# UPDATE ON THE USE OF NIRS IN ESTABLISHING FEEDING VALUES FOR FORAGES AND CONCENTRATES[a]

by

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## INTRODUCTION

Feedstuff quality testing is designed to provide livestock producers with estimates of the feeding value of their feeds. Feeds should be tested before they are fed so that ratios of home grown feeds and purchased supplements, or ratios of purchased feeds can be properly balanced to meet the nutrient requirements of animals being fed. Most feed companies have incoming ingredients and completed feeds tested for feeding quality. Generally, livestock producers that have their feeds tested, send a sample to a laboratory for wet chemistry analysis. Wet chemistry provides an accurate analysis of the chemical composition of feedstuffs. In some cases however, an extended period can elapse between the time a sample is sent for analysis and when results are returned.

Many university extension programs, private laboratories and feed companies use near infrared reflectance spectroscopy (NIRS) to analyze feeding value attributes of various feedstuffs. The advantage of using NIRS is that feeding quality can be analyzed in a few days as compared to weeks using conventional wet chemistry. The more rapid turnaround time is important for livestock producers so that feeding programs can be established, and can be useful as a basis for price negotiation of feeds.

The objectives of this paper are to: 1) discuss the concepts of NIRS technology, 2) discuss the importance of forage quality upon animal performance, 3) review methods of obtaining a forage sample and submitting it to the Florida Extension Forage Testing Laboratory, and 4) review results from the Florida Extension Forage Testing Program. A majority of comments made in this paper will be related to conserved forages, primarily hay. Also, comments presented will be general in nature and deal with grasses presently used by most Florida livestock producers for hay or silage such as bermudagrass, stargrass, digitgrass, limpograss, and bahiagrass.

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[a] Appreciation is expressed to those involved in the NIRS program and the Florida Extension Forage Testing Program, including J.E. Moore and W.E. Kunkle, Animal Science Department, Gainesville, C.G. Chambliss, Agronomy Department, Gainesville, F.M. Pate Animal Science Department, AREC-Ona, and C.K. Piacitelli, Chemist AREC-Ona.

## NIRS TECHNOLOGY

NIRS technology is based on the fact that each of the major chemical components of a sample has specific near infrared absorption properties which can be used to differentiate one component from another (Norris, 1989). The combination of these absorption properties in addition to radiation scattering properties of a sample determines the specific reflectance from a sample. Therefore, the near infrared reflectance signal contains information about the chemical composition of a sample.

Research and development in NIRS technology has been extensive over the last ten years. Basically, NIRS technology has involved use of either a scanning monochromator or a fixed filter-type instrument. Most feed companies and co-op's in Florida that have a NIRS system, and the Florida Extension Forage Testing Program use a scanning monochromator. In most scanning monochromators, a lamp emits light usually from the 1200- to 2500-nm portion of the near infrared region. A filter is used to break the light into individual wavelengths, usually every 2-nm. These individual wavelengths of light are directed toward the sample, and detectors measure the amount of radiation that is reflected from the sample. The amount of reflectance from each specific wavelength is stored in a computer. Therefore for each sample, the amount of reflectance from 1200-, 1202-, 1204-, 1206-, .... 2500-nm is collected and stored for further analysis. For calibration, many samples (50 to 250, depending upon objectives) will be analyzed by conventional wet chemistry procedures for feeding value attributes of interest. These samples will also be scanned with the monochromator. Reflectance data and wet chemistry values for all samples are related using regression techniques provided by the NIRS computer software. Resulting calibrations are then used to analyze samples rather than using conventional wet chemistry procedures.

Calibrations should be developed from the same type of samples which will be analyzed using NIRS. For example calibrations developed from cool season forages would not be expected to accurately analyze feeding value attributes of warm season forages. Users of commercial NIRS laboratories should cross-check a few samples with wet chemistry laboratories to check the accuracy of the calibrations used by the NIRS laboratory for their specific sample types.

