Changes in eating behaviour in pre-partum dairy cows

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ABSTRACT

Dairy cows meet a substantial number of changes in the last days prior to calving. Calving is an annual event which carries major priorities for the herd manager. Problems around calving are a risk factor for problems in early lactation, such as milk fever, metritis, displaced abomasum, retained placenta, ketosis, lameness or pneumonia. Prediction of calving time using electronic data loggers could potentially minimize these problems when discovered earlier. This study is aimed to investigate if changes in eating behaviour could be of use in automated calving time predictions.

In this study 359 healthy dairy cows from fourteen farms with normal spontaneous parturition and with the exact time of parturition known, are included. Eating behaviour is measured by an electronic data logger attached to a neck collar. The used data loggers measured the number of meals and the duration of meals the cow consumes with the help of a G-sensor. For number of meals, duration of meals and daily eating time, data of the last 28 days prior to calving are used. For eating time per two hours only data of the last seven days prior to calving is assessed.

This study shows that the last day before calving a significant increase in number of meals (8.2 to 9.2), a significant decrease in average length of meals (4.96 ± 0.51 minutes) and a significant decrease in the length of periods without meals (14.63 ± 2.90 minutes) was found. Total eating time did not change in the last days prior to calving. In addition, eating time per two hours shows a circadian rhythm. The circadian rhythm of dairy cows in this study is clearly visible.

The conclusion can be drawn that a cow shows an altering eating behaviour prior to calving. In order to predict the exact moment of calving from eating time, the circadian rhythm has to be taken into account and this requires further research. Electronic data loggers could be useful as predictors of calving time. More research has to be done in order to implement eating behaviour measurements in parturition prediction models.

INTRODUCTION

Dairy cows meet a substantial number of changes in the last days prior to calving. Calving is an annual event which carries major priorities for the herd manager. Problems around calving are a risk factor for problems in early lactation, such as milk fever, metritis, displaced abomasum, retained placenta, ketosis, lameness or pneumonia (Vergara, Döpfer et al., 2014). Therefore, automatic predictions of the moment of calving could become an useful tool for herd managers in order to create a healthy environment for dairy cows and calves, given that the number of cows being held on one farm is increasing (Georg, Beintmann et al., 2008). Practically, predicting the moment of calving could help the farmer's management and daily routine, for example deciding when to move a cow to the calving pen or the need for supervision during the night (Saint-Dizier, Chastant-Maillard, 2015). Dystocia may be recognized in an early stage by personnel, herd manager or farmer and this may help to reduce the number of stillbirths. Reducing stillbirth and dystocia will have a beneficial impact on productivity, lower veterinary costs and higher production (Bicalho, Galvao et al., 2007).

In cows, calving is triggered by the fetal hypothalamic-pituitary-adrenal axis. The unborn calf starts increasing cortisol production dramatically, approximately ten days before the actual calving occurs (Wood, 1999). The fetal cortisol initiates the conversion of progesterone to estrogens. Simultaneously, the fetal cortisol causes production of PGF2a by the placenta which lowers the progesterone levels due to regression of corpus luteum. As said, a few days before calving, the estrogen levels in the maternal blood increases (Kindahl, Kornmatitsuk et al., 2004). These hormonal changes are assumed to cause behavioural changes when calving approaches. Monitoring these behavioural changes may be of use in predicting the exact moment of calving. This study aims to investigate if eating parameters are useful in creating automated calving predictions in the near future.

There are several reports about the behavioural aspects of calving in dairy cows, for example Jensen et al., 2012. In this study they use video recording to examine the cows during the last 12 hours before calving and they used pedometers for measuring the cow's activity in the four days prior to calving (Jensen et al., 2012). Activity and number of lying bouts increased before calving, which coincided with the increase of uterine contractions and with the amount of inspection of the abdomen by the cow itself. Wehrend, Hofmann et al. (2006) also investigated behaviour during the first stages of calving. The suggestion was made that the rupture of the amniotic sac leads to a relief, triggering cows to start eating again before calving or ingest the amniotic fluid. They indicated that automatic measurement of eating behaviour could predict calving time(Wehrend, Hofmann et al. 2006). Maltz, Antler, (2008) measured eating behaviour using a computer controlled self-feeder (Maltz, Antler 2008). Cows were fed with hay ad lib at the feeding bunk during the whole dry period., Measurements were carried out when the cow entered the self-feeder for concentrates. They concluded that the attraction for concentrates was high and they monitored the number of eating windows cows missed during the days prior to calving. Cows only missed eating windows on the day of calving. Maltz concluded that this type of measuring could predict calving time and other changes, but that more data is needed.

