



NUTRITION and FEEDING



Essential Nutrients for Beef Cattle

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Overview

Proper nutrition is crucial for health, productivity and profitability for any livestock enterprise. Nutrients are feed components whose requirements for livestock vary depending on factors such as age, weight, growth rate, reproductive status and environmental conditions. Cattle are ruminant animals that have a four-compartment stomach in which microbial fermentation allows for efficient use of nutrients stored even in the most fibrous feeds such as pasture, hay and baleage (haylage). This section outlines the nutrients and their roles in beef cattle nutrition, aiding in the evaluation of feed analyses and decision-making by Louisiana beef ranchers.

Essential Nutrients for Beef Cattle Diets

1. Water

Importance: Water is the most vital nutrient. It facilitates digestion, nutrient transport, waste elimination and temperature regulation, among other functions.

Requirements: Water consumption varies by temperature, diet and physiological state. Louisiana's elevated temperature and humidity significantly increase water intake (refer to LSU AgCenter Pub. 3933 for more details). Cattle consume around 1.5 gallons of water per 100 pounds of body weight daily. Overall water intake by beef cattle can range from 4 gallons to 8 gallons.

Sources and Quality: Water quality can influence consumption. Several contaminants can be a risk to animal health and nutrition. Those contaminants can be determined in analyses that include:

- **Temperature:** Cattle prefer to ingest water at 40 F to 65 F.
- **Total dissolved solids (TDS):** This is an indicator of water salinity. A TDS of 1,000 ppm (parts per million) is considered acceptable for cattle.
- **Bacteria and blue-green algae:** Absence of microbes alone does not mean the water is safe for drinking because some microbes may produce toxins.
- **pH:** Should be between 6.0 and 9.0.
- **Mineral content:** Some minerals like sulfates can reduce intake, nitrates can be directly toxic to cattle, and other minerals can interact and reduce the utilization of other minerals (excessive iron for example).
- **Hardness:** A water sample is considered "hard" when a combination of calcium, manganese, iron and magnesium cations is elevated. Cattle may readily consume hard water, but the excessive content of those ions can limit

the utilization of other minerals such as copper, zinc and selenium.

Water deficiency can limit productivity and even lead to fatality quicker than the deficiency of any other nutrient (carbohydrates, protein, fats, minerals or vitamins). Plentiful availability of water of adequate quality is key for any beef operation.

2. Energy

Importance: Energy refers to the capacity of nutrients (like carbohydrates, lipids and proteins) to fuel physiological processes necessary for the body's basic functions (maintenance), growth, reproduction and lactation. Because the bulk of a diet is used as an energy source by the body, energy tends to be a main driver of feed intake.

Requirements: Energy needs depend on the stage of production. Nursing calves and lactating cattle have higher energy needs. Energy is estimated more often in terms of total digestible nutrients (TDN), given in % of the dry matter, but can also be expressed as net energy (NE), given in megacalories per pound or Mcal/lb.

Sources and Quality: Technically, energy is not a nutrient, but it is derived from nutrients, namely carbohydrates and fats. Proteins can also be used as energy sources but are expensive and less efficiently used for energy by cattle. Energy sources make up the bulk of the diet, given the amount of nutrients needed to fulfill an animal's energy requirements.

- **Carbohydrates:** Carbohydrates are the main source of energy for ruminants. Carbohydrates in feeds have roles in seed energy storage (starch and free sugars) or as structural components of the plants (fibers).

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» **Starch:** Storage carbohydrate found in seeds, particularly cereal grains such as corn, wheat, sorghum. It is quickly fermented by the rumen microbes releasing volatile fatty acids (VFA) that can be absorbed through the gastrointestinal wall and utilized as source of energy by cattle. Starch fermented in the rumen produces acetate > propionate > butyrate, with lower acetate to propionate among VFAs. Its content can be estimated as starch content (% starch), or more commonly as nitrogen-free extract (% NFE), nonstructural carbohydrates (% NSC), nonfiber carbohydrates (NFC), and more recently as non-NDF carbohydrates (non-NDF). Overfeeding starch to cattle can cause acid accumulation in the rumen (acidosis), reduce productivity or even result in animal losses. This condition is a higher risk for feedlot operations or grazing animals receiving high amount of concentrate without gradual adaptation.

