Evaluation of a continuous-release ytterbium bolus

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Abstract

Four ruminally cannulated steers were used in a 4 × 4 Latin square design to determine the efficacy of a continuous-release bolus containing Yb_2O_3 for estimation of fecal output. One bolus was placed in the reticulum of each steer at the beginning of the experiment. Four diets were fed, including alfalfa, alfalfa treated with a commercial preservative, and each of the 2 alfalfa hays in a 50:50 mixture with concentrate. Each period of the Latin square consisted of 15 d for adaptation to diets, followed by 5 d of total fecal collection. Fecal output was estimated from marker concentration in grab (0800, 1700, and 0800 + 1700) and composite (from total collection) fecal samples using 3 methods of dose calculation (manufacturer-formulated release, 160 mg Yb/d; trial average, based on bolus weight change over entire trial; and period average, based on bolus weight change during the week preceding and week of sampling period). Percentage of actual fecal output estimated by each calculation method was not affected by diet ($P>.10$). Calculated Yb release from the week before and the week of collection provided estimates of fecal output that were not different (11% overestimation; $P>.10$) from total collection, while estimates using formulated or trial average dose differed ($P<.10$; 37 and 34% overestimation, respectively). Across dose calculation method, actual fecal output was overestimated by 31, 27, and 29% from 0800, 1700, and 0800 + 1700 grab samples, respectively. Estimates based on composite fecal samples overestimated actual fecal output by 22% averaged across dose method. Composite fecal samples and dose based on period average provided the best estimation of actual fecal output (9% greater than total collection values). Regardless of method of dose calculation or fecal sampling method used, estimates were variable and greater than total collection values.

Key Words: beef steers, continuous marker, fecal output, ytterbium

Fecal output is difficult to measure directly with grazing ruminants. Markers have been used to estimate intake indirectly through the use of fecal output estimates coupled with some measure of indigestibility. Several external markers (e.g., Cr_2O_3, rare earth-labeled forage) have been used to estimate fecal output. However, such markers must be either infused continuously, mixed with feed and fed at least daily, or dosed orally or via cannula. Frequent fecal sampling is necessary and marker recovery often is incomplete (Galyean et al. 1986). In most experimental situations, markers are not administered continuously but instead are given often enough to achieve equilibrium and reduce diurnal variation.

Ytterbium appears to hold potential as a marker for estimation of fecal output. Prigge et al. (1981) reported a range of 6% overestimation to 14% underestimation of measured fecal output using Yb-labeled forage in cattle dosed either once or twice daily.

Recently, a ruminal bolus was developed in an attempt to achieve consistent, sustained-release of Yb. If effective, this bolus could eliminate the need for frequent oral dosing. Preliminary evaluation of this Yb bolus (Hatfield et al. 1986) indicated that measured fecal output of grazing steers was overestimated by 10 to 30%. The objective of our study was to evaluate the ability of a continuous-release Yb bolus to estimate fecal output of steers consuming alfalfa or alfalfa-concentrate diets under conditions controlled to allow precise comparisons.

Materials and Methods

Four ruminally cannulated crossbred beef steers (avg wt 300 kg), housed in digestion crates in an environmentally controlled building, were used in a 4 × 4 Latin square design. Steers were allotted randomly to 1 of 4 dietary treatments and fed 4.54 kg (as fed basis) twice daily in equal portions (0800 and 1700). The 4 dietary treatments were alfalfa hay from 2 locations (Las Cruces and Artesia, NM) and a 50:50 mixture (as fed basis) of a concentrate mixture with each of the 2 hays. Hay from Las Cruces was harvested (3rd cutting, early bloom) at 12% moisture, whereas the hay from Artesia was harvested (5th cutting, early bloom) at 25% moisture and treated with a commercial preservative (lactobacillus fermentation product[1]) during baling. The concentrate mixture contained (as fed basis) 33% whole cottonseed, 33% dried beet pulp, 17% ground corn, and 17% ground barley. Chemical composition of each diet is shown in Table 1. Periods of the Latin square included 13 d for adaptation to diets in individual outdoor pens and 2 d for adaptation to metabolism crates, followed by a 5-d collection period. Between periods 3 and 4, steers were housed and outdoors and maintained on alfalfa hay for 2 wk before the adaptation period began. The experiment lasted 102 d, and the 4 collection periods began on d 21, 42, 63, and 98.

Table 1. Chemical composition of diets fed to steers.

