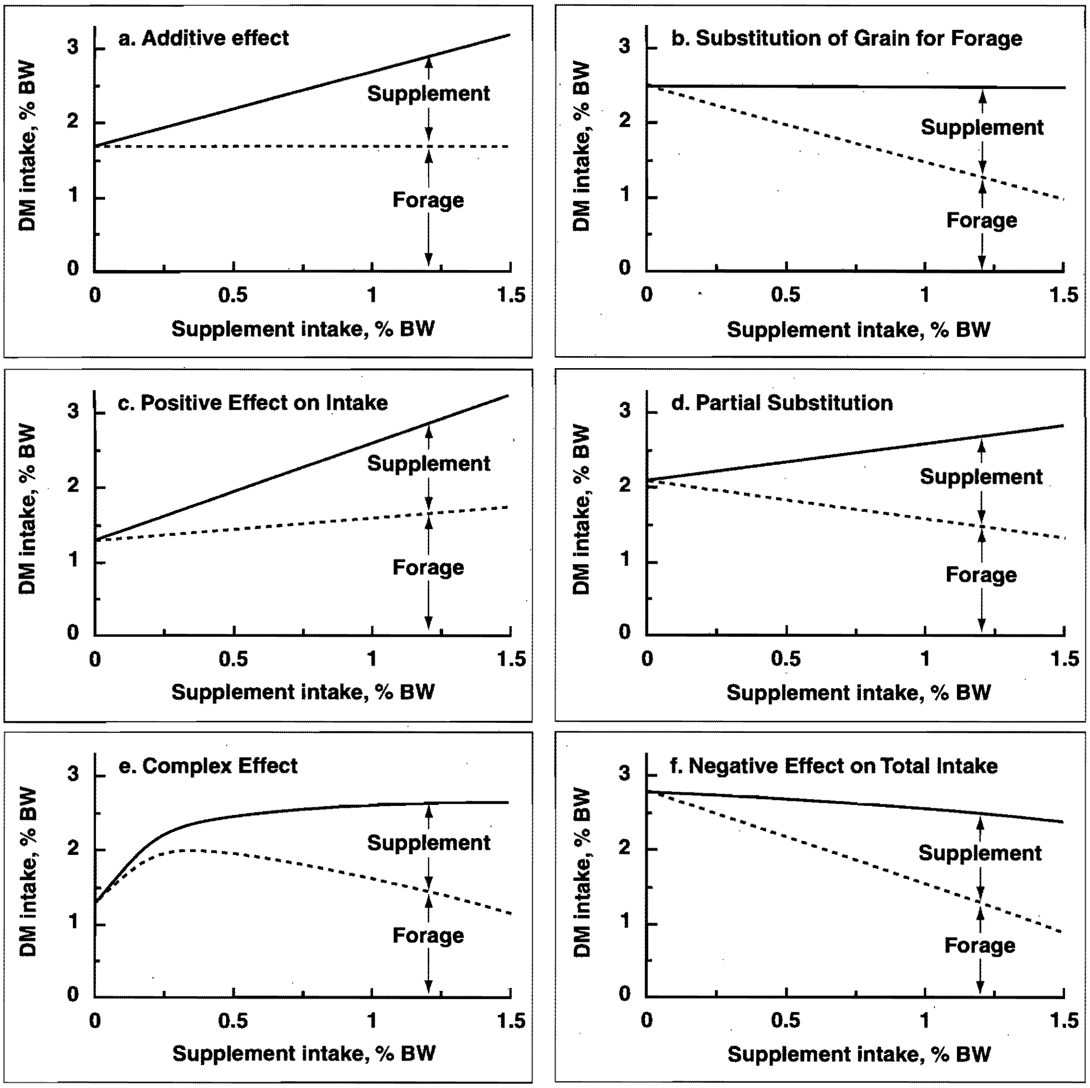

Figure 1. Examples of associative effects of supplemental feeds on intake of forage and total diet: (a) supplement has no effect on forage intake (supplement and forage are "additive"), and total intake increases in direct proportion to supplemental intake; (b) supplement "substitutes" for an equal amount of forage, and total intake does not change; (c) supplement increases intake of both forage and total diet across the entire range of supplement intake; (d) there is partial substitution and decreased forage intake, but total diet intake increases; (e) small amounts of supplement increase intake of low-quality forage, but larger amounts have a substitution effect and total intake plateaus; and (f) when large amounts of supplement are fed with high-quality forage, forage intake decreases to an extent greater than is accounted for by substitution alone, and total diet intake decreases.

Research teams in Texas over the last 20 years have generated a considerable body of excellent data on the science and practice of supplementing grazing beef cattle. The coauthors of this monograph are to be congratulated on their efforts to "pull it all together" in one document. They represent expertise in beef cattle management and nutrition, rumen physiology, and forage production, utilization, and evaluation. They understand the dynamics of grazing cattle management and nutrition, and the interactions among cattle, forage, and supplemental feeds that determine the economics of supplementation. In this document, they provide information on the forage base, describe the scientific basis for supplementation decisions, and show how to design supplementation programs appropriate for specific cattle on specific ranges or pastures at specific seasons of the year. The guidelines presented here about formulating and delivering supplements will be of value to managers, consultants, and students not only in Texas, but also in other similar regions of the world where beef cattle are grazed and supplements are fed.

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Introduction

Beef cattle producers have an assortment of goals and objectives, which may range from full-time, positive cash flow operations to part-time, aesthetic, life-style operations. Regardless of the scope of the production level, most ranchers seek grazing-management systems that provide for enhanced animal productivity. However, many of these management strategies are not linked to biological and/or economic efficiency. In fact, there may be no other aspect of beef production that deals as much with un-met expectations, perceptions, and commercialization as that of supplementation. A wide array of supplemental energy, protein, fiber, and mineral products is available for the grazing beef herds. The selection of a supplement that will enhance overall efficiency is a major dilemma for producers and requires critical, comparative, product evaluation. Likely, there are no existing data sets that compare all potential supplement products. However, pre-supplementation strategies and critical comparisons of ingredients as well as commercial products will allow for achievable expectations from a supplementation product or a supplementation program. Supplementation, by the nature of its definition, is intended to function in close association with nutrients available from forages and not as a source of nutrients independent from the principal forage diet. The objectives of this monograph are to provide factual information on an array of nutrients that may enhance forage utilization and beef production of the grazing animal. The discussions that follow provide some basic principles of supplementation and management strategies to complement grazing beef cattle.

Principles of Supplementation

Land devoted primarily to grazing can be described either as pasture or range. ***Pastureland*** encompasses an idea of being cultivated, fertilized, irrigated, or otherwise enhanced with cultural practices for increased forage quantity, quality, or uniformity. ***Rangeland*** depicts tracts that are larger, often undisturbed by mechanical means, usually with native vegetation, and unenhanced except by a manager exerting an influence with grazing animals or by restoring deteriorated plant communities. Pastureland often has relatively high dry matter (DM) production potential and will respond well to intensive management. Rangeland often lacks potential for high forage production because of low or poorly distributed rainfall, shallow soil, brush invasion, and/or steep slopes. Both pastureland and rangeland are valuable for beef cattle because forages grown on these resources contain nutrients that are in approximate proportions with those required by ruminant animals. Pastures, though, are often prepared and targeted for special uses (e.g., wheat pasture for stocker cattle), whereas rangelands provide their own characteristics that the manager must identify, understand, and properly exploit. The land area devoted to pastureland rather than rangeland is much greater in the higher rainfall areas of Texas (east of Interstate Highway 35). In the lower rainfall areas (West Texas), rangeland is the predominant grazing resource. Irrigation is sometimes used to enhance forage growth and establish introduced pastures in the more arid regions.

Forages, in broad definition, include both native and introduced plants that have consumptive value as a source of nutrients for animals and a non-consumptive value for resource conservation. Forages contain mixtures of chemicals that ruminant animals can use as nutrients for maintenance of body mass and for productivity. Protein can be digested in its present or similar form and the resulting amino acids used directly to synthesize milk, build muscle, support bone growth, etc. Other nutrients such as some vitamins and essential fatty acids also can be used by the animal in the form that they appear in the diet. Some materials such as cellulose must be fermented by microorganisms (mainly bacteria) in the rumen (first large compartment of the gastrointestinal tract) and reduced in size and complexity before they can be digested and used as nutrients. Environment and genotype cause forages to vary in concentration and in availability of these nutrients or nutrient precursors to the animal. Some forages are high in protein; others are low. Some forages are resistant to cellulose breakdown (even by rumen microorganisms); whereas cellulose in other forages is fermented readily. This variability not only exists among plant types but also within single plant species, depending on growing conditions and stage of maturity.

Almost as variable as concentrations of nutrients or potential nutrients in forages are the requirements for these nutrients by animals. In general, grazing beef cattle consume forage at a range of 1.5 to 3% of body weight. This intake is affected by type of animal as well as availability and nutritive value of forage. Beef cattle go through periods within their lifetime when nutrients must be supplied in relatively high amounts for normal physiological processes to occur. Growth and milk production are "expensive" metabolic processes. Conversely, maintenance of body weight in a mature, non-lactating cow may be achieved with relatively small quantities of nutrients. Some forages may be poor sources of nutrients for growing a stocker steer but adequate for maintaining an adult cow. Conversely, a high quality forage that would promote high milk production in lactating cows may not be economically advantageous for maintaining non-lactating, mature cows. A key economic objective in grazing animal production systems is to match animal requirements properly with the forage quantity and quality.

Because there are several nutrients supplied by forages and required by grazing animals, it is logical when considering the degree of match between the animal and forage that some nutrients may be adequate or in excess, yet others may be deficient. A perfect match is unlikely for a prolonged period of time because forage DM production, its nutritional value, and animal requirements are dynamic processes. ***For our purposes in this discussion, we will consider that an appropriate match is established when the energy requirements by the animals and the "potential supply of energy" by the grazed forage are equal.*** The supply of energy from the forage reaches potential when all other nutrients are present in proper balance. A matched situation (scenario 1; Table 1) occurs when animals consume forage that has potential to provide energy at the level required even though one or more other nutrients (e.g., protein) may be deficient. Animals that have high requirements for energy but are grazing forages with low supply are mismatched on the "negative" side of proper balance (scenario 2). When energy requirements by the grazing animal are lower than the potential supply by the forage, a mismatch on the "positive" side occurs (scenario 3).

Supplementation strategies for the different scenarios are defined in Table 1. Feeding of concentrated feeds in scenario 1 will be called ***supplemental feeding***. In supplemental feeding, the limiting nutrients are supplied in order that the energy supply in the forage can reach the potential level and that animal performance is not restricted by the deficiencies of other nutrients. Feeding in scenario 2 will be called ***enhancement feeding*** and can be viewed to be similar to increasing the concentrate level of a feedlot ration to increase rate of gain or feed efficiency. In this case, the energy level of the diet must be raised in balance with other nutrients to satisfy the requirements of grazing animals that are in negative mismatch. Feeding in scenario 3 will be called ***substitution feeding***. In this situation, animals are fed alternate feeds that reduce or substitute for the intake of the grazed forage. Motives to apply substitute feeding include feeding a roughage or grain to stretch the supply of a high quality forage such as a cereal grain or ryegrass pasture. A fourth category, ***supply feeding***, may be described as providing a major or exclusive portion of the animals' dietary DM when forage quantity is inadequate such as during drought or for short periods between pasture growth periods.

Table 1. Definition of supplementation strategies and effects.

Scenario	Forage quality/animal requirements	Feeding strategy	Effects of supplementation
1	Energy level in forage potentially matches energy requirements of the grazing animals; a low concentration of one or more needed nutrients limits intake and digestion of the forage being consumed.	Supplemental feeding	Limiting nutrients are provided to facilitate intake and digestion of the forage.
2	Low quality forage relative to requirements of grazing animals; digestible energy concentration is not adequate.	Enhancement feeding	Provides for increased intake and quality of entire diet thereby satisfying requirements of animals having higher nutrient needs.
3	High quality forage relative to requirements of grazing animals; one or more nutrients are present in excess.	Substitution feeding	Decreases intake of high quality forages by providing portions of the required nutrients in a concentrate form.
4	Forage is limited in quantity and may be limited in quality also.	Supply feeding	Provides the required nutrients above what the animals are able to consume in a limited supply of forage.

Characteristics of Forages in Texas

Environments in Texas differ greatly from east to west and from north to south. Gould (1962; 1969; 1975a) and Hatch *et al.* (1990) described 10 vegetational areas that are products of differences in topography, soil type, temperature patterns, and precipitation. The average annual temperature in the southern Rio Grande Valley, for example, is approximately 20 °F higher than in the northern panhandle. Average frost-free periods for these geographic extremes are >320 days and <185 days per year, respectively. Perhaps more importantly, average annual precipitation (mostly rainfall) ranges from 56 inches near Beaumont to 7 inches near El Paso, a distance of 800 miles and a decrease of one inch of precipitation for each 16 miles moving from east to west. Therefore, forages that are adapted and important in one region may not sustain plant growth in other regions or may not be as suitable as other forages.

Forage has been defined as "edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can be harvested for feeding and includes browse, herbage, and mast." (Forage and Grazing Terminology Committee, 1991). Further, herbage is described as biomass from non-woody plants, browse as leaf and twig growth from non-herbaceous plants, and mast as fruits and seeds also from non-herbaceous vegetation, all of which are available for animal consumption. Herbaceous vegetation includes grasses, grass-like plants (e.g., sedges and rushes), and forbs, which are broadleaf plants including herbaceous legumes. Hatch *et al.* (1990) identified 180 families, 1,284 genera, 4,834 species, and 690 subspecies and varieties of plants in Texas. Whereas almost all would qualify as forage under the above definition, about half of the species belong to only 10 families. Most species that are important as components of cattle diets are in either the *Poaceae* (545 species of grasses) family or the *Fabaceae* (360 species of legumes) family. Also important in the semiarid rangeland environment (especially for sheep, goats, and deer) are the *Asteraceae* (composite) family and an array of plant families for browse and mast that include a large number of trees, shrubs, and succulent plants.

Rangeland vegetation complexity is beneficial. A grouping of plants into functional groups to illustrate the advantages of multiple plant types and species was suggested by Huston *et al.* (1981). A mixture of a large number of plants, each having unique growth forms and periods, provides grazing animals opportunities to select high quality diets by shifting the species composition of the diet according to the most preferred at the time. Some plants contribute abundant biomass, much of which is stockpiled for use at a later time. Other plants produce relatively little dry matter but are of very high quality. Some plants are neither high nor low in quality but have extended growth periods and are of maximum value when the more productive plants are dormant.

Nutritional characteristics of forages

The nutritional potential of a forage is a measure of the amounts of nutrients that the forage can provide to grazing animals. It is determined by 1) the accessibility and attractiveness of the plants for consumption by grazing animals, 2) composition of nutritive entities present and in what proportions, and 3) the extent of digestion of these entities once consumed. It is important to appreciate that forages as well as feed supplements contain nutritive entities, chemicals, which are digested to produce nutrients required by the animal. These entities are classified and described in Table 2.

Carbohydrates

Quantitatively, the most important nutritive entities of forages are the carbohydrates that, when digested, provide sources of metabolizable energy. Metabolizable energy, a primary required nutrient, arises mostly from digestion of carbohydrates, although proteins and lipids also contribute metabolizable energy. Plant carbohydrates are either structural and found in the cell wall or non-structural and contained within the cell contents. The structural carbohydrates are analytically determined as neutral detergent fiber (NDF) or acid detergent fiber (ADF). The NDF contains all the structural carbohydrates together with other cement-like substances (e.g., lignin) that provide structure to the plant. The ADF contains only a portion of structural carbohydrates plus

Table 2. Nutritive entities in forages and supplements and their descriptions, resulting nutrients, and ultimate function in animals.

Nutritive entity	Analytical entity	Digested nutrient	Nutrient function
Proteins	Crude protein, CP	Amino acids	Components of body proteins and enzymes
Fiber, structural carbohydrates	NDF[a], ADF[b] or crude fiber	Various carbon compounds	Metabolizable energy for body synthesis and activity
Non-structural carbohydrates	Starch and sugars	Various carbon compounds	Metabolizable energy for body synthesis and activity
Fats or lipids	Crude fat	Fatty acids	Metabolizable energy for body synthesis and activity
Minerals	Specific minerals	Mineral elements	Components of tissues and involved in enzymatic activities

[a]Neutral detergent fiber.
[b]Acid detergent fiber.

the cement-like substances. The deposition of indigestible, cement-like substances is more common in some plant types than others and increases with maturity of all species of forages. Differences among types of forages are primarily due to differences in NDF content and its digestibility. Figure 2 depicts the effects of digestibility of classes of forage (determined by amounts and proportions of fiber components) on their adequacy for supplying required levels of metabolizable energy to different classes of cattle. Carefully matching forage characteristics and animal needs is an important element of economically successful livestock enterprises.

Warm-season forages differ from cool-season forages primarily in season of growth and photorespiration mechanism, which in turn affects DM and nutritive value. Two mechanisms of photorespiration, respiration during daylight hours, have been identified for plants based on different pathways of carbon dioxide (CO_2) fixation. Plants whose first carbon compound in photosynthesis consists of a three-carbon chain are called C_3 (Calvin Cycle) and include primarily cool-season forages. Plants whose first carbon compound in photosynthesis consists of a four-carbon chain are called C_4 (Hatch and Slack Pathway) and include warm-season forages. As summarized by Burger (1988), C_3 plants have a low net assimilation rate (NAR) because of their high photorespiration rate. On the other hand, C_4 plants have low photorespiration rate and hence a relatively high NAR. The warm-season perennial grasses that dominate pastures and rangeland of Texas are C_4 plants and have a superior ability to efficiently utilize energy from the sun and especially at high light intensities. The cool-season forages, C_3 plants, have been categorized as photosynthetically wasteful because they have high energy losses in photorespiration. The C_4 plants produce photosynthate (carbohydrates) during the day and execute most of their respiration at night.

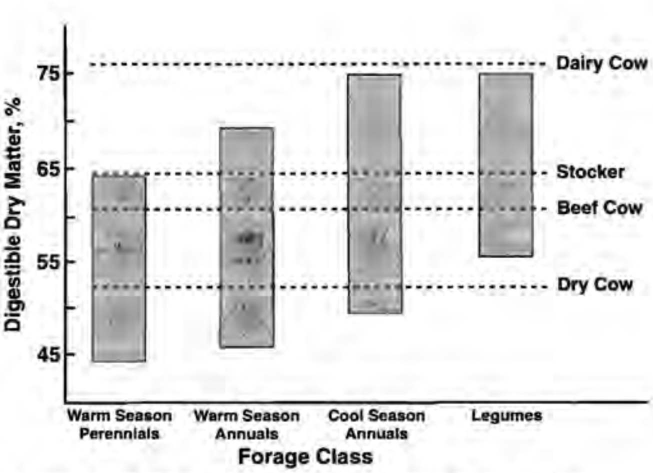

Figure 2. Ranges of dry matter digestibility of four classes of forages (Lippke, 1968).

The anatomical arrangements of leaves and stems and the compositions of the cell walls are primarily responsible for differences in forage quality between C_3 and C_4 plants. Moss (1988) summarized previous research and concluded that C_4 leaf structural arrangement was responsible for the efficiency of photorespiration and resultant DM production. In C_4 plants, the vascular bundle is surrounded by a prominent sheath or collar of cells, which contains many large chloroplasts. In contrast, the mesophyll cells containing chloroplasts in C_3 plants have no particular orientation to vascular bundles. The C_4 plants' anatomy (Kranz anatomy) is such that they have closely spaced vascular bundles with a distinct, thick-walled parenchyma sheath surrounding each bundle. The C_3 plants have widely spaced vascular bundles and less distinct parenchyma bundle sheaths. The high proportion of loosely arranged mesophyll cells in leaves of C_3 plants allows for a more rapid digestion compared to leaves of C_4 plants (Akin, 1989). The parenchyma bundle sheath of C_3 grasses is digested rapidly and extensively; whereas, cell wall digestion of C_4 plants is inhibited by anatomy and composition.

Plant cell walls consist primarily of polysaccharides (carbohydrates) bonded with lignin and proteins. Fermentation of plant cell walls by rumen microorganisms provides the primary source of energy for ruminants. The structural anatomy or organization of plant organs and their constituent tissues influences intake via controlling the ease of breakdown of forage particles, the nature of the particles produced, and their rate of passage from the rumen. In addition, plant anatomy influences DM digestibility through the characteristics of cell walls which determine the availability of their polysaccharides for rumen microbes (Wilson, 1993). Because of this digestive mechanism, ruminants can convert efficiently and effectively into food and energy a resource (forage) that can not be directly used by humans or other monogastrics. The effective utilization of plant cell wall carbohydrates (polysaccharides) is most often restricted by the complex relationship and cross-linking with lignin. Lignin, a phenolic polymer, is detrimental to forage digestibility and has been classified into "core" and "non-core" lignin (Hartley, 1972; Gordon and Neudoerffer, 1973; Gordon, 1975; Jung, 1989). Cell wall lignification, complex linkages between carbohydrates and lignin, is different for C_3 vs. C_4 plants. Although "lignin content," as measured by laboratory analyses, may be greater for alfalfa as compared to bermudagrass, for example, the lignin bonding with cellulose, hemicellulose, etc., has a much more detrimental impact on digestibility of C_4 (bermudagrass) as compared to C_3 (alfalfa).

Proteins

This nutritive entity is expressed as crude protein (CP), assuming the protein contains 16% nitrogen (% CP = % N X 6.25). The CP includes actual protein as well as non-protein compounds that contain nitrogen. Dietary protein, when digested, yields metabolizable amino acids that are required by the animal. Non-protein nitrogen can be converted to protein by

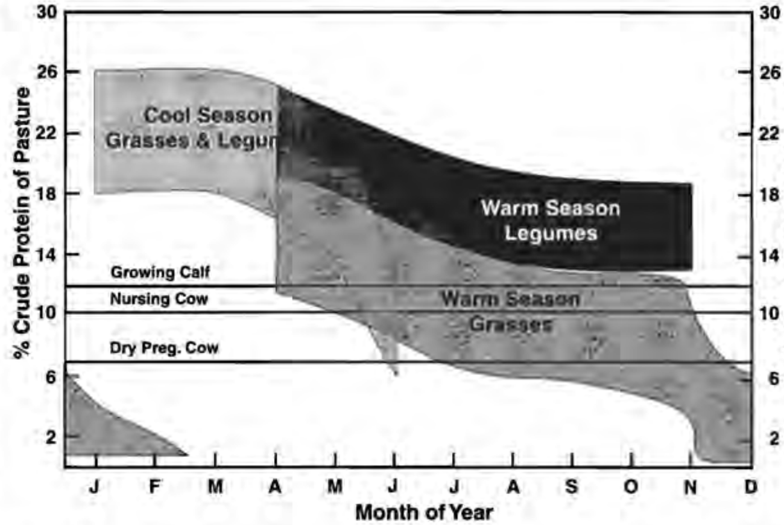

Figure 3. Temporal changes in crude protein contents of forage classes over a 12-month period.

the rumen microorganisms if diet supplies sufficient digestible carbohydrates. The CP content differs among forage classes and declines as plant growth rate declines as illustrated in Figure 3.

Lipids, vitamins and minerals

Actively growing forages contain sufficient levels of lipids and vitamins under most circumstances. With the exception of sodium and chlorine (common salt), the minerals vary in forages according to mineral content and pH of the soil. Thus, deficiencies of most minerals are regional and related directly to soil fertility, soil type, environment, etc.

Deficiencies and need for supplementation

The seasonality of forage growth rate and nutrient yield is the basic reason for the need for supplementation of foraging animals. Nutritional deficiencies of metabolizable energy and protein can be expected for forages and animal classes illustrated in Figures 2 and 3. Every attempt should be made to match seasonal supply of forage with animal requirements of energy. In optimal cases, energy requirements that exceed the animal's capacity to consume adequate nutritive entities can be partially satisfied with energy stored within the body (i.e., fat). Energy reserves within the animal (indicated by body condition scores; discussed later) should be accumulated during periods when forage supply (quantity and quality) exceeds requirements.

Deficiencies of metabolizable amino acids limit rates of cell wall digestion and forage intake by the grazing animals. Likewise, rapidly digested carbohydrates (e.g., starch and sugars from grains and molasses) limit the rate of forage digestion and intake. Thus, if the objective of supplementation of foraging animals is to enhance cell wall digestibility and increase intake of the available protein deficient forage, the most cost-effective supplementation likely will provide CP and minerals in the smallest possible daily level of supplement.

Appendix Table 3 describes the nutritional value of the more important forages in Texas. Table 2 shows those forages organized by functional groups relative to their nutritional value.

- Grasses
  - Warm-season perennials
  - Warm-season annuals
  - Cool-season perennials
  - Cool-season annuals
- Browse
  - Deciduous
  - Evergreen
- Forbs
  - Warm-season forbs
  - Cool-season forbs

Where available, information is provided on seasonal changes for the different plants and effects of location (area and/or site). It is important to understand that these are average values for samples of the collected forages. Variance above and below these values would be expected.

Animal Factors Contributing to Nutrient Requirements

A major consideration in selecting the type and amount of feed needed for grazing beef cattle is the animal's demand for nutrients, which is a product of genetic and physiological factors. Is the animal a small, light weight calf in rapid growth, an adult cow during the second trimester of pregnancy, or perhaps a pregnant heifer that is only 80% of mature size? Is the herd composed of small, medium, or large framed cattle? Are the cows above normal milkers, requiring a high level of nutrition, or are the cows adapted to marginal nutrition where low-er expectations for calf weaning weights are appropriate? Each circumstance is different, and performance expectations should be different also. Therefore, animal factors considered in identifying appropriate feeding practices within a vegetation zone or environment include 1) genetic potential, 2) physiological state, 3) body condition, and 4) production or performance expectations.

Cattle differ greatly in size, appearance, rate of growth, milk production, reproductive rates, time required to reach maturity, and behavioral characteristics. This is especially apparent when comparing beef cattle to dairy cattle. Even within beef breeds and types, there is considerable variation in these production traits. An animal's potential for these traits is determined genetically, i.e., inherited from its sire and dam. A small-framed animal is different from a large-framed animal throughout life even though body weights may be similar due to diet, etc. Cows with high vs. low milk production potential differ, even if actual milk production may be similar. Scores or quantitative classifications (low, medium, and high) are often used to describe these genetically determined characteristics (BIF, 1996) that include frame size, mature body weight, behavior, milk production, ability to store energy, adaptability to stress (e.g., heat, cold, parasites, etc), and calving ease. The level of production of a particular set of cattle is determined by how well the environment, including the level and pattern of nutrition, allows for the expression of these genetically determined characteristics. A general principle is that animals possessing high genetic potential for productivity are more productive under favorable but not necessarily under unfavorable environments than animals that have lower potential. Again, the primary goal of management is to match the animal's overall requirements (genetically determined) with the environment and the forage resource. A proper match is found when the animal is adapted to its surroundings.

An animal's physiological state determines how nutrients are utilized within the body. This is illustrated in simplistic form in Figure 4 for a pregnant, lactating cow. The first use of nutrients (in this case, energy) is to maintain the body tissue. Once maintenance requirements are satisfied, nutrients are available for reproduction, i.e., to feed the fetus carried by the cow. Nutrients in excess of those required for the unborn calf are available for lactation. If nutrients are in excess of those needed for lactation, some may be stored in the body (e.g., fat) for future use and trigger the cow to consume less, thereby bringing nutrient intake and requirements into balance. In some instances, the priority of use of nutrients is reversed for reproduction and lactation. Cows that are in a high state of lactation may fail to breed yet will continue to produce milk. However, once the cow becomes pregnant, the fetus usually will be supplied in preference to milk synthesis. The flow

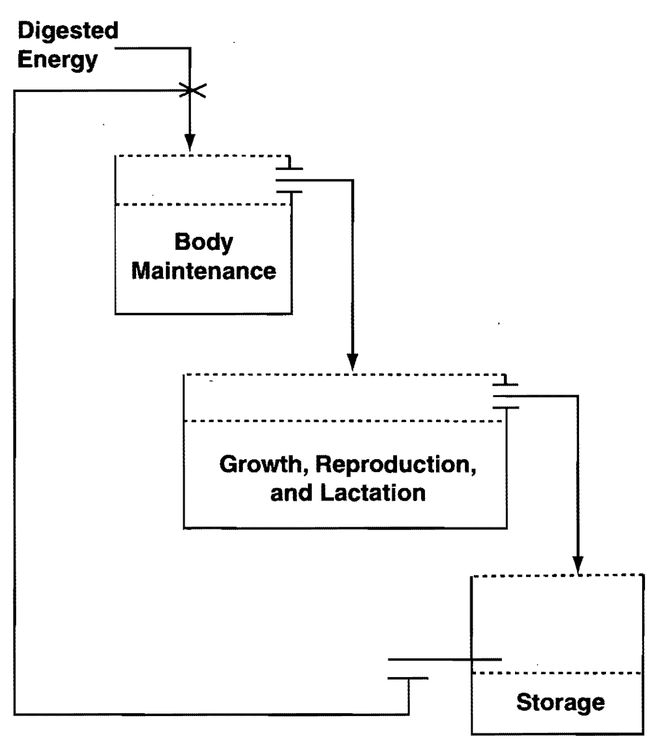

Figure 4. Generalized diagram indicating the prioritization of energy use by ruminants.

of nutrients is not always linear, especially in the short term. For a short period, a cow can be eating less than her maintenance requirement and still remain pregnant and produce some milk. If the undernutrition is prolonged, though, milk flow will cease and, in some cases, pregnancy will be terminated. Other physiological uses of nutrients (e.g., muscle and fiber growth) can be depicted similarly. In the growing calf, requirements for maintenance and growth costs are approximately equal. At maturity, growth ceases although weight will continue to fluctuate because of changes in the environmental circumstances. Maintenance costs reach 100% of requirements in animals that are not otherwise in a state of production.

Table 3. Beef cows body condition scores[1]

Score	Description
1 -	Severely emaciated. All ribs and bone structure easily visible and physically weak. Animal has difficulty standing or walking. No external fat present by sight or touch.
2 -	Emaciated. Similar to 1, but not as weakened.
3 -	Very thin. No palpable or visible fat on ribs, brisket or shoulder blades. Individual muscles in the hind quarter are easily visible and spinous processes are very apparent.
4 -	Thin. Ribs and pin bones are easily visible and fat is not apparent by palpation on ribs or pin bones. Individual muscles in the hind-quarter are apparent.
5 -	Moderate. Ribs are less apparent than in 4, and have less than 0.2 in. of fat on them. Last two or three ribs can be felt easily. No fat in the brisket. At least 0.4 in. of fat can be palpated on pin bones. Individual muscles in hindquarter are not apparent.
6 -	Good. Smooth appearance throughout. Some fat deposition in brisket. Individual ribs are not visible. About 0.4 in. of fat on the pin bones and on the last two or three ribs.
7 -	Very good. Brisket is full, tail-head and pin bones have protruding deposits of fat on them. Back appears square because of fat. Indentation over spinal cord due to fat on each side. Between 0.4 and 0.8 in. of fat on last two to three ribs.
8 -	Obese. Back is very square. Brisket is distended with fat. Large protrudin deposits of fat on tail-head and pin bones. Neck is thick. Between 1.2 and 1.6 in. of fat on last two to three ribs. Large indentation over spinal cord.
9 -	Very obese. Description of Score 8 taken to greater extremes.

[1]BIF (1996)

The replacement heifer is a special case in that while producing her first and possibly second calf she continues to grow and mature. During this critical period (2 to 4 years), the replacement heifer has requirements for maintenance, growth, reproduction, and lactation. Often, the inability of these young cows to consume adequate nutrients results in low weaning weights, low conception rates, less than expected mature weights, and reduced lifetime productivity.

A useful tool in monitoring the nutritional status of grazing beef cattle is that of visual body condition scoring (BIF, 1996). As indicated above, storage of energy for later use occurs

Body condition score 3.

Body condition score 5.

Body condition score 7.

after the energy requirements for other processes have been satisfied. Once energy is stored as fat during periods of excess energy intake, fat is available as a potential source of energy for the animal during periods of dietary deficiency. Therefore, the ability to fatten and then mobilize energy from fat is an important characteristic for animals that graze in environments having cyclical periods of nutritional prosperity and famine. The visual body condition scores (BCS) and descriptions shown in Table 3 depict the range of fatness that may be observed in beef cattle. The middle third (BCS 4, 5, and 6) describes the desirable range of body condition under normal circumstances. Winter-calving cows reach peak condition after weaning and a few weeks of grazing good quality forage during the fall. Body condition often decreases during winter, especially after calving, and during the first 3 months of lactation if: 1) cows are not mature, and/or 2) available nutrients are inadequate. Ideally, a cow with a BCS of 6 during late fall would have a BCS of 5 at the beginning of breeding season and no lower than 4 during lactation. Fall-calving cows usually will store more energy as fat during the growing season after weaning then will mobilize the fat for use during late fall and winter lactation and breeding. Scores lower than 4 indicate nutritional stress, which might decrease breeding and lactation efficiency. Scores greater than 6 in winter-calving cows and 7 in fall-calving cows may indicate inefficiencies in the management system. Perhaps animals having greater production potential should be considered in such cases. Supplemental feeding is a means to maintain cows within the desirable range of body condition.

Intake and Digestion of Forage

Plant tissues are composed of complex chemicals that can be converted by various processes of digestion to nutrients that, upon absorption from the digestive tract, can be metabolized by the animals' tissues as nutrients. Some of these chemicals, such as starches sugars, proteins, and fats, can be digested with the aid of hydrolytic enzymes secreted into the digestive tract by certain animal tissues. These plant chemicals are found primarily in the ***cell contents*** of plants and are relatively digestible. Insoluble chemicals that are found in the ***cell wall*** include lignin, cellulose, and hemicellulose and are not digested by enzymes secreted by the animal. ***However, components of the cell wall are partially but not completely digested by enzymes secreted by microorganisms.*** Cell wall constituents have been described analytically as neutral detergent fiber (NDF). Lignin is an indigestible fraction of the NDF. Furthermore, as cellulose and hemicellulose become "lignified" within the cell wall as plants mature, they too are rendered indigestible. The remaining, non-lignified portion of the fiber is the potentially digestible NDF (PDF). It is accessible to microbial colonization, and is capable of being digested by enzymes secreted by the rumen microorganisms.

