Effect of restricted forage intake in confinement on estimated fecal output from a sustained release bolus

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Abstract

Two experiments were conducted to investigate the effects of restricted forage intake on patterns of chromium excretion to determine sample window duration and the accuracy and precision of fecal output estimates derived from the Captec Chrome® sustained release bolus. In Experiment 1, 8 crossbred steers (x = 243 ± 14 kg) were assigned randomly to receive prairie hay (PH) at intake levels of either 1.12% body weight (BWT) or 0.75% BWT while maintained in individual metabolism crates and(or) pens. In Experiment 2, steers from Experiment 1 were rerandomized and assigned to receive PH at either 1.12% BWT or alfalfa hay (AH) at 1.30% BWT. The average post-dosing bolus failure rate across experiments exceeded 30%. Estimated fecal output exceeded actual fecal output under all experimental conditions (P < 0.05). Averaged across experiments, fecal chromium recovery was low (x = 55 ± 45%). When estimated fecal output was corrected for mean marker recovery within treatment, it did not differ from actual fecal output (P > 0.50). Treatment effects were similar for estimated fecal output, corrected estimated fecal output, and actual fecal output. Under conditions of pen feeding and restricted forage intake, estimated fecal output exhibited treatment differences similar to those of total fecal collection. However, unless adjusted for average marker recovery, these estimates were significantly greater than actual fecal output.

Key Words: chromic sesquioxide, marker recovery, Captec bolus, beef cattle, pen feeding

Interpretation of cattle responses to various grazing management and supplemental feeding systems is dependent upon realistic estimates of forage intake. Forage intake of grazing ruminants is usually estimated by dividing fecal output by diet indigestibility. Diet digestibility can be estimated reasonably well in vitro from esophageal extrusa. Fecal output estimation, however, requires labor intensive, complete fecal collection from bagged animals or use of indigestible markers of variable recovery rate and digesta phase association (Kotb and Luckey 1972, Galyean et al. 1986). Chromium is the most widely used fecal output marker (Le Du and Penning 1982), followed by the lanthanide metal (Galyean et al. 1986). Existing marker delivery protocols are either dosing or fecal collections. On day 11, animals were removed to individual pens until day 19. Cattle were returned to metabolism crates on day 20 and both rectal and total fecal collections were made through day 30. Total fecal collections were made from day 1 through day 11 at 0800. Daily individual total fecal collections were thoroughly mixed, weighed, and a 100-g sub-sample taken for moisture, dry matter (DM), and Cr analyses. The weight of rectal grab samples was added to that of daily total collections. On day 11, animals were removed to individual pens and then daily rectal samples were added to that of daily total collections. On day 11, animals were removed to individual pens and then daily rectal samples were added to that of daily total collections. On day 11, animals were removed to individual pens and then daily rectal samples were added to that of daily total collections.

Table 1. Chemical composition on an organic matter basis of prairie and alfalfa hays fed in Experiments 1 and 2.

<table>
<thead>
<tr>
<th>Hay</th>
<th>DM (%)</th>
<th>OM (%)</th>
<th>CP (%)</th>
<th>DDM (%)</th>
<th>NDF (%)</th>
<th>ADF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie</td>
<td>87</td>
<td>88</td>
<td>25</td>
<td>76</td>
<td>43</td>
<td>30</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>91</td>
<td>93</td>
<td>7</td>
<td>59</td>
<td>75</td>
<td>39</td>
</tr>
</tbody>
</table>

1Results from companion digestion trials at ad libitum feeding of these hays (Hunt et al. 1990).
2DM = dry matter, OM = organic matter, CP = crude protein, DDM = In vivo dry matter digestibility, NDF = neutral detergent fiber, ADF = acid detergent fiber.

days in individual concrete floored pens. On day 0 of the trial, steers were placed in individual metabolism crates, to which they had previously been adapted, and a Captec bolus was orally administered. Based on information supplied by the manufacturer, the daily dose of Cr was 1,049 mg. Rectal fecal grab samples were taken at 0800 from day 0 through day 30. Total fecal collections were made from day 1 through day 11 at 0800. Daily individual total fecal collections were thoroughly mixed, weighed, and a 100-g sub-sample taken for moisture, dry matter (DM), and Cr analyses. The weight of rectal grab samples was added to that of daily total collections. On day 11, animals were removed to individual pens and then daily rectal samples were added to that of daily total collections. On day 11, animals were removed to individual pens and then daily rectal samples were added to that of daily total collections. On day 11, animals were removed to individual pens and then daily rectal samples were added to that of daily total collections.

