Measuring Forage Quality: Sampling and Interpretation

Chris Teutsch, Forage Extension, UK Research and Education Center at Princeton

Forage quality is often described with terms like crude protein, neutral detergent fiber, acid detergent fiber, in vitro dry matter digestibility, neutral detergent fiber digestibility, and the list goes on! Perhaps the best definition of forage quality is the ability of a forage to produce a desired animal response. This concept is quite simple, but the process of getting from forage to actual animal performance is quite complex (Figure 1). It is important to realize that there is no perfect measure of forage quality. However, measures that are based on fiber digestibly provide better estimates of energy and dry matter intake.

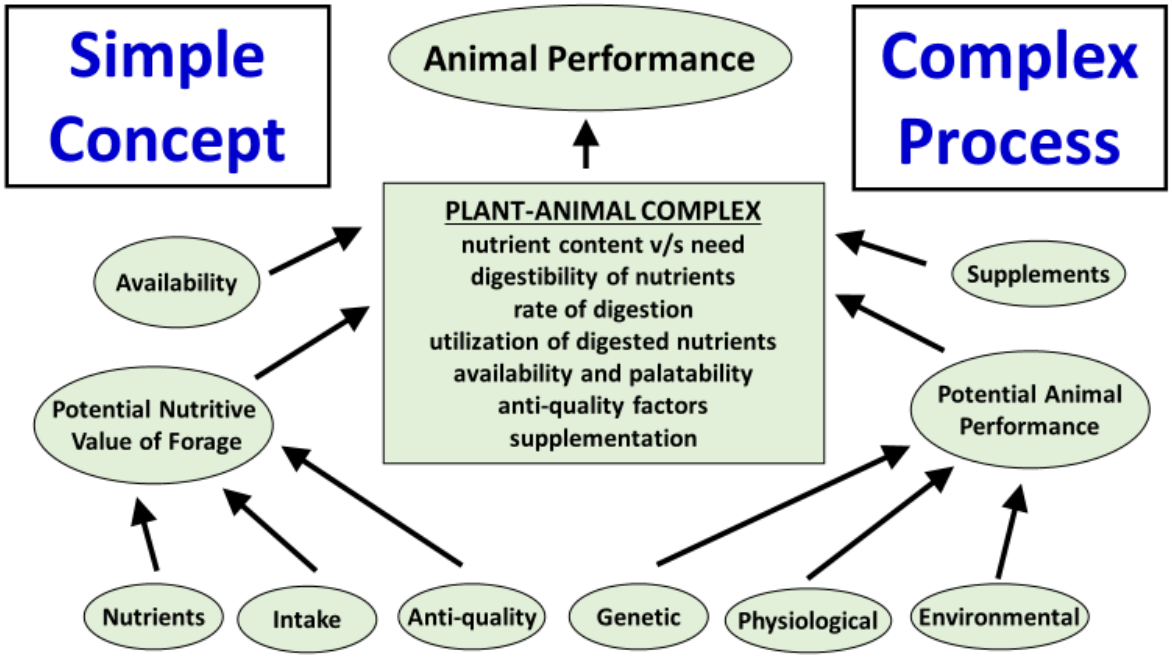


Figure 1. Forage quality is a simple concept, the ability of a forage to produce a desired animal response, but the process of getting to that animal response can be quite complex.

Getting a Representative Sample

Always use a hay probe to obtain representative sample. A representative sample starts with cores taken with a properly designed and maintained hay probe (Figure 1). Collecting grab samples or bale slices does NOT provide a representative sample. The hay probe should have internal diameter of at least 3/8 inches and a probe length of 15 to 18 inches.

Sample hay in lots. Hay should ALWAYS be sampled in lots. A lot consists of hay made from the same field and cutting. A lot should not represent more than 200 tons of dry matter. In the event that a lot exceeds 200 tons of dry matter, multiple samples should be taken and forage quality results should be averaged to represent the overall lot. It is very important the we keep track of where different hay lots stop and start (Figure 2). The quality from one hay lot to another can vary markedly.

Don't sample hay immediately after baling. Delay sampling until three to four weeks after baling for hay stored out of the weather. During this period bales undergo the heating or sweating process and forage quality can decline.

Sample hay stored outside just prior to feeding. Delay sampling hay stored outside until three to four weeks prior to feeding to account for weathering that occurs during the storage period.

Sample at least 20 bales from each hay lot. A representative sample will consist of at least 20 cores from 20 bales (one core per bale) resulting in a sample size of approximately one-half pound of hay from each lot. Sample bales at random and NOT on some predetermined characteristic such as leafiness, color, or weed content.

Remove weathered material prior to sampling. For round bales stored outside, remove weathered material from the area to be probed prior to sampling. Weathered material represents refusal and should not be included in the sample.

Core rectangular bales from the end. Center the hay probe in the end of the bale and insert at least 15-18 inches.

Core round bales from the side. Sample round bales by drilling or pushing the probe horizontally into center of the rounded side of the bale at least 15-18 inches (Figure 2).

Submit the entire sample for analysis. Do NOT subdivide the hay sample. This can result in the loss of smaller pieces of the sample that tend to be higher in nutritional value (Figure 3).

Do NOT submit excessively large samples. Forage testing labs will subdivide samples. They will NOT grind entire sample. This can significantly impact test results. The sample submitted should be no larger than one-half pound.

Clearly label samples. The entire sample should be placed into a labeled plastic bag and sealed. Make sure that the bag is clearly labeled with your farm's name, a description of the hay lot sampled that will allow you to reference the results back to the hay lot, the type of hay, cutting, and year, and the date it was sampled.