Ruminant digestion

Ruminants have developed a unique digestive system to maximize the efficiency of digestion of plant cell wall constituents. The compartmentalized, internal structure that has developed over time allows ruminants to accommodate fibrous as well as starchy feeds from which required nutrients can be extracted. The enlarged forestomach, composed of the rumen and reticulum and referred to as the ***reticulorumen***, is occupied in mature animals by a mixed population of microorganisms including bacteria, fungi, and protozoa. Plant tissue fragments are retained within the reticulorumen for a sufficient time to allow fractional digestion of cell walls. Typically, PDF is digested at 0.05 to 0.5 per hour. The efficiency of digestion of PDF equals the rate of digestion/(rate of digestion plus rate of escape of PDF). Thus, 71.4% of PDF will be digested at a digestion rate of 0.1/h and a rate of escape of 0.04/h (0.714 =0.1/[0.1+0.04]). A rate of escape of 0.04/h equals a mean residence time (MRT) of 1/0.04 or 25 h. The average residence time of particles in the reticulorumen ranges from < 20 h to > 48 hours. Small ruminants (goats and deer) that have proportionately smaller reticulorumens and animals consuming concentrate feeds have residence times at the low end of the range; large ruminants and those consuming roughages and fibrous forages are at the high end (Huston *et al.*, 1986b).

Upon entering the reticulorumen, ingested tissue fragments are mixed with fragments of tissue from prior meals, colonized by rumen microorganisms, reduced in size by rumination (regurgitating the digesta into the mouth, chewing, and re-swallowing), fermented by the microbial population, and ultimately become fractionated into new metabolites or residues that escape along with associated microorganisms from the reticulorumen (Deswysen and Ellis, 1990; Ellis *et al.*, 1987; Pond *et al.*, 1987). The end products of fermentation include short-chain fatty acids (2 to 6 carbons) known as volatile fatty acids (VFA), gases, and increased amounts of the microbial cells. Quantitatively, the most important VFA are the C_2 and C_3 compounds, acetic and propionic acids, respectively. Most of these fatty acids are absorbed directly through the ruminal wall into the portal blood and are transformed chemically into useable energy. Unfermented plant tissue residues, together with associated microorganisms and liquids, escape from the reticulorumen into the omasum then move to the abomasum and intestines. Microorganisms and soluble materials from the cell contents (starches, sugars, proteins, etc.) that escape the reticulorumen are then digested by enzymes secreted by the animal.

Digesta dynamics within the rumen

The regulation of feed intake and its digestion in the rumen is a dynamic process that includes mixing, retaining, and passing of plant tissues. It is the mixing of newly ingested plant tissue fragments with residues of plant tissues of prior ingestions that regulate the MRT that is of central importance in determining efficiency of ruminant digestion. Three basic physiological processes that have a role in determining ruminal MRT are as follows:

1. continual mixing of rumen digesta by the forces of muscular contractions within the ruminal wall,
2. continual "un-mixing" forces of buoyancy of younger fragments of plant tissues, and
3. forage intake, that is influenced by nutrient requirements and balance (hunger/satiety), compared with rumen digesta load (fill).

The opposing forces of processes 1 and 2 of mixing and "un-mixing" cause forage tissues to flow through two flow paths or pools of ruminal digesta referred to as the lag-rumination and mass action turnover pools, respectively. Newly ingested, recently masticated plant fragments first enter the lag-rumination pool. These particles have intrinsic buoyancy due to their large size and content of intact plant vascular tissues. With microbial colonization and the onset of fermentation, gases of fermentation (carbon dioxide and methane) within the fragments add to the buoyancy. These opposing forces of separation (buoyancy) and mixing (contractions) result in a sorting of the larger, younger, and less masticated fragments into the upper portions of the ruminal digesta. This fraction of forage fragments progressively decreases in buoyancy, particle size, and digestible portions during rumination and fermentation. The fragments lose buoyancy progressively faster with increasing time. While in the dynamic lag-rumination pool, potentially digestible entities may be either digested if residence time is adequate or may escape digestion if the particles prematurely pass from the reticulorumen by chance.

Once buoyancy is lost, the fragments move quickly from the lag-rumination pool to the ***mass action turnover pool*** from which fragment escape from the reticulorumen is of greater probability. Reticuloruminal digesta is a mixture of forage fragments, microorganisms that are attached to forage fragments, free-floating microorganisms, saliva and other components. Coordinated muscular contractions within the ruminal wall mix and move these components within the reticuloruminal space so that digesta fragments, old and new, compete for escape from the rumen into the omasum in route to the lower digestive tract. Particles that have resided longer in the ruminal digesta have a higher probability of passage because they have a smaller size with less buoyancy. Potentially digestible plant tissues disappear from the reticulorumen by both digestion and escape. Indigestible entities eventually pass out of the reticulorumen regardless of residence time because they are indigestible. These entities appear to escape via mass action resulting from intake of additional indigestible residues (e.g., water hose running into a barrel forces overflow equal to inflow).

The two sequential lag-rumination and mass action turnover pools have important functions in increasing the mean residence time. For example, the MRT for the two sequential pools of lag-rumination and mass action turnover is the product of the turnover rates for each pool, which results in a greater MRT for NDF and more efficient digestion of PDF than could be achieved for a single pool.

The MRT of plant tissue fragments in the ruminal fermentation pools is related positively to efficiency of digestion of PDF but inversely to efficiency of microbial protein synthesis per unit of PDF and the amount of dietary protein that escapes rumen fermentation. Extended residence time favors maintenance and sustainable levels of reproduction of ruminants grazing medium to low quality forages. However, greater levels of productivity (rapid growth, high milk production, etc.) would be favored by more rapid rates of hydrolysis and reduced particle residence time, thereby providing proportionately greater levels of metabolizable amino acids.

Regulation of intake and digestion in the foraging ruminant

The nutrition of ruminants involves the nutrition of two sequential biological systems. Upon ingestion, forage tissue fragments provide for the nutrition of the ruminal microbial population. The resulting products of rumen fermentation and microbial growth and any forage entities not degraded in the rumen then provide for the nutrition of the ruminants' tissues. The importance of this sequence of ruminal nutrition/digestion in supplying metabolizable nutrients for the animal's nutrition is illustrated in Figure 5.

As in other animals, intake in ruminants is regulated by responses to nutrient flux and the first limiting nutrient at the animal tissue level. In foraging ruminants, intake-constraining mechanisms at the rumen level may preclude regulation at the tissue level. Intake-constraining mechanisms at the rumen level are both physical and nutritional. Physically, intake rate may be limited by the physical capacity of the rumen to accommodate a further load of forage, which results in reduced size and number of main meals. The mean rumen load over days is a balance between intake and escape rates of indigestible fiber (IF). Until digested, PDF and IF are components of the same ingested plant tissue fragment, so rates of escape of IF and PDF are equivalent. The dominant mechanism that regulates rate of escape of IF from the rumen is rate of digestion of PDF, a process that appears first limited by inadequate amino acid nutrition of the rumen bacteria that digest these potentially digestible cell wall constituents.

The nutritional significance of this sequence of processes regulating intake and digestion of PDF illustrated in Figure 5 are supported by the results summarized in Table 4. In terms of the sequence of biological processes illustrated in Figure 5, feeding a 12.3% CP diet as compared to a CP insufficient diet (CSH, 5.1% CP) resulted in

1) an increased rate of growth of fiber-digesting bacteria as evidenced by an increased rate of digestion of PDF,
2) an increased flow of rumen microbial amino acids to the abomasum as the result of the increased growth rate of the total rumen microbial population,
3) an increased intake rate resulting from the nutrient deficit, intake driving mechanism in response to the increased flow of metabolizable amino acids,
4) an increased status of amino acid nutrition at the animal tissues as reflected by decreased blood plasma levels of the most limiting amino acids (methionine and lysine) and decreased loss of muscle protein as reflected by reduced 3-methylhistidine in the blood plasma, and
5) an increased rumen load of IF associated with increases in feed intake.

The results in Table 4 imply that rumen degradable intake protein (DIP) enhances cell

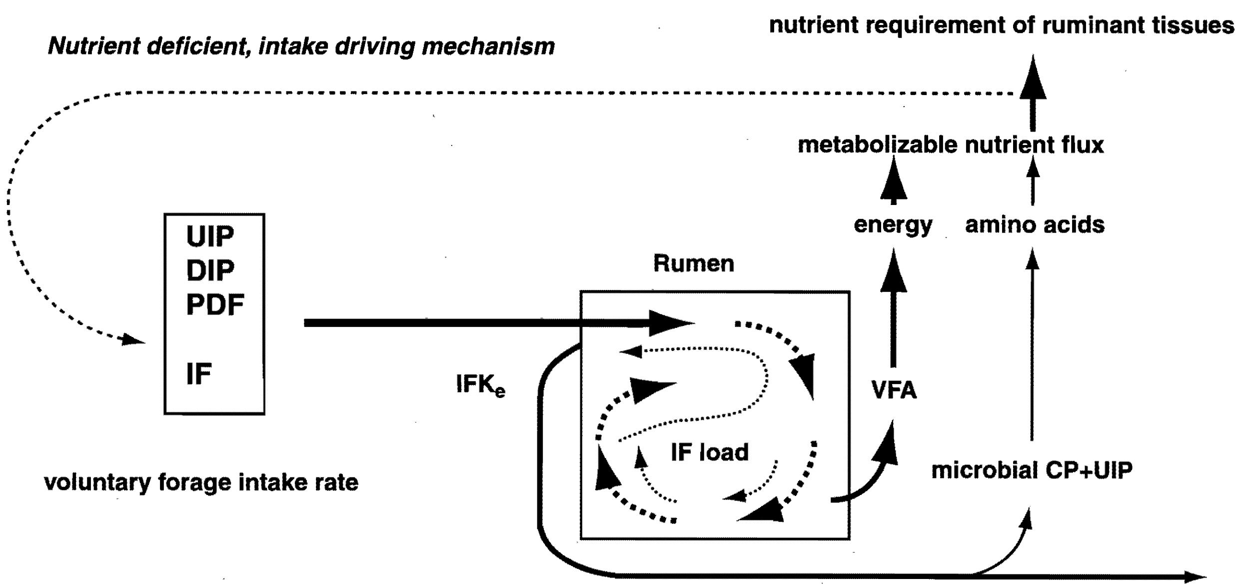

Figure 5. Forage intake rate as the result of a balance between forces of deficit driven intake (derived from the ruminants' tissues level) and forces in the rumen that constrain escape of forage residues from the rumen.

The voluntary intake rate of rumen undegraded intake protein (UIP), rumen degraded intake protein (DIP) and potentially digestible NDF (PDF) achieved is either 1) that which supplies tissue requirements for the metabolizable nutrient first limiting or 2) that which is constrained by digestion in the rumen. Constraints to escape of undigested forage residues from the rumen are due to 1) physical dilution of forage intake by rumen load of indigestible NDF (IF) and 2) nutritional deficits that constrain rumen microbial growth rate and, thereby, rates of digestion of PDF and escape of undigested forages residues (IF), i.e., IFk$_e$.

wall digestion. Fatty acids derived from rumen degraded amino acids are essential for growth of fiber-digesting bacteria and appear to be the effective nutrient derived from DIP in enhancing cell wall digestion and intake. Thus, dietary deficiencies of DIP appear to limit growth rate of PDF-fermenting microorganisms and thereby limit rates of digestion and intake of forages that contain high levels of PDF. Further evidence of this relationship is illustrated in Figure 6 with other results reported in the literature (Ellis *et al.*, 2001). The positive relationship between intake rate of PDF and DIP intake for all forages (Fig. 6a) supports the hypothesis of DIP as the dietary nutrient first limiting intake rate of PDF. Conceptually, PDF intake rate should be expressed more accurately as PDF intake rate vs. DIP/PDF among forages. However, this relationship lacks predictability across forages (Fig. 6). This lack of prediction simply means that although related, variations in DIP/PDF do not express the more basic biological cause and effect mechanisms. More specifically, it is the yield from DIP of the essential fatty acids required by the PDF digesting bacteria that is the basic deficiency. Similarly, it is the potential of DIP for increasing rate of digestion of PDF that is the more basic response. Evidence suggests that this potential may vary by individual forages and by the microbial population within individual animals (Lowe *et al.*, 2001).

Supplementation with feed sources of DIP to enhance utilization of available forage should conceptually always be most cost-effective. Supplementation with DIP should first be utilized to stimulate rumen microbial growth rate and digestion if DIP supply limits rumen microbial growth. If PDF first limits microbial growth rate, then supplementation with rumen undegraded protein (UIP; undegraded intake protein) should be utilized to enhance supply of metabolizable amino acids for more productive classes of ruminants.

Table 4. Effects of protein insufficiency upon voluntary intake and dynamics of ruminal fiber digestion and protein utilization in sheep fed diets containing minerals and cottonseed hulls (CSH) or minerals, CSH and cottonseed meal (CSH+CSM) (Summarized from Wylie, 1987 and Ellis *et al.*, 2001).

	Diet		[Ratio]
Item	CSH	CSH+CSM	CSH+CSM:CSH
CP, % of DM	5.1	12.3	2.41
Daily DM intake, % of BW	1.02	3.17[c]	3.11
Daily PDF[a] intake, % of BW	0.38	1.27[c]	3.34
Digestibility of PDF, %	58.0	65.0	1.12
Daily IF[b] intake, % of BW	0.51	0.47	0.92
Rumen load of IF, % of BW	1.62	7.41[c]	4.57
Rumen escape rate of IF, /d	1.5	3.0[c]	2.00
Daily flow of amino acids to abomasum, g	15.9	60.5[c]	3.81
PDF intake / amino acid flow to abomasum, g/g	6.58	7.29	1.11
Blood plasma amino acid concentrations: µmol/ml			
3-methylhistidine	26.0	10.8[c]	0.42
Increasers, asp+phe+thr+tyr+val	40.78	69.24[c]	1.70
Decreasers, gly+lys+met	2.01	1.17[c]	0.58

[a]PDF = potentially digestible NDF.
[b]IF = indigestible NDF.

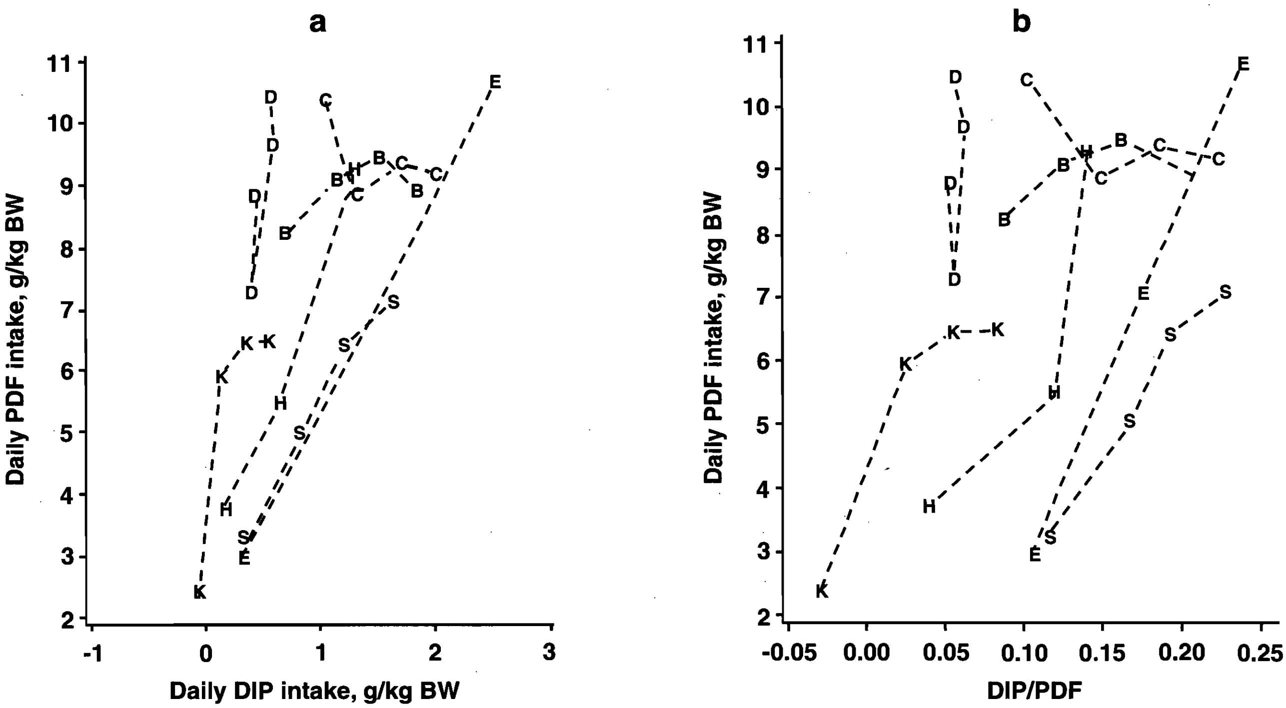

Figure 6. Effects of rumen flux degradable protein (DIP) and proportions of rumen degradable protein and potentially digestible NDF (PDF, DIP/PDF) upon rates of intake (Figure 6a and 6b), in seven experiments involving protein supplemented cotton seed hulls (E) tallgrass-prairie forage (K, H and D), bermudagrass (C), dormant bluestem range (B) or sorghum (S).

Voluntary intake

The key to managing cattle and prescribing supplemental feeding methods is the ability of the manager to predict or measure voluntary intake of forage by the grazing animal. Voluntary intake is determined by both animal and forage factors. Grazing animals consume forage to satisfy tissue requirements for metabolizable nutrients.

Forage quality

Forage consumption is constrained by limits imposed by the microbial digestion process. As forage quality (digestibility and protein content) increases, cows can consume greater amounts. Intake rate of most Texas forages is limited by slow rate of microbial digestion of the potentially digestible fiber (PDF) that is inherent to the forage. Forages that are coarse, low in leaf:stem ratio, high in dead vs. live tissue, and low in protein content will be slower to break down and are less digested. Whereas the ultimate size of particle that exits the reticulorumen will not be affected greatly by forage quality, time required for particle size reduction will be greater with lower quality forage, thereby decreasing available space for intake of new forage (Ellis *et al.*, 1987).

Individual animals that display greater voluntary intake likely are more efficient at reducing particle size and enhancing digesta passage rate (Deswysen and Ellis, 1990). Even with forages of very high digestibility (e.g., annual ryegrass and small grain pasture), the amount of DM exiting the reticulorumen to appear in the feces is somewhat constant (Ellis *et al.*, 1984) although reticuloruminal retention is shorter and passage rate is faster (6.5 to 8.5%/hr), which leads to greater forage intake (Pond *et al.*, 1981). Passage rates in cows grazing warm-season perennial pastures would be lower (3 to 6%/hr) depending on species and stages of growth of the plants in the diet (Ellis *et al.*, 1981; Forbes *et al.*, 1998; Grigsby *et al.*, 1987; Machen, 1984; Rector, 1983).

Forage availability

Voluntary intake is related to forage biomass. Cattle graze selectively both among available plant species and among the anatomical parts of individual plants (Rector, 1983). As grazing pressure (animal units/forage mass; Forage and Grazing Terminology Committee, 1991) increases, the forage available to the grazing animal is reduced. This can occur either from decreased available forage or increased *stocking rate*, i.e., number of animal units on a grazed area. In either case, the animal's ability to be selective in grazing has been diminished because of competition for a finite amount of forage. Fewer nutrients are consumed and animals have lower performance. This has a greater impact on rangeland than on pasture (Heitschmidt *et al.*, 1982; Holloway et al., 1994; Johnson *et al.*, 1981), probably because of the greater variation in quality of the available forage on rangeland. The cow-calf data in Table 5 indicate that animal performance does not decline significantly with increases in stocking rate on pasture until forage availability is limited severely. Increasing stocking rate (decreasing forage availability) at the low range of grazing pressure can stimulate regrowth, thereby changing the phenological stage of the grazeable forage and increasing diet quality (Roth *et al.*, 1990). For example, with bermudagrass pastures, increasing stocking rates resulted in lower NDF of available forage, which is likely due to changes in forage maturity. In this same study (Roth *et al.*, 1990), however, cattle selected leaves with lower NDF than that of the average of available forage. Thus, diet selectivity enables animals to buffer the effects of low nutritive value except in extreme cases of old, mature forage. Moderate declines in individual animal performance with increased stocking rate can be tolerated because of the increases in number of animals and total production on the area grazed. The classical concept on stocking rate (Figure 7c) developed by Riewe (1965) will be discussed in the section devoted to stocking rate.

Table 5. Effects of forage availability on weight changes in cows and nursing calves on bermudagrass pastures.[a]

Item	Stocking rate: Low	Medium	High
Forage mass, lb/ac	2,358	1,566	792
Stocking rate, AU/ac[b]	.82	1.35	2.89
Body weight, lb/ac[c]	1,423	2,315	4,462
Body weight change, lb/d			
Cows	1.00	.91	-.42
Calves	2.64	2.54	1.46
Gain per acre, lb/ac			
Cows	110	166	-138
Calves	291	463	575
Total	401	629	437

[a]Data were collected during a 135-day period in each of three years with cows and calves grazing either common or coastal bermudagrass overseeded with clover and ryegrass (Rouquette and Florence, 1983a,b).
[b]AU equals 1 cow with nursing calf.
[c]Cow and calf weights added together.

Animal requirements

Animals that are in a physiological state of high nutrient requirements (growing or lactating) will consume more forage than those at maintenance. Table 6 shows relative forage intake of adult dry and lactating cows, growing heifers and nursing calves grazing a common range during summer (Machen, 1984). According to these data, the nursing calf, growing heifer, and lactating cow consumed 25, 26, and 33% more forage (kg/100 kg BW) than the dry cow. Note also that digesta turnover was greatest in the calf and lowest in the adult cows. These data did not consider milk intake by the nursing calf.

Table 6. Relative forage intake of dry cows, growing heifers, lactating cows, and nursing calves grazing range vegetation during summer.[a]

Animal class	Forage intake: lb/day	g/kg$^{.75}$ BW	lb/100 lb BW	Turnover %/hr
Dry cow	13.9[c]	60.3[c]	1.28	3.0[b]
Growing heifer	11.9[c]	68.9[c]	1.61	3.0[b]
Lactating cow	17.6[d]	79.2[d]	1.70	2.8[b]
Nursing calf	4.0[b]	51.9[b]	1.60	3.9[c]

[a] Machen (1984).
[b,c,d] Means within columns that do not share a common superscript differ ($P < .01$).

Supplemental feeds

Forage intake may change with feeding of concentrates depending on the type of feed and whether the cattle and forage present senario 1, 2, or 3 as described previously. In scenario 1, the cattle are matched to the available forage but one or more nutrients (e.g., protein) are below requirements. Usually, if this nutrient is provided, forage intake will increase. Cattle whose requirements are higher than the forage has potential to supply (scenario 2) may not change forage intake or may either increase or decrease forage intake when an appropriate concentrate is fed. When forage is of higher quality than is required by the grazing animal (scenario 3), forage intake will be depressed when a concentrate feed is given. Also, the type of feed offered (e.g., high protein vs. high starch) influences the effect on forage intake. Table 7 shows an example of adult cows in scenario 1, where forage is adequate for the cows except for a protein deficiency. When a small amount of high-protein concentrate was provided, forage intake increased and weight loss decreased. Greater amounts of concentrates that provided the same amount of protein but increasing energy (starch) decreased forage intake. Therefore, voluntary intake becomes the net result of forage quality and quantity, the animal's requirements, its ability to process the consumed materials as a function of these two factors, and the effects of concentrate feeding.

Simple empirical model of forage intake and digestion

Lippke (1980) fed sorghum and bermudagrass hays grown in Oklahoma, Louisiana, and Texas to yearling steers in a 3-month intake and growth trial and found that physiological and chemical interactions involved in forage intake and digestion appeared related to the CP and acid detergent fiber (ADF) contents of the forages. Digestible organic matter intake, expressed as g/kg $BW^{.75}$, was described by CP and ADF in the equation, DOMI = 67.5 + (CP x 1.46) - (ADF x 0.98), with a precision (s = 2.1) much better than for either intake or digestibility alone (H. Lippke, unpublished). Crude protein appears to be positively related to many, if not all, forage attributes that lead to increased rate and extent of digestion. The ADF is composed of plant tissues that are difficult or impossible for rumen microorganisms to digest.

Lippke and Herd (1990) used the data of Lippke (1980) to develop a software program (FORAGVAL) for forage evaluation in terms of animal performance. Validation of the FORAGVAL model, using published data from 21 forages (including only 3 bermudagrass or sorghum forages), showed that FORAGVAL had no bias in predicting average daily gain (ADG) and that prediction error was less than the error among certified laboratories for measuring CP and ADF (Coleman *et al.*, 1999).

Table 7. Intake by adult cows supplemented on rangeland.[a]

Item	Feeding treatments				
	Control	Low	Medium	High	SE
Dry matter intake, g/kg BW					
Supplement[b]	0.0	1.5	2.7	4.8	
Forage	18.0	25.8	20.9	18.6	1.11
Total	18.0	27.3	23.6	23.4	1.12

[a]Huston *et al.* (1993b).
[b]Low, Medium, and High provided 300 g/day protein and 2, 4, and 8 Mcal of DE, respectively.

Stocking Rate

Stocking rate is an important consideration in optimal use of warm-season perennial grass pastures and rangeland. Increasing grazing pressure decreases the available forage, reduces the opportunity for selective grazing, but may either decrease diet quality or increase it if growth rate is not reduced and live leaf is increased as a proportion of the forage biomass (Roth *et al.*, 1984; Teague *et al.*, 1996; Heitschmidt and Taylor, 1991).

The effects of stocking rate on efficiency and productivity are expressed by two curvilinear relationships. As stocking rate is increased, individual animal daily gains initially may either increase, remain unchanged, or decrease only slightly depending on whether heavier grazing increases diet quality (Figure 7a). With further increases in stocking rate, average daily gain will decline because of greater competition among the grazing animals for the higher quality portions of the sward and the net lower quality of the diet. At a very high stocking rate, both quantity and quality of the forage biomass will limit intake of nutrients, and the decline in average daily gain will become exaggerated. The effects of increased stocking rate on animal weight gain per acre are shown in Figure 7b. The early pronounced increase is the result of only small decreases (perhaps even increases) in daily gains of the individual cattle but increased number of animals per acre. Similar gains in a larger number of animals results in a greater overall production. Gain per acre is maximized at a stocking rate where the positive effect of increased numbers of animals is exactly offset by the decrease in individual animal gains. At stocking rates higher than the maximized point, the magnified decrease in individual animal gains has a greater negative impact on gain per acre than the positive impact of increased numbers.

The grazing model developed by Riewe (1965) and shown in Figure 7c illustrates the relationship between stocking rate, individual animal performance, and production per unit area. As stocking rate increases on an area, animal performance increases to individual maximum before declining then reaching maximum production per area. Further increases in stocking rate will decrease both individual animal and area production, both of which will eventually drop below zero when forage supply and quality cannot satisfy dietary maintenance requirements. Optimal stocking rate can be considered the point of maximal economic return which will occur at less than maximal individual animal performance and approaching, but likely short of, maximal production per unit area. So, determining optimal stocking rate is largely an economic consideration

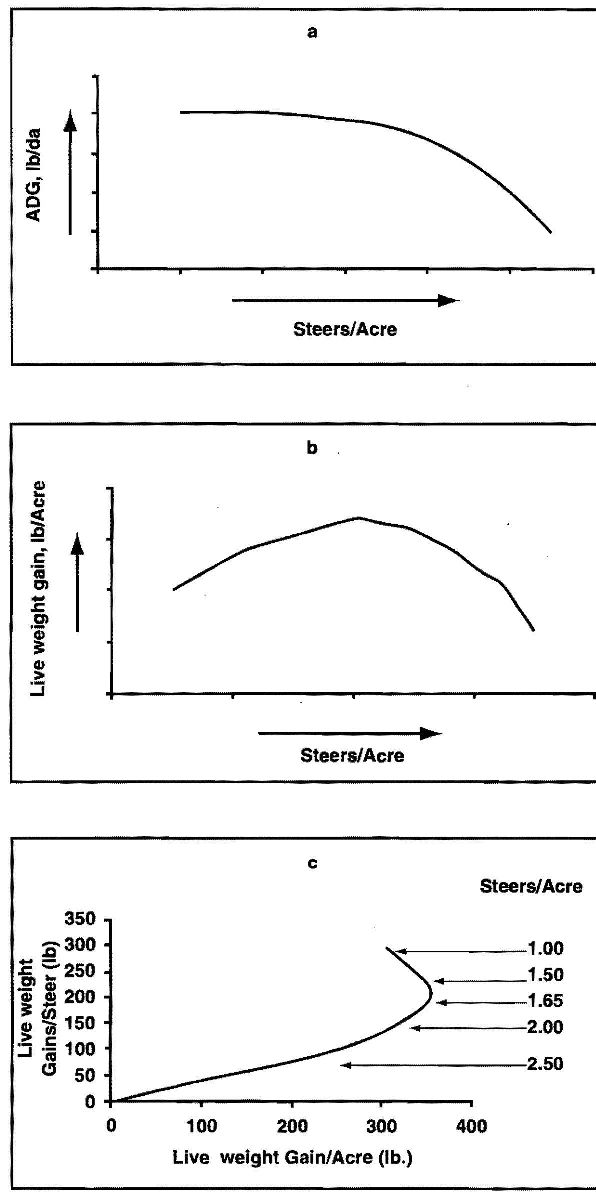

Figure 7. Effect of stocking rate on estimated live weight gain per steer and per acre on dallisgrass-white clover pastures, 1963, Angleton, Texas (Riewe, 1965).

with awareness of the association of stocking rate and animal gains.

McCartor and Rouquette (1977) provided additional explanations for the relationships between animal performance (ADG) and forage allowance (lb/lb BW). These multiple stocking rate data with pearl millet best fit a 2-phase linear model, rather than curvilinear (Fig. 8). Thus, ADG increased linearly with increases in forage available per unit of animal body weight (forage allowance) to a point of maximum gain at which a plateau or flat-line relationship occurred. Additional increases in forage allowance (decreased stocking rate) did not increase ADG.

Net returns from a grazing venture is dependent upon many factors including pasture costs, animal performance, length of grazing season(s), size of animal, absolute price of cattle, margin (purchase price-selling price), etc. In general, the two most important considerations determining profit are stocking rate and margin. Figure 9 illustrates the effect of stocking rate on return per ha (or acre) under three levels of margin: (1) 0; (2) +10¢, and (3) -10¢/kg. Given the pricing scenario used in this example, there was no profitable stocking rate when a negative margin occurred. Thus, if one recognizes a negative margin event, management may consider reducing pasture costs, increasing animal performance, and/or retaining ownership of cattle into the feedlot (even at a zero margin, i.e., selling price = purchase price). There was an opportunity for net profit only at the medium-high stocking rate. On the other hand, when a significant positive margin was in effect, almost any stocking rate was profitable. In general, with a positive margin, management should increase stocking rate to approach maximum gain per unit area. However, with a negative margin in place, management may opt to maximize gain per animal. Hildreth and Riewe (1963) suggested that positive margins tended to cause management to increase stocking rates to achieve maximum returns per unit area. From a forage management-resource conservation perspec-

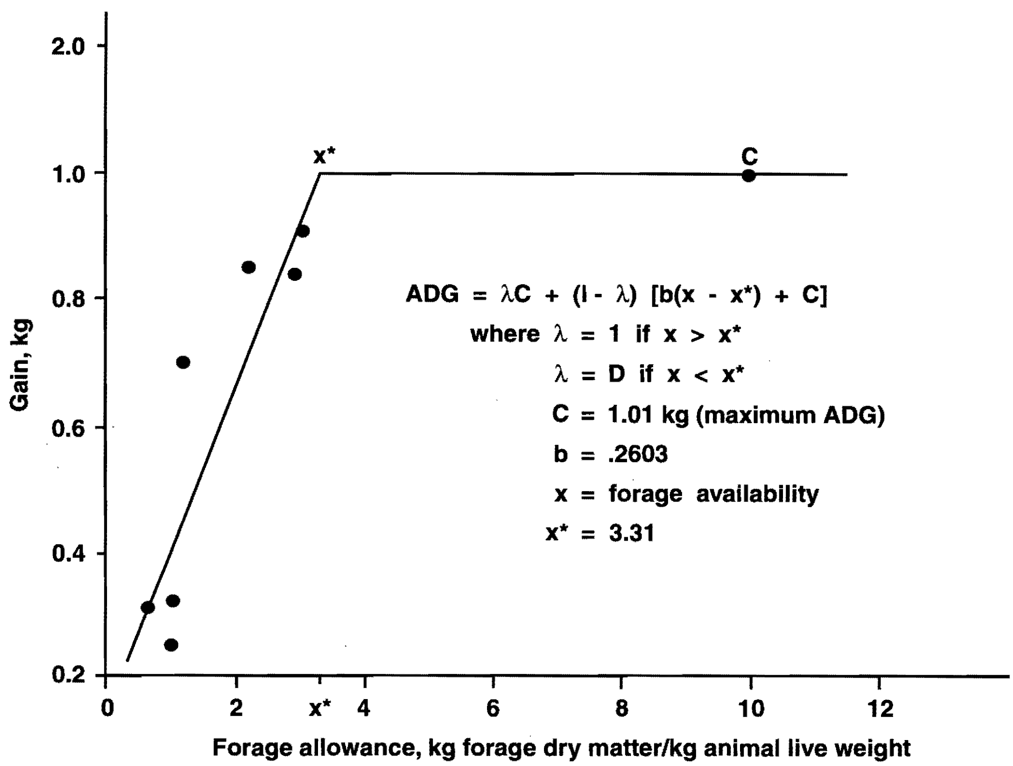

Figure 8. The influence of forage availability on animal gain.

