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Ability to estimate feed intake from feeding time, chewing and rumination activity

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Abstract

The feeding and rumination behaviour of dairy cows can be monitored by different techniques and can provide useful information for dairy herd management. Among feeding characteristics, individual feed intake of cows is of utmost interest, but as weighing troughs have high space and cost requirements their implementation is limited to the research area. The objective of the present study was to monitor feeding time (by feeding trough), chewing and rumination time (by pressure sensor) and to analyse their ability for estimation of feed intake in dairy cows. The feeding and chewing behaviour of seven cows was recorded on six to eight measuring days per cow. Feeding and chewing behaviour was evaluated in time slots (1 min) and additionally assigned to feeding bouts for further analysis. Overall cows, 92.2% of the recorded one-min time slots were classified concordantly as feeding and chewing activities by the two systems. On average, cows spent 270 +/- 39 min per day at the feeding troughs and chewed 262 +/- 48 min per day. The average feed intake was 49.6 +/- 5.1 kg per day. Feeding time per day was divided into 9.7 bouts during which cows fed 27.8 +/- 21.7 min per bout and chewed 27.0 +/- 23.1 min per bout. The correlation between fresh matter intake and feeding time was 0.891 and between fresh matter intake and chewing time 0.780 overall cows. Hence, both systems delivered useful indicators for estimation of feed intake.

Keywords: dairy cow, chewing, feed intake, sensor, rumination

1 Introduction

The knowledge about feeding behaviour, namely feeding time, feed intake and feeding rate of dairy cows can provide useful information for dairy herd management. Beside traditional methods like visual observation or video recording (Krawczel et al., 2012), systems independent from operators for the automated monitoring of feeding behaviour have been developed and disadvantages of former systems like high demands for time and work input have been overcome. Automated monitoring systems enable to collect information on individual feeding behaviour of dairy cows in loose housing systems continuously over long-term periods and their methodical ability has been confirmed in several studies (DeVries et al., 2003; Chapinal et al., 2007).

Changes in feeding behaviour of dairy cows have been identified as serious indicators for health disorders (Bareille et al., 2003). Reduced dry matter intake (DMI) often announces upcoming health disorders in the days before their acute breakout and thereby facilitates early detection, but changes in feeding behaviour during health disorders are not limited to feed intake and account for feeding time and feeding rate as well (González et al., 2008).

Different health disorders caused specific effects, but especially in case of ketosis a decrease in feeding time, feed intake and feeding rate (g of fresh matter/min) appeared several days before detection by the farm staff (González et al., 2008). Furthermore, the amount of feed intake is of particular importance for calculation of need-based feed composition.
Individual feeding behaviour of dairy cows can provide useful information for enhancement of animal welfare by early detection of upcoming health disorders (González et al., 2008). Next to feed intake, additional feeding characteristics like feeding time or feeding rate improve the informative value of feeding data. Despite the proven ability of weighing troughs and electronic identification systems for monitoring of feeding behaviour, the former are hardly applicable for commercial farms and predominantly find their field of application in dairy research. Automated systems like weighing troughs have higher space requirements than conventional feeding systems and are quite expensive. In consequence, benefits like early detection of health disorders gained by research work (González et al., 2008) are missing transfer into practical dairy management and a need for easier applicable methods arises. The traditional way of calculating feed intake of cows in practice by reweighing of residuals is imprecise as only average feed intake of the herd group can be estimated. Therefore, the objective of the present study was to analyse whether feed intake could be estimated with adequate accuracy by feeding time, chewing time and rumination time. Furthermore, the improvement of the accuracy for estimation of feed intake by combination of variables was analysed. In the same context, the accordance between time of feeding and time of chewing, measured by two different sensor types, was evaluated.

2 Materials and methods

The study was conducted at the federal state research farm LVZ Futterkamp (chamber of agriculture Schleswig-Holstein, Germany). The farm milked around 190 German Holstein cows with an average herd yield of 10,700 kg milk/305 d (3.9% milk fat and 3.2% milk protein) during the trial period. Seven cows were included in the trial and between five and eight measurement days per cow were incorporated in the analysis. Data recording was scheduled in August and September 2011.

