The Fairbanks Experiment Farm of the Agricultural and Forestry Experiment Station—AFES FILE PHOTO.

About the Agricultural and Forestry Experiment Station

The federal Hatch Act of 1887 authorized establishment of agricultural experiment stations in the U.S. and its territories to provide sicence-based research information to farmers. There are agricultural experiment stations in each of the 50 states, Puerto Rico, and Guam. All are part of the land-grant college system. The Morrill Act established the land-grant colleges in 1862. While the experiment stations perform agricultural research, the land-grant colleges provide education in the science and economics of agriculture.

The first experiment station in Alaska was established in Sitka in 1898. Subsequent stations were opened at Kodiak, Kenai, Rampart, Copper Center, Fairbanks, and Matanuska. The latter two remain. None were originally part of the Alaska land-grant college system. The Alaska Agricultural College and School of Mines was established by the Morrill Act in 1922. It became the University of Alaska in 1935. The Fairbanks and Matanuska stations now form the Agricultural and Forestry Experiment Station of the University of Alaska Fairbanks, which also includes the Palmer Research Center.

Early experiment station researchers developed adapted cultivars of grains, grasses, potatoes, and berries, and introduced many vegetable cultivars appropriate to Alaska. Animal and poultry management was also important. This work continues, as does research in soils and revegetation, forest ecology and management, and rural and economic development. Change has been constant as the Agricultural and Forestry Experiment Station continues to bring state-of-the-art research information to its clientele.

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—COOPERATIVE EXTENSION SERVICE (CES) PHOTO BY KEN KRIEG

Interpreting Feed Analysis of Alaska Forage

Many types of grass, hay, haylage, silage, and straw are consumed by livestock in Alaska, and the quality of forages is highly variable (Table 1). The nutrient content of these feeds depends upon variety, weather conditions, soil fertility, maturity at harvest, harvest procedures, and storage conditions. While book values for nutrient content of a feed type are helpful, the only accurate way to ensure that livestock are being fed properly is to know their nutrient requirements and to formulate diets based upon analyses of the specific forage to be included in the ration.

Obtaining a feed analysis is an important first step in formulating balanced, economical livestock rations, but it is just that—a first step. The next step is to study the analysis and determine how the feed can best be used for your animals. To do this, you must be able to interpret the data reported on the analysis form (Table 2).

Table 1. Statewide Average Feed Analysis for Alaska Bluegrass Hay, Bromegrass Hay, Timothy Hay, Grass Silage and Mixed Silage[1]

Crop	Crude Protein (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	ADF (%)	IVDMD (%)	TDN (%)	ME (Mcal/lb)
Bluegrass Hay	11.39	0.22	1.58	0.42	33.01	63.62	61.81	1.04
Bromegrass Hay	11.01	0.18	1.65	0.33	35.62	59.21	56.68	0.94
Timothy Hay	9.41	0.18	1.37	0.26	38.23	56.29	53.63	0.88
Grass Silage	12.13	0.18	1.59	0.40	37.19	57.45	55.70	0.91
Mixed Silage	11.87	0.22	1.97	0.59	36.23	56.55	57.00	0.89

Averages of sample analysis performed at the UAF Soil and Plant Analysis Lab in Palmer, Alaska (100% DM Basis). [1]Jahns et al., 2001.

Table 2. Sample Analysis of Domesticated Alaska Grass Hay

Sample Analysis	Moisture Free	As-Fed
Dry Matter %	100	84.41
Crude Protein %	18.01	15.20
Phosphorus %	0.30	0.25
Potassium %	1.11	0.94
Calcium %	0.60	0.51
Acid-Detergent Fiber %	27.86	23.52
Neutral-Detergent Fiber %	52.86	44.62
Total Digestible Nutrients %	67	57
Metabolizable Energy (Mcal/lb)	1.15	0.97
Net Energy $_{Maintenance}$ (Mcal/lb)	0.59	N/A
Net Energy $_{Growth}$ (Mcal/lb)	0.29	N/A
Net Energy $_{Lactation}$ (Mcal/lb)	0.69	0.66
Relative Feed Value (RFV)	118	100

Dry Matter and Moisture

Dry matter (DM) or conversely, moisture, is the first item to examine in a forage sample. Knowing moisture content is necessary for determining how much should be fed per animal per day, how the forage sample should be stored, and even how much the forage is worth. Feed nutrients (protein, carbohydrates, fats, vitamins, and minerals) are found only in the dry matter of the feed, not in the moisture component. Dry matter content influences the amount of forage that livestock consume. Since forage is fed by weight, it is necessary to know the moisture content (or conversely the DM content) so that the moisture plus the DM will supply all the nutrients necessary for the animal. "As-fed" refers to a sample as it came from the field or storage. As-fed contains all the DM plus the moisture measured at the time the sample was analyzed. For instance, a 10-pound sample of forage with 85% DM actually contains 8.5 pounds of DM and 1.5 pounds of water. That sample contains 10 pounds forage as-fed.

When considering feeds, it is important to recognize that besides the water, all the other nutrient classes (proteins, carbohydrates, fats, vitamins and minerals) are located only in the DM portion of that feed. Whether an animal is consuming wet feed (silage, haylage, or green chop) or dry feed (hay, straw, or stalk), it is the DM that supplies the nutrients.