## FORAGE QUALITY AND ANIMAL PERFORMANCE

Before the Extension Forage Testing Program is discussed, the importance of forage testing should be established. Why should livestock producers have their forages tested for quality? What the human eye and nose can determine about a given forage is not always related to the level of animal performance that will be obtained when that forage is fed. Forage forms the basis for cattle nutrition in Florida. Due to minimal pasture growth during the winter and generally low quality of hay fed, winter nutrition programs for heifers after weaning and lactating cows are typically inadequate. Poor winter nutrition is a major cause of low reproduction, and a main reason that heifers calve for their first time at three rather than two years of age.

From an animal nutrition standpoint in Florida, the time of year of most concern is October until April or May. During this time, calves born earlier in the year are weaned and have high nutritional requirements, cows are in the last third of pregnancy and then calving and lactating and can not lose too much weight or they will not rebreed. Crude protein, total digestible nutrient (TDN) and forage quality index (QI) requirements for these classes of cattle are shown in Table 1. These requirements can be related to quality of the forage fed, and used to determine the amount of supplement needed.

TABLE 1. CRUDE PROTEIN, TOTAL DIGESTIBLE NUTRIENT (TDN) AND FORAGE QUALITY INDEX (QI) REQUIREMENTS OF BREEDING AND GROWING BEEF CATTLE

| | Crude protein | | TDN | | |
|---|---|---|---|---|---|
| | % | lbs | % | lbs | QI |
| 1000 lb cow, last third of pregnancy | 8.0 | 1.6 | 55 | 10.5 | 1.1 |
| 1000 lb cow, nursing a calf | 10.0 | 2.0 | 60 | 12.0 | 1.5 |
| 850 lb first calf heifer, last third of pregnancy | 9.0 | 1.6 | 60 | 11.0 | 1.3 |
| 850 lb first calf heifer, nursing a calf | 10.5 | 2.0 | 65 | 12.0 | 1.5 |
| 500 lb growing heifers and steers | 11.5 | 1.4 | 65 | 9.0 | 1.7 |

Source: NRC, Nutrient Requirements of Beef Cattle, 6th Ed. 1984.

Hay quality is generally low primarily because more attention is placed on hay yield than hay quality. Under proper growing conditions most forages used for hay or silage production in Florida grow rapidly and produce large yields in a short period of time. However, forage quality declines at a rapid rate. Therefore, a trade-off exists between forage yield and quality. The objective is to harvest forages at the proper stage of maturity to assure adequate quality for the class of cattle to which the forage will be fed.

A significant amount of research has been conducted concerning changes in quality of Florida forages as they mature. Moore and Ruelke (1978) studied the influence of advancing maturity upon the quality of bermudagrass and digitgrass (Table 2). Crude protein, TDN and QI declined rapidly as forage harvest was delayed, with values below animal requirements by 6 to 8 weeks regrowth. Ultimately animal performance is the most important of all forage quality attributes. Changes in feed intake will have more of an influence upon animal performance than will changes in TDN concentration. Feed intake values also declined as the hays became more mature. Therefore, advancing maturity has a double-negative effect upon hay feeding value; less of a lower digestible material is consumed.

TABLE 2. MATURITY EFFECTS ON THE FEEDING VALUE OF TROPICAL GRASS HAY

| | Weeks of regrowth | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | 12 |
| Bermudagrass | | | | | | |
| Crude protein | 20.0 | 14.0 | 9.0 | 8.0 | 7.0 | 6.0 |
| TDN | 63.0 | 58.0 | 55.0 | 48.0 | 46.0 | 45.0 |
| QI | 1.6 | 1.4 | 1.3 | .9 | .8 | .8 |
| Intake | 2.7 | 2.7 | 2.5 | 2.0 | 2.0 | 1.9 |
| Digitgrass | | | | | | |
| Crude protein | 18.0 | 12.0 | 10.0 | 10.0 | 8.0 | 7.0 |
| TDN | 65.0 | 62.0 | 62.0 | 59.0 | 52.0 | 53.0 |
| QI | 1.7 | 1.5 | 1.3 | .9 | .7 | .8 |
| Intake | 2.6 | 2.5 | 2.2 | 1.6 | 1.5 | 1.6 |

Source: Moore and Ruelke (1978). Crude protein, %; TDN = total digestible nutrients, %; QI = quality index; Intake, % of body weight.

