Nutrition & Health: Beef

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One daunting task for writing about dietary nutrient allowances for beef cattle is related to the vast number of production systems used. Beef production varies widely from grazing systems utilizing native pastures or improved pastures to confinement feeding utilizing high-concentrate diets.

Therefore, this article will present a broad overview of beef cattle nutrition based on scientific literature and on National Research Council (NRC) 1996 recommendations.

Digestive physiology

There are several unique aspects of the digestive tract of beef cattle that deserve attention. Starting at the head, in the mouth, beef cattle have no upper incisors. When grazing, beef cattle will wrap their tongue around forage and with the muscles in the back of their head, use the bottom incisors to shear off the plant particles.

Another important aspect is the copious quantity of saliva that beef cattle produce. Besides aiding in moistening the feed bolus for swallowing and aiding in taste, saliva is a source of recycled nutrients for ruminants, particularly nitrogen (urea) and minerals (e.g., phosphorus, magnesium, sodium, potassium and chloride). Saliva is also important in buffering the rumen. The amount of saliva produced can be as much as 180 liters per day and is dependent on the diet consumed.

The esophagus is a hollow tube that allows the bolus to be transported to the next section of the gastrointestinal tract (GIT). Peristaltic actions in the esophagus are important to allow ruminants to regurgitate the feed bolus, remasticate and reswallow undigested material (rumination).

The time spent ruminating is dependent on diet with grazing cattle ruminating more than cattle consuming high-grain diets typical in feedlot settings. It has been estimated that beef cattle can ruminate up to 8 hours per day. In addition to regurgitation of undigested feedstuffs, the esophagus is important in eructation of gases produced during fermentation in the rumen.

When eructation is impaired and/or disrupted, bloat can occur, which, if gone undetected, can result in death. Two types of bloat can occur in ruminants. One type is free-gas bloat, which occurs secondary to factors that prevent eructation. The second type of bloat is frothy, where froth produced by fermentation prevents eructation of gases. Feeding the ionophore monensin has been shown to reduce bloat on wheat pasture and may be effective in reducing feedlot bloat either by reducing gas production or by altering the feeding patterns of the cattle.

The reticulum (honeycomb) is the next section of the GIT, and this section is responsible for regulating digesta flow into and out of the rumen. It is in this section where sharp objects (e.g., nails and wires) that may be consumed by the animals can accumulate and, over time, penetrate the reticulum lining, allowing rumen contents to leak into the peritoneal cavity causing "hardware disease." Dairy producers often place a magnet in the rumen to attract the objects.

The rumen of the animal is virtually a fermentation vat. Ruminal fluid contains anywhere from 30 billion to 50 billion microorganisms (bacteria and protozoa) per milliliter of ruminal fluid. Just like rumination, the microbial population present in the rumen is related to diet consumed. The various types of bacteria present is beyond the scope of the article, but with forage diets, the primary bacterial species will be cellulolytic and hemicellulolytic, whereas with grain-based diets, amylolytic bacteria will be in greater concentrations. In addition, proteolytic and lipolytic bacteria are present in the rumen and are responsible for digesting protein and lipids, respectively.

The omasum (many folds) is responsible for regulating flow to the abomasum and is a site of water absorption. The next section of the beef cattle digestive tract is the true stomach, referred to as the abomasum. It is similar in function to the stomach of monogastric animals such as the pig.

The lower digestive tract is virtually identical to other species; however, the duodenum is unique in that it secretes greater quantities of nucleases and less pancreatic amylase than other species of animals. The greater amounts of nucleases is related to breakdown of bacterial protein and less amylases is related to decreased amounts of starch entering the small intestine versus other species.

The large intestine in beef cattle is proportionally larger than omnivorous species and proportionally smaller than non-ruminant herbivores such as horses and rabbits. With high-concentrate diets, fiber digestion may be shifted to the large intestine due to decreased fiber digestion in the rumen as a result of decreased ruminal pH. However, it is not known whether the large intestine can fully compensate for the increased fiber load.

1. Nutrient requirements for growing and finishing beef cattle[a,b,c]

	Bodyweight, lb.					
	440	555	660	770	880	990
	Maintenance requirement per day					
NEm, Mcal	4.1	4.84	5.55	6.23	6.89	7.52
Metabolizable protein, g	202	239	274	307	340	371
Calcium, g	6	8	9	11	12	14
Phosphorus, g	5	6	7	8	10	11
Average daily gain, lb.	**Net energy for gain, Mcal per day**					
1.1	1.27	1.50	1.72	1.93	2.14	2.33
2.2	2.72	3.21	3.68	4.13	4.57	4.90
3.3	4.24	5.01	5.74	6.45	7.13	7.79
4.4	5.81	6.87	7.88	8.84	9.77	10.68
5.5	7.42	8.78	10.06	11.29	12.48	13.64
	Metabolizable protein required for gain, lb. per day					
1.1	0.34	0.34	0.35	0.35	0.32	0.29
2.2	0.66	0.66	0.67	0.66	0.60	0.54
3.3	0.97	0.97	0.97	0.95	0.86	0.77
4.4	1.27	1.27	1.27	1.24	1.11	0.99
5.5	1.57	1.57	1.56	1.51	1.36	1.20
	Calcium required for gain, g per day					
1.1	14	13	12	11	10	9
2.2	27	25	23	21	19	17
3.3	39	36	33	30	27	25
4.4	52	47	43	39	35	32
5.5	64	59	53	48	43	38
	Phosphorus required for gain, g per day					
1.1	6	5	5	4	4	4
2.2	11	10	9	8	8	7
3.3	16	15	13	12	11	10
4.4	21	19	18	16	14	13
5.5	26	24	22	19	17	15

[a]Adapted from 7th rev. ed., Nutrient Requirements of Beef Cattle, 1996, National Research Council.