For example, on a DM basis, stocker cattle will consume an average of 3% of their body weight per day (Taylor and Field, 1998). This means that an 800-pound steer will consume about 24 pounds of dry forage per day (800 pounds x 0.03 = 24 pounds). An 800-pound steer will consume about 26.7 pounds of 90% DM grass hay as-sampled or as-fed (24 pounds ÷ 0.90 = 26.7 pounds).

High-producing dairy cows may consume a DM equivalent of 3.5% of their body weight or more if high-quality forages are used as the basis of the ration formulation (Campbell et al., 2003). Maximizing DM intake for high-producing dairy cows is extremely important in order to supply nutrients used for producing milk and maintaining body condition. Such high-producing dairy cows should be consuming 45 to 55 pounds of DM per day. Many managers of high-producing dairy herds pride themselves in the fact that herd average DM intake exceeds 55 pounds per day.

Mature horses will generally consume 2 to 2.5% of their body weight in feed each day (Kline et al., 2000; Table 3). For example, a 1,200-pound horse should consume approximately 24 to 30 pounds of dry feed per day. A horse's digestive tract restricts effective digestion and utilization of high-fiber, low-quality forages. The poor digestibility of low-quality forages can reduce the amount of DM a horse can eat to a level below its nutritional needs. Therefore, a diet of high-quality forages should be considered essential for maintaining a healthy horse. Under ideal circumstances, horses should consume a minimum of 1% of their body weight in hay or pastures daily. If their daily activity consists of minimal to no work, mature horses can be maintained on high-quality forages without dietary supplements (Table 3). However, grain or concentrate supplements are required to meet growing, breeding, or working horse nutritional needs. Generally, forages should supply one-half or more of the total daily feed consumed for optimum horse growth and development. To determine the amount of moisture in a forage sample, the forage testing lab weighs a given amount of a forage sample, oven dries it to 0% moisture, then reweighs it and plugs the values into the following formula:

$$\frac{\text{wet weight - dry weight}}{\text{wet weight}} \times 100$$

Table 3. Minimum Equine Crude Protein and DM Requirements (Percent in Ration)

	% in Ration	% of Live Wt. Fed/Day*
Mature Idle Horse	8.5	1.5
Pregnancy (last 90 days)	11.0	1.5
Lactation	14.0	2.0
Foals (creep feed, nursing)	18.0	2.8
Weanlings	16.0	2.3
Yearlings	13.5	1.9
Yearlings (18 months)	11.5	1.7
Two-Year-Olds	10.0	1.5

*Percent of live weight fed is based on moisture-free feed. Actual percentage of weight eaten will be higher on an as-fed basis. Also, if the horse eats more or less than this percent of its weight per day in moisture-free feed, the percent needs to be adjusted accordingly.

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Beef cattle at Delta Junction area farm.
—CES PHOTO BY DON QUARBERG

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Note

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Sampling Techniques for Accurate Forage Analysis

Hay sampling probe—CES photo by Tom Jahns.

A forage analysis is only as good as the sample submitted to the lab. Careful sampling techniques are required to mitigate the potential variations that exist (both physically and nutritionally) within a field, a harvest period, or a "lot" of bales or silage.

Hay and haylage: Sample hay (and haylage) in groups or lots. "Lots" are defined as hay samples of the same species, at the same maturity, and handled in a similar manner. Hay put up dry, without rain damage, that was harvested within a relatively short time-frame would be physically and nutritionally different from hay that was cut a few weeks later; or hay that had been rained on for a couple of weeks and tedded a half-dozen more times prior to harvest. Other examples would include: a first-cutting hay versus a second-cutting hay, hay from different fields that are distinctly different in moisture holding capacity, soil depth, stand age, etc.; and between fields (or within a field) that received different fertilizer application rates.

"Grab" samples pulled from the outside or inside of a hay (or haylage) bale are very inaccurate and are not representative of the quality within a given "lot" of hay. A hay probe is the best way to accurately take a hay (or haylage) sample. Hay probes are made from ½-inch to 1-inch diameter cylinders or tubes approximately two feet long, with a toothed cutter on one end and a drill chuck attachment on the other end. The probe is loaded into a drill, tightened and then "drilled" into the bale to be sampled. A stick or dowel is handy to use for removing the forage samples from the inside of the tube. Square bales should be sampled ("drilled") lengthwise from the end of the bale inward, toward the center of the bale, while round bales should be sampled from the round side inward, toward the bale's center. A minimum of 12 samples per lot should be taken, placed in a clean bucket or bag, blended thoroughly and approximately one quart of representative material placed in a dry plastic bag, sealed and sent to the lab immediately for analysis.

Silage: Take silage samples at harvest time, making sure to identify each sample correctly. Carefully pull and mix grab samples from a minimum of 12 locations, making sure to avoid excessive mixing that, if not done properly, may cause the grains to fall out of the sample, rendering the sample inaccurate. A one-quart freezer bag should be filled with the sample, then depleted of any trapped air, sealed and shipped to the lab.

For all hay, haylage, and silage samples, if the shipment to the lab is delayed, freeze the sample and ship when convenient. Keep in mind that to maintain an accurate moisture reading, the sample must be kept air tight, whether in the freezer or in route to the lab for analysis.

A bromegrass research plot.
—CES photo by Don Quarberg

Where to have forage samples analyzed

The National Forage Testing Association certifies forage testing labs. They list those labs, including addresses, on their website: http://www.foragetesting.org/.

