Comparisons of In Situ Dry-Matter Disappearance Kinetics of Wheat Forages in Confined and Grazing Steers

W.K. Coblentz[1], K.P. Coffey[1], J.E. Turner[1], D.A. Scarbrough[1], J.V. Skinner[2], D.W. Kellogg[1], and J.B. Humphry[1]

Story in Brief

Ruminal disappearance kinetics of various forages are necessary components of many of the current nutritional models available for balancing the diets of livestock. Most of these evaluations are conducted in situ with ruminally cannulated animals that are offered controlled diets in confinement; the appropriateness of using this approach for grazing animals has been questioned. Previously we evaluated a set of 15 wheat (*Triticum aestivum* L.) forage samples for in situ disappearance kinetics of DM in confined steers using standard techniques. In this study, we evaluated these same 15 forages in steers consuming a basal diet of primarily wheat pasture. For the immediately soluble fraction (A), the fraction degraded at a measurable rate (B), the undegradable fraction (C), potential extent, rate of disappearance (k_d), and effective ruminal degradability, linear regressions of values obtained for steers grazing wheat pasture on those obtained from confined cattle had significant ($P < 0.0001$) slopes and exhibited high r^2 statistics (> 0.821). For fractions A and B, and k_d, the slope of these regression lines did not differ from unity ($P > 0.378$), and the intercept did not differ ($P > 0.07$) from zero. For fraction C, potential extent of disappearance, and effective ruminal degradability, slopes differed ($P < 0.011$) from unity. For effective degradability, deviation of the slope from unity can be explained, in part, on the basis of passage rate. From a practical standpoint, the in situ disappearance kinetics of DM for these wheat forages did not appear to be altered substantially by evaluating them in grazing steers.

Introduction

Evaluating the digestion kinetics of various forages provides information that is necessary for many of the most recent nutritional models used to balance diets for various livestock classes. Usually, these in situ evaluations are conducted with ruminally cannulated steers that are housed in confinement; this is done largely to control the intake and make-up of the basal diet offered to the experimental steers. This approach has been criticized by some researchers who work primarily with grazing animals. Numerous questions have been raised about the value of data generated from confined animals for use in balancing the diets of grazing livestock. Previously, we evaluated a set of 15 wheat forages that were harvested by various techniques for in situ disappearance kinetics of DM in confined steers consuming an alfalfa (*Medicago sativa* L.)-based diet (Coblentz et al., 2002). Our objectives in this study were to: 1) evaluate the ruminal disappearance kinetics of DM for these same 15 wheat forages in steers grazing a basal diet of wheat pasture; and 2) relate, by linear regression techniques, various parameter estimates associated with the disappearance kinetics of DM determined in grazing steers with estimates obtained previously when steers were housed and fed in confinement.

Experimental Procedures

Experimental Forages. The 15 experimental wheat forages were collected on three dates (March 6, March 27, and April 11, 2001) with five sampling techniques (freeze- or oven-dried masticate and top-half, whole-plant, and random-plucked samples clipped with garden shears). This sample set has been described in detail previously (Coblentz et al., 2002).

Establishment and Management of Experimental Wheat Pasture. A 4-acre site located at the University of Arkansas Forage Research Area in Fayetteville was clean-tilled and fertilized to meet the soil test recommendations of the Arkansas Cooperative Extension Service; this included an application of 60 lb/acre of actual N as NH_4NO_3. The site was seeded with 'Delta King 9027' soft-red winter wheat on September 18, 2000 at a rate of 120 lb/acre with a 7-ft Marliss drill (Marliss Industries, Jonesboro, AR). An additional 50 lb/acre of N was applied as NH_4NO_3 on March 9, 2001. Throughout the late fall of 1999 the site was grazed lightly to control fall growth. On March 16, 2001, five 986 ± 108-lb crossbred (Angus x Brangus x Angus) steers fitted with ruminal cannulae were given access to the entire 4-acre wheat pasture. Steers remained on the pasture continuously, except for approximately 30 min each day when a corn-based supplement was fed individually in corrals located adjacent to the wheat pasture. At 0730 h each day, steers were offered the supplement at 0.25% of BW; any supplement not consumed was manually placed in the rumen via the ruminal cannula. The supplement contained (as is basis) 90.4% ground corn, 4.0% trace mineral salt, 2.4% liquid molasses, and 3.2% Bloat Guard® (Pfizer Animal Health, Exton, PA).

