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Ruminal large and small particle kinetics in dairy cows fed primary growth and regrowth grass silages harvested at two stages of growth

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ABSTRACT

Passage, breakdown and digestion rates of large and small particles were estimated using the rumen evacuation technique and total faecal collection with four lactating dairy cows in a 4×4 Latin square experiment. Two primary growth grass (PG) and two regrowth grass (RG) silages, each harvested at two different growth stages, were fed as dietary treatments supplemented with 8.0 kg concentrate per day. Ruminal contents and faeces were divided into large (>1.25 mm; LP) and small (1.25–0.04 mm; SP) particles by wet sieving. Indigestible neutral detergent fibre (iNDF) was determined by 12-day ruminal *in situ* incubation followed by a neutral detergent extraction. Ruminal iNDF content of LP (LP-iNDF) and SP (SP-iNDF) for both PG and RG diets increased with advancing maturity of the grass. The passage rate of SP-iNDF tended to be faster (P<0.10) for PG than for RG diets (0.0478 *versus* 0.0418/h on average). Particle breakdown rate increased with advancing maturity for PG while it was not affected by maturity for RG diets (P<0.01 for interaction of harvest×maturity). The passage rate of potentially digestible neutral detergent fibre (pdNDF) for SP (SP-pdNDF) of PG decreased (0.0350 *versus* 0.0284/h) while it increased (0.0284 *versus* 0.0342/h) for SP-pdNDF of RG with advancing maturity (P<0.01 for interaction of harvest×maturity). The digestion rate of LP-pdNDF and pdNDF in SP (SP-pdNDF) decreased with advancing maturity for both PG and RG diets (P<0.05), and it was faster for SP compared to LP for all diets (P<0.001). Ruminal mean retention times (MRT) of LP-iNDF and SP-iNDF for RG were longer than those for PG diets (P<0.001 and P<0.05, respectively). Ruminal mean turnover time (MTT) of LP-pdNDF was longer for RG than PG diets (P<0.05) and it increased with advancing maturity for both PG and RG (P<0.05).

1. Introduction

Nutrient digestibility in the rumen is a result of competition between digestion rate (k_d) and passage rate (k_p) (Allen and Mertens, 1988), and many attempts have been made to estimate passage and digestion kinetic parameters of forage based diets in ruminants. External markers are usually used to estimate k_p, and *in situ* or *in vitro* methods

Abbreviations: aNDFom, neutral detergent fibre using α-amylase and corrected for ash; DM, dry matter; iNDF, indigestible aNDFom; k_d, digestion rate; k_i, intake rate; k_p, passage rate; k_r, breakdown rate; LP, large particles; LP-iNDF, iNDF content of large particles; LP-pdNDF, pdNDF content of large particles; MRT, ruminal mean retention time; MTT, ruminal mean turnover time; pdNDF, potentially digestible aNDFom; PG, primary growth grass; RG, regrowth grass; SP, small particles; SP-iNDF, iNDF content of small particles; SP-pdNDF, pdNDF content of small particles.

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are used to estimate k_d. The rumen evacuation technique is an alternative method to estimate rates of passage and digestion.

Based on modelling principles, material which is homogenous or kinetically indistinguishable can be considered as a compartment (Wastney et al., 1999). The plant cell wall fraction, expressed as neutral detergent fibre (NDF), is not a uniform entity because it contains indigestible (iNDF) and potentially digestible (pdNDF) fractions (Tamminga et al., 1989; Huhtanen et al., 2007), which exhibit different kinetic properties. In addition, particle size is one of the factors affecting ruminal digestion and passage. It has been shown that different ruminal particle size fractions differ in digestion and passage kinetics (Bruining et al., 1998; Bayat et al., 2007), but there is not very much information available in this regard. Considering these factors in models which predict NDF digestibility can improve the accuracy of the prediction.

Forage species, stage of growth, environmental conditions, primary growth *versus* regrowth and latitude are some of the important factors affecting nutritional quality of forages. The objective of this study was to evaluate effects of harvest *i.e.*, primary growth *versus* regrowth and maturity of ensiled grass on ruminal kinetics of iNDF and pdNDF for large and small particle pools using rumen evacuation, iNDF determination and wet sieving techniques.