» **Fibers:** Structural component of plants, including pasture, hay and silage/baleage. Rumen microbes can ferment fiber components and release VFAs, but it takes longer than starch fermentation. Fermentation process of fiber components (cellulose and hemicellulose) also yields acetate > propionate > butyrate, but with greater acetate to propionate ratio. Although it is not an essential nutrient, fiber is necessary to maintain a healthy environment in cattle forestomachs. Some laboratories report fibers as crude fiber (% CF), but that analysis methodology is being replaced by the more practical detergent fiber methodology:

◊ **Neutral detergent fiber (% NDF):** This analysis includes most fiber components (cellulose, hemicellulose and lignin). It represents the bulk of the diet and therefore correlates with rumen fill. The NDF content of a forage or a diet can be indicative of intake, meaning that as the NDF of a forage or a diet increases, the rumen tends to fill up quicker, thereby limiting intake. This is particularly important for cattle on diets where pasture, hay and/or baleage represent the majority of the feeds. On the other hand, ruminants evolved to ingest and digest fiber thanks to microbes present in their forestomach and a certain amount of fiber is required for proper microbial and rumen activities. This is critical for cattle in feedlots: Special diet formulation is warranted, and the supplementation of buffers may be necessary.

◊ **Acid detergent fiber (% ADF):** This analysis represents the less digestible and indigestible fractions (cellulose and lignin) of a forage or diet and can be a good indicator of digestibility and energy content, especially in forages. Lower concentration is better.

Fiber content (NDF and ADF) tend to increase with maturity (rapidly after seeding) in any forage, and are, on average, higher in Louisiana warm-season forages (for example bermudagrass and bahiagrass) when compared with temperate forages (for example, annual ryegrass) at similar maturity.

• **Lipids:** Lipids are energy-dense nutrients, containing on average, 2.25 times the amount of energy in proteins or carbohydrates. Cattle diets usually contain lesser amounts of lipids because most cattle feeds have low levels of lipids (1% to 4%). Rumen microbial activity can be limited when cattle are fed levels of dietary lipids higher than those mentioned above. Most lipids in a diet are comprised of fats and oils, and their building blocks are called fatty acids. Dietary lipids are estimated as ether extract (% EE), sometimes referred to as crude fat. Some laboratories determine total fatty acids (% dry matter) and may also specify the content of individual fatty acids (% of total fatty acids). Lipid-rich feeds (fats such as tallow and oilseeds such as soybean and cottonseed) can be supplemented to the diets of ruminants to boost energy content, to improve palatability, to improve animal health, and to minimize the impact of heat stress. Excess fat (e.g., more than 5% to 6% in the total diet consumed) supplementation should be avoided, because it can have a negative impact on fiber digestion in the rumen and potentially reduce intake.

3. Proteins

Importance: Proteins make up much of the body's molecules. The structure of proteins is composed of 20 amino acids (AA) in varying proportions, AA content and position in the structure of the protein. An AA presence in a specific position in the polymer can dictate the protein's structure and function. Proteins functions in the body include transportation, cell and tissue structures, muscle contraction and gene expression, among many others. Proteins are essential for muscle development, milk production and overall body growth.

Requirements: From a nutritional standpoint, the similarity between the animal's AA requirements and the composition of AA that are absorbed from the small intestine is referred to as protein quality. In the case of cattle, rumen fermentation plays a key role in protein quality and utilization. A portion of feed protein and nonprotein nitrogen (NPN such as urea, biuret, ammonia) are fermented by rumen microbes into peptides (short polymers of amino acids), amino acids and ammonia. Those components can be converted into microbial proteins if sufficient energy is also made available in the rumen at a timely rate. Microbial protein synthesis can vary based on factors such as the quality of the diet, rumen conditions and the type of feedstuffs used. The microbial protein produced by rumen microbes has great biological value and typically contains a balanced profile of amino acids, including most of the essential amino acids required by ruminants. The fraction of the protein in feeds that undergoes microbial digestion is called rumen degradable protein (RDP). Rumen microbes also have nutrient requirements to support microbial population. Rumen microbes need a minimum dietary protein of 7% crude protein in the dry matter to be able to digest dietary fiber properly. In most dietary conditions, 60% to 80% of the proteins that reaches the small intestine in ruminants are microbial proteins.

