Teaching Concepts of Forage Nutritive Value and Estimation of Energy in Forages at a Graduate Level[1]

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Abstract

This report describes a laboratory exercise for graduate students that was designed to provide practical experience in evaluating forage nutritive value. Ten graduate students at the University of Arkansas-Fayetteville who were enrolled in Forage-Ruminant Relations (a Ph.D.-level course) were paired and assigned either an alfalfa (*Medicago sativa* L.) hay sample or one of four bermudagrass [*Cynodon dactylon* (L.) Pers.] hay samples selected from the Arkansas Hay Show. A set of laboratory procedures was completed for each sample and the results were reported orally and in a written report. The energy content of these forages was predicted by several equations used in various states (Arkansas, Missouri, and Florida). The predicted energy content of these forages varied considerably, depending on the equations used; this aspect of the project led to considerable classroom discussion. Most students felt the activity was a valuable learning experience and should be repeated in subsequent classes. This activity may have been most beneficial to students pursuing advanced degrees in programs other than ruminant nutrition; these students may have no other exposure to these procedures during their advanced academic training, but some knowledge of the analyses necessary to evaluate forage nutritive value and subsequently estimate the energy content of forages may be extremely helpful in teaching, extension, or other service careers in agriculture.

Introduction

Concepts of forage nutritive value are best taught when laboratory experience supports the theoretical concepts discussed in the classroom. This approach to teaching is not unique to the subject of ruminant nutrition. Other teaching faculty have developed laboratory exercises to support experiential learning. Barker (1995) has described an in-depth laboratory project designed to assess plant responses to environmental stresses; this project allowed graduate and upper-level undergraduate students in plant nutrition to explore ideas that are presented as theory in classroom lectures. This approach can also be applied to topics directly related to agricultural production. Schweitzer and Semmel (1994) developed a field laboratory course designed to provide undergraduate and graduate students with practical experience in diagnosing and solving crop management problems, which may include insect pests, diseases, herbicide injury, and stress factors in the growth environment. These projects can also take a team approach; Antunes et al. (1998) described a class project that used a C_4 model of photosynthesis to study the influence of leaf N content and sky conditions on canopy gas exchange properties in corn (*Zea mays* L.). Many graduate students studying various topics associated with livestock production may never analyze forages for nutritive content on a routine basis, but still will need to have some understanding of these concepts in their future careers. Students that pursue careers as teachers, consultants, or in some other extension-related field can benefit greatly from having some knowledge of what information can and can not be gleaned from each laboratory procedure. In addition, an appreciation for the time, expense, and logistical requirements necessary to conduct these procedures may also be of great benefit when these students join the professional work force. In order to provide graduate-level students with this type of training, a laboratory study problem was designed for the graduate students enrolled in Forage-Ruminant Relations (a Ph.D.-level course) at the University of Arkansas-Fayetteville.

One concept that often surprises students, producers, and county extension personnel is that there is no standard method of estimating the energy content of forages. Because the direct determination of the energy content of feedstuffs using animals is prohibitively expensive and time consuming, energy estimates are usually predicted from equations (Weiss, 1997). These equations are typically based on routine analytical procedures that are used to evaluate forage nutritive value. However, these prediction equations are not standardized across the country, region, or even within a given state. For instance, forage samples sent to the University of Arkan-

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sas Agricultural Services Laboratory may have the associated energy content predicted by equations that are different from those used by private laboratories in Arkansas. In addition, some states have one prediction equation for all forages, while other states have separate equations for different forage types (legumes, corn silage, cool-season grasses, warm-season grasses, etc.). Our objectives in designing this problem were twofold: 1) supplement classroom discussions about forage nutritive value with valuable laboratory experience; and 2) demonstrate the effects that various prediction equations can have on estimates of energy for five different test forages.