Submit samples immediately. The sample should be sent immediately to the lab for analysis. Make sure and complete the sample submission form for the lab that you are using.

Use a certified lab. Make sure and use a lab that has been certified for accuracy and precision by the National Forage Testing Association. A list of certified labs can be found on the National Forage Testing Association webpage.

Sampling Baled Silage. Sample baled silage in the same manner as hay. Delay sampling until at least four weeks after harvest to allow complete ensiling. Samples should be placed into labeled plastic bags as previously described. Submit the samples immediately or refrigerate until shipped. Remember to immediately repair holes caused by coring using a UV-resistant tape designed for silage film.

Figure 2. Always use a hay probe to sample bales. Round bales should be sampled from the sides and square bales from the ends. Never submit a "grab" sample or a flake of hay.

Figure 3. Make sure and keep track of where different hay lots are located. This can be accomplished by labeling where lots start and stop and drawing maps. This best done when hay is moved from the field to its storage location. This will help with sampling later.

Figure 4. Never subdivide a sample before submitting it to the lab. Core samples are made up of both large and small particles that can segregate making it difficult to get a representative subsample. In this photo the fine particles have move to the bottom of the bag.

Interpretation and Use of Forage Test Results

Once you get your results back, you will need to determine if the hay will meet the needs of your cows at a given production stage. Animals that are growing or lactating have a higher nutritional requirement than dry cows in mid-gestation (Table 1).

Table 1. Nutritional requirement of various livestock classes.

Animal Class	Total Digestible Nutrients (%)	Crude Protein (%)
Growing steer @ 1.7 lb/day	68	11
Lactating beef cow	60	11
Dry beef cow	50	8
Lamb finishing	70	12
Lactating ewe	65	13
Dry ewe	55	9

Adapted from Southern Forages, Third Edition.

Forage testing Terminology

Hay test results are often a maze of unfamiliar terms and abbreviations. I want to take a few moments to define some of the key analyses and how they are used in ration formulation.

Dry matter (DM). The portion of the sample that is not water. When comparing forage samples or balancing rations, it should always be done on a dry matter basis.

As fed, as is, or as received. Constituent values that are on an "as is" basis are adjusted for the moisture in the samples when it was received at the lab. This values help to determine how much actual hay or silage should be fed in a ration.

Neutral Detergent fiber (NDF). Neutral detergent fiber represents the residue remaining after boiling a forage sample in neutral detergent solution. It contains the indigestible and slowly digestible components in plant cell walls, including cellulose, hemicellulose, and lignin. Neutral detergent fiber is often used to provide an estimate, albeit rough, of how much of the given forage that the animal will be able to eat in a day. This is done using the following using the following formula: Dry Matter Intake as % Body Weight = 120 / %NDF.

Acid detergent fiber (ADF). Acid detergent fiber is the residue remaining after boiling a forage sample in an acid detergent solution. It contains cellulose, lignin and silica, but not hemicellulose. The results are often used to estimate energy in forage samples. These values that are commonly expressed as total digestible nutrients (TDN) or net energy for lactation (NEL).

Crude protein (CP). In most cases, protein in forage samples is not directly measured, but rather estimates by multiplying the total N (%) by 6.25. This value is used to formulate rations. Because this is not a perfect representation of protein in the sample, it is referred to as "crude protein".

T*otal Digestible Nutrients (TDN).* Total digestible nutrients provide an estimate of energy in forage. This estimate is most commonly used to formulate rations for beef cattle. There are two approaches to estimating TDN. The first and more accurate approach is the summative. It utilizes multiple assays including crude protein, fat, non-structural carbohydrates, and digestible fiber to estimate energy. The more commonly used approach is based on a single assay, most commonly ADF.

Hay Test Example

The results found in Table 2 clearly indicate that these grass hay sample will NOT meet the nutritional requirements of a fall calving cow that is lactating. This hay will need to be supplemented in order to maintain body condition and production. The question then becomes with what and how much? The UK Beef Cow Forage Supplement Tool is an

application that can be used on-line or downloaded to your smart phone. This application allows you to enter the results from your forage test (dry matter, neutral detergent fiber, crude protein, and total digestible nutrients) and gives you a range of supplement options and how much of each supplement must be fed to meet the cow's nutritional requirements (Table 3). The UK Beef Cow Forage Supplement Tool can be found on-line at http://forage-supplement-tool.ca.uky.edu/. This application indicates that the hay samples found in Table 2 would need to be supplemented with 10.6 and 15.2 lb of soybean hulls daily (Tables 4 and 5).

Table 2. Hay test results. Constituents highlighted in yellow are required to use the UK Beef Forage Supplementation Tool.

Hay Samples	**Grass Hay-1**		**Grass Hay-2**	
	%		%	
Dry Matter	89.8		88.1	
Moisture	10.2		11.9	
Constituent	**Dry Matter Basis**	**As Fed Basis**	**Dry Matter Basis**	**As Fed Basis**
	%	%	%	%
Crude Protein	8.6	7.7	6.7	5.9
Acid Detergent Fiber	42.3	38.0	43.9	38.7
Neutral Detergent Fiber	66.3	59.6	67.3	59.3
Total Digestible Nutrients	53.0	47.6	52.5	46.3

Table 5. Steps for utilizing UK Beef Cow Forage Supplement Tool found at [http://forage-supplement-tool.ca.uky.edu/.](http://forage-supplement-tool.ca.uky.edu/)