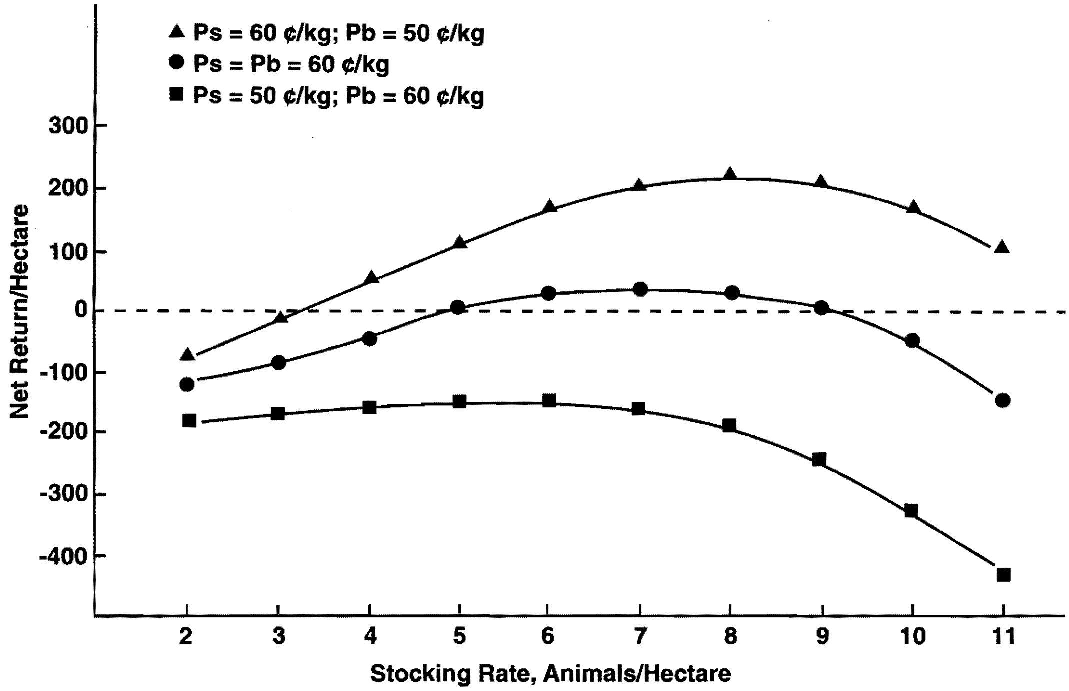

Figure 9. The effect of stocking rate and differences in purchase price (Pb) and selling price (Ps) on return per unit area.

tive, prolonged maximum forage utilization does not promote sustainable pasture systems. When stocking rate diminishes forage availability to the point of low to no ADG either by default or by design, supplementation may provide a short-term remedy. However, in the event of drought or other inclement conditions, the best management decision may be to destock the pasture and relocate cattle to another pasture, the feedlot, or the sale barn.

One strategy to increase production efficiency (gain per acre) by manipulating stocking rate without greatly sacrificing individual animal performance is intensive early stocking. Stocking intensity is increased (doubled, tripled, etc.) for the first part of the growing season when forage growth rate and quality are higher than the last half of the season due to plant age, drought, and temperature (McCollum *et al.*, 1986). Unlike summerlong stocking, grazing is terminated before the cattle are forced to consume lower quality forage, thereby eliminating poor gains. The rangeland supports the same number of grazing days but production per acre is increased about 30% and the grazing period is shorter, allowing longer recovery time. This strategy increases production by utilizing the forage production before the nutritional value decreases, thereby sparing the need for supplemental feeding.

Supplementation

When the available vegetation fails to provide for adequate nutrients to support satisfactory animal performance, these nutrients may be supplied by supplemental feeds. In a previous section, descriptions and nomenclature were presented in a functional way as supplemental, enhancement, and substitute feeding. The feed formulas and methods of feeding may be identical; but, the motives and responses to the feeding may be very different. Often these feeding practices are referred to collectively and interchangeably as either ***supplementation, supplementary feeding,*** or ***supplemental feeding.*** The grazed forage is available free choice and remains the primary component of the diet. The supplemental feed is intended to enhance the animal's performance or efficiency from forage. Many studies conducted in Texas attempted to quantify animal performance, feed:gain, and identify proper methods for supplementing grazing cattle. In addition to supplying limiting nutrients (protein, energy, minerals, etc.), supplementary feeds often serve as delivery methods for medications, probiotics, anthelmintics, ionophores, vaccines, etc.

Generally, feeding of supplemental feed is most profitable when small amounts of feeds are used that provide concentrated sources of the specific nutrients that are below optimal levels in the available forage. Salt is almost universally deficient in forages so should be universally provided. When indicated by soil and forage tests and observed benefit, phosphorus and trace minerals should also be provided. Dietary energy can be stored by the animal during seasons of excessive digestible energy in the forage for limited use during periods of low digestible energy concentrations in the forage. Surplus CP can be stored by the animal in amounts sufficient to pro- vide for only a few days of dietary CP deficiencies. Thus, CP should be the focus of most (but not all) supplemental feeding strategies for permanent pastures and rangeland. Results of two tests are presented in Tables 8 and 9 as exercises in interpreting responses that might be observed with supplemental feeds. In each trial, growing heifers were grazed unrestrained on pastures with adequate amounts of forage and supplements as described were given in addition in the indicated amounts. The results of the first trial (Table 8) led to the following conclusions with regard to crossbred heifers grazing bermudagrass pastures fertilized to soil test:

1. **Conclusion:** The grazed bermudagrass was adequate in all minerals for the observed growth rate of these heifers.
2. **Conclusion:** Monensin increased ADG, especially at the higher supplies of CP, indicating that monensin increased ruminal efficiency of microbial protein nutrition (protein sparing).
3. **Conclusion:** Supplemental energy with a small amount of supplementary CP (9% CP basal) resulted in slight increases in ADG over the mineral control.
4. **Conclusion:** Supplemental CP increased ADG, indicating that the grazed bermudagrass was deficient in CP for the observed growth rate of the heifers. However, the maximal level of supplementary CP was not defined.

Results from the second example trial are summarized in Table 9 to illustrate the need for different types of supplementation for growing calves grazing cool-season vs. warm-season forages. The more rapid ADG from ryegrass as compared to bermudagrass was due to smaller levels of NDF and consequent greater yield of metabolizable energy from ryegrass. Typically, 80% or more of the CP of grazed forages is DIP which, in the case of ryegrass, exceeds the requirement for DIP for microbial growth and digestion of PDF. For calves grazing cool-season grasses, use of grain-based (energy) supplements of low CP content and containing monensin proved as effective as supplemental CP and monensin. Thus, for forages containing surplus DIP, supplements rich in rapidly digestible starch are recommended in contrast to lower energy. Higher CP supplements are recommended for DIP deficit forages such as bermudagrass.

Stocker cattle

The use of small quantities of feed to supplement grazing immature cattle began in the early 1970s to: 1) evaluate the effects of feed and forage efficiency using monensin and 2 lb/hd daily of an energy ration and 2) enhance individual animal gains on warm-season perennial grasses (Raun *et al.*, 1974a,b). This effort to commercialize an ionophore led directly to additional research using minimal quantities of supplemental energy and/or protein (Oliver, 1975; Rouquette *et al.*, 1980). Grazing research initiated in the 1970s suggested that daily supplementation levels of 0.2 to 0.5% body weight (BW) were significantly more efficient than traditionally used daily levels of 1% BW. At 1% BW, the supplement ration substitutes for forage rather than providing an additive or enhancement effect. Since this supplementation on pasture research was initiated, other additives such as Bovatec™ (Lomas, 1982; Chirase *et al.*, 1989), Gain Pro™ (Rush *et al.*, 1996), and other ionophores (NRC, 1996) have emerged.

Stocker cattle are expected to increase weight, usually at a lower rate than their genetic potential for gain, at a low cost over a relatively long time preceding a finishing period in the feedlot. This stocker period may correspond with or include a preconditioning program, which is specifically to prepare the growing cattle to thrive when placed in the feedlot. The

Table 8. Effects of different supplemental nutrients and monensin upon average daily gain (ADG) of heifers grazing bermudagrass pastures containing 10 to 14% crude protein (CP) during grazing seasons of April 1 to October 3 (College Station, Texas).

	Daily intake of				
Feeding practice	DM lb/d	CP lb/d	DE Mcal/d	ADG lb/d	Increased ADG lb/lb suppl.
Pasture only	0.00	0.0	0.0	0.97a	0.00
Pasture + minerals	0.23	0.0	0.0	1.02[a]	0.20
Pasture + minerals + monensin	0.20	0.0	0.0	1.16[b]	1.00
9 % CP Basal[e]	2.77	0.25	2.0	1.15[b]	0.06
9 % CP Basal + monensin	2.55	0.23	1.8	1.19[b]	0.09
18% CP Basal[f]	2.55	0.46	1.8	1.30[c]	0.13
18 % CP Basal + monensin	2.55	0.46	1.8	1.45[c]	0.19
32% CP basal[f]	2.31	0.74	1.7	1.40[c]	0.19
32% CP basal + monensin	2.22	0.71	1.6	1.67[d]	0.32

a,b,c,d Means within column having unlike superscripts differ, $P < 0.05$.
e Basal supplement composed of rice mill feed, minerals and liquid fat.
f Basal with a mixture of feather meal, corn gluten meal, fish meal and blood meal being substituted for rice mill feed.

Table 9. Mean average daily gain (ADG) responses by growing steers fed 2 to 4 lb/d of supplements with monensin (M) when grazing pastures containing different levels of CP (Overton, Texas).

				ADG			
Pasture	No. of trials	Nutritive entities NDF %	CP %	Corn-based supplement[a]	Mineral supplement lb/day	Complete supplement lb/day	Increased ADG lb/lb suppl.
Bermudagrass	14	60-70	10-14	32% CP+M	0.97[c]	1.61[b]	0.50
Ryegrass	5	35-40	16-23	32% CP+M	2.18[c]	2.89[b]	0.50
Ryegrass	2	35-40	16-23	32% CP+M	2.31[c]	2.57[b]	0.41
Ryegrass	2	35-40	16-23	8% CP+M	2.31[c]	3.13[b]	0.45

a Supplement contained monensin to provide 200 mg/steer daily.
b,c Mean ADG for complete supplement is greater than for mineral supplement, $P < 0.05$.

structure of the stocker program depends on the available forage resources, which dictate type of cattle, period of grazing, and feeding program.

Summer pastures - introduced

Introduced forages for summer pastures usually are established either on cropped or previously cropped areas or to replace less productive native vegetation. These forages include bermudagrasses, bahiagrass, kleingrass, buffelgrass, lovegrasses, etc., that are generally well-adapted, responsive to fertilization, and tolerant to defoliation regimens. A gradual change in forage type can be observed while traveling across Texas, largely as a result of the gradation of annual rainfall. The best adapted species to the climate, management, and economic expectations usually prevail. Native vegetation is most common in the western, low-rainfall region and is gradually replaced by introduced species as rainfall and flexibility in management increases toward the eastern region. Virtually all intensively managed summer pastures in eastern Texas and along the gulf coast are introduced species. Unlike high-quality winter pastures (> 70% digestible organic matter), summer pastures seldom contain sufficient nutrient concentrations to produce high gains (> 2 lb/day) by individual stocker animals (Melton, 1965). However, summer pastures produce greater amounts of dry matter, especially when cultural practices are applied, and can produce high live animal gains per acre without supplementation. Supplements can further increase gains per acre by enhancing individual animal gains.

Feeding concentrates (supplements high in energy and/or protein) to stocker cattle grazing summer pasture is a strategy to enhance individual ADG and/or accommodate higher stocking rates for high harvest efficiency without reducing ADG. Using a 2 lb/hd daily ration of cracked corn and monensin, Oliver (1975) and Rouquette et al. (1980) illustrated the opportunities to move beyond the "pound-a-day gain" mind-set for stockers grazing bermudagrass throughout the summer months. These supplementation studies indicated increases of 50 to 70% in stocker ADG with gains of 1.5 to 1.7 lb/day. Perhaps the most noteworthy response detected was the feed:extra gain ratio of 2.9:1 (Oliver, 1975) to 4:1 (Rouquette *et al.*, 1980). Additionally the use of ionophores led to reports of enhanced forage:gain efficiencies of approximately 21 to 31% (Rouquette *et al.*, 1980).

Increased gains for calves grazing summer pastures can result from feeding either a high energy or high protein concentrate even when the CP content of the forage appears to meet animal requirements (NRC, 1996). A summary of six supplementation experiments with stocker cattle grazing warm-season grasses is shown in Table 10. Data from these experiments were similar in the respect that 1) Rumensin™ (trade name of monensin) enhanced ADG and/or supplement:incremental gain ratio efficiency, 2) small quantities of supplement (about 0.25% BW) were reliable in efficiency of action, and 3) protein sources high in undigested intake protein (UIP) fractions, such as fish meal and feather meal, were most effective and efficient in promoting increased gains by increasing absorbed amino acids and improving the protein:energy balance at the cellular level in growing cattle.

Most data support the concept that available energy is the first limiting factor in summer pasture forages, and protein (amino acid) quality and availability is the second (Hill *et al.*, 1991). Growth rate can be increased by feeding energy (grains) which partially replaces the forage but results in a greater digestible energy intake and increased efficiency of energy utilization (enhancement feeding; Lippke and Ellis, 1991; Oliver, 1975; Rouquette *et al.*, 1980). Feeding of a small amount of the condensed molasses block (CMB in Table 10) provides some readily available energy (molasses) and ammonia. These supplies stimulate ruminal microbial activity, increase fermentation and fiber digestion, release encapsulated (constrained by lignification) protein from the forage, and increase intake and daily gain. High protein concentrates that contain a good supply of digestible energy affect intraruminal activity and forage intake similarly with the condensed molasses blocks. In addition, high protein concentrates create an energy sparing effect by providing amino acid carbon skeletons for efficient synthesis into microbial protein (Ellis *et al.*, 1999) and provide undegraded intake protein (UIP) that further increases the quantity of absorbed amino acids. Therefore, concentrates fed to growing cattle on summer pastures increase intraruminal digestion efficiency, forage intake (if fed in small quantities and especially if protein > 32%), and absorbed amino acids. Protein sources that contain a high proportion of UIP with a favorable amino acid bal-

Table 10. Effects of concentrates on growing cattle grazing coastal bermudagrass pasture

Items	Treatments[a]										
	PAST	CORN	CMB	CSM	SOY	FISH	FEAT	CORN + R	CSM + R	FISH + R	FEAT + R
Suppl. intake, lb/d											
Hutcheson *et al.* (1986)								3.12	1.37	1.28	
Grigsby *et al.* (1989)			.44	1.92		.46				1.12	
Grigsby *et al.* (1989)			.50		1.05	1.60				.84	
Rouquette *et al.* (1993)						1.25	1.25				
Lippke and Ellis (1991)		.91				.74					
Ellis *et al.* (1995)				1.89					1.89		1.57
Average daily gain, lb/d											
Hutcheson *et al.* (1986)	1.50							1.84	1.88	2.14	
Grigsby *et al.* (1989)	1.04		1.29	1.52		1.21				1.92	
Grigsby *et al.* (1989)	.84		1.10		1.54	1.37				1.49	
Rouquette *et al.* (1993)	1.17									1.57	1.82
Lippke and Ellis (1991)	.60	1.00				1.02					
Ellis *et al.* (1995)	1.08			1.36					1.64		1.64
Supplement/incremental gain, lb											
Hutcheson *et al.* (1986)								9.2	3.6	2.1	
Grigsby *et al.* (1989)			1.8	4.0		2.7				1.3	
Grigsby *et al.* (1989)			1.9		1.5	3.0				1.3	
Rouquette *et al.*(1993)						3.2	2.0				
Lippke and Ellis (1991)		2.2				1.7					
Ellis *et al.* (1995)				6.8					3.4		2.8

[a] Treatments included pasture only (PAST) and pasture plus concentrates including corn (CORN), condensed molasses block (CMB), cottonseed meal (CSM), soybean meal (Soy), high fish meal concentrate (FISH), high feather meal concentrate (FEAT), Corn and Rumensin™ (CORN + R), cottonseed meal and Rumensin™ (CSM + R), low solubility fish meal and Rumensin™ (FISH + R), and feather meal plus Rumensin™ (FEAT + R).

ance are of greater value than those that are highly degraded (especially NPN sources) in the reticulorumen (Hill and Ellis, 1992; Hill *et al.*, 1991), especially for cattle having high growth potential (Grigsby *et al.*, 1988b). Ionophores appear to extend the protein effect in growing cattle grazing summer pastures and increase both gain and efficiency (Table 10; Rouquette *et al.*, 1980; Oliver, 1975; Pond and Ellis, 1981a,b).

Summer pastures - native

Feeding protein and energy concentrates to cattle grazing rangeland during the summer growing season gives similar results but is less common in Texas than as described for introduced pastures (Table 11). Studies in Oklahoma (McCollum and Lusby, 1989; McCollum *et al.*, 1986) show that gains by nonsupplemented steers grazing tallgrass prairie during the early summer growing season are relatively high (1.25 to 2.10 lb/day). Supplements that are high in protein can increase gains by about 35% in lightweight calves (< 400 lb). Gains during late summer are low (.83 to 1.06 lb/day) and generally unsatisfactory without supplementation (Fleck *et al.*, 1986; McCollum *et al.*, 1985).

With 1 to 2 lb/day of a high-protein (> 30% CP) supplement, gains may increase by about 50%. An additional increase (up to 20%) in gain results when an ionophore is included to provide 100 to 200 mg/head daily (McCollum *et al.*, 1988). Energy supplements (e.g., corn) at comparable levels, although sometimes effective in increasing gains during early forage growth and when protein content is high, are relatively ineffective in increasing gain in cattle graz-

Table 11. General expectations for growth rates and responses to supplemental feeds in stocker cattle (400 to 600 lb) grazing range during the growing season in Texas.[a]

Season	Forage type	Supplement type[b]	Feeding level, lb/d	Gain, lb/d
Spring/early summer				
	Warm-season	None		1.25 - 2.25
		High protein	.75 - 1.00	1.75 - 2.75
		High energy	.75 - 2.00	1.25 - 2.75
Late summer/early fall				
	Warm-season	None		0.50 - 1.25
		High protein	1.00 - 1.50	1.00 - 2.00
		High energy	1.00 - 3.00	0.50 - 1.50

[a] These estimates were compiled and extrapolated from data reported by Clanton and Zimmerman (1970), Huston *et al.* (1980), Huston and Spiller (1981), Lusby and Horn (1983), McCollum *et al.*. (1985), Fleck *et al.* (1986), McCollum *et al.* (1986), Judkins *et al.* (1987), McCollum *et al.* (1988), McCollum and Lusby (1989), Villalobos and Britton (1992), and Villalobos *et al.*. (1998).

[b] Supplements referred to as high protein are considered to contain > 30% CP from plant and animal by-product sources. High energy supplements typically would be composed of ingredients high in energy such as grains, molasses, and fat and contain < 20% crude protein and > 70% TDN.

ing low quality summer range (Lusby and Horn, 1983; Villalobos *et al.*, 1998).

Winter pastures - high quality

Cool-season annual forages have been used in the south and southeastern U.S. for many years for the purpose of adding weight to stocker cattle before the feedlot period was initiated and/or fattening cattle with limited to no additional feed required prior to slaughter (Burton *et al.*, 1949; McCormick *et al.*, 1958; Godbey, 1959; Harris *et al.*, 1971, Louisiana work, Texas work). In view of the high digestible nutrient content of these forages (Grigsby *et al.*, 1988c; Lippke *et al.*, 2000; Pinchak *et al.*, 1989), offering a variety of feed grains and rations to stocker cattle grazing winter pastures likely had two primary objectives: 1) to use cheap feed grain sources to add animal weight economically and 2) to buffer the effect of over-stocking pastures. Wagner *et al.* (1983), at the National Wheat Pasture Symposium in Oklahoma, cited several winter pasture grazing experiments from Oklahoma, New Mexico, Georgia, and Alabama in which various levels of high energy rations were fed to stocker cattle. Several of those experiments used daily concentrate rations of 1 to 2% BW. At these levels of feeding, the term, supplementation, may have been used erroneously, because the data clearly show the impact of substitution of feed grains for pasture. The average extra gain:daily feed consumption in these experiments were .059 (5.5 lb corn/day), .057 (10.7 lb corn/day), .034 (9.3 lb grain sorghum/day), .014 (9.5 lb corn/day), .050 (13 lb grain sorghum/day), .051 (13 lb corn/day), .027 (8.5 lb citrus pulp/day) .024 (5 lb corn/day), and .039 (8.7 lb corn and peanut skins/day).

Tables 12 and 13 illustrate the dynamics of intake and digestion of steers grazing high quality winter forages (ryegrass) (Telford *et al.*, 1984). Early in the grazing season, forage diets

Table 12. Dynamics of intake and digestion in steers grazing ryegrass at two maturity levels.[a]

Item	Maturity level of annual ryegrass pasture	
	Immature	Mid-maturity
IVDDM[b], %		
Standing forage	65.5	58.2
Diet	74.6	66.8
Diet DDM[c] (in vivo), %	71.6	70.1
Ruminal fill, lb/100 lb	.98	1.09
Turnover rate, %/hr	9.8	4.7
Dry matter intake, lb/100 lb	3.15	2.85

[a] Adapted from Telford *et al.* (1984).
[b] *In vitro* digestible dry matter - the fraction of the dry matter that is digestible estimated by *in vitro* fermentation.
[c] Digestible dry matter.

Table 13. Dynamics of intake and digestion in steers grazing annual ryegrass at three levels of stocking (forage allowance).[a]

Item	Forage allowance (lb forage DM/100 lb BW)		
	Low (68.0)	High (24.8)	Extreme (7.2)
IVDDM, %			
Standing crop	62.3	62.0	63.0
Diet	70.4	71.3	69.9
Diet DDM (in vivo), %	71.4	71.6	68.3
Ruminal fill, lb/100 lb	1.11	.96	.97
Turnover rate, %/hr	9.8	8.0	6.5
Dry matter intake, lb/100 lb	3.3	3.2	2.8

[a]Adapted from Telford *et al.* (1984).

were highly digestible. Later in the grazing season, ruminal fill was greater and turnover was slower (.047 vs .098 per hour). The IVDDM values in both tables demonstrate the differences in estimates of digestibility between standing crop and the diet selected despite the generally higher quality of these forages.

Unlike permanent warm-season pastures (Roth *et al.*, 1986) or mixed vegetation on rangeland (Allison, 1978; Ralphs *et al.*, 1986), the nutritional value of diets consumed by steers grazing winter annual pastures is minimally affected by stocking rate until grazing pressure becomes severe. Forage mass is relatively similar within a reasonable range in stocking rate. This allows increases in production per unit area with only slight negative effects on animal performance. However, when grazing pressure becomes extreme, quantity of forage becomes limited, opportunity for diet selection is minimized, prehension becomes difficult, and forage intake is reduced. These lowered forage intakes result in depressions in animal daily gains that exceed any advantage of increased numbers of animals and in a net decrease in production per unit land area. In the cited data with steers grazing ryegrass pastures (Table 13), forage and diet digestibilities were unaffected until grazing pressure became severe and forage intake and animal gains were reduced. Relationships between ADG and forage available had similar implications for pearl millet (McCartor and Rouquette, 1977) with respect to a ceiling or plateau of ADG (Fig. 8). Ceiling or plateau ADG occurs when substantial forage DM is available for diet selection and maximum live weight gains are not increased with additional forage or pasture area. For the novice grazier, forage mass and growth rate estimates or measurements are critical components for achieving optimum, economic stocking rates. For the experienced grazier, visual appraisals of pastures and animals have often become integrated unconsciously into management decisions.

The CP content of winter annual forage is usually one and one-half to two times the minimal level suggested for growing steers (NRC, 1996). However, ruminal fermentation and protein breakdown are so rapid with these high quality forages that stocker steers may not have enough amino acids supplied to muscle tissues to support high rates of growth. Providing dietary energy to utilize the apparent excess CP has not been beneficial (Lippke *et al.*, 2000), whereas small amounts of supplementary proteins that resist degradation in the rumen have increased ADG on winter annual forages. Grain supplements carrying the ionophore, monensin, have also increased ADG, presumably because monensin inhibits at least some ruminal species that are most active in amino acid breakdown.

Rouquette *et al.* (1982) supplemented a combination of steers and heifers grazing ryegrass pastures in eastern Texas (Table 14) with 2 lb cracked corn + monensin/hd daily. One of the most noteworthy occurrences in this winter pasture experiment was that during the first 56 days of grazing, Nov. 8 to Jan. 13, stockers that received the corn + monensin supplement gained 1 lb/hd daily more than stockers on pasture only (1.33 lb/day; 0.34 lb/day). Thus, the contribution of ration DM and/or energy plus monensin· likely influenced rumen function and adaptation to the high quality winter pasture. Supplement refusals measured on a weekly basis showed that the three replicate groups consumed about 95% of the self-limiting, targeted 2 lb/day ration. Supplement was fed at .37% BW, which increased ADG from 1.73 to 2.11 lb/day. The incremental (extra) gain of .38 lb was produced with a gain:supplement ratio of .189:1, which was similar to that found by Horn *et al.* (1981).

Table 14. Effect of corn plus monensin on gain of stocker cattle grazing rye-ryegrass pasture.[a]

Item	Treatments	
	Pasture only	Corn + monensin[b]
Number of cattle	30	30
Average daily gain, lb/d	1.73[d]	2.1[c]
Gain per acre, lb	517[d]	644[c]

a Rouquette *et al.* (1982).
b Corn plus monensin (200 mg/hd) self-limiting ration fed at 2 lb/hd daily.
c,d Numbers within a row followed by a different letter are different at P < 0.05.

Perhaps one of the most dramatic animal gain responses to supplementation offered to stockers grazing rye-ryegrass pasture occurred in a study conducted in the mid-1980s (Grigsby *et al.*, 1988c; Grigsby *et al.*, 1991). In this 2-year experiment, a pelleted supplement included rolled corn (82% of ration), salt, minerals, and monensin that was fed free-choice (self-limiting) with average daily intake of less than 2 lb/hd. A fish meal ration (UIP source) with monensin was also used. The ADG during the two successive years (Table 15) was 2.2 and 2.4 lb on pasture alone, 3.5 and 2.8 lb for pasture plus corn + monensin ration, and 2.6 and 2.5 lb for pasture plus fish meal + monensin ration. The level of supplement consumed was about 0.25% of BW for the corn ration and 0.1% of BW for the fish meal ration. The differences in animal performance in these experiments and those of Horn *et al.* (1990) and Rouquette *et al.* (1982) likely were because of differences in initial weight of cattle, forage availability, mild wintering conditions, and the inclusion of a broad spectrum of minerals and other ingredients.

Following the late 1970s to mid-1980s, grazing experiments using small daily quantities (<0.5% BW) of energy and/or protein rations illustrated the sensitive response to level of daily supplement, ionophore presence, and ration components (Rouquette *et al.*, 1990; Rouquette and Florence, 1993; Rouquette *et al.*, 1994). A summary of five experiments showed that as level of supplement increased, gain response diminished and extra gain:supplement ratio declined (Rouquette *et al.*, 1992).

Providing energy supplements to steers grazing wheat pasture resulted in similar increases in gain and efficiency (Horn *et al.*, 1990; Vogel *et al.*, 1989) with those cited for rye-ryegrass. Feeding energy at a higher level (supplement at 1% of body weight) does not further increase gain, and efficiency of converting supplement to extra gain is reduced. How-ever, stocking rate can be increased or grazing period lengthened because the higher supplement intake decreases forage intake (substitution effect). High-protein supplements (> 32% CP) fed at comparable levels seem to produce similar increases in gain, irrespective of the relative ruminal degradability of the supplemental protein (Smith *et al.*, 1990). A production advantage may occur only when supplement intake is low and the net effect is to maintain or stimulate increased forage intake and thereby gain.

Table 15. Performance of stocker calves grazing ryegrass pastures and receiving supplemental feeds.[a]

Item	Treatment[b]					
	Pasture alone		Pasture + CRN		Pasture + FML	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Average daily supplement consumption, lb/d	—	—	1.7	1.1	0.8	0.3
Average daily gain, lb/d	2.21[d]	2.40[d]	3.47[c]	2.77[c]	2.62[d]	2.53[d]
Additional gain	—	—	1.26[c]	0.37[c]	0.41[d]	0.13[d]
Gain/supplement ratio	—	—	0.75	0.33	0.54	0.41

a Summarized from Grigsby *et al.* (1991).
b Treatments were rye-ryegrass pasture with free-choice minerals, pasture plus a corn-based supplement (CRN; 8% CP), and pasture plus a fish meal-based supplement (FML; 37% CP).
c,d Numbers in rows, within a year, followed by the same letter do not differ at P < .05.

The loss in body weight during the first week after animals are turned onto high quality winter forage is associated primarily with loss of ruminal and lower gut fill as the change in diet markedly increases ruminal fermentation and turnover rates (H. Lippke, unpublished data; F. M. Rouquette, unpublished data). A longer period of low to medium growth rates is also commonly observed at the beginning of the grazing season (Riewe *et al.*, 1984), but it is not well understood or predictable (Lippke *et al.*, 2000). Lippke and Warrington (1984) observed elevated lactic acid levels in cattle that were switched from low-protein sorghum silage to synthetic diets that simulated ryegrass. However, Lippke *et al.* (2000) found no evidence of lactic acidosis in animals that had low initial weight gains on wheat pasture.

In the absence of ruminal lactic acid, other causes for the malaise exhibited by young cattle during the first days or weeks on winter pasture are being investigated (H. Lippke, unpublished). Provenza (1995) cites abundant evidence that an aversive learning event is a source of the malaise, with ammonia as the likely toxin reinforced by high rates of digestion. Although the liver is generally capable of handling the ammonia load resulting from rapid digestion of these grasses, its capacity to adapt within hours to an instantaneous switch from low to very high CP diets is in question. Even a short period of excessive ammonia escape into the peripheral blood flow could set in motion a cyclic pattern of reduced intake (Provenza, 1995).

Both researcher and producer observations suggest that judicious management of stocker cattle with respect to health programs and backgrounding diets is the best alternative to avoid low ADG during the first weeks on pasture. Although not rigorously tested, a diet composed of freechoice, medium quality hay and large amounts of a high-protein supplement fed twice weekly (e.g., cottonseed meal cake) for two weeks before turnout appears to give good results.

Bloat and wheat pasture poisoning (tetany) are intermittent, yet serious, problems in cattle grazing high quality winter forages. Bloat has long been recognized as a health risk in stocker cattle grazing high quality, cereal grain pastures (Clay, 1973). The compound poloxalene, proven effective in prevention of legume bloat (Bartley *et al.*, 1965) and free of adverse effects on growth (Lippke *et al.*, 1970) in calves, was shown to prevent, as well as treat, bloat in cattle grazing pasture (Bartley *et al.*, 1975; Lippke *et al.*, 2000). Ruminal changes favorable for prevention of bloat are created when monensin is fed to cattle grazing either legumes (Katz *et al.*, 1986) or wheat pasture (Branine and Galyean, 1990). Therefore, bloat is problematic but can be controlled to an acceptable level. Wheat pasture poisoning (grass tetany) can cause large losses, especially in lactating cows (Sims and Crookshank, 1956). This metabolic disorder is an expression of hypomagnesemia and can be prevented/treated with therapeutic administration of dietary magnesium.

Supplement forms and methods will be addressed in a separate section of this bulletin. However, supplementation on winter pasture is unique and has been studied in attempts to control intake, correct deficiencies, and deliver medications. Self-fed supplements often contain ionophores, salt, and other mineral ingredients to control the level of intake. Examples of rations designed for free-choice supplements are shown in Table 16.

Table 16. Free-choice supplements for stocker cattle grazing high quality winter pasture.[a]

	Desired daily consumption	
Item	**1 lb/hd**	**2 lb/hd**
Grain (corn, sorghum, etc), %	72.5	88.25
Salt (sodium chloride), %	6.0	3.0
Limestone (calcium carbonate), %	12.0	6.0
Magnesium oxide, %	1.5	.75
Dicalcium phosphate, %	4.0	2.0
Ionophore, mg/lb	180	90

[a]Taken from Hutcheson (1992).

One of the most efficient supplemental rations for stocker cattle grazing cool-season annual pastures such as wheat, rye, ryegrass, etc. is that suggested by Hutcheson (1992). This corn-based ration is reliable for self-limiting 500 to 600 lb stockers to about 2 lb/hd daily. Ingredients which contribute to the limited intake include salt (4%), limestone (2%), magnesium oxide (1%), dicalcium phosphate (7%), trace mineral pre-mix (0.25%), and monensin (60 mg/lb; .15%). Rouquette *et al.* (1990) evaluated the above-mentioned corn-based, self-limiting ration for its ability to limit cattle to 2 lb/hd or 4 lb/hd daily. Cattle fed the targeted 4 lb/hd daily were offered a supplement, which was a 50% dilution of non-corn ingredients (Table 17).

Table 17. Free-choice supplements to limit ration intake.

Ingredient	1 X ration[a]	2 X ration
	--------- % DM ----------	
Cracked corn	85.6	92.8
Salt	4.0	2.0
Limestone	2.0	1.0
Magnesium oxide	1.0	0.5
Calcium phosphate	4.0	3.5
Rumensin 60	.15	.075
Trace mineral pre-mix	.25	.125
Stocker intake, daily		
Rep 1, lb/hd	2.22	4.25
Rep 2, lb/hd	2.42	3.07
Avg, lb/hd	2.32	4.06

[a] The 1 X ration is that proposed by Hutcheson (1992) to limit stockers grazing winter pasture to about 2 lb/hd daily.

Using 650 lb stockers, weekly weigh-backs (orts) of the two self-limiting rations during a 15-week experiment showed group-fed daily intakes of 2.32 lb/hd for 1 X ration and 4.06 lb/hd for the 2 X ration (Table 17). Thus, during the winter pasture grazing period, this basic formulation was very effective at limiting daily intake to the targeted 2 lb or 4 lb/hd level. Certainly, daily supplement intake was not constant on a per head or per week basis. Replicate weekly intake averages for the 2 lb/day ration ranged from 1.5 lb/hd to 3.4 lb/hd daily, whereas weekly average intake for the 4 lb/day ration ranged from 3.0 to 5.8 lb/hd daily.