Diet	Dry matter	Ash	Crude protein	NDF	ADF
	%	---- % of dry matter ----			
Alfalfa	94.2	12.0	23.6	34.7	25.0
Treated alfalfa	94.4	10.1	17.3	41.2	30.4
Alfalfa + concentrate	94.2	7.6	16.8	28.3	20.4
Treated alfalfa + concentrate	94.2	6.5	14.0	33.8	22.8

A continuous-release bolus[2] containing Yb_2O_3 was placed in the reticulum of each steer via rumen cannula on d 1 and allowed to equilibrate for 14 d. The same bolus remained in each steer throughout the experiment. The bolus contained Yb_2O_3 in a polymer matrix surrounded by a plastic cylinder (11 cm length, 11 cm circumference). Slotted openings on each end of the plastic casing allowed contact of the polymer with ruminal fluid, such that Yb_2O_3 was released as the matrix dissolved. During the equilibration period, boluses increased in weight as a result of the wetting process; thus, an estimate of Yb loss during this phase was not possible. Thereafter, boluses were removed every 7 d at 1300, shaken to remove excess fluid, and weighed to estimate weekly release rate.

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[1]Culbac, TransAgra Corp., Storm Lake, Iowa.

[2]Continuous-release boluses were provided by Lilly Research Laboratories, Greenfield, Ind. Appreciation is expressed to Dr. David Yates for his assistance with the project.

Table 2. Fecal output of steers; actual and estimated with an intraruminal continuous-release ytterbium bolus.

Method		Fecal output, g DM/d	Standard error (N = 16)	Estimated minus actual	Standard error of difference	P (t-test) estimated = actual
Actual output, total collection		1117	62	–	–	–
Dose estimated from:	Sample method					
Manufacturer's formulation (160 mg/d)	Grab 0800	1587	229	470	207	0.04
	Grab 1700	1526	217	409	197	0.06
	Grab 0800 & 1700	1551	221	434	200	0.05
	Composite	1444	179	326	156	0.05
Average daily bolus weight loss over entire trial	Grab 0800	1548	221	430	200	0.05
	Grab 1700	1490	212	373	193	0.07
	Grab 0800 & 1700	1514	216	396	195	0.06
	Composite	1410	172	292	150	0.07
Average daily bolus weight loss over week before and week of collection	Grab 0800	1267	139	149	123	0.24
	Grab 1700	1239	137	122	123	0.34
	Grab 0800 & 1700	1250	138	132	123	0.30
	Composite	1217	145	100	131	0.46

Feed samples were obtained daily throughout experimental periods and pooled by period for each treatment. Total fecal output was measured during the last 5 d of each period. Feces were hand-mixed and a 10% subsample was collected daily and frozen. Rectal grab samples also were obtained twice daily (0800 and 1700) during each 5-d collection period. Total fecal output was corrected for the weight of grab samples. Fecal samples from daily total collections were thawed and composited by steer within period. Each composite and grab fecal sample was dried in a 50° C forced-air oven, and samples were ground to pass a 2-mm screen in a Wiley mill. Feed samples were composited across periods and ground to pass a 1-mm screen in a sample mill[3] before analysis for dry matter, ash, and crude protein (AOAC 1984), and neutral detergent fiber (NDF) and acid detergent fiber (ADF; Goering and Van Soest 1970). Fecal grab and composite samples were analyzed for dry matter and Yb. Samples (2 g) were ashed, solubilized with a 1:1 mixture of 3M HCl:3M HNO_3 (soaked for approximately 15 h at room temperature; modified procedure of Ellis et al. 1982a), filtered[4], brought to 25-ml vol, diluted (a KCl solution was added to provide 2,000 ug K/ml to prevent interferences), and analyzed for Yb by atomic absorption spectrophotometry with an acetylene plus nitrous oxide flame.

The daily Yb dose was calculated based on 4 approaches. One approach was to calculate average daily weight loss of each bolus (based on weekly net weight change) by animal within period (week before and week of collection), multiplied by the Yb percentage in the bolus (350 mg Yb/g bolus core). A second approach was to calculate average daily Yb release of each bolus for the entire trial (based on the difference between dry bolus weight at the beginning and end of the trial divided by number of days in the trial), multiplied by the Yb percentage in the bolus. A third approach was to use the manufacturer's formulated release rate (160 mg Yb/d). A fourth approach was to multiply mean daily fecal Yb concentration by mean daily total fecal output by steer within period, assuming complete marker recovery. Actual fecal output (g/d) was compared with that predicted by dose (g/d) divided by mean marker concentration (g/g of dry matter) in feces of 0800 grab samples, 1700 grab samples, 0800 + 1700 grab samples (averaged after chemical analysis), and from the Yb concentration in the 5-d composite sample, using the first 3 approaches of determining the Yb dose. Dose calculated from Yb recovered in feces (fourth approach) was excluded as a comparison for reasons discussed later.

