Forage Quality and Impact on Livestock Feeding

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Forage Feeding of Livestock:

- Defining forage quality and its assessment
- How to determine forage quality
  - Visual assessment
  - Laboratory assessment
- Interpreting forage reports
- Forage quality feeding challenges
  - Protein and Fiber
  - Macrominerals
  - Microminerals

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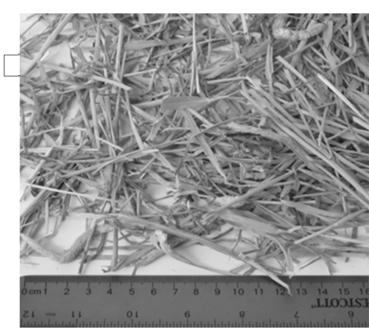

What is Forage Quality?

Two Aspects of Forage Quality:
- Consumption potential by the animal – a function of neutral detergent fiber (NDF) content
- Ability of the consumed forage to meet essential nutrient needs of the animal

Photo: R. Van Saun

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Forage Nutritional Glossary

- TDN = total digestible nutrients, a calculated measure of energy
- CP = crude protein, calculated amount of protein in a feed
- ADF = acid detergent fiber, slow-indigestible plant cell wall
- NDF = neutral detergent fiber, total plant cell wall
- NFC = nonfiber carbohydrates, anything other than NDF
- NSC = nonstructural carbohydrates, sugars and starches
- Lignin = complex polymer that is indigestible and hardens the plant cell wall making it less digestible
- Ash = total mineral content, influenced by soil contamination
- CF = crude fat, measure of total lipid content

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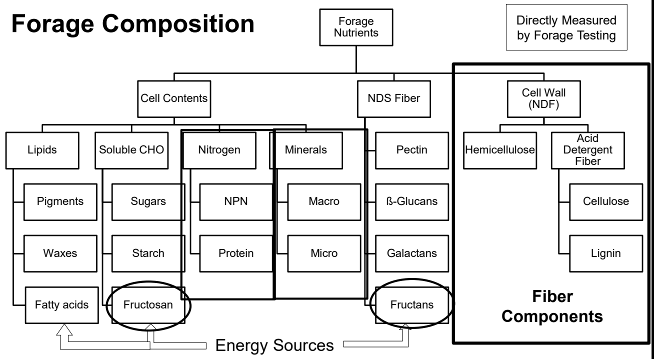
Forage Composition



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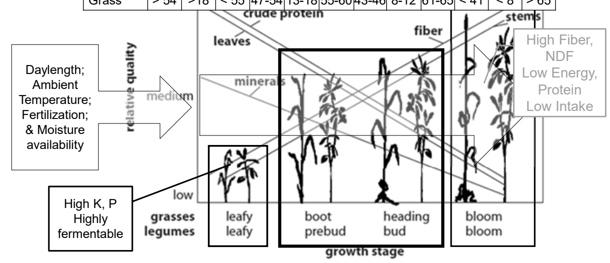
Plant Maturity

	TDN%	CP%	NDF%	TDN%	CP%	NDF%	TDN%	CP%	NDF%	TDN%	CP%	NDF%
Alfalfa	> 64	>19	< 40	56-60	17-19	40-46	50-55	13-16	47-51	< 50	<13	> 51
Grass	> 54	>18	< 55	47-54	13-18	55-60	43-46	8-12	61-65	< 41	< 8	> 65



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How to Evaluate Forage Quality

- Sensory appraisal of the forage
- Chemical analysis of the forage

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Sensory Evaluation	Description/Comments
Visual	
Stage of maturity	Look for the presence of seed heads (grass forages) or flowers or seed pods (legumes), indicating more mature forages
Leaf to Stem ratio	Look at forage and determine whether the stems or leaves are more obvious; good-quality legume forages will have a high proportion of leaves, and stems will be less obvious and fine
Color	Color is not a good indicator of nutrient content, but bright green color suggests minimal oxidation; yellow hay indicates oxidation and bleaching from sun, and hay will have lower vitamins A and E content

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Sensory Evaluation	Description/Comments
Foreign Objects	Look for presence and amount of inanimate objects (twine, wire, cans, etc.), weeds, mold, or poisonous plants
Touch	Feel stiffness or coarseness of leaves and stems; see if alfalfa stems wrap around your finger without breaking; good-quality hay will feel soft and have fine, pliable stems
Smell	Good quality hay will have a fresh mowed grass odor; no musty or moldy odors; Carmel or tobacco smell to hay indicates heat damage; Silage should have slight pleasant fermented smell. Vinegar, sweet, alcohol, tobacco, or rancid milk odors to silage indicate an abnormal fermentation has taken place and further diagnostic testing should be completed.

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Which is the better forage?

Photo credits: R. Van Saun

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Feed Analysis Reports

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ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% MOISTURE	9.0	******
% DRY MATTER	91.0	******
% CRUDE PROTEIN	12.1	13.3
% ADJUSTED CRUDE PROTEIN	12.1	13.3
% ACID DETERGENT FIBER	32.3	35.5
% NEUTRAL DETERGENT FIBER	46.5	51.1
% NonFiber Carbohydrates	24.0	26.4
% TDN	56	62
NEL, (MCAL/LB)	0.58	0.64
NEM, (MCAL/LB)	0.58	0.64
NEG, (MCAL/LB)	0.34	0.37
% CALCIUM	0.46	0.51
% PHOSPHORUS	0.23	0.25
% MAGNESIUM	0.17	0.19
% POTASSIUM	2.58	2.84
% SODIUM	0.013	0.014
PPM IRON	97	107
PPM ZINC	20	22
PPM COPPER	8	9
PPM MANGANESE	65	71
PPM MOLYBDENUM	1.6	1.8

B

ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% Moisture	8.9	******
% Dry Matter	91.1	******
% Crude Protein	6.3	6.9
% Adjusted Crude Protein	6.3	6.9
% Acid Detergent Fiber	34.0	37.3
% Neutral Detergent Fiber	52.8	58.0
% NonFiber Carbohydrates	23.7	26.0
% TDN	55	60
NEL. (Mcal/LB)	.51	.56
NEM. (Mcal/LB)	.51	.55
NEG. (Mcal/LB)	.27	.30
Relative Feed Value		96
% Calcium	.32	.35
% Phosphorus	.15	.16
% Magnesium	.14	.15
% Potassium	1.53	1.68
% Sodium	.021	.023
PPM Iron	95	104
PPM Zinc	19	21
PPM Copper	11	12
PPM Manganese	36	40
PPM Molybdenum	.9	1.0

