Relationships between Performance, Intake, Diet Nutritive Quality and Fecal Nutritive Quality of Cattle on Mountain Range

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Abstract

Correlations were developed between average daily gain (ADG), forage organic matter intake (INT), fistula sample in vitro organic matter digestibility (DID), fistula sample nitrogen (DN), fecal sample in vitro digestibility (FID), and fecal sample nitrogen (FN) of cattle on forest and grassland range in northeastern Oregon. FN and FID were more closely associated with ADG and INT than DN or DID. Linear regression equations were developed between fistula and fecal samples for both N ($r^2 = .83$) and ID ($r^2 = .71$). The inclusion of FN as an independent variable with FID improved the equation for predicting fistula sample ID ($R^2 = .83$). Forage intake could not be well predicted from either FN or FID in either simple or multiple regression equations. The closer relationship between fecal sample nutritive quality and ADG compared to fistula sample nutritive quality and ADG is attributed to greater sampling precision for fecal nutritive quality. Fecal N and ID appear to be closely associate with DN and DID when grasses comprise most of the ruminant diet but this relationship may not hold when the diet is dominated by forbs and shrubs. Nutritive evaluation of feces shows potential for monitoring trends in ruminant diet quality and performance but much more research is needed before these procedures can be applied.

Trends in ruminant fecal nutritive quality are associated to varying degrees with trends in diet quality (Raymond 1948, Fels et al. 1959, Jarrige 1962, Arman et al. 1975, Hinnant 1979, Holloway et al. 1981) and animal performance (Erasmus et al. 1978, Gates and Hudson 1981). Three studies have shown a close relationship between percentage nitrogen in the diet and percentage nitrogen in the feces of ruminant animals (Raymond 1948, Fels et al. 1959, Hinnant 1979). A recent study indicates diet and fecal in vitro digestibility are associated (Holloway et al. 1981). Erasmus et al. (1978), in South Africa, found that trends in wild ungulate body condition were closely associated with trends in fecal nutritive quality. Gates and Hudson (1981) accounted for 85% of the variation in daily gains of elk with fecal N concentration. Based on these studies it might be possible to monitor changes in ruminant condition and diet using fecal analysis. The study reported, herein, examined the relationships between cattle performance, intake, diet nutritive quality, and fecal nutritive quality on mountain range in northeastern Oregon during 3 grazing seasons. In vitro organic matter digestibility and nitrogen were the nutritive characteristics receiving evaluation.

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Methods

The study site was located on the Starkey Experimental Range and Forest 48 km southwest of La Grande, Oregon. The range is described by Skovlin et al. (1976). A complete description of the vegetation on the study area is given by Ganskopp (1978). Two grassland and two forest pastures were used. Data on cattle diet botanical composition have been reported by Holechek et al. (1982 b,c).

Grazing was conducted on 2 forest and 2 grassland pastures of equal grazing capacity in 1976, 1977, and 1978. Grazing management involved the grazing of 1 pasture on each vegetation type all season in 1976. In 1977, cattle were grazed on the pasture rested in 1976 until midseason, when they were moved to the other pasture. In 1978, cattle were grazed all season on the pasture rested in 1976. The grazing season lasted 120 days during each year of study. Cattle were placed on the pastures on June 20 and removed on October 10. Cattle performance on the pastures was evaluated in the late spring (June 20 to July 18), early summer (July 19 to August 15), late summer (August 16 to September 12), and fall (September 13 to October 10) in all 3 years of study with 18 head of pregnant yearling heifers weighed without shrink at the onset of grazing and the end of each period.

Diet samples from each pasture were collected with 4 cows equipped with esophageal fistulas. These animals were included as

part of the stocking rate and grazed continuously on each pasture throughout the grazing season. Diet samples from each cow were collected twice every other week on each pasture. Collections on the forest and grassland were always made during the same week. Data on nutritive quality of these samples were reported by Holechek et al. (1981).

Four steers in each pasture were used for fecal collections, so forage intake could be estimated. Forage intake data are reported by Holechek and Vavra (1982). One 24-hour collection was made with each steer on each pasture every other week on the same week that fistula samples were collected. Fistula samples were collected at the beginning of the week and fecal samples were collected near the end of the week. The period between ingestion and complete excretion is about 8 to 10 days for cattle fed medium quality roughages (Balch 1950). The highest rates of excretion occur 2 to 4 days after ingestion (Balch 1950). Because fistula samples were collected 3 to 4 days before fecal samples, we believe that fistula samples were representative of fecal samples. Each fecal collection was subsampled for laboratory analysis. Immediately after collection both esophageal and fecal samples were frozen. They were later dried in a forced air oven at 40° C for 7 days. After drying all samples were ground through a 1-mm screen. In vitro organic matter digestibility (ID) was determined for all samples at New Mexico State University by the technique of Tilley and Terry (1963). Nitrogen (N) was determined by Kjeldahl procedure using AOAC (1975) methods. All data were converted to an organic matter basis. Forage organic matter intake was determined from total 24-hour fecal organic matter output by using the equation of Van Dyne (1969):

$$\text{Organic matter intake} = \frac{100 \times (\text{Total fecal organic matter output})}{100 - \%\text{ in vitro organic matter digestibility}}$$

