



Ruminant Nutrition for Graziers

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Cattle, sheep and goats have the ability to convert plant carbohydrates and proteins into available nutrients for human use, making otherwise unusable land productive. However, proper care of the land and its grazing animals requires a sound understanding of ruminant nutrition. This publication provides managers with tools and references to consider biological and climatological variables and make decisions that ensure the ecological and economic viability of a grass-based ruminant livestock operation.



Cattle. Photo courtesy of NRCS.



Sheep. Photo by Linda Coffey, NCAT.



Goat. Photo courtesy of USDA.

Introduction

Grazing animals are very important to agriculture. Of course, they provide meat, milk, and fiber. But grazing animals also can be incorporated into a crop rotation to take advantage of nutrient cycling. They can be utilized to control weeds or to harvest crop residues. Grazing animals can also be an added source of income, diversifying farm enterprises and thereby rendering a farm more sustainable from an economic point of view.

This publication covers the basics of animal nutrition from a grazing perspective. Much of what we understand about livestock nutrition has been developed from studies and experience with confinement feeding operations, where concentrated nutrients in the form of grain, oilseed products, and harvested forages are delivered to animals in a drylot. These types of practices leave out many of the biological and climatological variables that accompany grazing situations: plant species, forage stage of maturity, soil fertility and water holding capacity, annual and



seasonal precipitation and mean temperature, etc. As they plan for the nutritional needs of their grazing animals, graziers need to take each of these variables into consideration. This publication provides livestock managers with the tools and references to consider all the variables and make informed decisions that ensure the ecological and economic viability of a livestock operation.

A ranching operation can appropriately be thought of as a forage production and utilization enterprise. Ranchers are in the business of converting sunlight, water, and carbon dioxide into a high-quality human food source. (Lalman, 2004a) Grasslands and rangelands occupy a large proportion of the U.S. land area. These ecosystems are naturally able to capture sunlight and convert it into food energy for plants. Humans have harvested plant energy for thousands of years—since the beginnings of agriculture. Literally millions of tons of plant-derived food energy is harvested off arable lands each year in the United States. But most of the land in the U.S., and indeed in most countries of the world, is not tillable and is considered rangeland, forest, or desert. These ecosystems can be very productive from a plant biomass perspective, but since they are generally non-farmable, the plants they produce (grasses, forbs,

shrubs, trees) are not readily usable (from a digestive standpoint) by humans.

However, grassland ecosystems (both rangeland and temperate grasslands) produce plant materials that are highly digestible to ruminant animals. *Ruminant* refers to grazing animals that have the ability to digest and metabolize *cellulose*, or plant fiber, and ferment it to form the volatile fatty acids and microbial proteins that the animal can then digest and use. This is of particular importance to the sustainability of agricultural production systems because grasslands and rangelands have the capacity to produce millions of tons of this energy source. Grazing of native and introduced forages on grasslands and rangeland thus is a very efficient way of converting otherwise non-digestible energy into forms available for human use: milk, meat, wool and other fibers, and hide.

The Value of Grassland Agriculture

Forages are plants, either wild or tame, that are consumed as livestock feed. Grasses, clovers and other forbs (broadleaf vascular plants), shrubs, and even some trees serve as forage for livestock, depending on the ecology of the region. Arable land in the United States, or land that is capable of being cultivated, accounts for only forty-three percent of the country's agricultural area (FAO, 2002). Arable cropland can be rotated into pasture to take advantage of the soil-building characteristics of perennial grass ecosystems. Also, perennial grasses tend to positively affect water quality by serving as buffers in riparian zones and increasing the water-holding capacity of soils. Perennial grasses and forbs as a component of annual cropping systems also help to reduce fuel and chemical use, allowing some fields to be in pasture or hayfield for several years between annual crop rotations.

In North America, more than 50 percent of the land area is rangeland and thus potentially grazable. The topography, soil characteristics, and water availability in these ecosystems usually limit

Seven Principles of Ruminant Nutrition

1. Ruminants are adapted to use forage because of microbes in their rumen.
2. To maintain ruminant health and productivity, feed the rumen microbes, which in turn will feed the ruminant.
3. Ruminant nutritional needs change depending on age, stage of production, and weather.
4. Adequate quantities of green forage can supply most—if not all—the energy and protein a ruminant needs.
5. Forage nutritional composition changes depending on plant maturity, species, season, moisture, and grazing system.
6. Supplementation may be necessary when grass is short, too mature, dormant, or if animal needs require it (i.e., high-producing dairy animal).
7. Excessive supplementation may reduce the ability of the rumen microbes to use forage.

Soil Building Characteristics of Grassland Ecosystems

Pastures help to increase organic matter and humus in the soil, which results in:

- Granulation of soil particles into water-stable aggregates
- Decreased crusting
- Improved internal drainage
- Better water infiltration
- Fixation of atmospheric nitrogen
- Release of bound nutrients
- Increased water and nutrient storage capacity

Source: Beetz, 2002

the kind of agriculture that can be developed on them to the grazing of livestock. Livestock management on arid rangelands has been extensively addressed by Allen Savory and Jody Butterfield of Holistic Management International (www.holisticmanagement.org). Savory coined the term “brittle environment” to denote ecosystems that receive either low annual precipitation or experience unpredictable and sporadic precipitation. (Savory and Butterfield, 1998) These environments are usually characterized by shallow soils, limited moisture, and drought-tolerant perennial grasses, forbs, and shrubs. Brittle environments respond very slowly to ecological disturbance. Savory has suggested that the proper distribution, timing, and intensity of grazing in these regions can have a significant and positive effect on the health of brittle environments. For more information see the above website or contact ATTRA at 800-346-9140.

The principal attribute describing grassland ecosystems and ruminant nutrition is *interconnectivity*. Grasslands and ruminant animals are intrinsically related, and practices that impact one will necessarily impact the other. From the soil the system derives water, nutrients, structural support, and temperature buffering. Soil populations of microorganisms recycle nutrients and make otherwise unavailable nutrients available for plant uptake. Microorganisms also populate the rumens of grazing

ruminant livestock and wildlife, performing symbiotic duties within the animal’s body. Animals occupy a niche and complete the nutrient cycle by returning up to 90 percent of ingested nutrients back to the soil in the form of feces, urine, and their own bodies after death. Humans play an important role in this system as well. We engage in agriculture and derive food and fiber from the system for our consumption.

Cattle, sheep, and goats have the ability to convert plant carbohydrates and proteins into available nutrients for human use, and therefore render productive vast portions of otherwise unusable land. Grasslands offer humans a nutritious supply of meat and milk. Many farmers and ranchers have changed production practices to take advantage of this natural process, bypassing the energy intensive grain-fed operations that have dominated American livestock production for the past several decades. Products from grass-finished livestock are higher in omega-3 fatty acids and conjugated linoleic acid than conventionally raised counterparts. Additionally, these products may reduce cholesterol and reduce the incidence of certain types of cancer. For more information on the nutritional



Photo courtesy of USDA, NRCS.

benefits of grass-based agriculture, visit Jo Robinson's website www.eatwild.org.