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Analysis Results

Components	As Fed	DM
% Moisture	6.9	
% Dry Matter	93.1	
% Crude Protein	16.0	17.1
% Available Protein	14.6	15.7
% ADICP	1.3	1.4
% Adjusted Crude Protein	16.0	17.1
Soluble Protein % CP		32
Degradable Protein %CP		67
% NDICP	4.6	5.0
% Acid Detergent Fiber	32.1	34.5
% Neutral Detergent Fiber	49.8	53.5
% Lignin	1.6	1.7
% NFC	12.2	13.1
% Starch	1.8	2.0
% WSC (Water Sol. Carbs.)	10.1	10.8
% ESC (Simple Sugars)	5.9	6.3
% Crude Fat	4.9	5.2
% Ash	14.84	15.94
% TDN	58	62

How to Read a Forage Report

- Forage testing is a critical part of ensuring adequate quality forage for the animal
- Forage reports have many numbers that need to be interpreted

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Forage Quality Measures

Dry matter: How stable is your forage? Moisture content will depend on method of storage

Crude protein: Is there sufficient protein for the animal?

Neutral Detergent Fiber: How mature is the forage and can the animal consume sufficient amounts?

Mineral: Are they adequate and appropriately balanced for animal needs?

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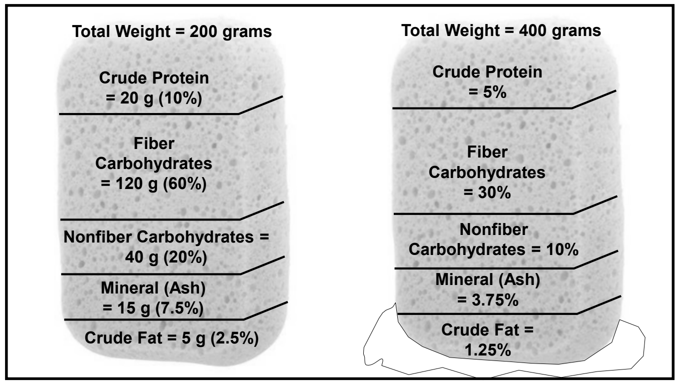

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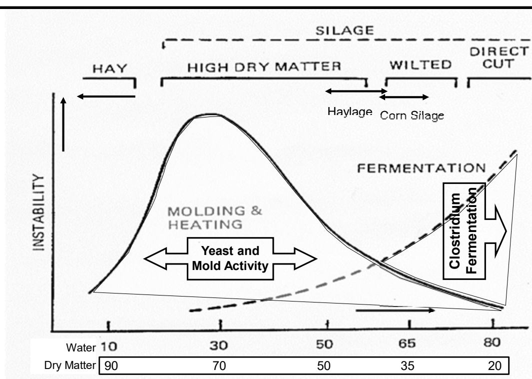

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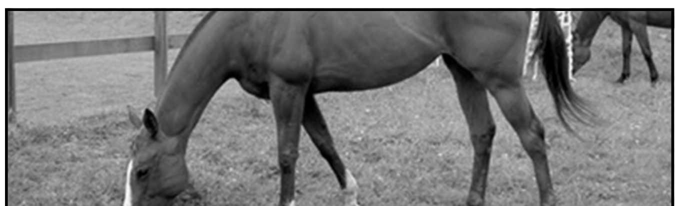

Forage Quality Concerns

- *Pregnancy toxemia*
- *Protein-energy malnutrition*
- *Pasture laminitis (horses)*

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Forage Quality Concerns

- High NDF reduces feed intake
  - NDF Intake: 1-1.2% BW
- Disease concerns:
  - Pregnancy toxemia – sheep, goats
  - Pregnancy toxemia, weak calves – beef cattle
  - Poor performance, weight loss – horses
  - Pasture laminitis in horses (high quality)

	TDN / CP / NDF	Sheep & Goat	Horses	Beef Cattle
Pregnancy	TDN	53-66%	53-55%	49-56%
	CP	10.5-15%	10-10.6%	7.5-10%
	NDF	30-40%	45-55%	35-45%
Lactation	TDN	55-68%	62-65%	55-60%
	CP	11-15.5%	11-13.2%	9-11%
	NDF	30-45%	45-55%	45-58%
Maintenance	TDN	50-53%	45-50%	46-52%
	CP	6.6-7.5%	8%	6-7.5%
	NDF	45-55%	48-60%	48-60%

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ANALYSIS RESULTS

Components	As Sampled	Dry Matter
% MOISTURE	6.1	#######
% DRY MATTER	93.9	#######
% CRUDE PROTEIN	4.3	4.6
% AVAILABLE PROTEIN		
% UNAVAILABLE PROTEIN		
% ADJUSTED CRUDE PROTEIN	4.3	4.6
% SOLUBLE PROTEIN		
% ACID DETERGENT FIBER	39.9	42.5
% NEUTRAL DETERGENT FIBER	62.4	66.5
% CRUDE FAT		
% QRQIIEHU#FDUERK\GUDWHV	18.5	19.7
% TDN	54	58
NET ENERGY-LACTATION (MCAL/LB)	0.56	0.60
NET ENERGY-MAINTENANCE (MCAL/LB)	0.54	0.57
NET ENERGY-GAIN (MCAL/LB)	0.29	0.31
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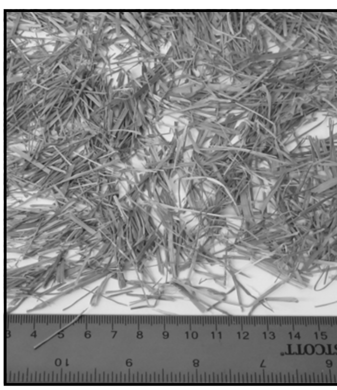

ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% Moisture	7.5	******
% Dry Matter	92.5	******
% Crude Protein	11.5	12.4
% Adjusted Crude Protein	11.5	12.4
% Acid Detergent Fiber	26.7	28.9
% Neutral Detergent Fiber	40.3	43.6
% NSC	32.2	34.8
% TDN	59	64
NEL. (Mcal/LB)	.61	.65
NEM. (Mcal/LB)	.58	.63
NEG. (Mcal/LB)	.34	.37
Relative Feed Value		142
% Calcium	.37	.40
% Phosphorus	.25	.27
% Magnesium	.23	.25
% Potassium	2.06	2.23
% Sodium	.047	.051
PPM Iron	151	164
PPM Zinc	34	37
PPM Copper	12	13
PPM Manganese	136	147
PPM Molybdenum	.5	< 1

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Macromineral Diseases

- *Milk fever, Lambing sickness, Eclampsia: Hypocalcemia*
- *Grass tetany, Transport tetany: Hypomagnesemia*
- *Rickets and Osteomalacia: Calcium, Phosphorus, Vitamin D deficiency*
- *Urolithiasis, Water belly: Phosphorus excess, imbalance*

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Milk Fever: Hypocalcemia

- Disease resulting from low blood calcium concentration
- Animal is weak and becomes recumbent leading to coma and death
- Occurs prior to birthing up to peak milk production
- Association with other diseases
- Generally older animals affected

Photos: www.sheepandgoat.com; https://www.nadis.org.uk/disease-a-z/cattle/

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Grass Tetany: Hypomagnesemia

- Inadequate magnesium and calcium concentration in blood
- Signs:
  - Early hyperexcitability, nervousness
  - Muscle twitching, stiff gait
  - Acute tetany and convulsions
- Etiology:
  - Inadequate dietary Mg (grasses) coupled with high K
  - Organic acids bind Mg
  - Mg only absorbed in rumen

Photo: Robert Van Saun

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Rickets

- Metabolic bone disease of young growing animal
- Potential causes are deficiencies in:
  - Calcium
  - Phosphorus
  - Vitamin D
  - Combination of all
- Low Ca:P ratio in forage
- Lack of exposure to sunshine

Photo: Robert Van Saun

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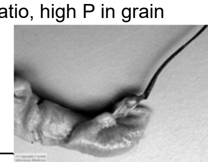
Urolithiasis

- Mineral blockage of male urethra
- Clinical presentation
  - Depends upon degree of blockage and
  - Severity of surrounding tissue reactions
- Problem more in feedlot high grain diets
- Low forage Ca:P ratio, high P in grain supplements
- Excess Ca intake



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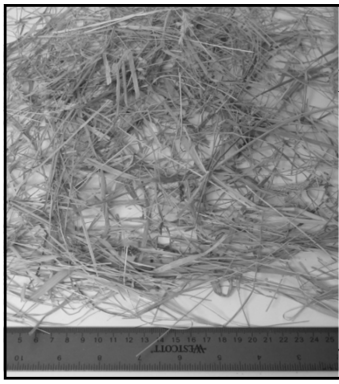

ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% MOISTURE	7.8	******
% DRY MATTER	92.2	******
% CRUDE PROTEIN	9.4	10.2
% ADJUSTED CRUDE PROTEIN	9.4	10.2
% ACID DETERGENT FIBER	36.1	39.2
% NEUTRAL DETERGENT FIBER	55.6	60.3
% NSC	18.7	20.3
% TDN	55	60
NEL, (MCAL/LB)	0.57	0.62
NEM, (MCAL/LB)	0.55	0.60
NEG, (MCAL/LB)	0.31	0.34
% CALCIUM	0.20	0.22
% PHOSPHORUS	0.30	0.32
% MAGNESIUM	0.15	0.16
% POTASSIUM	3.17	3.44
% SODIUM	0.013	0.014
PPM IRON	85	92
PPM ZINC	18	20
PPM COPPER	6	7
PPM MANGANESE	86	93
PPM MOLYBDENUM	1.7	1.8

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Trace Mineral Disease Conditions

- *Copper Deficiency and Toxicity disease conditions*
- *Goiter: Iodine deficiency*
- *White muscle disease: Selenium deficiency*

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Copper Deficiency

- Inadequate dietary copper or availability of copper
- High iron, sulfur and molybdenum can interfere with copper in ruminants, not horses
- Signs:
  - Reproductive inefficiency
  - Weak, stillborn newborns
  - Greater disease susceptibility
  - Angular limb deformities in foals

Goat kid from farm experiencing high rate of stillborn and early death neonates. Only copper deficiency was diagnosed.

Photo: Dr. Paul Hunter

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% CALCIUM	.38	.41
% PHOSPHORUS	.28	.30
% MAGNESIUM	.25	.27
% POTASSIUM	1.58	1.71
% SODIUM	.348	.377
PPM IRON	155	168
PPM ZINC	25	27
PPM COPPER	7	8
PPM MANGANESE	101	110
PPM MOLYBDENUM	2.4	2.6
% SULFUR		

Mineral Ratio	Value	Desired
Ca : P	1.4 : 1	> 2 : 1
K : Mg	6.3 : 1	< 8 : 1
Cu : Mo	3.1 : 1	6-10 : 1
Fe : Cu	21 : 1	>25 : 1

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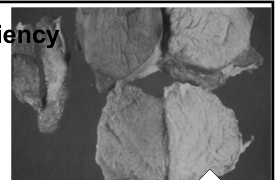
White Muscle Disease: Se Deficiency

- Pa is Se deficient state
- Mostly affects young, but any age or species can be affected
- Muscles affected:
  - Legs – stiffness, difficulty rising
  - Heart – fetal or neonatal death
  - Tongue – difficulty nursing



White-colored, gritty muscle fibers

Photo: Robert Van Saun; Cornell University

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Forage is Critical to Profitability

- Farm profitability is a function of:
  - Good female fertility
  - High survival of offspring
  - Efficient growth and lactation productivity
- Low feed costs
  - High forage diets
  - Minimal purchased feeds

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Questions?