[b]Crystalline vitamin A should be added at a level of 1,100 IU/lb. DM.

[c]Weight of animal at small marbling, 1,172 lb.; ADG range, 1.1 to 5.5 lb. per day; breed, Angus.

Ruminal development

During the first few months of age, a calf is anatomically ruminant but functionally monogastric. Anatomically, a suckling calf has the ability to bypass the reticulorumen and dump milk directly into the abomasum for digestion via the esophageal groove. This is particularly helpful because a calf is not born with a microbial population in its forestomach and must rely on its own digestive enzymes (secreted in the abomasum and intestine) for milk digestion. Eventually, as the calf commingles with other animals and begins to consume feedstuffs, the rumen becomes inoculated with the microbes needed for fermentation and volatile fatty acid (VFA) production. VFAs are particularly important in developing the rumen wall (increasing rumen surface area), which in turn improves maximal VFA absorption; although hay can stimulate rumen development, starter diets high in cereal grains (> 50% as fed) have proven more effective for rumen wall development in Holstein calves.

Ruminal fermentation

The first step in ruminal fermentation occurs in the mouth with the animals reducing the plant particle size with the molars. In addition, rumination is responsible for further reduction in particle size. These actions serve to increase the surface area of plant particle which allow bacteria to attach to plant particle.

A symbiotic relationship exists between the host animal and the bacterial species. The host animal supplies a warm, moist environment with substrates introduced and removal of end products of ruminal fermentation. This allows the microbes to break down the fibrous material and produce end products that the animal can utilize.

The microbes will ferment the carbohydrate portion of plants and produce VFAs. In addition, gases are produced including carbon dioxide and methane. The animals can utilize VFAs for energy with an estimated 70-80% of the caloric requirements met by VFAs. In addition, other components are fermented in the rumen resulting in production of microbial protein and B vitamins.

Nutrients

Although beef cattle require the same nutrients as other species of animals, dietary concentrations may differ because of the unique ability of ruminants to ferment dietary components.

Water

Without a doubt, water is a primary nutrient for all species. Beef cattle should be provided with an adequate source of water. If feed intake diminishes drastically for no apparent reason, the first thing producers should check is the water source. Another factor that will affect water requirements is environmental temperature.

Carbohydrates

Carbohydrates are important for all aspects of beef cattle nutrition. For grazing ruminants, forages comprise the majority of the diet. Depending on location, for cattle grazing native ranges, forages consumed include forbs, shrubs and grasses, whereas cattle in other regions of the country will rely heavily on introduced forages including brome grass, timothy, ryegrass, etc. For finishing beef cattle, carbohydrates are a major portion of the diet.

The microbial population produces the cellulases and hemicellulases to break down the structural carbohydrates in the plants. Starches and sugars are also extensively fermented by microbial population in the rumen. The primary VFAs produced are acetate, propionate and butyrate. Acetate is produced in the highest proportions, followed by propionate and butyrate. Adding cereal grains will increase the amount of propionate produced, albeit acetate will still be in the greatest proportion.

Protein

Bacterial protein synthesis may account for as much as 50% of the protein and amino acids needed by cattle. Beef cattle can metabolize dietary protein, as well as non-protein nitrogen sources such as urea. Ruminants have the ability to "upregulate" a low-quality protein. Ruminants can take a nitrogen source such as urea and turn it into a moderate-quality bacterial protein. Furthermore, it is generally recognized that ruminants "down-regulate" high-quality protein sources. Down-regulation would be taking a high-quality protein and turning it into a moderate-quality bacterial protein.

With the 1996 NRC, protein requirements for beef cattle were based on metabolizable protein rather than formulating on crude protein requirements as with previous publications. This method divides protein requirements into animal and microbial components. Significant progress was made in evaluating protein requirements with the 1996 NRC publication; however, complete implementation of the publication has not been accomplished.

It is generally recognized that the metabolizable protein system better describes requirements of beef cattle; however, formulation on total crude protein continues to be practiced. Crude protein concentrations used by consulting feedlot nutritionists ranges from 12.5% to 14.0% (mean 13.34%; mode 13.5%) with urea concentrations in the finishing diet of 0-2.0% (mean 1.01%; mode 1.2%; Vasconcelos and Galyean, 2007; J. Anim Sci. 85:2772-2781). In addition, only 9 (31.03%) out of 20 (68.97%) nutritionists responding to the questionnaire reported formulating based on degradable intake protein (DIP).