Ruminant Physiology

Proper care of the land and its grazing animals requires a sound understanding of ruminant nutrition. First we must understand how a ruminant animal (cattle, sheep, goats) digests plant matter.

Ruminant comes from the word “rumen,” which is the first major compartment in the four-compartment stomach of the cow, sheep, and goat. This structure is the “furnace” where microbial fermentation takes place. Millions of bacteria, protozoa, and fungi live in the rumen and break down energy-rich plant parts, making them digestible for the host animal. After the forage has been digested in the rumen and is broken down into small pieces, it can pass through the *reticulum* and *omasum*, which function as strainers that keep large pieces of material from passing into the *abomasum*, or “true stomach,” where digestion continues. From the abomasum onward, the ruminant digestive system closely resembles other animal digestive systems with a small and large intestine, colon, and anus.

Benefits of Ruminant Physiology

As stated earlier, grazing animals have the ability to harvest and convert plant energy, especially cellulose, from grasslands and rangelands not suited to

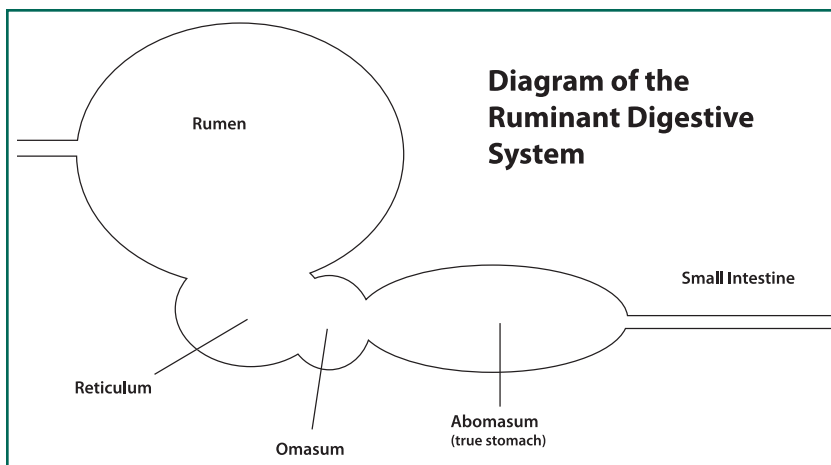
The Role of Rumen Microorganisms

- Production of cellulase (to break down fiber-rich plant material)
- Synthesis of volatile fatty acids (used as energy by the animal)
- Synthesis of vitamins
- Synthesis of microbial protein

cultivation. Cellulose is the portion of the plant structure that comprises the walls of the plant's cells, and is very fibrous and indigestible. Monogastric (single-stomach, non-ruminant) animals do not have the ability to digest cellulose. Rumen microbes, however, produce *cellulase*, the enzyme that breaks down the chemical bonds in cellulose, making it digestible to the microbe and, subsequently, to the ruminant animal.

Another advantage of rumen fermentation is microbial synthesis of important vitamins and amino acids. All the vitamins the animal needs are synthesized by microorganisms, except vitamins A, D, and E. However, animals fed high quality hay or green pasture get their requirement of vitamins A and E. Vitamin D is supplied through exposure to sunlight, which is another advantage of pasture production. Amino acids are the building blocks of protein—a crucial nutrient for growth and reproduction in animals. Rumen microbes synthesize these building blocks from ammonia, a by-product of fermentation in the rumen. Given this fact, even poor quality forage can supply some protein for the grazing animal.

Once it is understood how the rumen works to convert forage to digestible energy and protein, it becomes clear how important grazing animals are to the environment and, in turn, human culture. Grazing animals evolved with the prairies and ranges of the American West, the African steppes, and Mongolia and have contributed to the development of each specific ecological region. Without the ability to harvest plant energy from non-farmlands, humans would miss



this crucial contribution to the local and world food supply. Grazing animals are the necessary link between forages and people.

Ruminant Digestive Processes

“Nutrients absorbed from the digestive tract include volatile fatty acids, amino acids, fatty acids, glucose, minerals, and vitamins. These are used in the synthesis of the many different compounds found in meat, milk and wool, and to replace nutrients used for maintaining life processes including reproduction.” (Minson, 1990) Digestion begins when an animal takes a bite from the pasture. As the animal chews the feed is formed into a bolus—a packet of food capable of being swallowed. Saliva is excreted, which further aids in swallowing and serves as a pH buffer in the stomach. Once in the rumen, the feed begins to undergo fermentation. Millions of microorganisms ingest the feed, turning out end products which serve as a major source of nutrients for the animal. Some of the principle products formed are ammonia, methane, carbon dioxide, and *volatile fatty acids* (VFAs). VFAs are absorbed and used as energy by the animal. Ammonia can be absorbed into the animal’s system through the rumen wall, or can be consumed by bacteria to become microbial protein. This microbial protein is then passed through the digestive system to be absorbed in the small intestines.

Nutrient Requirements of Grazing Livestock

For producers, what are the important nutritional considerations for grazing livestock? This is a good question, since livestock nutritionists have developed a science of nutrient analysis and subsequent ration balancing. But the analyses are built on nutrient content of processed or harvested feedstuffs delivered to ruminants in pens, rather than grazing ruminants selecting a diet from pasture. For this reason, forage nutrient analysis may not be the most reliable method to determine feed quality for grazing livestock.

Critical Components of Feed Quality

Forage nutrient analysis can be a good tool to determine forage quality. However, forage quality for grazing animals is more accurately determined by the following factors, which are affected by observation and adaptive management of the grazing resource:

- forage intake
- forage diversity
- forage quantity, availability, and density
- appropriate supplementation (energy or protein), when necessary
- appropriate minerals—offered free choice
- and clean, fresh water offered at all times.

The Basics

The nutritional concern for ruminants centers around energy (i.e., carbohydrates), protein, minerals, vitamins, and water. Energy (carbohydrates) is responsible for maintenance and growth functions of the animal, and for the generation of heat. Protein grows tissue and performs other vital functions. Other nutrients and minerals such as vitamins A and E, calcium, phosphorus, and selenium can be fed “free choice” as a mineral supplement. The following section explores the nutrient requirements of ruminants, beginning with intake.