A study performed by Huzzey et al. (2005) used ear tags to detect cows nearby the feeding bunk, suggesting they were having their heads down. They concluded that the number of meals was a good tool to monitor cows during the transition period(Huzzey, Keyserlingk, M. A. G. von et al. 2005). Büchel et al.(2014) used rumination time as indicator for the onset of calving. On top of that, the relationship between eating time and dry matter intake and the onset of calving was examined as well. During the last week before calving, blocks of sixhours of data were analysed, eventually comparing the last six hours before the onset of calving with the previous 66 hour completing the last three days before the onset of calving. This showed a decrease of 28% in rumination time and 57% decrease in eating time during the last six hour before the first stage of labour was observed. The study of Büchel et al (2014) concluded that measurement of rumination time can be useful in predicting calving is approaching (Büchel, Sundrum 2014).

AIM OF THE STUDY

This study is aimed to investigate changes in eating behaviour which could be of use in automated calving time predictions.

MATERIAL AND METHODS

Housing and animals

An extensive study set up by Utrecht University (UU) and Wageningen University and Research (WUR) in cooperation with Nedap and Vetvice to generate big data. Nedap is a technology company operating in different markets. Their Livestock Management Department offers barn automation that identifies, monitors and helps the farmer look after animals individually.

The data collection occurs at 18 free stall farms with an average of 150 dairy cows, across the Netherlands. The farms contributing to this study can be considered as representative for the modern Dutch dairy industry. This data collection started in April 2014 and ran for at least two years. In order to acquire reliable data which can be used for different applications in the future, various farms are included in this study: half of participating farms milk their cows in a conventional way, the other half uses automatic milking systems. Both groups of nine farms use deep bedding systems or rubber matrasses in the cubicles. The cows are monitored for a timeframe of six weeks pre-partum to four weeks post-partum. Only data from the 28 days before parturition is used in this study.

Calving management

Farmers and their personnel are asked to fill the time of parturition and type of calving on a provided form. The calving type was scored on a five point scale: (1) easy calving without help, (2) easy calving with moderate traction, (3) difficult calving with considerable traction, (4) difficult calving with using a calf puller and (5) calving whereas veterinary assistance was required. Diseases and other abnormalities have to be written down so that these cows could be studied separately. During an eight week cycle, students visit the farmers for collecting data from the cows calved in the previous period. All the collected data is imported in an Excel database showing each cow and its specific information about calving.

Electronic data logger

Data of meals is generated in number of meals per day, average length of meals in minutes and average period between meals in minutes. More than 300 seconds of eating time in a 15 minute period is defined to be a meal. Consecutive 15 minute periods with more than 300 seconds of eating is registered as one meal. Meal length is the sum of all eating seconds within the meal period. Validation is performed by Ipema under grazing and feed bunk conditions (Ipema, 2015). The data logger used in this study is made by Nedap N.V.. It is a sensor attached to the neck collar of each individual cow. The ‘Nedap SmartTag neck’ uses a G-sensor. This sensor uses acceleration as measure of movement and on the x-, y-, and z-axis (three-dimensional space). Measurements are taken each second and are used to calculate the angle of the tag and the specific eating movements of the cow. With these parameters an algorithm can determine if the cow is eating or not. The following pattern will be recognized as active eating behaviour: head downwards → head (short distance) upwards → chewing → head downwards. Eating time is recorded and stored in seconds per 15 minutes and send to a central antenna on the farm so that data of all cows can be collected and processed on a central processing unit. Data are saved for 24 hours in the tag so eating outside the range of the system, does not influence the data collection. All data are visible for the farmer using the computer program Velos®. In Velos®, a program designed by Nedap, all sensors are linked to the cows and the system itself can be linked to the farmer's own management programme. This provides the opportunity to gather information about lactation, age and reproduction status of each cow. The program displays the data in two hour blocks to the farmer, therefore we will use the two hour blocks data of eating time instead of the 15 minutes data. The exact known calving time is used to define moment zero, calving is defined as the expulsion of the calf. During the evaluation of the individual activity data, clear circadian patterns of activity are shown. There is a substantial difference in daily and nightly activity and this has to be taken into account in the further analysis. . Therefore it was decided to sort cows by calving time in two hour groups, making it possible to take in to account the circadian rhythm in the data from the cows in our study.. Data about eating is also presented in hours per day.