Dose calculated by period for individual steers (based on period bolus weight loss and on mean Yb recovered in feces) was analyzed in a Latin square design using the GLM procedure of SAS (1987). Further, each method of calculating fecal output was expressed as a percentage of actual fecal output and analyzed in a Latin square analysis using the GLM procedure of SAS (1987). No effect of diet, period, or animal was observed ($P>.10$), so fecal output data were analyzed with a paired t-test (Means procedure; SAS 1987) to compare total fecal collection values with fecal output predicted from each method of estimation.

Results and Discussion

Predicted fecal output as a percentage of actual fecal output was not affected by diet, period, or animal ($P>.10$). Thus, the 4 diets used in this study did not appear to affect the relative ability of the continuous-release bolus to predict actual fecal output.

Comparison of actual fecal output with fecal output predicted by each method (Table 2) indicated differences ($P<.10$) between predicted and actual fecal output, except with the use of dose calculated by period average. The formulated dose and the trial average dose overestimated fecal output by an average of 37 and 34%, respectively, compared with 11% using period average. Average overestimation of total fecal collection was 31, 27, 29, and 22% from grab samples collected at 0800, 1700, 0800 + 1700, and composited fecal sampling, respectively (Table 2). Little difference was noted among grab sampling methods. The use of period average dose in conjunction with composite fecal sampling provided the closest estimate to total fecal collection (9% overestimation). Galyean et al. (1986) summarized several studies that estimated fecal output of steers, based on once or twice daily Yb dosing, and reported a mean of 104% with a range of 87 to 144% of total fecal collection with this method of estimation. Thus, fecal output estimated from the dose based on period average weight changes as a percentage of fecal output from total collection in the present study compares favorably to other methods of dosing Yb.

These data indicate an overestimation of fecal output using the Yb bolus and a large degree of variability, regardless of method of prediction. These findings are in agreement with those of Hatfield et al. (1986), and suggest that marker recovery may have been incomplete, analytical errors may have existed, or, more likely, that dose was overestimated when calculated from bolus weight loss or predetermined Yb release rate. Data from weekly bolus

[3]Model 1093 Cyclotec sample mill, Tecator, Inc., Herndon, Va.
[4]Whatman #541. Whatman Ltd., Maidstone, England.