Intake

Intake is critically important for acquisition of nutrients by ruminants. Intake is the ingestion of feedstuffs by the animal, and is regulated by the following factors, which are all interrelated:

- palatability
- foraging behavior
- chemical characteristics of the feedstuff
- forage quantity, density, and availability
- dietary energy and fiber content
- physiological stage of the animal
- and temperature

Related ATTRA Publications

A Brief Overview of Nutrient Cycling in Pastures

Assessing the Pasture Soil Resource

Cattle Production: Considerations for Pasture-Based Beef and Dairy Producers

Dairy Goats: Sustainable Production

Dairy Resource List: Organic and Pasture-Based

Dairy Sheep

Goats: Sustainable Production Overview

Grass-Based and Seasonal Dairying

Managed Grazing in Riparian Areas

Meat Goats: Sustainable Production

Sustainable Sheep Production

Pastures: Going Organic

Pasture, Rangeland, and Grazing Management

Pastures: Sustainable Management

Palatability is the flavor and texture of the feedstuff. Ruminants seek sweetness in their feed, probably because sweet is an indicator of soluble carbohydrates, the most critical dietary element for the animal after water. Ruminants will in turn avoid feedstuffs that are bitter, as these often are associated with toxic secondary chemicals.

Foraging behavior describes how an animal goes about the grazing process. According to Fred Provenza, range researcher at Utah State University, the study of animal grazing behavior involves understanding:

- food habits and habitat preferences, and
- the effects of nutrients and toxins on preference

“Our work has shown,” he writes, “how simple strategies that use knowledge of behavior can markedly improve the efficiency and profitability of agriculture, the quality of life for managers and their animals, and the integrity of the environment.” (Provenza, 2003) For instance, grazing livestock, unlike closely confined livestock, have the opportunity to graze selectively, and therefore tend to select a diet higher in leaf content than what the overall pasture has to offer. (Minson, 1990) For more information on grazing animal behavior see www.behave.net and www.livestockforlandscapes.com.

Bite size and bite rate also have an influence on intake. The more dense a pasture sward, the more forage the animal can take in with each bite. Research has shown that a dense, vegetative pasture yielding at least 2,000 pounds of dry matter per acre is adequate for maximizing bite size, and therefore intake. However, when pasture yield drops below 2,000 pounds of dry matter per acre, intake decreases. (Minson, 1990) This exemplifies the fact that the relationship between grazing management, animal behavior, and nutrient uptake is not a simple relation. It is complex and constantly changing, following the changes of the seasons, forage quality, and forage quantity.

Chemical factors include nutrients, but also secondary chemicals that are often

Secondary chemicals include “plant compound[s] capable of producing toxicosis by impairing some aspect of animal metabolism. Everything is toxic, including oxygen, water, and all nutrients if ingested in high enough doses. Most plants, grasses included, contain toxins. Toxins typically set a limit on the amount of food an animal can ingest. They do not produce harmful effects if ingested in limited amounts. Under certain circumstances, animals have difficulty refraining from overingesting certain plants that contain toxins—the so-called poisonous plants.” (Provenza, 2003)

associated with plant defense. Secondary chemicals are often referred to as toxic substances, but toxicity is really just a matter of degree, of dosage. All plants contain toxic secondary chemicals to some degree, but animals have evolved an innate sense of what is good to eat.

Animals limit the amount of plants they consume that contain secondary chemicals through a feedback mechanism that results in *satiety*, or the feeling that they have had enough. According to Webster, satiety is the “quality or state of being fed or gratified to or beyond capacity, or the revulsion or disgust caused by overindulgence or excess.” When ruminants consume enough of a certain toxic substance, a feedback mechanism induces a switch to an alternative source of nutrients. This is why cattle, sheep, and goats graze more (have higher intake) on a diverse pasture. The variety stimulates their appetite and provides alternative sources when they reach the limit of their first choice of plants.

Secondary Chemicals in Forages

- Alkaloids in reed canarygrass and lupines
- Tannins in trefoil and lespedeza
- Terpenes in sagebrush and bitterweed
- Endophyte toxin in tall fescue

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Forage quantity, density, and availability directly influence forage intake, and intake is directly related to the density of the pasture sward. Ruminants can take only a limited number of bites per minute while grazing, and cattle in particular will only graze for about 8 hours per day. It is important then to ensure that each bite taken by the grazing animal is the largest bite she can get. A cow grazes by wrapping her tongue around and ripping up forage; sheep and goats use their lips and teeth to select highly nutritious plant parts. Large bites of forage are therefore ensured by maintaining dense pastures.

Dense pastures are those with actively growing and tillering forage plants. Tillering occurs in grasses that are grazed or mowed while vegetative, resulting in the activation of *basal growing points* (clusters of cells that initiate growth near the bottom of the plant) and the growth of new stems and leaves. Tillering results in a plant covering more basal area, which helps make a pasture denser, while protecting the soil.

The length of the grazing period (the time an animal is in a paddock) also has a direct effect on pasture intake. An animal's intake decreases the longer she remains in a given paddock. This happens due to (1) the effect of plant disappearance (as plants are grazed) and subsequent searching by cattle for the next bite, and (2) the decrease in forage crude protein content beginning roughly two days after the animals have been turned in to the paddock. Jim Gerrish has shown that as an animal remains in a paddock, intake and liveweight gains decrease. (Gerrish, 2004) It is for this reason that most dairy graziers move high-producing cattle to new paddocks after each milking.

Dietary energy and fiber content. As has been mentioned, livestock eat to the point of *satiety*. Another good definition of satiety is *gastrointestinal satisfaction*. Ruminants possess nutritional wisdom and will select diets high in digestible organic matter, because the most critical nutrients selected by

ruminants are soluble carbohydrates. What an animal actually eats from a pasture is often of higher nutritional quality than the average of the pasture overall. Forages with a dry matter digestibility (DMD) of 60 to 69 percent are considered high quality forages from an energy perspective. Dietary fiber is also a forage quality indicator.

Fiber is necessary for proper rumen function, and is a source of energy as well. However, high levels of fiber in the diet decrease intake. Less digestible forages tend to stay in the animal's digestive system longer (slowing the rate of passage) so the animal remains "full" longer, and subsequently doesn't eat as much. However, the younger a plant is the more soluble carbohydrates it contains, and the less fiber (cell wall components) it contains as well. Younger plants therefore are generally more digestible than mature plants.

Physiological stage refers to the stage of life the animal is in, and what level and type of production are being supported. The key physiological stages in the life of ruminant animals are:

- growth (i.e., young lambs, kids, and calves, including feeder animals)
- late pregnancy (very important in sheep and goats)
- lactation (for dairy production or maintenance of offspring)
- and maintenance (such as the cow's dry period)

For example, the peak intake of dairy cattle occurs after peak lactation. Between peak lactation and peak intake, the body must draw on stores to maintain energy balance. Thus dairy animals generally lose body condition during this period. For this reason it is important to ensure high-quality pasture to maintain productivity and optimum health, as well as to ensure the animal's ability to rebreed and enter into lactation at the appropriate time the following season. On the other hand, a dry ewe can gain weight on "fresh air and sunshine"—maintenance requirements are low, and this

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is the perfect time to let the sheep clean up over-mature forage, with no harm done.