<u>Data refinement</u>
All collected data is combined in a database stored at Nedap in Groenlo, the Netherlands. In this database, data from over 2000 cows (and counting) is gathered and displayed from 42 days ante partum until 28 day postpartum. In this study only the 28 days before parturition is used and for the last week prior to calving the two hour data is used as well. Data used in this study has been obtained from April 2014 to November 2015. It is known that cows in a different lactation display different behaviour (Brzozowska, Łukaszewicz et al. 2014) This information was needed because in almost all studies a differentiation is made between heifers, second-lactation cows and older cows. In the setup of this study, information about lactation numbers was not included and therefore a lot of cows had to be searched for in Velos®. Cows are divided in three parity groups: heifers, second parity and older cows in accordance with the validation study performed by Idema (Ipema 2015). While data collection is performed at multiple farms, critical examination is needed in order to rule out insecurities. Therefore refinement and exclusion of cows had to take place in order to gain trustworthy data. Six farms were excluded, due to lack of reliable information provided by the farmers during the whole period. From the remaining 14 farms cows without an exact known time of calving were excluded first. When the farmer gave an estimated time of calving, as estimated calving times are not reliable for using in this study, these also were removed. Cows from which lactation number could not been determined were excluded. Inconsistent information about calving dates led to exclusion as well. After this, only cows with calving type 1 were selected for this study in order to relate to normal calving patterns, reducing influences of dystocia. Thirdly, it was verified if the whole period before calving was present in the data set. An incomplete set let to exclusion of the cow. Cows thought to be ill around the calving period were excluded from the study, leading to exclusion of cows with stillbirth, retentio secundinarum, abortion and milk fever. Lameness is a factor influencing the eating behaviour such that these cows were excluded as well (Norring, Häggman et al. 2014). Altogether, cows were excluded on the following grounds: missing or incomplete information regarding calving time, assistance during calving, illness or lameness around calving and other missing information or factors that might harm the quality of the obtained data. All of this led to a database to a usable database of 359 cows which were healthy and calved normally.

Data presentation and statistical analysis

Data refinement was performed with Microsoft Excel. Statistical analysis is performed by SPSS using a mixed model analysis. In this mixed model analysis the farm was set as a random farm effect and parity as fixed effect. The difference between day one and day two before calving will be compared with the average of the five previous days, which are respectively day seven until day three and day six until day two before calving. If no differences in parity are found, analysis will be repeated without parity as fixed effect. Before assessing the two hour data, a further division is made in the day of calving based on the exact known calving time. Taking into account the cicadian pattern of activity, analysis is performed on the two-hour groups containing the most cows (Group 6 and Group 8). The last three points before calving, -2 -4 and -6 hours are compared to the average of these identical moments on the previous five days. These data are analysed using the same method as the other data.

RESULTS

Meals per day

The number of meals registered by the sensors as calving approaches gradually increases from average 8.2 meals to 9.2 meals per day (fig 1) on the last day before calving (day -1). This increase in number of meals per day registered on the last day before calving was significant compared to the average of the five days before (P=0.000) (Table 1 and Table 2). Also a difference in parity was found. Older cows showed an increase with a mean of 1.09 ± 0.14 meals whereas heifers showed a less increase of 1.04 ± 0.34 meals than the older cows. This difference between heifers and older cows heifers was significant (P= 0.002). In figure 1 the heifers are shown with the red line., They seem to rise earlier which could explain the lesser increase in meals when calving is nearby. Second parity cows did not significantly differ from the older cows. This difference could also be seen in figure 1, which shows that heifers eat less meals per day the day before calving compared to older cows.