2. Materials and methods

2.1. Animals, diets, and experimental design

Two primary growth (PG) and two regrowth (RG) silages were prepared from a mixed timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward in Jokioinen, Finland (60°48′N). Detailed description on preparation of the silages was reported by Kuoppala et al. (2008). Briefly, the PG silages were harvested on 5 June at early and on 17 June at late growth stage. The RG silages were harvested on 29 July (from PG harvested on 17 June) and on 12 August (from PG harvested on 5 June).

The silages, supplemented with 8.0 kg concentrate per day, were fed in a 4×4 Latin square design to four lactating Finnish Ayrshire cows fitted with 10 cm i.d. rumen fistulae (Bar Diamond, Inc., Parma, ID, USA). Cows averaged 75 ± 11.9 days in lactation and 617 ± 64.0 kg in weight and produced 33 ± 3.5 kg milk/day at the beginning of the study. Each experimental period lasted 21 days and consisted of a 16-day adaptation period and a 5-day sample collection period. Cows had free access to silage during the adaptation period but, during sample collection, intake was restricted to 0.95 of that during the adaptation period in order to minimize intake variations between and within sampling days. All experimental procedures were approved by the MTT Agrifood Research Finland Care and Use of Animals Committee.

2.2. Procedures and chemical analyses

Details of feeding, management, sampling and chemical analysis of samples are reported by Kuoppala et al. (2010). Rumen evacuations were conducted on day 13 (prior to morning feeding) and day 15 (6 h after morning feeding). The times were chosen to represent minimum and maximum ruminal contents in order to estimate average of diurnal ruminal contents. Ruminal contents were emptied manually through the fistulae, mixed thoroughly, weighed and 2–3 kg was sampled. Immediately after sampling, ruminal digesta was returned into the rumen. Total faecal collection was performed on days 18–21.

Particle size distribution of ingested grass silages was assumed the same for all treatments. The particle size distribution of dietary concentrate, ruminal digesta (separately for the two sampling times) and faeces was determined by a Retsch AS200 Digit wet sieving apparatus (Retsch GmbH, Haan, Germany). Samples were divided into 7 particle size fractions by wet sieving using sieves with pore sizes of 2.5, 1.25, 0.63, 0.315, 0.16, 0.08 and 0.04 mm. Materials retained on 2.5 and 1.25 mm sieves were considered large particles (LP) and that retained on other sieves were considered small particles (SP).

In order to avoid errors in mixing the two ruminal evacuation samples, each sample was sieved separately but the average particle size distribution was used in further calculations. Four and two replicates of 60 g fresh weight of ruminal digesta (*i.e.*, two samples from each rumen evacuation time) and faecal samples were sieved, respectively. Ten replicates of 5.0 g dietary concentrate, pooled among periods, were sieved. Samples were sieved for 10 min using a water flow of 3.5 L/min. After sieving, material from each sieve was quantitatively collected into pre-weighed nylon bags (pore size 40 μm), dried at 60 °C for 48 h to determine the DM distribution of the particle size fractions and ground to pass a 1 mm screen. Ruminal and faecal samples with the same particle size from each treatment were pooled among periods before aNDFom and iNDF determinations.

The aNDFom concentration of sieved samples was determined by ANKOM^{220} Fiber Analyser (ANKOM Technology Corporation, Macedon, NY, USA) using sodium sulphite and heat stable α-amylase (Sigma Chem. Co., St. Louis, MO, USA), and expressed ash free (Van Soest et al., 1991). The concentration of iNDF in ruminal digesta and faecal samples were determined as described by Huhtanen et al. (1994) except that pore size of nylon bags was 17 rather than 6 μm and iNDF was expressed ash free. Duplicate bags were incubated for 12 days in the rumen of two cows fed a forage based diet. After ruminal incubation, bags were rinsed with cold water for 25 min using a household washing machine, boiled for 1 h in neutral detergent solution, rinsed, dried to a constant weight at 60 °C, and obtained NDF values expressed ash free. Potentially digestible aNDFom (pdNDF) was calculated as aNDFom-iNDF. Concentrations of aNDFom and iNDF in the particle size fractions of the ingested silages were not measured directly but estimated using total aNDFom and iNDF concentrations of the silages, and