2.1 Animals, housing and feeding

Primiparous (first lactation; n = 3) and multiparous (≥ second lactation; n = 4) cows were included in the trial and cows had been 145-294 days in milk (DIM) on the day of trial entrance. Cows in the study were kept in one of two separate compartments, each with 36 cow places, 18 feed weighing troughs (Insentec, Marknesse, The Netherlands) and two water troughs (Insentec, Marknesse, The Netherlands). The two compartments were integrated in a free-stall barn which was equipped with concrete solid floor, cleaned by folding slides, and high bed cubicles. Cows were fed total mixed rations (TMR) containing 51-57% corn silage, 22-32% grass silage, 9-21% concentrate, 1% straw and additives. The composition of the TMR fed was calculated to achieve a daily milk yield of 33 kg. Energy content was 6.9-7.1 MJ NEL/kg DM and crude fibre content amounted 15.9-16.4% of dry matter (DM). The basic components varied because of changes in management of the research farm. Both TMR and water were provided ad libitum. Fresh TMR was fed two times per day at 0600 h and 1600 h. Cows were milked in a milking parlour between 0500 h and 0700 h in the morning and between 1500 h and 1700 h in the afternoon.

2.2 Data recording

Monitoring of behaviour was conducted with two different systems: weighing troughs (Insentec, Marknesse, The Netherlands) for records on feeding time, and pressure sensors (ART-MSR, Agroscope Reckenholz-Tänikon, Switzerland) for records on chewing and rumi-

nation time. The weighing troughs were locked in passive state, opened after identifying the entering cow via transponder, and closed after the cow had left. The system recorded time of day, visit duration and feed intake for each feed bunk visit and stored the data together with the number of the visiting cow. Presence at trough was classified as feeding time if the visit duration within one minute was longer than 20 s.
Chewing and rumination raw data were recorded with ART-MSR sensors which consisted of a noseband sensor, fixed by a halter to the head of the cow, and a modular signal recorder MSR 145 logger (Nydegger et al., 2010). The evaluation of raw data was performed with R-based software (R, Boston, USA). Because of low pressure values, data from cow 54 were evaluated additionally with a low amplitude classification. Raw data contained 600 measurement readings per minute and the software RumiWatch Converter (ART and ITIN+HOCH, Switzerland) was used to aggregate chewing and rumination activity per minute. The activity within one minute was summarised and classified according to the prevailing activity (0 = other, 1 = ruminating, 2 = chewing).
The following variables were included in the evaluation:

- Feeding time (min; weighing trough): duration of presence at trough, including presence at trough without measurable feed intake
- Feeding time corrected (min; weighing trough): duration of presence at trough with measurable feed intake (weight loss > 100 g / visit) excluding zero values (trough presence without measurable feed intake)
- Feed intake (kg; weighing trough): weight loss (> 100 g / visit) of trough content during presence at trough
- Feeding intake rate (kg / min; weighing trough): feed intake per minute of corrected feeding time
- Chewing time (min; ART-MSR sensor): minutes classified as chewing activity
- Chewing intake rate (kg / min; weighing trough, ART-MSR sensor): feed intake per minute of chewing time
- Rumination time (min; ART-MSR sensor): minutes classified as rumination activity

2.3 Data analysis

Feeding and chewing activity were grouped into bouts whereby feed trough visits were used as determining variable. Feed trough visits were aggregated to one bout if time intervals between single visits were not longer than 5 min. A bout ended 3 min after the last feed trough visit of this bout. Chewing and rumination activity were assigned to the actual bout if they took place during the bout or at least no longer than 3 min after the last feed trough visit of the actual bout. In all other cases they were assigned to the next bout.
Feeding time, feed intake, chewing time, and rumination time were summed up per bout. Feeding activity occasionally contained times of feed trough visits during which no feed intake was measured. Feeding time was analysed including and excluding these zero values.
The program used for statistical analysis was PASW 18.0 (IBM, USA). Differences among groups of primiparous and multiparous cows were analysed by Mann-Whitney-test. Correlation coefficients between variables were tested by Pearson correlation test ($p < 0.01$). Coefficients of determination were calculated with a linear regression model. Feed intake served as dependent variable and feeding, chewing and rumination time solely or in combination as independent variables.

3 Results

The average daily milk yield varied between 27.5 kg and 42.8 kg per day per cow. Feed intake averaged between 46.2 kg and 54.0 kg per day per cow. Cows spent on average 270 min +/- 39 min per day at the weighing troughs and feeding time corrected for zero values was 243 min +/- 43 min per day. The average chewing time numbered 262 min +/- 48 min per day per cow while rumination time was 534 min +/- 58 min per day per cow. Feeding, chewing and rumination time per day did not vary between primiparous and multiparous cows. The average intake rate was 211 g/min for feeding and 190 g/min for chewing. The daily range of intake rate varied for feeding between 120 g/min (0400 to 0500 h) and 299 g/min (1500 to 1600 h) and for chewing between 88 g/min (0100 to 0200 h) and 238 g/min (1600 to 1700 h).