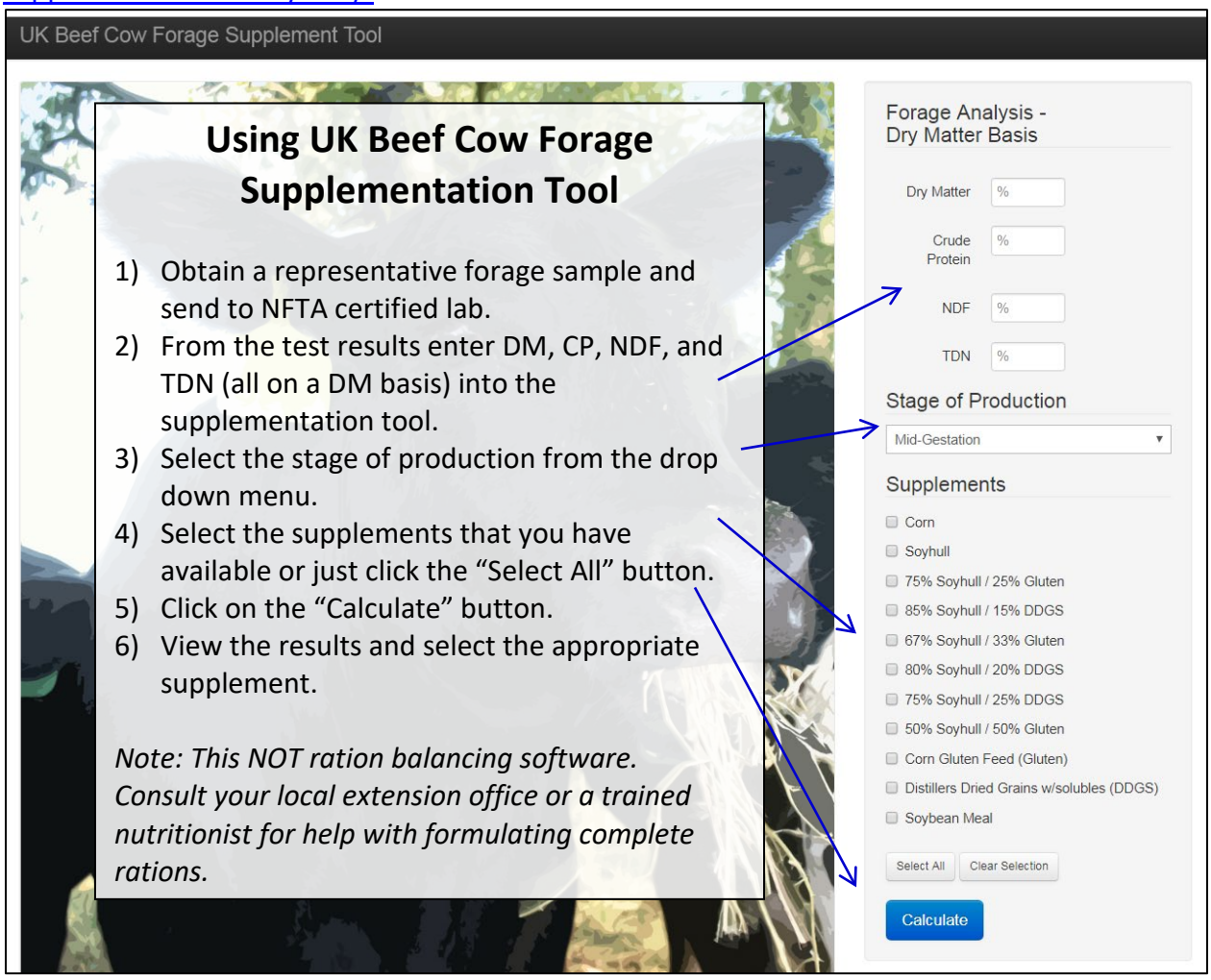


Table 6. Results from the UK Beef Cow Forage Supplement Tool for Grass Hay-1.

UK Beef Cow Forage Supplement Tool

Calculation Results

Lactation

Crude Protein: 8.6%
NDF: 66.3%
TDN: 53.0%

Expected daily intake of this forage for a 1250 lb cow is 1.81% of body weight, or 23 lbs on a dry matter basis, or 26 lbs on an as fed basis.

Protein	Supplement	Recommended Amount
8.5%	Corn *(6 lbs max)*	N/A
11%	Soyhull *(16 lbs max)*	10.6 lbs
13.75%	75% Soyhull / 25% Gluten *(16 lbs max)*	8.5 lbs
13.85%	85% Soyhull / 15% DDGS *(16 lbs max)*	8.5 lbs
14.6%	67% Soyhull / 33% Gluten *(16 lbs max)*	8 lbs
14.8%	80% Soyhull / 20% DDGS *(16 lbs max)*	7.9 lbs
15.75%	75% Soyhull / 25% DDGS *(16 lbs max)*	7.4 lbs
16.5%	50% Soyhull / 50% Gluten *(16 lbs max)*	7.1 lbs
22%	Corn Gluten Feed (Gluten) *(8 lbs max)*	6.2 lbs
30%	Distillers Dried Grains w/solubles (DDGS) *(8 lbs max)*	5.7 lbs
50%	Soybean Meal *(4 lbs max)*	N/A

Table 7. Results from the UK Beef Cow Forage Supplement Tool for Grass Hay-2.

UK Beef Cow Forage Supplement Tool

Calculation Results

Lactation

Crude Protein: 6.7%
NDF: 67.3%
TDN: 52.5%

Expected daily intake of this forage for a 1250 lb cow is 1.78% of body weight, or 22 lbs on a dry matter basis, or 25 lbs on an as fed basis.