Fecal and forage subsamples were oven dried at 50° C to a constant weight and analyzed for moisture, DM, and crude protein content following AOAC (1980) procedures. Utilizing a modified form of Williams et al. (1962) method, 1 g of each rectal grab sample was ashed for 12 h at 600° C and then digested in 3 ml of phosphoric acid manganese sulfate solution (30 ml of 10% W/V phosphoric acid manganese sulfate solution (30 ml of 10% W/V
Mn SO₄ • H₂O added to 1 liter 85% phosphoric (acid) and 4 ml potassium bromate (4.5% W/V) solution for 5–7 minutes. After cooling, samples were filtered through #41 Whatman filter paper into a 25-ml volumetric flask containing 3.25 ml of a calcium chloride solution (14706 g CaCl₂ • 2 H₂O/liter H₂O) and brought to volume in deionized water. Chromium concentration was determined by plasma emission spectrophotometry (Perkin Elmer Plasma 40). A reference fecal sample was prepared by mixing chromic oxide into a composited blank fecal sample to determine the analytical recovery of chromium. Chromic oxide was mixed at a rate of 2,500 ug/g to provide 100 ug/g Cr concentration after a 25 fold dilution. This reference sample was subjected to the same CR analysis as unknowns (1 reference sample was included in each set of 10 unknowns) and was used to determine the analytical recovery of chromium. The chromium concentration (ug/g) for the reference sample (mean of 19 replicates) was 100.6 ± 3.6 ug/g, indicating complete chromium recovery.

Experiment 2. Thirty days after Experiment 1, the same steers were rerandomized and utilized in Experiment 2. Four steers were fed PH at a rate of 1.12% BWT • hd⁻¹ • d⁻¹ or alfalfa hay (AH) at 1.30% BWT • hd⁻¹ • d⁻¹ to achieve similar levels of fecal output. The Cr bolus was administered orally on day 1 of the adaptation period. Based on the results of Experiment 1, sampling was confined to day 14 through day 22 post-dosing. From day 14 through day 22, rectal grab samples were collected and handled in the same manner as Experiment 1. Total daily fecal collections were made from day 14 through day 17 and were handled the same as in Experiment 1. Fecal Cr and forage chemical analysis were conducted as in Experiment 1.

Data Summarization and Statistical Analyses. Estimated fecal dry matter output (EFDMO), chromium recovery (CRREC), percentage recovery (PREC), and corrected estimated fecal dry matter output (CEFDMO), based upon Cr concentration in rectal grab samples, were calculated as follows:

\[
\text{EFDMO} = \frac{\text{Cr dose (g/d)}}{[\text{Cr}] \text{ feces (g/g)}}
\]

and;

\[
\text{CRREC} = \frac{([\text{Cr}] \text{ feces (g/g)}} \times \text{ fecal output (gDM/d)}}{\text{Cr dose (g/d)}}
\]

and;

\[
\text{PREC} = \text{CRREC} \times 100
\]

and;

\[
\text{CEFDMO} = \text{EFDMO} \times \text{Mean CRREC}
\]

Each experiment was analyzed separately employing an unbalanced, repeated measure analysis of variance (Gugievitch and Chester 1986) GLM routine (SAS 1985). A mixed model was used with treatments as the between animal effect and day as a within animal effect. Data were summarized by animal within treatment. Treatment effects were determined using animal (treatment) as the error term. Day and treatment X day interaction effects were tested with residual error. A paired t-test was utilized to determine whether EFDMO and CEFDMO differed from actual fecal output. Unless otherwise stated, significance level was P<0.05.

Results and Discussion

Sixteen boluses were utilized in the 2 experiments. Based upon plots of daily fecal Cr concentration, 3 boluses failed in Experiment 1 (38%) (Fig 1a) and 2 failed in Experiment 2 (25%) (Fig 1b). The cause of failures was not apparent, though 1 bolus was found shattered in a metabolism crate during Experiment 1. Ellis et al. (1981) and Parker et al. (1989) attributed the majority of failures in a similar bolus to improper oral administration. Observed failure rates were much greater than the 13% and 10% reported by Ellis et al. (1981) and Parker et al. (1989), respectively. After Experiment 1, 2 additional regurgitated boluses were found, similar to Adams et al. (1991). Cause of regurgitation loss is unknown; however, it may have been greater than expected because of limited fiber mat development at such low intake levels. Failed boluses (animals) were deleted from all subsequent analyses.