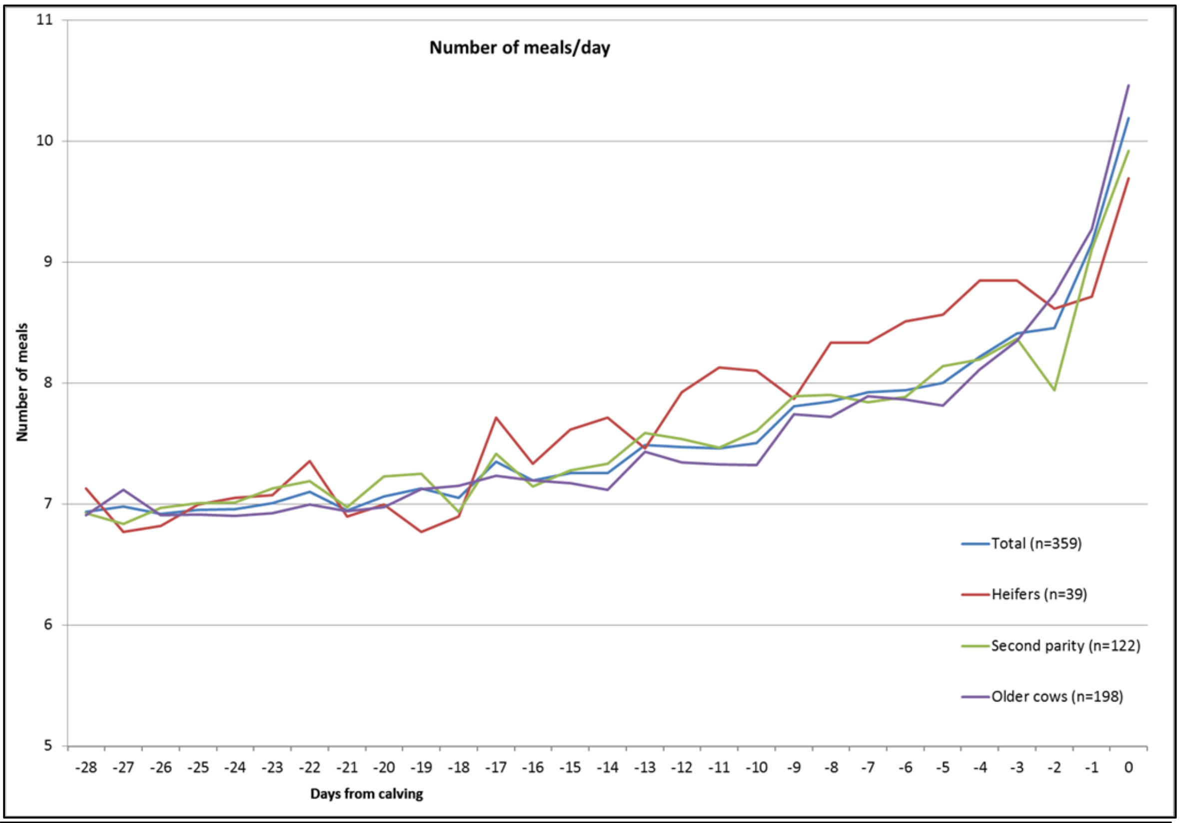

Figure 1: The increasing number of meals per day from day 28 before, up to calving.

Average meal length

In the period of 28 days before calving, the average length of registered meals per day decreases (fig 2). A significant decrease is found on the last day before calving (day-1) (P=0.000) (Table 1 and Table 2), no differences between parity groups were found in this model. The decrease in average meal length on the last day before calving compared to the average of the five days before in this analysis had a mean of 4.96 ± 0.51 minutes.

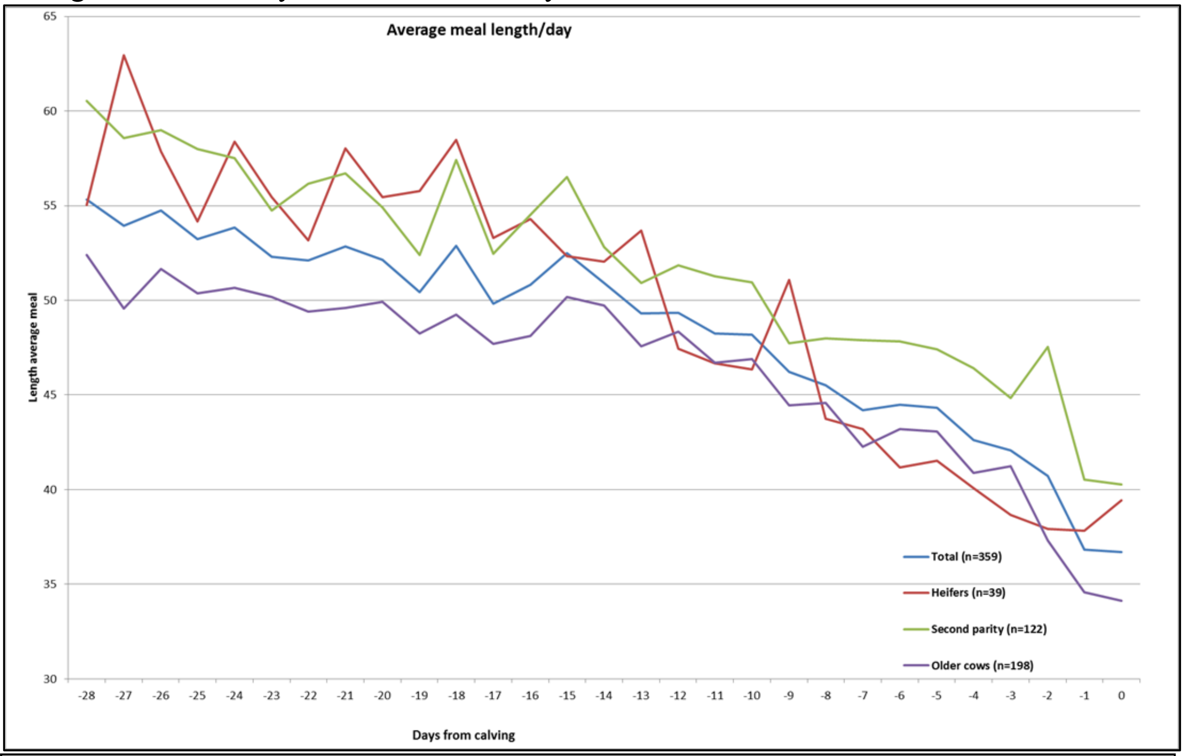

Figure 2: The decreasing average length of meals per day from day 28 before, up to calving.