Protein	Supplement	Recommended Amount
8.5%	Corn *(6 lbs max)*	N/A
11%	Soyhull *(16 lbs max)*	15.2 lbs
13.75%	75% Soyhull / 25% Gluten *(16 lbs max)*	12.2 lbs
13.85%	85% Soyhull / 15% DDGS *(16 lbs max)*	12.1 lbs
14.6%	67% Soyhull / 33% Gluten *(16 lbs max)*	11.5 lbs
14.8%	80% Soyhull / 20% DDGS *(16 lbs max)*	11.3 lbs
15.75%	75% Soyhull / 25% DDGS *(16 lbs max)*	10.6 lbs
16.5%	50% Soyhull / 50% Gluten *(16 lbs max)*	10.1 lbs
22%	Corn Gluten Feed (Gluten) *(8 lbs max)*	7.6 lbs
30%	Distillers Dried Grains w/solubles (DDGS) *(8 lbs max)*	6 lbs
50%	Soybean Meal *(4 lbs max)*	N/A

It is important to realize that both hay testing and the UK Beef Cow Forage Supplement Tool are NOT perfect. They are designed to get you in the ballpark and let you know if there is going to be a real problem with the hay that you are feeding. The true test is how your cows perform on a given hay lot. It is always a good idea to run your forage testing results by your local extension agent, veterinarian, or nutritionist. When it comes to hay feeding, it is important to be proactive rather than reactive. So make sure and test you hay and supplement accordingly before your cows loose condition and come up open.

This article is an adaptation of two articles published in the Cow Country News in September and October, 2019. These articles are available at https://kycattle.org/cowcountrynews.html#.

University of Kentucky
College of Agriculture, Food and Environment
Grain and Forage Center of Excellence



The KENTUCKY Forage and Grassland COUNCIL
KADF KENTUCKY AGRICULTURAL DEVELOPMENT FUND

Measuring Forage Quality: Sampling and Interpretation

Chris D. Teutsch
UKREC at Princeton
Chris.Teutsch@uky.edu
or 270-963-0066

Kentucky Master Grazer Educational Program

1

Topics

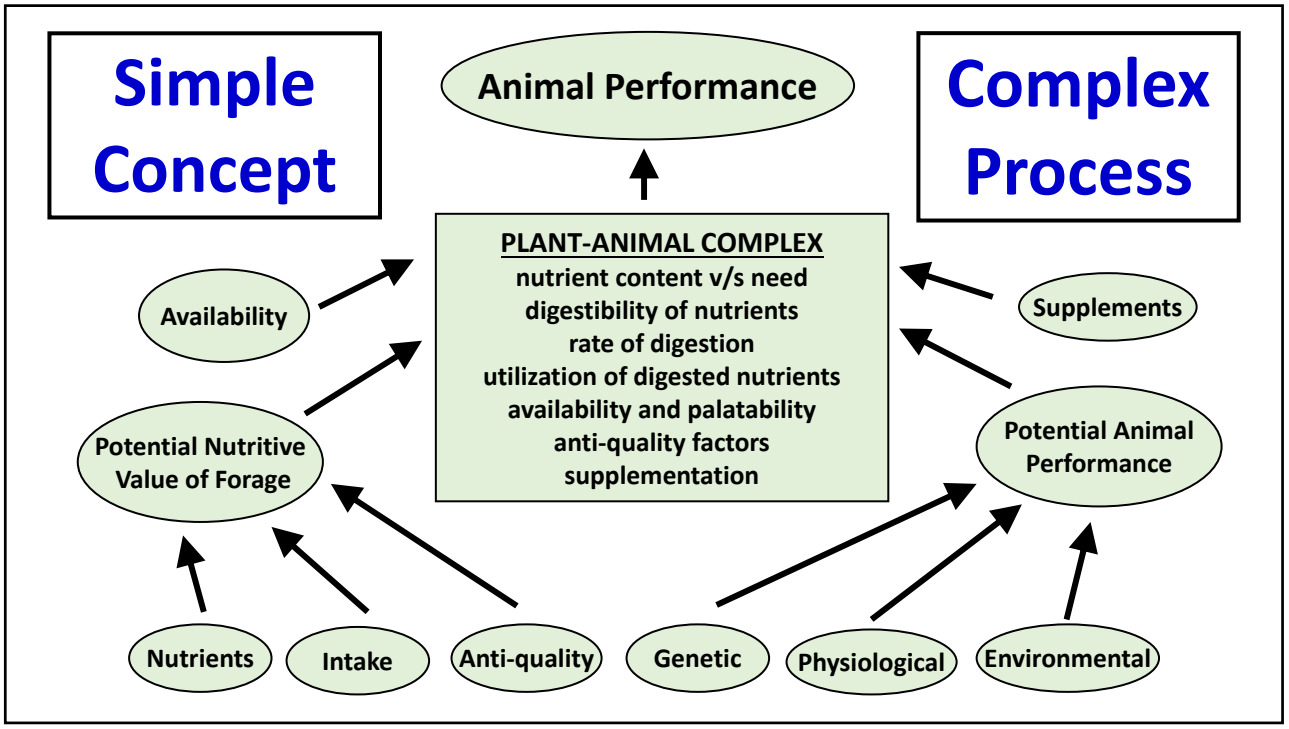
- Forage Quality
- Hay Sampling
- Interpretation

2

What is FORAGE QUALITY?

The ability of forage to produce desired animal response!!!