Materials and Methods

Sample Selection and Analysis

During the 1998 Arkansas Hay Show held in conjunction with the Arkansas Cattleman's Association Convention in Springdale, AR, four high-quality samples of bermudagrass hay were selected for this project. Most prediction equations rely heavily or solely on the concentration of acid detergent fiber (ADF) to estimate energy (Weiss, 1997). The prediction equation for energy or total digestible nutrients (TDN) used by the University of Arkansas for warm-season grasses also includes concentrations of neutral detergent fiber (NDF) and crude protein (CP). The four bermudagrass samples were selected because they had similar levels of ADF, but a wide range of CP concentrations (Table 1). Selection was based on the required laboratory analysis that was submitted with each entry at the 1998 Arkansas Hay Show. An alfalfa sample that had been analyzed previously (Coblentz et al., 1998) was included in the project as a control. All samples were dried to constant weight at 122°F and subsequently ground through a 1-mm screen with a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Samples were analyzed in the University of Arkansas Ruminant Nutrition Lab for nitrogen (N), NDF, ADF, cellulose, lignin, in vitro dry matter disappearance (IVDMD), and in vitro organic matter disappearance (IVOMD). Total plant N was determined using a macro-Kjeldahl procedure (Kjeltec Auto 1030 Analyzer, Tecator, Inc., Herndon, VA); CP was calculated as % N x 6.25. Neutral detergent fiber (omitting sulfite), ADF, lignin, cellulose, hemicellulose, IVDMD, and IVOMD were determined by or calculated on the basis of batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Prior to analysis, one sample was assigned to a pair of students. Each student conducted all of these analyses in duplicate on their sample.

Table 1. Laboratory analyses submitted with hay samples at the 1998 Arkansas Hay Show. These analyses were conducted by the University of Arkansas Analytical Services Laboratory in Fayetteville or by private laboratories. The alfalfa sample had been evaluated previously (Coblentz et al., 1998) and was placed in the project as a control.

Forage	Crude protein	ADF
	%	%
Bermudagrass A	22.4	28.0
Bermudagrass B	19.6	26.1
Bermudagrass C	17.3	27.9
Bermudagrass D	15.4	28.4
Alfalfa	21.1	34.7

Energy Equations

After completing the assigned laboratory procedures for each sample, students were asked to calculate TDN using the appropriate prediction equations of three states (Arkansas, Missouri, and Florida). Equations are shown below; units for all variables are in percent of total plant dry matter.

Florida: (all forages) TDN = organic matter x (26.8 + [0.595 x IVOMD]) / 100

Arkansas: (legume) TDN = 73.5 + (0.62 x CP) - (0.71 x ADF)

(warm-season grass) TDN = 111.8 + (0.95 x CP) - (0.36 x ADF) - (0.7 x NDF)

Missouri: (legume) TDN = 97.192 - (1.0664 x ADF)

(grasses) TDN = 93.9656 - (0.9632 x ADF)

At the end of the semester, students were asked to make an oral presentation in class and submit a written report of their work. Results were tabulated and discussed in class. In the written report, students were required to evaluate this activity and make suggestions to improve it for subsequent classes. At least one question on the final exam, which was an oral exam, was based on the class reports and subsequent classroom discussion; the oral format for the final examination permitted considerable dialogue to occur between students and the two faculty members who team-taught the class. Specifically, this technique permitted considerably flexibility with respect to questioning and encouraged good discussion of the points learned through this laboratory exercise.

Results and Discussion

Forage Analysis

Mean values for quality indices of each forage sample (from each pair of students) are shown in Table 2. Although the students were successful in achieving relatively good precision in most laboratory procedures (data not shown), class results did not agree well with those submitted at the Arkansas Hay Show. Forages B, C, and D had similar ADF concentrations (range = 33.0 to 34.2), but these values were substantially higher than those submitted with the samples at the Hay Show (range = 26.1 to 28.4). Our ADF concentration for forage A (25.0%) was somewhat lower than the submitted value (28.0%). Generally, agreement between class and submitted CP concentrations was better than for ADF. These results illustrated the differences that can occur between laboratories. Although the differences between values submitted with the samples at the 1998 Arkansas Hay Show and those obtained by students in the Ruminant Nutrition Laboratory (Tables 1 and 2, respectively) were due to chance laboratory-to-laboratory variation, they illustrated a valuable point to students: laboratory-to-laboratory variation due to differences in methodology, equipment, technicians, etc., are an everyday reality that should never be overlooked. This was a surprise to some students, but the practical value of this experience was obvious, especially for students desiring careers in extension or as consultants. Individuals working with these types of appointments generally do not have their own laboratory, and typically contract the services of private and state laboratories to obtain forage quality information.

