ASSESSING NUTRIENT COMPOSITION AND DIGESTIBILITY OF TALLGRASS-PRAIRIE HAY

K. C. Olson, R. C. Cochran, E. C. Titgemeyer, and T. J. Jones

Summary

Thirteen steers were used in a 4 13 incomplete Latin square to determine chemical composition and digestibility for 13 samples of tallgrass prairie hay. Hays were collected from a variety of locations in east-central Kansas and represented a wide array of harvest dates and storage conditions. Steers were fed prairie hay and soybean meal at 1.5% and .2% of body weight, respectively, to equalize intakes relative to body weight and prevent degradable intake protein (DIP) from limiting extent of digestion. Prairie hay samples were analyzed for N, ADIN, ADF, NDF, ADIA, monosaccharides (sugars), and alkali-labile phenolic acids (lignin components). The relationships of various forage chemical components to diet organic matter digestibility (OMD) were examined using simple, linear regression. There was a close relationship between OMD and ADF (r^2 = .62; OMD = .822 [ADF] + 96.47). In addition, the ratio of xylose:glucose (r^2 = .62; OMD = 41.93[X:G] + 94.14) explained significant amounts of the variation in OMD. Defining the chemical composition of bluestem hay may be of value in predicting organic matter digestibility and, ultimately, energetic value.

(Key Words: Hay Digestibility, Hay Chemical Composition, Forage.)

Introduction

In the Flint Hills, bluestem hay often comprises an important portion of beef cattle diets. However, the energetic value of bluestem hay is defined poorly. Because information about dietary energy is critical to predicting cattle performance, a clearer description of the energy availability of bluestem hay is needed. The largest loss of ingested energy for many forages is fecal energy, so precise definition of that loss from bluestem hay diets will improve prediction of beef cattle performance.

Digestible energy (DE; intake energy fecal energy) is related directly to dietary organic matter digestibility (OMD). Percent OMD and % DE rarely differ by more than a few units. However, neither can be measured conveniently by livestock producers. Dietary chemical composition, on the other hand, is measured easily and can be useful to predict both DE and OMD. The objective of this study was to construct mathematical models to predict DE and OMD of bluestem prairie hays from their chemical compositions. This preliminary paper discusses the inherent variability in chemical composition of bluestem hay and proposes mathematical models that can be used to predict OMD from chemical composition.

Experimental Procedures

Thirteen steers (average initial body weight = 609 lb) were used in a four-period incomplete Latin square design to determine chemical composition and digestibility of 13 samples of tallgrass prairie hay. Hays were collected from a variety of locations in east-central Kansas. Cutting dates ranged from late June to late August; seven hay samples were stored outdoors in large round bales and six were stored indoors in small square bales. All hay samples were tub ground to a uniform particle size (approximately 4 in.) and stored dry in weather-resistant receptacles. Samples that exhibited visual indications of mildew or were noticeably moist and warm in the interior of the bale at the time of grinding were considered to be heat damaged. Four samples were heat damaged to some degree.

Steers were housed in individual stanchions and fed prairie hay and soybean meal at 1.5% and .2% of body weight, respectively, to equalize intakes relative to body weight and prevent degradable intake protein (DIP) from limiting extent of digestion. The appropriate level of DIP was determined in a previous study. Four 23-day experimental periods were conducted during the late winter and spring of 1995, consisting of a 14-day adaptation phase and a 9-day collection phase. Hay and supplement were offered at 7 AM. Supplement consumption was complete each day, and, with the exception of 5 observations, hay consumption was complete as well. Hay intake and refusals were measured on days 15 - 21 and days 16 - 22, respectively. Fecal samples were collected on days 17 - 23. Acid detergent insoluble ash (ADIA) was used as a marker to determine fecal output.

Prairie hay samples were analyzed for crude protein (CP), acid detergent insoluble crude protein (ADICP), acid detergent fiber (ADF), neutral detergent fiber (NDF), ADIA, monosaccharides (sugars), and alkali-labile phenolic acids (lignin components). The relationships of various forage chemical components to diet organic matter digestibility (OMD) were determined via regression analysis.