3



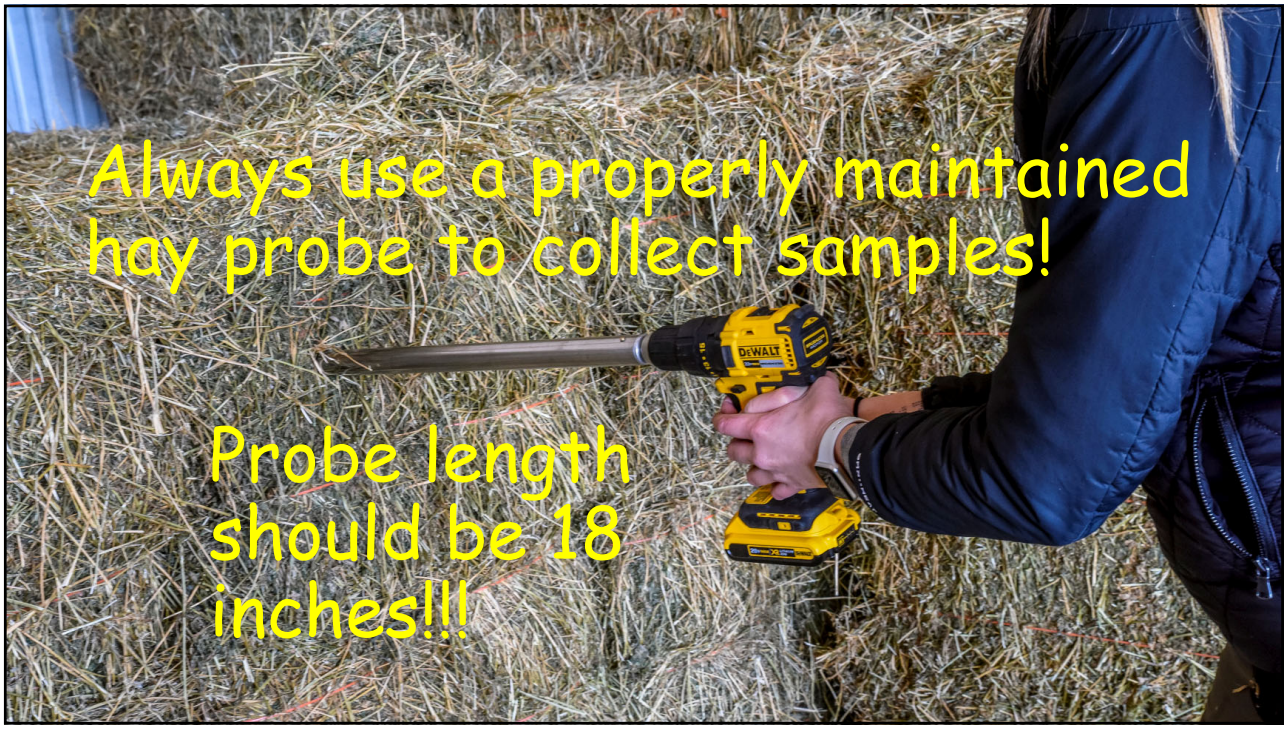
4


Hay Sampling 101
GOAL: Getting a sample that represents the hay that you will be selling or feeding!!!

5


Sample each HAY LOT separately!!!
HAY LOT = A cutting from the same field

6


Always use a properly maintained hay probe to collect samples!
Probe length should be 18 inches!!!

7


Collect at least 20 cores per HAY LOT!!!

8

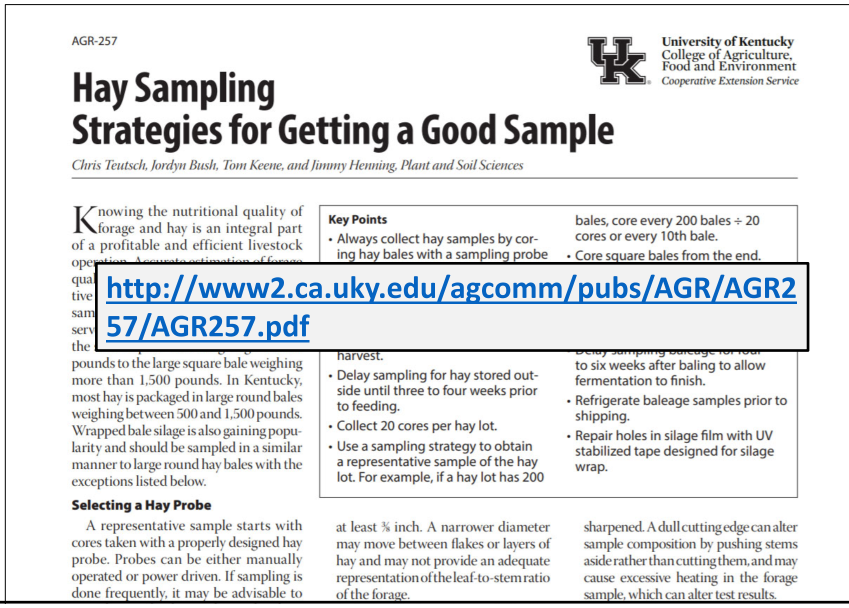

Sample square bales from ends and round bales from sides!!!

9


Submit ENTIRE sample in a clearly marked plastic bag to lab!!!

10

NEW Hay Sampling Publication



AGR-257

University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service

Hay Sampling
Strategies for Getting a Good Sample

Chris Teutsch, Jordyn Bush, Tom Keene, and Jimmy Henning, Plant and Soil Sciences

Knowing the nutritional quality of forage and hay is an integral part of a profitable and efficient livestock ope... qual... tive... sam... serv... the... pounds to the large square bale weighing more than 1,500 pounds. In Kentucky, most hay is packaged in large round bales weighing between 500 and 1,500 pounds. Wrapped bale silage is also gaining popularity and should be sampled in a similar manner to large round hay bales with the exceptions listed below.

