FECAL INDICATORS OF CATTLE PROTEIN STATUS ON DESERT GRASSLAND RANGE[1]

Mark Hakkila[2], Jerry L. Holechek,
Joe D. Wallace, Dean M. Anderson and Manuel Cardenas

Department of Animal and Range Sciences
New Mexico State University
Las Cruces, New Mexico 88003

ABSTRACT

Fecal indices, particularly fecal nitrogen concentration, have shown potential as indicators of diet quality of grazing cattle. Our study evaluated the utility of fecal nitrogen concentration and several other fecal chemical characteristics as indicators of protein status of cattle grazing southcentral New Mexico rangelands. Five esophageal fistulated steers and six steers equipped with fecal collection bags were used to evaluate diet quality, forage intake and fecal chemical composition for six collections during a 12-month period in 1984. Fecal phosphorus concentration was highly correlated with diet crude protein concentration (r^2 = .86). Fecal phosphorus appears to have potential for management decisions concerning protein supplementation. However, because of the lack of other research, we advocate further study before it is applied as a management tool to other ranges. Fecal nitrogen concentration was also correlated with diet crude protein concentration (r^2 = .67). Fecal phosphorus concentrations below 0.20%, and fecal nitrogen concentrations below 1.20% organic matter basis would indicate diet crude protein concentrations below those required for maintenance (7.7%, organic matter basis) on the range studied. Soluble phenolics and tannins associated with some forbs and shrubs can elevate fecal nitrogen concentrations relative to those in the diet. Based on insoluble fecal nitrogen concentrations, this was not a problem during periods of high (more than 50% of the diet) forb and shrub consumption in our study.

INTRODUCTION

Rangelands in the western United States and many other parts of the world vary widely in forage quality and quantity among seasons and years. This causes range cattle diet quality to fluctuate drastically. Many ranchers provide expensive supplemental feeds to range cattle, often with little knowledge of their true nutritional needs. In New Mexico, supplemental feed is a major variable cost associated with the range cow unit (Gray and Fowler 1982) (1). This variable cost could probably be

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[2]Authors are graduate research assistant, associate professor and professors, Department of Animal and Range Sciences, and professor of experimental statistics, New Mexico State University, Las Cruces 88003.

reduced 30 to 40%, with little reduction in cattle performance, if timing and severity of protein deficiency could be better detected.

In recent years, fecal chemical characteristics, particularly nitrogen and phosphorus, have shown potential as indicators of diet quality of grazing cattle (Holechek et al. 1982, Squires and Siebert 1983, Wofford et al. 1985, Holechek et al. 1985) (2, 3, 4, 5). Gates and Hudson (1981) (6) 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. (1982) (2) accounted for 48% of the variation in weight gains of heifers with total fecal nitrogen concentration. On semidesert rangeland in Australia, Squires and Siebert (1983) (3) explained 68% of the variation in daily weight gains of cattle with total fecal nitrogen concentration.

Rangelands in southcentral New Mexico are characterized by high forb and shrub content that are readily used by cattle. Certain forbs and shrubs, particularly those in the genera Larrea, Juniperus and Quercus, 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, Wofford et al. 1985) (7, 8, 4). However, careful consideration of food habit studies of cattle show they generally reject these species because they are unpalatable and poisonous (Johnson et al. 1976) (9). Total fecal nitrogen concentration may, therefore, have potential as an indicator of protein status of range cattle, even if the range contains a high forb and shrub component. The objective of our research was to evaluate the usefulness of fecal chemical characteristics such as total nitrogen concentration, soluble nitrogen concentration, phosphorus concentration, acid/pepsin disappearance and others as predictors for dietary protein status of cattle on desert grassland range in southcentral New Mexico. Although several studies in the United States have evaluated the utility of fecal indices with confined livestock, investigations with cattle under range conditions are restricted to one study in Oregon on mountain range (2).

METHODS

This study was conducted on the Jornada Experimental Range in Dona Ana County, southcentral New Mexico. Elevation ranges from 1310 to 1330 m. Long-term precipitation averages 22.8 cm with rainfall during the study in 1984 about 225% of the annual average. Soils are sandy loams, and vegetation is dominated by honey mesquite (Prosopis glandulosa), broom snakeweed (Gutierrezia sarothrae) and mesa dropseed (Sporobolus flexuosus). Swale sites are dominated by vine mesquite (Panicum obtusum). Range condition is classified as good. This type of rangeland is common in southern New Mexico and southeastern Arizona.