Temperature affects the amount of feed an animal needs to maintain its body functions. An animal's metabolic rate increases as the temperature drops below the animal's comfort zone. As temperature drops, more energy is needed to maintain internal heat, so intake increases accordingly. Subsequently, animals typically will not graze as much during hot, humid weather.

Options for Increasing Intake on High Quality Pasture

High intake is one of the simplest methods of ensuring adequate nutrition for high producing ruminants. Ensure high forage intake by:

- keeping forage in the vegetative stage through grazing management,
- diversifying pasture composition to include several grass species, with around 30 percent of the pasture in legumes, and
- maintaining a dense pasture so animals will take larger bites.

Energy

Energy is the single most important dietary component for an animal after water. Energy is derived from carbohydrates, fats, proteins, and from the animal's body reserves.

Energy intake maintains body functions and facilitates growth and development, including reproduction and lactation. Energy is supplied to ruminants by highly digestible plant cell contents and a portion of the less digestible plant cell wall fraction. Starches like corn and barley are also high energy sources, and are used extensively in the conventional livestock feeding industry as well as for pasture-based systems where energy supplementation is sometimes useful to enhance production.

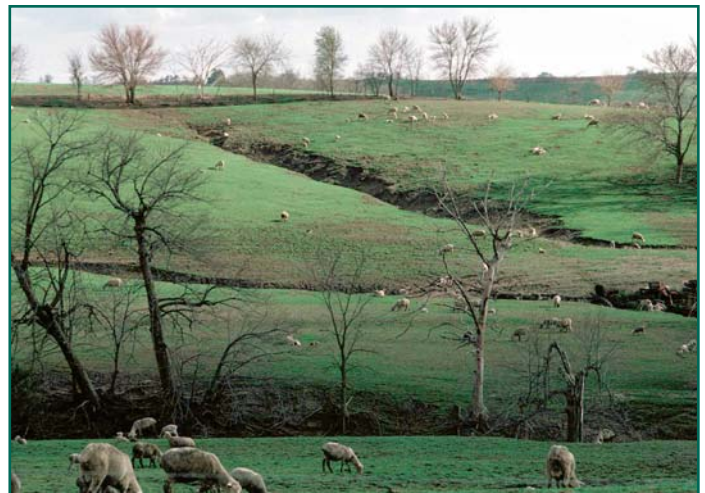
Not all the energy taken in by a grazing animal becomes meat, milk, or wool. The hierarchy of energy digestion begins with gross energy, which is the energy of intake. Some of the energy of intake is digestible, and some is not. What is not digestible is excreted as fecal energy, and what is left for use by the body is digestible energy. Metabolizable energy is the energy left after accounting for digestive and metabolism losses. Some of the digestible energy is lost as urine, and some as methane. What is left is energy used for the maintenance of body temperature, respiration, growth, reproduction, and milk production. This fraction is called net energy and is usually split into net energy for maintenance (NE_m), net energy for gain (NE_g), and net energy for lactation (NE_l). Animals can adjust to available energy by putting on fat or by using fat stores. For more information see the box entitled "Body Condition Scoring."

Intake is maximized when pastures are:

- dense
- digestible
- palatable
- diverse
- correctly stocked
- plentiful (8-10" tall for cattle, 6-8" for sheep)
- familiar to the animal
- fresh (not trampled or heavily manured)



Good, plentiful pastures assure healthy, productive animals. Photo courtesy of USDA, NRCS.



Animals are not productive when pastures are inadequate. Photo courtesy of USDA, NRCS.

Body Condition Scoring

Body condition scoring is a method of visually appraising animals to arrive at a qualitative description of nutritional status. Animals must not be too thin or too fat or complications can arise. If too thin, animals may not conceive, may be prone to disease, and usually have reduced milk production. If too fat, animals may experience difficulty giving birth (dystocia).

Body condition scores are ranked on a numerical scale. The lower the number on the scale, the thinner the animal. For sheep and dairy cattle, the scale is from 1 to 5. For beef cattle, the scale is 1 to 9.

Optimum BCS for Breeding Livestock

Sheep 3.0 to 4.0

Dairy Cattle 2.5 to 3.0

Beef Cattle 4.5 to 5.0

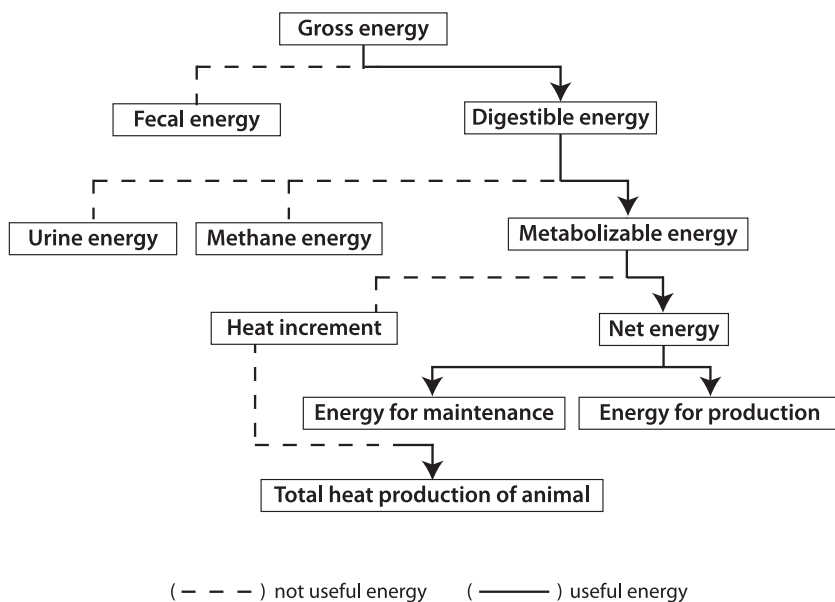
The **Resources** section of this paper lists several publications addressing body condition scores for various species. The publications include charts to assist producers in making visual appraisals of livestock and assigning the appropriate body condition score.

Protein

“Crude Protein (CP) is calculated from the nitrogen content of the forage. The CP value is important since protein contributes energy, and provides essential amino acids for rumen microbes as well as the animal itself. The more protein that comes from forage, the less supplement is needed. However, most nutritionists consider energy value and intake of forages to be more important than CP.” (Robinson et al, 1998) As has been discussed, the energy value of a forage is best determined by forage maturity, density, and availability. Protein in forages is most correlated with forage maturity, as more mature forages have a lower percentage of crude protein.