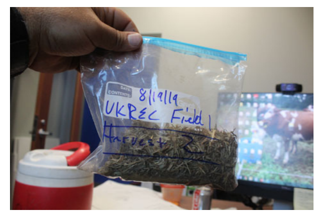
Key Points

- Always collect hay samples by coring hay bales with a sampling probe ... harvest.
- Delay sampling for hay stored outside until three to four weeks prior to feeding.
- Collect 20 cores per hay lot.
- Use a sampling strategy to obtain a representative sample of the hay lot. For example, if a hay lot has 200 bales, core every 200 bales ÷ 20 cores or every 10th bale.
- Core square bales from the end.
- ... to six weeks after baling to allow fermentation to finish.
- Refrigerate baleage samples prior to shipping.
- Repair holes in silage film with UV stabilized tape designed for silage wrap.

Selecting a Hay Probe

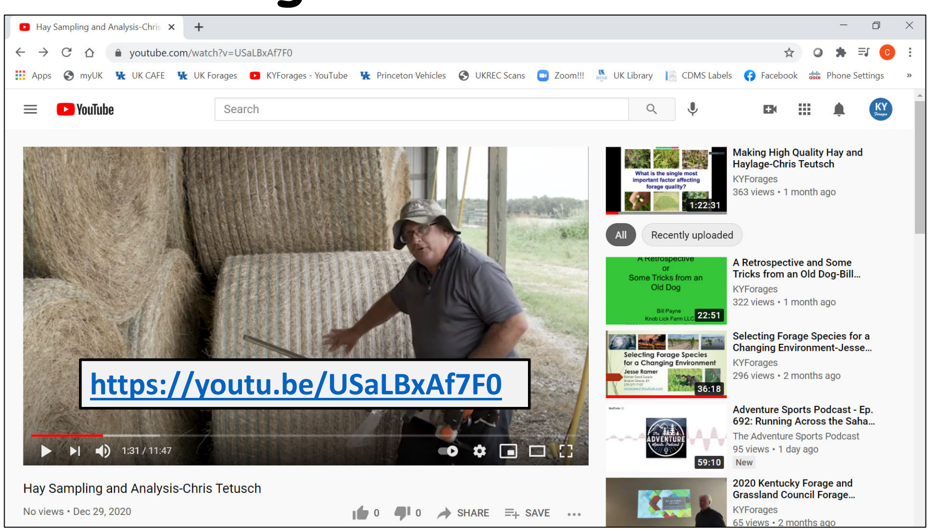
A representative sample starts with cores taken with a properly designed hay probe. Probes can be either manually operated or power driven. If sampling is done frequently, it may be advisable to ... at least ⅜ inch. A narrower diameter may move between flakes or layers of hay and may not provide an adequate representation of the leaf-to-stem ratio of the forage. ... sharpened. A dull cutting edge can alter sample composition by pushing stems aside rather than cutting them, and may cause excessive heating in the forage sample, which can alter test results.

http://www2.ca.uky.edu/agcomm/pubs/AGR/AGR257/AGR257.pdf



11

NEW Hay Sampling VIDEO on KYForages YouTube Channel

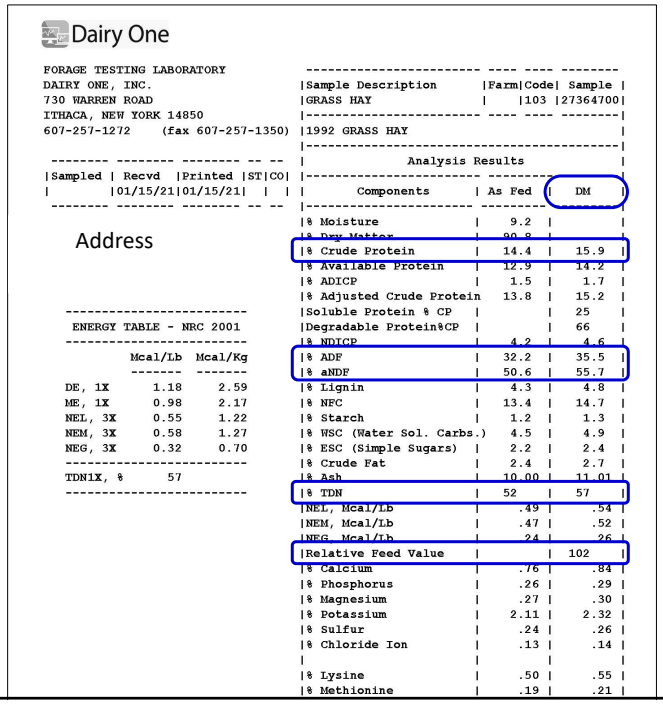


https://youtu.be/USaLBxAf7F0

12

Interpretation

- Test reports can be overwhelming!!!
- Traditionally we focus on
  - Acid Detergent Fiber, ADF
  - Neutral Detergent Fiber, NDF
  - Crude Protein, CP
    - %CP = %N x 6.25
  - Estimate ENERGY and DMI
    - Total Digestible Nutrients, TDN



Dairy One

FORAGE TESTING LABORATORY
DAIRY ONE, INC.
730 WARREN ROAD
ITHACA, NEW YORK 14850
607-257-1272 (fax 607-257-1350)

Sampled	Recvd	Printed	ST	CO
	01/15/21	01/15/21		

Address

ENERGY TABLE - NRC 2001

	Mcal/Lb	Mcal/Kg
DE, 1X	1.18	2.59
ME, 1X	0.98	2.17
NEL, 3X	0.55	1.22
NEM, 3X	0.58	1.27
NEG, 3X	0.32	0.70
TDN1X, %	57	

