Evaluation of Fecal Indices to Predict Cattle Diet Quality

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Abstract

A study involving 6 feeds of widely varying chemical properties fed to 6 steers in a Latin square design was conducted to evaluate the potential of fecal chemical characteristics for predicting ruminant nutritional status. Forage intake, diet in vivo digestibility %, and diet nitrogen % were used as dependent variables and fecal nitrogen %, nucleic acid %, nonfiber bound nitrogen %, ether extract %, neutral detergent fiber %, acid detergent fiber %, acid detergent lignin %, water soluble material %, and acid/pepsin disappearance % were used as independent variables in regression equations. Forage intake and diet in vivo digestibility could not be accurately predicted from any single variable or combination of independent variables. Fecal acid/pepsin disappearance was the independent variable most highly correlated with forage intake (r = .63) and diet in vivo digestibility (r = .33). Diet nitrogen % was highly correlated with fecal nitrogen % (r = .81) and fecal acid pepsin disappearance % (r = .83). Combined data from this and other studies give a generalized regression equation that shows potential for detecting nitrogen deficiencies in steer diets from fecal N % (organic matter basis) when steer diets contain low levels of soluble phenolics. When steer fecal nitrogen % drops below 1.7%, dietary nitrogen deficiencies should be suspected.

Determining the intake and diet nutritive quality of grazing ruminants remains one of the most difficult aspects of range nutrition. Typically, nutrition of ruminants grazing rangelands is complicated by diverse plant communities, changing topography and large seasonal and yearly variations in quantity and quality of available forage.

Selectivity of grazing ruminants greatly complicates the ability to obtain samples of grazed forage (Theurer et al. 1976). Therefore clipping or agronomic techniques are inadequate (Hardison et al. 1954). The development and use of the esophageal fistula has greatly improved the ability of scientists to obtain representative diet samples. However, the labor and expense associated with esophageal fistula sampling is quite high. Likewise, estimates of total fecal output via collection bags for forage intake estimation also requires large labor inputs. Although much effort has been dedicated to external indicators, total fecal collection still appears to be the method of choice for estimating forage intake (Cordova et al. 1978).

Nutritional research concerning grazing ruminants and the ability to monitor trends in nutritional status of range animals have been limited by the high labor demand and relatively low precision of current methodology (Holechek et al. 1982b, Holloway et al. 1981). Development of techniques which would allow quick and easy sampling could be beneficial to researchers, public land managers and livestock producers. Holechek et al. (1982 a,b) reviewed literature indicating that some fecal chemical characteristics may have potential for predicting ruminant diet quality, forage intake, and performance.

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Several studies show total fecal nitrogen concentration is associated with various measures of ruminant nutritional status. Gates and Hudson (1981) accounted for 85% of the variation in daily weight gains of elk with total fecal nitrogen concentration. On mountain range in Oregon, Holechek et al. (1982b) accounted for 48% of the variation in weight gains of heifers with total nitrogen concentration. On semidesert rangeland in Australia, Squires and Siebert (1983) explained 68% of the variation in daily weight gains by cattle with total fecal nitrogen concentration. After reviewing several studies relating total fecal nitrogen concentration to forage intake, Cordova et al. (1978) concluded that forage intake could not be predicted from fecal nitrogen using a general equation. Holechek et al. (1982) found fecal nitrogen was associated with both forage intake and digestibility of cattle on mountain range in Oregon. However the associations were not high enough for predictive reliability.

Concentrations of microbial matter in the ruminant feces increases as the quality of the diet improves (Mason 1969). Researches by Virtanen (1966) and Mason (1969) show that nearly all the nitrogen in ruminant feces is of microbial origin and very little is from the feed. Total fecal nitrogen concentration, and acid/pepsin disappearance all provide measures of microbial matter in the feces.

A major problem with the use of total fecal nitrogen concentration to evaluate range ruminant nutritional status is that many range forage species, particularly forbs and shrubs, contain high levels of soluble phenolic compounds with protein complexing capabilities that elevate fecal nitrogen concentrations relative to those in the diet (Mould and Robbins 1981, Sidahmed et al. 1981). Fecal nucleic acid concentration, nonfiber bound nitrogen concentration and acid/pepsin disappearance may provide better measures of rumen microbial activity and may be better related to forage intake and digestibility than total fecal nitrogen concentration, particularly when the diet contains high levels of soluble phenolic compounds; however, this has not been studied.