Results and Discussion

Chemical composition, measured OMD, and a brief description of each prairie hay sample are presented in Table 1. Dates of harvest ranged from June 23 (sample K) to August 31 (sample H), roughly a 9-week interval. Seven of the hay samples were stored as small square bales. The remaining samples were stored as large round bales. Of the four heat damaged samples, three were put up as large round bales. Mean, standard deviation, minimum, and maximum values for chemical composition and OMD of the hay samples are shown in Table 2. Directly measured diet OMD ranged from 55.1% for heat-damaged, late-harvested bluestem hay (sample H) to 69.5% for early-harvested hay with no heat damage (sample K). Sample H had the lowest crude protein content (1.4%) and sample C the highest (4.9%). Unavailable forage crude protein, as indicated by ADICP, was relatively uniform among hay samples when expressed on a dry matter basis. However, when unavailable CP was expressed as a percentage of the total CP, it ranged from approximately 17% (Sample B) to 68% (Sample H). The extent to which bluestem hay is digested is highly dependent upon available dietary protein. Nitrogen from dietary protein is necessary for ruminal bacteria to grow and reproduce. When bacterial growth is inhibited by a protein deficiency, hay digestibility decreases. At realistic intake levels, hay crude protein concentrations observed in this study were insufficient to meet protein requirements for growth or maintenance for nearly all classes of beef cattle. In the event that bluestem hay comprises a large proportion of a beef cattle diet, supplemental protein will likely be needed to optimize hay digestibility and support the desired level of production.

The relative amount of forage fiber varied considerably among hay samples. The minimum-maximum values for NDF and ADF were 60.7 to 74.0% and 36.2 to 49.6%, respectively. Forage NDF and ADF commonly are used as indices to judge the relative quality of many hay types. Typically, as ADF and NDF increase in a sample of hay, digestibility decreases, making these chemical characteristics of forage useful as indicators of quality. In our study, NDF was moderately correlated to OMD ($R = .56$); ADF was related more highly to OMD ($R = .78$).

Lignin is a fraction of forage fiber that is associated negatively with forage quality. Some specific constituents of lignin, namely para-coumaric acid (PA) and ferulic acid (FA), ranged from .42 to .85% and .43 to .57%, respectively. The largest fraction, PA, was correlated positively with forage NDF, ADF, and ADIN ($R>.74$; $P<.002$), indicating that PA increased as forage fiber and unavailable nitrogen increased. However, PA was correlated only moderately to OMD ($R = .41$).

Another factor that may be of use in estimating forage digestibility is the monosaccharide (simple sugar) composition of various forage carbohydrates. Carbohydrates differ in their monosaccharide profile. This information may be useful to predict forage OMD. Glucose is the major constituent of starch and cellulose. Both are highly digestible in their pure forms. Glucose constituted 20.0 to 24.6% of the hay dry matter in this study and was correlated moderately to OMD (R = .54). It is likely that very little starch was present in our hay samples, so most of the glucose came from cellulose. Xylose is the major monosaccharide in hemicellulose and ranged from 15.4 to 24.6% in the hays we studied. Xylose was correlated negatively to OMD (R = .65), indicating that as xylose, and presumably hemicellulose, increased, OMD decreased. The xylose to glucose ratio, which is indicative of the relative proportions of hemicellulose and cellulose, also had a high, negative correlation to OMD (R = .79).

Based on results from the regression analysis, various models were constructed to predict OMD from forage chemical components. Acid detergent fiber (ADF) was an acceptable predictor of OMD (Figure 1), accounting for 62% of the variation associated with hay digestibility. Although NDF was correlated moderately to OMD, it was less useful than ADF in predicting OMD in this study (y = .056[ADF]+98.97; R^2 = .31). Similarly, PA and FA did not predict OMD with accuracy (R^2<.17). The xylose to glucose ratio (X:G) was also an acceptable predictor of OMD (R^2 = .62; Figure 2). Xylose alone accounted for only 42% of the variation in hay OMD, despite its high correlation to OMD.

The formulae presented in Figures 1 and 2 can be used to predict OMD of bluestem hay by substituting forage ADF and X:G (%) for x in their respective equations. However, in order for the equation to produce a reliable estimate, the following conditions must be met: 1) the animal must not be deficient in ruminally degradable dietary protein and 2) the ADF and/or X:G value must fall within the range of ADF and/or X:G values for the hay samples used in this study.