The remaining portion of the dietary protein that is not digested in the rumen is deemed rumen undegradable protein (RUP). In diets based on high-quality forages, microbial protein can supply the needs of most beef cattle categories and rely minimally on RUP. The RUP fraction may be digested in the small intestine and utilized by the ruminant, and its quality (amino acid composition) plays a significant role. Overall, protein needs vary with age and production

stage. Young calves in initial stages of growth and high-producing dairy cows need higher protein levels. For those animal categories, special attention to RUP is warranted.

Sources and Quality: Protein analysis is reported as crude protein (% CP). Forages, grains, oilseed meals (such as soybean meal, cottonseed meal, dry distillers' grains – DDGS) and protein supplements (protein tubs). Most protein in forages are rumen degradable, therefore high-quality forages can supply plentiful protein for growing and mature beef cattle. Rumen available energy also plays a role in the synthesis of microbial proteins. Therefore, it is important to feed protein supplements when using poor-quality forages (high NDF and ADF) with low energy content and low protein content. Lick tubes, range cubes, protein blocks and liquid supplements often contain urea (or other sources of NPN) and molasses (energy source). It is important to ascertain that enough energy is available and NPN toxicity is avoided. Sufficient sulfur (S) is also warranted when supplementing NPN to ensure that rumen microbes can produce some specific sulfur-containing AA's (methionine and cysteine), optimizing microbial protein production.

4. Minerals

Importance: Minerals are required for many essential roles in beef cattle supporting overall health, optimum growth and reproduction. Some of the most crucial functions include:

- Calcium (Ca) is crucial for bone development, muscle contraction and milk.
- Phosphorus (P) is vital for bone structure, energy metabolism, and RNA and DNA structures.
- Sodium (Na), chlorine (Cl) and potassium (K) are important for maintaining water balance, nerve function and enzymatic activity.
- Magnesium (Mg) is required for bone structure, enzyme function and muscle contractions.
- Sulfur (S) is necessary for protein synthesis, and enzyme and vitamin activities.
- Iron (Fe) is present in red blood cells aiding in the transport of oxygen and participates in energy metabolism.
- Copper (Cu), manganese (Mn) and zinc (Zn) are important for enzyme systems, skin health and immune function.
- Selenium (Se) is a component of antioxidant molecules in the body.
- Iodine (I) is essential for the regulation of the basal metabolic rate.
- Cobalt (Co) is necessary for the synthesis of vitamin B₁₂ by microbes in the rumen.

Requirements: Minerals are required in minute amounts compared with water, energy and protein. Based on the amounts required by the animals, minerals are often classified as macrominerals or microminerals (or trace minerals). Macrominerals include Ca, P, K, Na, Cl, Mg and S, while microminerals most routinely supplemented include Fe, Zn, Cu, Mn, I and Se. Mineral deficiency can be associated with specific and with unspecific symptoms in cattle. Ca deficiency can lead to bone malformation in calves (rickets) and mature cattle (osteomalacia), while P deficiency may decrease calf weight gain. Louisiana warm summers increase losses of Na and K through sweat and decrease feed intake, thus

supplementation may need to be adjusted depending on the season. The macrominerals most deficient in forages in Louisiana are Na and Mg, and the trace minerals are Cu and Zn, and in some regions, Se.