In a related experiment (Rouquette, personal comm.), altering this basic Hutcheson ration from a 2 lb/hd daily to a 1 lb/hd daily was not nearly as functional nor as effective. When the non-corn ingredients were doubled as a percentage of the 1 X ration (Table 17), the targeted 1 lb/hd daily level was not achieved. The failure of this condensed ration was that some animals refused the ration, whereas other animals apparently consumed at a level in excess of 1 lb/hd daily. As a result, the simple approach of increasing non-corn ingredients to restrict intake to 1 lb/hd daily was not effective.

Winter pastures - dormant rangeland

Feeding growing cattle on dormant rangeland is essential to achieve satisfactory performance. Stocker calves grazing rangeland during winter in southern Texas (Holloway *et al.*, 1997), central Edwards Plateau (Huston *et al.*, 1980), southern Edwards Plateau (Huston and Spiller, 1981), and Southern High Plains (Villalobos and Britton, 1992) of Texas, and south-central New Mexico (Judkins *et al.*, 1987) gained on average .14 lb/day (range = -.10 to .56 lb/hd daily). Conditions ranged from a cold, dry winter with only dormant vegetation to a rather mild winter with plentiful growing Texas wintergrass (*Stipa leucotricha*) available for grazing. When supplemented with 1 to 2 lb/day of high-protein concentrates (> 30% CP), ADG was .64 lb/day, presumably because of increased forage intake and higher amino acid absorption. Again, energy (grain) supplements have been less effective, sometimes detrimental, for increasing gain of stocker cattle grazing dormant range forages (Clanton and Zimmerman, 1970).

Table 18 presents general expectations for feeding stocker cattle on rangeland. The differences in feeding levels and responses are extrapolations of actual data and expected differences in grazing circumstances. The highest rate of gain will occur during spring/early summer. However, the greatest response to supplements will occur late in the growing season after forage quality and intake have declined. Responses to supplementation during winter dormancy will be highly variable depending on plant species composition and climate severity. Generally, high protein concentrates fed at relatively low levels will be most effective. Energy supplements will usually be ineffective or even detrimental except when fed at very high levels (high substitution rate), thereby simulating feedlot conditions.

Breeding cattle

The emphasis in nutritional management of breeding cattle is on developing and maintaining a healthy and active reproductive system. Seldom does feeding of supplementary feeds to cows adapted to the environment in which they are managed lead to economic increases in

Table 18. General expectations for growth rates and responses to supplemental feeds in stocker cattle (400 to 600 lb) grazing dormant, winter rangeland in Texas.[a]

Season	Forage type	Supplement type[b]	Feeding level, lb/day	Gain, lb/day
Late fall/winter				
	Dormant	None		- 0.10 to 0.25
		High protein	1.00 to 2.00	0.35 to 0.75
		High energy	1.00 to 2.00	0.00 to 0.25
	Mixed (includes some green)	None		0.00 to 0.50
		High protein	1.00 to 1.50	0.75 to 1.25
		High energy	1.00 to 3.00	0.25 to 0.75

[a] These estimates were compiled and extrapolated from data reported by Clanton and Zimmerman (1970), Huston *et al.* (1980), Huston and Spiller (1981), Lusby and Horn (1983), McCollum *et al.* (1985), Fleck *et al.* (1986), McCollum *et al.* (1986), Judkins *et al.* (1987), McCollum *et al.* (1988), McCollum and Lusby (1989), Villalobos and Britton (1992), and Villalobos *et al.* (1998).

[b] Supplements referred to as high protein are considered to contain > 30% CP from plant and animal by-product sources. High energy supplements typically would be comprised of ingredients high in energy such as grains, molasses, and fat and contain < 20% crude protein and > 70% TDN.

weaning weights of calves. However, feeding for high reproductive success is often an economically sound decision. Actually, breeding cattle should be considered and managed as three separate groups. Stocker heifers must be grown to proper size at puberty and at calving to accommodate birth and re-breeding. First-calf heifers are expected to concurrently produce milk, continue to grow toward maturity, initiate estrous cycles, conceive, and maintain pregnancy. Mature cows succeed in reproduction by properly synchronizing fluctuations in body condition (fat stores) with differences in energy requirements for bodily processes and energy supply derived from the forage source. In each case, supplemental feed is often required to achieve performance expectations, especially in environments having highly variable and unpredictable weather.

Replacement stocker heifers

Replacement heifers are managed similarly to stocker steers except gain after weaning is managed to achieve a target weight at breeding rather than to minimize cost of gain. Heifers intended for breeding at 12 to 14 months of age should reach 60 to 70% of mature weight by the beginning of the breeding season in order for a large percentage to reach puberty (Sprott and Wiltbank, 1980) and to assure adequate skeletal dimensions for giving birth (Carpenter and Sprott, 1991). The actual target weight depends on breed, frame size, and season. Rate of postweaning weight gain depends on the age of heifer at weaning, weaning weight, and target breeding weight. Actually, the final breeding weight is more important than the periodic gains necessary to achieve it (Clanton *et al.*, 1983; Lynch *et al.*, 1997). Slow rates of gain after weaning followed by rapid rates of gain for a 45 to 60-day period before breeding seems as effective as moderate, uniform rates of gain during the prebreeding period for supporting the onset of puberty and estrous cycles. Alternatively, rapid gains followed by slower gains is also an acceptable management practice. This allows the manager flexibility to best manage available resources.

Elevated nutrition necessary to develop replacement heifers can be provided by high quality pasture or by concentrates fed to supplement low to medium quality pasture or range. By considering expected gains on high quality winter pasture (Table 15) and supplemented summer (Table 11) or dormant winter pastures/ranges (Table 18) and the weight gains necessary to achieve target breeding weights (Table 19), one can develop a strategy for replacement heifer management. As an example, consider a group of heifer calves expected to reach a mature weight of 1150 lb. If weaned October 1 at 8 months of age and weighing 550 lb, these heifers must gain 200 lb in order to breed beginning March 1 (age = 13 months). Rate of gain for this 150 days should average about 1.25 to 1.5 lb/day. High quality winter pasture (wheat, ryegrass, etc.) will produce the necessary gain in 100 days or less, allowing the heifers to graze lower quality pasture/range for

Table 19. Weight gain needed between weaning and breeding for replacement heifers of different frame sizes and weaning weights.

Expected wt at maturity, lb	Desired wt at breeding, lb	Weight at weaning, lb						
		400	450	500	550	600	650	700
900	585	185	135	85	35			
950	625	225	175	125	75	15		
1000	650	250	200	150	100	50		
1050	685	285	235	185	135	85	35	
1100	715		265	215	165	115	85	35
1150	750			250	200	150	100	50
1200	780			280	230	180	130	80
1250	815				265	215	165	115

up to 2 months after weaning. Alternatively, the heifers could be pushed to relatively high gains on good quality fall pasture/range with liberal amounts (> 2 lb/hd daily) of a high protein supplement (> 32%) before the decline in forage quality that generally occurs in Texas after frost in mid to late November. This supplementation practice would produce about half (100 lb) of the required gain in approximately 60 days leaving the remaining half to be achieved over 90 days on dormant forage and supplemented with up to 3 lb/hd daily of a 20% protein concentrate. Similar calculations could be applied to fall-born heifers for post-weaning gains during the growing season. It is clear that weights at weaning are very important in the management plan for developing replacement heifers.

Ionophore antibiotics such as monensin and lasalocid can be used effectively to enhance growth and development of replacement females. These ionophores can improve feed efficiency on bermudagrass pastures from 21 to 36% and gain in body weight from 18.4 to 28.6% (Rouquette *et al.*, 1980). Moseley *et al.* (1977) found replacement heifers that received monensin supplementation reached puberty earlier than control heifers. In a subsequent experiment, McCartor *et al.* (1979) found that supplementation with monensin or shifting the concentrate to roughage ratio in the diet to a higher concentrate diet had the same effect on ruminal production of volatile fatty acids and both groups of heifers reached puberty 29.5 days earlier than control heifers. When replacement heifers are supplemented, an ionophore antibiotic should be included in the ration.

First-calf cows

Cows nursing their first calf should be treated as special cases, especially if they were bred to calve at 2 years of age. Almost without exception, young cows nursing a calf while being exposed for breeding for the second calving season have nutritional requirements that exceed the supplies of nutrients that are considered appropriate for the mature cow. Conception for the second pregnancy is affected more negatively by low nutrition than subsequent pregnancies (Bellows *et al.* 1982). Work reviewed and reported by Bagley (1993), Randel (1990), Rutter and Randel (1984), and Williams (1990) indicated that the period of depressed synthesis and secretion of luteinizing hormone (LH), thus postpartum anestrus, is extended in cows that are young (demand for growth), thin (low gluconeogenesis), and being suckled (extended suppression of gonadotropic releasing hormone). Because 2-year-old, first calf cows are likely to be all of these, an extended period from parturition to first estrus and conception is expected without some extraordinary attention. A higher nutritional status (BCS $\geq$ 6) at calving is needed in first-calf cows compared to mature cows (BCS $\geq$ 5) in order to attain a comparable calving interval. Other strategies include early breeding (up to 1 month) of virgin heifers to allow for a longer interval for rebreeding. Also, temporary calf removal may stimulate first-calf cows to initiate estrous cycles.

The length of the postpartum interval is greater in suckled cows than in milked cows (Wiltbank and Cook, 1958). Other data indicate that suckling is a major cause of long postpartum intervals in young beef cows (Short *et al.*, 1972; Laster *et al.*, 1973; Bellows *et al.*, 1974). Early weaning is effective in shortening the interval from calving to first estrus and from calving to conception (Laster *et al.*, 1973; Bellows *et al.*, 1974) yet it produces a management problem of rearing early-weaned calves. In times of drought it may be an economically advantageous management practice but in normal times it may not be. A system of controlling suckling to a single event on a daily basis when calves are at least 28 days of age or older until the heifer reaches first estrus (normally about 6 weeks) resulted in postpartum intervals in first-calf heifers of 69 days, which compared with those of normal suckled mature cows (Randel, 1981).

Mature cows

Supplementation of adult beef cattle has received major attention in Texas because of the widespread practice of yearlong grazing. Although feeding of hay or silage during the winter is practiced in some areas, 12-month grazing is the most common management of adult beef cows. Quantity of forage is usually adequate, but quality fluctuates above and below requirement levels making supplemental feeding a necessary management consideration. As with stocker cattle, management of adult cows may be distinctly different for grazing improved pastures or native range. In the higher rainfall areas, nutrition management is built around a highly productive warm-season perennial grass, usually Coastal bermudagrass, that is grazed during the growing season and may be cut for hay to be fed during the dormant season (Crouch and Riggs, 1974). Alternatively, "complementary pastures" (ryegrass/clover, etc) are used for winter grazing, or these winter growing species are overseeded in bermudagrass sod and grazed along with dormant residue (Rouquette and Florence, 1983b).

Native vegetation is more variable than forage from improved pastures because of the larger number of plant species comprising the vegetation and absence of modifying cultural practices such as fertilization, irrigation, and weed control. Forage production and quality within a defined setting (e.g., location, soil type, and species composition) are determined by climate and animal use. Therefore, production data obtained from grazing studies on rangeland vary with climatic conditions. Results obtained during one year may not be repeated the following year.

Experiments were conducted annually over a 17-yr period (1982 to 1999) at the Texas A&M University Research & Extension Center at San Angelo to determine the effects of supplemental feeding of adult beef cattle on rangelands. Almost exclusively, these studies involved Hereford x Brangus cows (3 to 12 yr) that were bred to terminal sires (Charolais, Beefmaster, Simmental) during a 75-day breeding period beginning April 1. In a few cases, the cows in the herd were either Hereford or Brangus and were bred to either Brangus or Hereford bulls to produce replacements for the crossbreed herd. Mature weights of these cattle at 6 months pregnancy and BCS 5 were between 1050 and 1150 lb. These studies were conducted using Calan feeding gates to apply different treatments to individual cows that were in common herds. Supplemental treatments were imposed beginning about December 1 and ending about March 20, depending on when the first frost and spring green-up on rangeland occurred. In each experiment, one treatment was a negative control (NC; no feed given), and usually a second treatment was a positive control (PC; equivalent to 2 lb/hd daily of cottonseed meal [CSM] fed 3 times per wk). Other treatments were imposed and the results evaluated relative to the negative and positive control treatments. Except when phosphorus was a component of one of the experimental treatments, the cows had free access to a mineral mixture composed of 4% CSM, 45% salt (sodium chloride), 50% mono-dicalcium phosphate, and 1% vitamin A premix. Consumption of the miner-al:vitamin A mixture was not measured but varied considerably both between and within years. Data were reported for cows that calved during the experimental period, were healthy in all respects other than from nutritional stress related to the experimental treatments, and were nursing a calf at the termination date.

Available cows in the respective herds were assigned randomly to treatments then balanced among treatments for fall weight and condition score. When possible, individual cows were not included in an NC group in succeeding years. Live body weights and body condition scores were taken at the beginning and ending of the feeding periods and at weaning (approximately Dec. 1, Mar. 15, and Oct. 1, respectively). Cows were tested for pregnancy at weaning, and open cows were removed from the herds and replaced with similar cows from available auxiliary herds in preparation for the succeeding experiments.

Data for the NC and PC treatments for trials conducted from 1982 through 1999 are shown in Table 20. All or partial data collected during 1992, 1996, and 1997 were not included because of unaccountable difficulties in the data (malfunction of scales). The cows in PC compared with NC were slightly heavier (1127 vs 1093 lb) but similar in body condition (P = .48) at the beginning of the trials (Fall). Negative control cows lost more (P < .0001) weight from fall to spring and regained more (P < .0001) weight between spring and weaning compared with PC cows. For the combined periods, weight changes were not statistically different (P = .084) for the two groups but tended to remain higher for the NC cows. Although not measured because open cows were culled at weaning of calves, weight changes over an entire 12-month period (including the post-weaning period) likely would have been indistinguishable. Similar responses were recorded for body condition. The NC cows lost more (P < .0001) body condition between fall and spring, gained more (P < .0001) from spring to weaning, but body condition was similar (P = .50) for NC and PC cows at weaning. Supplement reduced losses of weight and condition during the winter period so that losses exceeded 15% of fall weight during only 19% of the time compared with 77% for the unfed

Table 20. Performance of adult cows on Texas Edwards Plateau rangeland without and with supplemental protein (1982 through 1998).[a,b]

Item	Negative control (Range + salt/mineral only) Mean	Positive control (Range + 1/2 CP requirements from CSM) Mean	Probability of difference
Number of cows (total)	224	239	
Cow weights, lb[c]			
Fall	1093	1127	.002
Spring	892	982	.0001
Weaning	1003	1046	.0002
Body condition[c,d]			
Fall	4.94	4.89	.48
Spring	3.70	4.13	.0001
Weaning	4.67	4.61	.50
Weight change, % fall wt			
Fall to spring	- 18.4	- 12.9	.0001
Spring to weaning	10.2	5.7	.0001
Fall to weaning	- 8.2	- 7.2	.084
Body condition change			
Fall to spring	- 1.23	- .75	.0001
Spring to weaning	1.08	.63	.0001
Fall to weaning	- .24	- .14	.315
Weaning weight, lb	552	561	.29
Pregnancy rate	.81	.91	.0025
Proportional critical wt. losses[e]	.77	.19	

[a] Adapted from Huston (2000).
[b] Includes data from four research sites within the Edwards Plateau Region (Winters Ranch, McCulloch County; Hill Ranch, Edwards County; and Texas Range Station, Crockett County) and South Texas Plains (Martin Ranch, Maverick and Kinney Counties).
[c] Fall, spring, and weaning data were taken about Dec. 1, March 25, and Oct. 1, respectively.
[d] Body condition scores were assigned by a scoring committee on a 1 to 9 scale (1 = thin; 9 = fat).
[e] Fractional proportion of years that average fall-to-spring weight losses exceeded 15% of fall weights.

cows. Supplement did not increase (P = .29) calf weaning weight but increased (P = .0025) cow conception rate. Because pregnant cows were randomized for the start of each new trial, carryover effects were not documented. Cows that bred late in the breeding season (greater than 365-day calving interval) because of treatment effects would be less likely to conceive during the subsequent breeding season even if assigned to a more favorable treatment. Similarly, cows that bred for an early calf would be more likely to conceive during the subsequent year even if assigned to a less favorable treatment. Cows in NC groups that conceived and were used in the next experiment were withheld intentionally from the NC treatment during that successive year. Therefore, the estimates of conception rate are greater for NC and smaller for PC than would be expected if the treatments were applied in recurring years.

Comparisons of other supplemental feed treatments were made after the data were corrected using the data from the NC groups that were included in each of the individual annual experiments. In each comparison, the NC group was assigned the overall average values for the NC groups in all experiments, and the values for the other treatments in the experiment were adjusted up or down proportionately. In this way, we took liberties in pooling data for similar treatments included during multiple years and comparing responses from different treatments that were imposed in different years. These data were used to estimate the relative effects of supplemental phosphorus, protein, and energy; protein level; energy level; patterns of distribution within the feeding period; types of supplemental feeds (oilseed meals, animal by-product meals, NPN, and others); and feeding frequency. For these comparisons, data for winter (feeding period) changes in live body weight and body condition score, calf weaning weight, and conception rate were analyzed using the General Linear Model of SAS (1991) with site (Brady, Sonora, Barnhart, and Uvalde) used as a co-variable. Standard errors (SE) are included with the summarized data to aid in comparisons of means. In certain instances, contrasts and probabilities were generated and included as footnotes in the table when these occurred.

Deficiencies are common with ***phosphorus***, ***energy***, and ***protein*** in diets of cattle grazing dormant range forages. In comparing the relative influence of these different nutrients (Table 21), phosphorus alone did not decrease (P = .52) the winter weight loss. However, when additional energy was provided also, the cows lost less (P = .02) weight than NC cows. When additional crude protein (NPN) was provided to the P and DE supply, the weight loss was intermediate between the PC cows and cows given P + DE but not statistically different from either (P = .17 and .34, respectively). Similar trends were observed for changes in BCS to that of winter weight change. All supplemental treatments appeared to increase conception rate but not calf weaning weight. These data suggest that all three of these nutrients are important, even P+DE without additional CP, and can increase cow performance when provided as a supplement to dormant rangeland.

The comparative effects of ***protein*** and ***energy*** supply in supplemental feeding are shown in Tables 22 and 23. When energy and phosphorus were held constant and protein supply increased, winter weight loss and BCS change decreased up to when a maximum of 600 g (1.3 lb) of CP was supplied, which was approximately 100% of total requirements (Table 22). On the other hand, when CP and P were held constant and energy supply increased up to a maximum of about 50% of requirements (Table 23), response beyond the lowest energy level was observed only for BCS at the highest step (medium to high). Conception rates were higher compared with NC in the fed groups in the protein level comparison and tended to be higher in those groups fed increasing levels of energy, but no differences were observed among supplemented groups. Increasing amounts of protein provided by the supplements probably stimulated the cows to consume and digest more forage and as a result retain more body tissue during the winter season. However, practical needs of the cow were met at the lower levels of supplementation (low to medium level) and productivity was not increased by additional supplemental protein. Energy supplementation beyond the lowest level was not beneficial. Higher energy supplies simply substituted for forage, and the overall nutritional welfare of the cow was not improved.

Cows that calve in January/February have relatively low energy requirements early in the

Table 21. Effects of phosphorus, energy, and protein in supplemental feed for mature cows grazing dormant rangeland.[a]

Item	Treatments[b,c]						SE
	NC (Range only)	PC	P	P+DE	DE+CP	P+DE+CP	
Number of cows	53	39	13	28	30	39	
Nutrients provided							
Crude protein, g/d	0	323	25	90	200	200	
Digestible energy, Mcal/d	0	2.8	.9	3.1	2.9	2.9	
Phosphorus, g/d	0	12	10	15	3	17	
Responses							
Weight change, %	-18.4	-12.6	-17.4	-15.5	-18.6	-14.2	1.01
BCS change	-1.19	-.75	-.98	-1.05	-1.29	-.96	.195
Conception rate, %	77.8	96.8	92.3	100	91.0	100	5.50
Calf weaning weight, lb	531	574	567	546	551	538	14.4

[a] Huston (unpublished data).
[b] Treatments were negative control (NC; no supplement), positive control (PC; cottonseed meal), phosphorus (P), phosphorus + digestible energy (P+DE), phosphorus + crude protein (P+CP), and phosphorus + digestible energy + crude protein (P+DE+CP).

[c] Inferences	Wt change	BCS change	Conception	Weaning wt
	Probability level			
NC vs. PC	.0001	.05	.003	.01
NC vs. P	.52	.51	.09	.10
NC vs. P+DE	.02	.56	.002	.39
NC vs. DE+CP	.88	.69	.06	.26
NC vs. P+DE+CP	.0003	.29	.0004	.65
P+DE vs. P+DE+CP	.34	.72	1.00	.66
PC vs. P+DE+CP	.17	.35	.63	.04

Table 22. Effects of increasing supplemental protein for mature grazing beef cows.[a]

Item	Supplemental protein				SE
	NC[b]	Low	Medium	High	
Number of cows	213	175	417	36	
Feeding levels					
Crude protein, g/d	0	164	355	600	
Digestible energy, Mcal/d	0	3.5	4.5	4.1	
Phosphorus, g/d	0	14.8	11.1	13.5	
Responses					
Winter weight change, %	-18.4	-15.1	-13.0	-11.0	.56
BCS[c] change	-1.19	-.98	-.74	-.46	.085
Calf weaning weight, lb	530	552	547	545	7.6
Conception rate, %	80.3	93.8	92.2	96.0	3.5

[a] Adapted from Huston *et al.* (1991, 1993, 1995, 1996, 1999) and unpublished data.
[b] Negative control (NC; range only).
[c] Body condition score (BCS).

Table 23. Effects of increasing supplemental energy for mature beef cows grazing dormant rangeland.[a]

Item	NC[b]	Supplemental energy Low	Medium	High	SE
Number of cows	108	131	109	47	
Feeding levels					
Crude protein, g/d	0	340	360	300	
Digestible energy, Mcal/d	0	2.3	5.7	8.0	
Phosphorus, g/d	0	10.6	11.2	9.0	
Responses[c,d]					
Winter body weight change, %	18.4	-13.3	-12.7	-13.7	.63
Body condition score change	1.19	-.87	-.78	-.58	.066
Conception rate, %	87.3	91.2	92.1	93.6	3.28
Calf weaning weight	531	544	542	544	7.2

[a] Adapted from Huston *et al.* (1991, 1993, 1995, 1996, 1999) and unpublished data.
[b] Negative control (NC; range only).
[c] Winter body weight change, % (Wt Ch).
Body condition score change (BCS Ch).
Conception rate, % (CR).
Calf weaning weight, lb (Wn Wt).

[d] Inferences	Wt Ch	BCS Ch	CR	Wn Wt
	Probability level			
NC vs. Fed	.0001	.0001	.1482	.092
Low vs. Medium	.40	.28	.82	.86
Medium vs. High	.33	.06	.78	.87

winter (December/January) compared with their requirements in late winter (February/March) during lactation and just prior to breeding. A study was conducted to determine the effects of ***pattern of distribution*** of supplemental feed throughout the winter season on body weight and condition changes and subsequent conception rate and calf weaning weight. In addition to NC and PC treatments, one group was fed protein equivalent to that fed the PC group but very low energy (1 Mcal/day) during the first 42 days of the feeding period, then energy at 50% higher (6 vs. 4 Mcal/day) compared with the PC group for the remaining 60 days (L-M-M). A fourth group was fed the low energy supplement for the first two periods (70 days), then a very high (10 Mcal/day) energy level during the last month before the beginning of breeding (L-L-H). All fed groups received the same amount of protein per day and the same amount of energy for the feeding season. The results (Table 24) show that neither of the step-up feeding patterns improved performance of the cows. Those fed uniformly throughout the winter season (PC group performed equally as well as those fed elevated amounts of energy later in the season. There was a trend for those fed higher amounts of energy later in the season to retain more body condition presumably because less fat was mobilized for milk synthesis. However, cow productivity was similar whether the attempt was to feed proportionate to requirements or evenly across the winter season.

Many supplement types are available for purchase. Several supplements were selected to represent the different types and were evaluated. Those evaluated included whole cottonseed (CS), a dry supplement containing hydrolyzed feather meal (FM), a high-urea dry mixture (NPN), a cooked molasses base self-limiting supplement containing approximately 28% crude protein (MOL-TUB), and a product similar to the MOL-TUB supplement but with a stronger intake limiter and containing a bacterial enzyme alleged to increase forage digestion (TUB+E). Performance was similar for cows fed the CSM-based supplement (PC), whole cottonseed, and FM-based supplement suggesting that each supplied adequate nutrients in available forms. The NPN, MOL-TUB and TUB+E supplements gave marginally successful results. The poorer response for NPN vs. PC is typical for large numbers of experiments. Supplements containing high levels of NPN (urea) are not equal to those containing actual protein for supplementing dormant forages. The MOL-TUB supplement was partially effective, but the variability in consumption was very large and average consumption was too low to provide adequate supplemental nutrients. Although the TUB+E supplement was not consumed readily, it was of significant value, possibly by improving forage digestibility and (or) providing important minerals. It seems that both MOL-TUB and TUB+E may be effective supplements, but probably should be fed along with another source of protein, perhaps at a reduced level.

Table 24. Effects of increasing supplemental energy during advancing periods within the winter season on mature beef cows grazing dormant rangeland.[a]

	Treatments[b]				
Item	NC	PC	L-M-M	L-L-H	SE
Number of cows	22	19	12	10	
Nutrients provided					
Crude protein, g/day	0	300	300	300	
Digestible energy, Mcal/day					
Period 1	0	4	1	1	
Period 2	0	4	6	1	
Period 3	0	4	6	10	
Phosphorus, g/d	0	10	10	10	
Body weight change, %	-18.4	-13.3	-14.2	-13.2	1.34
Body condition score change	-1.19	-0.73	-0.43	-0.18	.303
Conception rate, %	73.7	94.7	100.0	100.0	7.9
Calf weaning weight, lb	531	564	545	555	19.0

[a] Huston (unpublished data).
[b] Treatments were negative control (NC; range only), positive control (PC), low-medium-medium (L-M-M), and low-low-high (L-L-H).

Table 25. Comparison of feed types as supplements for mature beef cows grazing dormant rangeland.[a]

	Treatments[b]							
Item	NC	PC	CS	FM	NPN	MOL-TUB	TUB+E	SE
Number of cows	65	69	33	18	6	20	18	
Nutrients provided								
Crude protein, g/day	0	300	200	300	200	100	30	
Digestible energy, Mcal/day	0	3.2	3.6	3.2	2.8	1.2	0.4	
Phosphorus, g/day	0	10	5	10	9	10	10	
Weight change, %	-18.4	-11.4	-12.8	-12.1	-15.7	-15.1	-15.0	1.09
BCS change	-1.19	-0.89	-1.07	-0.83	-0.79	-0.97	-1.49	.145
Conception rate, %	90.4	92.9	95.2	94.4		85.0	83.3	6.1
Weaning weight, lb	530	553	608	548	000	531	560	15.1

[a] Adapted from Huston *et al.* (1991) and unpublished data.
[b] Treatments were negative control (NC; range only), positive control (PC), whole cottonseed (CS), hydrolyzed feather meal (FM), nonprotein nitrogen (NPN), cooked molasses tub supplement, 28% CP (MOL-TUB) and cooked molasses tub supplement with fiber digestive enzyme (TUB+E).

Adding trace minerals (TM) and undegraded intake protein (UIP) to a protein supplement did not reduce live body weight and BCS losses or increase conception rate or calf weaning weight (Table 26). These results suggest that under the conditions of this study, the combination of the forage and the PC supplement provided adequate minerals for acceptable performance. Further, amino acids supplied to the small intestines in amounts greater than is provided by properly functioning ruminal metabolism are not required by the cows used in this study. This conclusion may not be applicable to cows of higher productive potential.

Delivery system and frequency of feeding

Several studies were conducted on the effects of ***feeding interval***. A major cost of supplementation is the distribution of the feed. Self-feeding methods are attempts to minimize this cost but often are less than satisfactory because of highly variable intake of the supplement by individual cows. Added costs of products that can be self-fed may be prohibitive. Also, ingredients that are most useful in designing self-fed supplements may not be the best sources of the desired nutrients. Infrequent feeding is another approach to reducing distribution costs. Table 27 contains results of feeding cottonseed meal at the equivalent of 908 g (2 lb) per cow per day (CSM), a 20% crude protein supplement to provide equal energy with the CSM (LMIX), or the 20% supplement to provide equal crude protein with the CSM (HMIX) at different feeding intervals. Except for weaning weight that appears to be higher for LMIX compared with NC, LMIX was ineffective in this study whether fed three times or one time per week. Both CSM and HMIX were effective whether fed daily, three times per week, or only weekly. The cows fed weekly amounts (14 and 27 lb for CSM and HMIX, respectively) at once showed no signs of gastrointestinal problems, which in the case of HMIX was very surpriing. Possibly, the 1-wk

Table 26. Effects of supplemental feed, additional trace minerals and added undegraded intake protein on cows grazing dormant rangeland.[a]

	Treatments[b,c]				
Item	NC	PC	PC+TM	PC+TM+UIP	SE
Number of cows	20	40	19	18	
Nutrients provided					
Crude protein, g/day	0	400	400	600	
DIP	0	300	300	300	
UIP	0	100	100	300	
Digestible energy, Mcal/d	0	3.5	3.5	3.5	
Phosphorus, g/day	0	12	12	12	
Added trace minerals[d]	0	0	+	+	
Weight change, %	-18.4	-13.8	-14.6	-13.7	.95
BCS change	-1.19	-.69	-.76	-.77	.12
Conception rate (CR), %	66.7	88.9	88.9	85.7	11.2
Weaning weight, lb	531	538	561	535	26.1

[a] Adapted from Huston *et al.* (1993a).
[b] Treatments were negative control (NC; range only), positive control (PC), positive control + trace minerals (PC+TM), and positive control + trace minerals + undegraded intake protein (PC+TM+UIP).

[c] Inferences	Wt Ch	BCS Ch	CR	Wn Wt
	------------Probability level------------			
NC vs. fed	.0002	.0025	.15	.65
PC vs. PC+TM	.71	.57	.90	.71
PC+TM vs. PC+TM+UIP	.56	.93	.87	.51

[d] Added potassium, copper, zinc, and manganese were 30 g/day, 50 mg/day, 550 mg/day, and 250 mg/day, respectively.

interval is sufficiently long that strains of ruminal microorganisms that produce lactic acid rapidly when starch is fermented were not present in sufficient numbers to cause a lactic acidosis crisis. A major finding was that supplement intake, forage intake, and body weight change were less variable among cows that were fed one time per week rather than daily (Huston *et al.*, 1999).

In summary, mature cows grazing rangeland yearlong consume diets that fluctuate in nutritional value, especially between the growing and dormant seasons for warm-season perennial grasses, and benefit from periodic supplementation to supply limiting nutrients. Typically, cows should be supplemented for approximately 100 days beginning a few weeks following the first fall frost and continuing until the spring green up. Phosphorus and protein commonly are deficient to the extent that unsupplemented cows will suffer damaging losses of weight (greater than 15% of fall weight) and body fat, and conception rates during the spring will not be satisfactory. In the Edwards Plateau region, this will occur approximately 8 out of 10 years if the cows are not supplemented. If cows are in good condition (BCS = 6 or greater) entering the dormant season, adequate energy will be drawn from stored fat and is not required in addition to that contained in the high protein supplement. The supplement should supply approximately 300 g of protein and 10 g of phosphorus daily equivalent for a 450-kg (1000-lb) cow. Protein from grains, oilseed meals (CSM, SBM, etc), high protein seeds (cottonseed, peas, and other legumes), and manufacturing by-products (fish meal, feather meal, etc.) can be considered

Table 27. Effects of feed type, amounts, and feeding frequency on mature beef cows grazing dormant rangeland.[a]

		Treatments[b]								
		CSM			LMIX		HMIX			
Item	**NC**	**d**	**3T/wk**	**wk**	**3T/wk**	**wk**	**d**	**3T/wk**	**wk**	**SE**
Number of cows	47	14	41	24	15	10	10	29	21	
Nutrients provided										
Crude protein, g/d		380	380	380	170	170	380	380	380	
Digestible energy, Mcal/d		2.6	2.6	2.6	2.6	2.6	5.8	5.8	5.8	
Phosphorus, g/d		Free choice mineral								
Responses										
Cow weight change, %	-18.4	-13.0	-13.9	-15.2	-19.0	-18.1	-14.2	-13.3	-13.4	1.24
BCS change	-1.19	-.92	-.85	-.90	-1.07	-.93	-.83	-.69	-1.06	.148
Conception rate (CR), %	93	86	86	92	80	100	100	95	100	8.13
Weaning weight, lb	531	578	539	552	554	574	557	566	559	18.3

[a] Summarized from Huston *et al.* (1995, 1996,1999).
[b] Treatments were negative control (NC; range only), and either cottonseed meal (CSM), a 20% CP supplement fed to provide equal digestible energy with CSM (LMIX), or a 20% supplement fed to provide equal protein with the CSM (HMIX) each fed either daily (d), 3 times per week (3T/wk), or weekly (wk).

[c] Inferences	Wt Ch	BCS Ch	CR	Wn Wt
	Probability level			
NC vs. CSM	.0001	.012	.31	.052
NC vs. LMIX	.64	.23	.72	.05
NC vs. HMIX	.0001	.009	.44	.073
CSM vs. LMIX	.0005	.40	.70	.25
CSM vs. HMIX	.70	.81	.09	.78
LMIX vs. HMIX	.0001	.41	.32	.94
Daily vs. 3T/wk	.95	.46	.69	.46
Daily vs. wk	.62	.53	.76	.58
NC vs. wk	.0002	.10	.64	.10

equivalent unless palatability or some other characteristic affects consumption. Their relative value as a protein supplement is approximately proportionate to protein content.

