The relation between eating time and feed intake of dairy cows

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Abstract

The feed intake of individual dairy cows is important information for dairy farmers to monitor health and to evaluate feed efficiency. It is difficult to measure roughage intake in practical circumstances without dedicated equipment. An alternative for measuring intake in practice may be measuring the duration of feeding visits with sensor technology. The relation between feeding duration and feed intake is studied by using data from dairy research farm Dairy Campus, where feed intake and visit duration are recorded individually by transponder-controlled feeding bins. Data from trials performed in the years 2012 through 2015, were available. Some cows were fed concentrates and roughage separately (partially mixed ration, PMR), others were fed a total mixed ration (TMR). In all trials recordings of visits to feeding bins were available with starting time, ending time and intake, besides information on individual cows like parity, milk yield, body weight and rumination time. For the analysis all visits, with or without effective feed intake, were included. The total data set included 37,233 cow days with 1.251,156 visits. Visits were aggregated to meals by combining visits with an interval lower than a threshold (29 minutes), resulting in 286,576 meals with on average 7.7 meals per cow per day. The correlation between eating time (defined as duration of visits) and total feed intake per cow per day depended on the type of ration (PMR or TMR) and differed between cows. The average correlation between eating time and total feed intake was 0.59 (median 0.65) for PMR and 0.53 (median 0.56) in case of TMR feeding. Median values of feed intake and other cow characteristics, like parity, milk yield, body weight, rumination time, eating time, and number of meals were used in a REML model to predict feed intake. Parity, milk yield, body weight were relevant to estimate feed intake in both a PMR and a TMR system. Eating time was a significant term, but only in case of a PMR system. Rumination time and number of meals were not relevant in the current study to predict feed intake. These results show that data on feeding visits can be used to estimate eating time and number of meals per cow per day. Eating time can be used to improve the estimation of feed intake in a PMR system.

Keywords: feed intake, REML model, meal determination, rumination

1. Introduction

Efficiency is important in dairy husbandry due to limited availability of natural resources and statutory regulations, like formerly milk quota and nowadays constraints in land use or fertilizer use. It is in practice difficult to quantify individual efficiency, because available data on individual feed intake is limited. Feed intake per cow can be measured in experimental conditions using dedicated feeding equipment: the Roughage Intake Control (RIC) system (Hokofarm, Marknesse, the Netherlands) recognizes cows when they enter a feeding place and the difference in bin weight between start and end of a visit is recorded.
Sensors are available to support dairy management. Automatic milk yield measurements and computerized concentrates feeders are being used in practice. Sensors for measuring feeding and rumination behavior are available. Results on the value of data on rumination behaviour to estimate feed intake are ambiguous. On the one hand, Schirmann *et al.* (2012) and Clément *et al.* (2014) found that rumination time is a bad indicator for dry matter intake of dairy cows. On the other

hand, Byskov *et al.* (2015) concluded that the daily intakes of forage NDF and starch were positively related to rumination time, whereas intakes of sugar and the remaining fraction were negatively related to rumination time. Differences among studies could be related to the method to determine rumination behavior or differences in feed composition.
Rumination or eating sensor data, in combination with data on body weight, milk yield, concentrate intake and parity might be useful to estimate the individual feed intake of dairy cows. The objective of this research is to explore the possibilities of estimating feed intake by using sensor data of feeding and rumination behavior in addition to cow characteristics like parity, milk yield and body weight.