Dr. Robert Van Saun, Extension Veterinarian, email: rjv10@psu.edu

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Determining Forage Quality: Understanding Feed Analysis

Learn how to use feed analysis to determine forage quality, and exactly what feeding a high quality forage means.

ARTICLES | UPDATED: SEPTEMBER 18, 2013

A goal for any feeding program is to achieve an appropriate balance among available feed ingredients where total ration nutrient composition meets daily nutritional needs of the animal or animals. To accomplish such a feat on a day-to-day basis, one needs to have some information as to the nutrient content of feed ingredients. Tremendous variation exists in nutrient composition between different feeds. Even within a feed ingredient, there is potential for significant variation in composition. This is especially true for forages. Forages harvested off the same field within the same year can have very different composition as influenced by environmental conditions and cutting time. In a previous column, the concept of forage quality was defined and its affect on a feeding program described. Low quality forages have less available nutrients, thus require larger amounts of supplements to be added. Unsupplemented low quality forages may predispose pregnant or lactating females to hepatic lipidosis or slow rate of gain in growing animals. Supplemental feeds are often cereal grain based and their over consumption may increase risk of digestive upsets and acidosis. In this column I will address forage testing practices as they relate to evaluating quality of your forage.

A variety of biologic, chemical, enzymatic, and other sophisticated analytical methods are used to evaluate nutrient content and availability of feeds. Chemical methods can directly measure quantities of compounds associated with an essential nutrient; however, they tell us nothing about availability. Biologic, enzymatic, and other sophisticated methods provide a more nutritional perspective to feed analysis; thus helping us to better understand just how the animal will interact with its feed. More information is needed to routinely apply these analytical techniques to feeding camelids. The most practical approach to feed analysis is one of chemical composition--direct determinations of moisture, ether extract (fat), ash (mineral), nitrogen (crude protein), and fiber fractions. A comparison between required essential nutrients, feed chemical composition, and analytic methods used in feed analysis is summarized in Figure 1. Although wet chemistry analysis is considered the "gold standard" for feed testing, simpler and less expensive methods with shorter turnover time were needed. Newer technologic advances have brought a rapid, lower cost analytical technique termed near infrared reflectance (NIR) spectroscopy. In general, NIR analysis has high accuracy in measuring crude protein and fiber fractions compared to wet chemistry, but is less accurate in measuring feed mineral content. Many certified feed analysis laboratories are capable of completing wet chemistry, NIR analyses, or both. Certified feed analysis laboratories around the world can be found through the National Forage Testing Association website. This site also provides information on how to take a representative feed sample for analysis. The basic tests to evaluate forage quality described below can be determined by most laboratories at a cost between $12 and $30 depending upon methodology used (wet chemistry vs. NIR) and number of tests performed.

Figure 1. Comparison of essential nutrients, feed chemical composition, and analytical testing procedures.

<table>
<tr><td colspan="2">Essential Nutrients</td><td>Chemical Components</td><td colspan="2">Analytical Procedures</td></tr>
<tr><td colspan="2">Fatty acids, Fat-soluable vitamins</td><td>Lipids, pigments, sterols</td><td colspan="2">Ether Extract</td></tr>
<tr><td colspan="2">Protein, amino acids</td><td>Nitrogen-containing compounds - Protein, Nonprotein nitrogen</td><td colspan="2">Kjeldahl Procedure
(Crude Protein)</td></tr>
<tr><td colspan="2">Inorganic minerals</td><td>Ash</td><td colspan="2">Ashing (complete combustion)</td></tr>
<tr><td rowspan="6">Carbohydrates</td><td rowspan="2">Glucose</td><td>Sugars</td><td rowspan="2">Nonstructural Carbohydrates**</td><td rowspan="3">Nonfiber Carbohydrates+</td></tr>
<tr><td>Starches</td></tr>
<tr><td rowspan="4">Dietary Fiber</td><td>Soluable Fiber</td><td></td></tr>
<tr><td>Hemicellulose</td><td></td><td rowspan="3">Neutral Detergent Fiber</td></tr>
<tr><td>Cellulose</td><td rowspan="2">Acid Detergent Fiber</td></tr>
<tr><td>Lignin*</td></tr>
<tr><td colspan="5">*Lignin is not truly a carbohydrate compound but is so intimately associated with cell wall carbohydrates that it is often included as such.
**Newer methods are being used to measure starch content.
+Determined by difference (100 - CP - EE - NDF - Ash).</td></tr>
</table>

Determinants of Forage Quality

As previously described, forage quality reflects the ability of a given forage to meet the nutrient needs of the consuming animal. Forage fiber content is the primary detractor to high intake and nutrient availability. Relative to assessing forage quality, fiber tests are our single best method, though additional tests for protein and moisture can help to further characterize the forage. The following are brief descriptions of forage analysis tests and their interpretation relative to forage quality.

Dry Matter (DM)

Dry matter is defined as the non- moisture portion of a feed ingredient or diet. The sum of moisture and dry matter content of a feed on a percent of total will always equal 100. Dry matter contains the essential nutrients within a given feed ingredient or forage. Feeds, and thereby diets, vary widely in their moisture content. Pastures and liquid feeds have moisture content between 75 and 90% (10-25% DM). Dried feeds usually have less than 15% moisture (>85% DM). Moisture or dry matter content of a feed is determined by heating a weighed sample of feed in a convection drying oven until a constant weight is reached (24-48 hours). Dry weight is expressed as a ratio to original sample weight (moisture + DM) or converted to a percent. For example, a feed sample weighs 150 g wet and 50 g dry. The DM ratio would be 0.33 (50/150) and percent DM 33.3% (50/150 x 100). The moisture content of this feed would be 66.7% (100-33.3 or [150-50]/150 x 100).

Why is knowing moisture content important? One important aspect is our ability to compare nutrient content of different feeds on an equal basis. Nutrient content of a feed can be determined on an "As Fed" (AF; moisture included), or dry matter (moisture excluded) basis. Intuitively, nutrient content will always be higher on a DM compared to AF basis for any feed. Feeds having more water content (i.e., pastures) will have much lower nutrient content than dry hay when compared on an as fed basis. From Table 1, it can be seen the pasture has much lower nutrient content on an AF basis; however, when corrected for water content, both pasture and hay have equal nutrient content. To appropriately compare these two feeds equally, nutrient content needs to be converted to a DM basis. Feed moisture determinations also facilitate calculations and monitoring of animal DM intake. Finally, DM determinations can be used to evaluate whether or not feed moisture content is within expected ranges. For hay or any dry feed, moisture content should not exceed 15%, as this amount of moisture is necessary to promote mold growth.