Sample Description	Farm Code	Sample
GRASS HAY	103	27364700
1992 GRASS HAY		

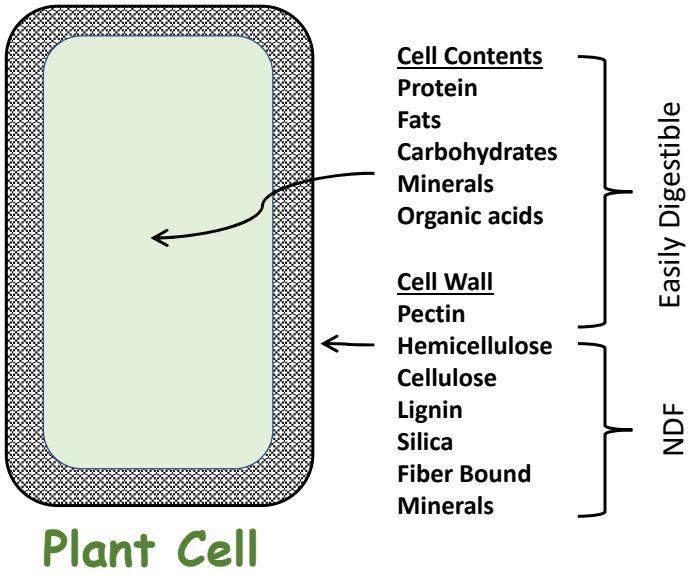
Analysis Results

Components	As Fed	DM
% Moisture	9.2	
% Dry Matter	90.8	
% Crude Protein	14.4	15.9
% Available Protein	12.9	14.2
% ADICP	1.5	1.7
% Adjusted Crude Protein	13.8	15.2
Soluble Protein % CP		25
Degradable Protein%CP		66
% NDICP	4.2	4.6
% ADF	32.2	35.5
% aNDF	50.6	55.7
% Lignin	4.3	4.8
% NFC	13.4	14.7
% Starch	1.2	1.3
% WSC (Water Sol. Carbs.)	4.5	4.9
% ESC (Simple Sugars)	2.2	2.4
% Crude Fat	2.4	2.7
% Ash	10.00	11.01
% TDN	52	57
NEL, Mcal/Lb	.49	.54
NEM, Mcal/Lb	.47	.52
NEG, Mcal/Lb	.24	.26
Relative Feed Value		102
% Calcium	.76	.84
% Phosphorus	.26	.29
% Magnesium	.27	.30
% Potassium	2.11	2.32
% Sulfur	.24	.26
% Chloride Ion	.13	.14
% Lysine	.50	.55
% Methionine	.19	.21

13

Neutral and Acid Detergent Fiber

- Neutral Detergent Fiber
  - Boiling in a neutral detergent solution
  - Cellulose, hemicellulose, lignin, and fiber bound minerals
  - <u>Used to estimate DMI</u>
- Acid Detergent Fiber
  - Boil in acid detergent solution
  - NDF – Hemicellulose
  - <u>Used to estimate energy</u>



14

Interpretation

- Test reports can be overwhelming!!!
- Traditionally we focus on
  - Acid Detergent Fiber, ADF
  - Neutral Detergent Fiber, NDF
  - Crude Protein, CP
    - %CP = %N x 6.25
  - Estimate ENERGY and DMI
    - Total Digestible Nutrients, TDN
- **Nontraditional approach**
  - **In vitro FIBER digestibility**
  - **Calculate ENERGY and DMI**

Dairy One

FORAGE TESTING LABORATORY
DAIRY ONE, INC.
730 WARREN ROAD
ITHACA, NEW YORK 14850
607-257-1272 (fax 607-257-1350)

Sampled	Recvd	Printed	ST	CO
	01/15/21	01/15/21		

Address

ENERGY TABLE - NRC 2001

	Mcal/Lb	Mcal/Kg
DE, 1X	1.18	2.59
ME, 1X	0.98	2.17
NEL, 3X	0.55	1.22
NEM, 3X	0.58	1.27
NEG, 3X	0.32	0.70
TDN1X, %	57	

Sample Description	Farm	Code	Sample
GRASS HAY		103	27364700
1992 GRASS HAY			

Analysis Results

Components	As Fed	DM
% Moisture	9.2	
% Dry Matter	90.8	
% Crude Protein	14.4	15.9
% Available Protein	12.9	14.2
% ADICP	1.5	1.7
% Adjusted Crude Protein	13.8	15.2
Soluble Protein % CP		25
Degradable Protein%CP		66
% NDICP	4.2	4.6
% ADF	32.2	35.5
% aNDF	50.6	55.7
% Lignin	4.3	4.8
% NFC	13.4	14.7
% Starch	1.2	1.3
% WSC (Water Sol. Carbs.)	4.5	4.9
% ESC (Simple Sugars)	2.2	2.4
% Crude Fat	2.4	2.7
% Ash	10.00	11.01
% TDN	52	57
NEL, Mcal/Lb	.49	.54
NEM, Mcal/Lb	.47	.52
NEG, Mcal/Lb	.24	.26
Relative Feed Value		102
% Calcium	.76	.84
% Phosphorus	.26	.29
% Magnesium	.27	.30
% Potassium	2.11	2.32
% Sulfur	.24	.26
% Chloride Ion	.13	.14
% Lysine	.50	.55
% Methionine	.19	.21

15

Determining Fiber Digestibility

Rumen fluid is collected from donor animals that have a rumen cannula.

16

Determining Fiber Digestibility

Ground forage material is sealed in mesh bags and incubated with rumen fluid.