Therefore the objective of this study was to evaluate usefulness of fecal chemical characteristics such as total nitrogen concentration, non-fiber bound nitrogen concentration, acid/pepsin disappearance, nucleic acid concentration and others as predictors of forage intake, forage digestibility and forage nitrogen concentration of cattle.

Methods

This study was conducted during the spring and summer of 1982 on the farm lot of the New Mexico State University campus. Six different hays representing 2 forage classes (3 grasses and 3 nongrasses) were fed to the 6 steers in a Latin square design. All 6 hays were fed in each 15-day trial and randomized within rows and columns. The hays used were alfalfa *(Medicago sativa)*, Eski sainfoin *(Onobrychis viciaefolia)*, kochia *(Kochia scoparia)*, millet *(Panicum miliaceum)*, timothy *(Phleum pratense)*, and silver bluestem *(Bothriochloa saccharoides)* prairie hay. Steers were confined to individual pens. Hays were chopped to a 2-4 cm particle size to avoid selective feeding.

Intake was determined by the conventional hand-fed method described by Schneider and Flatt (1975). For each trial, feed was on

Table 1. Chemical composition and nutritive characteristics of 6 feeds pooled across 6 steers.

	Alfalfa	Sainfoin	Kochia	Millet	Timothy	Bluestem
Chemical[1]						
Crude protein %	20.25	21.25	8.94	13.06	7.78	6.50
N %	3.24	3.38	1.43	2.09	1.26	1.04
Neutral detergent N %	0.32	0.97	0.45	0.46	0.49	0.55
Acid detergent N %	0.20	0.61	0.19	0.14	0.13	0.22
Cell soluble N %	2.92	2.41	0.98	1.63	0.77	0.49
Ether extract %	1.98	1.94	1.62	2.01	2.22	2.19
Neutral detergent fiber %	44.39	52.26	68.10	68.73	70.17	77.92
Acid detergent fiber %	35.16	47.03	43.41	40.75	40.46	47.46
Acid detergent lignin %	7.53	9.30	6.80	3.18	5.32	6.24
Hemicellulose %	9.23	5.25	24.69	27.98	29.71	30.46
Cellulose %	27.63	37.73	36.61	37.57	35.14	41.22
Tannin[2]	0.13	0.86	0.08	0.12	0.19	0.39
Phenolics[3]	8.14	28.94	18.55	13.13	17.92	35.15
Nutritive[1]						
Intake (% BW)	2.74	2.32	1.18	2.55	2.23	1.21
Intake, digestible organic matter (% BW)	1.89	1.62	0.70	1.84	1.54	0.73
Intake, crude protein (% BW)	0.55	0.49	0.11	0.33	0.17	0.08
In vivo digestibility %	69.00	70.00	59.00	72.00	69.00	60.00

[1]All data are on an organic matter basis.
[2]Tannins are expressed as mg/.1 g sample (catechin equivalents).
[3]Phenolics are expressed as mg/g sample.

offer free choice throughout the day, and intake was evaluated for each steer daily for 5 days after a 10-day adjustment period. All intake data were expressed as organic matter intake as a percentage of body weight (BW). Samples of the feed and feces for each animal were collected during the 5 days of intake measurement for each trial.