Table 1. Comparison of nutrient content expressed on As Fed (AF) or Dry Matter (DM) basis for generic grass pasture and hay.

	Nutrient Density Basis*	% Nutrient Content				
		DM	Protein	NDF	ADF	Calcium
Grass Pasture	AF	20	2.2	11.0	8.0	0.12
	DM	100	11.0	55.0	40.0	0.60
Grass Hay	AF	90	9.9	49.5	36.0	0.54
	DM	100	11.0	55.0	40.0	0.60
*Conversion formula: As Fed nutrient content = DM nutrient content x DM ratio or DM nutrient content = As Fed nutrient content/DM ratio. DM ratio is 0.2 for pasture and 0.9 for hay in this example.						

Fiber

The detergent feed analysis system is used to characterize fiber or total cell wall content of a forage or feed. That portion of a forage or feed sample insoluble in neutral detergent is termed *neutral detergent fiber (NDF)*, which contains the primary components of the plant cell wall, namely, hemicellulose, cellulose, and lignin. As cell wall production increases, as occurs in advancing plant maturity, NDF content will increase. As NDF content of a feed increases, dry matter intake will decrease and chewing activity will increase. Within a given feed, NDF is a good measure of feed quality and plant maturity. For legume forages, NDF content below 40% would be considered good quality, while above 50% would be considered poor. For grass forages, NDF < 50% would be considered high quality and > 60% as low quality.

Another measure of fiber is *acid detergent fiber (ADF)*, a subset of NDF. Acid detergent fiber contains the poorly digestible cell wall components, namely, cellulose, lignin, and other very resistant substances. Due to its nature, ADF is often used to predict energy content of feeds. Like NDF, ADF is a good indicator of feed quality; higher values within a feed suggest lower-quality feed. A goal would be to have < 35% ADF in either legume or grass forages. Refer back to table 1 shown in the first column (page 33 in June 2006 issue) for the changes in NDF and ADF with forage maturity.

Crude Protein (CP)

Feed protein content is often considered a good determinant of quality. In actuality protein cannot be directly measured, it is estimated from feed sample nitrogen (N) content. On average all biological proteins contain 16% N, therefore protein content is estimated by multiplying N% by 6.25 (6.25 = 1) 0.16). Thus, crude protein does not differentiate between N in feed samples coming from true protein or other nonprotein nitrogen (NPN) compounds, nor does it differentiate between available and unavailable protein.

Although issues have been raised concerning application of crude protein as a feed measure, it continues to be a commonly used measure of feed quality. Crude protein content is very different across feeds, but within a feed, higher protein is usually associated with higher quality. This certainly is true in forages. As forages mature, their crude protein is diluted with increasing fiber content. Forage fertilization practices can alter this relationship, suggesting crude protein should not be solely used as a quality criterion without evaluating fiber content.

Energy

Energy content is often used to compare feeds and evaluate quality. Feed energy content is not directly measured like other nutrients but derived through regression equations. Traditionally ADF alone or with CP were used to predict energy value of various feeds. Most laboratories report feed energy values based on cattle equations, reporting total digestible nutrients (TDN) and net energy (NE) values. The question is how applicable are these predicted values to camelids? Cattle TDN values are the best estimate we have and should reasonably reflect feed energy for llamas and alpacas given the similarity in digestive function. In comparison, predicted cattle feed energy availability would be inappropriate for use in swine or horse diets given anatomic and physiologic differences in digestive capacity. However, in considering the differences in fiber degradability between ruminants and camelids, one would anticipate that cattle energy predictions may be too low for lower-quality forages.

In Figure 1, a large portion of feed carbohydrates, especially those associated with higher digestibility and glucose production, are not measured. The neutral detergent soluble carbohydrate fraction of feed is termed nonfiber carbohydrates (NFC). This fraction is not directly measured, but determined by difference. Inherently, all laboratory analytical method errors associated with other feed fractions will be compiled into the NFC fraction. Although susceptible to error, NFC represents a highly available portion of a feed and as such positively reflects on evaluation of feed quality. More recently some laboratories have offered an enzymatic analysis for feed starch content; helping to further define the more digestible portion of NFC, termed *nonstructural carbohydrates (NSC)*. Higher values for NFC and NSC would reflect higher quality forages. For grasses and legume forages, NFC values >20 and >30%, respectively, would be considered higher quality, especially if associated with lower fiber values.

Other Feed Fractions

Additional analyses may be completed on a feed sample, including fat content (ether extract) and mineral analysis. Ether extract is a chemical method by which all lipid (fat) soluble compounds are extracted by being dissolved in ether (Figure 1). This technique is of little value in evaluating feed quality except in the cases of comparing feeds with high fat content.

Total feed mineral content can be measured by a procedure where the feed sample is completely combusted into ash. This does not separate out any individual minerals and does not separate macro- and microminerals of interest from silica and other less important minerals. Selected macrominerals (calcium, phosphorus, magnesium, potassium, sodium, and sulfur) and microminerals (iron, copper, zinc, manganese, and molybdenum) can be determined using sophisticated wet chemistry atomic absorption spectroscopy. As previously stated, NIR analyses are not very accurate in determining feed mineral content. Mineral analysis is not always done since it is the most expensive test. Feed mineral content has no bearing on feed quality evaluation, but can provide insight as to the type of mineral supplement required.

Visual Assessment of Forage Quality

Although forage testing is the most definitive method of determining forage quality, it often is not complete. Associated costs, lack of laboratory availability or constant forage turnover are the most often reasons people cite for not testing their forages. The first two reasons are not good excuses; however, the third is an issue on many farms that purchase small lots of hay often. One can use their various senses to evaluate small amounts of forages, though sensory evaluation does not provide any sense of nutrient content. Table 2 summarizes visual and chemical analysis of forages with guidelines for assessing quality.