17

Determining Fiber Digestibility

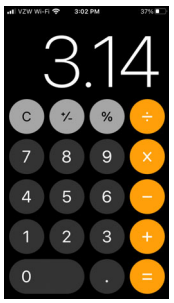
- **Near Infrared Reflectance Spectroscopy (NIRS)**
- **Rapid and nondestructive analysis that is based on wet chemistry**
- **Both accurate and precise**
- **Currently used on about 80% of forage samples being tested**

18

Estimating Total Digestible Nutrients

- Total Digestible Nutrients with ADF
  - TDN_{grass} (%) = 100.32 – 1.118 * ADF (%) (VPI)
  - Lots of different ADF based equations
  - Used to calculate Relative Feed Value (RFV)

- Total Digestible Nutrients with summative equation
  - TDN_{grass} (%) = (NFC*.98) + (CP*.87) + (FA*.97*2.25) + (NDFn*NDFDp/100) – 10 (Moore and Undersander, 2002)
  - Based on fiber digestibility and more complex
  - Better estimate of energy
  - Used to Calculate Relative Forage Quality (RFQ)



19

Bale Density and Storage Study

- Conducted in Princeton, KY
- Random complete block with four replications
- Low, medium, and high bale density bales
  - Stored inside or outside

- Weighed, measured, and sampled for nutritive value (72 bales)
  - At baling, 16-June-20
  - At feed out, 2-February-20

- Nutritive value was determined using NIRS
  - NIRS Consortium equation for GRASSES
- Using data to compare methods for estimating TDN and DMI

20

Comparison of TDN from ADF and Summative Based Equations

Summary Statistic	CP	NDF	ADF	IVTDMD48	TDN_{adf1}	TDN_{adf2}	TDN_{sum}
	----------% of DM ----------						
Minimum	4.7	61.0	38.6	64.1	51.9	45.5	53.7
Maximum	6.0	65.7	41.7	70.6	56.3	50.6	58.3
Median	5.8	64.2	40.5	70.6	55.0	49.0	58.2
Average	5.8	64.2	40.5	70.6	55.0	49.0	58.2
Standard Deviation	0.3	2.1	1.7	0.0	1.9	2.2	0.1




21

Estimating Dry Matter Intake

- Dry Matter Intake (DMI) with NDF
  - DMI (% BW) = 120 / NDF (%)
  - Example: DMI = 120 / 60% = 2% BW
    - 1200 cow could eat 24 lb/day

- Dry Matter Intake (DMI) with summative TDN
  - Based on fiber digestibility
  - More complicated calculation
  - DMI (%BW) = -2.318 + 0.442*CP - 0.0100*CP2 - 0.0638*TDN + 0.000922*TDN2 + 0.180*ADF - 0.00196*ADF2 - 0.00529*CP*ADF

22

Comparison of DMI from NDF and Summative Based Equations

Summary Statistic	CP	NDF	ADF	IVTDMD48	DMIndf	DMIsum
	----------% of DM ----------				% of Body Wt	
Minimum	4.7	61.0	38.6	64.1	1.74	1.98
Maximum	6.0	65.7	41.7	70.6	1.91	2.18
Median	5.8	64.2	40.5	70.6	1.87	2.15
Average	5.8	64.2	40.5	70.6	1.87	2.15
Standard Deviation	0.3	2.1	1.7	0.0	0.06	0.04




23

Relative Feed Value

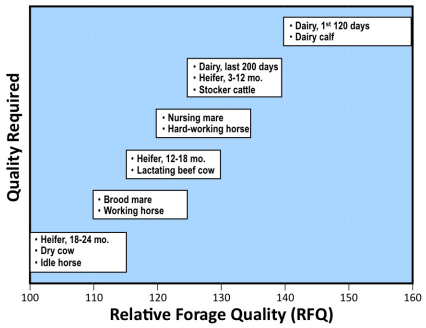
- Compares to Alfalfa at FULL BLOOM
  - 75 = Worse than alfalfa at full bloom
  - 100 = Alfalfa at full bloom
  - 125 = Better than alfalfa at full bloom
- Used to rank forages
  - Feeding decisions and marketing

- Relative Feed Value (RFV) = DMI, % BW * DDM, % DM /1.29
  - Traditional measure of fiber (Van Soest fiber analysis)
  - Dry Matter Intake (% BW) = 120 / NDF (%)
  - Digestible DM (% DM) = 88.9 – 0.779 * ADF (%)

24

Relative Forage Quality

- Compares to Alfalfa at FULL BLOOM
- Used to rank forages
  - Feeding decisions and marketing
- Relative Forage Quality (RFQ)
  - RFQ = DMI, % BW * TDN, % DM / 123
  - Uses TDN and DMI based on fiber digestibility
- More representative of animal performance
- Appropriate for all forage types
  - EXCEPT for corn silage



25

Comparison of RFV and RFQ

Summary Statistic	CP	NDF	ADF	IVTDMD48	RFV	RFQ
	----------% of DM ----------					
Minimum	4.7	61.0	38.6	64.1	70	88
Maximum	6.0	65.7	41.7	70.6	83	103
Median	5.8	64.2	40.5	70.6	80	103
Average	5.8	64.2	40.5	70.6	80	102
Standard Deviation	0.3	2.1	1.7	0.0	5.3	1.8

26

27

Summary

- Get representative sample
  - Sample each hay lot
  - Always core bales
  - Submit entire sample
- Estimate energy and DMI using NRC equations that include fiber digestibility
- Use Relative Forage Quality for feeding and marketing decisions
- Weigh your hay!!!

28



Questions and Discussion?




29