The use of trivalent metal markers for estimating the individual feed intake of young pigs

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Abstract

Twenty-four individually housed male pigs (6.6 ± 0.24 kg) were used in a pilot study to validate two trivalent metal markers, one in the feed and the other dosed orally to piglets, for the estimation of voluntary feed intake. Pigs were randomly assigned to one of three oral dosing treatments using 15 mg lanthanum oxide/day as the internal marker: once daily, twice daily, or 3 times daily. Piglets were offered a diet containing 1 g/kg of yttrium as the external marker. After a 7-day adaptation period, total faecal collection was made for the next 3 days. The first faecal sample voided after 1000 h was considered as the 'grab sample', to allow comparison of the technique with total collection. Intake of diets was recorded daily, and compared to feed intake using the ratio of the markers in the faeces. Daily samples were analysed for marker concentrations and a mean of the three-day data was used for regression analysis. Total collection data demonstrated that the accuracy of the estimation using the trivalent metals depended on the frequency of oral marker administration, as the estimation principle relies on the continual flow of a known amount of marker in the gastrointestinal tract (GIT). Nevertheless and using total collection, dosing the oral marker 3 times a day estimated individual feed intake with reasonable accuracy (R^2 = 0.85). In contrast, the ‘grab sampling’ technique reduced the accuracy of estimation (R^2 = 0.74), indicating that continual flow of the oral marker in the GIT is required for such a method. In conclusion, there is some potential in using trivalent metal markers to quantitatively estimate the feed intake of an individual pig, however the level of accuracy requires improvement.

Keywords: feed intake; Lanthanum; Yttrium; markers; Weaner pigs.

1. Introduction:

Pig producers traditionally offer a creep diet to sucking piglets during lactation to supplement their nutrition because the sow produces less milk as lactation advances. Our previous experiment (Pluske et al., 2007) qualitatively categorised piglets into “eaters” and “non-eaters” of creep feed using a colour marker and demonstrated that piglets eating more creep feed during lactation perform better after weaning, which is in agreement with Bruininx *et al.* (2002). A greater understanding of factors influencing creep feed consumption during lactation could have commercial implications, such as improved management of piglets after weaning. Greater understanding in this area, however, is hindered because it is not possible at the moment to determine how much creep feed an individual piglet in a litter consumes.

It is possible to estimate the herbage intake of an individual grazing sheep by chemically analysing natural (alkane) markers in the pasture and faeces (Dove and Mayes, 1991). Trivalent metal markers could be used in replacement of the alkane markers but using the same method of calculation. Trivalent metal markers such as Lanthanum III oxide (La_2O_3), Yttrium III oxide (Y_2O_3) and Ytterbium III chloride hexahydrate ($YbCl_3$-$6H_2O$) have been successfully used as markers in fish (Austreng et al., 2000), ruminants (Sowell et al., 2003), dogs (Vhile et al., 2007) and pigs (Mavromichalis et al., 2001) for estimation of nutrient digestibility. In this pilot experiment, we tested the validity of trivalent metal markers to estimate the feed intake of young pigs that were housed individually, to verify whether the technique could be used to estimate the creep feed intake of an individual piglet in a litter.

2. Materials and Methods

2.1. Preparation of the oral marker solution

The oral marker, lanthanum oxide (La_2O_3, Sigma-Aldrich, Inc., St. Louis, Mo, USA), is 96% soluble in pH 3 solution and re-precipitates at pH 7 (Austreng et al., 2000). Therefore the lanthanum oxide was dissolved in diluted table vinegar (1:5 with distilled water, pH 2.8) at a rate of 5 mg/mL. Table sugar (5 mg/mL) was also dissolved in the solution to increase the palatability of the solution. The lanthanum oxide was dissolved with a magnetic stirrer under heat (110 °C) for 30 min. The solution was then filtered through filter paper (No. 541, Whatman) and stored at 4 °C until use.

2.2. Animal and experimental procedure

The experiment was approved by the Department of Agriculture and Food Western Australia Animal Ethics Committee. Twenty-four male weaner pigs weaned at 21 ± 2 days of age (Large White × Landrace, 6.6 ± 0.24 kg) and provided creep feed from 14 d were individually housed in a metal mesh-floored weaner crate with a space allowance of 1.6 m^2 and randomly allocated to one of 3 treatments (n=8). The three treatments were an oral dose (directly into mouth through a sterile injection tube) of 15 mg lanthanum (dissolved in 3 mL diluted table vinegar) either as a once daily dose of 3 mL (0800 h), a twice-per-day dose of 1.5 mL each (0800, 2000 h), or a dose of 1 mL three times per day (0800, 1600 and 2400 h). The solution was dosed into the oropharynx while restraining pigs in an up-right position until pigs had apparently ingested all of it. Piglets were fed a commercial weaner diet containing 1 g/kg of a marker, yttrium (Y_2O_3, Sigma-Aldrich, Inc., St. Louis, Mo, USA). After 7 days of adaptation, faecal samples were collected using the total collection method and "grab" sampling method daily for three days. The first faecal sample voided after 1000 h was collected as "grab sample" and the amount of grab sample was numerically adjusted for the total collection data. Daily samples were analysed for marker concentrations and a mean of the three-day data was used for regression analysis. Voluntary feed intake (VFI) was recorded daily by measuring feed offered and residues each morning. The VFI estimation included any spillage on the floor.