Organic matter intake was expressed as a percentage of body weight as discussed by Cordova et al. (1978).

Regression and correlation analyses were used to determine the relationships between performance, intake, diet nutritive quality and fecal nutritive quality. Ranges of values of the different parameters used in regressions are shown in Table 1. Data on diet nutritive quality and fecal nutritive quality were pooled across animals and collections within each period and vegetation type when average daily gain and intake were used as dependent variables. Livestock performance and intake data for the late spring of 1976 were not used in regression models because of a water quality problem on both vegetation types which was corrected in early July. Fistula sample values were pooled across animals (4) and collections (2) within each sampling week when diet ID and diet N were used as dependent variables. Fecal sample N and ID values were pooled across animals for use as independent variables in these regressions. Regression equations were developed for the forest and grassland pastures both individually and together using

Table 1. Range of values of average daily gain, intake, diet nutritive characteristics and fecal nutritive characteristics.

Grassland	Range of values
Average daily gain	−.37 – +0.80 kg
Intake	1.49 – 2.31%[3]
Diet nitrogen percentage[2]	1.04 – 2.36%
Diet in vitro digestibility[2]	39.6 – 65.1%
Fecal nitrogen percentage[3]	1.53 – 3.21%
Fecal in vitro digestibility[2]	11.20 – 27.50%
Forest	
Average daily gain	−.40 – +1.10 kg
Intake	1.50 – 2.39% BW[3]
Diet nitrogen percentage[2]	1.21 – 2.36%
Diet in vitro digestibility[2]	38.90 – 66.90%
Fecal nitrogen percentage[2]	1.58 – 3.41%
Fecal in vitro digestibility[2]	9.20 – 26.30%

[1]Forage intake is expressed as organic matter as a percentage of body weight.
[2]All nutritive quality data are on an organic matter basis.
[3]BW = Body Weight

Table 2. Matrix of correlation between livestock performance, forage intake, diet nutritive characteristics and fecal nutritive characteristics for forest and grassland vegetation types combined.

	ADG[1]	INT[2]	DN[2]	FN[2]	DID[2]
INT	+.51*				
DN	+.53*	+.56*			
FN	+.69**	+.66**	+.91**		
DID	+.60**	+.43*	+.67**	+.74**	
FID	+.65**	+.61*	+.66**	+.68**	+.84**

[1]n = 22
[2]n = 48
* Significant at $P<.05$.
**Significant at $P<.01$.
ADG = Average daily gain.
INT = Intake expressed as organic matter as a percentage of body weight.
DN = Diet nitrogen percentage.
FN = Fecal nitrogen percentage.
DID = Diet in vitro digestibility.
FID = Fecal in vitro digestiblity.

the procedures of Neter and Wasserman (1974). Differences between regression coefficients for vegetation types and years were tested using the t-test discussed by Neter and Wasserman (1974). Simple correlation coefficients were tested for significance using the t-test discussed by Steel and Torrie (1960). The equation of Stein (1945) discussed by Steel and Torrie (1960) was used to evaluate sample size required. The formula is as follows:

$$n = \frac{(t^2)\,(s^2)}{d^2}$$

In this formula n is the computed sample size, t is the tabulated t value for the desired confidence level and the degrees of freedom of the initial sample, d is the half-width of the desired confidence interval, and s^2 is the variance of the initial sample. The individual variances associated with cows and collections for each diet sampling period were calculated using a completely randomized analysis of variance as discussed by Steel and Torrie (1960). Cow and collection variances were then calculated by the formula of Steel and Torrie (1960):

$$s^2 = \frac{s_w^2}{nm} + \frac{s_a^2}{n}$$

In this formula S^2 represents the total variance, n represents the number of cows used for sampling, m represents the number of collections, s_a^2 is the sum of squares for cows, and s_w^2 is the sum of squares for collections. The number of cows needed for adequate sampling was calculated using s_a^2/n as the variance and the number of collections needed was calculated using s_w^2/nm as the variance.