A microwave and an accurate scale can be used at home to derive similar results (Quarberg and Jahns, 2000).

As stated above, nutrients other than water are located only in the DM portion of the forage. Therefore, when viewing a forage sample, always calculate nutrients based on the 100% DM (Moisture Free) column. All figures in "As-Fed" or "As-Received" column, except the Dry Matter percent, should be ignored.

Protein

Protein is an important nutrient in animal production and is generally least expensive if supplied by forages. Protein is necessary for muscle development, milk production, and growth. Protein content of the sampled forage (Table 2) is indicated as crude protein (% CP). It is called crude protein because it is only a crude estimate, although often a reasonably good one. The CP value of a forage sample includes true protein and nonprotein nitrogen compounds. Protein is the major organic nutrient class that contains nitrogen. In fact, nearly all of the total nitrogen in a forage sample will be contained in protein. Nitrogen constitutes about 16% of each amino acid, the building blocks of protein. With this information, a reasonable estimate of forage protein content is possible when the amount of N in the sample is known. Since 16% goes into 100% 6.25 times, the lab will measure the total N and multiply that figure by 6.25 to get an estimate of protein content.

Protein concentrations are extremely variable in forages. Young and growing grass forages contain higher percentages of protein than older, mature forages. Fertilization of grasses with nitrogen (N) will increase CP content. However, fertilization with other nutrients usually has little effect on forage nutrient content. The protein in Alaska-grown timothy hay may be as low as 3% in over-mature hay and as high as 17 % in the early growth stage. Clovers and alfalfa legumes are higher in protein than grass hays, but vary widely in quality. Quality of these and other forages is highly dependent upon maturity stage and weather conditions during harvest.

There are some cases where the above method of estimating crude protein will produce erroneous results. Urea (46% N) is a good example. By running urea through the CP calculations we get 287.5% CP (46 x 6.25) which is obviously impossible. In fact, urea contains no protein. This example is the exception, though, for in most common feeds the estimated CP is a decent measure of protein content.

Digestible protein (DP) is a calculated value, based on the kind of forage analyzed. About 70% of CP is found in the green leafy parts of growing forages. Digestible protein is an estimate of protein digestibility only and has little value in formulating rations for beef cattle or dairy, but may be useful in formulating horse rations.

Acid detergent fiber nitrogen (ADFN) can be used to calculate adjusted crude protein (ACP). Acid detergent fiber nitrogen, or bound nitrogen, indicates the percentage of protein unavailable because of heating and carmelization. A portion of true protein becomes tied up with carbohydrates during the heating process, making them unavailable to the animal. Cattle often favor the brownish or blackish, sweet-smelling and condensed sugary-like syrup of heat-damaged forages. Forages heat when excessive moisture (>12%) and oxygen are present (at 160° F, hay becomes a fire hazard) or in the case of haylage, when too little moisture is in the presence of too much oxygen. Nitrogen becomes bound (heat damaged) when these forages become heated. Forage samples average about 12% bound nitrogen. Forage samples with ADFN values greater than 12% result in decreased protein digestibility, an indication that harvesting or storage conditions were not ideal and some reduction in CP availability has occurred. The higher the percent CP in the ADF, the more extensive is the reduction.

Fiber

Cattle and horses require fiber in their diet to stimulate the microorganisms that assist in nutrient production through fiber fermentation. While horses utilize a highly developed hindgut to accomplish fermentation, in cattle the rumen is the site of fiber decomposition and fermentation. Cattle raised on a diet deficient in fiber may develop permanent rumen wall damage. The amount of fiber in the diet does not always indicate that the diet contains adequate fiber. If the fiber is chopped or ground too short or fine, the fiber requirements of cattle may not be met because it will pass through their digestive system too rapidly to be utilized. A minimum length of ¼ to ½ inch is required to adequately meet the rumen needs. Fiber, an energy source often overlooked in horse nutrition, is an essential element of good horse health. Billions of bacteria and protozoa, capable of fermenting large quantities of fiber, are found in the well-developed hindgut of horses. Because fiber fermentation continues long after a meal has been eaten, the end products of fiber fermentation can be used as energy sources. Because proper gut function is essential to a horse's health, fiber should be considered an essential nutrient. As previously mentioned, to optimize horse midgut function and animal health, hay should be supplied and ingested at amounts greater than or equal to 1% of animal body weight per day. Grass hays cut prior to heading and seed fill provide higher quality feed than those grasses cut at a later, more mature stage of growth.

Crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent fiber nitrogen (ADFN) are the four components of fiber that are used to help in determining forage quality. Different methods of estimating CF are used for different feedstuffs. One method is used for legume hay/silage, mixed feeds, and grains, while a different method is used for determining CF in nonlegume hays and silage. CF values alone, derived from a local forage sample by a standard forage analysis, are inadequate for predicting the fiber quality of a given sample. While young, weaned cattle normally require a diet of at least 22% CF, and cattle being finished may need only 8 to 10% CF, the quality of feed-fiber will determine the actual amount needed to meet an animal's dietary needs.