2. Materials and methods

2.1 Experimental data

Data from seven feeding experiments on the experimental farm in Lelystad of Wageningen UR Livestock Research were available. In all experiments data on visits to the RIC system were available. Recordings of these visits included time of arrival and time of departure, bin weight at arrival and bin weight at departure (kg) and feed intake (kg). The duration of a visit was based on arrival and departure time. Total duration per day was the sum of all visit durations per day (but overlapping visits were counted only once); this was considered as the eating time per day. Eating time was not used for the first and last day in a sequence of days for which RIC data were available as these days might be incomplete. Visits could be combined into meals if the interval length between successive visits was below a threshold. For the determination of this threshold the method of Tolkamp (1998) was used. RIC data were not available on some days due to failures. The intervals between successive visits of a cow were calculated to determine which visits belong to the same meal.
Other data available in all experiments included milk yield, body weight, parity and rumination time. Milk yield (kg) was recorded per milking (twice a day) and totalized to day level. Body weight (kg) was recorded once a day. Rumination was measured by rumination sensors (SCR HR tags, SCR Engineers Ltd., Netanya, Israel) attached to neck collars (Schirmann *et al.,* 2009). Rumination time was recorded in minutes per 2 hour interval and totalized to daily rumination time if at least 10 recordings per day were available. Daily totals based on 10 or 11 intervals were corrected proportionally to estimate daily rumination time.
The experiments differed in lactation stage of the cows and feeding method (Table 1). The feeding method was partially mixed ration (PMR) or totally mixed ration (TMR). In a PMR system a roughage mixture is fed at the feeding fence, concentrates are supplied in a computerized concentrates feeder or in the milking parlor according to an individual daily maximum which is generally predetermined by the farmer. In a TMR system all ration components are supplied at the feeding fence in a predetermined mixture of roughage and concentrates.

2.2 Statistical analysis

All data were available on a daily level; this made it possible to calculate to correlations between variables.
Variables like milk yield, feed intake, mostly show a more or less constant level per cow when restricted to a project and a treatment. The median values per cow, project and treatment were calculated to represent this level. The median was used instead of the average to compensate for possible outliers. Medians were calculated for milk yield, total feed intake, roughage intake, concentrate intake, body weight, rumination time, eating time, number of meals per day in all experiments. The medians were explored in a restricted maximum likelihood (REML) analysis using the statistical software package GenStat for Windows (VSN International Ltd., Hemel Hempstead, UK).

Table 1. Characteristics of seven feeding experiments on the experimental farm in Lelystad of Wageningen UR Livestock Research; ration type is partially mixed ration (PMR), totally mixed ration (TMR) or a combination.

Experiment	Number of cows	Number of cow days	Lactation stage	Feeding method
1	29	1,236	beginning	PMR
2	54	5,224	middle	PMR/TMR
3	72	4,104	beginning	PMR
4	49	4,030	end	PMR/TMR
5	182	7,728	middle	TMR
6	60	3,420	beginning	PMR
7	69	11,491	complete	PMR