The 210 ha study pasture was stocked in February 1984 at a moderate rate (30-35% use of palatable perennial forage species) with 11 experimental cattle (Hereford x Brangus steers). These animals were gentled and trained during the previous fall and winter. Five of the steers were equipped with esophageal fistulae; the other six were intact and trained to carry fecal bags. All animals were trained to be easily caught in the pasture.

Total fecal collections were made in March, May, July, August, October and December 1984. Fecal collection steers were weighed without shrink 14-d before each collection period. Steers grazed for a 14-d period in the pasture before esophageal fistula collections were taken between 0600 and 0900 hrs on three consecutive days during each fecal collection period. Steers were then removed from the study pasture until 14-d before the next collection period. The steers were not penned before collections, and were allowed to graze freely for the duration of each collection period.

Esophageal fistula and fecal samples were placed in a forced-air oven at 50°C within 2 hr after collection. Dried samples were ground through a 1 mm screen in a Wiley mill, mixed and composited by animal across days using equal weights of daily samples.

Dry matter and ash content of all diet and fecal samples were determined by AOAC (1984) (10) methods. Diet and fecal nitrogen concentrations were determined by the Kjeldahl method (10). Soluble and insoluble dietary and fecal nitrogen concentrations were determined by procedures of Crooker et al. (1978) (11), using sample sizes and incubation times of Waldo and Goering (1979) (12). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by Goering and Van Soest (1970) (13) procedures. Fecal phosphorus content was determined by AOAC (1984) (10) methods. Percentage acid/ pepsin disappearance from the feces was determined by using the second stage of the Tilley and Terry (1963) (14) in vitro digestion method. Organic matter in vitro digestibility of diet samples was determined by Tilley and Terry (1963) (14) procedures as modified by Moore (1970) (15) and Harris (1970) (16). Inoculum was obtained from two penned steers fed an alfalfa (Medicago sativa) hay diet. Digestion times of 4, 24, 36, 48, 60, 72 and 84 hr were used for all samples. Organic matter intake was calculated by the standard equation of Van Dyne (1969) (17):

$$\text{Organic matter intake} = \frac{(100) \times (\text{total fecal organic matter output})}{100\%\text{-IVOMD (48 hr)}}$$

Holechek et al. (1986) (18) found improved in vitro estimates of in vivo digestibility by selecting the maximum in vitro digestibility value for times ranging from 36 to 96 hr. We also calculated forage intake using this approach:

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

Intake was expressed as a percentage of body weight (BW) as discussed by Cordova et al. (1978) (19). Nutritional characteristics of the diet and feces are shown in Table 1. All diet and fecal data are on an organic matter basis.

Relationships between various diet and fecal nutritive characteristics were determined using linear regression and correlation procedures

TABLE 1. MEANS AND STANDARD ERRORS OF CHEMICAL COMPOSITION AND NUTRITIVE CHARACTERISTICS OF STEER DIETS AND FECES FROM DESERT GRASSLAND RANGE.

	MARCH		MAY		JULY		AUGUST		OCTOBER		DECEMBER	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Diet Characteristics[a]												
Neutral detergent fiber	71.2	3.8	90.2	1.4	75.2	1.3	75.0	.8	66.4	1.6	80.8	1.0
Acid Detergent fiber	63.1	7.3	66.2	1.4	52.3	1.0	48.1	.4	51.9	.5	59.6	.5
Acid detergent lignin %	10.7	.4	8.4	1.1	9.3	1.0	5.9	.4	10.7	1.2	9.7	.4
4 hr in vitro organic matter digestibility %	27.5	2.1	21.4	.6	21.8	.8	21.8	.6	27.0	2.2	14.2	1.2
48 hr in vitro organic matter digestibility %	47.9	1.1	55.4	1.2	50.2	1.0	62.7	1.2	47.5	1.6	41.1	.9
Maximum in vitro organic matter digestibility %	60.4	1.1	70.1	1.4	66.7	1.8	66.2	.8	52.0	2.4	50.7	1.2
Crude protein %	15.6	1.6	13.5	.3	13.9	.3	14.0	.2	12.7	.5	7.2	.4
Soluble crude protein %	12.8	1.3	10.8	.3	11.1	.3	11.6	.1	10.4	.4	6.1	.3
Insoluble crude protein %	2.7	.3	2.5	.1	2.7	.1	2.4	.1	2.2	.1	1.1	.1
Organic matter intake (48 hr IVOMD % body weight)	.9	.1	1.4	.1	1.3	.1	1.5	.1	1.4	.1	1.1	<.1
Organic matter intake (maximum IVOMD % body weight)	1.2	.1	2.2	.1	1.9	.1	1.7	.1	1.5	.1	1.3	<.1
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fecal Characteristics[a]												
Fecal output (organic matter, % of body weight)	.47	.04	.65	.02	.66	.03	.58	.04	.72	.05	.64	.03
Total nitrogen %	1.77	.03	1.47	.07	1.84	.07	1.97	.03	1.75	.05	1.16	.02
Insoluble nitrogen %	.36	.01	.37	.02	.40	.02	.44	.01	.37	.01	.25	.01
Soluble nitrogen %	1.40	.03	1.10	.05	1.46	.05	1.56	.02	1.38	.04	.91	.02
Phosphorus %	.51	.05	.42	.05	.52	.04	.49	.02	.34	.03	.19	.01
Acid pepsin digestion %	11.50	.75	11.22	1.85	10.88	.33	11.12	.44	12.43	.86	7.23	.32