Creep feed intake was calculated using the methodology of Dove and Mayes (1991),

Feed intake (g DM) = Faecal output (FO) / Dilution index (DI), where:

FO = Lanthanum marker consumed (g/day) / Lanthanum in faeces (g/g DM) and

DI = Yttrium marker in diet (g/g DM) / Yttrium in faeces (g/g DM).

2.3. Chemical analyses

The dry matter content of diet and faecal samples was determined by weighing each sample, oven drying for 2 h at 135 °C, then reweighing. The concentrations of lanthanum and yttrium in diets, the oral marker solution and faeces were determined using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) (Austreng et al., 2000).

2.4 Statistics

The feed intake and faecal output of pigs fluctuated day by day causing a large variation in the feed intake when it was estimated from the daily data. Therefore, the mean value for each pig for the 3 day collection period was taken and used for the regression analyses. Linear regression analysis was conducted to validate the accuracy of the marker method against reference measurement for estimation of individual feed intake (Minitab 13, Minitab Inc., State College, PA).

3. Results and Discussion

An important source of error can be an incomplete ingestion of orally-dosed lanthanum oxide. Pigs accepted the solution very well; however, some degree of regurgitation could have happened with the saliva. The oral marker lanthanum has a number of advantages than other trivalent metal markers, as it is known to completely dissolve in solution at pH 3 and re-precipitate in the duodenum (at pH 5-6), and flows with solid digesta (Austreng et al., 2000). Nevertheless, a critical aspect of this methodology is whether the steady flow of the oral marker lanthanum in the faeces occurs, and hence whether a once-daily faecal ‘grab sample’ is valid for the estimation of feed intake with reasonable accuracy compared to total collection of faeces. Therefore, the suitability of using an external marker procedure to estimate the intake of creep by individual piglets while remaining in group was tested in this study. Specifically, this study tested weather a fixed amount of lanthanum oxide given orally as a La_2O_3 solution in a single dose or split in two or three doses allows the estimation of creep intake with adequate accuracy.

Linear relationships between measured and estimated VFI using the three dosing frequencies and two collection methods are presented in Table 1. Results obtained from the total collection study demonstrated that trivalent metal markers (lanthanum and yttrium) are a valid method for estimating the individual feed intake of a pig, however the accuracy of the estimation depended on the number of times the oral marker was administered because an increasing number of doses significantly increased the accuracy of the estimation (Table 1). This, presumably, is because the estimation principle relies on the continual flow of a known amount of marker in the GIT, and more frequent dosing would have increased the stability of marker flow along the GIT. Nevertheless, by the total collection method, dosing the oral marker three times per day estimates individual feed intake with reasonable accuracy (R^2 = 0.85, Figure 1).

Since total collection of faeces would not be possible from an individual piglet in a litter, ‘grab sampling’ was also investigated in this study. Taking a ’grab sample’ significantly reduced the accuracy of estimation and increased variability (RSD) of the estimated feed intake, indicating the continual flow of oral marker solution was most likely not achieved even by dosing the oral marker three times per day (Table 1). However, our data showed that the higher variability was caused by those pigs eating more than 600 g diet per day (high standard error, see Fig. 1), most likely because these pigs may consumed larger meals before or after the dose of oral markers. This, in turn, would presumably alter the concentrations of oral and in-feed markers in the digesta. As sucking piglets most probably consume far less solid feed than this (Pluske *et al*., 2007), we believe that the potential of the trivalent metal marker method to estimate creep feed intake in a litter would be higher than that found in the present study. As found in this pilot study, further research is warranted to verify this hypothesis. Although this methodology can be considered an improvement to previous qualitative methods of estimating individual pig feed intake, the accuracy of the estimation should be improved using better methodology that can ensure quantitative ingestion and steady flow of the oral marker.

In conclusion, despite the accuracy of the 'grab sampling' method being significantly lower than total collection, a mean estimation of the three-day observations using the trivalent metal marker technique can be used with moderate accuracy for the estimation of individual feed intake in suckling piglets.

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Table 1. Linear regression results for estimated (Y) and measured (X) feed intake in pigs given in-feed yttrium (Y^{+++}) and oral lanthanum (La^{++})[a].