Sources and Quality: Minerals may be required depending on animals, plants, soils and environment and their interactions. Those include animal category and level of production, mineral status in the body, diet content and bioavailability, mineral and vitamin interactions, forage species, and soil fertility, among several others. Bioavailability refers to the fraction of a mineral that may be utilized by the animal. Mineral bioavailability varies widely, particularly in forages. Mineral bioavailability may be enhanced or may require the presence of certain vitamins (for example, iron and vitamin C). Similarly, certain minerals may enhance the absorption of other minerals, but more often, excess supplementation of some minerals may decrease the utilization of others. For instance, P, Zn, Mn and Cu can decrease Fe absorption while higher dietary Zn may enhance Cu absorption. It is also important to note that overfeeding minerals is not only wasteful and a potential environmental risk, but it can also be toxic to the animals. Minerals may be found associated with other feed components such as proteins, carbohydrates and vitamins. Microminerals associated with those organic compounds tend to be slightly better utilized by cattle than when inorganic supplements are offered. Mineral concentration in feeds (forages and grains) vary widely and mineral content should be determined by laboratory analyses whenever feasible. Mineral analyses have to be requested for specific elements, but some laboratories offer packages that include multiple mineral elements for convenience. Contents of macrominerals are usually expressed in percentage (%) and microminerals in parts per million (ppm). Some commercial supplements include organic mineral supplements, but their cost-effectiveness must be carefully evaluated. The commercial minerals are often balanced for regional deficiencies, but depending on the situation may need to be fine-tuned for individual farm conditions.

5. Vitamins

Importance: Vitamins are nutrients required in small quantities that have essential roles in beef cattle. Those nutrients can be divided into fat-soluble vitamins (A, D, E and K), and water-soluble vitamins (B-complex vitamins including thiamin, B₁; riboflavin, B₂; niacin, B₃; pantothenic acid, B₅; pyridoxine, B₆; biotin, B₇; folic acid, B₉; and vitamin B₁₂; as well as vitamin C). Vitamin deficiencies are associated with specific syndromes, such as pellagra in pigs (niacin deficiency), rickets in calves and osteomalacia in mature cattle (vitamin D deficiency), and nutritional muscular dystrophy in lambs (vitamin E deficiency). The main functions of the vitamins most commonly supplemented include:

- **Vitamin A:** Important for vision, immune function and reproduction. Sources include green forages and certain supplements, but sun-drying and storage may decrease its contents in hay and baleage.
- **Vitamin D:** Essential for calcium and phosphorus metabolism. Synthesized in the skin with sunlight exposure or supplemented in feed.
- **Vitamin E:** Acts as an antioxidant and supports immune function. Found in green forages and some grains, such as peanuts, soybeans and sunflower seeds.

Requirements: Water-soluble vitamins and vitamin K are synthesized in the rumen and intestine of cattle and rarely need to be supplemented for beef cattle. Vitamin D is also synthesized in the skin exposed to UV-light from the sun, thus grazing cattle in Louisiana are rarely deficient in vitamin D. Vitamin A deficiency can result in vision loss (particularly in the dark/night), poor conception rates and abortion, and poor fetal and calf development. The deficiency of vitamin E can result in muscular dystrophy that can be partially reversed with the supplementation of Se. Other signs of vitamin E deficiency in cattle include retained placenta, metritis, cystic ovaries and infertility.

Sources and Quality: Grazing cattle are rarely subject to vitamin deficiencies; however, most vitamins have little to no storage in the body. Supplementation of vitamins A and E is warranted when cattle are feeding on crop residues such as corn stalks, and stemmy or weathered hay (subject to UV light, heat and rain/humidity) and have little access to fresh pastures. Vitamin premixes may be added to mineral supplements or vitamin injection should be indicated in case of cattle already showing clinical signs of deficiency. For more information on minerals and vitamins, visit the section Mineral and Vitamin Supplementation in the Nutrition and Feeding Management chapter.

Nutrient Availability to the Beef Herd – Feeding Systems

Pasture: The primary source of nutrients for cow-calf operations in Louisiana are pastures. Quality and quantity depend on forage type, maturity and management practices. Louisiana is blessed with two forage growing seasons: warm-season forages (typically bermudagrass and bahiagrass) and cool-season forages (usually annual ryegrass and clover). Supplementation is necessary to meet energy and protein needs, especially during periods of low forage quantity and/or quality. Pasture availability varies throughout the year, but it is critical during the transition from cool-season to warm-season pastures in the late spring/early summer when cool-season forages reach maturity, and vice-versa, in the late summer/fall, when warm-season forage stands decline. Supplementation is necessary to fill those nutritional gaps. Nutrient shortages typically occur during those periods of seasonal transition and could be minimized by offering preserved forages

(hay and baleage/haylage) or grain/concentrate supplements. Table 1 (on page 5) describes a typical nutrient profile of Louisiana forages. Commercial supplements, mineral blocks and specific feed additives can be used, but regular monitoring of body condition, weight gain and overall health is essential.