In Experiment 1, the functional form of fecal excretion curves was not affected across time by intake level; however, the amplitude of excretion curves was affected by intake (Fig. 2). There was a
significant day × intake level interaction resulting from mid-trial changes in Cr excretion that we propose is an artifact of animal movement out of and back into metabolism crates rather than bolus variation (Fig. 2). Across animals and treatments, dynamic equilibrium, in terms of fecal Cr concentration, was attained at 6 ± 1 day post-dosing and was maintained for 16 ± 1.4 day (Fig. 2). Daily variation in fecal Cr concentration could have resulted from sampling technique (Raleigh et al. 1980), animal handling, animal variation (Adams et al. 1991), and/or dose variation (Burns et al. 1989, Estell et al. 1990); the latter 2 were completely confounded in these experiments. Burns et al. (1989), utilizing this delivery system, suggested animal to animal variation in Cr release rate is more likely than variable release rates in an animal. Conversely, Parker et al. (1989) reported no significant effect of animal or diet on Cr release rate.

As expected, rectal Cr concentrations were greater (P < 0.01) when intake was restricted to 0.75% BWT vs. 1.12% BWT (Table 2). Chromium concentrations were similar when PH and A were fed at 1.12% and 1.30% BWT levels, respectively, in Experiment 2 (Table 2), indicating no effect of forage quality on Cr excretion.

During 6 days at marker equilibrium, when both rectal and total collections were made in Experiment 1, there was no day or day × treatment interaction effect on FDMO or EFDMO. Fecal output of steers fed PH was greater (P < 0.01) at 1.12% BWT than 0.75% BWT in Experiment 1 (Table 3). Fecal output estimates based on EFDMO and CEFDMO revealed similar differences between feeding levels in Experiment 1 as FDMO (Table 3). However, estimates based upon EFDMO were greater than FDMO at 1.12% BWT (P < 0.01) and 0.75% BWT (P < 0.09) intake levels (Table 3), 78 and 81% greater than actual FDMO, respectively. Conversely, there were no differences between FDMO and CEFDMO estimates within intake level (Table 3).

There was no difference in FDMO between PH and AH in Experiment 2 (Table 3). Similarily, no hay effect was detected using EFDMO or CEFDMO. The trend to overestimate FDMO utilizing EFDMO continued in Experiment 2. Estimated fecal dry matter output overestimated FDMO of steers fed PH (P < 0.01) and AH (P < 0.04) by 106% and 88%, respectively. In contrast, CEFDMO did not differ from FDMO, consistent with the results from Experiment 1.

Adams et al. (1991) found under grazing conditions that estimated fecal output tended to be lower than actual fecal output from fecal bagged steers. Those authors also found no advantage to adjusting estimated fecal output by recovery, which was apparently near 100%. Hatfield et al. (1991), in a grazing study with sheep, found EFDMO tended to underestimate FDMO. They found no difference between estimated and actual fecal output in unsupplemented grazing wethers. Conversely, under confinement feeding in metabolism crates, estimated fecal output was greater than actual fecal output. Hatfield et al. (1991) postulated the dichotomy found between pen fed and grazing conditions may have resulted in part from discontinuous forage/feed intake under pen fed, once daily feeding.

Pond et al. (1990a) concluded fecal output estimates of pen fed sheep from the sustained release bolus were similar to and predicted well (R² = .92) FDMO actual fecal output. However, in a companion study using cattle (Pond et al. 1990b), a bolus designed for cattle grossly overestimated actual fecal output of pen fed steers receiving either Bermudagrass or alfalfa hay. Burns et al. (1989)

### Table 2. Effect of hay and level of feeding on intake of fecal chromium concentration and apparent chromium recovery.

<table>
<thead>
<tr>
<th>Intake (% BWT)</th>
<th>Fecal chromium concentration (ug/g)</th>
<th>Chromium recovery (mg/d)</th>
<th>Percentage chromium recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairie 1.12%</td>
<td>642 a1</td>
<td>604 a</td>
<td>58 a</td>
</tr>
<tr>
<td>Prairie 0.75%</td>
<td>1069 b</td>
<td>588 a</td>
<td>56 a</td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairie 1.12%</td>
<td>567 a</td>
<td>520 a</td>
<td>50 a</td>
</tr>
<tr>
<td>Alfalfa 1.30%</td>
<td>589 a</td>
<td>560 a</td>
<td>53 a</td>
</tr>
</tbody>
</table>

1Chromium recovery (mg/d) = [(Fecal Cr (ug/g) × fecal dry matter output (g/d)]/1000.
2Percentage chromium recovery = chromium recovery (mg/d)/Cr dose (1049 mg/d) × 100.
3Means within a column and experiment not having a common letter differ (P < 0.05).