Table 4. Percent of cattle body weight intake of feed based on percent of NDF

Percent NDF	Dry Matter Intake as Percent Body Intake
38	3.16
40	3.00
42	2.73
44	2.68
46	2.61
48	2.50
50	2.40
52	2.31
54	2.22

Source: *Pioneer Forage Manual, A Nutritional Guide*, 1990

CF is a function of neutral detergent fiber (NDF). Neutral detergent fiber content of the sampled forage (Table 2) is indicated as neutral detergent fiber %. Neutral detergent fiber is negatively correlated with dry matter intake (DMI) (Table 4). As NDF increases in forage, DMI decreases. In other words, as NDF increases in forages, animals eat less. The prediction for DMI is a function of NDF and is expressed as a percentage of body weight. To predict DMI in cattle: DMI = 120 divided by % NDF.

Acid detergent fiber (ADF) is negatively correlated with forage digestibility. The ADF content of sampled forage (Table 2) is indicated as Acid Detergent Fiber %. As the ADF increases, forages become less digestible. Both the NDF and ADF increase as forages mature. The amount of dry matter digested is a function of forage ADF level and is expressed as a percentage. Digestible dry matter (DDM) can be estimated based on the amount of ADF in forage: % DDM = 88.9 - (0.779 x % ADF).

Fiber and lignin content increase as plants mature. Digestibility and intake potential are reduced with increasing fiber (ADF and NDF) and lignin content. Digestible dry matter (DDM) decreases three to four percentage units for each percentage unit increase in lignin. Relative feed value (RFV) can be calculated after DDM and DMI have been calculated based on the NDF and ADF in a forage sample. The purpose of RFV is to allow a producer to compare two or more forage samples: RFV = % DDM x % DMI divided by 1.29.

It is important to remember that RFV is based on % ADF and % NDF and is only used as a reference value. For reference purposes, an RFV of 100 equals full bloom alfalfa. Even though little alfalfa is grown in Alaska, RFV can still be used as a forage comparison tool. Forage samples near an RFV of 100 are satisfactory for beef cattle and nonlactating horses, but may be inadequate for dairy cattle. If the calculated RFV of bromegrass forage A is 100 and the RFV of bromegrass forage B is 110, then forage B is worth somewhat more than forage A. For example, let us say forage A is priced at $160.00 per ton. That means each point of RFV in Forage A costs $1.60 (160/100). Let us also say that forage B is priced at $170.00 per ton. That means each point of RFV in Forage B costs $1.55 (170/110). A buyer can see that each point of relative feed value costs less for forage B compared to forage A. Relative feed value will aid producers in comparing the monetary and nutrient value of two or more forages, but it is not used to calculate the actual ration.

Energy

The energy provided by feeds is similar to fuels for cars and trucks. Fuels, like forages, vary in the amount of energy per unit volume. The energy in gasoline is expressed as its octane rating. As the octane number increases, so does the energy per gallon. Forages vary in energy content and not all the energy in any feedstuff is available to the animal (Figure 1). Animals consume feed containing energy, but are unable to use undigested energy lost in feces, energy released in gases and urine, and energy lost as heat to the environment. The remaining energy available to the animal is called net energy. This net energy is used first for maintenance requirements. Energy available after maintenance requirements have been met can be put towards production efforts like growth, lactation, reproduction and activity.

Energy is expressed several ways in a forage sample. Total digestible nutrients (TDN) and net energy for lactation (Net Energy-L), maintenance (Net Energy-M), and gain (Net Energy-G) are the most common ways of expressing energy for ruminants. Energy is expressed in megacalories per kilogram or per pound.

Energy in a forage crop such as timothy or bromegrass hay will vary with growing conditions and maturity. As forages mature, the amount of energy available decreases. This is not true for forages that produce a seed or grain such as oat silage. Acid detergent fiber values are used in the calculation of TDN and net energy values of forages.

Total Digestible Nutrients = 96.35 – (ADF x 1.15)

Net Energy - L = (TDN x 0.0245) - 0.12

Net Energy - M = (TDN x 0.029) - 0.29

Net Energy - G = (TDN x 0.029) - 1.01

Metabolizable Energy = (TDN x 1.01 x 0.04409) - 0.45

Comparisons should be made between energy values in available forages and the nutrient requirements of the livestock to determine if the forages meet nutrient requirements. Grain or concentrates should be used to supplement the forage if additional energy is required. See Figure 1.

Selenium

Most Alaska soils and all forages grown in these soils are deficient in selenium (Table 13). In fact, within Alaska, only grass and forb forages grown on the Kenai Peninsula contained selenium concentrations adequate for maintaining good animal health (Brundage, 1985). See Table 13.

Although not regularly a part of a standard forage analysis, selenium is an essential micronutrient in animal diets, and it should be considered a critical ingredient when feeding only Alaska-based forages. Selenium interacts with vitamin E (in an antioxidant capacity) to keep the immune system strong and cell membrane integrity protected. Too little or too much selenium in an animal's diet can lead to poor health or even death. Selenium dietary requirements are roughly 0.05-0.3 parts per million (ppm) in the dry ration. Selenium toxicity can be reached at levels as low as 3-5 ppm selenium (one ppm equivalent to 1 pound in 500 tons).