Average length of periods without meals

In the period of 28 days before calving, the average length of periods without meals decreases (fig 3). A significant decrease is found on the last day before calving (day-1) (P=0.000) (Table 1 and Table 2), no difference between parity groups were found in this model. The decrease in average length of periods without meals on the last day before calving was significant compared to the average of the five days before in this analysis had a mean of 14.43 ± 2.90 minutes.

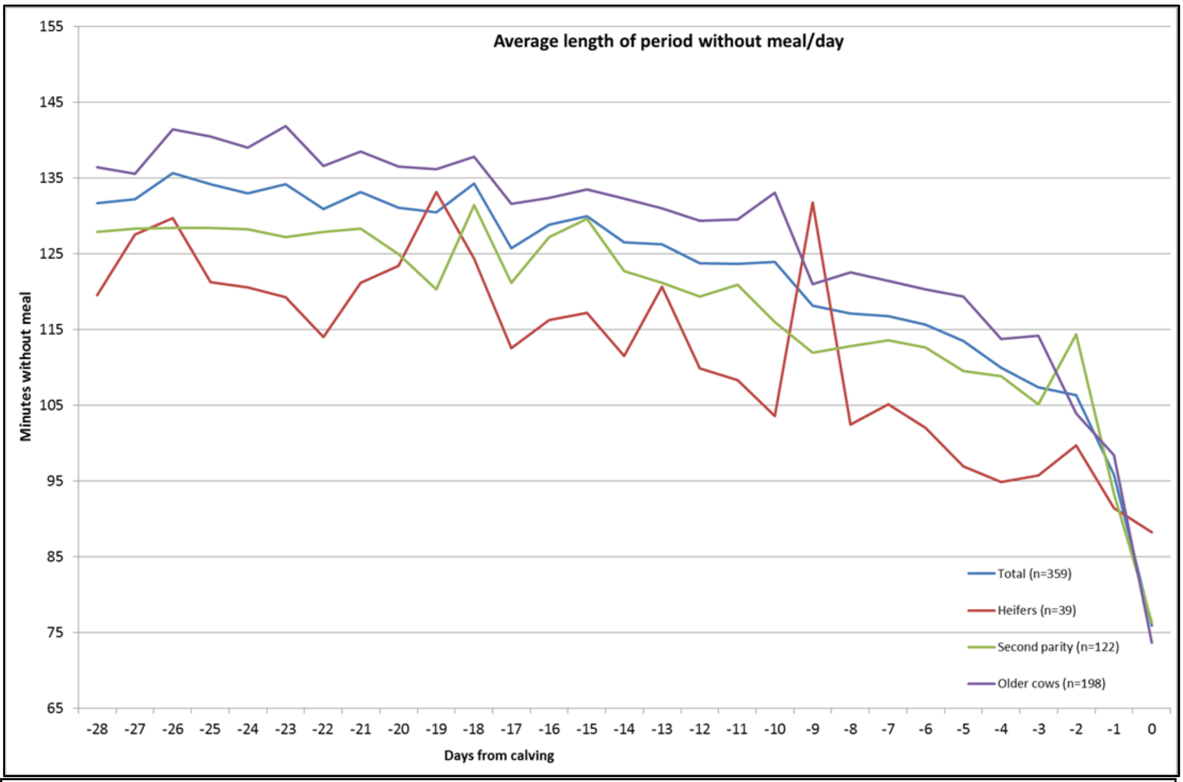

Figure 3: The decreasing average length of periods without meals per day from day 28 before up to calving.

Total eating time per day

In the period of 28 days before calving the total eating time per day does not change significally. No difference was found on the last day before calving (day-1) compared to the control period (day-2 until day-6 before calving). Individual variations were high. No differences in parity groups were found, in contrast with what is shown in figure 4 due to graph enlargement.