After collection, feed and fecal samples were dried at 50° C. Both feed and fecal samples were ground through a 1-mm mesh screen in a Wiley laboratory mill and dry matter and ash content were determined by Association of Official Chemists (1980) methods. Feed samples were analyzed for Kjeldahl nitrogen and ether extract (Association of Official Chemists 1980) and neutral detergent fiber, acid detergent fiber, and acid detergent lignin (Goering and Van Soest 1970). Nitrogen concentrations in the neutral detergent fiber and acid detergent fiber residues were determined using the Kjeldahl procedure (Association of Official Chemists 1980). Nucleic acid concentrations in the feces were determined using the procedure of Zinn and Owens (1982). Procedures of Price et al. (1978) and the Folin-Denis Method (Association of Official Chemists 1980), respectively, were used to determine total tannin and phenolic concentrations in the feed and feces. Percentage acid/-pepsin disappearance from the feces was determined by using the second stage of the Tilley and Terry (1963) in vitro digestion method. Fecal samples were incubated with acid/pepsin solution for 48 hours in a water bath at 32° C. Because pepsin hydrolyzes protein, it was used as a measure of microbial matter in the feces. Chemical and nutritive analyses for the 6 feeds and feces pooled across the 6 steers are shown in Tables 1 and 2, respectively.

Table 2. Chemical composition and nutritive characteristics of the feces of 6 feeds pooled across 6 steers.

	Alfalfa	Sainfoin	Kochia	Millet	Timothy	Bluestem
Chemical[1]						
N %	2.28	3.97	2.10	2.41	1.81	1.75
NDF N %	0.87	2.03	0.51	0.59	0.62	0.55
ADF N %	0.77	1.61	0.51	0.54	0.56	0.61
Non-fiber bound N %[2]	1.41	1.94	1.59	1.82	1.19	1.20
Neutral detergent fiber %	75.25	89.12	92.44	73.03	73.43	84.95
Acid detergent fiber %	60.69	75.37	69.94	52.21	54.75	66.38
Acid detergent lignin %	20.12	39.43	18.85	14.63	16.65	18.46
Cellulose %	40.57	35.94	51.09	37.58	38.10	47.92
Hemicellulose %	14.56	13.74	22.49	20.82	22.84	18.58
Nucleic acids %	0.48	0.72	0.34	0.52	0.41	0.29
Ether extract %	2.09	2.13	1.78	2.14	2.39	2.58
Tannin[3]	0.35	0.30	0.19	0.28	0.27	0.22
Phenolics[4]	10.26	10.42	11.87	20.96	20.22	18.44
Nutritive[1]						
Acid pepsin solubles %	28.00	25.00	20.00	25.00	18.00	18.00
Water soluble material %	14.00	13.00	12.00	15.00	12.00	13.00

[1]All data are on an organic matter basis.
[2]Non-fiber bound nitrogen = Total nitrogen % — Neutral detergent fiber nitrogen %.
[3]Tannins are expressed as mg/.1 g sample (catechin equivalents).
[4]Phenolics are expressed as mg/g sample.

Intake and in vivo digestibility % of the feed and nitrogen %, acid/pepsin disappearance %, fiber % and fiber nitrogen % of the feed and feces were analyzed using a Latin square analysis of variance (Steel and Torrie 1960). Relationships between diet and fecal nutritive characteristics were determined using linear regression and correlation procedures (Neter and Wasserman 1974). All relationships were evaluated both excluding and including animal variation. Dependent variables in regression equations were intake (organic matter, % body weight), digestible organic matter intake (OM, % BW), diet in vivo organic matter digestibility % and diet nitrogen %. More details on experimental procedures are provided in Wofford (1983).

Results and Discussion

Intake and Digestible Organic Matter Intake

Fecal acid/pepsin disappearance was the independent variable most highly correlated with forage intake ($r = +.63$, n = 32). However, we consider the standard error of the estimate ($Sy \bullet x = 0.59$) of the regression equation too high for predictive accuracy.