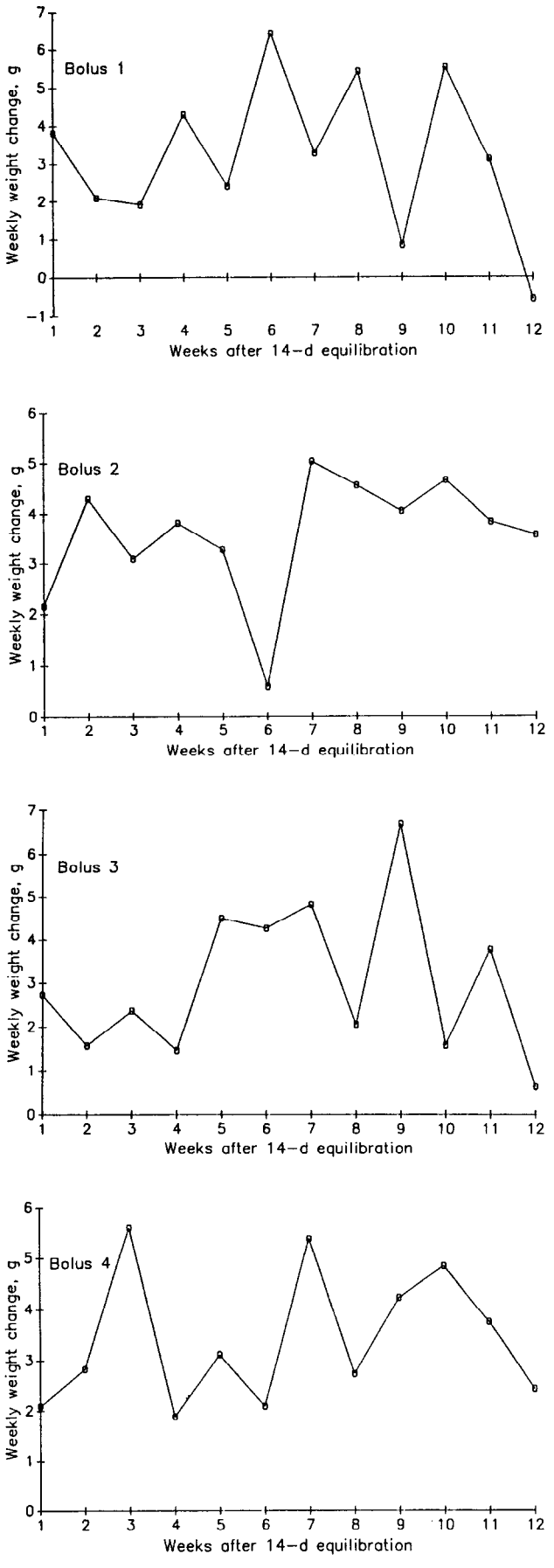

Fig. 1. Weekly weight change of boluses.

weights indicated a variable pattern of release of the Yb-containing polymer both from week to week, and among boluses (Fig. 1). However, as instructed by the manufacturer, boluses were merely shaken to remove excess water before weighing rather than drying, to avoid damage to the bolus. Thus, differences in retention of water and(or) feed particles could have interfered with obtaining an accurate measurement of marker release. Boluses did not retain a uniform surface over time, but became uneven, and the pattern varied among boluses. This variation in surface could have produced variation in the rate of Yb release.

Gravimetric determination of bolus Yb release is impractical or impossible in certain situations when large numbers of animals are needed, particularly with noncannulated animals or when working under range conditions. Thus, the weekly method of dose measurement by weight loss determination, while providing estimates of fecal output closest to total collection values, would have limited experimental application. Furthermore, composite fecal sampling resulted in more precise estimates than did grab sampling techniques. This observation further limits the suitability of this technique for use in grazing situations without fecal collection bags.

Although dose calculated by bolus weight change has limitations in a grazing situation, an alternative method would be to assume complete Yb recovery in feces and calculate dose based on Yb concentration in feces and total fecal output. For example, a large number of animals could be bolused and a sub-group could be fitted with fecal collection bags while grab samples were obtained from the larger group. Presumably, average Yb payout in the sub-group would provide an accurate estimate of Yb payout in the larger group. The use of this method, however, would depend on uniform Yb release among animals (boluses). When dose was calculated based on fecal Yb recovery (Table 3), differences

Table 3. Variation in ytterbium release among animals, periods, and diets, calculated from bolus weight loss and from recovery in feces of steers.

Source of variation	Ytterbium release, mg/d, calculated from: Bolus weight loss (SE = 22.3)	Recovery in feces (SE = 11.1)
Animal number		
1	193	193[a]
2	114	132[b]
3	153	107[b]
4	142	141[b]
Period number		
1	135[ab]	158[ab]
2	154[ab]	134[bc]
3	208[a]	175[a]
4	105[b]	106[c]
Diet		
Alfalfa	137	123[a]
Treated alfalfa	139	158[b]
Alfalfa + concentrate	161	124[a]
Treated alfalfa + concentrate	165	168[b]

[a,b,c]Means within method and source of variation followed by different letters are significantly different ($P<0.10$).

($P<.10$) existed for animal (or bolus), period, and diet. In contrast, only period effects were noted for dose calculated by bolus weight change within period.

Nevertheless, to illustrate the use of an average dose with both methods of dose calculation, Yb release was averaged across steers within period and used to calculate fecal output for individual steers with grab samples taken at 1700. Fecal output predicted with bolus weight change averaged within period was 98, 137, 122, and 124% of total fecal collection for periods 1 through 4, respectively. With dose calculated from fecal Yb recovery within period, pre-

dicted fecal output was 116, 119, 103, and 125% of total fecal collection for periods 1 through 4, respectively. While using the recovery approach on an individual animal (or bolus) basis for determination of dose improves the precision of grab sampling, not using average Yb release defeats the purpose of applying the bolus to a grazing context. Minimal variation in average dose obtained from a sub-group would be critical to this situation; but, uniform bolus Yb release was not the case with our data.

In general, a high degree of variability was associated with estimates of fecal output based on a continuous-release Yb bolus. Such a finding, however, is not inconsistent with previous results for once or twice daily dosing of Yb or Cr_2O_3 (Galyean et al. 1986). Bolus weight changes suggest that the bolus technology has not yet been refined to the point that a constant marker release is achieved among boluses or over time. Nonetheless, the advantages of such technology, should it be developed satisfactorily, warrant further refinement of this methodology. As a case in point, a chromic oxide ruminal delivery device has shown potential as a fecal output marker (Ellis et al. 1982b).

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