2. Nutrient requirements for growing bulls[a,b,c]

	Bodyweight, lb.					
	660	880	1,100	1,320	1,540	1,760
	Maintenance requirement per day					
NEm, Mcal	6.38	7.92	9.36	10.73	12.05	13.32
Metabolizable protein, g	274	340	402	461	517	572
Calcium, g	9	12	15	19	22	25
Phosphorus, g	7	10	12	14	17	19
Average daily gain, lb.	Net energy for gain, Mcal per day					
1.1	1.72	2.13	2.52	2.80	3.25	3.59
2.2	3.68	4.56	5.30	6.18	6.94	7.67
3.3	5.74	7.12	8.42	9.65	10.83	11.97
4.4	7.87	9.76	11.54	13.23	14.85	16.41
5.5	10.05	12.47	14.74	16.90	18.97	20.97
	Metabolizable protein required for gain, lb. per day					
1.1	0.35	0.32	0.27	0.22	0.17	0.13
2.2	0.67	0.60	0.49	0.39	0.29	0.19
3.3	0.97	0.86	0.69	0.53	0.37	0.22
4.4	1.27	1.11	0.88	0.66	0.44	0.24
5.5	1.56	1.36	1.06	0.77	0.50	0.24
	Calcium required for gain, g per day					
1.1	12	10	9	7	6	4
2.2	23	19	16	12	9	6
3.3	33	27	22	17	12	7
4.4	43	35	28	21	14	8
5.5	53	43	34	25	16	8
	Phosphorus required for gain, g per day					
1.1	5	4	3	3	2	2
2.2	9	8	6	5	4	2
3.3	13	11	9	7	5	3
4.4	18	14	11	8	6	3
5.5	22	17	14	10	6	3

[a]Adapted from 7th rev. ed., Nutrient Requirements of Beef Cattle, 1996, National Research Council.

[b]Crystalline vitamin A should be added at a level of 1,100 IU/lb. DM.

[c]Weight at maturity, 1,958 lb.; ADG range, 1.1-5.5 lb. per day; breed, Angus.

Energy

Although not a nutrient per se, it is important to discuss energy requirement of beef cattle. Energy is a term used to define the capacity to do work. In the U.S., the calorie, kilocalorie (kcal) and mega calories (mcal) are the common terms used in nutrition. Gross energy (GE) is the amount of heat produced when a feedstuff is completely oxidized using a bomb calorimeter. Digestible energy (DE) is obtained by subtracting fecal energy from GE consumed and is the amount of energy apparently absorbed from a feed. Metabolizable energy (ME) is determined by subtracting urinary and combustible gas loss from DE. Net energy (NE) is determined by subtracting energy losses from rumen fermentation and tissue metabolism from ME. Net energy will predict the amount of energy available for maintenance and production.

The maintenance energy requirements of beef cattle have been well established as 77 kcal/$W^{0.75}$ where weight (W) is bodyweight in kilograms.

Energy is considered first when balancing for beef cattle. Beef cattle will obtain a majority of their energy requirements from fermentation of carbohydrates. Lipids and proteins can also supply energy to cattle. As mentioned previously, 70-80% of the animal's caloric requirements will be met by VFAs.

