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EVALUATION OF CHROMIC OXIDE, LIGNIN, CRUDE FIBER, NITROGEN AND INDIGESTIBLE DRY MATTER AS INDICATORS TO DETERMINE FECAL PRODUCTION AND FORAGE INTAKE[1]

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A reliable method of predicting forage intake is needed as a tool for researchers to evaluate the nutrient consumption of grazing animals. Various methods have been reported with varying degrees of success. External indicators, those originating outside of the feed source, have been utilized as an aid in predicting fecal output which is necessary for estimating forage intake. Chromic oxide, iron oxide, mineral salts, metal or plastic particles and dyes have been used to predict fecal production (Kotb and Luckey, 1972).

Pryor (1966) used fecal bags to collect excreta and noted considerable discomfort to the animals. This type of distraction and discomfort may cause some alteration in normal grazing patterns and reduce daily gains.

Internal indicators are substances which occur naturally within the forage. These include lignin, crude fiber, chromogens, silica, nitrogen and cell wall constituents. Forage intake can be estimated from the relationship between forage and fecal concentrations of the internal indicators once fecal output is known.

This study was designed to determine the diurnal fluctuation of chromic oxide (Cr_2O_3) and the optimum time to obtain representative fecal samples with intent of applying these results to the grazing situation in subsequent trials. Lignin (L), crude fiber (CF), nitrogen (N), and indigestible dry matter (IDM) as estimators of forage intake were also evaluated.

Experimental Procedure

Six steers averaging 208 kg were individually confined on 2.4 x 3.6 m pads. Each steer had access to 3.6 m of bunk space and was provided water in 40 liter buckets. Barley was fed in plastic pans approximately 30.4 x 30.4 x 15.2 cm deep. The trial comprised 5 feeding periods with barley to meadow hay ratios of 1:10, 1:5, 1:1, 1.5:1, and 2.5:1.

Chromic oxide was mixed with fine ground barley. The Cr_2O_3 concentration fed during periods 1 and 2 was 13g/227g of grain and for periods 3, 4 and 5 was 10g/227g of barley. Steers were fed the Cr_2O_3 mixture at 0700 daily for 10 days prior to the first collection period and continually throughout the trial. Each collection period was 3 days long with at least 4 days between periods to allow for adaptation to the new grain to forage ratios.

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Daily fecal production was determined by collecting and weighing feces from the concrete pad. After thorough mixing of the daily excrement a composite sample was taken for each steer. Grab samples were randomly taken from fresh excreta at 0700, 1200 and 1700 hours. Grab samples from each steer were combined for the three-day collection period so that 0700, 1200, 1700 and composite samples were analyzed for each period. Grain, hay and fecal samples collected during each period were oven dried at 45 C prior to chemical analysis. Grain and hay samples were analyzed for L, CF and N. The fecal samples were analyzed for Cr_2O_3, L, CF and N. Fecal production for each steer was estimated for the 0700, 1200, 1700 and composite samples using the following equation:

$$\text{Daily fecal production (gDM)} = \frac{\text{indicator consumed (g/day)}}{\text{indicator concentration in feces (g/g)}}$$

Forage intake was determined by the following equation which accounts for grain consumption:

$$\text{Forage intake (gDM)} = \frac{\text{fecal production(g) X conc. of indicator in the feces(g/g)} - \text{grain consumption(g) X concentration of indicator(g/g)}}{\text{concentration of indicator in the forage(g/g)}}$$

Dry matter digestibility was determined for hay and grain samples by a modification of the *in vitro* method of Tilley and Terry (1963). Chromic oxide content was determined using the method described by Bolin *et al.* (1952). Nitrogen, CF and 72% L were analyzed by the AOAC method (1970). Data were subjected to analysis of variance to determine if sampling times were significantly different. Relationships between actual and estimated fecal production and actual and estimated forage intake were determined by regression analysis (Steel and Torrie, 1960)

Results and Discussion

Mean recovery of chromic oxide and the standard error are given in Table 1 for each period. The mean overall recovery for the entire study was 94.05 $\pm$ 3.91%. This recovery rate is comparable to those of other researchers using Cr_2O_3 (Corbett *et al.*, 1958; Pryor, 1966; Nelson and Green, 1969). Barnicoat (1945), working with chromic oxide, noted problems with incomplete recovery.

Each steers estimated fecal production for the 0700, 1200, 1700 and composite samples were correlated to that animal's measured fecal production. Table 2 presents the respective correlation coefficients and F values. The 0700 and 1200 collections gave the poorest predictions of fecal production with the 1700 and composite samples being the best predictors of fecal output. The mean of the 1700 sample was greater ($P < .05$) than the 0700 or composite sample means but not significantly different from the 1200 sample mean.