Brown (1988) compared the feeding value of stargrass hay harvested after 5 and 10 weeks regrowth (Trial 1) and 6 and 12 weeks regrowth (Trial 2; Table 3). In each trial, crude protein content of the less mature hay was greater than that of the more mature hay, with 5 week regrowth hay being adequate for most classes of cattle. Five week regrowth stargrass hay will meet the TDN requirement of a gestating cow and would require less supplemental energy to meet the TDN requirements of other classes of cattle listed in Table 1 compared to mature hay. Feed intake and daily gain can not be compared across trials, because in trial 1 heifers (450 lbs) were fed on bahiagrass pasture (January 6 to April 24), while in trial 2 steers (430 lbs) were fed in drylot. Within a trial, cattle fed less mature hay ate more feed, gained much more weight and were more efficient than cattle fed more mature hay.

From the above data it can be concluded that for grasses presently used in Florida for hay production, the main factor controlling hay quality is age of the forage when it is harvested. Given proper moisture and fertilization, these grasses should be harvested after 5 and no later than 6 weeks regrowth if the hay is to be fed to lactating cows or growing calves.

TABLE 3. FEEDING VALUE OF STARGRASS HAY HARVESTED AFTER 5 AND 10 WEEKS REGROWTH (TRIAL 1) AND 6 AND 12 WEEKS REGROWTH (TRIAL 2)

| | Trial 1 | | Trial 2 | |
|---|---|---|---|---|
| | Weeks of regrowth | | Weeks of regrowth | |
| | 5 | 10 | 6 | 12 |
| Crude protein, % | 10.6 | 4.4 | 7.0 | 4.4 |
| TDN, % | 58 | 44 | 52 | 43 |
| Intake, lbs DM/day | 9.5 | 6.4 | 11.9 | 10.1 |
| Daily gain, lbs | .5 | .0 | .6 | .3 |
| Feed/gain | 19.0 | | 19.8 | 33.7 |

TDN = total digestible nutrients, DM = dry matter.

## FORAGE TESTING

The forage testing program was developed to provide rapid and accurate quality analysis of forages for livestock producers. Forage quality analysis is determined using NIRS located at the Ona Research Center. The forage testing program consists of 5 phases:

1) Sampling - The most important part of the forage testing program begins on the farm. It is very important that the sample sent for analysis is truly representative of the forage that will be fed. Hay samples should be obtained using a "Penn State Forage Sampler". The sampler is attached to an electric drill and driven into the end of rectangular bales, or the rounded side of round bales. The outer layer of weathered bales should be removed before sampling and should not be a part of the sample sent for analysis. Approximately 12 bales should be sampled from each lot or harvest in order to obtain a representative sample.

2) Identification and Handling - Extension agents have a supply of sample information forms, sample bags and envelops. Samples, completed forms and NIRS fee ($8.00) should be sent to: NIRS Laboratory, Agricultural Research Center, Route 1 Box 62, Ona, FL 33865. As much information as possible should be included on the sample information form such as species, harvest date, weeks regrowth, additives, etc. Presently tropical grass hay, corn and sorghum silage are accepted for quality analysis utilizing NIRS. Samples should be packaged so as to preserve them while in transit to the Research Center. As much air as possible should be removed from the sample bag.

3) Analysis - Upon arrival at the Research Center, the sample is dried for moisture content determination, ground and prepared for analysis by the NIRS instrument. Once a sample is dried and prepared for NIRS analysis, forage quality estimates are obtained in approximately 90 seconds. Therefore, a major factor affecting turnaround time for analysis is the time required to dry the sample, which is dependant upon the initial moisture content.

4) Report and Evaluation - Forage quality estimates provided by the forage testing program include: moisture, crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF) and quality index (QI). Crude protein is a measure of the nitrogen content, while TDN is a measure of the energy content of the forage. Both of these quality traits are required for maintenance and milk production by the cow, and growth by heifers and steers. Neutral detergent fiber is a measure of the fiber content of the forage, and gives an indication of feed intake by the animal. Quality index is an estimate of TDN intake when the forage is fed alone and free choice. A forage with a quality index of 1.0 would be expected to meet the maintenance energy requirements of a mature dry beef cow. Heifers gaining 1.0 lb/day, and lactating beef cows require forage with a quality index of 1.5 to 1.7 or must be supplemented with protein and energy. Quality index requirements for various classes of cattle are summarized in Table 1.

