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Intake estimation in dairy cows fed roughage-based diets: An approach based on chewing behaviour measurements

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ABSTRACT

Chewing behaviour of 23 lactating Swiss Fleckvieh cows was analysed in order to evaluate the predictive potential for quantitative dry matter intake in a roughage-based indoor cattle feeding system. Cows were fed total mixed rations (TMR) based on silages and hay with different concentrate supplements. They were kept in a tie stall enabling individual feed intake measurements. Two measurements were conducted within one month. Chewing behaviour was recorded with RumiWatch® sensor collars, based on pressure tubes in the collar's noseband. Cows were equipped with collars for 96 h per measurement period. First 24 h were accounted as adaptation time; data of the subsequent 72 h were used for analysis. Data included ruminating, eating (min/day), rumination boli (n per day), chewing frequency and intensity during ruminating (chews/min and chews/bolus), and activity changes (switching between ruminating, eating and idle; n per h). The constancy of parameters within cows across measurement days was tested with linear regression models. A linear mixed-effects model was applied to estimate a regression on measured feed intake. Average feed intake per day across all measurements was 19.7 kg dry matter per cow, average eating time was 389 min/day and ruminating time was 551 min/day. For most of the chewing behaviour variables, factor 'cow' was significant, while 'day' was not, indicating a between-animals variance but good consistency of the data within animal. After a stepwise backward procedure in the mixed-effects model, the remaining significant variable was 'chewing frequency' (chews per minute during rumination). Inclusion of 'animal' as a random factor resulted in an equation with conditional $R^2 = 0.7$. The model without random factor revealed a very low R^2. In conclusion, the random factor model allowed estimation of individual changes in feed intake within animal but not across animals. Chewing behaviour measurements proved to have a potential for the detection of relative intake alterations with roughage-based TMR diets but data were not sufficient for quantitative estimations.

1. Introduction

On the background of global feed-food competition for arable land (Wilkinson, 2011; Schader et al., 2015), the efficient utilisation of grassland resources for ruminants gains importance (Hofstetter et al., 2014). Research efforts are needed to develop low-concentrate feeding systems aiming at reducing the use of human-edible food as feedstuffs for ruminants (Ertl et al., 2016). In order to maintain individual animal performances at acceptable levels in case that dietary concentrates are reduced, a good roughage-based feeding management is required. Because nutrient density is usually lower in roughages than in concentrates, a high roughage intake will be a crucial factor, especially in systems with dairy cattle. Thus, roughage-based feeding strategies to increase intake and fibre conversion efficiency need to be developed on the practical and the scientific level. Adequate predictions of roughage intake and fibre digestion or conversion under practical conditions are needed for the assessment of such strategies.

Estimations of feed intake have so far been developed under highly controlled conditions, which do not necessarily correspond to conditions found on-farm. Since new technologies (different kinds of chewing sensors) for the monitoring of chewing behaviour of individual animals are increasingly available (Rutter et al., 1997; Zehner et al., 2012; Braun et al., 2014; Büchel and Sundrum, 2014), it appears reasonable to use these data for the assessment of intake and feed utilisation. Several recent publications show a general potential in this respect (Umemura et al., 2009; Galli et al., 2011; Oudshoorn et al., 2013; Clément et al., 2014). The approaches seem

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to have a potential to be developed as prediction tools applicable under practical conditions, e.g. in extension services for dairy farms. However, only few data exist, on which such prediction systems for dairy cattle could be based. It seems that it still has to be confirmed whether such approaches would work for practice conditions at all.

On this background, the aim of the study reported here was to establish regressions between measured individual intakes and chewing behaviour under controlled but practical conditions in a tie stall dairy cow system during winter feeding with a very high proportion of roughages.

2. Animals, material and methods

A dataset from an experiment with lactating cows comparing different winter feeding strategies rich in roughage was used for calculating regressions between measured dry matter (DM) intake, and feeding and rumination behaviour. The results of the feeding strategy comparison and details of the experiment are reported elsewhere (Leiber et al., 2015a).