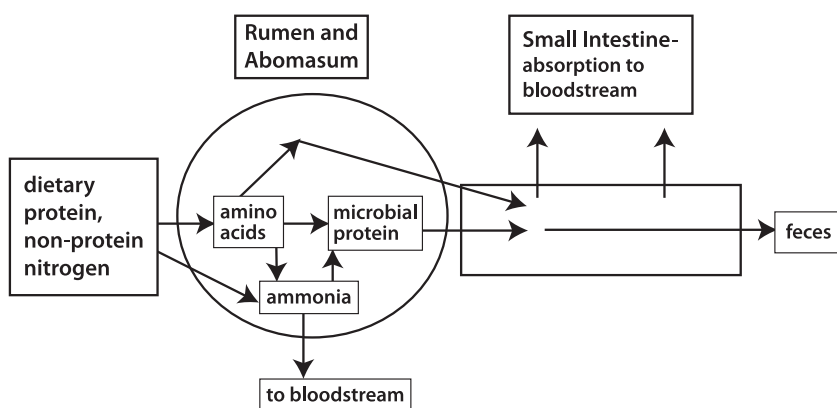
Cattle require two types of protein in their diet. One type is degraded in the rumen and is used to meet the needs of the microbial population, and the other bypasses the rumen and is used primarily to meet the productive needs of the animal.

Energy Partitioning. From USDA, 2003.



When protein is degraded in the rumen it is called *rumen degradable protein*. Rumen degradable protein is essentially food for rumen bacteria. When the microbes die they are passed through to the stomach and small intestines where they are digested by the animal. The resulting microbial protein is then absorbed into the animal’s bloodstream. Some of the protein in the diet does not undergo degradation in the rumen, but passes straight to the abomasum or stomach for digestion. When protein escapes rumen breakdown and passes to the stomach it is referred to as *rumen undegradable protein* or *bypass protein*.

Protein Flow.



Vitamins are important for the formation of catalysts and enzymes that support growth and body maintenance in animals.

Bypass protein is important because a large percentage of the rumen degraded protein is absorbed as ammonia and, if in high concentrations, can be lost through the urine as urea. In high-producing animals this represents an inefficient utilization of protein, so increasing the amount of protein that is bypassed to the intestines constitutes a more efficient utilization of protein for growing or lactating animals on high-quality pastures. In forages, roughly 20 to 30 percent of the protein taken in by the animal is bypassed to the intestines. Lactating or growing cattle generally require 32 to 38 percent of their total protein intake to be in the undegradable form. (Muller, 1996) High-quality pastures can meet almost all the needs of high-producing livestock. For those animals that require supplementation, corn, cottonseed and linseed meals, brewers dried grains, corn gluten meal, distillers dried grains, and fish meal are typically high in bypass protein.

The microbial degradation of protein is an energy-dependant process. Carbohydrates are the energy-yielding nutrients in animal nutrition and are supplied by the production of volatile fatty acids in the rumen. Generally more microbial protein is synthesized from green forage diets than from hay or mature forage diets. When a ruminant animal grazes fresh forage on high-quality pasture, about 70 percent of the protein is degraded in the rumen by microorganisms, and about 30 percent escapes to the small intestine for absorption. Ruminant animals need approximately 65 to 68 percent of the protein to be rumen degradable for adequate rumen function and the development of microbial protein. But if more protein is degraded in the rumen, less is available to the animal for absorption in the small intestine. This is important because researchers believe that rumen undegradable or bypass protein consists of certain essential amino acids that are missing or deficient in rumen degradable protein. Much of the rumen degraded protein is absorbed as ammonia and excreted out of the body via the urine, and is therefore a waste of protein. This is why bypass or undegradable protein is

important, especially for high-producing livestock such as dairy animals, even in protein-rich-pasture diets.

Some animal nutritionists suggest that bypass protein has been overemphasized. This is because the total proportion of bypass protein in most forages is around 30 percent, which is very close to the requirements of the ruminant animal. In this case, they suggest, feeding the rumen microorganisms takes on particular importance, for if the rumen microorganisms are healthy, they will supply the ruminant with the nutrients they need to maintain body functions and remain productive. We must remember that ruminant animals evolved in symbiosis with rumen microorganisms in a grassland environment, and they are inherently adapted to this function.

Minerals and Vitamins

The principle minerals of concern for livestock on growing forages are calcium and magnesium. Others to consider are salt, phosphorus, potassium, and sulfur. These minerals are very important for cellular respiration, nervous system development, protein synthesis and metabolism, and reproduction. Mineral supplements are available in many formulations. Because soils differ in mineral content from place to place, it is difficult to recommend a mineral mix that works in all places, although most animal scientists suggest at the very least a mineral mix with a calcium to phosphorus ratio of 2:1. Consider using a loose mineral mix fed free choice rather than mineral blocks for cattle on lush spring or small grain pasture to avoid grass tetany (hypomagnesemia) and to ensure the animals are getting enough mineral.

Vitamins are important for the formation of catalysts and enzymes that support growth and body maintenance in animals. Green growing plants contain carotene, which is a precursor to vitamin A. If ruminants are on green forage (including green hay) vitamin A should not be deficient. Vitamin A deficiencies occur when ruminants are placed on concentrate feeds, or when fed dry,

stored forage during the winter. B vitamins are synthesized by rumen microorganisms so supplementation is not necessary. Vitamin D is synthesized in the skin from exposure to sunlight, so Vitamin E is the only other vitamin of concern that sometimes requires supplementation.

Mineral and vitamin supplementation is very important to maintain herd health, and careful attention must be paid in developing a mineral and vitamin supplementation plan. Keep these things in mind when feeding these supplements to livestock:

1. Keep mineral mixes dry. Wet mineral is unpalatable and is known to lose some of its efficacy when damp.
2. Monitor consumption to make sure it's always available. Keep the feeders full.
3. Don't forget that some animals display social dominance. Older, more dominant animals will often eat more than their share of mineral mix. Remedy this by having more than one feeder, separated into different parts of the pasture.

Sheep and Copper Toxicity

Sheep are very sensitive to copper. If you have cattle and/or goats, and sheep on the same farm it is extremely important to supply them with different mineral mixes, as a mix that is formulated for cattle or goats will likely be lethal for sheep. Loose mineral mixes are better than blocks for sheep and goats.

Check with your local Extension agent or veterinarian to determine the mineral and vitamin mixes and recommendations common to your area.

Water

Sheep and goats require one gallon of water per day for dry ewes, 1.5 gallons per day for lactating ewes, and 0.5 gallons per day for finishing lambs. Water consumption will increase during the heat of the summer, and when the animals are grazing or browsing plants with high concentrations of secondary,



Photo courtesy of USDA, NRCS.

toxic chemicals. Examples are knapweed, sagebrush, and scotchbroom.