[a]All data are on an organic matter basis.

(Neter and Wasserman 1974) (20). These are discussed in detail by Hakkila (1986) (21). The most promising associations were between cattle diet crude protein concentration and fecal total nitrogen, fecal soluble nitrogen, fecal acid pepsin digestion and fecal phosphorus percentages. Therefore, further discussion will concern these relationships.

RESULTS AND DISCUSSION

Growing conditions during our study were much more favorable than in average years. However, diet quality trends and values (Table 1) are generally similar to those reported by Rosiere et al. (1975) (22) for cattle in a two-year study on a similar southern New Mexico desert grassland range. Crude protein values (organic matter basis) in their study ranged from 7.3-13.7% compared to 7.2-15.6% in our study. In both studies, crude protein values of cattle diets were highest in spring and lowest in the late fall-early winter period. During summer, both studies show cattle diet crude protein concentrations are well over the 10% level recommended by NRC (1984) (23) for growing heifers, growing steers and lactating cows. Both studies also reflect an inconsistency between fiber and in vitro digestibility data. The high fiber but moderate in vitro digestibility values in some periods (May) is explained by a switch from a forb to a grass dominated diet (Hakkila et al. 1987) (24). At comparable stages of maturity, grasses have higher total fiber concentrations than forbs (Huston et al. 1981) (25). However, unlike forbs, a large portion of fiber in grasses is digestible (Smith et al. 1972, Short et al. 1974) (26, 27). This is due to less lignification of cellulose and hemicellulose in grasses compared to shrubs.

Forage intakes were lower in our study than those reported for other western ranges (Cordova et al. 1978, Van Dyne et al. 1980) (19, 28). This is attributed to the high summer temperatures and fibrous nature of the forage on the range studied (24).

Crude protein concentrations of 7.7% (organic matter basis) are required to meet maintenance needs of pregnant, nonlactating cows based on NRC (1984) (23) requirements. When the crude protein concentration of ruminant diets drops below this level, forage intake drops precipitously (Milford and Minson 1965) (29). Apparently, diet crude protein concentrations below these levels do not meet the needs of rumen bacteria. Cattle show weight losses (3) and increases in forage intake and digestibility from supplemental protein can be expected when diet crude protein levels are below 7.7% (organic matter basis) (Cook and Harris 1968, Rittenhouse et al. 1970, Kartchner 1981) (30, 31, 32).

In our study, cattle diet crude protein concentrations fell below the critical 7.7% level in December. During this period, the diet crude protein concentration of 7.2% corresponded to a fecal nitrogen concentration of 1.16%. Therefore, a fecal nitrogen concentration below 1.20-1.30% would indicate a crude protein deficiency on the range we studied. Squires and Siebert (1983) (3) found cattle on semidesert range in Australia experienced weight losses when fecal nitrogen concentrations dropped below 1.35%. However, other studies, summarized in Table 2, show diet threshold crude protein values (7.7%) are reached at higher fecal nitrogen levels (1.5-1.8%) than those in our study or the Squires and

TABLE 2. REGRESSION COEFFICIENTS FOR EQUATIONS PREDICTING CATTLE DIET NITROGEN % USING FECAL NITROGEN % USING THE MODEL Y = A + BX.

	A	B	r^2	n	Syx
Present study	-0.11	1.30	0.67	6	.11
Wofford et al. 1985 (4)	-0.25	0.98	0.61	6	.01
Squires and Siebert 1983 (3)	0.05	0.94	0.38	12	-
Cordova 1977 (33)					
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 (34)	-1.04	1.62	0.92	14	-
Hinnant 1979 cows (35)	0.11	0.79	0.88	4	-
Hinnant 1979 steers (35)	0.09	0.66	0.90	4	-
Holechek et al. 1982 (2)					
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 et al. 1981 (36)	-1.35	1.78	0.62	4	-
Arman et al. 1978 (37)					
Bos indicus	-3.61	2.27	0.88	5	-
Bos taurus	-2.54	1.87	0.90	5	-

Siebert (1983) (3) investigation. It appears that separate threshold fecal nitrogen values must be established for different types of rangeland.