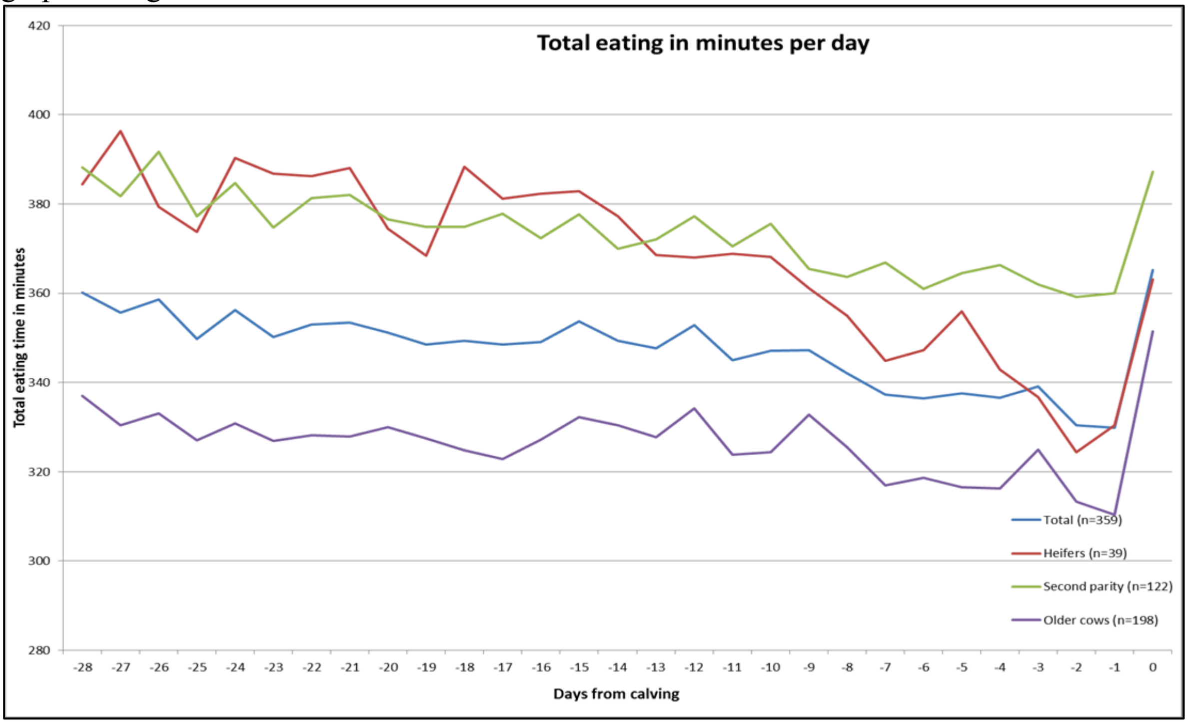

Figure 4: The total eating time in minutes per day from day 28 before, up to calving.

Eating per two hours
Eating data per two hours showed a circadian rhythm for all groups. In figure 5 the circadian rhythm for all cows is shown, when two hour data are synchronised for calving. The figure shows a strong circadian rhythm in the ten days prior to parturition. In figure 6 and 7 two groups of cows calved between respectively 10:00 till 12:00 am and 14:00 till 16:00 pm are displayed. These two figures show a similar circadian rhythm. As shown in Table 3, 4 and 5 no significant differences were found at any point in the two hour data compared to the identical time points in the previous days.