It is evident from these data that bluestem hay is not a uniform entity. Factors such as growing conditions, plant maturity, and storage methodology play a role in determining its nutritional quality. These environmental factors can interact to create wide variations in nutritional quality of bluestem hay, even in a relatively small geographical area like the Flint Hills.

The ability to predict performance of animals consuming a bluestem hay-based diet is contingent upon knowing the diet's energetic value. Our results suggest that, with an adequate description of forage chemical composition, one can do an acceptable job of predicting digestibility and, ultimately, energetic value.

Table 1. Description and Chemical Composition of Prairie-Hay Samples

	Hay Sample												
Item	A	B	C	D	E	F	G	H	I	J	K	L	M
Harvest date	8/6	8/2	8/2	7/17	7/19	8/13	8/20	8/31	7/19	8/25	6/23	8/25	7/23
Bale type	Round	Square	Round	Round	Round	Round	Round	Square	Square	Square	Square	Square	Square
Heat damage	Yes	No	No	Yes	No	No	Yes	Yes	No	No	No	No	No
% OMD[a]	58.3	61.5	63.1	58.7	63.3	61.9	58.7	55.1	64.3	66.2	69.5	57.0	62.6
	% dry matter												
Crude protein	4.3	4.4	4.9	4.5	4.4	3.4	4.3	1.4	4.1	3.5	4.7	3.4	3.6
ADICP	1.13	.75	.94	1.13	.88	.94	1.13	.94	.88	.88	.81	.81	.75
NDF	69.0	62.4	66.7	68.8	67.0	68.7	73.9	74.0	69.3	66.2	60.7	62.4	67.4
ADF	46.3	38.4	40.2	43.4	42.1	45.0	47.3	49.6	41.4	38.9	36.2	41.3	42.9
Glucose[b]	22.4	23.0	23.3	21.5	24.3	22.2	21.2	21.9	22.1	24.6	22.1	20.0	24.1
Galactose[b]	1.6	1.9	1.8	1.8	1.6	1.5	1.6	1.6	1.6	1.6	1.9	2.1	1.7
Mannose[b]	.75	.71	.62	.55	.76	.85	.58	.50	.52	.53	.73	.84	.60
Xylose[b]	17.4	16.5	16.6	17.5	17.5	19.0	18.8	19.6	17.1	16.7	15.4	16.9	18.0
Arabinose[b]	3.4	3.8	3.7	3.8	3.5	3.1	3.5	3.9	3.5	3.7	3.7	4.1	3.7
Rhamnose[b]	.34	.37	.36	.38	.29	.38	.23	.29	.27	.32	.40	.40	.22
Para-coumaric acid[c]	.66	.46	.48	.70	.51	.74	.85	.60	.55	.50	.45	.42	.54
Ferulic acid[c]	.46	.52	.52	.57	.51	.47	.54	.46	.54	.52	.52	.43	.51

[a]OMD directly measured. [b]Monosaccharide sugars. [c]Alkali-labile phenolic acids.

Table 2. Mean, Standard Deviation, Minimum, and Maximum Values of Organic Matter Digestibility and Chemical Composition of Bluestem Prairie-Hay Samples (DM Basis)

Variable	# Observations	Mean (%)	Standard Deviation	Minimum	Maximum
OMD[a]	13	61.5	4.0	55.1	69.5
DM	13	91.4	.99	89.3	92.6
OM	13	83.4	1.6	80.4	85.5
NDF	13	67.4	4.0	60.7	74.0
ADF	13	42.5	3.8	36.2	49.6
ADIA	13	4.8	.94	3.6	6.7
Crude protein	13	3.9	.88	1.4	4.9
ADICP	13	.94	.13	.75	1.13
Glucose[b]	13	22.5	1.3	20.0	24.6
Galactose[b]	13	1.7	.17	1.5	2.1
Mannose[b]	13	.66	.12	.50	.85
Xylose[b]	13	17.5	1.2	15.4	19.6
Arabinose[b]	13	3.6	.25	3.1	4.1
Rhamnose[b]	13	.33	.06	.22	.40
Para-coumaric acid[c]	13	.57	.13	.42	.85
Ferulic acid[c]	13	.50	.04	.43	.57

[a]OMD directly measured. [b]Monosaccharide sugars. [c]Alkali-labile phenolic acids.