To compensate for deficiency, selenium should be made available to livestock either through "free choice" salt/mineral blocks, injections, or orally. Selenium supplementation has been observed to be especially effective during pregnancy, nursing, and lamb-growth phases in sheep; in horses, it is especially helpful in reducing the rate of "no retained placentas" in pregnant mares (Richards, 2003). All livestock need some form of selenium supplementation if fed totally on Alaska-grown forages. Selenium deficiencies in livestock lead to forms of myopathy, or the development of lesions on muscle fibers or muscle groups. Three major muscle groups are normally affected: the locomotary, the respiratory, and the heart. Deficiency symptoms include painful standing and the inability to walk; short, rapid and loud breathing; and rapid, muted, almost metallic-like heartbeats. Also linked to selenium deficiencies are reproductive disorders, stunted growth, cataracts, and liver and pancreatic damage.

Excessive selenium exposure in livestock (and humans) has led to alkali disease (ill-health associated with dullness of coat, sluggishness and stiffness to lameness), blind staggers, aimless wandering, impaired vision, exhaustion, paralysis, and death. The most common symptom associated with excessive selenium exposure is "garlic breath."

Table 12. Effect of nitrate concentration on livestock.

Note: Because no Alaska data exists that sets specific nitrate (NO_3) and nitrate nitrogen (NO_3N) toxicity levels, the authors have chosen to stay on the safe side by utilizing Montana State's guidelines, which are more conservative than those published from other states.

Reported on 100% DM Basis* as:		Comment
NO_3N (ppm)	NO_3 (ppm)	
0	<1500	Generally safe for all conditions and livestock
350 - 1130	1500 - 5000	Generally safe for nonpregnant livestock. Potential early-term abortions or reduced breeding performance. Limit use to bred animals to 50% of the total ration.
1130 - 2260	5000 - 10,000	Limit feed to 25-50% of ration for non-pregnant livestock. **DO NOT FEED TO PREGNANT ANIMALS**: may cause abortions, weak calves and reduced milk production.
>2260	>10,000	**DO NOT FEED.** Acute symptoms and death.

* If nitrate content of a feed is reported on an as-fed basis, convert to 100% dry matter basis to compare it to levels in this table. For example, silage at 50% moisture that contains 600 ppm NO_3N on an as-fed basis contains 1200 ppm on 100% dry basis; thus it fits the second group in this table. (Cash et. al., 2002.)

Table 13. Average selenium content of feed and plant samples from different regions of Alaska.

Note: The number of samples included in this survey are shown in parentheses.

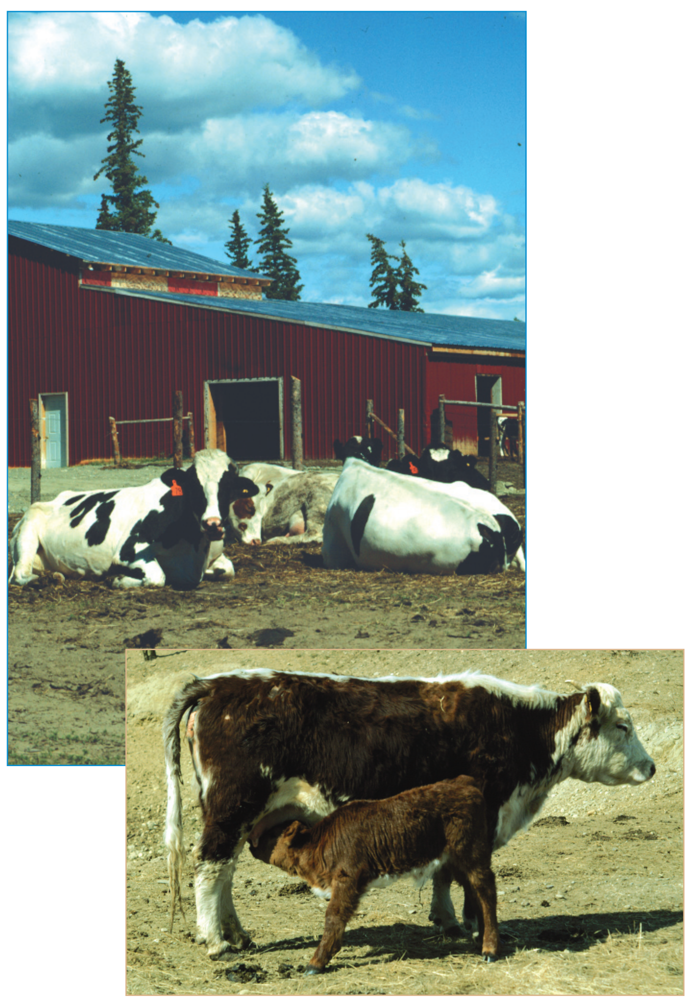
	— Se (ppm) by Region —			
Sample Description	Kenai	Mat-Su	Interior	Western
Grain forage	--	.0605 (8)	.0130 (2)	--
Grain	--	.0122 (13)	.0130 (18)	--
Legume	--	.0423 (3)	.1370 (2)	--
Grass	.2525 (11)	.0869 (24)	.0278 (8)	.0250 (6)
Mixed feed	--	.3645 (9)	--	--
Shrubs	--	.0140 (1)	.0257 (20)	.0260 (3)
Forbs	.0916 (12)	.1713 (16)	.0477 (7)	.0312 (5)
Trees	--	--	.1183 (2)	--
Lichens	--	--	--	.1636 (11)

Brundage, A.L. 1985

Fat

Fats are high in energy and calories, making them an excellent supplement to an animal's diet. Fat percentages in forages are extremely low. Fats have 2.25 times more energy (calories) per pound than starches and carbohydrates, which are the primary energy sources in most grains. Feeds contain natural fat. Cottonseed has one of the highest fat contents (24%), while corn contains a minimal amount of fat (4%).