Cattle require from 3 to 30 gallons of water per day. Factors that affect water intake include age, physiological status, temperature, and body size. A rule of thumb is that cattle will consume about one gallon of water per 100 pounds of body weight during winter and two gallons per 100 pounds of body weight during hot weather. In general, you can easily double the estimates for lactating cattle. Water should be clean and fresh, as dirty water decreases water intake. It is good to remember that all other nutrient metabolism in the body is predicated on the availability of water, and if an animal stops drinking, nutrient metabolism (which results in growth and lactation) will decrease.

Forage Resources and Grazing Nutrition

Nutrient content of forages varies with plant maturity. As the plant matures, it shunts sugars and proteins to the reproductive centers of the plant, namely the seed (in the case of annuals) and the roots (in the case of perennials). Plant maturity results in more fibrous, and less digestible, leaves and stems. Various circumstances affect plant maturity. Among the most common

factors contributing to plant maturity and subsequent forage quality are:

- length of growing season (plants mature faster in shorter growing seasons)
- moisture availability (moisture stress reduces photosynthetic activity and initiates dormancy)
- pasture plant species composition (some species remain vegetative longer than others)
- and the grazing system

Of these factors, the one that livestock managers have the most control over is the grazing system. Controlled defoliation and adequate rest are crucial for plants to remain vegetative, and therefore more nutritious, during the growing season. This topic is summarized in the **Grazing Management** section of this publication and covered in detail in the ATTRA publications *Pasture, Rangeland, and Grazing Management*, *Rotational Grazing*, and *Pastures: Sustainable Management*.

Plant Type, Species, and Nutritional Quality on Native Range

There are three basic plant types commonly found in pastures, and each has its place in animal nutrition. These plant types are:

- Grasses
- Shrubs
- Forbs

Grasses tend to be high in nutrients in the spring, and begin to decline as the growing season progresses. By the time winter sets in, rangeland grasses such as rough fescue and bluebunch wheatgrass will have

relatively high TDN levels and protein compositions of 5 percent. (Ricketts, 2002) Shrubs tend to have their highest nutrient content in the spring as well, but generally retain a higher nutrient content throughout the growing season and into the dormant period. Most shrubs, such as greasewood and saltbush carry a protein content of greater than 12 percent in the winter. Forbs are high in protein as well. Purple prairie clover and dotted gayfeather have as much or more protein, when green, than alfalfa and clover. “These forbs are like little protein blocks scattered on the landscape.” (Ricketts, 2002)

Grasses. Grasses are divided into two types: warm season and cool season. On semi-arid prairies and western ranges, warm season grasses do most of their growing from May to August, whereas cool season grasses do their growing from March to June. Knowledge of which grasses are in your pastures will help you to decide when to graze them to take advantage of highest nutrient content. In the spring, grasses will have a protein content of approaching 20 percent and will be around 10 percent protein when in mid-bloom, or when half the plants have developed a seedhead.

On deteriorated dry western range sites, you might see a proliferation of Kentucky bluegrass, bottlebrush squirreltail, and cheatgrass. The weedy grasses can be good in nutrient value, but generally do not produce enough annual forage to meet the needs of grazing livestock, and are often vegetative for a very short period of time, as with cheatgrass and squirreltail. Broadleaf weeds become coarse and unpalatable very soon after they begin to mature. Pastures that have greater than about 50 percent of these plants should be considered for a serious revision of the grazing system, or pasture renovation if appropriate. Consider multi-species grazing, because sheep and goats may eat the weeds that cattle do not, thus bringing the pasture back in balance.

Shrubs. Shrubs are very good to have on native range because they are high in protein for a greater part of the year. Many

Feeding Value of Forages			
	TDN %	Crude Protein %	
		Grass	Legume
Vegetative	63	15	21
Boot or bud	57	11	16
Bloom	50	7	11
Mature	44	4	7

Adapted from Fisher, 1980

livestock and wildlife find these plants important for getting them through the winter. Shrubs on many western ranges include winterfat, sagebrush, fringed sagewort, four-wing saltbush, snowberry, and rabbitbrush. These plants will generally have more than seven percent protein content through the winter. Combined with other dormant forages, these plants can often supply an animal with its maintenance needs for protein if there are enough plants.

Cattle are typical grazers, and utilize grass as their primary food source. They will, much like goats and sheep, browse on winterfat and saltbush. A range site with 20 to 30% of its cover in a diverse population of shrubs serves to sustain all classes and species of livestock as well as provide winter food and cover for wildlife.

Forbs. Forbs, or non-woody broadleaf plants, are generally higher in protein than grasses. Many forbs are considered weeds, but most are often palatable and nutritious when immature. Typical rangeland forbs that are high in protein and digestibility include gayfeather, western yarrow, prairie clover, and Indian paintbrush. On dryland ranges, high-dormancy alfalfa can make a very good supplement for livestock, as do birdsfoot trefoil and cicer milkvetch, which in addition to being high-quality forage, have anti-bloat characteristics as well.

Plant Type and Species on Temperate Pasture

Grasses and forbs generally dominate shrubs in temperate regions. On temperate pastures, warm season grasses exhibit growth from as early as March to as late as September, and cool season grasses grow well from October into June, with reduced growth during the winter months. Indicators of poor pasture condition on temperate pastures are grasses such as sandbur, rattail smutgrass, and little barley, and broadleaf weeds like curly dock, croton, and hemp sesbania.

The most common forbs used on temperate pastures include clovers, alfalfa, and vetches. White clover, hairy vetch, red clover, or

A Case for Species Diversity

As shrubs and forbs typically have higher protein concentrations than most grasses, why are they generally considered substandard as livestock forage? The main reason is that most shrubs and many forbs contain secondary chemicals that are often toxic to grazing animals. Animals grazing sagebrush, for example, will very quickly get their fill as the level of alkaloids accumulates in their systems. However, livestock display nutritional wisdom and often eat small portions of various species in order to (1) obtain essential nutrients, and (2) neutralize the effects of more toxic plant species.

Berseem clover are often overseeded into warm season pastures with annual ryegrass or small grains in the humid South to supply high quality winter pasture to cattle from October through April. Some excellent warm season legumes to consider in temperate regions are annual cowpeas and perennial peanuts. Turnips also make an excellent season extension annual crop for providing high-quality grazing into the fall in some temperate regions. For more information on alternative forages to extend the grazing season, see the ATTRA publication *Pasture, Rangeland, and Grazing Management* at www.attra.ncat.org or call the ATTRA help line at 1-800-346-9140.