Testing Method	Description/Comment
Sensory Evaluation	
Visual	
Stage of maturity	Look for the presence of seed heads (grass forages) or flowers or seed pods (legumes), indicating more mature forages
Leaf to Stem ratio	Look at forage and determine whether the stems or leaves are more obvious; good-quality legume forages will have a high proportion of leaves, and stems will be less obvious and fine
Color	Color is not a good indicator of nutrient content, but bright green color suggests minimal oxidation; yellow hay indicates oxidation and bleaching from sun, and hay will have lower vitamins A and E content
Foreign Objects	Look for presence and amount of inanimate objects (twine, wire, cans, etc.), weeds, mold, or poisonous plants
Touch	Feel stiffness or coarseness of leaves and stems; see if alfalfa stems wrap around your finger without breaking; good-quality hay will feel soft and have fine, pliable stems
Smell	Good quality hay will have a fresh mowed grass odor; no musty or moldy odors
Chemical Testing	
Moisture/Dry Matter	Measures amount of moisture in forage; moisture content will determine how well the forage will store without molding; Goal for any hay <15% moisture (>85% dry matter)
Neutral Detergent Fiber	Measures total cell wall content of plant and indicates maturity; the higher the value, the more mature and lower quality the forage; Goal < 40% Alfalfa and < 55% Grasses
Acid Detergent Fiber	Measures the more indigestible portion of cell wall and reflects degree of lignification; Higher values indicate more mature, lower quality forages; Goal: < 35% Alfalfa and < 35% Grasses
Crude Protein	Crude protein content reflects maturity of forage as well as fertilization amount; Good-quality forages generally will have higher protein content; Goal > 9% Grasses and >15% Alfalfa

Although the general idea is that forages grown in North America are of better quality than South American forages, forage quality can not be ignored in our feeding programs. Many factors influence forage quality, the most critical being plant maturity. Feeding programs consisting of low quality forage and limited variety of feedstuffs can potentially result in protein- energy malnutrition, failure to thrive and hepatic lipidosis disease problems. There is no best single feeding program that fits all situations, but extremes of only high quality alfalfa hay or low quality grass hay are not appropriate. Feeding programs with pasture access may have the greatest application, allowing the animals to best express their selective feeding behaviors. When hay is the primary forage in a feeding program, critical assessment of nutrient content via laboratory analysis is highly recommended. Further questions or comments about forage quality and nutrition are welcomed.

Understanding Your Forage Test Results

S. Arispe and S. Filley

Forage analysis is a management tool that gives you the information you need to properly balance livestock rations. Unfortunately, forage test results can be difficult to interpret and use without understanding the terminology. This publication defines and describes common terms found in most laboratory forage reports.

Taking a representative sample is an important step for forage testing (Figure 1). You can find instructions for proper sampling of hay for all species of livestock on the Oregon State University Beef Cattle Sciences website (http://blogs.oregonstate.edu/beefcattle/). To ensure accuracy, use laboratories that are certified by the National Forage Testing Association (http://www.foragetesting.org/).

Photo by Shelby Filley, © Oregon State University

Figure 1. Multiple core samples were taken with an approved hay probe, combined, and then submitted to the laboratory for testing.

Terms and Definitions

For the most part, forage laboratories conduct and report similar forage analysis tests. However, the presentation of results may be different among laboratories. See the sample test result sheet on page 5.

The following terms and definitions pertain to both ruminants and non-ruminants. Where differences occur, an explanation is included.

Feed

Moisture is the percent water in a sample.

As-fed is the actual feed, including moisture content, as it is offered to the animal. This feed is also called "as-sampled" or "as-received" if it has not been altered between sampling, testing, and feeding time.

Dry matter (DM) is the feed without the moisture:

$$DM\% = 100\% - Moisture\%$$

It represents everything in the sample—including protein, fiber, fat, minerals, and carbohydrates—without the water.

When balancing rations for livestock, be sure to correct for percentage DM. This is important for determining the actual quantities of feed (as-fed basis) to give your animals to meet nutrient requirements and/or performance expectations. For example:

Two sources of forage are available: one is 89% DM and the other is 40% DM. If you want your animals to consume 25 lb of DM, then on an as-fed basis the animals must eat 28.1 lb of the dryer feed and 62.5 lb of the wetter feed to consume equal amounts of DM.

$$25 \text{ lb DM} \div 89\% \text{ DM} = 25 \div 0.89 = 28.1 \text{ lb}$$
$$25 \text{ lb DM} \div 40\% \text{DM} = 25 \div 0.4 = 62.5 \text{ lb}$$

Sergio Arispe, Extension livestock and natural resources faculty; and Shelby Filley, Extension regional livestock and forage specialist, both of the Department of Animal and Rangeland Resources, Oregon State University

EM 8801
Revised November 2016

Oregon State University

Correcting for DM helps ensure that feeding programs provide the correct quantity of nutrients to meet management goals.

Dry matter basis (DM basis) means nutrient results for the sample with the water removed. Feeds vary in their moisture content, but nutrient content of feeds can be compared directly by disregarding the water.

For example, let's compare the crude protein (CP) content (see "Crude protein," below) of alfalfa-grass hay (90% DM) and corn silage (33% DM). Suppose the alfalfa-grass hay tested 9% CP and the corn silage tested 2.7% CP on an as-fed basis. Initially, it looks like the alfalfa-grass hay has CP levels three times higher than the corn silage. However, converting the nutritional value on a DM basis (without the water), the two feeds have relatively similar values:

The alfalfa-grass hay is 9 CP ÷ 0.9 DM = 10% CP

The corn silage is 2.7 CP ÷ 0.33 DM = 8.2% CP

Assuming equal dry matter (DM) intake, animals consuming the alfalfa-grass hay will get more CP compared to animals consuming corn silage.

Be sure to use DM values when you want to compare the nutritional value of different feeds. Also note that animal nutrient requirements are reported on a DM basis. Therefore, be sure to use those values when formulating diets.

Protein

Proteins are made up of amino acids. They are essential for reproduction, lactation, growth, and maintenance of the body.