While fats are beneficial in a feed ration, care must be taken to limit the total amount of fat in both supplements and existing foodstuffs. Rumen-protected fats are utilized in the dairy industry to protect rumen microbes while increasing energy and maintaining consumption levels. Cattle should not be fed a diet consisting of more than 8% total fats. Diets containing high fat contents (> 8%) may seriously reduce feed consumption and cause loss of minerals (from the binding of minerals with fats, forming insoluble soaps), scouring, and reduced digestibility. A fat-rich cattle diet also should be monitored for appropriate calcium (0.55%) and phosphorus (0.35%) levels to maintain good animal health.



Dairy and beef cattle at Delta Junction area farms.
—CES PHOTOS BY DON QUARBERG

Table 11. Symptoms of nitrate poisoning

Signs of Early or Chronic Toxicity	Signs of Acute Toxicity
Watery eyes	Accelerated pulse rate
Reduced appetite	Labored breathing, shortness of breath
Rough hair, unthrifty appearance	Muscle tremors
Weight loss or no weight gain	Weakness
Signs of Vitamin A deficiency	Staggering gait
Reduced milk production	Cyanosis: membranes (such as the tongue, mouth, vulva and the whites of eyes turn blue)
Abortion	Death
Source: Cash et. al., 2002.	

NO_3 or Nitrate Nitrogen

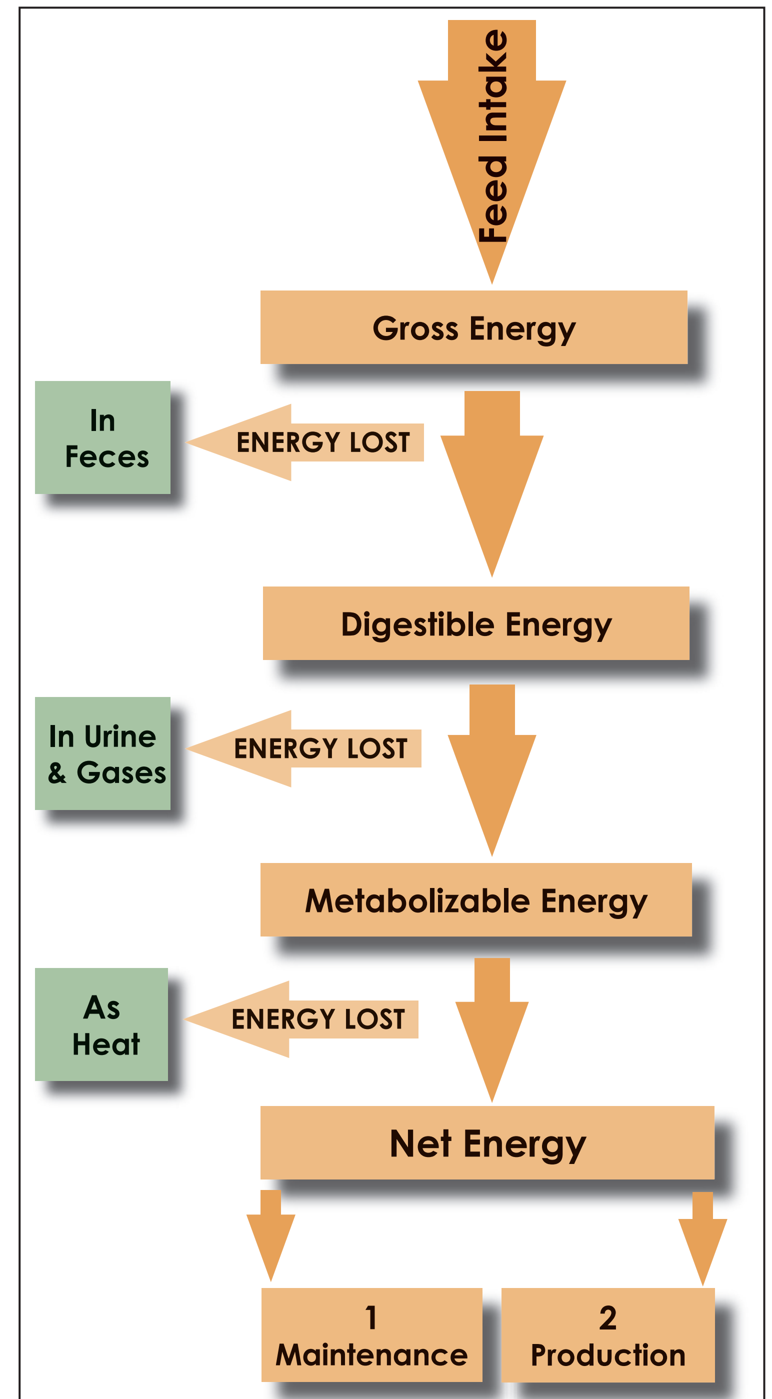
High concentrations of nitrates in feed can be extremely toxic to horses, cattle, sheep, and goats. Nitrate itself is nontoxic, but when present at high levels in feed, it is converted to nitrite (NO_2) and ammonia (NH_3). In ruminants the ammonia is converted into protein by microbes in the rumen. The nitrite is toxic to animals in high concentrations (nitrite poisoning). As nitrite accumulates, it is absorbed into the blood, where it combines with hemoglobin to form methemoglobin, which reduces the blood's ability to carry oxygen from the lungs to the tissues.