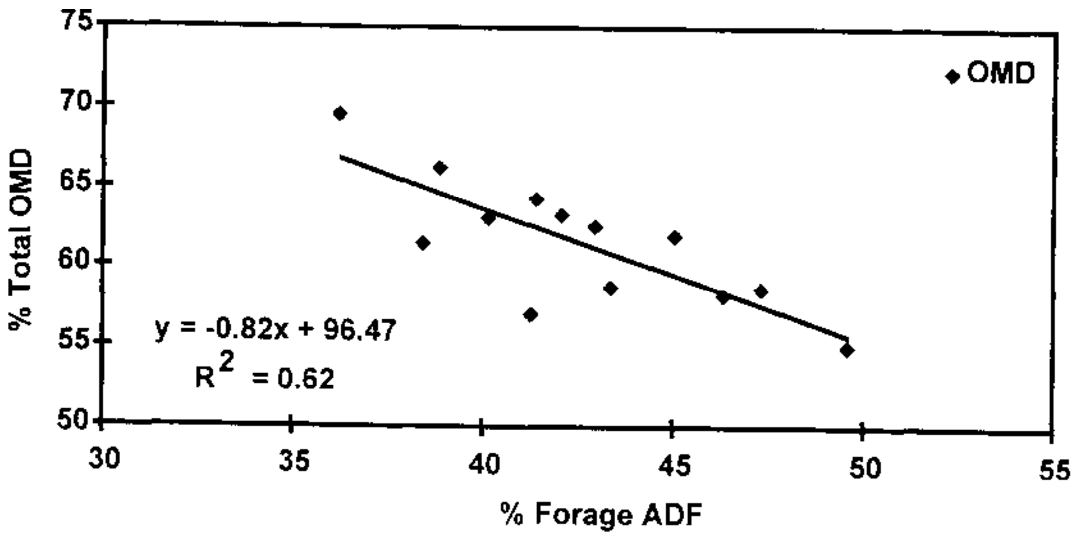

Figure 1. **Prediction of Total OMD (%) from Forage ADF**

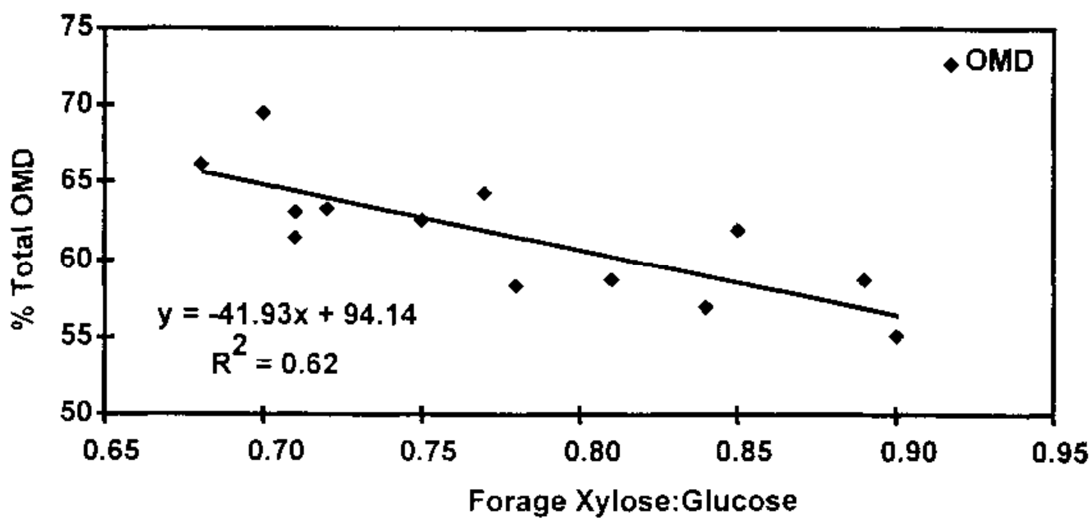

Figure 2. **Prediction of Total OMD (%) from Forage Xylose:Glucose Ratio**