Our research is consistent with other studies reviewed in Table 2 which show that cattle diet and fecal nitrogen concentrations are closely associated. The coefficient of determination for this relationship in our study (r^2 = .67) is well within the range of values (r^2 = .38-.92) for other studies reviewed in Table 2. Regression coefficients for this relationship between cattle diet and fecal nitrogen concentration differ substantially between studies. Type of range, fertilization, class of cattle, and breed of cattle are all factors that can influence the relationship. However, Holechek et al. (1982) (2) found that regression coefficients did not differ between years on the same ranges. It appears that the utility of fecal nitrogen as a predictor of protein status in grazing cattle varies considerably between ranges. However, equations developed for specific ranges can be useful for some management decisions.

Forbs and shrubs comprised over 50% of diet botanical composition during March, October, and December collections (24). Fecal insoluble nitrogen concentrations were well below 1.00%, indicating low levels of tannins and soluble phenolics in the diet. Insoluble fecal nitrogen concentrations above 1.00% are indicative of high levels of tannins and soluble phenolics in the diet (4).

Fecal phosphorus concentration was the best single indicator of diet crude protein concentration in our study (Table 3). A crude protein deficiency (below 7.7% in diet) would be indicated by a fecal phosphorus concentration below 0.20% (organic matter basis). Other research evaluating this relationship in grazing ruminants is unavailable. We consider the equation in Table 3 to have high predictive reliability based on the low standard error of the estimate (Syx = 0.38). Other unpublished studies we have conducted show fecal phosphorus concentration is not elevated by tannins and/or soluble phenolics in the diet. Due to lack of other information, we advocate more research on this relationship before it is used as a management tool.

Soluble fecal nitrogen percent, bound fecal nitrogen percent, and fecal acid pepsin digestibility percent were all significantly ($P<.05$) associated with diet crude protein concentration. Soluble fecal nitrogen and fecal acid pepsin digestibility are both measures of microbial matter in the ruminant feces. They differ from total fecal nitrogen concentration in that they do not include fiber bound nitrogen or nitrogen bound by phenolics and/or tannins. The use of these three indicators, together with fecal nitrogen or phosphorus concentration, may be more reliable than the use of any single indicator. This, however, needs further study.

Soluble nitrogen concentration represents the portion of total nitrogen not bound by lignin, soluble phenolics or tannins and is readily available to the animal. This may be a better measure of protein status of ruminants than crude protein when the diet contains variable quantities of forbs and shrubs. Fecal phosphorus was closely associated with soluble nitrogen ($r^2 = .86$) (Table 3).

Crude protein intake and soluble nitrogen intake were both highly associated ($r^2 = .88$) with insoluble fecal nitrogen concentration. Although these relationships appear promising, research by Holechek et al. (1986) (18) shows some reliability problems with our techniques for intake estimation. The use of 48-hr IVOMD values can give inaccurate estimates of forage intake using the total collection method, particularly for diets high in grass. Holechek et al. (1986) (18) found the selection of the maximum in vitro digestibility coefficient from digestion times ranging from 36 to 96 hr improved intake estimates over the use of the standard 48-hr digestion time. In the present study, we estimated intake using both approaches. Crude protein intake and soluble nitrogen intake estimated from the maximum IVOMD approach were not well enough associated with any fecal nutritive characteristic for predictive reliability.

TABLE 3. SIMPLE LINEAR REGRESSION EQUATIONS FOR PREDICTING CATTLE DIET PROTEIN STATUS FROM FECAL CHARACTERISTICS USING THE MODEL Y = A + BX.

Y	A	B	r^2	Syx	n
Crude protein %	-0.68	8.13 (Fecal nitrogen %)	.67	.68	6
Crude protein %	+4.05	21.28 (Fecal phosphorus %)	.88	.38	6
Crude protein %	+0.10	9.82 (Soluble fecal nitrogen %)	.64	.58	6
Crude protein %	-0.75	36.98 (Bound fecal nitrogen %)	.65	.55	6
Crude protein %	+2.18	1.40 (Fecal acid pepsin digestibility %)	.74	.48	6
Soluble nitrogen %	+0.82	7.43 (Soluble fecal nitrogen %)	.62	.56	6
Soluble nitrogen %	+3.63	16.65 (Fecal phosphorus %)	.86	.46	6

[a]Determined from intake calculated with 48 hr in vitro organic matter digestibility.

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