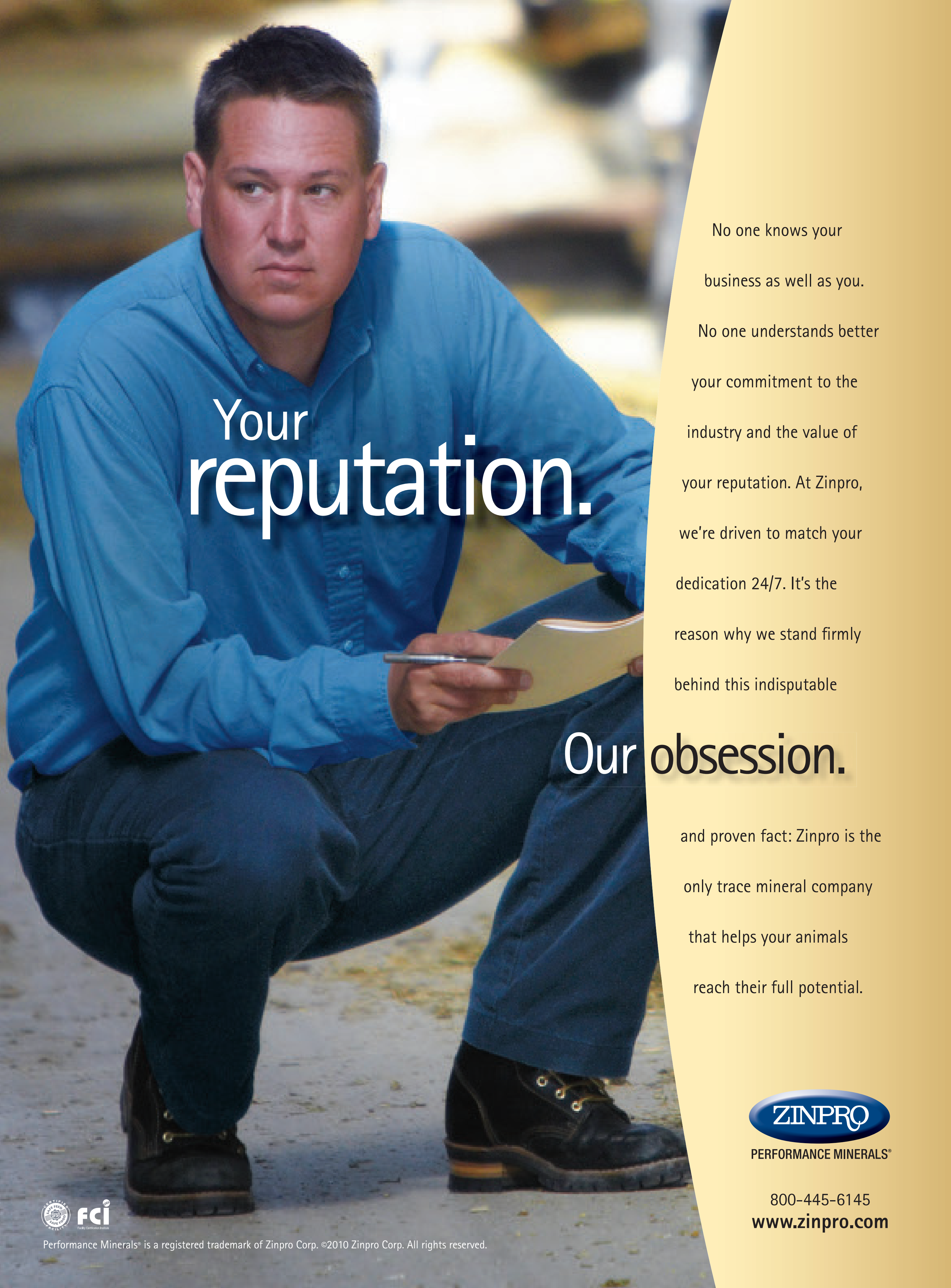
Minerals

Vitamin and mineral requirements for beef cattle remains unchanged from previous versions of this article. When formulating for newly received beef calves, trace mineral concentrations should be increased to account for decreased feed intake during the first few weeks after arrival. Table 6 has been included as a reference to compare formulations from consulting nutritionists vs. NRC recommendations. It appears that most macro and micro minerals are formulated slightly higher than NRC recommendations. Vasconcelos and Galyean (2007) suggested that over supplying nutrients may reflect the nutritionist's desire to "err on the side of caution."

The total mineral or ash content of the animal body represents a very small percentage of the total dry matter content. One author has expressed a bovine — on a fat-free basis, minus the contents of the gastrointestinal tract — as approximately 73% water, nearly 22% protein and 5.3% ash, plus small amounts of carbohydrates. Researchers at the University of Missouri analyzed the bodies of several bred animals and found mineral values of 1.3% calcium, 0.74% phosphorus, 0.16% sodium, 0.19% potassium, 0.11% chloride, 0.04% magnesium and 0.15% sulfur. Naturally, there was a whole host of other mineral elements in very minute quantities.

The 1996 NRC bulletin states that there are 17 mineral elements required by beef cattle. However, because of the nature of the diets of most beef animals, it is rare that more than 10-12 of such mineral elements are deficient. A brief discussion of those mineral elements that might be expected to be deficient in typical diets of cattle will follow.

Calcium. Several dietary ingredients supply near optimal levels of calcium, including the family of legume forages, plus several other types of forages — especially young, fast-growing plants. The cereal grains are quite low in calcium. Thus, foraging cattle might be expected to obtain nearly adequate calcium from their grazing, whereas feedlot cattle on very high-energy diets can be expected to obtain insufficient calcium from their diets. Calcium can be supplied so economically from ground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3. Nutrient requirements for pregnant replacement heifers[a,b,c]

	Months since conception								
	1	2	3	4	5	6	7	8	9
NEm, Mcal per day									
Maintenance	5.98	6.14	6.30	6.46	6.61	6.77	6.92	7.07	7.23
Growth	2.29	2.36	2.42	2.48	2.54	2.59	2.65	2.71	2.77
Pregnancy	0.03	0.07	0.16	0.32	0.64	1.18	2.08	3.44	5.37
Total	8.30	8.57	8.88	8.26	8.79	10.54	11.65	13.22	15.37
Metabolizable protein, g per day									
Maintenance	295	303	311	319	326	334	342	349	357
Growth	118	119	119	119	119	117	115	113	110
Pregnancy	2	4	7	18	27	50	88	151	251
Total	415	426	437	457	456	501	545	613	718
Calcium requirement, g per day									
Maintenance	10	11	11	11	12	12	12	13	13
Growth	9	9	9	8	8	8	8	8	8
Pregnancy	0	0	0	0	0	0	12	12	12
Total	19	20	20	19	20	20	32	33	33
Phosphorus requirement, g per day									
Maintenance	8	8	8	8	9	9	10	10	10
Growth	4	4	3	3	3	3	3	3	3
Pregnancy	0	0	0	0	0	0	7	7	7
Total	12	12	11	11	12	12	20	20	20
Average daily gain, lb. per day									
Growth	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Pregnancy	0.07	0.11	0.18	0.26	0.42	0.62	0.88	1.25	1.69
Total	0.92	0.96	1.03	1.11	1.27	1.47	1.73	2.10	2.54
Bodyweight, lb.									
Shrunk body	730	755	781	807	834	860	887	913	937
Gravid uterus mass	2.2	6.6	8.8	15.4	26.4	41.8	63.8	96.8	140.8
Total	732	761	790	822	850	902	951	1,010	1,078

[a]Adapted from 7th rev. ed., Nutrient Requirements of Beef Cattle, 1996, National Research Council.
[b]Crystalline vitamin A should be added at a level of 1,100 IU/lb. DM.
[c]Mature weight, 1,172 lb.; calf birth weight, 88 lb.; age at breeding, 15 months; breed, Angus.

limestone that there is no reason for a calcium deficiency except lack of attention to the cattle-feeding enterprise.