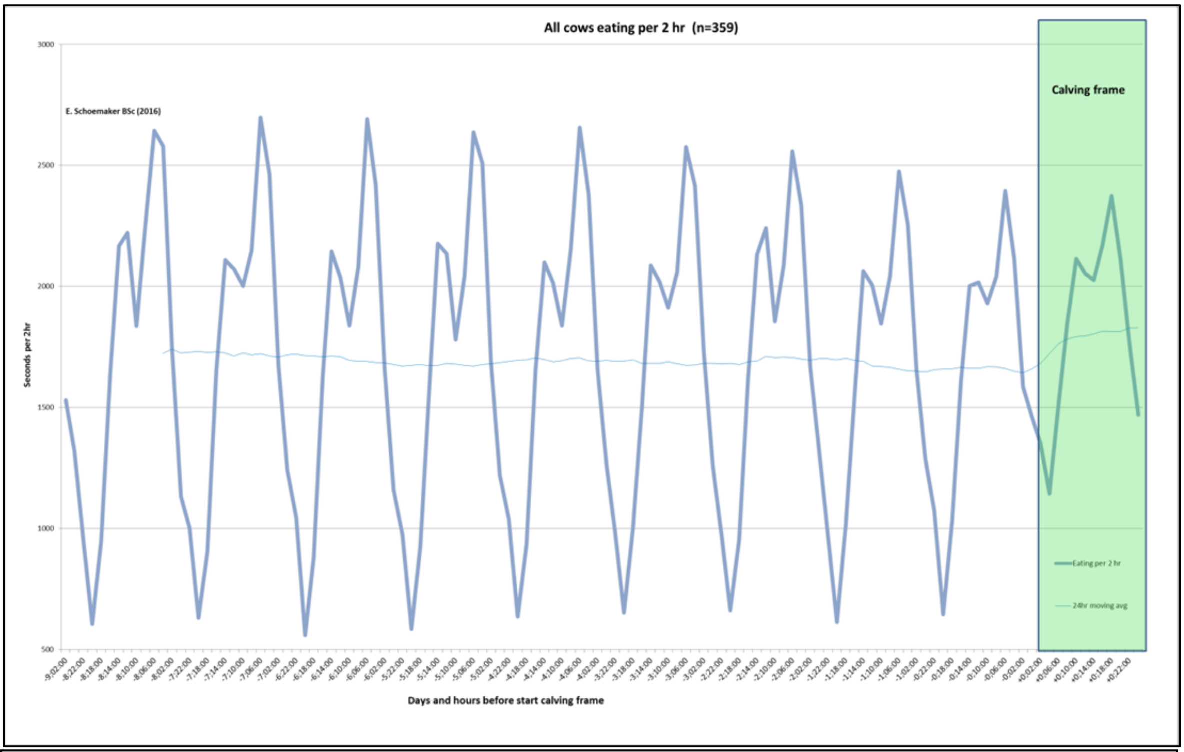

Figure 5: From 10 days before parturition, eating time per 2hr is shown. This figure shows the daily routine of all cows in this study, the thin line representing the moving average of 24 hour is also displayed. The green area represents the timeframe of calving.

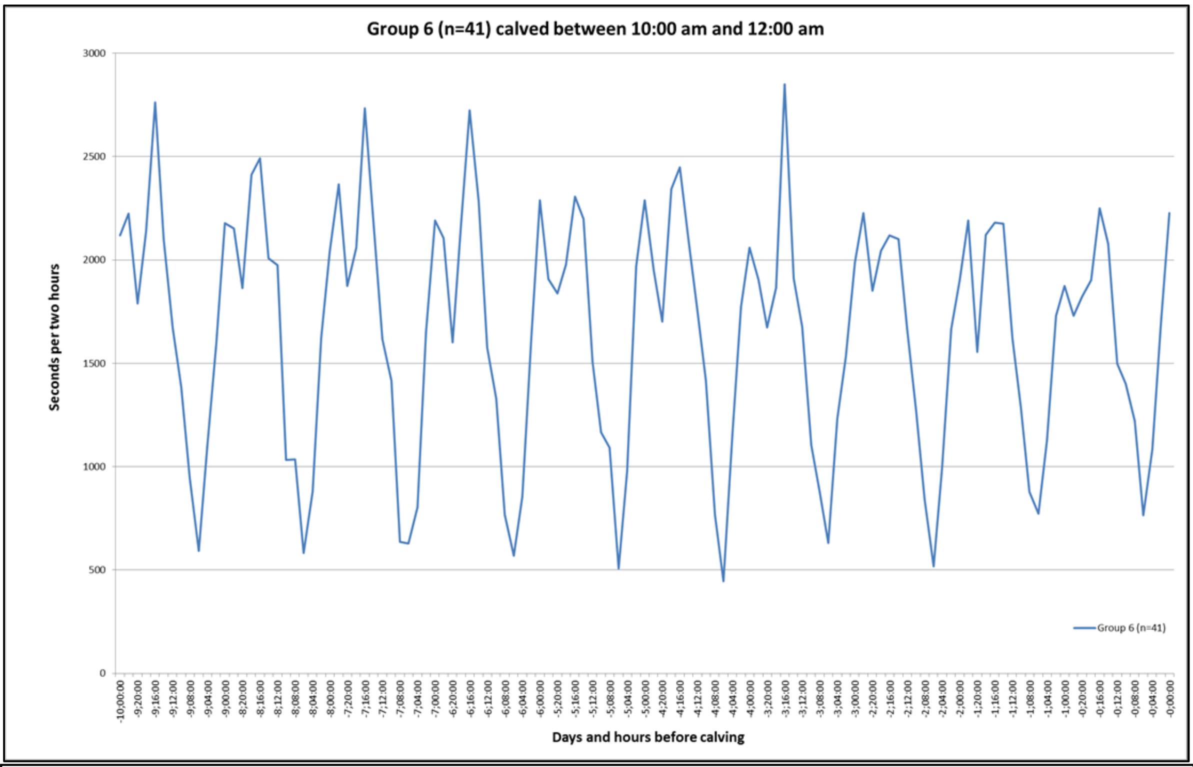

Figure 6: From 10 days before parturition, eating time per 2hr is shown, this figure shows the daily routine of the cows that calved between 10:00 am and 12:00 am, n =41.