The number of bouts per cow per day ranged between 8.4 and 11.8 and was 9.7 on average. Most feeding bouts started between 0600 and 0700 h (12%) and between 1700 and 1800 h (8%). Fewest bouts were initiated between 0200 and 0600 h (together 2.5%). The average feeding time per bout was 27.8 min +/- 21.7 min while average chewing time per bout was 27.0 min +/- 23.1 min. Cows consumed 5.2 kg +/- 4.5 kg per bout on average. No differences concerning feeding time per bout, chewing time per bout and feed intake per bout were found between primiparous and multiparous cows. Feeding time corrected per bout and chewing rate per bout were higher in primiparous cows than in multiparous cows, for feeding rate it was vice versa ($p < 0.05$).

The temporal accordance of weighing trough and ART-MSR sensor for classification of corrected feeding time and chewing time per minute (“one-min time slot”) is exemplified in Table 1 for the cow with the highest and the lowest accordance.The highest accordance between both systems was achieved in cow 110 as 94.1% of the recorded one-min time slots were classified identically as feeding / chewing (11) or no feeding / no chewing (00; Table 1). The lowest accordance was estimated for cow 910 with 89.6% of time slots classified identically. In six of the seven cows more than 90% of the time slots were assigned into concordant classification by both systems. In average, more time slots were designated as chewing by ART-MSR sensor and not feeding by weighing troughs (10) than vice versa (01). Absolute number of classification as feeding exceeded those as chewing in five of seven cows.

Table 1: Accordance (%) between weighing trough and ART-MSR sensor for classification of cow activity as feeding time corrected and chewing time (00 = no chewing / no feeding; 10 = chewing / no feeding; 01 = no chewing / feeding; 11 = feeding / chewing)

Classification	00	10	01	11	00 + 11	10 + 01
Best (cow 110; n = 10,095 min)	74.2	2.5	3.4	19.9	94.1	5.9
Worst (cow 910; n = 11,557 min)	76.3	8.2	2.2	13.3	89.6	10.4
Average (n = 70,697 min)	77.2	5.3	2.5	15.0	92.2	7.8

Correlations between feed intake per bout and feeding time per bout ($r = 0.891$) and feed intake per bout and chewing time ($r = 0.907$) per bout were highly significant ($p < 0.01$) for each cow (Table 2). Correlations between feed intake per bout and feeding time per bout were on a similar level as correlations between feed intake per bout and chewing time per bout, except for cow 54. This led to a lower correlation between feed intake per bout and chewing time per bout for the complete group of cows in comparison to correlation between feed intake per bout and feeding time per bout. Feed intake per bout and rumination time per bout were correlated significantly ($p < 0.05$) but correlation was only of medium strength ($r = 0.337$, cow 991; $r = 0.362$, cow 994). The exclusion of time spent at feeding troughs without feed intake (feeding time corrected) improved correlations per bout for individual cows and for the group.

The ability to estimate feed intake was tested with a linear regression model using feeding and chewing time as input variables. Coefficient of determination (R^2) per cow ranged between 0.699 and 0.940 when feeding time comprised time slots without measurable feed intake and between 0.874 and 0.950 for corrected feeding time (Table 2). In general, the contribution of chewing time to feed intake estimation was equal or slightly higher than that of feeding time, indicated by higher correlation coefficients. However, chewing time was more susceptible to individual cows as exemplified in cow 54. For this cow a high correlation between feed intake and chewing time was reached if low amplitude classification was chosen but not for the common classification. The additional consideration of rumination time led to increases in coefficients of determination for individual cows (chewing and feeding time; $R^2 = 0.743$ – $R^2 = 0.950$).

Table 2: Correlation (r) and coefficient of determination (R^2) for relationship between feed intake per bout (dependent variable) and feeding and chewing time per bout (independent variables; solely and combined), respectively.