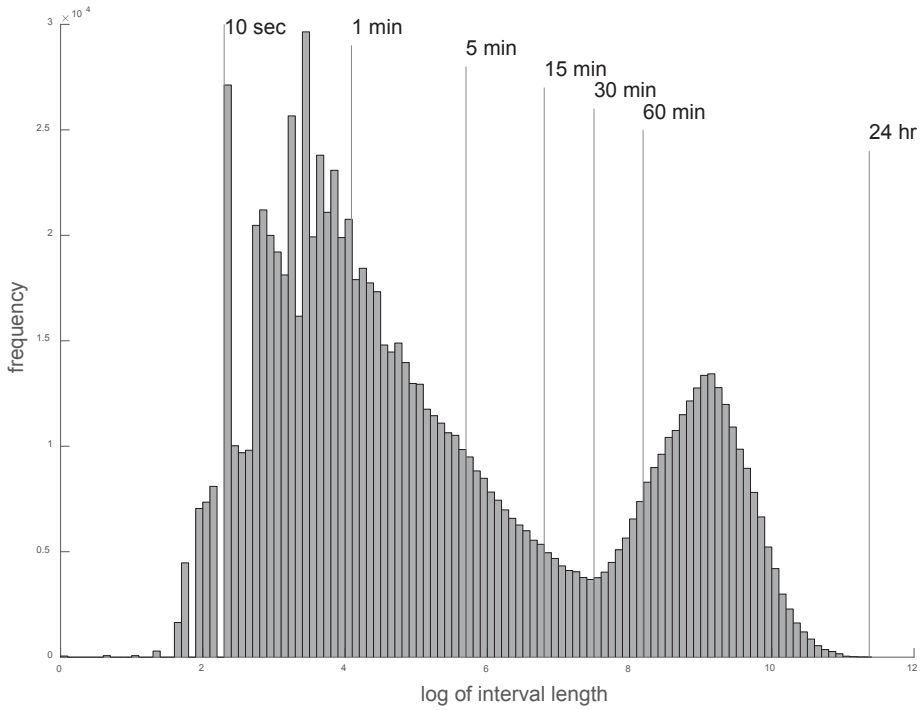

Figure 1. Histogram of log-transformed interval between visits of all cows.

3. Results

3.1 Visits and meals

The total number of cow days was 37,233 (Table 1), the corresponding number of visits was 1.251,156. A histogram of the logarithms of the interval between visits is depicted in Figure 1. There are two peaks in the histogram; the minimum between these two peaks was around 7.45, corresponding with an interval length of 1,720 seconds (28.7 minutes). This minimum value in interval length,

the 'meal criterion' was used to distinguish meals (Tolkamp *et al.,* 1998): a successive visit with an interval less than 1,720 seconds belonged to the same meal; otherwise it was the beginning of a new meal. This resulted in 286,576 meals, with on average 7.7 meals per cow per day.

3.2 Correlation between rumination behavior, eating time and feed intake

Correlations between feed intake and rumination or eating time differed between cows and depended on parity. Histograms of the correlation per parity are included in Figure 2. The average correlation between feed intake and rumination per day was 0.06 (0.00, 0.07, 0.08 and 0.09 for parity 1, 2, 3 and 4 or more respectively). The average correlation between feed intake and eating time per day was 0.59 in a PMR system (0.56, 0.58, 0.60 and 0.61 for parity 1, 2, 3 and 4 or more respectively). The corresponding median was 0.65 (0.65, 0.59, 0.66, 0.67 per parity). The average correlation between feed intake and eating time per day was 0.53 in a TMR system (0.46, 0.57, 0.59 and 0.54 for parity 1, 2, 3 and 4 or more respectively). The corresponding median was 0.56 (0.50, 0.57, 0.57, 0.59 per parity).

3.3 REML analysis

Median values were calculated per cow, project and treatment for all variables. These medians were interpreted as a measure for the level of a variable for that cow in that project under that treatment. In total there were 680 sets of medians, each representing a combination of cow, project and treatment. Medians from treatment with a mixture of roughage and PMR were excluded, as well as medians from experiment 2 with an extreme low roughage share in the diet. 519 sets of medians have been