In Situ Procedures. Steers were adapted to these grazing conditions for 11 d prior to evaluating the DM disappearance kinetics of the 15 experimental wheat forages. All procedures associated with the determination of in situ disappearance kinetics were identical to those used when these wheat forages were evaluated in confined steers (Coblentz et al. 2002). Previously, Lippke et al. (2000) reported a rate constant of 0.062/h for the turnover rate of the age-independent compartment for 416-lb steers grazing winter wheat pasture and receiving a cottonseed hull/steam-rolled corn supplement. This passage rate was used subsequently in our calculations of effective degradability of DM.

On March 16 (d 1), March 27 (d 12), and March 31 (d 16), the wheat pasture was evaluated for canopy height, forage availability, and nutritive value (Table 1). These dates correspond to the date the steers began their adaptation period, and the beginning and end of the in situ evaluations, respectively. An additional steer of approximate-

[1] Department of Animal Science, Fayetteville
[2] Resident Director, Arkansas Agricultural Experiment Station

ly the same weight as those used for determining in situ disappearance kinetics was evacuated manually and allowed to collect a representative diet sample on d 12 and d 16 of the trial. Masticate samples were collected immediately after the other experimental steers were supplemented at 0730 h; all masticate samples were immediately frozen (-25°F) and freeze-dried prior to grinding. Samples (clipped and masticate) collected to characterize the nutritive value of the basal diet of wheat pasture were analyzed for NDF, ADF, CP, and ash by standard methodology.

Statistics. Disappearance kinetics were evaluated as a randomized complete block design with a factorial arrangement of five sampling techniques and three harvest dates; the five steers served as replications (blocks). All analyses were conducted by PROC ANOVA (SAS Inst., Inc., Cary, NC). Parameters associated with disappearance kinetics determined in steers grazing wheat pasture were related to those determined in confined steers by linear regression; additional test statements were included to evaluate whether slope = 1 and intercept = 0 (PROC REG; SAS Inst., Inc., Cary, NC).

Results and Discussion

Disappearance Kinetics in Grazing Steers. Generally, the statistical analysis of disappearance kinetics of DM evaluated in grazing steers was quite similar to that described previously for disappearance kinetics determined in confined steers (Coblentz et al., 2002). Sampling date and technique for the 15 experimental forages and their associated interaction affected ($P < 0.0001$) the immediately soluble fraction (A), the fraction disappearing at a measurable rate (B), the fraction undegradable in the rumen (C), the potential extent of disappearance, and the effective ruminal disappearance of DM. Within each sampling date, freeze-dried masticate had a larger ($P < 0.05$; Table 2) fraction A and effective rumen degradability than did oven-dried masticate or any of the clipping treatments. However, fraction C and the potential extent of disappearance for freeze-dried masticate did not differ ($P > 0.05$) from oven-dried masticate on any date; this suggests that oven-drying did not cause plant components to become unavailable in the rumen via nonenzymatic browning (Maillard) reactions. The potential extent of disappearance was high (> 81.6%) for all forages, indicating that forage quality was excellent on all dates.

Estimates of disappearance rate (k_d; Table 3) were affected ($P < 0.0001$) by sampling date and technique, but not by their associated interaction ($P = 0.349$). Freeze-dried masticate had the fastest k_d (0.092/h). The top-half clipping treatment had a slower k_d (0.079/h; $P < 0.05$) than freeze-dried masticate, but this rate was faster ($P < 0.05$) than all other treatments. Oven-dried masticate exhibited a disappearance rate (0.068/h) that did not differ ($P > 0.05$) from the whole-plant and random pluck clipping treatments. Therefore it appears that oven-drying slowed the rate of DM disappearance, relative to freeze-dried masticate, but did not affect the extent of potential disappearance in the rumen. Rates of disappearance slowed ($P < 0.05$) from 0.096/h on the March 6 sampling date to 0.054/h on the final (April 11) sampling date. These changes are likely associated with the growth stage of the wheat plants on these dates, which ranged from vegetative (pre-jointing) on March 6 to early boot stage on April 11. Lag time exhibited no significant treatment effects ($P > 0.073$) in grazing steers; this was in contrast with the significant ($P = 0.027$) effect for sampling technique described previously (Coblentz et al., 2002).