Crude protein (CP) is an estimate of a feed's protein content. Most forage has a range of 4% to 24% CP on a DM basis. Laboratories measure the nitrogen (N) content of forage and then calculate CP as %N x 6.25. The factor 6.25 is used because protein is approximately 16 percent N (100 ÷ 16 = 6.25).

Crude protein includes both true protein and non-protein nitrogen (NPN). True proteins are organic compounds made up of amino acids. They are a major component of vital organs, tissue, muscle, hair, skin, milk, hormones, and enzymes. In contrast, molecules classified as NPN include urea, ammonia, and building blocks for proteins, such as amino acids and peptides. Dietary NPN may be useful when it is digestible and needed by rumen microbes.

Adjusted crude protein is the CP with adjustments for its availability to the animal. Some protein might be tied up with the fiber, making it indigestible.

Acid detergent insoluble nitrogen (ADIN or ADF-N) is a measure of the protein bound to fiber due to overheating of stored forage. This indigestible protein is called "heat-damaged protein." Some amount of ADIN is also the result of natural processes. If ADIN is significant, CP of a feed is listed as adjusted CP.

Carbohydrates

Carbohydrates are parts of the plant. They can be structural (cell wall components) or nonstructural (cell contents). Both serve as potential energy sources for the animal.

Structural carbohydrates

Neutral detergent fiber (NDF) measures three cell-wall components: hemicellulose, cellulose, and lignin. These carbohydrates give a plant structure and rigidity. Cellulose and hemicellulose can be partially broken down by microbes in the rumen to provide energy to the animal, but lignin is indigestible. Because of its bulk, NDF is negatively correlated with feed intake: the higher the NDF% of forage, the lower the intake. Generally, forages in Oregon range from 29% to 66% NDF on a DM basis.

Acid detergent fiber (ADF) is a measure of cellulose and lignin. It is negatively correlated with digestibility: the higher the ADF% of a forage, the lower the digestibility. Most forages in Oregon range from 24% to 51% ADF on a DM basis.

Nonstructural carbohydrates

Nonfiber carbohydrates (NFC) are starch and sugars inside the cell that can serve as energy sources for the animal.

Water-soluble carbohydrates (WSC) are a part of NFC. WSC include several types of sugars that are soluble in water, including an important one called fructan. It is important to note that WSC does not include starch.

Ether-soluble carbohydrates (ESC) are also a part of NFC. ESC include several types of sugars that are soluble in ether (a solvent for extracting certain compounds from feeds), but they contain only a small amount of the fructans. ESC do not include starch. WSC and ESC can be used to estimate how much of these certain carbohydrates (sugars) that may negatively impact horse health conditions (such as insulin insensitivity, laminitis, and colic) is in the feed.

Fat

Crude fat is comprised of fats, oils, and other compounds soluble in ether. Fats and oils contain 2.25 times the energy found in carbohydrates and proteins. They can be added to rations to increase energy concentration when feed intake is limited.

Energy

Energy is used in all biological processes and is essential for life. For livestock, specific energy requirements have been determined for reproduction, lactation, growth, and maintenance. Failure to supply adequate energy results in poor performance.

A feed's energy values usually are not measured directly but are calculated using equations and relationships with various nutrients that have been determined previously in animal experiments.

Total digestible nutrients (TDN) can be calculated several ways. Basically, TDN is the sum (total) of the digestible protein, digestible carbohydrates, and 2.25 times the digestible fat.

Ruminants: The main TDN value on the lab report is for use in ruminants.

Non-ruminants: A separate "TDN for horses" may be listed, usually at the bottom of the report.

Digestible energy (DE) is the total energy of the feed (gross energy) minus the energy remaining in the feces (fecal energy).

Non-ruminants: Be sure you use the "DE for horses" if you are formulating rations for them.

Net energy for maintenance (NE_m) is an estimate of the energy value of a feed to maintain animal tissue without gain or loss of weight. In formulating beef cattle and sheep rations, NE_m values include energy for maintenance plus energy for pregnancy and lactation.

Net energy for lactation (NE_l) is used to formulate rations for dairy cattle. NE_l estimates the energy available from the feed to support an animal's requirements for maintenance plus milk production during lactation, and for maintenance plus the final 2 months of gestation for dry, pregnant cows.

Net energy for gain (NE_g) is an estimate of a feed's energy value for body weight gain above the energy required for maintenance. It is used in ration balancing for ruminants when weight gain is desired (Figure 2).

Photo by Shelby Filley, © Oregon State University

Figure 2. Fast-growing steers require high-energy forage. Pasture in excellent condition will meet this requirement, whereas low to moderate quality hay will not.

Ash

Ash is the inorganic residue that remains when a forage is ignited in a furnace at a very high temperature and all the organic matter is burned. Ash consists of minerals.

Minerals

Minerals make up 3 to 5 percent of an animal's body weight on a DM basis and enable structural and physiological functions. They are classified into two groups: **macrominerals** (major minerals) that normally are present at greater levels in the animal body or needed in relatively larger amounts in the diet, and **microminerals** (trace minerals) that are present at lower levels or needed in very small amounts. Minerals cannot be synthesized; they must come from the diet (feed plus mineral supplement).

Macrominerals and their functions

Calcium (Ca)—bone and teeth formation, blood clotting, muscle contraction, transmission of nerve impulses, cardiac regulation, and enzyme function. Calcium is also a component of milk.

Phosphorus (P)—bone and teeth formation, key component of energy metabolism, body fluid buffer systems. Phosphorus is also a component of milk.