	Cow 12	**Cow 54**	**Cow 110**	**Cow 111**	**Cow 910**	**Cow 991**	**Cow 994**	**Group**
r (feeding time)	0.937**	0.938**	0.938**	0.932**	0.907**	0.950**	0.800**	0.891**
r (corrected feeding time)	0.960**	0.942**	0.942**	0.950**	0.946**	0.966**	0.932**	0.917**
r (chewing time)	0.937**	0.532** [0.958**]	0.955**	0.929**	0.917**	0.966**	0.824**	0.780** [0.907**]
R^2 (chewing and feeding time)	0.922	0.898 [0.928]	0.913	0.874	0.848	0.940	0.699	0.785 [0.825]
R^2 (chewing and corrected feeding time)	0.934	0.908 [0.929]	0.914	0.904	0.907	0.950	0.874	0.833 [0.844]

**: correlation on significant level ($p < 0.01$)

[ ]: evaluation of results from low amplitude classification instead from normal amplitude classification

4 Discussion

Feed intake in dairy cows is influenced by manifold factors (Ingvartsen and Andersen, 2000). Cows involved in the current study were kept under constant environmental conditions, but varied in actual milk yield and stage of lactation. Cows were neither suffering from apparent health disorders nor affected by management activities during the trial, like e. g. hoof trimming. As the present study represents a random sampling of five to eight observation days per cow, effects like e. g. season or health disorders were not included. Both variables, feeding and chewing time, indicated their potential for estimation of feed intake. For broader application, however, the correlation has to be confirmed and validated by a broader data base which enables to include unconsidered effects herein.

In general, stationary electronic feed monitoring systems are validated by comparison to records from direct visual observation (DeVries 2003 et al.; Bach et al. 2004; Chapinal et al. 2007). The current study differs from the cited works as time of presence at a stationary feeding trough system was compared to chewing time recorded by a mobile pressure sensor. The amount of non-uniform classified one-min time slots per cow was between 5.9% and 10.4% (Table 1), for which several scenarios deliver possible explanations. Cows can be logged in to weighing troughs while just idling or browsing the ration. Correction of feeding time for feed trough visits without feed intake reduced non-uniform classification in the study. Feed thrown-off from troughs can become unreachable for cows and might be monitored as feed intake. Although, the incidence of the latter was unlikely because high side panels of the weighing troughs mostly avoided throw-off. The classification of time slots as chewing by ART-MSR sensors and not feeding by weighing troughs (10) was much more likely than vice versa (01, Table 1). Cows can show chewing activity beside troughs because they simply may continue chewing after having left weighing troughs. Furthermore, continuous grooming or licking of other cows (> 10 s) might have caused pressure shifts which led to classification as feeding (Zehner, 2014; personal communication). Altogether, the accordance between the two monitoring systems was high (> 92%).

Feed intake was correlated with feeding and chewing time for multiparous cows, which was very similar to findings of Dado and Allen (1994) ($r = 0.89$). In contrast, results for primiparous cows differed between Dado and Allen (1994; $r = 0.40$) and the current study ($r > 0.9$). The prediction accuracy for estimating feed intake based on corrected feeding time only was already on a high level and varied between $R^2 = 0.869$ and $R^2 = 0.934$ among individual cows. The combination of chewing time with feeding time led to an improved prediction accuracy, but increase was low (0.2-3.1%).In five of seven cows, corrected feeding time delivered higher prediction accuracies than chewing time (Table 2). When compared to the original, i.e. not corrected feeding time, the prediction accuracy gained by chewing time was higher in six cows. The consideration of feeding time instead of corrected feeding time led to a slight decline of prediction accuracy in six of seven cows while it worsened remarkably in one of the cows, namely cow 994. Cow 994 displayed by far the highest percentage of feeding time without feed intake on total feeding time (20.3%). Consequently, the amount of feeding time without feed intake had an effect on prediction accuracy. For cows with low percentages of feeding time without feed intake the original, i.e. not corrected feeding time appeared to be nearly as appropriate as the corrected one. The relationship between feed intake and rumination time was less strong. As rumination of cud generally occurs time-delayed to intake, the assignment into bouts was probably not appropriate.

5 Conclusions

In the current study, feeding time, feed intake and feeding rate by weighing troughs and chewing and rumination time by ART-MSR sensors were evaluated for seven cows each. The results showed a high accordance between time of feed trough visit and time of chewing activity. Feeding time and chewing time per bout were strongly correlated with feed intake per bout and explained a great amount of variation in feed intake data. In contrast, rumination time appeared to be less usable for estimation of feed intake. The combination of feeding and chewing time improved prediction accuracy only to a low extent. Both variables separately showed potential for estimation of feed intake but were also susceptible to individual cows. Future studies have to broaden the data base in order to get more information on variations due to e.g. lactation, health status, season or management, and to include and cope with cow individuals.

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