Exceptions to this general rule are when the particular feedstuff has other benefits or detriments. Whole cottonseed is high in vegetable oil, which can increase conception (Williams *et al.*, 1989); whereas, fish meal and feather meal cannot be fed alone because of palatability and should not be valued as much above oilseed meals as the relative protein content would suggest. Feeds containing crude protein supplied by nonprotein nitrogen (NPN) are of less value than feeds containing only actual protein. The portion of the crude protein supplied by NPN is approximately three-fourths the value of that supplied by an equivalent amount of actual protein. Supplements can be fed equally across the feeding period or in a step-up program to approximate increases in supply to increases in requirements of advancing pregnancy and onset of lactation. Results are similar probably because cattle are equipped to cope with variability. Similarly, cows can be fed supplements infrequently (up to intervals of one week) without depressed performance. Actually, weekly feeding may be more effective in extensive areas than daily feeding because normal grazing patterns are less interrupted and feed is distributed more evenly among the individual cows.

Several experiments have been conducted and cited that provided a free-choice, self- limiting ration to stocker calves grazing either winter or summer pastures. In other supplementation experiments, energy rations (corn) which were hand-fed and ionophore-free, (Rouquette *et al.*,1994; Rouquette and Florence, 1993; Rouquette *et al.*, 1993) appeared to be less effective in promoting additional gain on winter pastures compared to self-limiting rations. Additionally, rations in the above-mentioned experiments did not include minerals as in the Hutcheson ration. For stocker grazing operations, the inclusion of minerals and an ionophore plus the aspect of self-limiting should be considered as a best management practice. With daily hand-fed rations, cattle are extremely competitive at the feed bunk site, and with the total daily ration being consumed during a 5 to 10 minute feeding period, timid animals often do not receive their appropriate share of the supplement. However, a remedy for the aggressive vs timid animals may be overcome in part by including ingredients that would slightly inhibit immediate consumption. Self-limiting rations that are offered free-choice eliminate the feeding frenzy and gorging of ration. Stocker calves on self-limiting rations may actually experience enhanced forage intake and digestion with the periodic, daily consumption of supplement. This conjecture, however, is both forage and supplement specific.

The method of delivery of supplements offers the most discouragement to producers. In order to use only the specific ingredients desired for a class of livestock, feed bunks or self-feeders must be used. In addition, some form of custom mixing, bagging, handling, and storage of supplement ration is a necessary, expensive and often burdensome component of supplementation. Thus, in practice, producers may compromise using a custom supplement in favor of a commercial, "user-friendly" product. Most commercial products attempt to add convenience to the supplemental feeding activity. And, although many commercial products have accomplished this goal, the uncontrollable factors often include non-specific ingredients for desired animal class or function, level of daily intake, and increased cost of the supplement program. Supplemental feeding is not management-free and is not an automatic cost-effective practice. With some of the science of supplement ingredient and rate function that has been included in this text, the art of tailoring specific requirements with specific situations can approach not only cost-effectiveness but also personal satisfaction.

Economic Considerations

Supplementation of beef cattle involves choosing from among various available options. These choices usually will be influenced strongly by cost/return considerations. Clearly, these include estimates of 1) responses to supplementation options, 2) costs associated with those options, and 3) values of the expected responses. The decision process is complicated by the fact that none of these considerations are static; all are continually changing. The data provided in this document are useful in estimating responses to supplementation. Armed with these response estimates and estimated prices of feed and cattle, the producer can develop a matrix of options from which the most appropriate can be selected.

A computer spread sheet is very efficient for developing this matrix. Table 28 is an example of a cost/return matrix for supplemental feeding of stocker cattle grazing ryegrass pasture. To simulate the application of a computer spreadsheet in the analysis, columns A through Q are designated at the top and rows 1 through 34 on the left.

Data included in Tables 14 and 15 were used to estimate feeding levels and average daily gains, which were entered on rows 9 and 18, respectively. Feed costs (rows 12 and 13) were estimated from current prices. The user may enter any values appropriate for his situation in these cells. All of the values in the shaded cells were generated by formulas from the feeding levels, feed costs, and average daily gain inputs. Formulas used for the corn column (column H) are shown in the footnotes. Those used for the other two columns are similar except that columns L and P, respectively, are substituted for column H in the formulas. In this simple example, rate of gain was greater when each of the supplements was fed at the indicated feeding level. When 1.4 lb of corn was fed daily, the cattle gained 2.56 lb/d compared with 2.3 lb/d for those grazing without supplement (row 18) increasing gain by .26 lb (row 20). The total cost for supplying 1.4 lb of corn per day was 8.4 cents (row 16). Because .26 lb of gain was created by feeding 8.4 cents worth of corn, 1 lb of extra gain would cost 32.3 cents (1 divided by .26, then multiplied by 8.4; row 22). If the sale price of the calves was 60 cents/lb (line 26), the net return to feeding 1.4 lb corn/day would be 27.7 cents/lb of increased weight sold. At $1/lb calf price, the net return on the increased gain would be 67.7 cents (line 30). Including an ionophore with corn (column L), which raises the price of the feed slightly, would be even more profitable because the 22% increase in gain (from 2.56 to 3.12 lb/day) was much greater than the 1.7% increase in cost of supplement (8.4 to 8.54 cents/day). The high protein supplement (cottonseed meal; CSM) at greater cost but fed at a lower level also is more profitable than corn fed alone. A higher feed cost or lower incremental gain produced by the supplements results in reduced profitability or may result in a net loss. For example, if total feed cost (price of supplement plus delivery cost) was $20/cwt ($400/ton) and the supplement was fed at 2 lb/day, supplement cost would rise to 40 cents per day. At an incremental gain of .5 lb/day (.5 lb greater gain for supplemented cattle compared with expected gain for cattle consuming pasture only), cost of extra gain would be unprofitable at 80 cents/lb and lower calf prices.

A second example, supplementing mature cows, is shown in Table 29. Usually for mature cows, protein is both the most important and the most expensive nutrient in supplements. Again, a spreadsheet format is used to facilitate the comparison of three supplements. Cottonseed meal is used as a standard and is compared with other products referred to as "20% cubes" and "20% cubes (NPN)." Nutrient composition of the products (rows 9, 10, 11, and 12), desired level of protein to be provided (row 14), feed prices (row 17), and delivery costs (row 18) must be entered by the user. The total crude protein, maximum proportion of crude protein provided by NPN, and total phosphorus will be provided on the feed label or stipulated for the custom feed mixture. Energy (TDN) must be estimated from values provided in a feed composition table such as the Appendix Table 4. Caution should be used when determining crude protein provided from NPN (row 10). If the language on the feed label states, "Crude Protein = 20% (Max. one-third from NPN)," the proper interpretation is that the product contains, at most, but possibly

A B C D E F G H I J K L M N O P Q

1 Table 28. Example economic analysis of supplementing growing cattle on high quality winter pasture.

Row	Item	None		Corn	Corn + ionophore	CSM
2						
3						
4		Supplement type				
5						
6	Item	None		Corn	Corn + ionophore	CSM
7						
8						
9	Feeding levels, lb/d	0.00		1.40	1.40	0.54
10						
11	Feed costs, $/cwt					
12	Feed prices			5.50	5.60	9.00
13	Delivery costs			0.50	0.50	0.50
14	Total		(1)	6.00	6.10	9.50
15						
16	Supplement costs, cents/d		(2)	8.40	8.54	5.13
17						
18	Average daily gain, lb/d	2.30		2.56	3.12	2.58
19						
20	Incremental gain, lb/d		(3)	0.26	0.82	0.28
21						
22	Cost of extra gain, cents/lb		(4)	32.3	10.4	18.3
23						
24	Return on feed cost, cents/lb					
25	@ calf price, $/cwt					
26	60		(5)	27.7	49.6	41.7
27	70		(6)	37.7	59.6	51.7
28	80		(7)	47.7	69.6	61.7
29	90		(8)	57.7	79.6	71.7
30	100		(9)	67.7	89.6	81.7
31	110		(10)	77.7	99.6	91.7
32	120		(12)	87.7	109.6	101.7
33	130		(13)	97.7	119.6	111.7
34	140		(14)	107.7	129.6	121.7

Formulas (Precede the parentheses with an "=" if using Excel spreadsheet.)

(1) (H12+H13)
(2) (H9*H14)
(3) (H18-E18)
(4) (H16÷H20)
(5) (B26-H22)
(6) (B27-H22)
(7) (B28-H22)
(8) (B29-H22)
(9) (B30-H22)
(10) (B31-H22)
(12) (B32-H22)
(13) (B33-H22)
(14) (B34-H22)

	A–F		G	H–J	K–M	N–Q
1	**Table 29. Example economc analysis of supplementing mature cattle on dormant pasture/rangeland.**					
2						
3						
4				**Supplement type**		
5						**20% cubes**
6	**Item**	**None**		**CSM**	**20% cube**	**(NPN)**
7						
8	Protein content					
9	Natural CP, %			41	20	14
10	CP from NPN, %			0	0	6
11	Energy (optional), % TDN			65	70	72
12	Phosphorous content, %			1	1	1
13						
14	Desired CP supply, lb/d			1	1	1
15						
16	Feed costs, $ cwt					
17	Feed prices			10.00	8.00	7.50
18	Delivery costs			0.50	0.50	0.50
19	Total		(1)	10.50	8.50	8.00
20						
21	Feeding levels, lb/d					
22	CP basis	0.00	(2)	2.44	5.00	5.41
23	Energy (credit)		(3)	0.00	1.37	1.60
24	Energy credit basis		(4)	2.44	3.63	3.80
25	CP provided, lb/d		(5)	1.00	0.73	0.70
26	TDN provided, lb/d		(6)	1.59	2.54	2.74
27	P provided, g/d		(7)	1.07	16.49	17.27
28						
29	Supplement costs for approximate					
30	equal value, cents/d					
31	CP basis		(8)	25.61	42.50	43.24
32	Energy credit basis		(9)	25.61	30.88	30.43

Formulas (Precede the parentheses with an "=" if using Excel spreadsheet.)

(1) (H17+H18)
(2) (H14/((H9+(H10*.75))/100))
(3) ((((H22*(H11/100))-($H22*($H11/100)))/(H11/100))*0.5)
(4) (H22-H23)
(5) (H24*((H9+(H10*.75))/100))
(6) (H24*(H11/100))
(7) (H24*(H12/100))
(8) (H22*H19)
(9) (H24*H21)

less than, one-third (6.7%) of the 20% crude protein from NPN. In the example, 14 of the 20% was estimated to be natural crude protein and the remainder (6%) from NPN. The value of CP from NPN can range from less than 50% to approaching 100% of the value of actual protein, depending on the class of animals being fed and nutrient contents of associated feeds. In this example, the CP from NPN was given three-fourths (.75) the value of the natural crude protein in providing protein for the animal (formulas 2 and 5).

Feeding levels are calculated from the desired CP supply and the nutrient composition of the supplements. On a CP basis, the cows should be fed 2.44, 5.0, or 5.41 lb/day of CSM, 20% cubes, or 20% cubes (NPN), respectively, to provide 1 lb of CP in the diet each day. However, the extra energy provided when the lower protein supplements are fed at higher levels can have a sparing effect on protein. That is, an extra amount of energy can increase the efficiency of use of the protein. Therefore, the extra feed energy that accompanies a higher feeding level of a lower protein feed should be given credit when determining the overall value of the supplement. This extra value is considered in calculating feeding levels on an "energy credit basis." In the example, the appropriate feeding level for the lower protein supplement was selected to supply energy at the midway point between that provided by the higher and lower protein supplements when both were fed to supply the target amount of protein. This is referred to in Table 29 as the feeding level calculated on an "energy credit basis." Although the CP provided is lower for the 20% cubes and 20% cubes (NPN) (.73 and .70 vs. 1.0 lb/day), energy supplementation is higher (2.54 and 2.74 vs. 1.59 lb/day TDN) compared with cottonseed meal. These supplements fed at these levels can be considered to be approximately of equal value and to have a similar effect on cow performance. At the prices entered in the analysis, feed costs are lower for CSM than either alternative whether feeding level is calculated on a CP or energy credit basis. Again, formulas for cottonseed meal (column H) are provided in the footnote. Formulas entered in the shaded cells of the spreadsheet for columns L and P would be identical except L and P, respectively, would replace H.

These examples illustrate the use of information presented in this monograph to make proper selections for supplemental feeding including economic considerations. Greater sophistication can be added to the spreadsheet as the user develops greater understanding and confidence. For example, different feeds may have different delivery costs in that some must be hand-fed daily but require only a very simple, inexpensive trough. Others can be self-fed thereby requiring fewer trips and less vehicle and labor expenses, but may require very expensive self-feeders. These differences in cost should be considered. Also, feeding cattle while they are grazing affects forage consumption (Table 7), especially when high quality forages are grazed. To the extent that feed substitutes for forage, stocking rate can be increased for optimal harvest of the forage. Therefore, in some instances supplements can increase cattle gains per acre by increasing both rate of gain and stocking rate. Both are very important in the economic assessment of the practice of supplemental feeding.

Implications

These feeding responses and comments are reasonably accurate for average conditions for which the data reported addressed. Average conditions should be used in the planning process for cattle supplementation. However, existing conditions should drive the actual supplementation practice. Starting and ending dates, feed types and amounts, etc. will vary with conditions as the cattle manager attempts to apply the "Eleven Commandments" presented below. Variations in management are necessary in order to accommodate changing environmental conditions, livestock carryover effects, livestock prices, and feed prices. Dealing with these changes will improve with experience and many choices of supplementation programs can be justified. Those presented are intended as a benchmark for managers to apply modifications formulated from their knowledge gained through experience.

The Eleven Commandments of Supplemental Feeding of Beef Cattle

1. Remember that cattle are well adapted to grazing and efficient in utilizing forages.
2. Know your forage base including plant species, anatomical parts of the plants, growing seasons, responses to climatic changes, resilience to damage by defoliation (grazing), etc.
3. Learn to recognize the grazing habits of your cattle, i.e., which plants and plant parts are preferred and which are avoided.
4. Study forage composition tables, such as the appendix, to know and understand changes in nutrient concentrations (protein, energy, phosphorus) in forage throughout the year.
5. Realize that productivity and nutrient requirements are closely related; cattle with high genetic potential (e.g., high vs. low potential to gain weight) or cattle in a high productive state (e.g., lactating vs. dry) require a higher level of nutrition.
6. Strive to match cattle nutrient demand with forage nutrient supply.
7. Develop a supplemental feeding strategy based on biological (effects on animal health and productivity), economic (cost:benefit ratio), and social considerations (convenience and personal satisfaction).
8. Understand that supplemental feeds can be used for four motives:
   a. To provide nutrients deficient in forages that limit forage intake and digestion (supplemental feeding),
   b. To add to the value of low-quality forage and increase diet quality (enhancement feeding),
   c. To partially replace forage in the diet (substitute feeding), and
   d. To provide nutrition during a shortage of forage (supply feeding).
9. Become knowledgeable about available supplemental feed sources and types, label information, and recommended procedures for use.
10. Scrutinize the effectiveness of the chosen supplemental feeding strategy by closely observing (measuring) the behavior, condition, and performance of the cattle.
11. Adjust and observe.

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Appendix

Table A-1. Definitions, abbreviations and acronyms.

ADF	–	Acid Detergent Fiber. The portion of the NDF that is insoluble in acid detergent solution and difficult to digest or is indigestible.
ADG	–	Average Daily Gain. The amount of live body weight (lb) an animal gains divided by the number of days in the measured period.
AU	–	Animal Unit. A standardized unit of grazing. Usually defined as the equivalent of a 1000 lb cow with her calf over a 12-month period that imposes an average demand of approximately 26 lb of typical forage per day.
BCS	–	Body Condition Score. A subjective score in a range of 1 to 9 of the amount of fat covering being carried by the animal (BCS 1 = very thin; BCS 9 = very obese; see Table 1).
Biomass	–	The sum total of living plants and animals above and below ground in an area at a given time. Often used in general discussions of vegetation and animal diets to mean "above ground plant biomass."
Browse	–	Leaf and twig growth from non-herbaceous vegetation. Generally, foliage from trees and shrubs.
BW	–	Body Weight. Live body weight (lb).
C_3 Plants	–	Plants that photosynthesize carbohydrates beginning with a 3-carbon compound. Generally, cool-season plants that are relatively inefficient in solar energy capture, lower in NDF content, and higher in digestibility compared with C_4 plants.
C_4 Plants	–	Plants that photosynthesize carbohydrates beginning with a 4-carbon compound. Generally, warm-season plants that are relatively efficient in solar energy capture, higher in NDF content, and lower in digestibility compared with C_3 plants.
Cell Contents	–	That portion of the cell dry matter that is soluble in neutral detergent solution opposed to cell wall (NDF). Composed of soluble substances (e.g., carbohydrates, protein, lipids) that are readily digested by hydrolytic enzymes secreted by mammals.
Cellulose	–	The most prevalent chemical compound in nature and the principal structural carbohydrate in plants. Chemically, cellulose is a polymer of glucose molecules linked together in a beta linkage, which is resistant to digestive enzymes secreted by mammals.
Cell Wall	–	Dry matter making up the cell wall portion of the plant cell opposed to cell contents. Composed of cellulose, hemicellulose, and lignin. Synonym of neutral detergent fiber (NDF).
CP	–	Crude Protein. An estimate of protein (both digestible and indigestible) in feeds and other substances. CP (%) is calculated by multiplying the amount (%) of nitrogen (N) by a factor of 6.25.

Table A-1. (Continued)

DE	– Digestible Energy. The amount of energy consumed by the animal that is digested. Measured in calories (cal), kilocalories (Kcal, 1000 cal), and megacalories (Mcal, 1000 Kcal).
DIP	– Degraded Intake Protein. CP that is degraded in the rumen.
FM	– Forage Mass. The amount (lb) of forage present for a given area of land (acre).
Forage Allowance	– The relationship between the weight of forage dry matter per unit area and the number of animal units or forage intake units at any one point in time. May be expressed as lb forage DM per 100 lb animal BW.
Forbs	– Herbaceous broadleaf plants including nonwoody legumes.
GP	– Grazing Pressure. A scaling of the amount of forage available at any one time to a grazing animal unit. A large FM/AU would equal a small GP and vice versa.
Hemi-cellulose	– A structural carbohydrate often co-mingled with cellulose as cell wall substances. Chemically, hemicellulose is a polymer of pentoses (5-carbon sugars).
Herbage Mass	– Total above ground biomass from nonwoody plants. Low growing. Includes grasses, grass-like plants (e.g., sedges and rushes), and forbs, which are broadleaf plants including herbaceous legumes.
IIP	– Indigestible Intake Protein. Protein that is consumed but passes through the animal to the feces (manure) without being digested.
IF	– Indigestible Fiber. The portion of the ADF that is indigestible.
Lignin	– An indigestible substance that is a part of the ADF within the cell wall of plants. This substance increases as plants mature and acts as a "cementing agent" to bind other cell wall components (cellulose and hemicellulose) hindering their digestion, also.
Mast	– Fruits and seeds from non-herbaceous vegetation.
Microbial protein	– Protein that is synthesized by microorganisms in the rumen using some form of nitrogen and energy derived during fermentation.
MRT	– Mean Residence Time. The average time that undigested particles reside in the reticulorumen. Often called mean retention time or ruminal retention time.
NDF	– Neutral Detergent Fiber. The fraction of a substance (usually plant biomass) that is insoluble in neutral detergent solution. The fiber portion (cell wall) of a forage or feed as opposed to the soluble portion (cell contents).
NPN	– Non-Protein Nitrogen. A supply of nitrogen, usually urea, that can be used by rumen microorganisms in synthesis of microbial protein which can then be digested and used as a protein source. The CP equivalent of NPN is considered to be approximately 75% the value of actual protein for grazing ruminants, although this value may vary considerably.

Table A-1. (Continued)

Nutrients –	Chemicals derived from forages, feeds, and supplements that animals must receive in adequate and balanced amounts to support normal life processes. These include or are derived from protein, energy-yielding compounds, vitamins, minerals, water, and air.
PDF –	Potentially Digestible Fiber. That portion of neutral detergent fiber (NDF) that is accessible for fermentation by ruminal microorganisms. The balance of the NDF is indigestible fiber (IF).
Ruminant –	An animal with a complex gastric system that includes a rumen (paunch), reticulum, omasum, and abomasum (resembling the stomach of monogastric animals). Referred to also as polygastric animals.
SR –	Stocking Rate. An expression of the amount of area (acres) that is provided for each grazing animal unit or conversely, the number of animal units grazing an area (acre, section, etc).
TDN –	Total Digestible Nutrients. An indicator of the digestible energy content of feeds. One pound of TDN = 2 Mcal DE (approximate).
UIP –	Undegraded Intake Protein. CP that is consumed, passes to the small intestine undegraded, and is then absorbed from the small intestine.
VFA –	Volatile Fatty Acids. Energy yielding compounds that are released by microorganisms during fermentation in the rumen and are absorbed and used for energy by the ruminant.

Appendix

Table A-2. Forage and browse species arranged by season of production and generalized functional grouping.

Group	Species
Introduced warm-season annual grasses	
	Pearlmillet, Millex 24 (*Pennisetum americanum*)
	Pearlmillet, Tifleaf (*Pennisetum americanum*)
	Sorghum (*Sorghum bicolor*)
	Sudangrass (*Sorghum bicolor*)
	Sorghum, Beef Builder (*Sorghum bicolor*)
	Sorghum, FS1-A (*Sorghum bicolor*)
	Sorghum, Rio Sweet (*Sorghum bicolor*)
Introduced warm-season perennial grasses	
	Bahiagrass (*Paspalum notatum*)
	Bermudagrass, Coastal (*Cynodon dactylon*)
	Bermudagrass, Coastcross (*Cynodon dactylon*)
	Bermudagrass, common (*Cynodon dactylon*)
	Buffelgrass (*Cenchrus ciliaris*)
	Gordo bluestem (*Dichanthium aristatum*)
	Johnsongrass (*Sorghum halepense*)
	King Ranch bluestem (*Bothriochloa ischaemum* var. *songarica*)
	Kleingrass (*Panicum coloratum*)
	Weeping lovegrass (*Eragrostis curvula*)
Introduced cool-season annual grasses	
	Little barley (*Hordeum pusillum*)
	Oats (*Avena sativa*)
	Rescuegrass (*Bromus unioloides*)
	Ryegrass (*Lolium multiflorum*)
	Wheat (*Triticum aestivum*)
Introduced warm-season perennial non-grasses	
	Alfalfa (*Medicago sativa*)
	Common horehound (*Marrubium vulgare*)
Introduced cool-season annual non-grasses	
	Clover, berseem, Bigbee (*Trifolium alexandrinum*)
	Clover, Hubam (*Melilotus albus*)
	Clover, subterranean, Meteora (*Trifolium subterranium*)
	Clover, white, Louisiana S-1 (*Trifolium repens*)
	Clover, white, Regal ladino (*Trifolium repens*)
	Clover, white, Tillman ladino (*Trifolium repens*)
	Clover, white, Sacramento (*Trifolium repens*)
Native warm-season perennial grasses	
	Buffalograss (*Buchloe dactyloides*)
	Cane bluestem (*Bothriochloa barbinodis* var. *barbinodis*)
	Common curlymesquite (*Hilaria belangeri*)
	Fall witchgrass (*Digitaria cognata*)
	Green sprangletop (*Leptochloa dubia*)
	Hairy grama (*Bouteloua hirsuta*)
	Hairy tridens (*Erioneuron pilosum)*
	Halls panicum (Panicum hallii var. *hallii*)
	Hooded windmillgrass (*Chloris cucullata*)
	Little bluestem (*Schizachyrium scoparium* var. *frequens*)
	Meadow dropseed (*Sporobolus asper* var. *drummondii*)
	Pinhole bluestem (*Bothriochloa barbinodis* var. *perforata*)
	Pink pappusgrass (*Pappophorum bicolor*)
	Plains bristlegrass (*Setaria leucopila*)
	Plains lovegrass (*Eragrostis intermedia*)
	Red grama (*Bouteloua trifida*)
	Sand dropseed (*Sporobolus cryptandrus*)
	Sideoats grama (*Bouteloua curtipendula* var. *caespitosa*)

Table A-2. (Continued)

Group	Species
	Silver bluestem (*Bothriochloa saccharoides* var. *torreyanus*)
	Slim tridens (*Tridens muticus* var. *muticus*)
	Tanglehead (*Heteropogon contortus*)
	Texas cupgrass (*Eriochloa sericea*)
	Tobosa (*Hilaria mutica*)
	Tumble windmillgrass (*Chloris verticillata*)
	Tumblegrass (*Schedonnardus paniculatus*)
	Vinemesquite (*Panicum obtusum*)
	White tridens (*Tridens albescens*)
	Wright threeawn (*Aristida purpurea* var. *wrightii*)
Native cool-season perennial grasses	
	Canada wildrye (*Elymus canadensis*)
	Texas winter-grass (*Stipa leucotricha*)
Native warm-season grasslike non-grasses	
	Sacahuista (*Nolina texana*)
	Yucca (*Yucca* sp.)
Native cool-season grasslike non-grasses	
	Sedge (*Carex* sp.)
Native deciduous browse	
	Blackbrush (*Acacia rigidula*)
	Bluewood (*Condelia hookeri*)
	Capul (*Schafferia cuneifolia*)
	Catclaw acacia (*Acacia greggii* var. *greggii*)
	Elbow bush (*Forestiera pubescens* var. *pubescens*)
	Feather dalea (*Dalea formasa*)
	Guajillo (*Acacia berlandieri*)
	Honey mesquite (*Prosopis glandulosa*)
	Huisache (*Acacia smallii*)
	La Coma (*Bumelia celastrina*)
	Lotebush (*Zizyphus obtusifolia*)
	Mesquite (*Prosopis glandulosa*)
	Netleaf hackberry (*Celtis reticulata*)
	Orange zexmenia (*Wedelia hispida*)
	Plateau oak (*Quercus virginiana*)
	Sage (*Salvia* sp.)
	Shrubby blue sage (*Salvia ballotiflora*)
	Skunkbush (*Rhus aromatica* var. *flabelliformis*)
	Spiny hackberry (*Celtis pallida*)
	Texas kidneywood (*Eysenharditia texana*)
	Texas persimmon (*Diospyros texana*)
	Twisted acacia (*Acacia schaffneri* var *bravoensis*)
	Twoleaf senna (*Senna roemeriana*)
	White honeysuckle (*Lonicera albiflora*)
	White shin oak (*Quercus durandii* var. *breviloba*)
Native evergreen browse	
	Agarita (*Mahonia trifoliolata*)
	Ashe juniper (*Juniperus ashei*)
	Guayacan (*Guaiacum angustifolium*)
	Lime pricklyash (*Zanthoxylum fagara*)
	Mescalbean (*Sophora secundiflora*)
	Prickly pear (*Opuntia* sp.)
	Pricklyash (*Zanthoxylum* sp.)
	Redberry juniper (*Juniperus pinchotii*)
	Vine ephedra (*Ephedra pedunculata*)
Native warm-season forbs	
	Blue-eye grass (*Sisyrinchium* sp.)
	Broadleaf milkweed (*Asclepias latifolia*)
	Buffalo gourd (*Cucurbita foetidissima*)
	Common broomweed (*Xanthocephalum* sp.)
	Common dyssodia (*Thymophylla pentachaeta* var. *pentachaeta*)

Table A-2. (Continued)

Group	Species
	Croton (*Croton* sp.)
	Dayflower (*Commelina* sp.)
	Dutchmans britches (*Thamnosma texana*)
	Engelmandaisy (*Engelmannia pinnatifida*)
	Evening primrose (*Oenothera* sp.)
	Fleabane (*Erigeron* sp.)
	Illinois bundleflower (*Desmanthus illinoensis*)
	Indianmallow (*Abutilon fruticosum*)
	Lemon beebalm (*Monarda citriodora*)
	Louisiana sagewort (*Artemisia ludoviciana*)
	Mountain pink (*Centaurium beyrichii* var. *beyrichii*)
	Noseburn (*Tragia* sp.)
	Oxalis (*Oxalis* sp.)
	Pepperweed (*Lepidium* sp.)
	Purple groundcherry (*Quincula lobata*)
	Purslane (*Portulaca* sp.)
	Ragweed (*Parthenium hysterophorus*)
	Roemer sensitivebriar (*Schrankia roemeriana*)
	Silverleaf nightshade (*Solanum elaeagnifolium*)
	Spreading sida (*Sida abutifolia*)
	Sweet gillardia (*Gaillardia sauvis*)
	Upright prairie coneflower (*Ratibida columnifera*)
	Western bitterweed (*Hymenoxys odorata*)
	Western ragweed (*Ambrosia cumanensis*)
	Yellow stonecrop (*Sedum nuttallianum*)
Native cool-season forbs	
	Anemone (*Anemone berlandieri*)
	Bladderpod, Gordon (*Lesquerella gordonii*)
	Cedar plantain (*Plantago helleri*)
	Evax, bighead (*Evax prolifera*)
	Nuttall milkvetch (*Astragalus nuttallianus* var. *nuttallianus*)
	Redseed plantain (*Plantago rhodosperma*)
	Texas bluebonnet (*Lupinus texensis*)
	Texas filaree (*Erodium texanum*)

Appendix

Table A-3. Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible energy (DE), and phosphorus (P) contents for forage and browse species harvested in Texas.