Regressions of Disappearance Kinetics in Grazing Steers on Those in Confinement. Excepting lag time, linear regressions (Table 4) of all in situ disappearance parameters determined in grazing steers on those determined in confined steers had significant slopes ($P < 0.0001$) and exhibited very high r^2 statistics ($r^2 > 0.821$). Lag time did not exhibit a significant slope ($P = 0.173$). Additional tests of slope = 1 and intercept = 0 indicated that the slope and intercept did not differ from unity ($P > 0.378$) and zero ($P > 0.070$), respectively, for fractions A and B, or for k_d. For fraction C, the potential extent of disappearance, and estimates of effective ruminal degradability, the relationship between the two methods was close ($r^2 > 0.964$), but the slopes ($P < 0.011$) and intercepts ($P < 0.032$) differed from unity and zero, respectively.

In agreement with the results observed when the 15 experimental forages were evaluated in confined animals, none of the clipping treatments was effective in mimicking the diet selected by grazing steers. Although oven-drying at 122°F is a much simpler technique for drying masticate samples, ruminal disappearance parameters clearly differed from those of freeze-dried masticate.

For fractions A and B, and k_d, it is encouraging that linear regressions of values obtained from grazing steers on similar estimates determined in confined steers had a slope and intercept that did not differ from unity ($P > 0.378$) and zero ($P > 0.070$), respectively (Table 4). This suggests that disappearance kinetics were not radically altered by the different experimental conditions, most notably the chemical composition and intake of the basal diets. However, it should be noted that the nutritive value of the forage component of the basal diets was relatively high in both cases. The high r^2 statistics ($r^2 > 0.821$) for all kinetic parameters, excepting lag time, further indicates that the relationship between methodologies was very close. It remains unclear whether these relationships would be altered appreciably if a forage with lower nutritive value had been used for the basal diet in our confinement study.

The negative intercepts associated with regressions of the potential extent of DM disappearance and effective ruminal degradability (Table 4) indicate that these estimates were numerically lower for steers grazing wheat pasture than they were in evaluations performed in confinement. Slopes in each of these cases (1.19) were greater than unity, thereby indicating that agreement between the two methods improved as the potential extent of disappearance and effective degradability increased. Overall (n = 15 forages), the mean potential extents of DM disappearance in confined and grazing steers were 91.6 and 88.6%, respectively; in practical terms, these estimates of the potential extent of DM disappearance determined in grazing steers do not represent a radical departure from estimates made in confinement. Overall means for effective degradability were 73.3 and 65.6% for confined and grazing steers, respectively. Numerically greater estimates of effective degradability in confined steers can be explained, in part, on the basis of the slower passage rate (0.035 vs. 0.062/h) used to calculate effective degradability. This is particularly relevant because the slope and intercept for fractions A and B, and k_d, which are the other factors required to calculate effective degradability, did not differ from unity and zero, respectively.

Implications

Although our estimates of the potential extent of disappearance and effective degradability of DM were lower in grazing steers, these results did not represent a radical departure from those observed in confined steers consuming a basal diet of primarily alfalfa hay. These results are encouraging because they suggest that parameter estimates for in situ disappearance kinetics obtained from confined steers may be relevant within a grazing context. This is helpful because the logistics of conducting these trials in confined animals are much simpler than conducting a similar trial with grazing animals.

Literature Cited

Coblentz, W. K., et al. 2002. Arkansas Anim. Sci. (submitted).
Lippke, H., et al. 2000. J. Anim. Sci. 78:1625-1635.

Table 1. Agronomic and nutritive value characteristics of wheat pasture used as the basal diet for determination of in situ DM degradation kinetics on pasture in Fayetteville during 2001

Date	Sample type	Forage availability	Plant height	CP	NDF	ADF	Ash
		lbs/acre	inches	---------- % of DM ----------			
16 March	clipped	802	7.5	22.0	45.4	26.7	14.5
27 March	clipped	1,069	5.9	19.4	50.0	30.5	14.6
	masticate			27.0	45.0	23.9	20.0
31 March	clipped	891	5.1	18.4	55.8	35.9	14.9
	masticate			26.7	46.3	23.8	25.8

Table 2. In situ DM disappearance characteristics for wheat forage harvested on three dates by various techniques. In situ evaluation of disappearance kinetics was performed on pasture; for clarity, only mean separation within an individual harvest date is shown.