2.1. Animals and feeding

In a commercial organic dairy herd (Swiss Fleckvieh, average milk yield 7000 kg per year, average body weight 660 kg), 24 cows were assigned to a feeding experiment. They were split into two groups, balanced by milk yield, milk protein concentration and days in milk: group Conc+, which received on average 2.4 kg/d individually fed protein concentrates and group Conc-, which received no individually fed concentrates. The experiment was conducted in February and March 2014 and all animals were kept indoors in a tie stall with feeding places, separated by metal panels. This allowed individual feeding and weighing of offered feed and residuals. Before the experiment started and during the whole period 1 (weeks 1–3), all cows received a total mixed ration (TMR) *ad libitum*, composed of dry matter proportions of 0.3 maize silage, 0.32 grass silage, 0.21 hay, 0.09 dried alfalfa meal, 0.05 potatoes and 0.03 soybean cake. During period 2 (weeks 4–6) all cows received a modified TMR *ad libitum*, composed of dry matter proportions of 0.35 maize silage, 0.38 grass silage, 0.06 hay, 0.11 dried alfalfa meal, 0.06 potatoes and 0.04 soybean cake. Additionally, during period 2, all cows received 2nd-cut hay *ad libitum* instead of TMR during the first morning feeding (6.00 a.m. until 8.00 a.m.). The nutrient contents of the different feedstuffs are presented in Table 1. Cows had access to a yard with concrete floor outside the barn for 1 h every second day. They were milked twice daily at 6.00 and at 17.00 at their places. All cows were weighted once in every experimental period. The animal trial was approved by the Swiss veterinary authorities (approval No. 75656; Veterinäramt Aargau).

2.2. Intake and behaviour recording, and sample analysis

Individual intake of each cow was measured during weeks 3 and 6 of the experiment (sampling weeks) by weighing the offered feed and the residuals with a mobile electronic scale. These intake measurements were done on days 1–4 of each sampling week. During this time, for each group one person was permanently present during the normal feeding times (6.00–8.00, 10.00–12.00, 16.00–18.00, and 19.00–19.30). The respective persons were feeding the cows and observing and documenting stealing and throwing of feed. Feed samples were drawn twice per sampling from all feedstuffs, and DM was determined by drying 48 h at 60 °C followed by 4 h at 105 °C. Intake was calculated on DM basis. Feces samples were drawn twice per sampling from each individual cow and analysed as described in Leiber et al. (2015b).

All cows were equipped with collars comprising noseband sensors, for recording jaw movements (RumiWatch®, Itin + Hoch GmbH, Liestal, Switzerland; Zehner et al., 2012; Selje-Aßmann et al., 2015; Ruuska et al., 2016). A pressure tube in the noseband of the head collar is connected with an electronic sensor, which registers every jaw movement and its intensity. Data are sampled at 10 Hz. A posteriori, software identifies eating, rumination and other activities (idle) based on the regularity of the curve and the identification of pauses for swallowing the rumination boli (RumiWatch Converter® V0.7.3.2, Itin + Hoch GmbH, Liestal, Switzerland). Thus, eating and rumination time (min/d), number of rumination boli (n per day), rumination chewing frequency and intensity (chews per minute and per bolus) and activity changes (changes between eating, ruminating and idle; n per h) were calculated. The measurements were conducted for 96 h starting in the morning of day 1 at 5.00. Data showed that during the respective first day of each collection week, chewing behaviour of several cows altered and rumination time was significantly lower than during the following days. Therefore, the respective first 24 h of each measurement were defined as adaptation time and excluded from the dataset. Chewing data were converted to one-hour summaries. The data from these summaries were subsequently averaged for each cow to intervals of 24 h and of 72 h.

2.3. Data processing and statistics

Some records had to be excluded from the datasets presented in the current paper due to incomplete data from several chewing sensors, caused by unexpected breakdown of the batteries or due to irregular intake data (stealing of feed). The dataset with complete and valid individual data for measured intake, and chewing behaviour comprised 23 cows, of which 10 had data from both sampling periods and 13 had complete data only from one of the two periods. These datasets became the basis for the calculations presented here. Because groups were no longer balanced, we did not directly compare the groups for the data presented here; however, the statistical models comprised group as a correction factor (see below).

Time spent eating or ruminating was summed up over 24 h. Numbers of rumination chews per bolus and per minute were averaged per day. Data from the DM intake measurements during the sampling days were averaged as well. For regressing DM intake by

Table 1
Nutrient concentrations in the different feedstuffs (N = 2)[a].

	TMR first period		TMR second period		Hay		Concentrates[b]
	Average	SD	Average	SD	Average	SD	Average (N = 1)
Crude protein [g/kg DM]	140	±4.5	133	±3.0	172	±13.0	302
Acid detergent fibre [g/kg DM]	298	±30	293	±0.0	335	±20.5	79.3
Lignin [g/kg DM]	41.9	±0.65	38.9	±1.35	48.0	±6.45	2.6
Crude Ash [g/kg DM]	91.6	±0.05	85.8	±0.10	90.2	±0.95	80
NEL [MJ/kg]	5.65	±0.05	5.70	±0.000	5.40	±0.300	7.3

[a] Data initially published in Leiber et al., 2015a.
[b] Concentrates (mixture of No 1064 and No 1078, Lehmann Biofutter, Gossau, Switzerland) based on soybean cake, wheat, barley, rapeseed cake, corn, and sunflower cake.