Phosphorus. Most grains are a pretty good source of phosphorus (0.25+%), with legume hays somewhat less (0.20%) and grass hays at 0.20%. Supplemental feed-grade phosphorus is more expensive than sources of calcium.

However, it is foolish to limit the intake of phosphorus below that recommended by NRC, because such a practice can decrease rate of gain, even though all the other nutrient requirements have been met. Supplemental phosphorus — as well as supplemental calcium — can be supplied by either dicalcium phosphate or steamed bone meal. Naturally, there are many other sources of dietary phosphorus, including phosphoric acid (utilized in liquid-supplements production) and defluorinated rock phosphate. It should be pointed out that there is no known benefit in feeding levels of phosphorus greater than those recommended by NRC. Furthermore, it is critical that phosphorus is not supplied to beef cattle in excessive quantities because unused phosphorus will interfere with calcium absorption and be excreted from the body, which may eventually find its way to surface water, thus having environmental implications.

Salt. Many people provide salt in a total mixed ration, whereas others may feed it on an *ad libitum* basis, alone or mixed with sources of calcium and phosphorus. Often, salt, as trace-mineralized salt, is utilized as a carrier for most of the so-called trace minerals. Because the feeding of selenium is controlled by the Food & Drug Administration, it would not fit too well into a free-choice salt situation. There is no benefit to overfeeding salt. Furthermore, because of the ease of feeding salt, and because salt is not expensive, there is no cause for a salt deficiency except poor management.

Potassium. Legumes are exceptionally good sources of potassium (alfalfa hay contains 1.5%); corn silage contains potassium at about the requirement for cattle (0.8%), and the cereal grains are deficient in potassium (0.3%). Therefore, cattle fed on very high-grain diets should have their total dietary potassium checked, probably requiring considerable supplementation. Optimal potassium level is related directly to optimal rates of gain so it is expensive to not feed adequate potassium.

Iodine. Supplemental iodine is needed by reproducing cattle, but there is little rationale to feeding iodine to growing and finishing cattle. A possible exception to this is that iodine compounds are utilized in alleviating the symptoms of footrot.

Selenium. In beef cattle, the supplementation of diets with selenium is restricted largely to reproducing animals, since the use of supplemental selenium for growing and finishing cattle, largely, has not shown a positive response. As indicated above, the addition of selenium to beef cattle diets is under the control of FDA and so is handled by feed manufacturers who have been given permission to make such additions. However, a new aspect of selenium supplementation has arisen. It has been demonstrated that lactating cattle given supplemental selenium in the form of a selenium-yeast compound utilized selenium more efficiently than those whose supplemental selenium was in either the selenite or selenate form. Since the range between optimal and toxic levels of selenium is narrow, possibly less of the selenium yeast source would be required.

Cobalt and copper. In certain areas of the U.S., especially parts of Florida and Michigan, the soil is so deficient in cobalt and copper that crops grown on such soils reflect the deficiencies. Both of these elements are identified with the production of red blood, and a deficiency of either will be reflected in anemic conditions. Both are supplied readily in manufactured feed and in trace-mineralized salt.

Magnesium. Grass tetany is the name given to a malady that seems to occur most often in cattle grazing lush pasture in early spring when the weather is especially cool. However, there have been reported clinical observations under other conditions. The feeding of 1-2 oz. of magnesium oxide per head, daily, seems to prevent grass tetany. However, magnesium oxide appears to not be palatable to cattle, so methods of masking its flavor, such as mixing it with a pound or two of corn, may be helpful. Magnesium can be suspended in free-choice liquid supplements, and grazing cattle seem to consume sufficient amounts of the mixture to prevent grass tetany.

Vitamins

Cattle out-of-doors, consuming green grass, were thought to be obtaining all the vitamins their bodies needed. It was proposed they could convert sufficient amounts of the beta-carotene contained in their green forage to meet their vitamin A requirement adequately; that the ultraviolet rays of the sun would convert fatty substances just under their hide to meet their vitamin D requirements adequately; that the marvelous microbes of the rumen should synthesize adequate levels of the B vitamins, plus vitamin K; and finally, there should be sufficient vitamin E in their diet to meet that requirement. There are exceptions to this supposition.

Thiamin (vitamin B1). Although cattle should be able to manufacture sufficient amounts of this vitamin by their rumen microbes, there are times — especially under feedlot conditions — when a relative B1 deficiency may exist. Under such a condition, a malady known as polio-encephalomalacia may occur, but only in limited numbers of cattle. This condition also is known as "circling disease," because afflicted cattle tend to walk aimlessly in circles. The condition seems to occur most on corn silage diets and is caused by an enzyme called thiaminase, meaning it is an organism that blocks the normal functioning of thiamin. A sudden fall to the ground, followed by a scissoring action with the legs, then death, characterizes this condition. An intramuscular injection of vitamin B1 will give almost instantaneous relief, and a calf will jump to its feet and start acting like the rest of the calves in the pen very shortly. As with coproducts, high concentrations of sulfur in the feed or water can