TABLE 1. CHROMIC OXIDE RECOVERY (%)

Period		1	2	3	4	5
Recovery	(mean)	89.50	90.06	98.92	95.34	98.14
	(s.e.)*	11.46	9.22	12.81	13.92	8.81

*P < .05.

TABLE 2. DAILY FECAL PRODUCTION ESTIMATES USING Cr_2O_3

Sample	Mean	r	F
	g		
0700	1884^{c}	.63	16.72**
1200	2240^{ab}	.59	13.94**
1700	2323^{a}	.80	45.37**
Composite	2056^{bc}	.79	42.82**

abcd Means having different superscripts are significantly different at (P < .05).

Diurnal fluctuations of external markers such as chromic oxide have hindered their use as predictors of fecal production (Raymond and Minson, 1955; Putnam et al., 1958; Hayes et al., 1964). Keisling et al. (1969) obtained the highest average recovery (79.5%) at 1700. This recovery was significantly higher (P < .05) than the recoveries for 0500 through 1500. Rittenhouse et al. (1970) used morning rectal grab samples to estimate total fecal production. Putnam et al. (1964) took fecal grab samples at 0900 and 1500. Each researcher using Cr_2O_3 needs to determine the best time of collection based on the conditions of his work.

Care must be taken in extrapolating confined feeding trials to grazing trials as pointed out by Raymond and Minson (1955). They found that fluctuations in the field ranged from 70% to 130% of the mean, as compared to 85% to 120% for indoor feeding. The results of this study illustrate the problems encountered in utilizing Cr_2O_3 as a dependable marker to predict fecal excretion. Before utilizing this technique in the field it must be tested under grazing conditions.

Table 3 gives the r values obtained when actual hay intake was correlated with predicted hay intake using L, CF and N as internal indicators. It appears that these forage constituents may be used to predict hay intake. Analysis of variance indicated that there were no significant differences between collection times for L, CF or N. When comparing the 1700 hour collections, the mean and standard error (P < .05) for intakes predicted by L, CF and N were 3243 ± 478, 3240 ± 382 and 3244 ± 1407, respectively. The mean and standard error of actual forage intake was 3244 ± 542. The L and CF methods appear to predict forage intake were more precision than the N technique.

Indigestible dry matter (IDM) was also used to predict the hay intake by the following equation:

$$\text{Forage intake (g)} = \frac{\text{fecal output (g) - grain(g)}}{\text{X grain IDM}} \Big/ \text{forage IDM}$$

Indigestible dry matter is equal to one minus the precent digestibility as determined by the in vitro technique. The correlation coefficient for predicted to actual hay intake was .89. The lower r value as compared to L, CF and N would indicate less accuracy in predicting forage intake with the IDM method.

The results of this confined feeding trial indicate that the L, CF, N or IDM technique can be utilized to estimate hay intake with varying degrees of precision. However, extrapolating this data to the grazing animal without further testing under grazing conditions may result in erroneous estimates of forage consumption. As noted by Theurer (1970) the validity of these techniques depends upon collection of forage samples representative of the animal's diet and a representative fecal sample. The in vitro digestibilities of hay used in this study ranged from 47.8% to 52.0%. The digestibility of range forage is higher in the spring and lower in the fall. Thus, the L, CF and N components may also vary to a greater degree than under the controlled conditions of this trial.

TABLE 3. PREDICTED FECAL PRODUCTION MEANS[a] AND CORRELATION COEFFICIENTS

	Mean (r)					
Sample	L		CF		N	
	g		g		g	
0700	3749	(.95)	1389	(.94)	206	(.96)
1200	3817	(.96)	1360	(.94)	232	(.95)
1700	4025	(.93)	1401	(.93)	327	(.96)
Composite	3908	(.92)	1402	(.93)	259	(.96)

[a]LSD ($P < .05$) values were 1183, 356, and 832 for L, CF and N, respectively.

Summary

The Cr_2O_3 technique was used to determine individual fecal output of six 208 kg steers fed 5 different ratios of barley to hay. Total daily fecal output derived from grab samples collected at 0700, 1200, 1700 and composite samples were correlated to actual daily fecal output. Respective correlation coefficients were .63, .59, .80 and .79. The average recovery of Cr_2O_3 for the entire study was $94.05 \pm 3.91\%$. Estimates of forage intake using L, CF, N and IDM were correlated to actual forage consumption with the respective coefficients (r) of .92, .93, .96 and .89. No significant differences were found between collection times of 0700, 1200, 1700 and the composite sample for L, CF or N estimates of forage consumption.

The results of this study indicate that Cr_2O_3 may be used to predict fecal output. However, it appears that further work under grazing situations must be conducted to determine the reliability of this technique. Once the fecal output is accurately determined, the use of L, CF, N or IDM could be used to determine forage intake.

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