Results and Discussion

Fecal in vitro organic matter digestibility (FID) and fecal nitrogen (FN) were more closely associated with average daily gains and intake than fistula sample in vitro digestibility (DID) or fistula sample nitrogen (DN) (Table 3). Strong relationships occurred between the diet and feces for N ($r^2 = .83$) and ID ($r^2 = .71$) (Table 2).

No differences ($P>.05$) were found between forest and grassland linear regression equations for diet and fecal relationships for either N or ID (Tables 3 and 4). Regression equations were not different ($P>.05$) between years on either vegetation type. Linear regression equations for the relationship between diet and fecal N compare well with those reported by other investigators (Table 3). Standard errors associated estimates for N and ID were 0.26% and 2.68% respectively, when the 2 vegetation types were combined (Tables 3 and 4). Therefore it appears that reasonable estimates on the ranges studied can be obtained for both cattle diet N and ID by fecal evaluation.

The addition of fecal ID as an independent variable with fecal N did not improve ($P>.05$) the regression equation for predicting DN. However, a multiple regression equation using FID and FN as independent variables improved ($P<.01$) the equation for predicting DID:

Table 3. Linear regression equations using diet nitrogen percentage as a dependent variable and fecal nitrogen percentage as a independent variable (y = a + bx).

Vegetation type	Regression characteristic				
	a	b	r^2	n	Sxy
Forest[1]	-0.276	+.855	.78	24	.29
Grassland[1]	-0.262	+.815	.88	24	.23
Forest and Grassland[1]	-0.269	+.835	.83	48	.26
Other Research					
Raymond (1948) sheep	-0.14	+0.795	—	—	—
Fels et al. (1959) sheep	+0.66	+0.928	.86	—	—
Mould and Robbins (1981)[3] elk	+0.77	+0.490	.97	11	—
Hinnant (1979)[1] cows	-0.11	+0.789	.88	4	—
Hinnant (1979)[1] steers	-0.09	+0.662	.90	4	—
Robbins et al. (1975) deer[3]	-3.43	+2.780	.57	7	—

[1]Data are on an organic matter basis.
[2]Forages containing a high soluble phenolic content were not included in the regression.
[3]Diets were dominated by browse high in soluble phenolic content.

$$DID = .659(FID) - 5.948(FN) + 28.48$$

The coefficient of determination (R^2) and standard error of the estimate (S_{xy}) for this equation were .83 and 2.43, repsectively.

Better regressions between fistula and fecal samples for both N and IVOMD may have resulted if fecal samples had been collected from fistulated cows rather than steers. An average of 4 cows and 5 collections (20 fistula samples) were needed to sample DN on the forest pastures with 90% confidence that estimate was 10% of the mean. In order to sample DN on the grassland pastures with the same level of precision, 4 cows and 4 collections (16 fistula samples) were required. A total of 4 cows and 2 collections (8 samples) were actually used. An average of 4 steers would adequately sample FN on either vegetation type. Wallace and Van Dyne (1970), on sandhill range in Colorado, reported that 3 steers would evaluate FN with 90% confidence that the estimate was within 10% of the mean. At least 4 cows and 4 collections (16 samples) were needed to sample the forest pastures for DID with 90% confidence that the estimate was within 10% of the mean. In order to sample the grassland pastures with the same level of precision, 3 cows and 3 collections (9 samples) would be required. A total of 8 and 11 fecal samples would adequately sample FID on the grassland and forest, respectively, with the same precision level. These data show that FN and FID of fecal samples can be estimated with much greater precision than DN or DID. Coefficients of determination may have been improved if more fistula samples had been collected during each sampling period. The reduced precision of fistula sampling also explains why FN and FID were better correlated with average daily gain and intake.

Our equations (Table 3) for N agree well with those of Raymond (1948) and Hinnant (1979). Mould and Robbins (1981) found that DN and FN were closely associated for elk except when the diet contained a high percentage of soluble phenolic compounds. FN is elevated by soluble phenolic containing species because they have protein complexing capabilities. Although grasses are low in soluble phenolics, many shrubs and forbs contain high percentages of these compounds. The phenolic problem may be solved by removal of these compounds using the neutral detergent solution of Van Soest (1967) although this has not been studied. The high correlation between DN and FN in the present study is attributed to the fact cattle were consuming grass dominated diets (Holechek et al. 1982 b,c). Most of the shrub and forb species that were important in these diets are considered to have low soluble phenolic concentrations. Data reported by Mould and Robbins (1981) indicate that species high in soluble phenolics must comprise over 25% of the diet before they appreciably elevate FN values.