4. Nutrient requirements for beef cows[a,b,c]

	Month since calving											
	1	2	3	4	5	6	7	8	9	10	11	12
NEm required, Mcal per day[d]												
Maintenance	10.3	10.3	10.3	10.3	10.3	10.3	8.5	8.5	8.5	8.5	8.5	8.5
Lactation	4.8	5.7	5.2	4.1	3.1	2.2	0	0	0	0	0	0
Pregnancy	0	0	0.01	0.03	0.07	0.16	0.32	0.64	1.18	2.08	3.44	5.37
Total	15.03	16.00	15.43	14.41	13.42	12.64	8.87	9.18	9.72	10.62	12.00	13.91
Metabolizable protein required, lb. per day[d]												
Maintenance	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Lactation	0.77	0.92	0.83	0.66	0.50	0.36	0	0	0	0	0	0
Pregnancy	0	0	0.01	0.01	0.01	0.02	0.03	0.06	0.11	0.19	0.33	0.55
Total	1.70	1.85	1.77	1.60	1.44	1.31	0.96	0.99	1.04	1.12	1.26	1.48
Calcium required, g per day[d]												
Maintenance	16	16	16	16	16	16	16	16	16	16	16	16
Lactation	16	20	18	14	11	8	0	0	0	0	0	0
Pregnancy	0	0	0	0	0	0	0	0	0	12	12	12
Total	32	36	34	40	27	24	16	16	16	28	28	28
Phosphorus required, g per day[d]												
Maintenance	13	13	13	13	13	13	13	13	13	13	13	13
Lactation	9	11	10	8	6	4	0	0	0	0	0	0
Pregnancy	0	0	0	0	0	0	0	0	0	5	5	5
Total	24	24	23	21	19	17	13	13	13	18	18	18
Gain in weight from pregnancy, lb. per day[d]	0	0	0.04	0.07	0.11	0.18	0.26	0.42	0.62	0.88	1.25	1.70
Milk, lb. per day	14.7	17.6	15.8	12.8	9.5	6.8	0	0	0	0	0	0
Bodyweight, lb. per day												
Shrunk weight	1,172	1,172	1,172	1,172	1,172	1,172	1,172	1,172	1,172	1,172	1,172	1,172
Conceptus	0	0	2	2	7	9	15	26	42	64	97	141
Total	1,172	1,172	1,174	1,174	1,179	1,181	1,187	1,198	1,214	1,236	1,269	1,313

[a]Adapted from 7th rev. ed., Nutrient Requirements of Beef Cattle, 1996, National Research Council.

[b]Crystalline vitamin A should be added at a level of 1,100 IU/lb. DM.

[c]Mature weight, 1,173 lb.; calf birth weight, 88 lb.; age at calving, 5 years; age at weaning, 30 weeks; peak milk, 17.6 lb.; breed, Angus; milk fat, 4%; milk protein, 3.4%; calving interval, 12 months.

[d]No allowances made for gain since this a mature cow.

cause this disease with a production of hydrogen sulfide in the rumen and absorption in the bloodstream. This condition does not occur very often and should not discourage feeders from utilizing corn silage or co-products in their feeding programs.

Vitamin B12. Vitamin B12 should be synthesized in adequate quantities in the bovine rumen. Many research studies have demonstrated performance improvement in cattle — especially those on high-energy diets. Perhaps the ability of the rumen to synthesize vitamin B12 is borderline, at best.

Vitamin A. Green and yellow feeds contain beta-carotene, which is the precursor of vitamin A. In other words, many animals possess the capability to convert beta-carotene to meet their vitamin A needs. However, it is now known that, under certain conditions, the beef animal is not capable of converting sufficient beta-carotene to meet its vitamin A needs. It is a safe recommendation to supply the majority of the vitamin A needs of beef cattle in the crystalline form. Fortunately, vitamin A is not very expensive.

Vitamin E. Sometimes, a condition occurs in calves called "white muscle disease." This condition is attributed to a deficiency of vitamin E, selenium or both. Many cattle producers make it a practice to inject young calves with a combination of vitamin E and selenium. Most feeds consumed by cattle — except in early calfhood — are adequate in vitamin E. However, research has shown that increasing concentrations of vitamin E during the receiving period for newly received beef calves may decrease the incidence of bovine respiratory disease. Furthermore, supplemental vitamin E to feedlot cattle will increase the "shelf-life" of beef in the grocery meat case.

Commodities

Grains. Increases in fuel ethanol production and high fuel prices have dramatically increased the costs of commodities used in cattle feeding. The primary grains used for ethanol production are corn and sorghum. Albeit prices have increased, corn continues to be the primary cereal grain used by consulting feedlot nutritionists (Vasconcelos and Galyean, 2007). In this survey, wheat was used most often by nutritionists that used secondary grains, followed by sorghum and barley. Six nutritionists did not use secondary grain sources.

Grain co-products. As a result of increased fuel ethanol production, grain co-products have become common ingredients in beef cattle diets. This is, however, greatly dependent on location of the milling facility and feedlot, particularly wet milling facilities. Of the feedlot consulting nutritionists

5. Mineral requirements and maximum tolerable levels for beef cattle[a,b]

	Requirement			Maximum
Mineral	Growth and finishing	Gestation	Early lactation	tolerable level
Chlorine, %	—	—	—	—
Chromium, ppm	—	—	—	1,000
Cobalt, ppm	0.10	0.10	0.10	10
Copper, ppm	10	10	10	100
Iodine, ppm	0.50	0.50	0.50	50
Iron, ppm	50	50	50	500
Magnesium, %	0.10	0.12	0.20	0.40
Manganese, ppm	20	40	40	1,000
Molybdenum, ppm	—	—	—	5
Nickel, ppm	—	—	—	50
Potassium, %	0.60	0.60	0.70	3
Selenium, ppm	0.10	0.10	0.10	2
Sodium, %	0.06-0.08	0.06-0.08	0.10	—
Sulfur, %	0.15	0.15	0.15	0.40
Zinc, ppm	30	30	30	500

[a]Adapted from 7th rev. ed., Nutrient Requirements of Beef Cattle, 1996, National Research Council.