Harvest date/technique	A[1]	B	C	Extent[2]	Effective degradability[3]
	------------------------------- (% of DM) ---------------------------------				
6 March					
Freeze-dried masticate	53.8[a]	38.3[c]	7.9[abc]	92.1[abc]	77.9[a]
Oven-dried masticate	44.3[b]	46.1[b]	9.6[a]	90.4[c]	69.9[c]
Random pluck	42.3[c]	50.9[a]	6.9b[c]	93.1[ab]	71.3[c]
Top half	42.1[c]	51.4[a]	6.5[c]	93.5[a]	74.4[b]
Whole plant	40.2[d]	51.2[a]	8.6[ab]	91.4[bc]	69.1[c]
27 March					
Freeze-dried masticate	50.3[a]	40.4[d]	9.3[b]	90.7[a]	73.9[a]
Oven-dried masticate	38.8[b]	51.9[b]	9.3[b]	90.7[a]	64.8[b]
Random pluck	33.7[d]	49.4[c]	16.9[a]	83.1[b]	55.5[c]
Top half	35.1[cd]	54.4[a]	10.5[b]	89.5[a]	63.5[b]
Whole plant	36.3[c]	47.9[c]	15.8[a]	84.2[b]	57.2[c]
11 April					
Freeze-dried masticate	50.3[a]	42.6[c]	7.1[d]	92.9[a]	74.4[a]
Oven-dried masticate	36.5[c]	55.8[a]	7.7[d]	92.3[a]	62.9[b]
Random pluck	36.7[c]	42.0[c]	21.3[a]	78.7	53.0[c]
Top half	39.4[b]	45.8[b]	14.8[c]	85.2[b]	60.9[b]
Whole plant	38.9[b]	42.7[c]	18.4[b]	81.6[c]	54.7[c]
SEM[4]	0.5	0.8	0.6	0.6	0.9

[a,b,c,d] Means in a column and within a given harvest date that are without common superscripts differ ($P < 0.05$).

[1] Abbreviations: A = Immediately soluble fraction, B = fraction disappearing at a measurable rate, and C = undegraded fraction.

[2] Potential extent of disappearance in the rumen.

[3] Calculated as $A + B(k_d/k_d + \text{passage rate})$, where k_d = disappearance rate and the passage rate (0.062/h) was based on the work of Lippke et al. (2000).

[4] Standard error of sampling date by sampling technique interaction means (n = 5 steers).

Table 3. Summary of main effects for disappearance rate (k_d) determined in grazing steers for experimental wheat forages. Both sampling technique and sampling date were significant ($P < 0.0001$), but the interaction of these effects was not ($P = 0.349$)

Main effect/treatment	k_d
	/h
Sampling Technique	
Freeze-dried masticate	0.092[a]
Oven-dried masticate	0.068[c]
Random pluck	0.061[c]
Top half	0.079[b]
Whole plant	0.059[c]
SEM[1]	0.004
Sampling Date	
6 March	0.096[a]
27 March	0.064[b]
11 April	0.054[c]
SEM[1]	0.003

[a,b,c] Means in a column and within a given main effect that are without common superscripts differ ($P < 0.05$).

[1] Standard error of main effect mean.

Table 4. Regressions (n = 15 forages) of parameter estimates for disappearance kinetics of DM obtained from in situ evaluations conducted in steers grazing wheat pasture on those obtained from in situ evaluations conducted in confinement

Parameter	Slope[1]	SE_{slope}[2]	P > F[3]	Intercept[4]	$SE_{intercept}$[5]	P > F[6]	r^2
Fraction A[7]	1.03	0.05	0.507	- 4.0	2.0	0.070	0.975
Fraction B	0.95	0.08	0.563	2.0	3.9	0.624	0.913
Fraction C	1.19	0.06	0.011	1.4	0.6	0.032	0.964
Extent	1.19	0.06	0.011	- 20.0	5.8	0.004	0.964
Lag time	NS[8]	- - -	- - -	- - -	- - -	- - -	- - -
k_d	1.13	0.15	0.378	- 0.007	0.010	0.541	0.821
Degradability[9]	1.19	0.06	0.010	- 21.7	4.6	< 0.001	0.965

[1] Slope of regression line.
[2] Standard error of the slope.
[3] Probability that slope = 1.
[4] Intercept of regression line.
[5] Standard error of the intercept.
[6] Probability that intercept = 0.
[7] Abbreviations: A = Immediately soluble fraction, B = fraction degradable at a measureable rate, C = undegraded fraction, and k_d = ruminal disappearance rate.
[8] Slope was not significant (P = 0.173).
[9] Calculated as A + B(k_d/k_d + passage rate), where k_d = disappearance rate. Passage rate (0.062/h) for steers was based on the work of Lippke et al., 2000). The passage rate for five steers housed in confinement was determined experimentally as 0.035 + 0.009/h.