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
Agarita (*Mahonia trifoliolata*)									
	Shoots	13.0	20.0		1.75	0.25		04/13/73	Hu81
	Leaves and stem	15.0			1.81	0.29		03/28/74	Hu81
	Shoots	16.0	14.0		1.75	0.27		03/27/73	Hu81
	Shoots	16.0	14.0		1.77	0.27		10/25/73	Hu81
Alfalfa (*Medicago sativa*)									
	Hay, dehy., 1st cutting	17.8	46.0	30.6	**1.22**		Brazos	05/17/67	Bu69
	Hay, dehy., 2nd cutting	20.4	47.3	32.5	**1.24**		Brazos	05/17/67	Bu69
	Hand plucked	21.4	33.6	30.4	1.24		Rusk	07/13/69	Ro1
	Hand plucked	23.5	33.5	29.3	1.27		Rusk	09/19/69	Ro1
	Hay, dehy.	23.6	46.1	35.0	**1.26**		Brazoria		Qu66
	Hand plucked	24.5	34.9	33.6	1.33		Rusk	06/08/69	Ro1
	Hand plucked	24.6	29.9	25.4	1.27		Rusk	08/11/69	Ro1
	Hand plucked	26.5	29.4	26.8	1.31		Rusk	04/11/69	Ro1
	Hand plucked	29.3	30.2	30.2	1.38		Rusk	05/05/69	Ro1
Anemone (*Anemone berlandieri*)									
	Whole plant	11.0	28.0		1.46	0.19		04/13/73	Hu81
	Whole plant	11.0			1.58	0.17		01/08/76	Hu81
	Leaves and stems	12.0			1.58	0.15		12/17/74	Hu81
	Whole plant	13.0	20.0		1.50	0.18		03/27/73	Hu81
Ashe juniper (*Juniperus ashei*)									
	Leaves	5.0			1.29	0.07		05/24/74	Hu81
	Leaves	5.0			1.32	0.12		08/15/74	Hu81
	Leaves	6.0	34.0		1.36	0.08		04/13/73	Hu81
	Leaves and stems	6.0	31.0		1.24	0.08		02/28/74	Hu81
	Leaves	6.0			1.21	0.09		04/15/75	Hu81
	Leaves	6.0			1.18	0.09		07/11/75	Hu81
	Leaves and stems	7.0	33.0		1.29	0.12		11/29/73	Hu81
	Leaves and stems	7.0	34.0		1.24	0.11		12/27/73	Hu81
	Leaves and berries	7.0			0.98	0.10		06/25/74	Hu81
	Leaves	7.0			1.32	0.11		11/15/74	Hu81
	Leaves	7.0			1.37	0.11		12/17/74	Hu81
	Leaves	7.0			1.28	0.10		02/11/75	Hu81
	Leaves	7.0			1.33	0.12		06/04/75	Hu81
	Leaves	7.0			1.28	0.10		09/11/75	Hu81
	Leaves	7.0			1.33	0.11		10/31/75	Hu81
	Leaves	7.0			1.44	0.10		12/11/75	Hu81
	Leaves	7.0			1.32	0.10		01/08/76	Hu81
	Leaves and stem	8.0	32.0		1.28	0.11		02/01/74	Hu81
	Leaves	10.0			1.25	0.15		10/10/74	Hu81
Bahiagrass (*Paspalum notatum*)									
	Hand plucked	6.5	69.4	37.4	0.91		Rusk	08/13/70	Ro1
	Hand plucked	7.4	79.6	43.7	0.95		Rusk	11/24/69	Ro1
	Hand plucked	7.6	72.7	31.6	0.93		Rusk	08/26/70	Ro1
	Hand plucked	7.9	71.4	39.7	0.96		Rusk	07/16/69	Ro1
	Hand plucked	8.0	78.0	34.6	0.95	0.16	Rusk	07/16/71	Ro1
	Hand plucked	8.4	73.6	35.7	0.96		Rusk	07/30/69	Ro1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hand plucked	8.5	76.5	39.5	0.97		Rusk	08/13/69	Ro1
	Hand plucked	9.0	76.2	32.1	0.97	0.14	Rusk	09/15/71	Ro1
	Hand plucked	9.3	70.1	35.1	0.98		Rusk	07/16/70	Ro1
	Hand plucked	9.5	74.3	38.2	1.00		Rusk	09/10/70	Ro1
	Hand plucked	9.5	73.5	37.1	1.00		Rusk	07/28/70	Ro1
	Hand plucked	9.7	67.8	39.1	1.01		Rusk	06/19/70	Ro1
	Hand plucked	9.7	68.7	37.7	1.00		Rusk	07/02/69	Ro1
	Hand plucked	10.2	76.0	32.6	1.00	0.16	Rusk	06/17/71	Ro1
	Hand plucked	10.7	75.9	35.5	1.02		Rusk	06/18/69	Ro1
	Hand plucked	10.8	75.2	29.3	1.00	0.20	Rusk	06/04/71	Ro1
	Hand plucked	11.2	63.1	32.7	1.03		Rusk	05/21/70	Ro1
	Hand plucked	11.5	74.5	39.0	1.06		Rusk	08/27/69	Ro1
	Hand plucked	11.8	68.5	33.0	1.04		Rusk	07/01/70	Ro1
	Hand plucked	11.9	65.8	33.9	1.05		Rusk	06/04/70	Ro1
	Hand plucked	12.3	74.5	29.9	1.04	0.25	Rusk	10/28/71	Ro1
	Hand plucked	12.7	72.6	31.4	1.06	0.22	Rusk	07/02/71	Ro1
	Hand plucked	12.7	71.4	30.1	1.05	0.22	Rusk	07/28/71	Ro1
	Hand plucked	12.7	68.1	30.9	1.06		Rusk	05/06/70	Ro1
	Hand plucked	13.2	62.6	32.4	1.07		Rusk	11/05/69	Ro1
	Hand plucked	13.5	66.2	31.5	1.08		Rusk	06/05/69	Ro1
	Hand plucked	13.6	73.1	31.4	1.08	0.22	Rusk	11/12/71	Ro1
	Hand plucked	13.7	73.9	30.9	1.08	0.27	Rusk	10/01/71	Ro1
	Hand plucked	14.5	69.6	23.7	1.07	0.26	Rusk	05/07/71	Ro1
	Hand plucked	14.8	73.8	33.8	1.12	0.24	Rusk	08/13/71	Ro1
	Hand plucked	15.2	61.0	33.2	1.12		Rusk	05/09/69	Ro1
	Hand plucked	15.5	65.3	33.9	1.14		Rusk	09/24/69	Ro1
	Hand plucked	15.9	72.1	26.9	1.11	0.27	Rusk	05/19/71	Ro1
	Hand plucked	16.0	68.1	36.2	1.16		Rusk	09/10/69	Ro1
	Hand plucked	16.1	73.2	29.8	1.13	0.22	Rusk	10/15/71	Ro1
	Hand plucked	16.4	60.8	24.9	1.11	0.28	Rusk	04/23/71	Ro1
	Hand plucked	17.0	68.8	32.1	1.16		Rusk	10/22/69	Ro1
	Hand plucked	17.5	63.7	34.1	1.18		Rusk	10/08/69	Ro1
	Hand plucked	18.1	57.0	28.2	1.16		Rusk	04/23/69	Ro1
	Hand plucked	18.5	61.3	30.2	1.18		Rusk	05/21/69	Ro1
	Hand plucked	20.7	63.6	27.4	1.21		Rusk	04/22/70	Ro1
Bermudagrass, Coastal (*Cynodon dactylon*)									
	Hay, dehy., fer. 25-0-0	6.7	74.7	38.5	**1.02**		Brazos	10/20/67	Bu69
	8-wk hay	6.9	79.5	43.0	**0.92**		Wharton	06/21/71	Li80
	Hay	6.9	77.6	37.3	0.92		Bee	07/15/84	Oc95
	Hand plucked	7.0	68.9	35.5	0.92		Rusk	07/30/69	Ro1
	Hay, fer. 100-0-0	7.6	72.0	36.4	**1.05**		Brazos	10/24/67	Bu69
	Hand plucked	7.8	68.1	28.9	0.93	0.12	Rusk	11/12/71	Ro1
	6-wk hay	8.0	78.9	44.8	**0.90**		Wharton	05/23/71	Li80
	Hand plucked	8.1	81.2	39.3	0.96		Rusk	11/24/69	Ro1
	Hay, dehy.	8.5	74.1	38.6	1.05		Brazos	07/20/65	Qu66
	Hand plucked	8.6	77.2	33.4	0.96	0.22	Rusk	07/16/71	Ro1
	Hand plucked	9.0	73.9	31.8	0.97	0.17	Rusk	09/15/71	Ro1
	Hand plucked	9.6	75.0	34.3	0.99		Rusk	08/13/69	Ro1
	Hand plucked	9.7	73.5	37.1	1.00		Rusk	07/16/69	Ro1
	Hand plucked	10.1	69.1	34.3	1.00		Rusk	07/02/69	Ro1
	Plucked forage	10.4	76.5	36.5	*1.02*		Wilson	06/01/95	Wa95
	Hay, dehy.	10.4	75.9	40.2	**0.94**		Brazos	05/09/67	Bu69
	Hand plucked	10.6	76.4	34.4	1.02		Rusk	08/26/70	Ro1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hay, fer. 200-0-0	10.6	73.0	36.2	**1.05**		Brazos	10/24/67	Bu69
	Hand plucked	10.6	72.8	34.9	1.02		Rusk	08/12/70	Ro1
	Hand plucked	10.7	67.3	35.3	1.02		Rusk	06/19/70	Ro1
	Hay, fer. 300-0-0	10.8	73.4	36.8	**1.03**		Brazos	10/24/67	Bu69
	Hay, ammoniated	11.0	72.9	38.5	*1.04*		Bee	07/15/84	Oc95
	Hand plucked	11.4	69.8	33.4	1.03		Rusk	11/05/69	Ro1
	Hand plucked	11.7	76.5	32.1	1.04	0.18	Rusk	06/17/71	Ro1
	Hand plucked	12.2	70.3	33.5	1.05		Rusk	06/18/69	Ro1
	4-wk hay	12.4	76.8	39.8	**1.10**		Wharton	06/07/71	Li80
	Hand plucked	12.4	63.4	32.1	1.05		Rusk	05/21/70	Ro1
	Hand plucked	12.5	67.2	28.6	1.04	0.25	Rusk	10/28/71	Ro1
	Hand plucked	12.6	66.6	33.0	1.06		Rusk	06/05/69	Ro1
	Hand plucked	13.0	78.3	31.0	1.06	0.22	Rusk	08/26/71	Ro1
	Hand plucked	13.0	77.6	34.6	1.08		Rusk	07/16/70	Ro1
	Hand plucked	13.2	66.0	29.0	1.06		Rusk	07/01/70	Ro1
	Hand plucked	13.4	65.1	26.6	1.05	0.23	Rusk	10/01/71	Ro1
	Hand plucked	13.9	76.9	31.5	1.08	0.22	Rusk	06/04/71	Ro1
	Hand plucked	14.1	73.7	30.1	1.08	0.24	Rusk	07/02/71	Ro1
	Hand plucked	15.0	73.5	34.3	1.12		Rusk	07/28/70	Ro1
	Hand plucked	15.1	78.2	32.2	1.12	0.27	Rusk	07/28/71	Ro1
	Hand plucked	15.2	71.0	29.3	1.10		Rusk	05/06/70	Ro1
	Hand plucked	15.3	67.0	28.2	1.10	0.22	Rusk	10/15/71	Ro1
	Hand plucked	16.1	73.8	32.2	1.14		Rusk	09/10/70	Ro1
	Hand plucked	16.6	69.6	28.8	1.13	0.28	Rusk	05/19/71	Ro1
	Hand plucked	16.8	74.2	36.1	1.18		Rusk	10/22/69	Ro1
	Hand plucked	17.5	69.3	34.6	1.18		Rusk	10/08/69	Ro1
	Hand plucked	17.6	71.0	25.4	1.13	0.27	Rusk	05/07/71	Ro1
	Hand plucked	17.7	63.9	29.8	1.16		Rusk	06/04/70	Ro1
	Hand plucked	19.4	68.0	31.7	1.21		Rusk	08/27/69	Ro1
	Hand plucked	21.2	55.0	27.5	1.22		Rusk	05/09/69	Ro1
	Hand plucked	21.4	49.2	25.3	1.21		Rusk	04/23/69	Ro1
	Hand plucked	21.5	59.3	28.7	1.23		Rusk	05/21/69	Ro1
	Hand plucked	22.0	63.2	30.3	1.25		Rusk	09/10/69	Ro1
	Hand plucked	22.6	62.6	29.3	1.25		Rusk	09/24/69	Ro1
	Hand plucked	26.0	57.5	25.8	1.29		Rusk	04/22/70	Ro1
	Hand plucked	28.8	64.1	29.1	1.37	0.35	Rusk	04/23/71	Ro1
Bermudagrass, Coastcross (*Cynodon dactylon*)									
	Hand plucked	7.6	77.8	42.6	0.95		Rusk	01/21/70	Ro1
	Hand plucked	8.2	60.1	39.4	0.97		Rusk	11/24/69	Ro1
	Hand plucked	8.8	66.6	23.0	0.94		Rusk	07/30/69	Ro1
	Hand plucked	9.3	69.3	27.2	0.96		Rusk	06/19/70	Ro1
	Hand plucked	10.7	72.8	34.7	1.02		Rusk	08/13/69	Ro1
	Hand plucked	11.3	62.0	31.7	1.02		Rusk	07/02/69	Ro1
	Hand plucked	11.5	69.3	32.6	1.03		Rusk	07/16/69	Ro1
	Hand plucked	12.2	72.9	34.0	1.06	0.31	Rusk	08/13/71	Ro1
	Hand plucked	12.3	73.6	31.3	1.05	0.25	Rusk	07/16/71	Ro1
	Hand plucked	12.7	73.6	31.3	1.06	0.16	Rusk	06/17/71	Ro1
	Hand plucked	13.4	74.7	33.0	1.08	0.22	Rusk	11/12/71	Ro1
	Hand plucked	14.0	66.1	24.4	1.06	0.15	Rusk	05/19/71	Ro1
	Hand plucked	14.1	69.9	32.2	1.09		Rusk	08/26/70	Ro1
	Hand plucked	14.7	73.1	32.6	1.11	0.30	Rusk	07/28/71	Ro1
	Hand plucked	14.9	67.9	30.2	1.10		Rusk	08/13/70	Ro1
	Hand plucked	15.3	70.3	29.3	1.11		Rusk	07/28/70	Ro1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hand plucked	15.5	71.7	29.7	1.11	0.36	Rusk	10/15/71	Ro1
	Hand plucked	15.6	68.9	26.8	1.10	0.22	Rusk	06/04/71	Ro1
	Hand plucked	16.0		23.8	1.10		Rusk	07/16/70	Ro1
	Hand plucked	16.4	73.4	30.0	1.13	0.28	Rusk	10/28/71	Ro1
	Hand plucked	16.5	72.9	29.9	1.13	0.27	Rusk	09/15/71	Ro1
	Hand plucked	16.6	58.9	30.0	1.14		Rusk	06/05/69	Ro1
	Hand plucked	16.6	50.9	26.9	1.12		Rusk	05/21/70	Ro1
	Hand plucked	16.8	70.6	25.2	1.12	0.34	Rusk	10/01/71	Ro1
	Hand plucked	17.6	62.6	29.4	1.16		Rusk	09/10/70	Ro1
	Hand plucked	17.7	58.5	26.5	1.14		Rusk	06/18/69	Ro1
	Hand plucked	18.1	66.0	32.4	1.18		Rusk	08/27/69	Ro1
	Hand plucked	18.4	56.1	26.5	1.16		Rusk	07/01/70	Ro1
	Hand plucked	18.8	64.4	30.3	1.19		Rusk	10/08/69	Ro1
	Hand plucked	18.9	64.2	30.6	1.19		Rusk	11/05/69	Ro1
	Hand plucked	18.9	56.0	30.2	1.19		Rusk	05/21/69	Ro1
	Hand plucked	19.0	64.9	27.1	1.17	0.36	Rusk	07/02/71	Ro1
	Hand plucked	19.4	63.8	21.6	1.15	0.31	Rusk	05/07/71	Ro1
	Hand plucked	19.5	53.7	22.7	1.16		Rusk	05/06/70	Ro1
	Hand plucked	20.3	61.0	29.8	1.21		Rusk	09/10/69	Ro1
	Hand plucked	21.2	59.0	28.8	1.22		Rusk	09/24/69	Ro1
	Hand plucked	22.9	53.2	28.0	1.25		Rusk	05/09/69	Ro1
	Hand plucked	26.1	44.5	20.6	1.26		Rusk	04/22/70	Ro1
	Hand plucked	26.5	43.5	18.4	1.25	0.52	Rusk	04/23/71	Ro1
Bermudagrass, common (*Cynodon dactylon*)									
	7-wk hay	7.3	67.7	34.7	*0.93*		Brazoria	08/06/84	Li87
	Hand plucked	7.8	73.1	33.0	0.94		Rusk	07/30/69	Ro1
	Clipped sward	7.9	72.8	43.3	0.97		Brazoria	10/18/88	Li89
	Hand plucked	8.2	77.1	36.3	0.96		Rusk	11/24/69	Ro1
	Hand plucked	8.3	77.2	37.8	0.96		Rusk	08/13/69	Ro1
	Hand plucked	8.8	72.2	35.9	0.97		Rusk	07/16/69	Ro1
	Clipped sward	8.9	71.5	37.5	0.98		Brazoria	08/25/88	Li89
	Hand plucked	10.1	69.8	31.5	0.99		Rusk	08/26/70	Ro1
	Hand plucked	10.4	64.8	34.1	1.01		Rusk	06/19/70	Ro1
	Hand plucked	10.4	65.1	32.6	1.01		Rusk	07/02/69	Ro1
	Hand plucked	10.5	69.0	33.2	1.01		Rusk	08/12/70	Ro1
	Hand plucked	11.5	73.9	36.5	1.05		Rusk	08/27/69	Ro1
	Leaves and stems	12.0	62.0		1.10	0.22		05/24/73	Hu81
	Leaves and stems	12.0	65.0		1.07	0.21		06/28/73	Hu81
	Cow selected	12.2	68.8	37.5	1.07		Brazoria	08/25/88	Li89
	Hand plucked	12.2	73.7	31.8	1.05	0.15	Rusk	06/17/71	Ro1
	Cow selected	12.7	66.7	39.3	1.09		Brazoria	10/18/88	Li89
	Hand plucked	12.9	65.5	31.9	1.06		Rusk	06/18/69	Ro1
	Hand plucked	13.4	72.5	28.9	1.06	0.19	Rusk	09/15/71	Ro1
	Hand plucked	13.5	73.1	30.7	1.07	0.17	Rusk	07/16/71	Ro1
	Hand plucked	14.0	60.4	31.2	1.09		Rusk	05/21/70	Ro1
	Hand plucked	14.1	60.6	39.8	1.13		Rusk	06/04/70	Ro1
	Hand plucked	14.4	62.9	28.3	1.08		Rusk	11/05/69	Ro1
	Hand plucked	14.4	69.6	31.7	1.10		Rusk	09/10/70	Ro1
	Hand plucked	14.4	72.2	27.0	1.08	0.19	Rusk	08/26/71	Ro1
	Hand plucked	14.7	67.7	28.0	1.09	0.19	Rusk	07/02/71	Ro1
	Hand plucked	15.4	59.6	25.7	1.09		Rusk	07/01/70	Ro1
	Hand plucked	15.4	68.6	27.1	1.10		Rusk	07/28/70	Ro1
	Hand plucked	15.6	70.0	26.8	1.10	0.24	Rusk	06/04/71	Ro1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hand plucked	15.7	71.2	29.3	1.11	0.20	Rusk	07/28/71	Ro1
	Hand plucked	15.7	70.1	27.2	1.10	0.20	Rusk	08/13/71	Ro1
	Hand plucked	15.8	70.5	30.8	1.12		Rusk	10/22/69	Ro1
	Hand plucked	15.9	54.5	20.2	1.08		Rusk	05/06/70	Ro1
	Hand plucked	16.0	48.8	25.0	1.10		Rusk	05/07/71	Ro1
	Hand plucked	16.8	66.4	31.9	1.15		Rusk	09/10/69	Ro1
	Hand plucked	17.0	55.6	26.7	1.13	0.33	Rusk	05/19/71	Ro1
	Hand plucked	17.5	65.1	28.9	1.15		Rusk	10/08/69	Ro1
	Hand plucked	17.8	70.6	26.3	1.14	0.26	Rusk	10/01/71	Ro1
	Hand plucked	18.1	69.5	28.7	1.16		Rusk	07/16/70	Ro1
	Hand plucked	19.1	54.6	30.5	1.19		Rusk	05/09/69	Ro1
	Hand plucked	19.3	57.6	28.6	1.19		Rusk	06/05/69	Ro1
	Hand plucked	19.5	39.9	26.1	1.18		Rusk	04/22/70	Ro1
	Hand plucked	20.2	42.5	25.0	1.18		Rusk	04/07/71	Ro1
	Hand plucked	22.0	36.0	16.5	1.17		Rusk	02/24/71	Ro1
	Hand plucked	22.1	57.8	27.0	1.23		Rusk	09/24/69	Ro1
	Hand plucked	22.4	39.9	17.1	1.18		Rusk	03/11/71	Ro1
	Hand plucked	22.8	39.9	22.5	1.22		Rusk	04/23/71	Ro1
	Hand plucked	23.2	55.8	26.5	1.25		Rusk	05/21/69	Ro1
	Hand plucked	24.1	36.0	19.5	1.22		Rusk	03/24/71	Ro1
	Hand plucked	26.3	48.6	25.3	1.29		Rusk	04/23/69	Ro1
	Hand plucked	27.7	29.0	17.8	1.27		Rusk	04/05/70	Ro1
Blackbrush (*Acacia rigidula*)									
	Leaves	13.1	56.2	29.6	1.06		Maverick	06/29/79	Va1
	Hand plucked	13.3	56.6	43.1	1.13		Jim Wells	06/15/88	Ko91
	Hand plucked	15.8	55.6	43.4	1.21		Jim Wells	08/15/88	Ko91
	Hand plucked	17.0	64.2	57.6	1.44		Jim Wells	05/15/89	Ko91
Bladderpod, gordon (*Lesquerella gordonii*)									
	Whole plant	9.0	37.0		0.97	0.16		04/13/73	Hu81
	Whole plant	10.0	31.0		0.72	0.17		03/27/73	Hu81
	Whole plant	11.0			0.87	0.15		03/28/74	Hu81
	Fruit	17.0	35.0		1.47			04/13/73	Hu81
Blue-eye grass (*Sisyrinchium* sp.)									
	Whole plant	10.0	52.0		1.18	0.12		04/13/73	Hu81
Bluewood (*Condelia hookeri*)									
	Hand plucked	13.8	38.2	24.1	1.05		Jim Wells	08/15/88	Ko91
	Leaves	14.2	33.8	12.9	1.03		Maverick	06/29/79	Va1
	Hand plucked	16.3	43.2	23.9	1.10		Jim Wells	06/15/88	Ko91
	Hand plucked	20.1	44.5	27.4	1.19		Jim Wells	05/15/89	Ko91
Broadleaf milkweed (*Asclepias latifolia*)									
	Leaves	11.0	18.0		1.46	0.13		08/30/73	Hu81
Buffalo gourd (*Cucurbita foetidissima*)									
	Leaves	16.0	19.0		0.72	0.19		10/25/73	Hu81
	Leaves	17.0	17.0		1.06	0.21		10/03/73	Hu81
	Leaves	20.0	22.0		1.20	0.19		08/30/73	Hu81
	Leaves	27.0	19.0		1.14	0.23		07/27/73	Hu81
	Leaves	27.0			1.13	0.33		10/10/74	Hu81
	Leaves	30.0			1.53	0.36		05/24/73	Hu81
Buffalograss (*Buchloe dactyloides*)									
		5.4		40.6	*		Maverick	01/24/75	Va1
		5.6		41.5	*		Maverick	07/05/74	Va1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Leaves	6.7	74.0	42.1	*		Maverick	06/29/79	Va1
		6.8		40.5	*		Maverick	06/19/74	Va1
		6.9		45.6	*		Maverick	09/06/75	Va1
		7.0		39.5	0.93		Maverick	08/22/75	Va1
		7.1		40.7	0.93		Maverick	08/15/74	Va1
		7.2		46.3	0.95		Maverick	07/24/74	Va1
		7.2		38.1	0.93		Maverick	05/15/75	Va1
		7.5		38.8	0.94		Maverick	07/24/75	Va1
		7.6		43.8	0.96		Maverick	06/06/74	Va1
		7.7		36.9	0.94		Maverick	06/26/75	Va1
		7.8		37.1	0.95		Maverick	08/07/75	Va1
		7.9		39.0	0.96		Maverick	05/29/75	Va1
	Leaves and stems	8.0	68.0		0.61	0.21		10/25/73	Hu81
	Whole plant	8.0			0.58	0.21		10/10/74	Hu81
		8.1		41.9	0.97		Maverick	02/20/75	Va1
		8.5		41.4	0.98		Maverick	04/04/75	Va1
		8.7		38.8	0.98		Maverick	04/16/75	Va1
	Leaves and stems	9.0	66.0		0.69	0.22		07/27/73	Hu81
		9.3		41.1	1.00		Maverick	12/12/74	Va1
		9.5		39.8	1.01		Maverick	12/20/74	Va1
		9.8		38.7	1.01		Maverick	05/01/75	Va1
		9.9		37.4	1.01		Maverick	06/12/75	Va1
		10.0		42.2	1.03		Maverick	05/22/74	Va1
		10.0		40.3	1.02		Maverick	12/20/74	Va1
		10.2		37.9	1.02		Maverick	03/19/75	Va1
	10.3		38.0	1.02	Maverick		11/27/74	Va1	
		10.6		39.3	1.04		Maverick	03/06/75	Va1
		10.8		38.1	1.04		Maverick	06/26/75	Va1
	Leaves	11.0	67.0		1.13	0.16		05/24/73	Hu81
	Leaves	11.0	69.0		0.83	0.23		06/28/73	Hu81
		11.4		39.4	1.06		Maverick	11/14/74	Va1
		11.5		40.3	1.07		Maverick	09/26/7	Va1
		11.6		39.6	1.07		Maverick	10/10/74	Va1
	Leaves and stems	12.0			1.15	0.21		04/24/74	Hu81
		12.7		37.0	1.08		Maverick	02/07/75	Va1
	Green forage	13.0	70.0		1.15	0.13		05/03/73	Hu81
		14.8		39.6	1.15		Maverick	09/12/74	Va1
Buffelgrass (*Cenchrus ciliaris*)									
		4.4		51.3	*		Maverick	02/07/75	Va1
		4.8		48.0	*		Maverick	02/20/75	Va1
		5.3		50.4	*		Maverick	03/06/75	Va1
		5.4		48.1	*		Maverick	07/05/74	Va1
		5.4		47.2	*		Maverick	07/24/74	Va1
		6.2		47.3	*		Maverick	06/19/74	Va1
	Hay, dehy.	6.2	74.9	44.2	**1.04**		Brazos	06/13/67	Bu69
		6.5		49.9	*		Maverick	12/20/74	Va1
		7.7		53.4	1.00		Maverick	12/20/74	Va1
	Leaves	7.8	68.5	38.0	0.95		Maverick	06/29/79	Va1
		8.1		43.0	0.97		Maverick	06/06/74	Va1
		10.7		40.2	1.04		Maverick	06/26/75	Va1
		11.9		43.2	1.09		Maverick	05/22/74	Va1
		12.4		45.5	1.12		Maverick	03/19/75	Va1
		12.8		39.0	1.10		Maverick	08/15/74	Va1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
		14.8		44.9	1.19		Maverick	04/04/75	Va1
		14.9		34.2	1.12		Maverick	10/10/74	Va1
		15.6		45.1	1.22		Maverick	08/15/74	Va1
		16.0		39.8	1.18		Maverick	10/23/74	Va1
		16.1		38.6	1.18		Maverick	08/07/75	Va1
		17.0		46.3	1.27		Maverick	09/06/75	Va1
		17.1		41.6	1.23		Maverick	05/01/75	Va1
		17.5		38.5	1.21		Maverick	05/15/75	Va1
		18.0		40.4	1.24		Maverick	08/22/75	Va1
		18.7		40.3	1.26		Maverick	11/27/74	Va1
		18.8		35.6	1.22		Maverick	09/26/74	Va1
		19.8		39.4	1.28		Maverick	07/24/75	Va1
		20.4		40.1	1.30		Maverick	06/26/75	Va1
		20.9		40.4	1.31		Maverick	09/12/74	Va1
		22.2		38.6	1.32		Maverick	04/16/75	Va1
		23.2		38.4	1.34		Maverick	06/12/75	Va1
		27.9		36.0	1.41		Maverick	05/29/75	Va1
Canada wildrye (*Elymus canadensis*)									
	Leaves and stems	7.0	60.0		0.83	0.20		07/27/73	Hu81
	Leaves and stems	8.0	65.0		0.92	0.22		06/28/73	Hu81
	Leaves and stems	9.0	64.0		1.05	0.13		05/24/73	Hu81
	Leaves and stems	9.0	66.0		0.90	0.22		10/25/73	Hu81
	Leaves	14.0	56.0		1.32	0.11		04/13/73	Hu81
Cane bluestem (*Bothriochloa barbinodis* var. *barbinodis*)									
	Leaves and stems	3.0	71.0		0.93	0.03		12/27/73	Hu81
	Leaves and stems	3.0			0.68	0.04		12/17/74	Hu81
	Leaves and stems	4.0			0.73	0.06		06/25/74	Hu81
	Leaves and stems	5.0	70.0		1.03	0.08		10/25/73	Hu81
	Leaves and stems	6.0	68.0		0.92	0.08		08/30/73	Hu81
	Leaves and stems	6.0	74.0		0.81	0.07		10/03/73	Hu81
	Old and new growth	8.0	68.0		0.62	0.12		04/13/73	Hu81
	Leaves and stems	8.0			0.99	0.09		04/24/74	Hu81
	Leaves	9.0	65.0		1.05	0.14		05/24/73	Hu81
	Leaves and stems	9.0	66.0		1.10	0.15		06/28/73	Hu81
Capul (*Schafferia cuneifolia*)									
	Leaves	12.2	53.1	24.5	1.02		Maverick	06/29/79	Va1
Catclaw acacia (*Acacia greggii* var. *greggii*)									
	Leaves	17.0	33.0		***1.25***	0.15		07/27/73	Hu81
	Leaves and twigs	19.0	36.0		***1.25***	0.13		06/28/73	Hu81
	Leaves	21.0	25.0		***1.59***	0.27		05/24/73	Hu81
	Leaves	30.0			***1.69***	0.41		04/13/73	Hu81
Cedar plantain (*Plantago helleri*)									
	Whole plant	9.0	40.0		1.31	0.14		04/13/73	Hu81
	Whole plant	12.0			1.27	0.14		03/28/74	Hu81
Clover, berseem, Bigbee (*Trifolium alexandrinum*)									
	Clipped sward	16.7	52.4	36.8	1.18		Brazoria	04/30/85	Li86
	Clipped sward	16.7	54.4	38.4	1.19		Brazoria	05/14/85	Li86
	Clipped sward	18.0	46.2	32.4	1.18		Brazoria	04/16/85	Li86
	Silage	20.8	40.1	33.5	1.25		Brazoria	07/01/86	Li90
	Cow selected	23.0	45.8	29.4	1.26		Brazoria	04/30/85	Li86
	Cow selected	25.3	50.3	28.4	1.30		Brazoria	05/14/85	Li86

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Cow selected	26.2	44.4	28.1	1.31		Brazoria	04/16/85	Li86
Clover, sweet, hubam (*Melilotus albus*)									
	Hay, dehy.	13.8	62.9	42.2	**1.04**		Brazos	05/09/67	Bu69
Clover, subterranean, Meteora (*Trifolium subterranium*)									
	Clipped sward	18.6	46.0	37.0	1.23		Brazoria	04/30/85	Li86
	Clipped sward	19.2	51.3	42.5	1.29		Brazoria	05/14/85	Li86
	Clipped sward	20.1	41.3	31.8	1.22		Brazoria	04/16/85	Li86
	Cow selected	24.1	49.6	30.1	1.29		Brazoria	05/14/85	Li86
	Cow selected	24.1	44.9	29.9	1.29		Brazoria	04/16/85	Li86
	Cow selected	24.3	49.2	31.4	1.30		Brazoria	04/30/85	Li86
Clover, white, Louisiana S-1 (*Trifolium repens*)									
	Whole plant	22.0			1.16		Rusk	06/12/81	Ro1
	Whole plant	22.4			1.06		Rusk	05/21/81	Ro1
	Whole plant	30.3			1.41		Rusk	03/20/81	Ro1
	Whole plant	31.2			1.33		Rusk	04/13/81	Ro1
Clover, white, Regal ladino (*Trifolium repens*)									
	Whole plant	21.7			1.31		Rusk	07/16/81	Ro1
	Whole plant	24.9			1.34		Rusk	06/12/81	Ro1
	Whole plant	25.3			1.24		Rusk	05/21/81	Ro1
	Whole plant	29.8			1.34		Rusk	04/13/81	Ro1
	Whole plant	35.0			1.43		Rusk	03/20/81	Ro1
Clover, white, Tillman ladino (*Trifolium repens*)									
	Whole plant	23.1			1.24		Rusk	07/16/81	Ro1
	Whole plant	26.7			1.33		Rusk	06/12/81	Ro1
	Whole plant	28.8			1.39		Rusk	05/21/81	Ro1
	Whole plant	31.6			1.38		Rusk	04/13/81	Ro1
	Whole plant	32.6			1.45		Rusk	03/20/81	Ro1
Clover, white, Sacramento (*Trifolium repens*)									
	Whole plant	18.5			1.32		Rusk	07/16/81	Ro1
	Whole plant	22.5			1.24		Rusk	06/12/81	Ro1
	Whole plant	22.6			1.30		Rusk	05/21/81	Ro1
	Whole plant	30.3			1.32		Rusk	04/13/81	Ro1
	Whole plant	31.4			1.48		Rusk	03/20/81	Ro1
Common broomweed (*Xanthocephalum* sp.)									
	Leaves and stems	12.0	39.0		1.16	0.18		05/24/7	Hu81
Common curlymesquite (*Hilaria belangeri*)									
	Leaves and stems	4.0			0.54	0.06		09/11/75	Hu81
	Leaves and stems	5.0	65.0		0.80	0.06		08/30/73	Hu81
	Leaves and stems	5.0	68.0		0.60	0.07		12/27/73	Hu81
	Leaves and stems	5.0	64.0		0.57	0.07		02/01/74	Hu81
	Leaves and stems	5.0			0.53	0.07		11/15/74	Hu81
	Whole plant	5.0			0.44	0.07		12/17/74	Hu81
	Leaves and stems	5.0			0.52	0.06		12/11/75	Hu81
	Whole plant	5.0			0.58	0.06		01/08/76	Hu81
		5.4		44.5	*		Maverick	08/15/74	Va1
		5.5		44.8	*		Maverick	06/19/74	Va1
		5.7		42.0	*		Maverick	10/10/74	Va1
	Whole plant	5.0			0.71	0.06		07/11/75	Hu81
		5.8		45.8	*		Maverick	07/24/74	Va1
		5.9		32.7	*		Maverick	07/05/74	Va1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Old leaves	6.0	65.0		0.55	0.09		04/13/73	Hu81
	Leaves and stems	6.0	67.0		0.58	0.09		10/25/73	Hu81
	Leaves and stems	6.0	60.0		0.60	0.09		02/28/74	Hu81
	Whole plant	6.0			0.75	0.08		06/25/74	Hu81
	Leaves and stems	6.0			0.65	0.12		10/10/74	Hu81
	Leaves and stems	6.0			0.50	0.06		02/11/75	Hu81
		6.0		41.5	*		Maverick	08/22/75	Va1
	Leaves and stems	6.0			0.70	0.08		10/31/75	Hu81
		6.2		38.0	*		Maverick	08/07/75	Va1
		6.4		44.5	*		Maverick	11/27/74	Va1
		6.7		38.5	*		Maverick	06/12/75	Va1
	Leaves	6.7	73.3	41.4	*		Maverick	06/29/79	Va1
		6.8		44.4	*		Maverick	06/06/74	Va1
	Whole plant	7.0	64.0		0.99	0.13		07/27/73	Hu81
	Leaves and stems	7.0	65.0		0.73	0.13		10/03/73	Hu81
	Leaves and stems	7.0	55.0		0.55	0.09		11/29/73	Hu81
	Leaves and stems	7.0			0.60	0.12		03/28/74	Hu81
	Whole plant	7.0			0.87	0.11		08/15/74	Hu81
	Whole plant	7.0			0.66	0.11		06/04/75	Hu81
		7.4		43.0	0.95		Maverick	12/20/74	Va1
		7.4		41.1	0.94		Maverick	01/24/75	Va1
		7.5		47.8	0.97		Maverick	11/14/74	Va1
		7.5		43.5	0.95		Maverick	02/07/75	Va1
		7.6		40.8	0.95		Maverick	05/15/75	Va1
		7.9		45.5	0.97		Maverick	09/26/74	Va1
	Leaves and stems	8.0	61.0		0.92	0.21		07/27/73	Hu81
	Whole plant	8.0			0.77	0.12		05/24/74	Hu81
	Leaves and stems	8.0			0.66	0.16		04/15/75	Hu81
		8.1		44.4	0.98		Maverick	12/12/74	Va1
		8.1		41.5	0.97		Maverick	07/24/75	Va1
		8.4		39.9	0.97		Maverick	04/04/75	Va1
		8.4		41.7	0.98		Maverick	06/26/75	Va1
		8.5		41.0	0.98		Maverick	12/20/74	Va1
		8.6		39.0	0.98		Maverick	05/01/75	Va1
		8.6		40.1	0.98		Maverick	06/26/75	Va1
		8.7		39.6	0.98		Maverick	03/06/75	Va1
		8.8		37.8	0.98		Maverick	05/29/75	Va1
		9.0	66.0		0.82	0.12		05/24/73	Hu81
		9.1		42.0	1.00		Maverick	02/20/75	Va1
		9.5		44.2	1.02		Maverick	0/23/74	Va1
		9.6		41.0	1.01		Maverick	03/19/75	Va1
		9.8		39.5	1.01		Maverick	04/16/75	Va1
		9.9		40.1	1.02		Maverick	05/22/74	Va1
	New leaves	10.0	65.0		0.88	0.12		04/13/73	Hu81
	Leaves and stems	10.0			0.96	0.14		04/24/74	Hu81
	Leaves and stems	11.0	66.0		0.99	0.19		06/28/73	Hu81
		11.3		38.8	1.05		Maverick	09/12/74	Va1
Common dyssodia (*Thymophylla pentachaeta* var. *pentachaeta*)									
	Leaves and stems	6.0			0.95	0.06		06/25/74	Hu81
Common horehound (*Marrubium vulgare*)									
	Whole plant	17.0	19.0		0.80	0.22		03/27/73	Hu81
	Leaves and stems	21.0	32.0		1.03	0.34		10/25/73	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Leaves and stems	22.0	32.0		1.00	0.32		11/29/73	Hu81
	Whole plant	22.0			1.24	0.22		03/28/74	Hu81
	Whole plant	22.0			1.16	0.25		08/15/74	Hu81
	Leaves and stems	22.0			1.29	0.37		11/15/74	Hu81
	Leaves	30.0	28.0		1.21	0.03		04/13/73	Hu81
Croton (*Croton* sp.)									
	Leaves and stems	9.0			1.02	0.08		06/25/74	Hu81
	Whole plant	11.0	46.0		0.92	0.15		07/27/73	Hu81
	Leaves and stems	12.0			0.95	0.12		05/24/74	Hu81
	Whole plant	12.0			1.00	0.15		10/10/74	Hu81
	Whole plant	12.0			1.04	0.17		11/15/74	Hu81
	Whole plant	14.0	46.0		1.05	0.23		06/28/73	Hu81
	Whole plant	15.0			1.01	0.19		08/15/74	Hu81
	Whole plant	16.0			1.03	0.21		02/11/75	Hu81
	Whole plant	17.0			1.20	0.14		08/15/74	Hu81
	Leaves and stems	18.0	42.0		1.07	0.17		10/25/73	Hu81
Dayflower (*Commelina* sp.)									
	Whole plant	12.0	41.0		1.03	0.13		10/03/73	Hu81
Dutchmans britches (*Thamnosma texana*)									
	Whole plant	13.0	35.0		1.22	0.16		03/27/73	Hu81
Elbow bush (*Forestiera pubescens* var. *pubescens*)									
	Leaves	7.0	28.0		1.46	0.07		10/25/73	Hu81
	Leaves	8.0	28.0		1.58	0.07		08/30/73	Hu81
	Leaves	8.0			1.43	0.07		09/11/75	Hu81
	Leaves	10.0	35.0		1.58	0.12		06/28/73	Hu81
	Leaves	10.0			1.32	0.08		07/11/75	Hu81
	Leaves	11.0			1.32	0.11		06/04/75	Hu81
	Leaves and twigs	13.0	30.0		1.62	0.16		04/13/73	Hu81
	Leaves	13.0	33.0		1.54	0.16		05/24/73	Hu81
	Leaves	14.0			1.42	0.21		04/15/75	Hu81
	Leaves	20.0			1.37	0.26		03/28/74	Hu81
	Leaves and twigs	21.0	34.0		1.47	0.32		03/27/73	Hu81
Engelmandaisy (*Engelmannia pinnatifida*)									
	Whole plant	9.0	49.0		0.83	0.17		05/24/73	Hu81
	Leaves	12.0	26.0		1.03	0.13		05/24/73	Hu81
	Whole plant	14.0	22.0		0.51	0.18		04/13/73	Hu81
	Whole plant	14.0			1.21	0.20		11/15/74	Hu81
Evax, bighead (Evax prolifera)									
	Whole plant	10.0	39.0		0.97	0.19		04/13/73	Hu81
	Whole plant	10.0			0.57	0.15		04/24/74	Hu81
	Whole plant	12.0			0.57	0.16		03/28/74	Hu81
	Whole plant	14.0	45.0		0.91	0.20		03/27/73	Hu81
Evening primrose (*Oenothera* sp.)									
	Whole plant	11.0	16.0		1.28	0.17		03/27/73	Hu81
	Whole plant	12.0	17.0		1.42	0.23		04/13/73	Hu81
Fall witchgrass (*Digitaria cognata*)									
	Leaves and stems	5.0	71.0		0.80	0.05		10/25/73	Hu81
	Leaves and stems	6.0	66.0		1.03	0.09		10/03/73	Hu81
	Leaves	6.0	78.2	43.8	*		Maverick	06/29/79	Va1
	Leaves and stems	8.0			1.13	0.13		08/15/74	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
Feather dalea (*Dalea formasa*)									
	Leaves and twigs	17.0	46.0		1.14			04/13/73	Hu81
Fleabane (*Erigeron* sp.)									
	Whole plant	9.0	41.0		1.00	0.25		07/27/73	Hu81
	Whole plant	11.0	25.0		1.24	0.14		04/13/73	Hu81
	Whole plant	12.0	33.0		0.98	0.22		03/27/73	Hu81
Gordo bluestem (*Dichanthium aristatum*)									
	10-wk hay	8.9		39.6	*0.99*		Jackson	09/14/82	Li92
	6-wk hay	9.4		33.7	*0.98*		Jackson	08/16/82	Li92
Green sprangletop (Leptochloa dubia)									
	Leaves and stem	5.0	76.0		1.03	0.05		08/30/73	Hu81
	Leaves	6.0	74.0		0.51	0.08		10/25/73	Hu81
	Whole plant	7.0	74.0		1.05	0.15		10/03/73	Hu81
Guajillo (*Acacia berlandieri*)									
	Hand plucked	15.6	49.3	26.9	***1.10***		Jim Wells	08/15/88	Ko91
	Leaves	18.2	47.8	25.0	***1.15***		Maverick	06/29/79	Va1
	Hand plucked	18.7	52.4	29.5	***1.18***		Jim Wells	06/15/88	Ko91
	Hand plucked	21.2	62.0	37.9	***1.29***		Jim Wells	05/15/89	Ko91
Guayacan (*Guaiacum angustifolium*)									
	Leaves	17.5	43.2	30.5	1.16		Maverick	06/29/79	Va1
Hairy grama (*Bouteloua hirsuta*)									
	Leaves and stem	4.0	68.0		0.65	0.04		02/01/74	Hu81
	Leaves and stem	5.0	70.0		0.94	0.07		08/30/73	Hu81
	Leaves and stem	5.0	75.0		0.84	0.08		10/03/73	Hu81
	Leaves and stem	5.0	70.0		0.74	0.05		10/25/73	Hu81
	Leaves and stem	5.0	65.0		0.60	0.05		12/27/73	Hu81
	Leaves and stem	6.0	64.0		0.64	0.06		02/28/74	Hu81
	Leaves and stem	6.0			0.84	0.08		10/10/74	Hu81
	Leaves and stem	7.0	68.0		0.66	0.09		04/13/73	Hu81
	Leaves and stem	8.0	69.0		1.18	0.09		07/27/73	Hu81
Hairy tridens (*Erioneuron pilosum*)									
	Whole plant	8.0	64.0		0.88	0.09		04/13/73	Hu81
	Whole plant	9.0	67.0		1.05	0.23		07/27/73	Hu81
	Leaves and stems	10.0	64.0		0.90	0.15		10/03/73	Hu81
	Leaves and stems	11.0	69.0		1.17	0.14		06/28/73	Hu81
Halls panicum (*Panicum hallii* var. *hallii*)									
	Leaves and stems	4.0	66.0		0.80	0.08		12/27/73	Hu81
	Leaves and stems	5.0	61.0		0.81	0.09		02/28/74	Hu81
	Leaves and stems	6.0	65.0		0.97	0.08		08/30/73	Hu81
	Leaves and stems	6.0	66.0		0.82	0.08		10/25/73	Hu81
	Leaves and stems	8.0	68.0		1.00	0.11		06/28/73	Hu81
	Leaves and stems	8.0	62.0		1.05	0.13		07/27/73	Hu81
	Leaves and stems	8.0	67.0		0.98	0.14		10/03/73	Hu81
Honey mesquite (*Prosopis glandulosa*)									
	Ripe pods	12.7		30.0	1.05		Lubbock	08/15/80	Ha1
Hooded windmillgrass (*Chloris cucullata*)									
	Leaves	4.7	73.1	40.3	*		Maverick	06/29/79	Va1
Huisache (*Acacia smallii*)									
	Hand plucked	20.7	46.8	25.5	***1.20***		Jim Wells	08/15/88	Ko91

