Passage kinetics of maize silages determined with ^{13}C isotopes and Cr-mordanted fibre

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Introduction

Within the Dutch protein evaluation system (DVE/OEB system; Van Duinkerken et al., 2011) fermentation behaviour of protein and starch in the rumen is described by feed-specific fractional degradation rates and fixed fractional passage rates (K_p). Yet digestion of feed is a dynamic process. It is therefore necessary to take into account variation in fractional rumen passage rates related to diet composition, to change from an animal requirement-based system to an animal response-based system. This enables to determine responses of dairy cows to diet changes and predict nutrient availability and utilisation within the digestive tract more accurately (Dijkstra et al., 2007). Fractional passage rates are conventionally determined using indigestible external markers, which have been often criticised for behaving differently from feed particles (Tamminga et al., 1989). Internal markers like stable isotopes (e.g. ^{13}C) are truly associated with the fraction under investigation and, hence, would be more representative of the in vivo situation.
Fractional passage rates were found to vary with different grass silage qualities, and in particular increased with increasing maturity of grass silage (Rinne et al., 1997). However, no data are available for maize silage. This research aims at quantifying fractional passage rates of different maize silage qualities with external (Cr-mordanted fibre; Cr-NDF) and internal markers (^{13}C), the latter determined both in the DM and cell wall fraction.

Material and Methods

Six multiparous rumen-fistulated dairy cows received one of the six maize silage treatments in a 6 × 6 Latin square design. Maize silages were prepared from two maize cultivars (Aastar, Baleric) harvested at three maturity stages: early (270 g DM/kg), mid (330 g DM/kg), and late (390 g DM/kg). At the start of the experiment, cows produced 39.1 ± 4.90 kg of milk/d (values expressed as means ± SE), and were 53 ± 11.3 DIM; body weight was 571 ± 66.0 kg. Animals were housed in tie stalls and were offered a total mixed ration composed of 62.5% maize and grass silage (1:1; DM basis) and 37.5% concentrates. Animals were adapted to their individual diet for 12 d and fed 95% of the individual DM intake from day 9 onwards. A pulse dose of Cr-NDF (100 g DM) and corresponding ^{13}C-labelled maize silage (30 g DM) was administered into the rumen on day 13. The ^{13}C markers were prepared for each treatment from continuously labelled maize plants grown in climate-controlled isotope assimilation chambers. Labelled plants were chopped into pieces of about 1 cm, ensiled together with field maize plants and cut further into pieces of about 2.5 mm to resemble ingested maize components. Cr-NDF was ground to 0.5 mm. Spot samples of faeces and chyme were taken in blocks of 3 h for about 120 h after pulse dosing, resulting in 22 sampling points per cow-treatment combination. Chyme samples were collected from the omasal canal (Huhtanen et al., 1997). Marker concentrations were analysed in faeces and chyme. ^{13}C was determined in the DM and in the acid-detergent residue (ADR). Acid-detergent residue was obtained by washing the material with acid detergent in filter bags. Dry matter and ADR fractions were pulverised in a bullet mill and analysed for ^{13}C enrichment by isotope ratio mass spectrometry. The K_p values were estimated from marker concentration patterns in faeces and chyme using a nonlinear multicompartmental model (Dhanoa et al., 1985). Values were log transformed and tested with analysis of variance for effects of maize silage quality and choice of marker on passage (GLM procedure of SAS 9.2).

Results and Discussion

Milk production (36.6 ± 0.30 kg/d) and milk protein content (34.3 ± 0.28%) was not influenced by maize silage quality whereas DM intake (21.7 ± 0.26 kg/d) and milk fat content (4.27 ± 0.46%) increased with maturity ($P = 0.006$ and $P = 0.007$, respectively).

Fractional passage rates (Table 1) were estimated for the slowest (K_{p1}; rumen) and second slowest compartment (K_{p2}; large intestine). K_{p2} values were highest in chyme samples and might reflect mixing time in the rumen. Maize silage quality had no effect on any of the estimated parameters. Marker choice influenced both faecal K_{p1} (P = 0.003) and K_{p2} values (P = 0.001), with higher K_{p1} estimates based on Cr-NDF than based on ^{13}C in both faeces and chyme. A good overall correlation (r = 0.71) was found between sampling locations for Cr-NDF. A lack of correlation for ^{13}C (r = 0.08) and a somewhat higher variation in ^{13}C marker concentrations in chyme indicate some difficulties with recovering labelled maize silage from the omasal canal. This might be due to differences in particle size of the pulse-dosed maize silage and its rather heterogeneous content with the fibre-containing stem/leaf fraction and starch-containing kernels leaving the rumen-reticulum, as compared to Cr-NDF. Accuracy of the model in predicting fractional passage rates from faeces was considerably better for Cr-NDF (mean prediction error (MPE) of 22%) than for ^{13}C (MPE of 31-42%). The MPE for omasal chyme excretion patterns were similar among markers (24-26%).

Table 1. Fractional passage rates of different maize silages (Aastar, Baleric) harvested at three maturity stages (early, mid, late) through the digestive tract of dairy cows.

Marker	Aastar			Baleric			SE
	Early	Mid	Late	Early	Mid	Late	
Faeces							
Cr-NDF							
K_{p1}	0.045	0.035	0.037	0.047	0.045	0.045	0.003
K_{p2}	0.413	0.505	0.465	0.391	0.416	0.374	0.037
^{13}C-DM							
K_{p1}	0.019	0.026	0.026	0.023	0.023	0.025	0.005
K_{p2}	0.174	0.088	0.130	0.126	0.129	0.209	0.050
^{13}C-ADR							
K_{p1}	0.016	0.024	0.025	0.016	0.028	0.030	0.010
K_{p2}	0.699	0.206	0.107	0.400	0.630	0.439	0.246
Omasal chyme							
Cr-NDF							
K_{p1}	0.060	0.049	0.037	0.051	0.041	0.052	0.014
K_{p2}	2.713	1.464	3.848	2.934	2.242	1.343	2.031
^{13}C-DM							
K_{p1}	0.023	0.080	0.020	0.038	0.027	0.033	0.018
K_{p2}	1.499	0.175	1.586	0.767	2.573	0.499	1.566

K_{p1}: fractional passage rate (/h) of the slowest compartment; K_{p2}: fractional passage rate (/h) of the second slowest compartment; ADR: acid-detergent residue; SE: standard error of mean

Conclusions

The ^{13}C-labelled cell wall (ADR) and DM fractions of maize silages passed more slowly out of the entire gastro-intestinal tract than Cr-NDF. Maize silage quality had no effect on fractional passage rates in this study. Mean rumen fractional passage rates of ^{13}C in DM (0.024/h) and ADR (0.026/h) determined in faeces were higher than cell wall fractional passage rates calculated according to the DVE/OEB system (on average, 0.016/h). Rumen fractional passage rates based on the external marker Cr-NDF seemed to overestimate the fractional passage rates for both the DM and cell wall fractions.

References

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