Fecal nitrogen was poorly correlated with forage intake ($r = .43$, n = 32). Cordova et al. (1978) reviewed several studies which are inconsistent in regard to the value of fecal nitrogen concentration as an indicator of intake. Table 1 shows sainfoin has much higher tannin levels than the other forbs. Tannins were bred into sainfoin because of their anti-bloat qualities (Reid et al. 1974, Ulyatt et al. 1976). McLeod (1974) classified tannins as belonging to a group of secondary plant compounds called soluble phenolics, which have enzyme and protein binding capabilities. Fecal nitrogen concentrations of goats were elevated by diets with high levels of tannins when compared to those with low tannin levels in 2 different studies (Nastis and Malechek 1981, Sidahmed et al. 1981). Holechek et al. (1982a) speculated that using nonfiber bound rather than total nitrogen concentration in the feces may reduce phenolic (tannin) problems. However, in our study, fecal nonfiber bound nitrogen (total nitrogen % – neutral detergent fiber nitrogen %) concentration had a lower association with intake than total nitrogen (Table 3). Sainfoin, in our study, had a much higher fecal fiber bound nitrogen concentration (NDF N) than the other 5 species (Table 2). Our study indicates both total fecal nitrogen and fecal nonfiber bound nitrogen are unsuitable predictors of forage intake for ruminant diets of diverse chemical properties. However, fecal fiber bound nitrogen levels above 1% may indicate tannin or phenolic problems. Diet and fecal concentrations of tannins and soluble phenolics were not correlated ($r = .17$, $r = .08$, respectively). Therefore, we concluded that the fecal analyses we used for tannins and soluble phenolics cannot be used to detect elevated tannin and soluble phenolic concentrations in the diet.

Fecal acid/pepsin disappearance and fecal neutral detergent fiber provided the best estimate of forage intake when stepwise procedures were used to obtain the best multiple regression equation. However, we consider this model to have low predictive value based on the coefficient of determination ($R^2 = .70$) and standard error of the estimate ($Sy \bullet x = .38$). Holloway et al. (1981) also reported fecal chemical characteristics had low potential for predicting forage intake of steers. Their best multiple regression equation had a coefficient of determination of .69 and used fecal nitrogen, ether extract and neutral detergent fiber concentrations as independent variables.

Although feed differences were highly significant ($P < .001$) for intake, steer and trial effects were not significant ($P > .05$). Our study is consistent with Holloway et al. (1981) who found, when cattle weights were taken into account, animal variation was no longer an important influence on intake.

Intake and digestible organic matter intake were highly associated ($r = .98$). Therefore, any discussion would be redundant with that for intake. Correlations between digestible organic matter intake and fecal nutritive characteristics are given in Table 3.

Digestibility

Diet in vivo digestibility was poorly correlated with all fecal nutritive characteristics (Table 3). None of the correlations were high enough to indicate predictive value.

Holechek et al. (1982b) reviewed studies evaluating the relationship between diet digestibility and fecal nitrogen concentration. Their review shows considerable difference in this association between studies. Our data show fecal nitrogen concentration is not a good indicator of digestibility when ruminants are consuming forages of highly dissimilar chemical properties. The soluble phenolic/tannin problem previously discussed can elevate fecal nitrogen concentration in relation to digestibility (Sidahmed et al. 1981, Nastis and Malechek 1981).

Multiple regression equations to predict digestibility from fecal nutritive characteristics did not greatly improve coefficients of determination compared to simple linear regressions. It appears that reliable prediction of forage digestibility using the fecal nutritive characteristics evaluated in this study is not possible when forages have widely varying chemical properties.

Trial but not steer effects were significant ($P < .05$) for digestibility. Digestibility values for trials 1–6 were 70, 72, 68, 64, and 62, respectively. The decline in digestibility during the period of study is attributed to environment, confinement, and handling stress on the animals.

Diet Versus Fecal Nitrogen Concentration

Fecal acid/pepsin disappearance and fecal nitrogen concentration showed the highest correlations ($r = .82$, n = 32; $r = .81$, n = 32, respectively) with diet nitrogen concentration. The present study

Table 3. Coefficients of simple correlation between diet and fecal nutritive and chemical characteristics for 6 feeds fed to 6 steers.

	Data Pooled Across Steers (n = 6)				Data Includes Steer Variation (n = 33)			
	Intake (OM, % BW)	Intake, digestible organic matter (OM, % BW)	Diet in vivo digestibility %	Diet N%	Intake (OM, % BW)	Intake, digestible digestible organic (OM, % BW)	Diet in vivo digestibility %	Diet N%
Fecal nutritive characteristics								
N %	+.38	+.39	+.45	+.78	+.43	+.46	+.39	+.81
Non-fiber bound N %[1]	+.32	+.34	+.41	+.61	+.51	+.51	+.28	+.42
Neutral detergent fiber %	−.70	−.71	−.68	−.03	−.55	−.51	−.20	−.01
Acid detergent fiber %	−.46	−.47	−.47	+.27	−.37	−.32	−.06	+.18
Acid detergent lignin %	+.14	+.14	+.20	+.66	+.21	+.26	+.26	+.53
Ether extract %	−.06	−.90	+.04	−.36	–	–	–	–
Acid pepsin solubles %	+.76	−.04	+.62	+.91	+.63	+.61	+.33	+.83
Water soluble material %	+.60	+.62	+.57	+.44	–	–	–	–
Nucleic acids %	+.68	+.69	+.75	+.84	+.55	+.58	+.39	+.61