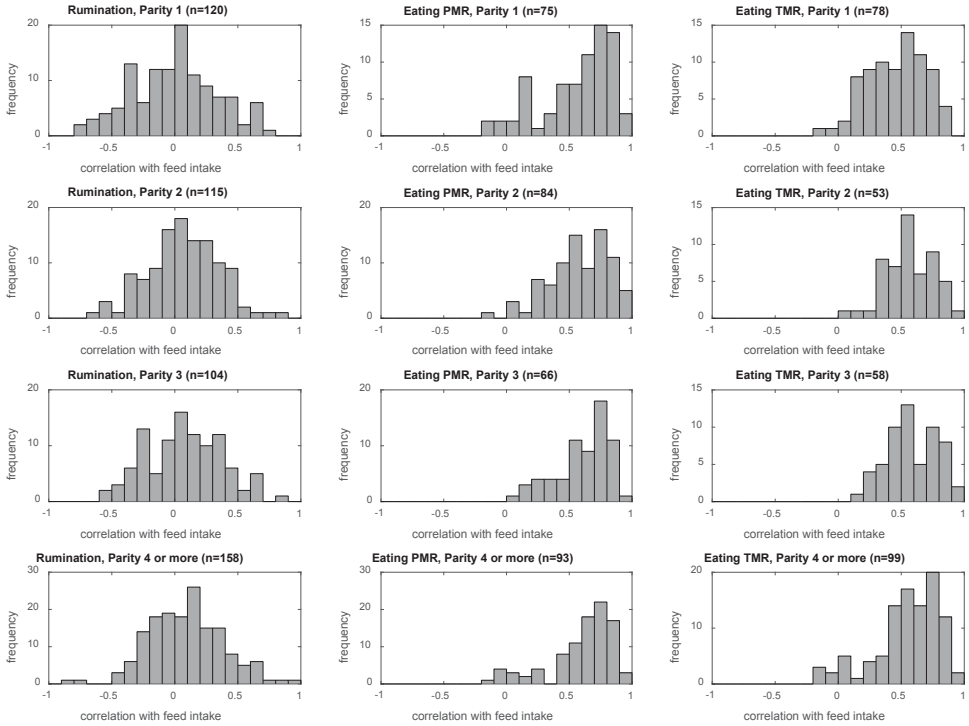

Figure 2. Histograms of the correlations between daily feed intake and rumination (left column), eating time in PMR system (middle) and eating time in TMR system (right) for parity 1, 2, 3 and 4 or more (downwards).

used (278 with PMR and 241 with TMR). The global results of the REML analysis are presented in Table 2. In a PMR system parity, concentrates intake, milk yield, body weight and eating time are significant terms in predicting the feed intake, while number of meals and rumination time are not significant. In a TMR system parity, milk yield, body weight are significant, while eating time, number of meals and rumination time are not.

Table 2. Results of the REML model for feed intake, terms in the model are successively added (with significance) and the explained part of the variance is given; both for partial mixed ration (PMR) and total mixed ration (TMR) systems.

Terms	PMR system (n=278)		TMR system (n=241)	
Constant	0.0%		0.0%	
+Parity	23.6%	***	47.7%	**
+Concentrates intake	34.3%	***	n/a	
+Milk yield	62.6%	***	79.0%	***
+Body weight	70.2%	***	80.7%	***
+Eating time	73.2%	***	80.6%	
+Number of meals	73.1%		80.6%	
+Rumination time	73.9%		80.7%	

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

4. Discussion

Data on visits from the RIC system could be used to calculate the eating time per cow per day. The histogram of the log-transformed interval length between visits gave a meal criterion. The histogram and criterion are comparable with results from literature (e.g. Maselyne *et al.,* 2015). The histograms per cow resulted in comparable meal criterion per cow (data not shown). The number of meals was not a significant term in predicting the feed intake.

Eating time and rumination time were correlated with feed intake, but only eating time in PMR system was a significant term in the REML model for feed intake. The difference concerning the added value of eating time to explain feed intake between the TMR and PMR system might be due to the high proportion of explained variation in the basic model for the TMR system (>80%) and the fact the PMR system mostly concerned cows in early lactation, with possibly more variation in feed intake between cows.

The significance of terms appeared to be depending on parity (data not shown). Body weight was not significant for cows with parity 4 or higher. Rumination time was significant (*) in TMR system for parity 4 or higher.

Connor (2015) states in her review that because data on dairy cattle are limited, additional research is needed to determine how much feeding behavior and physical activity contribute to variation in residual feed intake within dairy populations. She concluded that more efficient cows (heifers and dairy cows) spent less time eating. The results in the REML model were similar when body weight was replaced by metabolic weight, and also when feed intake was replaced by residual feed intake (data not shown).

These results showed that it can be useful to estimate individual feed intake based on the eating time. In practice, this may be measured by applying a location sensor (is the cow near the feeding gate) or an eating sensor estimating eating time by head movements. These alternatives are easier

to implement than measuring individual feed intake with RIC bins, while it may help to determine individual feed efficiency and thereby improve cow and farm performance.

5. Conclusions

Eating time can be estimated by using visit data from the RIC system, the number of meals can be derived from these visits. The current study shows that eating time, combined with parity, milk yield and body weight, is relevant for estimating feed intake in lactating dairy cows fed PMR. Rumination time and number of meals did not have an added value to predict feed intake.

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