Other research is limited on digestibility relationships between fecal and diet samples of ruminant animals. Hollway et al. (1981) and Arthun et al. (1982) found significant correlations between DID and FID of cattle consuming pasture forages. The study by Arthun et al. (1982) showed that diet and fecal ID were highly correlated ($r = .97$) when cattle were consuming grass diets, but the relationship was greatly reduced ($r = .41$) by the inclusion of an alfalfa *(Medicago sativa)* diet in the correlation. Feces digestibility is probably determined primarily by the quality of fiber the ruminant animal has consumed and to some extent by the N concentration of the diet. Grasses typically are low in cell contents and high in cell wall constituents relative to forbs and shrubs (Short et al. 1974). However, the fiber component of grasses is more digestible than that of forbs and shrubs because it has a lower lignin content (Smith et al. 1972). Therefore fecal digestibility of animals on forb and/or shrub dominated diets should theoretically be lower than that of animals consuming grass dominated diets of similar digestibility. This theory is supported by Arthun et al. (1982). They found cattle on bermuda grass *(Cynodon dactylon)* pasture had a DID of 62% with a FID of 23%. In contrast the same cattle fed alfalfa hay had a DID of 68% with a FID of 19%. In our investigation cattle were consuming grass dominated diets (Holechek et al. 1982 b,c) in most periods of study, which may explain the high correlation between DID and FID.

Several studies evaluating the relationship between diet digestibility and FN were reviewed by Holechek et al. (1982c). Their review shows that diet digestibility and FN are positively related although the strength of the association has varied greatly between studies. On the basis of recent research by Van Eys (1978) it appears that FN can give reasonable predictions of diet digestibility when the diet consists primarily of grasses and the objective is to compare relative digestibility between pastures. However, FN may be a poor predictor of digestibility when diets are high in browse which can have both a high lignin and N content. Soluble phenolic compounds in many browse species can further elevate FN values in relation to digestibility (Mould and Robbins 1981). In our study the correlation between DID and FN was much higher on the grassland than on the forest pastures ($r = .64$) ($r = .84$). Browse was always a minor component in diets from the grassland pastures

Table 4. Linear regression equations using diet in vitro digestiblity as a dependent valuable and fecal in vitro digestiblity as an independent variable (y = a + bx).

Vegetation type	a	b	r^2	n	Sxy
Forest[1]	28.7	1.41	.67	24	3.13
Grassland[1]	26.9	1.47	.75	24	2.21
Forest and Grassland[1]	27.8	1.44	.71	24	2.68

[1]Data are on an organic matter basis.

(Holechek et al. 1982b) but it was a major component in diets from the forest pastures in some periods (Holechek et al. 1982c). Our results support the contention that FN concentration is a satisfactory indicator of digestibility when ruminant diets consist almost entirely of grasses but FN is a poor indicator of digestibility of diets high in browse.

Our study is consistent with several other studies reviewed by Cordova et al. (1978) which have shown FN concentration is not a good single indicator of forage intake of range ruminants (Table 2). Intake was better correlated with FN on the grassland pastures ($r = .74$) than on the forest pastures ($r = .58$). On both vegetation types intake was more closely associated with FN than FID. Arthun et al. (1982) reported FN and FID explained 97% and 37%, respectively, of the variation in intake by cattle fed 4 pasture forages. Another recent study by Holloway et al. (1981) showed FN and FID accounted for 31% and 19%, respectively, of the variations in intake of several grass-legume mixtures fed to cattle. Their coefficients of determination were substantially improved for both FN ($r^2 = .44$) and DID ($r^2 = .31$) by using digestible dry matter intake as their dependent variable. In our study use of digestible organic matter intake as the dependent variable resulted in higher correlations for both FN ($r = .71$) and FID ($r = .65$). When FN and FID were used as independent variables in a multiple regression to predict digestible organic matter intake as a percentage of body weight the correlation coefficient was improved ($r = .78$). However the standard error of the estimate (S_{xy}) was .31%, which we consider too high for predictive purposes. Holloway et al. (1981) also found intake prediction equations could be substantially improved by including more than one fecal nutritive quality characteristic in regression models.

Conclusions

Several studies show that trends in ruminant fecal nutritive quality are associated to varying degrees with trends in diet quality and animal performance. Fecal sampling is relatively simple, quick, and inexpensive compared to fistula sampling or rumen sampling techniques that involve animal sacrifice. Our results indicate FN and DID are well related to diet quality and animal performance for ruminants consuming grass dominated diets. However, our review of the literature indicates a high forb and/or browse component in the diet can substantially lower these relationships. We believe more research is needed before nutritive analyses of the feces can be accepted as a tool for diet quality and animal performance evaluation of range ruminants.

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