[1]Non-fiber bound N % = Total nitrogen % – Neutral detergent fiber nitrogen %.

Table 4. Regression coefficients for equations predicting diet nitrogen % using fecal nitrogen.

	a	b	r^2	n	sy.x
Present Study (cattle)					
Pooled across steers (All treatments)	-0.25	0.98	0.61	6	0.01
Pooled across steers (w/o sainfoin and alfalfa)	-1.46	1.45	0.97	4	0.03
Other Research					
Mubanga (1983)	-1.72	2.08	0.52	7	0.73
Mule deer	-2.99	2.70	0.79	4	0.10
Raymond (1948) sheep	-0.14	0.80	-	-	-
Fels et al. (1959) sheep	0.66	0.83	0.86	-	-
Wallace (1969) sheep	-0.98	1.68	0.99	4	-
Cordova (1977) cattle:					
Fertilized range	-0.55	1.40	0.64	7	-
Unfertilized range	-0.55	1.22	0.66	7	-
Fertilized and unfertilized range	-1.06	1.53	0.69	14	-
Bredon et al. (1963) cattle	-1.04	1.62	0.92	13	-
Hinnant (1979) cows	0.11	0.79	0.88	4	-
Hinnant (1979) steers	0.09	0.66	0.90	4	-
Holechek et al. (1982a) cattle:					
Forest range	-0.28	0.86	0.78	24	0.29
Grassland range	-0.26	0.82	0.88	24	0.23
Forest and grassland range	-0.27	0.84	0.83	48	0.26
Arthun (1981) steers	-1.35	1.78	0.62	4	-
Robbins et al. (1975)[1] deer	-3.43	2.78	0.57	7	-
Mould and Robbins (1981)[2] elk	0.08	0.49	0.97	11	-
Arman et al. (1975)					
Batch 1					
Eland	-3.73	3.13	0.94	5	-
Hartebeest	-4.58	3.93	0.98	5	-
Thomson's gazelle	-5.77	3.32	0.96	5	-
Duiker	-6.39	3.53	0.96	5	-
Sheep	-3.34	2.30	0.90	5	-
Batch 2					
Sheep	-5.36	2.98	0.94	5	-
Boran Zebus	-3.61	2.27	0.88	5	-
Friesians	-2.54	1.87	0.90	5	-

[1]Forages were dominated by browse high in soluble phenolic content.
[2]Forages high in soluble phenolic content were omitted from the regression.

and other research summarized in Table 4 are consistent in showing fecal nitrogen concentration can provide a reasonable indication of trends in ruminant diet nitrogen concentration provided the diet does not contain high levels of soluble phenolics.

Pooling data across steers did not improve the correlation between diet nitrogen and fecal nitrogen concentration ($r = .81$, n = 32; $r = .78$, n = 6). However, grasses showed a higher correlation between diet and fecal nitrogen concentrations ($r = .91$, n = 3) than nongrasses ($r = .81$, n = 3) (Table 4). This response was attributed to sainfoin, which had a higher percentage of fiber bound nitrogen in the feces relative to the feed than the other forages (Tables 1 and 2).

Careful review of the studies relating dietary to fecal nitrogen concentrations shows the best associations occur when diet nitrogen concentrations are not over 2.4%. Data for steers from Hinnant (1979), Arthun et al. (1981), and the present study, in Figure 1 display this relationship. The regression equation for all 3 studies combined using only dietary nitrogen concentrations of 2.4% or below is:

$$Y = -.706 + 1.072\,X$$

$$r^2 = .96 \qquad n = 9 \qquad Sy \bullet x = .07$$

We consider this equation to have potential predictive capability based on the standard error of the estimate.