Digestibility and Energy Calculations

Determinations of IVDMD, IVOMD, and calculations of TDN are shown in Table 3 and indicate clearly the high quality of these bermudagrass hays. Estimates of TDN by the Arkansas equation were consistently higher than other estimates; the inclusion of CP as a predictor variable in the Arkansas equation for warm-season grasses clearly had a large impact on predicted TDN values (Figure 1). Prediction of TDN by other equations was clearly less sensitive to CP concentrations. Considerable class discussion time was devoted to possible explanations for this trend. Current management practices in Arkansas, particularly the heavy reliance on poultry litter or commercial N fertilizer, may drive CP concentrations in bermudagrass beyond the range in which the Arkansas TDN equations were developed a generation ago. When this happens, substantial overestimation of TDN may occur. All students entering this class had some appreciation for the need to estimate the energy content of forages adequately in order to formulate diets that meet the energy requirements of livestock; therefore, the negative consequences of overestimating the energy content of forages were readily apparent to all students. More importantly, the discussion associated with this project forced students to critically evaluate a problem that would be typical of those encountered by consultants or extension personnel.

Class Evaluation

All students were required to evaluate this activity in their final written report. Most comments (Table 4) were favorable; students generally recommended that this project be repeated in subsequent classes because it gave them some practical experience with forage analysis and interpretation of results that could be useful in the future. Some students indicated informally (not in their written report) that they liked being paired because they could share laboratory responsibilities when conflicts arose with other commitments. Similarly, most felt the work load was reasonable, given there was no scheduled laboratory period. Some students expressed frustration with some of the calculations. Detailed example calculations will be provided if the activity is repeated in the future. From the standpoint of the instructors, one change that should be made for future classes is to ask paired-student teams to analyze all samples in duplicate, rather than assigning a single sample to each pair of students. Because of the batch procedures utilized in the ruminant nutrition laboratory, there would be little difference in the time commitment for students. Po-

Table 2. Analysis of five test forages by five student pairs.

Forage	DM[Z]	OM	Ash	NDF	ADF	Hemicellulose	Cellulose	Lignin	Nitrogen	Crude protein
	%	% of dry matter								
Bermudagrass A	95.3	91.7	8.26	66.1	25.0	41.1	24.5	2.71	3.80	23.9
Bermudagrass B	95.9	93.9	6.15	68.2	34.2	34.0	27.4	3.51	3.28	20.5
Bermudagrass C	93.0	92.0	7.98	71.0	33.0	38.0	27.3	3.85	2.92	18.3
Bermudagrass D	94.4	93.3	6.69	73.6	33.4	40.3	29.6	3.19	2.64	16.5
Alfalfa	93.0	90.1	9.97	42.6	31.8	10.8	25.1	5.97	3.41	21.4

[Z] Abbreviations: DM = dry matter, OM = organic matter, NDF = neutral detergent fiber, and ADF = acid detergent fiber.

Table 3. Determinations of digestibility and energy calculations for five test forages.

Forage	IVDMD[Z]	IVOMD	Arkansas TDN equation	Missouri TDN equation	Florida TDN equation
	%				
Bermudagrass A	71.8	70.9	79.2	69.9	63.3
Bermudagrass B	67.9	67.3	71.3	61.0	62.8
Bermudagrass C	62.1	63.3	67.6	62.2	59.3
Bermudagrass D	61.4	59.7	64.0	61.8	58.2
Alfalfa	71.4	71.8	64.2	63.3	62.6

[Z] Abbreviations: IVDMD = in vitro dry matter disappearance, IVOMD = in vitro organic matter disappearance, and TDN = total digestible nutrients.

Figure 1. Relationship between CP concentration and predicted TDN values for four bermudagrass samples selected from the Arkansas Hay Show and evaluated by graduate students.