5) Follow-up - After analysis by NIRS, each sample is analyzed by conventional wet chemistry methods for the same variables that were predicted by NIRS. Wet chemistry results are used to determine the accuracy of NIRS predications, and to recalibrate the NIRS machine.

## FORAGE TESTING RESULTS

Forty-three percent of all samples submitted to the forage testing program were bermudagrass, with approximately equal numbers of stargrass, digitgrass and bahiagrass samples (Table 4). Only 7% of samples submitted by livestock producers for forage testing were limpograss. The average protein value of all samples submitted to the testing laboratory was 7.4%, with a minimum value of 1.9% and a maximum of 15.9%. Only 21% of the samples were above 10% protein which is the level of protein required for lactating cows and the minimum level of protein required for growing cattle. Generally, bermudagrass samples were highest in protein, with a mean of 8.8%. Fewer bermudagrass samples were lower than 8% protein compared to the average for all the samples, and 33% of bermudagrass samples were above 10% protein. Stargrass samples were next highest in protein, with a mean of 8.1%. Only 25% of stargrass samples were greater than 10% protein. Digitgrass and bahiagrass samples submitted to our laboratory were low in protein primarily because producers allow the grasses to grow too long before they are harvested. Limpograss hay is generally very low in protein. None of the limpograss hay samples submitted to the testing laboratory were above 8% protein.

Total digestible nutrient distribution of hay samples submitted to the forage testing laboratory are shown in Table 5. These values can be compared to animal requirements listed in Table 1. The average TDN value of all samples submitted for forage testing was 49.4%, with a minimum value of 40% and a maximum value of 60%. Only 4% of all samples were above 55% TDN, and only 43% were above 50% TDN.

TABLE 4. SPECIES AND CRUDE PROTEIN DISTRIBUTION OF HAY SAMPLES SUBMITTED TO THE FLORIDA EXTENSION FORAGE TESTING PROGRAM

| | All samples | Bermuda | Star | Digit | Bahia | Limpo |
|---|---|---|---|---|---|---|
| Total distribution, % | - | 43 | 19 | 17 | 14 | 7 |
| Crude protein, % | | | | | | |
| Mean | 7.4 | 8.8 | 8.1 | 5.2 | 6.6 | 4.0 |
| Minimum | 1.9 | 4.3 | 2.8 | 2.6 | 3.4 | 1.9 |
| Maximum | 15.9 | 15.9 | 14.6 | 12.1 | 10.5 | 6.8 |
| Crude protein distribution, % | | | | | | |
| < 4.0 | 8 | 1 | 4 | 15 | 5 | 55 |
| 4.0 - 5.9 | 27 | 15 | 20 | 59 | 36 | 28 |
| 6.0 - 7.9 | 26 | 25 | 29 | 21 | 39 | 17 |
| 8.0 - 9.9 | 18 | 26 | 22 | 3 | 17 | 0 |
| 10.0 - 11.9 | 13 | 21 | 19 | 1 | 3 | 0 |
| 12.0 - 13.9 | 5 | 10 | 5 | 1 | 0 | 0 |
| > 14.0 | 3 | 2 | 1 | 0 | 0 | 0 |

Except for limpograss hay, only a very small number of any grass hay samples were greater than 55% TDN, which is the minimum TDN required for a cow in the last third of pregnancy. If managed and fed properly limpograss has good feeding potential because it tends to be greater in TDN than other grasses; however, proper protein supplementation programs must be established due to the low protein concentration of limpograss. Stargrass hay had 54% of its samples above 50% TDN (Table 5). Stargrass also has good feeding potential because it grows rapidly with good rainfall and fertilization; however, it should be harvested after 5 weeks regrowth to obtain adequate quality hay. Bahiagrass, which was low in protein was also low in TDN.