Allden and Jennings (1969) have suggested that crude protein deficiencies occur in the grazing ruminant diet when fecal nitrogen concentration falls below 1.65%. Based on the equation we deve-

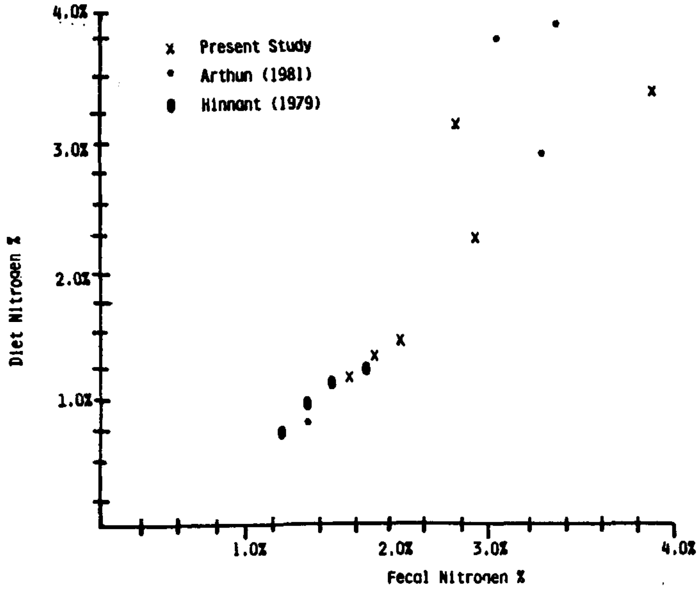

Fig. 1. *Diet nitrogen % (OM basis) versus fecal nitrogen % (OM basis) for steers.*

loped from Hinnant (1969), Arthun et al. (1981) and the present study, a fecal nitrogen concentration of 1.65% would give a diet nitrogen concentration of 1.06% (6.64% CP). Research by Milford and Minson (1964) shows forage intake by ruminants drops precipitously if dietary crude protein concentration falls below 7%. The National Research Council (1976) indicate that dry, mature, pregnant cows need about 6.5% crude protein in the diet for maintenance. It appears that the equation we have developed using data from Hinnant (1979), Arthun et al. (1981), and the present study may have some utility for detecting crude protein deficiencies in grazing steer diets providing the diet contains low levels of soluble phenolics/tannins. When fecal NDF-N concentrations exceed 1.00%, diet nitrogen predictions from our equation appear unreliable. When tannin levels exceed 0.050 mg/g and/or phenolic levels exceed 20.0 mg/g in forage or diet samples, elevated nitrogen levels in fecal samples should be suspected. We advocate more study with a wider variety of forages before the equation we have developed is applied.

Both trial and steer effects were significant ($P<.05$) for fecal nitrogen concentration and fecal acid/pepsin disappearance. We attribute this to both changing environmental conditions (higher temperatures during the last 3 trials) and increased stress on the steers due to confinement and handling as the study progressed. It does appear that environmental and animal physiological status can influence fecal nitrogen concentration or acid/pepsin disappearance. Data from Cordova (1977) indicates nitrogen fertilization of a pasture can also alter regression equations. Hinnant (1979) found cows had lower fecal nitrogen values than steers. This is explained by nitrogen excretion in the milk and fetus. The equation of Hinnant (1979) may have usefulness for detecting nitrogen deficiencies in cows (Table 4).

Summary and Conclusions

The following conclusions are drawn from this study:

1. Generalized equations based on the fecal chemical characteristics we evaluated cannot be used to predict forage intake and diet digestibility when ruminants are consuming diets of widely varying chemical properties.

2. Fecal nitrogen % has utility for detecting crude protein deficiencies in cattle diets if their diets contain low levels of soluble phenolic compounds. Protein deficiencies in steer diets should be suspected when fecal nitrogen % (OM basis) drops below 1.7%. When fecal NDF-N concentrations exceed 1.00%, a soluble phe-

nolic problem should be suspected.

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