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hand plucked	26.2	55.9	31.3	***1.34***		Jim Wells	06/15/88	Ko91
	Hand plucked	27.8	54.6	28.9	***1.35***		Jim Wells	05/15/89	Ko91
Illinois bundleflower (*Desmanthus illinoensis*)									
	Leaves	20.1	43.6	15.1	1.14		Maverick	06/29/79	Va1
Indianmallow (*Abutilon fruticosum*)									
	Whole plant	11.0			0.86	0.22		11/15/74	Hu81
	Whole plant	12.0			0.81	0.27		10/10/74	Hu81
	Whole plant	13.0			0.95	0.17		08/15/7	Hu81
Johnsongrass (Sorghum halepense)									
	Hay, dehy.	9.2	67.9	39.2	**1.10**		Brazos	05/09/67	Bu69
	Leaves	10.0	66.0		1.22	0.16		10/25/73	Hu81
	Leaves and stem	12.0	60.0		1.35	0.21		06/28/73	Hu81
	Leaves	15.0	55.0		1.39	0.38		05/24/73	Hu81
King Ranch bluestem (*Bothriochloa ischaemum* var. *songarica*)									
	Leaves and stems	8.0	66.0		1.06	0.20		06/28/73	Hu81
	Leaves and stems	8.0	68.0		1.03	0.11		07/27/73	Hu81
	Leaves and stems	8.0	68.0		1.02	0.12		10/03/73	Hu81
	Leaves and stems	4.0	71.0		0.83	0.04		12/27/73	Hu81
	Leaves and stems	4.0	70.0		0.77	0.04		02/28/74	Hu81
	Leaves and stems	4.0			0.68	0.05		02/11/75	Hu81
Kleingrass (*Panicum coloratum*)									
		3.5		47.9	*		Maverick	12/20/74	Va1
		3.6		49.2	*		Maverick	12/20/74	Va1
		3.8		49.8	*		Maverick	02/20/75	Va1
		4.1		42.9	*		Maverick	09/06/75	Va1
		4.2		49.5	*		Maverick	01/24/75	Va1
		4.4		45.0	*		Maverick	06/26/75	Va1
		5.1		46.1	*		Maverick	08/22/75	Va1
		5.4		46.1	*		Maverick	06/26/75	Va1
	Hand plucked	5.7	73.6	38.8	*		Rusk	08/13/70	Ro1
	Hand plucked	5.7	72.8	37.9	*		Rusk	08/26/70	Ro1
	Hay, dehy., fer. 25-0-0	5.9	72.2	36.8	**1.06**		Brazos	10/20/67	Bu69
		6.4		45.2	*		Maverick	07/24/75	Va1
		6.4		43.3	*		Maverick	08/07/75	Va1
	Hay	6.7	71.4	42.3	*0.92*		Uvalde	06/15/92	Li94
	Hand plucked	7.1	66.4	36.8	0.93		Rusk	07/02/69	Ro1
	Hand plucked	7.2	71.8	33.8	0.92		Rusk	07/30/69	Ro1
		7.2		44.8	0.95		Maverick	06/12/75	Va1
	Hand plucked	8.2	69.1	37.3	0.96		Rusk	06/18/69	Ro1
	Hand plucked	8.6	63.3	33.2	0.96		Rusk	06/04/70	Ro1
	Hand plucked	8.6	67.9	37.1	0.97		Rusk	07/16/69	Ro1
	Hay, oven dried	8.9	70.6	37.4	**1.17**		Brazos	06/13/67	Bu69
	Hand plucked	9.7	70.9	35.6	1.00		Rusk	07/28/70	Ro1
	Hay, dehy., fer. 200-0-0	9.8	71.7	36.6	**1.05**		Brazos	10/20/67	Bu69
	Hay, dehy., fer. 100-0-0	9.8	71.7	36.6	**1.08**		Brazos	10/20/67	Bu69
		10.0		41.4	1.03		Maverick	05/29/75	Va1
	Hay, dehy., fer. 300-0-0	10.8	69.1	35.3	**1.12**		Brazos	10/20/67	Bu69
	Hand plucked	10.8	72.4	35.3	1.03		Rusk	08/13/69	Ro1
	Hand plucked	10.9	59.4	32.2	1.02		Rusk	05/21/70	Ro1
		11.5		37.3	1.05		Maverick	05/15/75	Va1
	Hay, oven dried	11.6	69.6	35.4	**1.10**		Brazos	05/06/67	Bu69

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hand plucked	11.8	70.4	33.4	1.04		Rusk	08/13/71	Ro1
	Hand plucked	12.4	65.3	33.0	1.05		Rusk	09/10/70	Ro1
	Hand plucked	13.0	58.8	26.0	1.04		Rusk	07/01/70	Ro1
	Hand plucked	13.2	68.5	30.2	1.06		Rusk	06/17/71	Ro1
	Hand plucked	13.4	61.3	32.1	1.08		Rusk	06/05/69	Ro1
		13.9		38.6	1.12		Maverick	03/06/75	Va1
	Hand plucked	14.0	65.2	29.9	1.08		Rusk	07/16/70	Ro1
	Hand plucked	14.6	65.4	24.7	1.07		Rusk	05/19/71	Ro1
	Hand plucked	14.7	63.2	22.2	1.06		Rusk	05/07/71	Ro1
	Hand plucked	15.4	75.6	33.4	1.13		Rusk	10/15/71	Ro1
		15.9		36.6	1.16		Maverick	05/01/75	Va1
	Hand plucked	16.0	59.7	25.1	1.10		Rusk	05/06/70	Ro1
	Hand plucked	16.7	63.4	27.6	1.13		Rusk	11/05/69	Ro1
	Green leaves & stems	17.0	63.0		1.26	0.21		05/03/73	Hu81
		17.0		35.7	1.18		Maverick	04/04/75	Va1
	Hand plucked	17.0	65.4	24.7	1.12		Rusk	07/28/71	Ro1
	Hand plucked	17.3	63.1	29.6	1.15		Rusk	10/08/69	Ro1
		17.8		37.6	1.21		Maverick	03/19/75	Va1
		18.3		38.4	1.23		Maverick	04/16/75	Va1
	Hand plucked	18.4	61.4	27.0	1.16		Rusk	08/27/69	Ro1
	Hand plucked	19.1	58.0	29.3	1.19		Rusk	05/21/69	Ro1
	Hand plucked	19.4	60.7	24.1	1.16		Rusk	04/22/70	Ro1
	Hand plucked	20.2	54.6	28.6	1.20		Rusk	05/09/69	Ro1
	Hand plucked	20.4	59.3	28.0	1.20		Rusk	09/24/69	Ro1
	Hand plucked	20.9	51.7	24.7	1.19		Rusk	04/23/71	Ro1
	Hand plucked	21.0	56.1	24.5	1.19		Rusk	04/23/69	Ro1
	Hand plucked	22.1	57.4	26.9	1.23		Rusk	09/10/69	Ro1
La Coma (*Bumelia celastrina*)									
	Hand plucked	12.3	30.9	25.8	1.03		Jim Wells	08/15/88	Ko91
	Hand plucked	13.4	30.4	23.7	1.04		Jim Wells	06/15/88	Ko91
	Hand plucked	14.6	35.1	26.0	1.08		Jim Wells	05/15/89	Ko91
Lemon beebalm (*Monarda citriodora*)									
	Leaves and flowers	10.0	41.0		1.06	0.18		05/24/73	Hu81
Lime pricklyash (*Zanthoxylum fagara*)									
	Hand plucked	18.5	33.5	23.4	1.14		Jim Wells	08/15/88	Ko91
	Hand plucked	18.9	27.2	19.9	1.13		Jim Wells	06/15/88	Ko91
	Hand plucked	24.8	31.9	19.5	1.23		Jim Wells	05/15/89	Ko91
Little barley (*Hordeum pusillum*)									
	Leaves and stems	9.0	65.0		1.02	0.19		05/24/73	Hu81
Little bluestem (*Schizachyrium scoparium* var. *frequens*)									
	Whole plant	2.0			0.52	0.02		01/08/76	Hu81
	Leaves and stems	3.0	71.0		0.64	0.03		12/27/73	Hu81
	Leaves and stems	3.0	74.0		0.59	0.04		02/01/74	Hu81
	Leaves and stems	3.0			0.53	0.04		12/17/74	Hu81
	Whole plant	3.0			0.51	0.03		10/31/75	Hu81
	Leaves	4.0	75.0		0.59	0.05		10/25/73	Hu81
	Leaves and stems	4.0			0.57	0.04		11/15/74	Hu81
	Leaves and stems	4.0			0.44	0.04		02/11/75	Hu81
	Whole plant	4.0			0.76	0.07		09/11/75	Hu81
	Leaves and stems	4.0	70.0		0.80	0.06		08/30/73	Hu81
	Leaves and stems	6.0			0.86	0.07		10/10/74	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Leaves and stems	8.0	68.0		1.15	0.11		06/28/73	Hu81
	Leaves	9.0			1.00	0.11		05/24/74	Hu81
Lotebush (*Zizyphus obtusifolia*)									
	Leaves	12.3	26.5	13.5	1.00		Maverick	06/29/79	Va1
Louisiana sagewort (*Artemisia ludoviciana*)									
	Whole plant	6.0	53.0		0.97	0.11		08/30/73	Hu81
	Whole plant	8.0	51.0		1.13	0.15		07/27/73	Hu81
	Whole plant	8.0	51.0		0.98	0.16		10/03/73	Hu81
	Leaves and stems	10.0	56.0		1.01	0.15		10/25/73	Hu81
	Leaves and stems	12.0	50.0		1.25	0.22		05/24/73	Hu81
Meadow dropseed (*Sporobolus asper* var. *drummondii*)									
	Leaves	7.0	69.0		0.93	0.16		07/27/73	Hu81
Mescalbean (*Sophora secundiflora*)									
	Seeds	12.0	35.0		1.75	0.11		06/28/73	Hu81
	Leaves	17.0	41.0		1.14	0.10		06/28/73	Hu81
	Leaves	18.0	46.0		1.06	0.12		07/27/73	Hu81
Mesquite (*Prosopis glandulosa*)									
	Leaves and twigs	16.0	47.0		0.90	0.08		06/28/73	Hu81
	Leaves	26.0	35.0		1.16	0.22		05/24/73	Hu81
	Leaves	32.0	25.0		1.34	0.46		04/13/73	Hu81
Mountain pink (*Centaurium beyrichii* var. *beyrichii*)									
	Whole plant	7.0			1.30	0.10		07/11/75	Hu81
	Whole plant	9.0			1.37	0.14		06/04/75	Hu81
Netleaf hackberry (*Celtis reticulata*)									
	Leaves	8.0	26.0		0.89	0.08		10/25/73	Hu81
Noseburn (*Tragia* sp.)									
	Whole plant	15.0			0.96	0.20		08/15/74	Hu81
Nuttall milkvetch (*Astragalus nuttallianus* var. *nuttallianus*)									
	Whole plant	17.0			1.24	0.14		04/24/74	Hu81
	Whole plant	18.0	33.0		1.23	0.15		03/27/73	Hu81
Oats (*Avena sativa*)									
	Clipped at 3 inches	29.0	35.4	13.4	1.26		Uvalde	12/19/96	Li1
	Clipped at 3 inches	19.2	46.7	21.5	1.15		Uvalde	03/20/97	Li1
	Clipped at 3 inches	10.8	51.2	24.6	0.99		Uvalde	04/22/97	Li1
Orange zexmenia (*Wedelia hispida*)									
	Whole plant	8.0			0.67	0.18		09/11/75	Hu81
	Leaves and stems	8.0			0.91	0.08		10/31/75	Hu81
	Leaves and stems	9.0			0.75	0.16		06/25/74	Hu81
	Whole plant	9.0			0.82	0.07		07/11/75	Hu81
	Leaves and stems	11.0			0.65	0.12		10/10/74	Hu81
	Leaves and stems	11.0	30.0		1.09	0.12		07/27/73	Hu81
	Leaves	12.0	27.0		0.88	0.10		10/25/73	Hu81
	Leaves and stems	4.0			0.84	0.19		05/24/74	Hu81
	Whole plant	20.0	39.0		1.00	0.31		03/27/73	Hu81
Oxalis (*Oxalis* sp.)									
	Whole plant	17.0			1.27	0.40		11/15/74	Hu81
	Leaves and stems	18.0	20.0		1.25	0.19		11/29/73	Hu81
	Leaves and stems	21.0			1.37	0.47		10/10/74	Hu81
	Whole plant	21.0	19.0		1.47	0.22		03/27/73	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
Pearlmillet, Millex 24 (*Pennisetum americanum*)									
	Whole plant	11.3	70.7	29.3	1.02		Rusk	07/20/83	Ro1
	Whole plant	13.9	65.5	27.6	1.07		Rusk	07/13/83	Ro1
	Whole plant	14.3	60.3	25.6	1.07		Rusk	07/07/83	Ro1
	Whole plant	24.1	55.0	25.4	1.26		Rusk	06/28/83	Ro1
Pearlmillet, Tifleaf (*Pennisetum americanum*)									
	Whole plant	14.1	68.2	28.3	1.08		Rusk	07/20/83	Ro1
	Whole plant	15.9	64.2	29.2	1.12		Rusk	07/13/83	Ro1
	Whole plant	18.6	57.1	24.3	1.15		Rusk	07/07/83	Ro1
	Whole plant	25.0	53.2	24.1	1.26		Rusk	06/28/83	Ro1
Pepperweed (*Lepidium* sp.)									
	Whole plant	9.0	42.0		1.11	0.21		04/13/73	Hu81
	Whole plant	15.0	46.0		1.01	0.14		05/24/73	Hu81
Pinhole bluestem (*Bothriochloa barbinodis* var. *perforata*)									
	Leaves and stems	2.0	72.0		0.76	0.04		11/29/73	Hu81
	Leaves and stems	3.0			0.70	0.06		12/17/74	Hu81
	Leaves and stems	3.0			0.92	0.06		10/31/75	Hu81
	Leaves and stems	4.0	68.0		0.74	0.04		02/28/74	Hu81
	Leaves and stems	4.0			0.70	0.05		11/15/74	Hu81
	Leaves and stems	4.0	68.0		1.00	0.08		10/03/73	Hu81
	Leaves and stems	7.0	63.0		1.08	0.12		07/27/73	Hu81
Pink pappusgrass (*Pappophorum bicolor*)									
	Leaves	7.9	69.7	41.6	0.96		Maverick	06/29/79	Va1
Plains bristlegrass (*Setaria leucopila*)									
		6.0		46.3	*		Maverick	11/27/74	Va1
		7.5		47.8	0.97		Maverick	02/20/75	Va1
	Leaves and stems	8.0	70.0		0.70	0.21		10/25/73	Hu81
		8.1		44.6	0.98		Maverick	07/24/74	Va1
		8.5		47.0	1.00		Maverick	06/06/74	Va1
		8.9		43.8	1.00		Maverick	02/07/75	Va1
		9.0		41.6	1.00		Maverick	12/20/74	Va1
		9.0		44.4	1.01		Maverick	03/06/75	Va1
		9.1		49.5	1.04		Maverick	04/04/75	Va1
		9.1		43.5	1.01		Maverick	06/26/75	Va1
		9.2		46.4	1.02		Maverick	01/24/75	Va1
		9.3		45.8	1.02		Maverick	12/20/74	Va1
		9.6		45.2	1.03		Maverick	10/23/74	Va1
		9.6		44.4	1.03		Maverick	09/06/75	Va1
		9.8		47.9	1.05		Maverick	06/19/74	Va1
		9.8		48.2	1.06		Maverick	08/15/74	Va1
		9.8		44.5	1.03		Maverick	11/14/74	Va1
		9.8		47.2	1.05		Maverick	12/12/74	Va1
		11.5		43.0	1.08		Maverick	06/12/75	Va1
		11.9		42.0	1.09		Maverick	05/22/74	Va1
		12.0		46.7	1.12		Maverick	09/12/74	Va1
		12.2		44.4	1.11		Maverick	08/07/75	Va1
		12.8		43.7	1.12		Maverick	06/26/75	Va1
	Leaves	13.0	64.4	34.6	1.08		Maverick	06/29/79	Va1
		13.5		40.2	1.12		Maverick	05/15/75	Va1
		13.6		44.5	1.15		Maverick	05/01/75	Va1
		9.9		43.9	1.04		Maverick	07/05/74	Va1
		9.9		46.5	1.05		Maverick	03/19/75	Va1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
		10.2		47.3	1.06		Maverick	07/24/75	Va1
		11.2		45.1	1.08		Maverick	08/22/75	Va1
		14.1		42.2	1.15		Maverick	09/26/74	Va1
		14.9		42.6	1.18		Maverick	04/16/75	Va1
		15.1		42.8	1.18		Maverick	05/29/75	Va1
		16.0		41.2	1.20		Maverick	10/10/74	Va1
Plains lovegrass (*Eragrostis intermedia*)									
	Leaves	5.0	72.0		0.71	0.08		10/25/73	Hu81
	Leaves and stems	5.0	72.0		0.71	0.11		11/29/73	Hu81
	Leaves and stems	6.0	69.0		0.99	0.09		10/03/73	Hu81
	Whole plant	6.0			0.94	0.10		08/15/74	Hu81
	Leaves and stems	7.0	70.0		1.02	0.12		07/27/73	Hu81
Plateau oak (*Quercus virginiana*)									
	Leaves	8.0			0.98	0.09		02/11/75	Hu81
	Leaves	9.0	49.0		0.84	0.08		02/01/74	Hu81
	Leaves	9.0	42.0		0.91	0.08		02/28/74	Hu81
	Leaves	9.0			0.75	0.10		06/25/74	Hu81
	Leaves	9.0			0.87	0.08		10/10/74	Hu81
	Leaves	9.0			0.83	0.08		11/15/74	Hu81
	Leaves	9.0			0.95	0.11		12/17/74	Hu81
	Leaves	9.0			0.84	0.08		07/11/75	Hu81
	Leaves	9.0			0.99	0.09		10/31/75	Hu81
	Leaves	9.0			0.84	0.08		12/11/75	Hu81
	Leaves	9.0			0.93	0.08		01/08/76	Hu81
	Leaves	10.0	48.0		0.90	0.10		06/28/73	Hu81
	Leaves	10.0	46.0		0.88	0.08		07/27/73	Hu81
	Leaves	10.0	48.0		0.87	0.09		11/29/73	Hu81
	Leaves	10.0	47.0		0.88	0.09		12/27/73	Hu81
	Leaves	10.0			0.77	0.11		05/24/74	Hu81
	Leaves	10.0			0.82	0.08		08/15/74	Hu81
	Leaves	10.0			0.75	0.10		09/11/75	Hu81
	Leaves	11.0			0.78	0.12		06/04/75	Hu81
	Leaves	12.0	36.0		1.22	0.19		05/24/73	Hu81
	Leaves	12.0	48.0		0.88	0.12		10/25/73	Hu81
	Leaves	13.0			0.86	0.18		04/15/75	Hu81
	New leaves	19.0	22.0		1.57	0.28		04/13/73	Hu81
	Leaves and catkins	20.0	34.0		1.13	0.38		03/27/73	Hu81
Prickly pear (*Opuntia* sp.)									
	Cladophylls	2.0	21.0		1.09	0.03		03/27/73	Hu81
	Cladophylls	2.0			0.77	0.03		02/01/74	Hu81
	Cladophylls	3.0			1.08	0.05		02/28/74	Hu81
	Leaves	7.0			1.39	0.07		10/31/75	Hu81
	Leaves	11.0	17.0		1.28	0.09		10/03/73	Hu81
	Leaves	12.0			1.41	0.14		08/15/74	Hu81
	Leaves	13.0	28.0		1.58	0.12		06/28/73	Hu81
	Leaves	15.0			1.52	0.16		10/10/74	Hu81
	Leaves	15.0			1.54	0.14		07/11/75	Hu81
	Leaves	16.0			1.56	0.19		06/04/75	Hu81
	Leaves	18.0	16.0		1.47	0.22		05/24/73	Hu81
	Leaves	18.0	20.0		1.51	0.18		07/27/73	Hu81
	Cladophylls	4.0	33.0		1.07	0.06		04/13/73	Hu81
	Cladophylls	7.0	32.0		1.28	0.16		05/24/73	Hu81
	Fruit	7.0	52.0		0.65	0.13		07/27/73	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
Pricklyash (*Zanthoxylum* sp.)									
	Leaves	6.0			1.36	0.06		11/15/74	Hu81
	Leaves	7.0	21.0		1.31	0.08		10/25/73	Hu81
	Leaves	20.0			1.66			04/24/74	Hu81
	Leaves and twigs	23.0	21.0		1.58	0.37		04/13/73	Hu81
Purple groundcherry (*Quincula lobata*)									
	Whole plant	24.0			1.01	0.31		05/24/74	Hu81
Purslane (*Portulaca* sp.)									
	Whole plant	11.0			1.22	0.22		08/15/74	Hu81
Ragweed (*Parthenium hysterophorus*)									
	Leaves	14.8	23.2	32.4	1.11		Maverick	06/29/79	Va1
Red grama (*Bouteloua trifida*)									
	Leaves and stems	4.0	69.0		0.52	0.09		12/27/73	Hu81
	Leaves and stems	5.0	67.0		0.50	0.05		02/01/74	Hu81
	Whole plant	5.0	68.0		0.67	0.06		02/28/74	Hu81
	Leaves and stems	6.0	65.0		0.79	0.11		05/24/73	Hu81
	Leaves and stems	6.0	71.0		0.89	0.07		08/30/73	Hu81
	Leaves, stems & seeds	8.0	72.0		0.77	0.13		10/03/73	Hu81
	Leaves and stems	8.0	71.0		0.61	0.09		10/25/73	Hu81
	Leaves and stems	9.0	69.0		0.93	0.19		07/27/73	Hu81
	Leaves	11.0	71.0		1.04	0.16		06/28/73	Hu81
Redberry juniper (*Juniperus pinchoti*)									
	Leaves	6.0			1.29	0.09		06/25/74	Hu81
	Leaves	6.0			1.33	0.09		01/08/76	Hu81
	Leaves	7.0	34.0		1.32	0.10		04/13/73	Hu81
	Leaves	7.0			1.29	0.10		02/11/75	Hu81
	Leaves	7.0			1.17	0.08		07/11/75	Hu81
	Leaves	7.0			1.15	0.11		10/31/75	Hu81
	Leaves	8.0	37.0		1.21	0.11		12/27/73	Hu81
	Leaves	8.0			1.28	0.14		12/17/74	Hu81
	Leaves	9.0			1.28	0.15		11/15/74	Hu81
Redseed plantain (*Plantago rhodosperma*)									
	Leaves	8.0	20.0		0.88	0.10		05/24/73	Hu81
	Whole plant	8.0			0.99	0.13		04/15/75	Hu81
	Whole plant	10.0	32.0		0.84	0.16		04/13/73	Hu81
	Whole plant	10.0			1.00	0.13		11/15/74	Hu81
	Whole plant	11.0	28.0		0.71	0.14		03/27/73	Hu81
	Whole plant	11.0	21.0		0.87	0.17		12/27/73	Hu81
	Whole plant	11.0			0.86	0.16		03/28/74	Hu81
	Inflorescence	12.0			1.06	0.22		05/24/73	Hu81
	Whole plant	12.0			0.84	0.17		12/17/74	Hu81
	Whole plant	20.0	17.0		1.09	0.14		02/28/74	Hu81
Rescuegrass (*Bromus unioloides*)									
	Leaves and heads	13.0	57.0		1.38	0.19		04/13/73	Hu81
	Mostly leaves	14.0	46.0		1.40	0.19		03/27/73	Hu81
Roemer sensitivebriar (*Schrankia roemeriana*)									
	Leaves	30.0			1.39	0.22		04/24/74	Hu81
	Leaves and twigs	32.0	25.0		1.57	0.22		05/24/73	Hu81
Ryegrass (*Lolium multiflorum*)									
	Silage	17.6	55.3	39.1	1.22		Brazoria	07/01/86	Li1
	Hay, dehy.	18.5	61.0	37.5	1.30		Brazoria	04/12/65	Qu66