Similarly, there was no apparent effect of severe intake restriction on fecal Cr recovery in Experiment 1 or forage quality effect in Experiment 2 (Table 2). Across experiments, Cr recovery averaged 54 ± 4%. Overall, Cr recovery tended to be lower in Experiment 2 than Experiment 1 (51 vs. 57%, P = 0.11). Parker et al. (1989), utilizing a similar delivery system in sheep, reported Cr recoveries of 97 to 104%. Average recovery of 55 is well below the 92 to 102% reported for daily oral administration of Cr (Kobt and Lucky 1972, Raleigh et al. 1980, Le Du and Penning 1982, Galwyn et al. 1986). Two possible explanations exist for the low fecal Cr recovery observed in this study. Chromium could have been lost through regurgitation, urination, incomplete recovery in feces, incomplete quantitative recovery during laboratory analyses, or a combination thereof. Analytical recovery of Cr from reference fecal samples averaged 100%. We believe the consistently low Cr recovery observed across animals, treatments, and trials indicates a systematic error existed. A daily release rate below the manufacturer's estimate of 1,534 mg chronic sesquioxide (1,049) would have caused systematic underestimation of Cr recovery. Based upon the results of this study, release rates below manufacturer's specifications were the probable cause of systematically low estimates of Cr recovery.

Table 3. Effect of hay and level of feeding on actual and estimated fecal output utilizing a controlled release intraruminal delivery system.

<table>
<thead>
<tr>
<th>Intake (% BWT)</th>
<th>n</th>
<th>FDMO1 (g · d⁻¹)</th>
<th>EFDMO¹ (g · d⁻¹)</th>
<th>CEFDMO¹ (g · d⁻¹)</th>
<th>Δ₁ (%)</th>
<th>Δ₀%²</th>
<th>p²</th>
<th>Δ₁ (g)</th>
<th>Δ₀% (g)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairize 1.12% BWT</td>
<td>3</td>
<td>944 a³</td>
<td>1683 a</td>
<td>968 a</td>
<td>739</td>
<td>78</td>
<td>&lt;0.01</td>
<td>24</td>
<td>3</td>
<td>0.60</td>
</tr>
<tr>
<td>Prairize 0.75% BWT</td>
<td>2</td>
<td>550 b</td>
<td>993 b</td>
<td>558 b</td>
<td>445</td>
<td>81</td>
<td>0.02</td>
<td>8</td>
<td>2</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairize 1.12% BWT</td>
<td>3</td>
<td>918 a</td>
<td>1887 a</td>
<td>935 a</td>
<td>969</td>
<td>106</td>
<td>0.02</td>
<td>16</td>
<td>2</td>
<td>0.82</td>
</tr>
<tr>
<td>Alfalfa 1.30% BWT</td>
<td>3</td>
<td>971 a</td>
<td>1826 a</td>
<td>974 a</td>
<td>855</td>
<td>88</td>
<td>0.01</td>
<td>3</td>
<td>&lt;1</td>
<td>0.93</td>
</tr>
</tbody>
</table>

1FDMO = actual fecal dry matter output, EFDMO = estimated fecal dry matter output, CEFDMO = estimated fecal dry matter output corrected for mean Cr recovery, Δ₁ = EFDMO - FDMO, Δ₀ = CEFDMO - FDMO, Δ₀% = (Δ₀ / FDMO) × 100, P = t-test probability Δ = 0. Column means within an experiment not having a common superscript differ (P < 0.05).
proposed the release rate of Cr from the bolus was influenced by individual animal specific conditions in the reticulo-rumen. In contrast, Parker et al. (1989) found very little variation among sheep in estimated Cr release rates.

**Conclusions**

The sustained release bolus delivery system dramatically overestimated actual fecal output under all experimental conditions. Overestimation, however, did not lead to misinterpretation of relative differences between intake levels or hay types. Overestimation of fecal output under pen fed conditions may largely result from feeding frequency and not reflect inherent limitations of the bolus system. Results from other laboratories indicate actual fecal output under grazing conditions does not differ from estimated fecal output utilizing the Captec system. Similarly, estimated fecal output did not differ from actual fecal output when adjusted for average Cr recovery in this study. Lower fecal Cr recovery was experienced than previously reported, which probably resulted from release rates less than that supplied by the manufacturer. Based on restricted intake under pen fed conditions utilized in this study, a subset of animals would have to be utilized for complete fecal collection to adjust for variable recovery rates when this bolus is used. Of greatest concern is the excessive rate of bolus failure (>30%). Bolus administration protocols supplied by the manufacturer were followed, and after review, there was no apparent procedural cause for these failures. Fecal sampling protocols will have to provide for daily individual animal collections and Cr analysis to determine bolus failure. Within the limitations a high incidence of bolus failure and low marker recovery impose, the Captec system deserves further evaluation.

Further research is warranted on the effects feeding frequency and intake restriction have on the accuracy and precision of fecal output estimates from this system. Further grazing research is needed to determine if the impacts of severe intake restriction on the degree of fecal output overestimation are the result of feed restriction or feeding frequency under pen fed conditions.

**Literature Cited**


