Journal of Animal and Feed Sciences, 13, Suppl. 1, 2004, 19–22

Passage kinetics of internal and external markers in lactating dairy cows

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ABSTRACT

Particle passage kinetics in dairy cows was assessed using acid detergent fibre (ADF) associated ^{15}N as an internal marker and chromium (Cr) mordanted grass silage, ytterbium (Yb) labelled grass silage and dysprosium (Dy) labelled faecal particles as external markers. Kinetic parameters were estimated using two-compartment models assuming gamma time-dependent (G3) passage rate in the first compartment and age-independent (G1) in the second compartment. Parameter estimates were consistent between ADF-^{15}N and Cr, but for Yb and Dy the total mean retention time and retention time in the age-independent compartment was shorter.

KEY WORDS: passage kinetics, markers

INTRODUCTION

Modelling of ruminal nutrient degradability requires quantitative information on passage kinetics of digesta from the reticulo-rumen. Passage kinetics of soluble substrates follows first order kinetics, whereas particulate matter passage rate is dependent on the physical characteristics of particles. Ingested particles have a low probability of entering the omasal canal before they have been comminuted smaller than a critical size (Poppi et al., 1981). In addition, physical entrapment within particulate matter raft may decrease particle passage rate (Poppi et al., 2001). Particle passage kinetics has been studied using external markers labelled onto feed particles. External markers have been criticized for altering the physical characteristics of particles (Ehle, 1984) or that they may dissociate from the

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labelled material and associate to small particulate matter and microbes (Combs and Satter, 1992). Huhtanen and Hristov (2001) assessed particle passage kinetics using fibre-bound ^{15}N as an internal marker. Theoretically, use of internal markers might overcome the problems associated with external markers. The current study compared the passage kinetics of ADF-^{15}N to that of Cr, Yb and Dy.

MATERIAL AND METHODS

Particle passage rate was studied on four multiparous Ayrshire dairy cows of 660 kg (SD 40.1) liveweight. Cows were 96 days in milk (SD 27.0), produced 33.0 kg/d (SD 5.98) of milk and consumed 14.8 (SD 0.97) and 8.9 kg/d (SD 0.11) of grass silage and concentrate DM, respectively. Timothy grass grown on a field on clay soil was fertilized with ammonium sulphate (Isotec Inc. Miamisburg, OH; 10% $^{15}N/N$) at a rate of 100 kg N/ha. Grass was harvested when 62% of ears had emerged, coarsely chopped using a laboratory scale chopper, wilted until dry matter concentration of 220 g/kg and then preserved in plastic silos (1.6 kg DM each) with formic acid applied at a rate of 5 L/ton.

Chromium was mordanted onto grass silage as described by Udén et al. (1980) modified such that Cr concentration was 24 g/kg DM. Grass silage was labelled with Yb by incubation in ytterbium acetate solution (Dasico a/s, Birkerod, Denmark) for 48 h at room temperature, followed by removal of loosely bound element with distilled water adjusted at pH 4.5 with acetic acid. Faecal particulate matter was collected from each animal, washed with hot water and laundry detergent, then labelled with dysprosium ($DyCl_3 \cdot 6H_2O$; Sigma-Aldrich, Corp., St. Louis, MO, USA) similar to the procedure described for Yb.

Passage kinetic parameters were estimated using two-compartment models assuming gamma time-dependent (G_n, n=2-4) passage rate in the first compartment and age-independent (G1) in the second compartment (Pond et al., 1988). Currently, parameter estimates using G3G1 model have been reported on the basis of least residual sums of squares.

RESULTS

Estimates of kinetic parameters were consistent between ADF-^{15}N and Cr, whereas Yb and Dy indicated significantly different passage kinetics (Table 1). Highest total mean retention time was estimated for Cr and ADF-^{15}N. Total mean retention time of Yb was significantly smaller and use of Dy resulted in lowest estimates.

Table 1. Effect of marker on passage kinetic parameters estimated based on excretion patterns in faeces

Item	Marker				SEM
	ADF-^{15}N	Chromium	Dysprosium	Ytterbium	
τ, h	6.4^{b}	6.3^{b}	8.1^{a}	5.8^{b}	0.46
CMRT1, h	13.1^{b}	15.9^{ab}	7.6^{c}	19.3^{a}	1.27
CMRT2, h	25.7^{a}	24.1^{a}	13.1^{b}	13.9^{b}	1.76
CMRT, h	38.8^{a}	40.1^{a}	20.7^{c}	33.2^{b}	0.77
TMRT, h	45.2^{a}	46.3^{a}	28.8^{c}	39.0^{b}	1.02

$^{a, b, c}$ means within a row without a common supercript letter differ significantly ($P<0.05$)

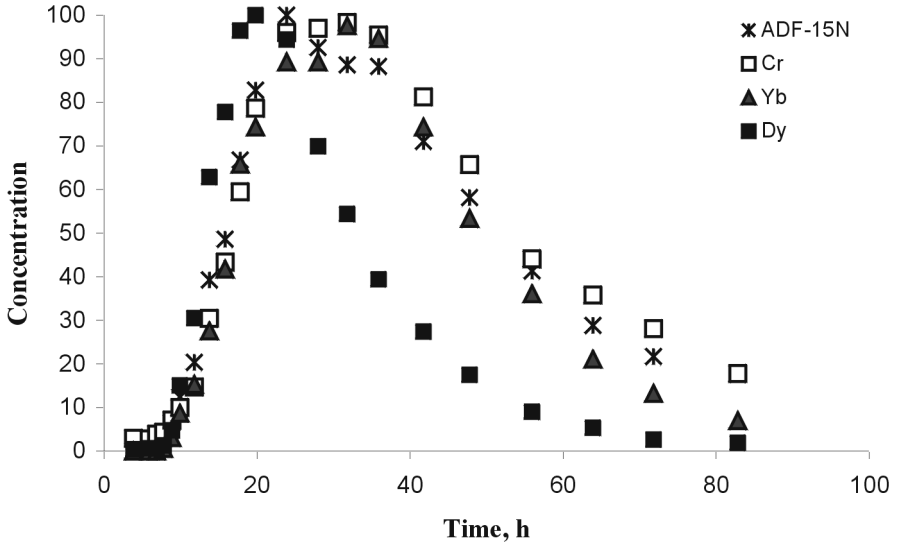

Figure 1. Marker concentration in faeces expressed as percentage units of maximum concentration

Compared with ADF-^{15}N the total mean retention time of Yb and Dy was 6.2 h and 16.4 h shorter, respectively. Retention time in the age-dependent compartment was highest for Yb, intermediate for Cr and ADF-^{15}N and lowest for Dy. Retention time in the age-independent compartment was higher for Cr and ADF-^{15}N compared with Yb and Dy. Shorter retention time of Yb in the age-independent compartment is reflected in a steeper slope of the descending part of marker excretion curve in faeces (Figure 1).

DISCUSSION

Current estimates of CMRT and TMRT based on ADF-^{15}N are similar to those observed by Huhtanen and Hristov (2001) in Holstein cows in late lactation (39.3 h and 47.0 h, respectively). Shorter retention time estimated with Yb compared with ADF-^{15}N is probably explained by dissociation of rare earth element from originally labelled material (Combs and Satter, 1992). Differences between Yb and Dy are attributed to smaller particle size and lower digestibility of faecal particles compared with grass silage.

CONCLUSIONS

Use of ADF-^{15}N and Cr resulted in similar passage kinetics, whereas the compartmental retention time was underestimated using Yb.

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