Preconditioning Programs: Cattle raised in Louisiana are often sold at weaning as stocker calves or later for finishing at feedlots elsewhere. Preconditioning programs often involve feed bunk training, feed transitioning and health programs. They are designed to prepare growing cattle for the next stage in beef production systems, thus improving the adaptation process and usually increasing the sale value to producers. Close attention should be paid to balancing rations with adequate fiber to prevent digestive disorders.

Summary

Meeting the nutrient requirements of beef cattle through a balanced diet is essential for their health, productivity and the economic success of beef production operations. Providing adequate water, energy, protein, minerals and vitamins tailored to the specific needs of the cattle ensures optimal growth and

reproductive performance and is more economical. Nutritional plans should be designed based on performance, forage availability and changing requirements throughout the production cycle. Consulting with a livestock nutritionist can optimize feeding programs and improve cattle performance.

References

- National Academies of Sciences, Engineering, and Medicine. 2016. Nutrient Requirements of Beef Cattle, Eighth Revised Edition. Washington, DC: The National Academies Press. doi: 10.17226/19014.
- Edwards, A. K., and M. Ferreira. 2024. Preparing Beef Cattle Operations for Drought. LSU AgCenter Fact Sheet. <https://www.lsuagcenter.com/articles/page1719950002833>.

Table 1. Composition (average $\pm$ standard deviation) of typical Louisiana forages.

Composition ¹								
Forages	DM	CP	NDF	ADF	TDN ²	Ca	P	K
	%	% of DM						
Bahia grass								
Pasture	25.5±2.5	10.1±2.1	69.9±9.3	42.7±3.7	49.4±3.4	0.31±.12	0.21±0.04	1.42±0.41
Baleage	51.4±15.6	8.95±2.6	71.5±10.6	42.7±3.5	49.3±2.8	0.34±0.12	0.21±0.06	1.22±0.48
Hay	90.8±0.64	7.76±2.2	67.5±11.8	42.1±3.2	49.9±3.2	0.30±0.13	0.20±0.06	1.15±0.46
Bermudagrass								
Pasture	23.8±5.7	14.9±4.4	65.5±8.5	35.8±5.1	56.4±4.4	0.40±0.17	0.30±0.06	1.93±0.51
Baleage	54.7±15.2	10.4±3.5	70.6±11.1	39.0±4.0	53.2±3.7	0.36±0.11	0.24±0.06	1.58±0.69
Hay	90.8±0.9	10.1±3.1	70.4±8.9	38.0±3.4	54.0±3.3	0.33±0.10	0.24±0.06	1.61±0.62
Clover								
Pasture	22.4±3.5	21.0±3.5	36.3±11.0	30.5±7.5	66.1±8.0	0.88±NA	0.40±0.06	3.52±0.58
Hay	87.9±4.2	16.4±3.5	47.3±8.7	34.5±5.2	61.7±5.6	1.03±0.10	0.22±0.05	1.75±0.75
Ryegrass								
Pasture	19.0±5.9	17.5±5.4	51.5±14.9	31.1±8.1	67.4±8.9	0.52±0.17	0.30±0.10	3.04±1.43
Baleage	48.4±12.1	13.8±4.1	56.5±8.1	35.7±5.5	62.4±5.5	0.55±0.17	0.28±0.07	2.32±1.01
Hay	90.6±2.6	11.6±4.7	65.7±8.9	38.2±5.9	59.4±6.6	0.41±0.13	0.26±0.09	1.93±0.82

¹Composition: DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; TDN = total digestible nutrients; Ca = calcium; P = phosphorus.

²TDN is estimated by equations based on ADF content.

Disclaimer: Given the large variability, we recommend submitting feed samples for laboratory analyses to ensure an adequate feeding program.