Nitrates are found in the vegetative stages of most Alaska forages, hays, and haylages. If a forage becomes stressed, usually as a result of drought, an early killing frost, a heavy nitrogen fertilizer application, or certain herbicide applications, nitrates may reach potentially toxic levels. These nitrate "hot spots" can vary within pastures and even between bales of hay and haylage. Nitrate becomes potentially lethal at 9,000 ppm (0.9%) and nitrate nitrogen at 2,100 ppm (0.21%). Under the right conditions, Alaska oat and barley hays and haylages, as well as common weeds such as lambsquarter and quackgrass, are all capable of containing high nitrate levels. Feeds with high nitrate levels are detrimental to livestock (Tables 11 and 12). Because no Alaska data exists that sets specific nitrate (NO_3) and nitrate nitrogen (NO_3N) toxicity levels, the authors have chosen to stay on the safe side by utilizing Montana State's guidelines, which are more conservative than those published from other states (Tables 11 and 12).

Minerals

Minerals play an important role in animal development and growth. Mineral levels needed in the diet vary depending on the animal's age and developmental stage. Different levels of dietary minerals create variations in animal growth performance, soundness, reproduction, and longevity. These levels are important, as are the ratios of certain minerals to each other.

A forage analysis report from the feed testing laboratory will give values of calcium (Ca), phosphorus (P) and potassium (K). Values for magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and sulfur (S) are not routinely included but are available upon request.



Mineral levels in a forage sample are expressed as a percent of the total sample or in parts per million (ppm). Minerals needed in relatively large amounts are macrominerals, and minerals needed in relatively small amounts are microminerals (or trace minerals). Macro or micro does not denote importance, but rather the amount of the mineral required by livestock. The levels of calcium and phosphorus necessary for maximum growth rate and mineralization of the bones are not always adequate in forages.

Having the correct ratios of minerals in the diet are also important. The interaction of minerals as they affect one another is listed in Table 5. A forage analysis provides calcium-phosphorus ratios. A high calcium-phosphorus ratio lowers phosphorus absorption resulting in reduced growth and bone mineralization in cattle. A good calcium-phosphorus ratio for the maintenance of mature animals is between 1.3:1 and 1.5:1. The ratio is less important if the diet contains amounts of phosphorus in excess of the animal's requirements. High levels of macrominerals, such as calcium or phosphorus, can be responsible for making certain microminerals, such as zinc, less available.

Minerals can be supplied to cattle in a complete diet or provided free choice. A forage analysis will determine how much mineral must be added to an animal's ration. Phosphorus is the most expensive mineral fed to cattle

Table 5. Mineral Interrelationships in Animals

Mineral	Minerals Affected
Ca	Mn, Mg, Zn, F, S, P
P	Fe, Ca, Be, Al, Cu, Mn, Mo, Mg, Zn
S	Se, Ca, Cu, Mo, Zn
Na	K
Cl	---
Zn	S, P, Fe, Ca, Cd, Cu
Mg	P, Ca, Mn, K
I	As, F, Co
Mo	S, P, Cu
K	Mg, Na
Mn	Mg, P, Fe, Ca
Fe	Zn, P, Co, Mn, Cu
Se	As, S
Cu	Cd, Fe, Ag, Fe, P, S, Zn, Mo
Source: *Nutrient Requirements of Beef Cattle*, Sixth Edition, 1984.	

Table 6. Calcium-Phosphorus Requirements for Horses as Percent of Ration

	Calcium (%)	Phosphorus %
Mature Maintenance	0.30	0.20
Mares – Last 90 days pregnancy	0.50	0.35
Lactating Mares (first 4 months)	0.50	0.35
Foal (creep feed; first 6 mos.)	0.85*	0.60*
Weaning	0.70	0.50
Yearling (12 mos.)	0.55	0.40
Yearling (18 mos.)	0.45	0.35
Two-Year-Olds	0.45	0.35
Mature Horses (all levels of work)	0.30	0.20

*These levels may be too low for foals being fed for maximum growth. The values should be Ca=1.0% and P=0.80% for foals being fed all they can eat. Source: Kline et al., 2000.

Table 8. Mineral Requirements of Beef Cattle

Major or Macro Minerals	Recommended Level (%)	Maximum Tolerance (%)
Sodium (Na)	0.08	10.0
Chlorine (Cl)	--	--
Calcium (Ca)	0.40	2.0
Phosphorus (P)	0.30	1.0
Magnesium (Mg)	0.10	0.4
Potassium (K)	0.65	3.0
Sulfur (S)	0.10	0.4
Trace or Micro Minerals	**Recommended Level (ppm)**	**Maximum Tolerable Level (ppm)**
Silicon (Si)	--	--
Chromium (Cr)	--	--
Cobalt (Co)	0.1	5
Copper (Cu)	8.0	115
Fluorine (F)	--	20–100
Iodine (I)	0.5	50
Iron (Fe)	50.0	1,000
Manganese (Mn)	40.0	1,000
Selenium (Se)	0.2	2
Molybdenum (Mo)	--	6

Source: *Nutrient Requirements of Beef Cattle*, Sixth Edition, 1984.