Matching Nutritional Requirements of Livestock to the Forage Resource

One of the most important questions a livestock manager can ask is “what do I need to know in order to match the nutritional requirements of my animals to the forage resource?” To answer this question with the highest level of certainty, the producer should perform the following crucial management tasks:

- inventory available forage resources (documenting re-growth, crop residue, etc.)
- prioritize grazing of highest quality pastures by animals with highest nutrient requirements (growing, lactating)
- observe and determine the forage growth curve for your pastures

- coincide the forage growth curve with peak animal demand
- monitor to ensure animal numbers and type are appropriate to forage resource

Forage Growth Phases

Forage supply is not continuous throughout the year. You can expect anywhere from three to nine months of growing season, and three to nine months of dormancy, depending on the region. Cool-season pasture growth begins in the early spring and quickly produces very large amounts of forage, then tapers off toward mid-summer. Given adequate moisture, cool-season pastures will often produce a second surge of growth in the fall before going dormant.

Warm-season pasture begins later in the spring and continues into early autumn when day length shortens and temperatures fall. Warm-season pastures complement cool-season pastures nicely by providing forage when cool-season growth wanes in mid-summer. A diverse mix of cool- and warm-season pastures benefits livestock managers by overlapping the growth curves of both types, meaning more high-quality pasture than otherwise.

Peak Animal Demand

The highest nutrient demand for beef cattle is one to three months after parturition

(birth) and lowest demand is three to four months before parturition. (Gerrish, 2004) For sheep, just before lambing to weaning are crucial times when nutrient requirements are highest, especially just prior to lambing. For dairy animals, the entire lactation period is critical. Knowing the forage growth curve for your pastures will allow you to match forage growth with animal demand. For example, consider having ewes lamb when grass is at optimum productivity and when the ewes need it the most. On the other hand, think about the needs of young stock. Unless you are selling at weaning, you need a plan for high-quality pasture for young growing animals.

Supplementing Protein or Energy: When is it Necessary?

Cattle, sheep, and goats, by nature grazing and browsing animals, grow and reproduce well on pasture alone. However, an intensive and industrial agricultural production philosophy has dictated that crops and animals should be raised faster, larger, and more consistently than a pasture system can deliver. Thus confinement systems with delivered forages and concentrated feeds have been the norm since the 1950s. Raising animals on grass is slower than raising animals on grain. However, a pasture-based livestock producer will, with careful planning, realize cost savings and subsequent profitability through the efficiency of relying on the natural systems of nutrient cycling, biological pest controls, and perennial pasture productivity.

The major operational expense confronting the livestock industry in most parts of the United States is for supplemental feed. In temperate regions of the country that experience adequate rainfall and a lengthy grazing season, supplementation on green, growing, vegetative, well-managed pastures should not be necessary. However, young and lactating stock require more energy and protein than mature, non-lactating animals.

Well-managed grass-legume pastures can be highly digestible with protein concentrations approaching 25 percent while



District Conservationist Rhonda Foster and Grasslands management Specialist Ralph Harris discuss intensive grazing rotations at a farm in Benton County, Georgia. The producer grazes his cattle on a 3 week rotation. Photo courtesy of USDA, NRCS.

vegetative. These pastures can supply the nutrients needed to raise lambs, kids, heifers, or steers, or support lactating cattle, sheep, or goats. The problem on high-quality pastures often becomes one of inefficient protein use. Supplementing energy with digestible fiber in these situations can make the animals utilize protein more efficiently. Digestible fiber (energy) sources include wheat middling (a coproduct of wheat processing sometimes called midds), soybean hulls, corn gluten feed, and whole cottonseed. (Jackson, undated)

Corn is grown on many small diversified farms, in rotation with pasture, legumes, or vegetables, as animal feed, and is an excellent source of low-fiber energy for grazing ruminants. However, if corn is fed in high quantities, forage intake will decline. A pound or two a day for sheep and goats and five or six pounds per day for cattle will generally provide enough supplemental energy without decreasing forage intake. Limiting corn supplementation to no more than 0.5 to 1.0 percent of body weight per day is recommended for cattle on pasture. (Sewell, 1993)

When to Supplement

- Supplementing energy is helpful on vegetative, well-managed pastures for more efficient utilization of forage protein (for high producing animals).
- Supplementing with protein is necessary on low-quality pasture and rangeland or when continuously grazing temperate warm-season pastures.

When supplementing ruminants on pasture, consider the following questions:

- Will the added production cover the expense, especially if the feed is shipped from off the farm?
- Is there an inexpensive local source of protein?
- Do you raise the feed on the farm?
- Do you have necessary harvest, storage, and feeding equipment?

Remember:

- Substitution effect—forage intake decreases with less fibrous, more digestible supplements like corn.
- Supplementation of protein on low-quality forages will increase forage intake, and therefore increase energy intake.

Concept of First Limiting Nutrient

Determine which nutrient is limiting and supplement that one first. For instance, degradable intake protein requirements need to be met for microbial growth first. Then and only then consider bypass protein supplementation, and only if it is deficient. Likewise, if energy is deficient, protein supplementation will be wasteful and expensive.

Remember: on high-quality pastures, energy is often the limiting nutrient. Digestible fiber feeds are good for ruminants on high quality forage because they do not reduce intake, and provide energy for protein metabolism. Examples are: corn gluten feed (corn gluten meal plus the bran), wheat midds (screenings from wheat flour processing), and whole cottonseed.

Feeding Cottonseed Products to Cattle

Three types of cottonseed products are typically fed to beef and dairy cattle. These are *whole cottonseed* with lint, *cottonseed meal*, and *cottonseed hulls*. Whole cottonseed is a very good source of protein for cattle. However, whole cottonseed contains a chemical called *gossypol* that can inhibit the reproductive performance of breeding cattle, particularly bulls. For this reason it is recommended that producers limit whole cottonseed supplementation to calves at 1.5 pounds per day, stocker cattle at no more than 3 pounds per day, and mature cows at 5 pounds per day. Avoid feeding whole cottonseed to bulls.

Forage Sampling and Production (Yield) Estimates

If you choose to have your forage analyzed for nutrient content, the key nutrients to consider are crude protein (CP) and total digestible nutrients (TDN). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) are useful as well for determining energy content. ADF and NDF measure fiber, or cell wall contents. The higher the fiber the lower the energy value is for a feedstuff.

Your Local Cooperative Extension Office

Contact your local Cooperative Extension office for information on poisonous plants, forage analysis, and locally adapted forages. The USDA maintains an online database of local Cooperative Extension offices on its website at www.csrees.usda.gov/Extension/index.html. You will also find the phone number for your Cooperative Extension office in the county government section of your telephone directory.