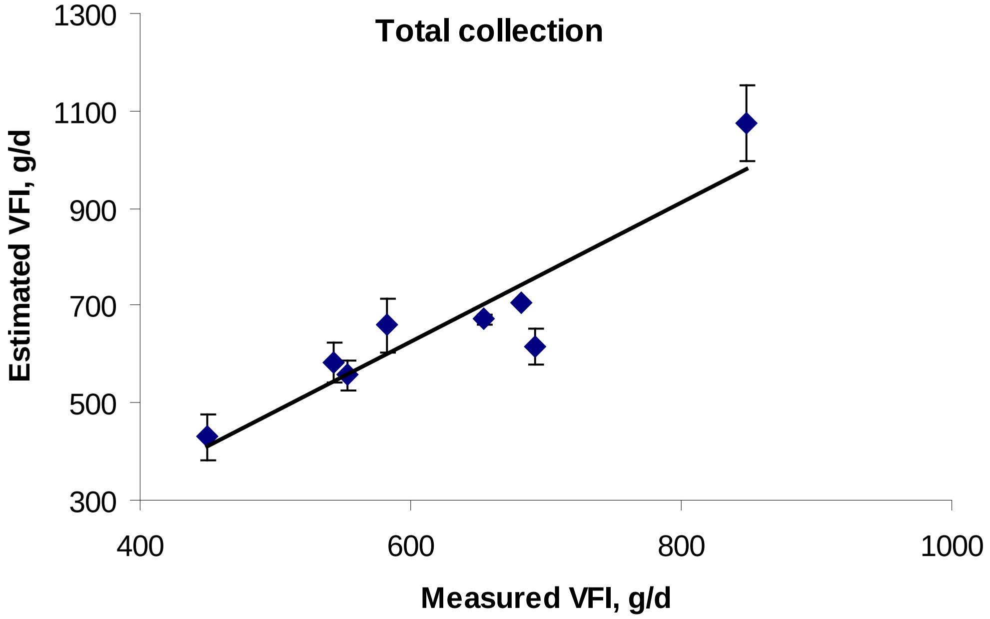
Method	Oral maker dose[b]	Intercept	Slope	R^2	RSD[c]	Number of observation[d]	P=
Total collection							
	1	69 (290)	1.19 (0.51)	0.47	127	8	0.06
	2	106 (88)	0.77 (0.14)	0.82	40	8	0.002
	3	-231 (156)	1.43 (0.25)	0.85	73	8	0.001
Grab sampling							
	1	-520 (347)	2.65 (0.67)	0.72	152	8	0.008
	2	-274 (310)	1.80 (0.53)	0.66	145	8	0.015
	3	-21 (160)	1.19 (0.29)	0.74	72	8	0.006

[a]Standard errors are reported in parentheses.

[b]Number of daily oral marker administration. The same amount of marker (15 mg of lanthanum oxide in 3 mL diluted vinegar solution) per day was orally administered once, twice or three times.

[c]Residual standard deviation.

[d]Mean of three daily observations.



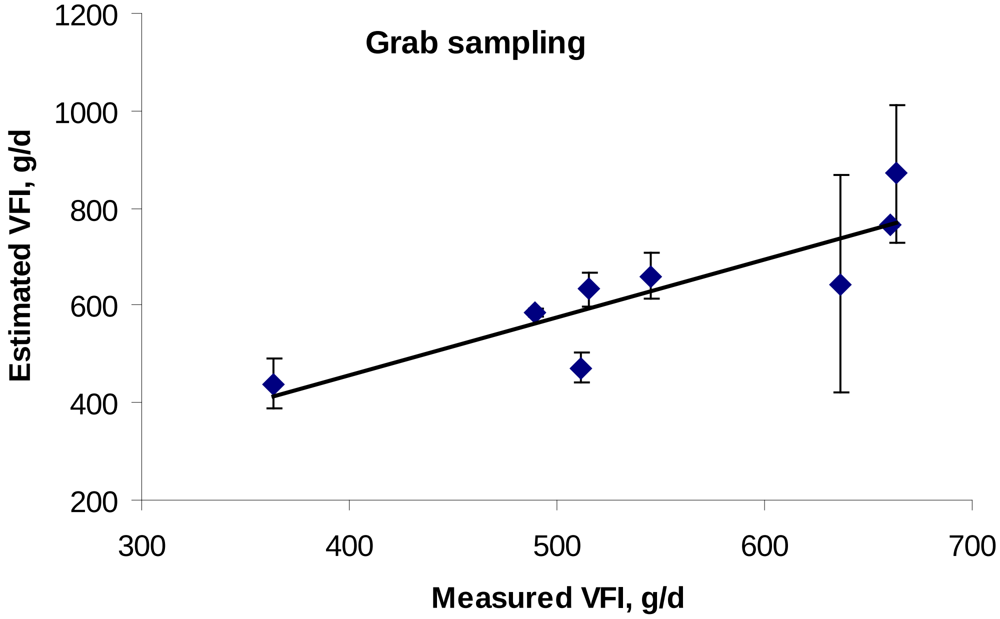


Figure 1. Predictability of feed intake using the trivalent metal marker method. The oral marker was dosed three times per day. Total collection Y=-231 + 1.43X R^2=0.85 (RSD = 73); grab sampling Y= -21 + 1.19X, R^2=0.74 (RSD = 72).