Table 7. Maximum Tolerable Levels of Certain Toxic Elements in Beef Cattle[1]

Element	Maximum Tolerable Level (ppm)
Aluminum	1000
Arsenic	50
Bromine	200
Cadmium	0.5
Fluorine	20-100
Lead	30
Mercury	2
Strontium	2000

[1]Toxicities for dairy cattle are identical. Exceptions are the additions of molybdenum, 10 ppm; nickel, 50 ppm; vanadium, 50 ppm; and the exclusion of strontium.
Source: *Nutrients of Beef Cattle*, Sixth Edition, 1984

Table 9. Equine Trace Mineral Levels Required, Toxic Levels and Levels Found in Feedstuffs

Mineral	Required	Toxic	Normal Range Found in Feed: Roughages	Normal Range Found in Feed: Grain
Potassium %	0.4		1.50 – 2.5	0.3 – 0.05
Magnesium %	0.09		0.15 – 0.6	0.1 – 0.02
Sulfur %	0.15		0.15 – 0.5	0.15 – 0.4
Iron (ppm)	50		150 – 400	30 – 90
Zinc (ppm)	40 – 60	200	17 – 22	17 – 50
Manganese (ppm)	40		25 – 190	6 – 45
Copper (ppm)	20 – 30		5 – 25	4 – 9
Cobalt (ppm)	0.1			
Selenium (ppm)	0.1	5.0		
Iodine (ppm)	0.1	4.8		

Source: Kline et al., 2000.

Table 10. Recommended Nutrient Content of Diets for Dairy Cattle

Cow Wt. (lb.)	Fat (lb.)	Wt. Gain (lb./day)	Diets Based on Milk Yield (lb./day)					Early Lactation (wks. 0-3)	Dry Pregnant Cows	Maximum Tolerance Level
900	5.0	0.50	14	29	43	58	74			
1,100	4.5	0.60	18	36	55	73	91			
1,300	4.0	0.72	23	47	70	93	117			
1,500	3.5	0.82	26	52	78	104	130			
1,700	3.5	0.94	29	57	86	114	143			
Minerals										
Calcium, %			0.43	0.53	0.60	0.65	0.66	0.77	0.39 a	2.0
Phosphorus, %			0.28	0.34	0.38	0.42	0.41	0.49	0.24	1.0
Magnesium (b), %			0.20	0.20	0.20	0.25	0.25	0.25	0.16	0.5
Potassium(c), %			0.90	0.90	0.90	1.00	1.00	1.00	0.65	3.0
Sodium, %			0.18	0.18	0.18	0.18	0.18	0.18	0.10	--
Chlorine, %			0.25	0.25	0.25	0.25	0.25	0.25	0.20	--
Sulfur, %			0.20	0.20	0.20	0.20	0.20	0.25	0.16	0.4
Iron, ppm			50.00	50.00	50.00	50.00	50.00	50.00	50.00	1,000.0
Cobalt, ppm			0.10	0.10	0.10	0.10	0.10	0.10	0.10	10.0
Copper (d), ppm			10.00	10.00	10.00	10.00	10.00	10.00	10.00	100.0
Manganese, ppm			40.00	40.00	40.00	40.00	40.00	40.00	40.00	1,000.0
Zinc, ppm			40.00	40.00	40.00	40.00	40.00	40.00	40.00	500.0
Iodine (e), ppm			0.60	0.60	0.60	0.60	0.60	0.60	0.25	50.0f
Selenium, ppm			0.30	0.30	0.30	0.30	0.30	0.30	0.30	2.0
Vitamins										
A, IU/lb.			1,450	1,450	1,450	1,450	1,450	1,800	1,800	30,000
D, IU/lb.			450	450	450	450	450	450	540	4,500
E, IU/lb.			7	7	7	7	7	7	7	900

(a) The value for calcium assumes that the cow is in calcium balance at the beginning of the dry period. If the cow is not in balance, then the dietary calcium requirement should be increased by 25 to 33 percent.

(b) Under conditions conducive to grass tetany, magnesium should be increased to 0.25 or 0.30 percent.

(c) Under conditions of heat stress, potassium should be increased to 1.2 percent.

(d) The cow's copper requirement is influenced by molybdenum and sulfur in the diet.

(e) If the diet contains as much as 25 percent strongly goitrogenic feed on a dry basis, the iodine provided should be increased two times or more.

(f) Although cattle can tolerate this level of iodine, lower levels may be desirable to reduce the iodine content in milk.

Source: *Nutrient Requirements of Dairy Cattle*, Sixth edition, 1989.

because of cost and amount fed. If phosphorus is included in the diet, the inclusion rate should be about 0.35% of the diet. Calcium should be added at the rate of about 0.4 to 0.45% of the diet. These calcium and phosphorus levels will provide adequate amounts of both minerals at the correct ratio (1.3 to 1.5:1). With some forages, calcium-phosphorus ratios may be as high as 2:1. This is acceptable, and no additional phosphorus is needed in the ration. Table 6 summarizes the calcium-phosphorus requirements for horses as a percent of the ration.

Potential elemental toxicities are listed in Table 7. Some minerals such as aluminum and fluorine are toxic to cattle. Others are required, but are toxic above certain dietary levels. Mineral requirements for beef cattle (Table 8), horses (Table 9), and dairy cattle (Table 10) are shown here.