Grazing Management

Grazing management is the regulation of the grazing process by humans through the manipulation of animals to meet specific, predetermined production goals. (Briske and Heitschmidt, 1991) The primary considerations of grazing management are:

- temporal distribution of livestock (time)
- spatial distribution of livestock
- kind and class of livestock
- and number of livestock (Heitschmidt and Taylor, 1991)

If given a choice, livestock will only eat the highest quality, most palatable plants in a pasture. In order to ensure that plant biodiversity is maintained in the pasture it is necessary to set up a grazing management system to better control livestock grazing. The elements of grazing to control are timing and intensity of grazing. This means controlling the number of animals and how long they are in a pasture.

Rotational grazing systems take full advantage of the benefits of nutrient cycling as well as the ecological balance that comes from the relationships between pastures and grazing animals. High density stocking for short periods helps to build soil organic matter and develops highly productive, dense, resilient pastures.

Some other measurements to consider in managing livestock grazing include:

Although determined by a system that relies on harvested forages, these two measures will give the producer a good starting point to make decisions about supplementation. For cattle, forage with 10 to 13 percent CP and 55 to 60 percent TDN will meet all the needs of most classes of livestock. Growing and lactating livestock need added protein and energy if the forage resource is not of adequate quality. Also important is mineral content. Different soils in different areas of the country can be deficient in different nutrients. Selenium and copper availability are a problem in the southeast and northwest, for instance. Check with your Cooperative Extension office or state Extension forage or beef specialist to determine the mineral needs in your area.

Estimating forage yield in a pasture also plays a very important role in developing a nutrition plan for grazing livestock. There are many ways to estimate forage yield, from the more time-consuming clip-and-weigh approach to more generalized estimates from plant height and density. The ATTRA publication *Pasture, Rangeland, and Grazing Management* includes formulas and instructions for estimating forage yield and developing an appropriate stocking rate.

Plant Toxicity and Grazing-Related Disorders

Graziers must pay careful attention to the negative health effects that certain plants can cause in livestock. Plant toxicosis occurs either through the ingestion of (1) poisonous plants or (2) forage plants that contain toxic substances due to environmental or physiological conditions. Plant poisoning can be significantly reduced by proper grazing management. Poisonous plants contain resins, alkaloids, and/or organic acids that render them unpalatable. If the pasture contains enough good forage, there is little reason for the animals to select bad-tasting plants. The ATTRA publication *Pasture, Rangeland, and Grazing Management* contains detailed information on plant toxicity and grazing-related disorders. In addition, your local Cooperative Extension office has information on poisonous plants in your area.

Grazing management is the regulation of the grazing process by humans through the manipulation of animals to meet specific, predetermined production goals.

- forage density
- after-grazing plant residue
- paddock rest time
- range condition and trend,
- animal body condition, health, and physiological stage
- grazing systems, including stocking rate and stock density
- and pasture and rangeland monitoring

These considerations are covered extensively in other ATTRA publications. For more information on grazing management see the ATTRA publications *Pasture, Rangeland, and Grazing Management; Rotational Grazing;* and *Paddock Design, Fencing, and Water Systems for Controlled Grazing.*



Photo courtesy of USDA, NRCS.

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Resources

Some of the resources listed below are Web-based documents and programs. If you do not have Internet access at home, contact your local public library. Many libraries have free Internet computers and training for their patrons.

General Ruminant Nutrition and Body Condition Score

Beef Cattle Nutrition Workbook, EM 8883-E. December 2004. Oregon State University Extension. <http://oregonstate.edu/Dept/EOARC/about/home/scientists/documents/DWB26.pdf>

Beginner's Guide to Body Condition Scoring: A Tool for Dairy Herd Management. Penn State University. www.das.psu.edu/dairynutrition/documents/363eng.pdf

Body Condition Scoring Beef Cows. Virginia Cooperative Extension. www.ext.vt.edu/pubs/beef/400-795/400-795.html

Body Condition Scoring of Sheep. Oregon State University. <http://extension.oregonstate.edu/catalog/pdf/ec/ec1433.pdf>

Church, D.C., (editor). 1993. The Ruminant Animal: Digestive Physiology and Nutrition. Waveland Press. ISBN: 0881337404. (Order online from www.amazon.com).

Langston University, Agricultural Research and Extension Programs. Goat Nutrient Requirement Calculators. www2.luresext.edu/goats/research/nutr_calc.htm
Nutrient Requirements for Goats
www2.luresext.edu/GOATS/research/nutreqgoats.html

Maryland Small Ruminant Page: Feeding and Nutrition. www.sheepandgoat.com/feed.html

Penn State University Dairy Cattle Nutrition
www.das.psu.edu/dairynutrition

University of Wisconsin-Madison, Dairy Science Department. Dairy Nutrition. www.wisc.edu/dysci/wwex/nutritn/nutritn.htm

Nutritional Requirements of Cattle, Sheep, and Goats

National Research Council. 1996. Nutrient Requirements of Beef Cattle: Seventh Revised Edition, Update 2000. National Academy Press, Washington, DC.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle: Seventh Revised Edition. National Academy Press, Washington, DC.

National Research Council. 1981. Nutrient Requirements of Goats. National Academy Press, Washington, DC.

National Research Council. 1985. Nutrient Requirements of Sheep, Sixth Revised Edition. National Academy Press, Washington, DC.

The preceding four resources can be downloaded as PDF files for free from the National Academies Press website at www.nap.edu or by contacting:

*The National Academies Press
500 Fifth Street NW
Lockbox 285
Washington, DC 20055
(888) 624-8373*

Estimating Forage Production

Barnhart, Stephen. 1998. Estimating Available Pasture Forage, PM 1758. Iowa State University Extension. www.extension.iastate.edu/Publications

Brence, L. and R. Sheley, 1997. Determining Forage Production and Stocking Rates: A Clipping Procedure for Rangelands, MT199704AG. Montana State University Extension. www.montana.edu/wwwpub/pubs/mt9704.html

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Grazing Management

Blanchet, K., H. Moechnig, and J. DeJong-Hughes. 2003. Grazing Systems Planning Guide. St. Paul, MN: University of Minnesota Extension Service Distribution Center. www.extension.umn.edu/distribution/livestocksystems/DI7606.html

McCrary, Lisa and Charlotte Bedet. 2007. Organic Livestock and Grazing Resources, Updated January

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Ohlenbusch, P.D., and S.L. Watson. 1994. Stocking Rate and Grazing Management, MF-1118. Kansas State University Extension. www.oznet.ksu.edu/library/crpsl2/MF1118.pdf

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USDA. 2003. National Range and Pasture Handbook. Fort Worth: Natural Resources Conservation Service, Grazing Lands Technology Institute. www.glti.nrcs.usda.gov/technical/publications/nrph.html

The Stockman Grass Farmer Magazine
234 W School Street
Ridgeland, MS 39157
800-748-9808

www.stockmangrassfarmer.net/index.html

A publication devoted to the art and science of grassland agriculture.

Notes

Ruminant Nutrition for Graziers

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