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hay, dehy.	21.9	55.8	35.5	1.35		Brazoria	03/12/65	Qu66
	Plucked forage	22.8	37.5	21.8	1.21		Brazoria	01/15/93	Li97
	Plucked forage	31.2	39.9	21.7	1.33		Uvalde	01/15/93	Li97
	Plucked forage	32.1	32.1	16.6	1.30		Rusk	01/15/93	Li97
Sacahuista (*Nolina texana*)									
	Leaves	5.0	67.0		0.82	0.06		02/01/74	Hu81
	Leaves	5.0	62.0		0.95	0.06		02/28/74	Hu81
	Leaves	5.0			0.82	0.08		03/28/74	Hu81
	Leaves	6.0	70.0		1.01	0.05		04/13/73	Hu81
	Leaves	6.0	61.0		0.93	0.06		10/25/73	Hu81
	Leaves	6.0	64.0		0.91	0.06		11/29/73	Hu81
	Leaves	6.0	58.0		1.03	0.08		12/27/73	Hu81
	Buds	19.0	25.0		1.42	0.36		03/27/73	Hu81
	Buds	19.0	28.0		1.34	0.38		04/13/73	Hu81
Sage (*Salvia* sp.)									
	Whole plant	11.0			1.00	0.14		04/24/74	Hu81
Sand dropseed (*Sporobolus cryptandrus*)									
	Leaves and stems	9.0	69.0		1.15	0.16		07/27/73	Hu81
Sedge (*Carex* sp.)									
	Leaves	6.0			0.62	0.06		03/28/74	Hu81
	Leaves	6.0			0.65	0.07		09/11/75	Hu81
	Leaves	6.0			0.49	0.09		12/11/75	Hu81
	Leaves	6.0			0.53	0.07		01/08/76	Hu81
	Leaves	7.0	64.0		0.84	0.08		06/28/73	Hu81
	Leaves	7.0	64.0		0.80	0.08		08/30/73	Hu81
	Leaves	7.0	64.0		0.60	0.07		12/27/73	Hu81
	Leaves	7.0	64.0		0.65	0.08		02/01/74	Hu81
	Leaves	7.0	63.0		0.72	0.07		02/28/74	Hu81
	Leaves	7.0			0.78	0.08		06/25/74	Hu81
	Whole plant	7.0			0.80	0.07		07/11/75	Hu81
	Leaves	7.0			0.57	0.08		10/31/75	Hu81
	Leaves	8.0	66.0		0.72	0.11		05/24/73	Hu81
	Leaves	8.0			0.64	0.10		06/04/75	Hu81
	Leaves	9.0	66.0		0.85	0.10		07/27/73	Hu81
	Leaves	9.0			0.57	0.10		12/17/74	Hu81
	Leaves	9.0			0.81	0.09		04/15/75	Hu81
	Leaves	10.0			0.70	0.11		02/11/75	Hu81
	Leaves	11.0	68.0		0.80	0.09		10/25/73	Hu81
	Whole plant	12.0	65.0		0.93	0.15		03/27/73	Hu81
	Leaves	12.0	63.0		1.02	0.13		04/13/73	Hu81
	Leaves	12.0	62.0		0.84			11/29/73	Hu81
	Leaves	12.0			0.70	0.17		11/15/74	Hu81
	Leaves	13.0	66.0		0.64	0.09		10/03/73	Hu81
Shrubby blue sage (*Salvia ballotiflora*)									
	Leaves	10.9	33.3	22.7	0.99		Maverick	06/29/79	Va1
Sideoats grama (*Bouteloua curtipendula* var. *caespitosa*)									
	Leaves and stems	3.0	68.0		0.55	0.05		02/28/74	Hu81
	Leaves and stems	3.0			0.53	0.04		12/17/74	Hu81
	Whole plant	3.0			0.58	0.06		12/11/75	Hu81
	Whole plant	3.0			0.52	0.04		01/08/76	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Leaves and stems	4.0	65.0		0.50	0.05		12/27/73	Hu81
	Leaves and stems	4.0			0.68	0.08		10/10/74	Hu81
	Whole plan	4.0			0.65	0.06		09/11/75	Hu81
	Whole plant	4.0			0.75	0.04		10/31/75	Hu81
	Leaves and stem	5.0	68.0		0.75	0.05		08/30/73	Hu81
	Leaves and stems	5.0	70.0		0.76	0.08		10/03/73	Hu81
	Leaves and stems	5.0	66.0		0.45	0.08		11/29/73	Hu81
	Leaves and stems	5.0	67.0		0.52	0.05		02/01/74	Hu81
	Leaves and stems	5.0			0.66	0.07		06/25/74	Hu81
	Leaves and stems	5.0			0.51	0.06		11/15/74	Hu81
	Leaves and stems	5.0			0.51	0.05		02/11/75	Hu81
	Leaves and stems	5.0			0.92	0.05		07/11/75	Hu81
	Leaves and stems	6.0			0.73	0.09		04/24/74	Hu81
	Leaves and stems	6.0			0.91	0.15		08/15/74	Hu81
	Leaves and stems	6.0			0.66	0.08		04/15/75	Hu81
	Whole plant	6.0			0.70	0.08		06/04/75	Hu81
	Leaves and stems	7.0	68.0		0.92	0.11		07/27/73	Hu81
	Leaves	7.0	67.0		0.65	0.08		10/25/73	Hu81
	Greem forage	8.0	67.0		1.00	0.11		05/24/73	Hu81
	Leaves and stems	8.0			0.89	0.14		05/24/74	Hu81
	Leaves and stems	9.0	70.0		0.99	0.17		06/28/73	Hu81
	New leaves	11.0	71.0		1.20	0.17		04/13/73	Hu81
Silver bluestem (*Bothriochloa saccharoides* var. *torreyanus*)									
	Leaves and stems	9.0	63.0		1.18	0.16		05/24/73	Hu81
Silverleaf nightshade (*Solanum elaeagnifolium*)									
	Leaves and stems	20.0	41.0		1.05	0.21		05/24/73	Hu81
Skunkbush (*Rhus aromatica* var. *flabelliformis*)									
	Leaves	11.0	16.0		1.63	0.14		05/24/73	Hu81
	Leaves and twigs	13.0	16.0		1.65	0.17		04/13/73	Hu81
	Leaves and twigs	14.0	14.0		1.69	0.23		03/27/73	Hu81
	Leaves	17.0			1.55	0.35		03/28/74	Hu81
Slim tridens (*Tridens muticus* var. *muticus*)									
	Leaves and stems	6.0	72.0		0.95	0.11		10/03/73	Hu81
	Leaves and stems	7.0	73.0		1.09	0.13		05/24/73	Hu81
	Leaves	8.0	70.0		0.69	0.09		04/13/73	Hu81
	Leaves	8.0	70.0		0.69	0.09		04/13/73	Hu81
	Leaves and stems	8.0	69.0		0.77	0.30		10/25/73	Hu81
	Leaves and stems	13.0	70.0		1.13	0.20		06/28/73	Hu81
Sorghum (*Sorghum bicolor*)									
	Silage	2.8	56.9	34.7	0.80		Brazoria	07/08/84	Li87
	Hay. dehy.	4.1	68.0	38.5	**1.03**		Brazos	06/13/67	Bu69
	Early bloom hay	6.9	74.5	46.9	**0.97**		Brazoria	06/06/70	Li80
	Plot clippings	6.9		32.0	***0.91***		Erath	07/15/91	Sa93
	Boot stage hay	8.7	67.6	39.3	**1.03**		Brazoria	06/16/70	Li80
	Hay, dehy.	1.2	66.8	38.0	**1.22**		Brazos	05/09/67	Bu69
	Immature stage hay	16.5	61.3	33.8	**1.12**		Brazoria	07/03/70	Li80
Sorghum, Beef Builder (*Sorghum bicolor*)									
	Hay, dehy.	11.1	66.2	40.7	**1.20**		Brazoria	07/23/64	Qu66
Sorghum, FS1-A (*Sorghum bicolor*)									
	Hay, dehy.	9.9	63.1	37.7	**1.18**		Brazoria	07/02/64	Qu66

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
Sorghum, Rio Sweet (*Sorghum bicolor*)									
	Hay, dehy.	6.9	57.1	38.3	**1.22**		Brazoria	10/16/64	Qu66
Spiny hackberry (*Celtis pallida*)									
	Leaves	15.4	22.2	14.2	1.05		Maverick	06/29/79	Va1
	Hand plucked	24.1	35.2	20.6	1.23		Jim Wells	08/15/88	Ko91
	Hand plucked	27.7	42.7	25.2	1.32		Jim Wells	06/15/88	Ko91
	Hand plucked	32.3	37.4	21.1	1.36		Jim Wells	05/15/89	Ko91
Spreading sida (*Sida abutifolia*)									
	Whole plant	14.0			1.28	0.20		08/15/74	Hu81
Sudangrass (*Sorghum bicolor*)									
	Hay, dehy., Sudax	14.3	61.7	35.8	1.10		Brazoria	06/28/65	Qu66
	Hay, dehy	18.4	59.6	31.6	1.21		Brazos	05/09/67	Bu69
Sweet gaillardia (*Gaillardia sauvis*)									
	Whole plant	19.0	26.0		1.21	0.28		03/27/73	Hu81
	Leaves and stems	19.0			1.10	0.22		03/28/74	Hu81
Tanglehead (*Heteropogon contortus*)									
		3.3		42.6	*		Maverick	07/10/75	Va1
		3.7		49.1	*		Maverick	11/14/74	Va1
		3.8		47.6	*		Maverick	02/07/75	Va1
		4.1		47.4	*		Maverick	07/05/74	Va1
		4.3		47.7	*		Maverick	08/22/75	Va1
		4.8		46.6	*		Maverick	01/06/75	Va1
		4.8		43.6	*		Maverick	08/07/75	Va1
		5.4		46.7	*		Maverick	01/24/75	Va1
		5.5		45.6	*		Maverick	04/04/75	Va1
		5.8		47.0	*		Maverick	10/23/74	Va1
		5.9		53.4	*		Maverick	03/06/75	Va1
		6.5		42.4	*		Maverick	06/06/74	Va1
		8.0		38.8	0.96		Maverick	06/12/75	Va1
		8.1		42.5	0.97		Maverick	06/26/75	Va1
		8.4		38.9	0.97		Maverick	05/01/75	Va1
		9.0		42.1	1.00		Maverick	05/22/74	Va1
	9.7		39.2	1.01	Maverick		05/29/75	Va1	
		10.1		44.2	1.04		Maverick	09/26/74	Va1
		10.5		38.0	1.03		Maverick	05/15/75	Va1
		11.1		43.0	1.07		Maverick	09/12/74	Va1
Texas bluebonnet (*Lupinus texensis*)									
	Leaves	15.0	24.0		1.17	0.11		10/25/73	Hu81
	Whole plant	15.0			1.34	0.12		03/28/74	Hu81
	Whole plant	17.0	23.0		1.36	0.16		03/27/73	Hu81
	Whole plant	17.0			1.35	0.16		02/11/75	Hu81
	Whole plant	18.0	25.0		1.41	0.17		04/13/73	Hu81
Texas cupgrass (*Eriochloa sericea*)									
	Leaves and stems	4.0	71.0		0.71	0.05		12/27/73	Hu81
	Leaves and stems	4.0	67.0		0.63	0.05		02/28/74	Hu81
	Leaves and stems	4.0			0.66	0.07		11/15/74	Hu81
	Leaves and stems	4.0			0.67	0.06		12/17/74	Hu81
	Leaves and stems	4.0			0.71	0.06		10/31/75	Hu81
	Whole plant	4.0			0.69	0.06		01/08/76	Hu81
	Leaves and stems	5.0	70.0		0.53	0.05		02/01/74	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Whole plant	5.0			0.71	0.10		09/11/75	Hu81
	Leaves and stems	6.0			0.66	0.12		03/28/74	Hu81
	Leaves and stems	6.0			0.58	0.08		06/25/74	Hu81
	Leaves and stems	6.0			0.60	0.09		02/11/75	Hu81
	Leaves and stems	6.0			0.60	0.17		07/11/75	Hu81
	Leaves and stems	7.0	68.0		0.88	0.09		08/30/73	Hu81
	Leaves and stems	7.0	70.0		0.75	0.11		10/25/73	Hu81
	Leaves and stems	7.0			0.69	0.10		10/10/74	Hu81
	Leaves and stems	8.0	67.0		0.91	0.11		07/27/73	Hu81
	Leaves and stems	8.0	68.0		0.75	0.14		10/03/73	Hu81
	Leaves and stems	8.0	67.0		0.64	0.11		11/29/73	Hu81
	Leaves and stems	8.0			0.78	0.12		04/15/75	Hu81
	Whole plant	8.0			0.77	0.11		06/04/75	Hu81
	Leaves and stems	9.0			0.79	0.16		05/24/74	Hu81
	Leaves	10.0	74.0		0.99	0.13		05/24/73	Hu81
	Leaves and stems	10.0	68.0		0.88	0.18		06/28/73	Hu81
	Leaves and stems	10.0			0.82	0.14		08/14/74	Hu81
	Leaves and stems	11.0			0.99	0.18		04/24/74	Hu81
	Leaves	13.0	69.0		1.11	0.18		04/13/73	Hu81
Texas filaree (*Erodium texanum*)									
	Whole plant	14.0	32.0		1.20	0.26		04/13/73	Hu81
Texas kidneywood (*Eysenharditia texana*)									
	Hand plucked	15.5	52.5	31.7	1.12		Jim Wells	08/15/88	Ko91
	Leaves	18.6	36.6	22.1	1.14		Maverick	06/29/79	Va1
	Hand plucked	22.1	45.4	26.3	1.23		Jim Wells	06/15/88	Ko91
	Hand plucked	24.1	43.1	24.7	1.25		Jim Wells	05/15/89	Ko91
Texas persimmon (*Diospyros texana*)									
	Leave	9.0			1.15	0.08		11/15/74	Hu81
	Leaves	10.0	32.0		1.08	0.08		07/27/73	Hu81
	Leaves	10.0	34.0		1.12	0.08		10/25/73	Hu81
	Leaves	10.0			1.21	0.09		08/15/74	Hu81
	Leaves	10.0			1.17	0.09		10/31/75	Hu81
	Leaves	11.0	31.0		1.12	0.09		10/03/73	Hu81
	Leaves	11.0			1.11	0.09		10/10/74	Hu81
	Leaves	11.0			1.10	0.09		07/11/75	Hu81
	Leaves	12.0			1.13	0.09		06/25/74	Hu81
	Hand plucked	12.8	47.7	35.2	1.08		Jim Wells	06/15/88	Ko91
	Leaves	13.0	43.0		1.07	0.13		06/28/73	Hu81
	Hand plucked	13.8	43.4	33.6	1.09		Jim Wells	08/15/88	Ko91
	Leaves	14.0	39.0		1.18	0.16		05/24/73	Hu81
	Leaves	15.0			1.30	0.17		04/24/74	Hu81
	Hand plucked	15.4	53.8	39.3	1.17		Jim Wells	05/15/89	Ko91
	Leaves	24.0			1.4	0.41		03/28/74	Hu81
	Leaves and twigs	25.0	28.0		1.48	0.40		04/13/73	Hu81
Texas winter-grass (*Stipa leucotricha*)									
	Whole plant	5.0			0.34	0.06		12/11/75	Hu81
	Whole plant	5.0			0.47	0.06		01/08/76	Hu81
	Leaves	6.0	66.0		0.56	0.08		12/27/73	Hu81
	Leaves and stems	6.0	65.0		0.48	0.06		02/01/74	Hu81
	Leaves and stems	6.0	68.0		0.70	0.06		02/28/74	Hu81
	Whole plant	6.0			0.48	0.07		09/11/75	Hu81
	Leaves and stems	6.0			0.55	0.08		10/31/75	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Leaves and stems	7.0			0.53	0.07		12/17/74	Hu81
	Leaves and stems	7.0			0.62	0.08		07/11/75	Hu81
	Leaves and stems	8.0			0.75	0.08		06/25/74	Hu81
	Leaves and stems	8.0			0.71	0.11		06/04/75	Hu81
	Leaves and stems	9.0	68.0		0.69	0.12		10/25/73	Hu81
	Leaves and stems	9.0			0.45	0.11		11/15/74	Hu81
	Leaves	10.0	68.0		0.83	0.10		07/27/73	Hu81
	Leaves and stems	10.0			0.74	0.10		08/15/74	Hu81
	Leaves	10.0			0.70	0.11		02/11/75	Hu81
	Leaves and stems	10.0			1.00	0.15		04/15/75	Hu81
	Leaves	11.0	69.0		0.93	0.12		05/24/73	Hu81
	Leaves	11.0	66.0		0.68	0.12		11/29/73	Hu81
	Leaves	11.0			0.70	0.12		10/10/74	Hu81
	Mostly leaves	12.0	67.0		0.82	0.12		03/27/73	Hu81
	Leaves and stems	13.0			0.85	0.21		05/24/74	Hu81
	Green leaves	14.0	65.0		0.90	0.18		04/13/73	Hu81
Tobosa (*Hilaria mutica*)									
	Green leaves	13.0	70.0		1.07	0.16		05/03/73	Hu81
Tumble windmillgrass (*Chloris verticillata*)									
	Leaves and stems	9.0	64.0		0.64	0.36		10/25/73	Hu81
	Leaves and stems	8.0			0.71	0.11		06/04/75	Hu81
Tumblegrass (*Schedonnardus paniculatus*)									
	Leaves and stems	6.0	69.0		1.04	0.12		05/24/73	Hu81
	Whole plant	6.0	77.0		1.15	0.09		10/03/73	Hu81
	Leaves and stems	7.0	67.0		0.98	0.23		07/27/73	Hu81
Twisted acacia (*Acacia schaffneri* var *bravoensis*)									
	Leaves	17.7	49.5	33.5	***1.18***		Maverick	06/29/79	Va1
Twoleaf senna (*Senna roemeriana*)									
	Whole plant	9.0			1.15	0.09		06/25/74	Hu81
	Leaves and stems	10.0			1.27	0.10		06/04/75	Hu81
	Whole plant	11.0			1.10	0.14		09/11/75	Hu81
	Tops	12.0	18.0		1.20	0.11		06/28/73	Hu81
	Leaves and stems	12.0			1.26	0.14		10/10/74	Hu81
	Whole plant	13.0			1.29	0.15		05/24/74	Hu81
	Leaves and twigs	17.0	25.0		1.32	0.23		07/27/73	Hu81
	Whole plant	17.0			1.30	0.19		04/24/74	Hu81
	Leaves and stems	20.0			1.43	0.2		03/28/74	Hu81
	Leaves and stems	21.0			1.45	0.27		04/15/75	Hu81
Upright prairie coneflower (*Ratibida columnifera*)									
	Whole plant	4.0			0.47	0.06		10/31/75	Hu81
	Whole plant	6.0			0.65	0.10		06/25/74	Hu81
	Whole plant	6.0			0.77	0.08		07/11/75	Hu81
	Whole plant	6.0			0.61	0.07		09/11/75	Hu81
	Whole plant	10.0	46.0		0.80	0.17		07/27/73	Hu81
	Leaves and stems	10.0			0.84	0.14		10/10/74	Hu81
	Whole plant	11.0			0.93	0.15		06/04/75	Hu81
	Whole plant	12.0			0.94	0.20		11/15/74	Hu81
	Whole plant	13.0			1.03	0.18		05/24/74	Hu81
	Whole plant	14.0			1.14	0.28		12/17/74	Hu81
	Whole plant	18.0	32.0		1.11	0.24		04/13/73	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Leaves and stems	19.0			1.18	0.29		04/15/75	Hu81
	Leaves and stems	20.0			1.03	0.27		03/28/74	Hu81
	Leaves, stems and new growth	21.0	25.0		1.07	0.41		10/25/73	Hu81
	Whole plant	22.0			1.11	0.26		02/11/75	Hu81
Vine ephedra (*Ephedra pedunculata*)									
	Stems	9.0	67.3	53.1	1.06		Maverick	06/29/79	Va1
Vinemesquite (*Panicum obtusum*)									
		5.1		48.2	*		Maverick	02/07/75	Va1
		5.3		50.3	*		Maverick	12/20/74	Va1
		5.6		51.2	*		Maverick	08/15/74	Va1
		5.7		47.0	*		Maverick	03/06/75	Va1
		5.9		48.2	*		Maverick	11/27/74	Va1
		5.9		46.8	*		Maverick	04/04/75	Va1
		6.1		45.9	*		Maverick	01/24/75	Va1
		6.1		50.2	*		Maverick	08/22/75	Va1
		6.4		47.7	*		Maverick	02/20/75	Va1
	Leaves and stems	7.0	70.0		1.04	0.14		07/27/73	Hu81
	Leaves and stems	7.0	71.0		0.80	0.10		10/25/73	Hu81
		7.0		48.2	0.95		Maverick	06/26/75	Va1
		7.0		48.1	0.95		Maverick	08/07/75	Va1
		7.7		47.3	0.97		Maverick	05/15/75	Va1
		7.7		47.3	0.97		Maverick	07/24/75	Va1
		7.9		47.2	0.98		Maverick	12/12/74	Va1
		8.2		47.7	0.99		Maverick	06/06/74	Va1
		8.5		45.8	1.00		Maverick	06/12/75	Va1
		8.8		47.5	1.01		Maverick	10/23/74	Va1
		8.9		47.4	1.02		Maverick	04/16/75	Va1
		9.2		46.9	1.03		Maverick	05/01/75	Va1
		9.5		46.2	1.03		Maverick	10/10/74	Va1
		9.5		47.2	1.04		Maverick	05/29/75	Va1
		10.1		47.1	1.06		Maverick	03/19/75	Va1
		11.2		47.2	1.10		Maverick	05/22/74	Va1
		12.0		44.3	1.10		Maverick	06/26/75	Va1
	Leaves	12.5	64.1	42.8	1.11		Maverick	06/29/79	Va1
		12.6		42.9	1.11		Maverick	09/26/74	Va1
		14.3		49.0	1.22		Maverick	09/12/74	Va1
Weeping lovegrass (*Eragrostis curvula*)									
	Hand plucked	6.3	85.0	38.9	*		Rusk	01/05/71	Ro1
	Hand plucked	7.2	79.8	39.4	0.93		Rusk	08/26/70	Ro1
	Hand plucked	7.8	81.4	39.6	0.95		Rusk	08/12/70	Ro1
	Hand plucked	8.1	79.3	36.9	0.96		Rusk	07/30/69	Ro1
	Hand plucked	8.2	78.8	40.3	0.97		Rusk	07/16/69	Ro1
	Hand plucked	8.8	78.6	42.2	0.99		Rusk	06/19/70	Ro1
	Hand plucked	8.9	85.6	41.2	0.99	0.10	Rusk	09/15/71	Ro1
	Hand plucked	9.0	86.0	35.5	0.98	0.08	Rusk	06/17/71	Ro1
	Hand plucked	9.1	81.3	34.4	0.98		Rusk	07/16/70	Ro1
	Hand plucked	9.1	81.9	38.4	0.99		Rusk	08/13/69	Ro1
	Hand plucked	9.4	73.6	37.3	0.99		Rusk	05/21/70	Ro1
	Hand plucked	9.7	80.0	39.9	1.01		Rusk	10/15/70	Ro1
	Hand plucked	9.9	81.6	33.3	0.99	0.10	Rusk	06/04/71	Ro1

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
	Hand plucked	10.2	78.0	41.4	1.03		Rusk	05/21/69	Ro1
	Hand plucked	10.3	78.0	38.7	1.02		Rusk	07/02/69	Ro1
	Hand plucked	10.3	76.6	39.7	1.03		Rusk	06/05/69	Ro1
	Hand plucked	10.5	80.2	39.5	1.03		Rusk	06/18/69	Ro1
	Hand plucked	10.8	86.6	35.9	1.03	0.11	Rusk	07/16/71	Ro1
	Hand plucked	11.0	83.0	36.2	1.03		Rusk	05/06/70	Ro1
	Hand plucked	11.1	84.0	33.6	1.03	0.19	Rusk	07/02/71	Ro1
	Hand plucked	11.3	65.4	33.5	1.03		Rusk	04/23/69	Ro1
	Hand plucked	11.5	81.0	32.4	1.03	0.18	Rusk	07/28/71	Ro1
	Hand plucked	11.7	76.9	33.5	1.04		Rusk	04/22/70	Ro1
	Hand plucked	11.8	70.9	34.9	1.05		Rusk	07/28/70	Ro1
	Hand plucked	11.8	82.6	41.5	1.08	0.17	Rusk	08/13/71	Ro1
	Hand plucked	11.9	74.3	34.7	1.05		Rusk	06/04/70	Ro1
	Hand plucked	12.1	77.0	36.1	1.06		Rusk	01/21/70	Ro1
	Hand plucked	12.4	66.3	36.8	1.07		Rusk	05/09/69	Ro1
	Hand plucked	12.5	75.6	33.0	1.06		Rusk	07/01/70	Ro1
	Hand plucked	13.6	79.2	37.2	1.11		Rusk	08/27/69	Ro1
	Hand plucked	14.1	73.9	31.8	1.09		Rusk	04/22/70	Ro1
	Hand plucked	14.3	84.4	41.1	1.15	0.18	Rusk	10/01/71	Ro1
	Hand plucked	14.8	83.0	36.9	1.13		Rusk	11/24/69	Ro1
	Hand plucked	15.3	80.9	31.1	1.11	0.22	Rusk	05/07/71	Ro1
	Hand plucked	15.7	77.4	38.0	1.16		Rusk	10/08/69	Ro1
	Hand plucked	16.0	71.5	26.8	1.11	0.22	Rusk	04/07/71	Ro1
	Hand plucked	16.1	78.1	34.8	1.15		Rusk	11/05/69	Ro1
	Hand plucked	16.4	82.5	37.0	1.17		Rusk	10/22/69	Ro1
	Hand plucked	17.2	73.8	34.7	1.18		Rusk	09/24/69	Ro1
	Hand plucked	18.3	72.9	33.2	1.19		Rusk	04/05/70	Ro1
	Hand plucked	18.5	73.4	35.7	1.21		Rusk	09/10/69	Ro1
	Hand plucked	19.2	72.1	30.1	1.19	0.24	Rusk	05/19/71	Ro1
	Hand plucked	20.1	70.1	29.7	1.21	0.24	Rusk	03/24/71	Ro1
	Hand plucked	21.9	69.0	28.3	1.23		Rusk	04/11/69	Ro1
	Hand plucked	23.3	70.1	28.7	1.26		Rusk	04/05/70	Ro1
Western bitterweed (*Hymenoxys odorata*)									
	Whole plant	10.0			1.02	0.16		05/24/74	Hu81
	Whole plant	11.0	27.0		1.45	0.21		04/13/73	Hu81
	Whole plant	11.0			0.78	0.16		08/15/74	Hu81
	Whole plant	12.0	35.0		0.99	0.15		06/28/73	Hu81
	Whole plant	12.0			1.15	0.17		04/24/74	Hu81
	Whole plant	13.0	25.0		1.32	0.24		03/27/73	Hu81
	Whole plant	13.0	41.0		1.10	0.23		05/24/73	Hu81
	Leaf, stem, & flower	13.0	46.0		0.98	0.25		07/27/73	Hu81
	Whole plant	13.0			0.99	0.23		06/25/74	Hu81
	Leaves and stems	16.0	20.0		1.39	0.22		12/27/73	Hu81
	Whole plant	16.0			1.34	0.24		11/15/74	Hu81
	Whole plant	16.0			1.53	0.23		12/17/74	Hu81
	Whole plant	17.0	26.0		1.34	0.23		02/28/74	Hu81
	Leaves and stems	18.0	18.0		1.24	0.25		11/29/73	Hu81
	Leaves and stems	18.0			1.11	0.31		10/10/74	Hu81
	Leaves and stems	18.0			1.34	0.19		02/11/75	Hu81
	Leaves and stems	20.0			1.17	0.27		03/28/74	Hu81
	Leaves and stems	23.0	21.0		1.28	0.22		02/01/74	Hu81

Table A-3. (Continued)

Species	Harvest notes	CP %	NDF %	ADF %	DE[1] Mcal/lb	P %	County	Harvest date	Reference[2]
Western ragweed (*Ambrosia cumanensis*)									
	Leaves	14.4	24.0	18.3	1.05		Maverick	06/29/79	Va1
Wheat (*Triticum aestivum*)									
	Clipped sward	10.8	64.8	39.8	1.04		Uvalde	04/27/92	Li00
	Plucked forage	28.1	32.4	20.6	1.29		Uvalde	11/21/91	Li00
White honeysuckle (*Lonicera albiflora*)									
	Leaves	8.0	17.0		1.45	0.08		05/24/73	Hu81
	Leaves	12.0	23.0		1.51	0.14		04/13/73	Hu81
White shin oak (*Quercus durandii* var. *breviloba*)									
	Leaves	7.0			0.74	0.06		12/17/74	Hu81
	Leaves	8.0			0.92	0.09		10/31/75	Hu81
	Leaves	9.0	45.0		0.87	0.12		12/27/73	Hu81
	Leaves	9.0			0.90	0.07		07/11/75	Hu81
	Leaves	10.0	40.0		0.99	0.11		07/27/73	Hu81
	Leaves	10.0	39.0		0.98	0.09		08/30/73	Hu81
	Leaves	10.0			0.72	0.09		06/25/74	Hu81
	Leaves	11.0	44.0		0.92	0.10		06/28/73	Hu81
	Leaves	11.0	41.0		0.88	0.11		10/03/73	Hu81
	Leaves	11.0			0.90	0.13		06/04/75	Hu81
	Leaves	12.0	40.0		0.99	0.11		10/25/73	Hu81
	Leaves	12.0	40.0		0.99	0.12		11/29/73	Hu81
	Leaves	14.0			1.10	0.21		03/28/74	Hu81
	Leaves	14.0			0.89	0.26		11/15/74	Hu81
	Leaves	14.0			0.93	0.18		04/15/75	Hu81
	Leaves	15.0	31.0		1.53	0.22		04/13/73	Hu81
	Leaves and twigs	17.0	23.0		1.57	0.31		03/27/73	Hu81
	Leaves	17.0	33.0		1.24	0.22		05/24/73	Hu81
White tridens (*Tridens albescens*)									
	Leaves and stems	8.0	70.0		1.13	0.15		07/27/73	Hu81
Wright threeawn (*Aristida purpurea* var. *wrightii*)									
	heads	5.0	75.0		0.78	0.05		12/27/73	Hu81
	Leaves and stems	5.0	71.0		0.60	0.05		02/28/74	Hu81
	Leaves and stems	6.0	79.0		0.87	0.07		10/03/73	Hu81
	Leaves and stems	6.0	69.0		0.57	0.06		02/01/74	Hu81
	Leaves	5.0	74.0		0.77	0.05		08/30/73	Hu81
	Leaves and some old								
Leaves	7.0	71.0		0.68	0.08		04/13/73	Hu81	
	Old and new growth	7.0	74.0		0.81	0.08		05/24/73	Hu81
	Whole plant	7.0	74.0		0.91	0.09		07/27/73	Hu81
	Leaves and stems	7.0	74.0		0.66	0.09		10/25/73	Hu81
	Leaves and stems	7.0	74.0		0.62	0.08		11/29/73	Hu81
	Leaves and stems	8.0	77.0		0.96	0.10		06/28/73	Hu81
Yellow Stonecrop (*Sedum nuttallianum*)									
	Whole plant	6.0	11.0		0.90	0.20		04/13/73	Hu81
	Whole plant	7.0	26.0		0.88	0.14		05/24/73	Hu81
Yucca (*Yucca* sp.)									
	Leaves	7.0	69.0		0.86	0.10		10/25/73	Hu81
	Flowers	14.0	11.0		1.13	0.47		05/24/73	Hu81
	Flowers	22.0	14.0		1.76	0.51		03/27/73	Hu81
	Flowers	22.0	15.0		1.70	0.45		04/13/73	Hu81

[1] Values in **bold type** were measured directly in animal trials. Vaues in *italic type* were estimated from animal trials. Vaues in plain type were estimated from in vitro dry matter disappearance or from CP and ADF content. Values in ***bold italic type*** are unreliable from species with toxic non-protein nitrogen compounds that inflate the crude protein value. An astrisk indicates that valid estimates could not be made.

[2] References for data sources in Appendix Table 3.

Code	Reference
Bu69	Buentello, J. L. 1969. Nutritive Characteristics of Forage Chemical Components. Texas A&M University. MS Thesis.
Hu81	Huston, J.E., B.S. Rector, L.B. Merrill, and B.S. Engdahl. 1981 Nutritional value of range plants in the Edwards Plateau region of Texas. Texas Agricultural Experiment Station. Bulletin B-1357.
Ko91	Koerth, B.H. and J.W. Stuth. 1991. Instantaneous intake rates of 9 browse species by white-tailed deer. Journal of Range Management, 44:614-618.
Li80	Lippke, H. 1980. Forage characteristics related to intake, digestibility and gain by ruminants. J. Anim. Sci. 50:952-961.
Li86	Lippke, H. and G.W. Evers. 1986. Forage quality under grazing for Bigbee berseem and Meteora subterranean clovers. Forage Research in Texas, Texas Agricultural Experiment Station. Consolidated Progress Report CPR-4499. pp. 27-28.
Li87	Lippke, H. 1987. Intakes and digestibilities of bermudagrass and sorghum silages. Forage Research in Texas, Texas Agricultural Experiment Station. Consolidated Progress Report CPR-4537. pp. 7-8.
Li89	Lippke, H. and W.C. Ellis. 1989. Protein supplements fed to yearling steers grazing common bermudagrass pastures. Forage Research in Texas, 1989. Texas Agricultural Experiment Station. Consolidated Progress Report CPR-4731. pp.5-7.
Li90	Lippke, H. 1990. Intake and digestibility of beerseem clover and ryegrass silages. Texas Agricultural Experiment Station. Progress Report PR-4723. In Beef Cattle Research in Texas, 1989. pp. 210-212.
Li92	Lippke, H. and G.W. Evers. 1992. FORAGVAL for economic interpretation of forage quality data from small-plot studies. Forage Research in Texas. Texas Agricultural Experiment Station. Progress Report PR-5042. pp.89-91.
Li94	Lippke, H. and T.D.A. Forbes. 1994. Effect of pregrazing diet on early season gains by stocker steers grazing rye-ryegrass. Forage Research in Texas, 1993. Texas Agricultural Experiment Station. Progress Report PR-5098. pp. 61-63.
Li97	Lippke, H. and W.C. Ellis. 1997. Forage quality of annual ryegrass. pp. 71-78. *In* F. M. Rouquette, Jr., and L. R. Nelson (ed.) Ecology, Production, and Management of *Lolium* for Forage in the USA. CSSA Spec. Bul. 24, CSSA, Madison, WI.
Li00	Lippke, H., T.D.A. Forbes, and W.C. Ellis. 2000. Effect of supplements on growth and forage intake by stocker steers. J. Anim. Sci. 78:1625-1635.
Oc95	Ocumpaugh, W.R., G.L. Williams, and D.H.D. Swakon. 1995. Forage quality and cattle performance on ammoniated Coastal bermudagrass hay with and without supplemental feed. Forage Research in Texas, 1994. Texas Agricultural Experiment Station. Consolidated Progress Report CPR-5252. pp. 77-83.
Qu66	Quddoos, A. 1966. Relationship between Forage Chemical Composition and its Digestibility. Texas A&M University. PhD Dissertation.
Ro1	Rouquette, F.M. Unpublished data.
Sa93	Sanderson, M.A., R.M. Jones, J. Ward, and R. Wolfe. 1993. Silage sorghum performance trial at Stephenville, 1991. Forage Research in Texas. 1992. Texas Agricultural Experiment Station. Progress Report PR-5018. pp. 16-18.
Va1	Varner, L.W. Unpublished data.
Wa95	Warrington, B.G., R. V. Machen, and J.W. Holloway. 1995. Self-limited, molasses-based supplements for yearling steers grazing Coastal bermudagrass. Beef Cattle Research in Texas, 1995. pp. 75-77.

Appendix

Table A-4. Estimated nutrients in feed ingredients used in supplemental feeds.

	Nutrient content, % of air dry matter			
Ingredient or feedstuff	**CP[a]**	**TDN[b]**	**Calcium**	**Phosphorus**
Alfalfa, dehydrated	17.5	55	1.20	0.20
Barley, grain	10.0	78	0.05	0.40
Corn, grain	9.0	80	0.02	0.28
Cottonseed, whole	22.0	90	0.15	0.70
Cottonseed meal	42.0	65	0.15	1.00
Molasses	3.0	65	0.90	0.05
Oats, grain	12.0	70	0.10	0.35
Peanut meal	45.0	75	0.15	0.55
Rice, bran	12.0	55	0.06	1.40
Soybean meal	45.0	75	0.25	0.65
Wheat, bran	15.0	60	0.10	1.10
Wheat, grain	12.0	80	0.10	1.15

[a] Crude protein.
[b] Total digestible nutrients. Multiply by .02 to estimate digestible energy (Mcal/lb) contents.

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