[b]Requirements for calcium and phosphorus are not included since they are listed in each of the nutrient requirement tables.

surveyed by Vasconcelos and Galyean (2007), 82.76% reported using grain co-products with wet distillers grains most common, followed by dry distillers grains with solubles (corn and/or sorghum), wet corn gluten feed and dry corn gluten feed. Level of inclusion in finishing diets ranged from 5% to 50% (average 16.5%; mode = 20%). It should be pointed out, however, that concentrations of sulfur in these co-products should be monitored. One debate that remains is the level of inclusion and carcass merit. Roeber et al. (2005; J. Anim. Sci. 83:2455-2460) reported that feeding up to 50% distillers grains did not affect tenderness or sensory traits of strip loins from Holstein steers.

Liquid feeds. Fat is added to finishing diets from 0% to 4.5%; (mean = 3.1%; mode = 3.0%; Vasconcelos and Galyean, 2007). Common fat sources included tallow, yellow grease, choice white grease and a blend of sources. In addition, 32.4% of clients added non-fat liquids to the diet. The nonfat liquids identified in the survey included corn distillers solubles used most often, followed by molasses, molasses blends and corn distillers solubles in combination with blends (Vasconcelos and Galyean, 2007).

Roughage source and level. Roughage is commonly added to finishing diets in small amounts (0-13.5%; dry-matter basis) and may vary with season (Vasconcelos and Galyean, 2007). Just as with other commodities, roughage sources vary with locale. In one survey (Galyean and Gleghorn, 2001; available at www.asft.ttu.edu/burnett_center/progress_reports/bc12.pdf), the primary roughage source used was alfalfa hay (68%), but a more recent survey by Vasconcelos and Galyean (2007) indicated that corn silage was the most common roughage source. The later authors suggested that perhaps the more recent survey included a broader geographical area and more consultants were from midwestern cattle feeding areas. Other common roughage ingredients include grass hays, other silages (wheat, and grasses) and byproducts (cottonseed hulls, cotton burrs, etc.).

6. Formulation information for finishing diets (DM basis) used by the consulting nutritionists surveyed by Vasconcelos and Galyean (2007)

Major minerals, %	Mean	n	Minimum	Maximum	Mode
Calcium	0.70	29	0.6	0.9	0.70
Phosphorus	0.30	25	0.16	0.45	0.30
Is phosphorus added?	24 (82.8%) =	No	5 (17.2%) = Yes		
Magnesium	0.22	28	0.15	0.40	0.25
Potassium	0.70	28	0.50	0.80	0.70
Sulfur	0.22	28	0.15	0.40	0.20
Salt	0.30	29	0.15	0.50	0.25
Trace minerals, mg/kg					
Copper	17.61	28	10.0	40.0	20.0
Zinc	92.95	28	40.0	212.5	100.0
Manganese	47.86	28	20.0	80.0	50.0
Iron	51.73	26	5.0	150.0	0.0
Selenium	0.24	28	0.1	0.6	0.2
Iodine	0.75	25	0.1	2.3	0.5
Cobalt	0.38	28	0.1	1.5	0.2
Vitamins, IU/kg					
A	5,215.0	29	2,205.0	11,023.0	4,409.2
E	25.7	28	5.5	110.2	11.0
D	329.9	27	0.0	1,102.3	0.0

Reproduced from Vasonelos and Galyean: Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim Sci. 85:2772-2781.

7. Beef breed maintenance requirements[1]

			--Birth weight--		Peak milk production/day	
Breed	Code	NEm	kg	lb.	kg	lb.
Angus	1	1.00	31	68.2	8.0	17.6
Braford	2	0.95	36	79.2	7.0	15.4
Brahman	3	0.90	31	68.2	8.0	17.6
Brangus	4	0.95	33	72.6	8.0	17.6
Braunvich	5	1.20	39	85.8	12.0	26.4
Charolais	6	1.00	39	85.8	9.0	19.8
Chianina	7	1.00	41	90.2	6.0	13.2
Devon	8	1.00	32	70.4	8.0	17.6
Galloway	9	1.00	36	79.2	8.0	17.6
Gelbvieh	10	1.00	39	85.8	11.5	25.3
Hereford	11	1.00	36	79.2	7.0	15.4
Holstein	12	1.20	43	94.6	15.0	33.0
Jersey	13	1.20	31	68.2	12.0	26.4
Limousin	14	1.0	37	81.4	9.0	19.8
Longhorn	15	1.0	33	72.6	5.0	11.0
Maine Anjou	16	1.0	40	88.0	9.0	19.8
Nellore	17	0.90	40	88.0	7.0	15.4
Piedmontese	18	1.0	38	83.6	7.0	15.4
Pinzgaur	19	1.0	40	88.0	11.0	24.2
Polled Hereford	20	1.0	33	72.6	7.0	15.4
Red Poll	21	1.0	36	79.2	10.0	22.0
Sahiwal	22	0.90	38	83.6	8.0	17.6
Salers	23	1.0	35	77.0	9.0	19.8
Santa Gertrudis	24	0.90	33	72.6	8.0	17.6
Shorthorn	25	1.0	37	81.4	8.5	18.7
Simmental	26	1.20	39	85.8	12.0	26.4
South Devon	27	1.00	33	72.6	8.0	17.6
Tarentaise	28	1.00	33	72.6	9.0	19.8

[1]Adapted from the National Research Council, Nutrient Requirements of Beef Cattle, 7th rev. ed., 1996.