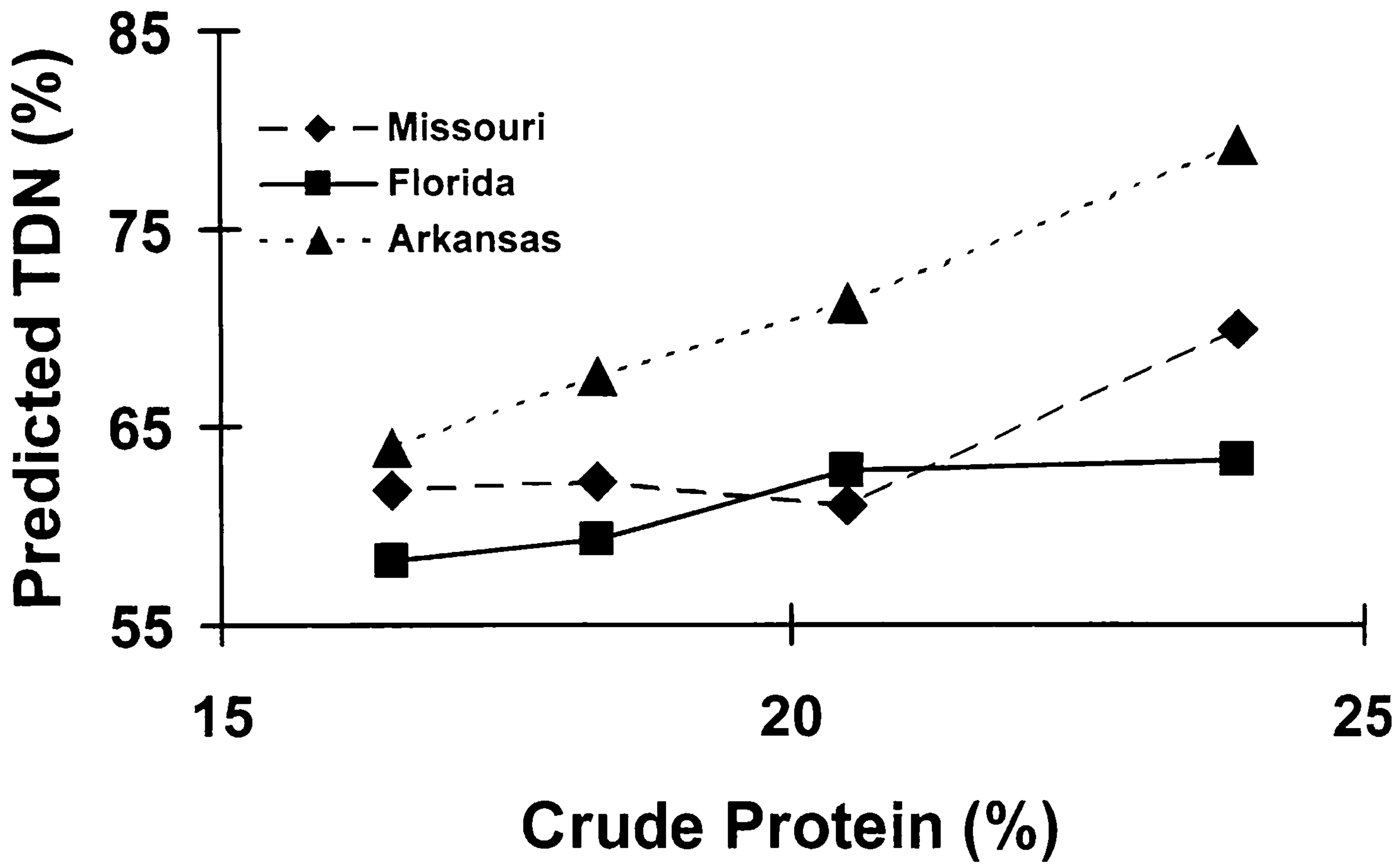

Table 4. Summary of evaluations of the laboratory exercise from 10 graduate students. Comments are listed in order from most common to least common. Frequency of each comment appears in parenthesis.

Positive comments	Weaknesses of the activity
1.excellent learning experience, especially for students concentrating on subject areas outside forages (10)	1. procedures and calculations were frustrating (4)
2. project should be repeated (9)	2. start the activity early in the semester so that all laboratory work, reports, and other evaluations conclude before the end of the semester (4)
3. forces students to understand laboratory procedures and associated calculations (7)	3. project required too much time (2)
4. project reinforces the scientific theory behind each procedure (5)	4. need to develop detailed handouts for laboratory procedures and calculations (1)
5. time commitment was reasonable, considering there was no scheduled lab period (2)	5. provide more background information about each sample (1)
6. project broadened student's background (2)	
7. flexibility with scheduling was enhanced by pairing students (1)	

tentially, this approach would have the added benefit of illustrating technician-to-technician variability to the students in the class.

Summary

This activity was conducted in an effort to promote better understanding of the analyses necessary to evaluate forage nutritive value. In addition, it was designed to help students understand the problems inherent in predicting the energy content of forages. Students generally felt the activity was helpful in meeting these goals. This activity may have been most beneficial to students pursuing advanced degrees in programs other than ruminant nutrition; these students may have no other exposure to these procedures during their advanced academic training.

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