TABLE 5. TOTAL DIGESTIBLE NUTRIENT (TDN) DISTRIBUTION OF HAY SAMPLES SUBMITTED TO THE FLORIDA EXTENSION FORAGE TESTING PROGRAM

| | All samples | Bermuda | Star | Digit | Bahia | Limpo |
|---|---|---|---|---|---|---|
| Total digestible nutrients, % | | | | | | |
| Mean | 49.4 | 49.4 | 50.4 | 49.3 | 46.6 | 53.3 |
| Minimum | 40.9 | 40.9 | 42.6 | 43.6 | 41.9 | 49.4 |
| Maximum | 60.8 | 60.8 | 56.7 | 55.5 | 51.2 | 57.6 |
| TDN distribution, % | | | | | | |
| 40.0 - 44.9 | 12 | 11 | 9 | 7 | 31 | 0 |
| 45.0 - 49.9 | 45 | 48 | 37 | 48 | 59 | 4 |
| 50.0 - 54.9 | 39 | 37 | 47 | 44 | 10 | 71 |
| 55.0 - 59.9 | 4 | 4 | 7 | 1 | 0 | 25 |

Level of animal performance obtained from a given forage is closely related to both TDN concentration of the forage and quantity of forage consumed. Improved forage quality (less mature forage) has a double-positive effect on animal performance: cattle consume more of a less mature compared to a more mature forage, and the less mature forage is greater in TDN compared to the more mature forage. Quality index (QI) is a forage quality measure that combines intake and TDN concentration of a forage. Quality index is expressed as TDN intake as a percentage of the maintenance TDN requirement of the animal. A forage with a QI of 1.0 will provide enough TDN to maintain a dry pregnant cow. A forage with a QI greater than 1.0 contains enough energy for maintenance plus additional energy that can be utilized for gain, lactation or fetal development. Quality index is a measure of TDN intake, and care must be taken to ensure that sufficient protein is provided.

The mean QI for all samples submitted for forage testing was slightly greater than 1.0, with a minimum of .76 and a maximum of 1.35 (Table 6). Approximately 32% of all forage samples submitted will not meet the energy requirements of a dry pregnant cow (less than a QI of 1.0). Digitgrass, stargrass and limpograss have more samples with a QI greater than 1.0 compared to bermudagrass and bahiagrass.

TABLE 6. QUALITY INDEX (QI) DISTRIBUTION OF HAY SAMPLES SUBMITTED TO THE FLORIDA EXTENSION FORAGE TESTING PROGRAM

| | All samples | Bermuda | Star | Digit | Bahia | Limpo |
|---|---|---|---|---|---|---|
| Quality index | | | | | | |
| Mean | 1.04 | 1.03 | 1.05 | 1.08 | .99 | 1.06 |
| Minimum | .76 | .76 | .81 | .90 | .81 | .98 |
| Maximum | 1.35 | 1.35 | 1.27 | 1.29 | 1.16 | 1.27 |
| QI distribution, % | | | | | | |
| .80 - .89 | 8 | 10 | 8 | 0 | 14 | 0 |
| .90 - .99 | 24 | 24 | 14 | 20 | 44 | 25 |
| 1.00 - 1.09 | 45 | 44 | 53 | 41 | 37 | 50 |
| 1.10 - 1.19 | 18 | 16 | 19 | 31 | 5 | 14 |
| > 1.20 | 5 | 6 | 6 | 8 | 0 | 11 |

These results are not intended to indicate that bermudagrass or stargrass makes better hay than other grasses. In some cases, bermudagrass and stargrass are managed better for hay than some of the other grasses. Much of the bermudagrass we test will be fed to horses or dairy cattle. There is a feeling among some beef producers that beef cattle do not need the same quality hay that is fed to horses or dairy cattle in Florida. However, much of the grass that is managed for 'horse or dairy hay' in Florida will not meet the requirements of lactating beef cows or developing heifers.

The important point to consider is that it is possible to produce higher quality forage; 33% of bermudagrass hay and 25% of stargrass hay samples were above 10% protein. Feeding a higher quality forage (less mature) will result in a reduction in the amount of supplemental feed that will have to be purchased. This is because more of the desired cattle performance will be met by the higher quality forage compared to a situation where a lower quality forage is fed.

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