Supplementation

During certain times of the year, supplementation of grazing cattle may be necessary. Supplements are normally classified as either protein or energy based on crude protein concentration. Protein supplements contain higher concentration of protein (normally more than 25%) and energy supplements contain normally less than 18% crude protein.

It is generally recommended that cattle grazing dormant mature forages be supplemented. Protein supplements are generally fed to these cattle. When the crude protein concentration of the forage is less than 6-7%, protein supplementation can be used to increase forage intake. The microbes will break down the protein into amino acids and ammonia and then utilize the ammonia for use in microbial synthesis and fiber digestion will be improved. Passage rate is then increased and intake can be increased.

Supplementation with non-structural carbohydrates often decreases fiber digestion and forage intake. Several factors have been proposed for the decreased digestion including: a decrease in pH as a result of increased VFA production thereby negatively affecting growth of pH sensitive fibrolytic bacteria, competition between bacteria for the starch and/or preferential use of the non-structural carbohydrates by fibrolytic bacteria and the associated increase in lag time. Regardless, energy or protein supplementation in growing steers has been observed to improve gains above unsupplemented steers in grass pasture.

Use of byproduct feedstuffs is an alternative to using cereal grains. Products such as soybean hulls, wheat middlings, corn gluten feed, etc., have more fiber and less starch than the unprocessed feed. In addition, the fiber components are generally highly digestible and higher in digestibility than forage fiber. Therefore, use of byproduct feedstuffs has increased forage intake and digestibility.

Feeding behavior

While we have the ability to provide proper nutrition through various feedstuffs and grazing management, it is ultimately up to the animal to decide what and how it eats. Cattle are gregarious in nature and depend on a social hierarchy. In terms of feeding behavior, dominant animals essentially get first choice. For example, the "pecking order" within a feedlot pen delineates that the more dominant animals eat first if bunk space is limiting. For grazing cattle, dominant animals eat what is most desirable first, which is often the supplement. Subordinate cattle must wait their turn at the trough or consume forage that is less desirable and nutritious.

Individual and learned feeding behavior also play a part in animal nutrition. Any cattle producer can attest that some cattle prefer a particular feedstuff, while others may prefer another. Dairy cattle are notorious for sorting diets, which is one reason they are more prone to acidotic episodes compared to beef cattle. Beef calves learn grazing behavior and plant selection from both mother and experimentation, which may lead to preference for either riparian or non-riparian plant species. Placement of water and supplements can also influence grazing distribution and essentially plant consumption; cattle are willing to travel away from water source for supplement consumption, including above riparian areas and in more rugged terrain.

Essentially, feeding behavior on a social and individual level can influence nutrient intake and subsequent performance.

Breed multiplier for maintenance requirements. Tables 1, 2, 3 and 4 present the nutrient requirements for production and maintenance for various beef production situations. Naturally, maintenance requirements are tied to several situations, including body size and hair coat thickness. Those requirements set forth in the tables were intended for the Angus breed of cattle. The NRC committee that prepared the recommendations published in the 1996 requirements made recommendations for adjustments that need to be made for various breeds. These are presented in Table 7. As may be noted, these adjustments represent changes in maintenance requirements, since requirements for gain and production are not affected by body size. As an example, NEm for Holstein cattle (Code No. 12, Table 7) would be 1.20 times as great as for Angus (Code No. 1), whereas NEg would be the same for either breed. Table 7 also contains anticipated birth weights and peak milk yields for the various breeds of cattle.

Feed Analysis Tables. A special section in this *Reference Issue* contains tables of feed analyses that represent "average values" for all the feedstuffs used commonly in feed formulation. However, caution must be exercised in formulating least-cost rations in which proposed requirements represent minimal levels. A recent study conducted simultaneously over a three-year period at 15 state experiment stations compared the chemical analyses for corn and soybean meal (J. Anim. Sci. 1999. 77:3262-3273). Among the corn sources, the range in protein analysis was from 7.31% to 9.06% (air-dry basis), representing a 24% increase from low to high. Similarly, over a two-year period, for nine state sources for soybean meal there was a range of 42.8-44.6% protein (air-dry), representing an increase just greater than 4% from lowest to highest. Finally, to demonstrate that all corn is not alike, some of the newer genetically engineered varieties are quite different. One of the newer such "high-oil" corns contains 6.5% more crude protein (9.83% versus 9.23%, dry-matter basis), 82.6% more oil, 5.1% more total digestible nutrients for beef and 58% more tocopherols than "typical" dent corn.

Formulating rations

It is recommended that the reader refer to the Feed Ingredient Analysis Table in this issue for analyses of potential feedstuff inclusion in beef cattle rations. ■