Sodium (Na)—muscle contraction, nerve transmission, acid–base balance, osmotic pressure regulation and water balance, glucose uptake, and amino acid transport

Chloride (Cl)—osmotic pressure regulation and water balance, acid–base balance, component of gastric secretions

Magnesium (Mg)—enzyme activator, found in skeletal tissue and bone, neuromuscular transmissions

Potassium (K)—osmotic pressure regulation and water balance, electrolyte balance, acid–base balance, enzyme activator, muscle contraction, nerve impulse conductor

Sulfur (S)—used for microbial protein synthesis, especially when NPN is fed

Microminerals and their functions

Cobalt (Co)—required for vitamin B_{12} synthesis

Copper (Cu)—required for hemoglobin synthesis and coenzyme functions

Fluoride (F)—prevents tooth decay

Iodine (I)—required for proper thyroid function and to guard against goiter, stillbirths, and woolless lambs

Iron (Fe)—hemoglobin and oxygen transport, enzyme systems

Manganese (Mn)—growth, bone formation, enzyme activation, fertility

Molybdenum (Mo)—component of enzymes, may enhance rumen microbial activity

Selenium (Se)—antioxidant properties, prevention of white muscle disease and retained placenta

Zinc (Zn)—enzyme activation, wound healing, skin health, some positive impact on udder health

pH, Nitrates, RFV and RFQ

pH measures the degree of acidity. Good corn silage typically has a pH of 3.5 to 4.5, and haylage or baleage a pH of 4.0 to 5.5.

Nitrates. Forage plants can accumulate nitrates under stressed conditions such as drought, freezing, or heavy fertilization. Corn, sorghum, sudangrass, and oat hay tend to accumulate nitrates more easily compared to other plants.

Forage with nitrate nitrogen levels of less than 1,000 ppm are safe to feed. Those with nitrate levels higher than this are problematic. Learn more about nitrates in feeds for all classes of livestock from the Oregon State University Beef Cattle Library (http://blogs.oregonstate.edu/beefcattle/).

Relative Feed Value (RFV) and **Relative Forage Quality (RFQ)** are terms used to compare forage quality. They are an objective way to determine a market value for forages. They are not used for balancing livestock rations.

A RFV or a RFQ of 100 is assigned to full-bloom alfalfa hay for "relative" comparisons. The higher the RFV or RFQ, the better the forage quality. The RFV is based on the concept of an animal's potential digestible DM intake of forage, and is calculated from forage ADF and NDF. RFQ uses TDN and NDF to estimate intake.

Dairy One

FORAGE LABORATORY
730 Warren Road, Ithaca, NY 14850
Ph: 800.496.3344 Fax: 607.257.1350
http://www.dairyone.com

DATE SAMPLED	LAB RECEIVED	DATE PRINTED	LAB USE
	02/13/14	02/14/14	.919

ADDITIONAL DESCRIPTIONS
LOT D ALFALFA

JOHN A FARMER
123 STREET
SOMEWHERE, NY 12345

ENERGY TABLE - NRC 2001		
	Mcal/Lb	Mcal/Kg
DE, 1X	1.25	2.75
ME, 1X	1.05	2.32
NEL, 3X	0.60	1.32
NEM, 3X	0.63	1.39
NEG, 3X	0.37	0.81
TDN1X,%	59	

KIND DESCRIPTION	CODE	LAB SAMPLE
LEGUME HAY	100	3046900

DESCRIPTION 1
STANDARD

ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% Moisture	8.1	
% Dry Matter	91.9	
% Crude Protein	18.7	20.4
% Available Protein	17.6	19.2
% ADICP	1.1	1.2
% Adjusted Crude Protein	18.7	20.4
Soluble Protein % CP		47
Degradable Protein%CP		73
% NDICP	2.7	3.0
% Acid Detergent Fiber	28.2	30.7
% Neutral Detergent Fiber	36.9	40.2
% Lignin	5.9	6.4
% NFC	26.2	28.5
% Starch	.9	1.0
% WSC (Water Sol. Carbs.)	8.5	9.3
% ESC (Simple Sugars)	6.5	7.1
% Crude Fat	2.3	2.5
% Ash	10.42	11.34
% TDN	58	63
NEL, Mcal/Lb	.61	.66
NEM, Mcal/Lb	.58	.63
NEG, Mcal/Lb	.33	.36
Relative Feed Value		150
% Calcium	1.13	1.23
% Phosphorus	.20	.22
% Magnesium	.20	.22
% Potassium	1.50	1.63
% Sodium	.124	.135
PPM Iron	1,550	1,690
PPM Zinc	22	24
PPM Copper	11	12
PPM Manganese	42	46
PPM Molybdenum	1.1	1.2
% Sulfur	.21	.23
% Chloride Ion	.41	.45
IVTD 30hr, % of DM		78
NDFD 30hr, % of NDF		44
kd, %/hr		4.99
% Lysine	.95	1.04
% Methionine	.29	.32
Horse DE, Mcal/Lb	.99	1.08

Using the results

Once you have your forage test results, carefully go through each item and consider how the results will influence the way you use the feed in your livestock nutrition program. You can use the information to formulate a balanced ration for your livestock or for general feeding decisions (Figure 3).

You will need to understand the nutrient requirements for different livestock in order to match forage resources with animal needs. You can find these requirements in *Nutrient Requirements of Domestic Animals* (see "For more information") and other resources available through your local OSU Extension Service office (http://extension.oregonstate.edu/find-us) and from the OSU Extension Service Catalog (https://catalog.extension.oregonstate.edu).

Photo by Shelby Filley, © Oregon State University

Figure 3. Heifer development at the OSU Soap Creek Ranch requires rations with high quality alfalfa hay as a supplement to grass hay, which tests low in crude protein.

For more information

Nutrient Requirements of Domestic Animals (National Research Council, National Academy Press, Washington, DC). https://www.nap.edu/search/?term=Nutrient+Requirements+of+Domestic+Animals

Oregon State University Extension Service Catalog, "Beef Cattle." (https://catalog.extension.oregonstate.edu/topic/agriculture/beef-cattle)

Oregon State University Beef Cattle Extension Library. http://blogs.oregonstate.edu/beefcattle/extension-publications/

Oregon State University Beef Cattle Library. Sample Collection and Submission (http://blogs.oregonstate.edu/beefcattle/forage-evaluation/)

References

Undersander, D. and J. Moore. 2002. Relative Forage Quality (RFQ), Indexing Legumes and Grasses for Forage Quality. *Focus on Forage* 4, no. 5. University of Wisconsin Board of Regents

Understanding and Significance of Forage Analysis Results. Dairy One, Ithaca, NY. http://dairyone.com/wp-content/uploads/2014/01/Understanding-Significance-of-Forage-Results.pdf

Published April 2002. Revised November 2016.