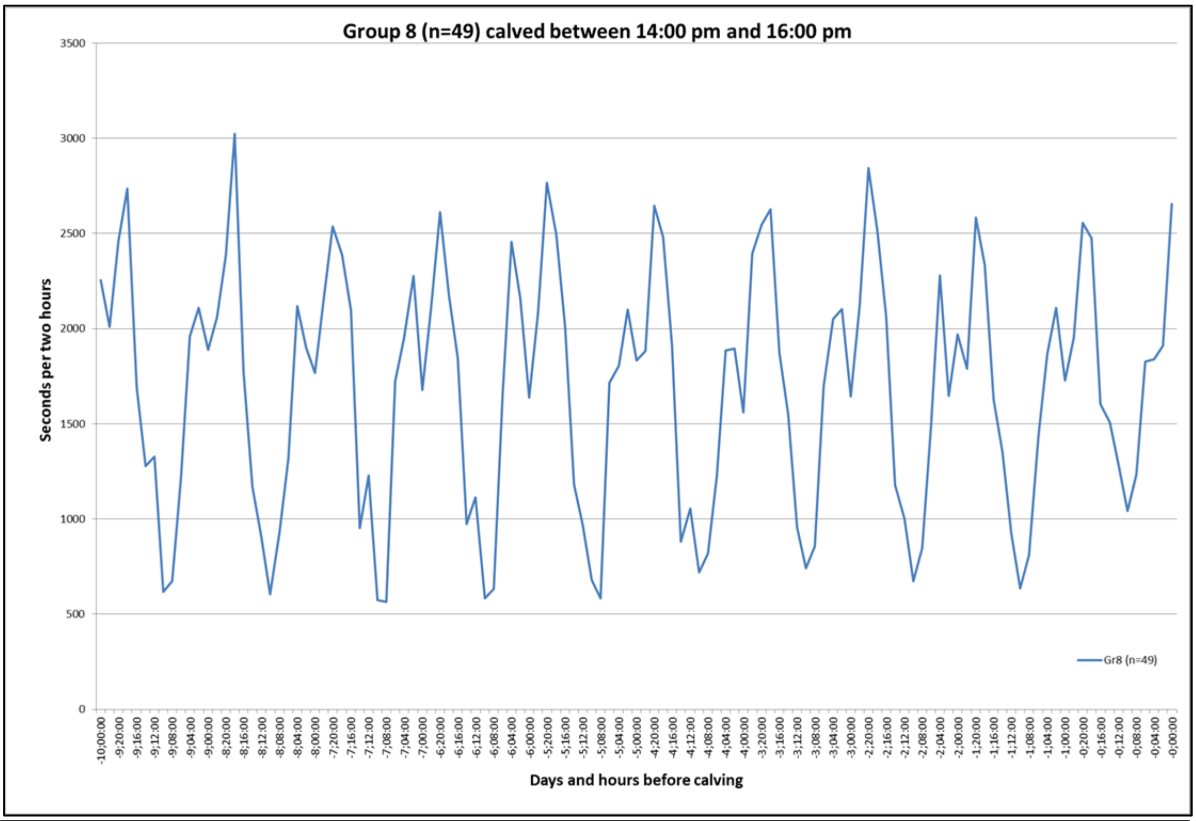

Figure 7: From 10 days before parturition, eating time per 2hr is shown, this figure shows the daily routine of the cows that calved between 14:00 pm and 16:00 pm, n =49.

Table 1. Eating behaviour during the second to last day before calving (day-2) compared to the control period (day -3 to -7). Means (±S.D.) and P-values. (* Bonferroni corrected)

Eating Behaviour	Control period	Day -2	P-value
Meals per day (no.)	8.1 ± 1.5	8.5 ± 2.2	0.125
Average duration of meals (min)	43.0 ± 13,5	40,7 ± 17.2	0,191
Average duration of periods between meals (min)	112.6 ± 31.0	106.3 ± 41.5	0.191
Eating time per day (min)	336 ± 82	330 ± 96	0.360*

Table 2. Eating behaviour during the last day before calving (day-1) compared to the control period (day -2 to -6). Means (±S.D.) and P-values. (* Bonferroni corrected)

Behaviour	Control period	Day -1	P-value
Meals per day (no.)	8.2 ± 1.5	9.2 ± 2.1	0.000*
Average duration of meals (min)	41.8 ± 13.2	36.8 ± 14.9	0.000*
Average duration of periods between meals (min)	110.6 ± 30.6	95.8 ± 49.1	0.008*
Eating time per day (min)	338 ± 85	326 ± 102	0.400*

Table 3. Eating behaviour during the last two hours before calving (-0.00 until -0.02 hours) compared to the control period (day -2 to -6). Means (±S.D.) and P-values.

	Control period	-0.00 until -0.02	*p*-Value
Group 6 (n=41)	28.9 ± 18.7	28.2 ± 21.8	0.821
Group 8 (n=49)	32.8 ± 13.5	31.8 ± 18.5	0.865

Table 4. Eating behaviour during the last two hours before calving (-0.02 until -0.04 hours) compared to the control period (day -2 to -6). Means (±S.D.) and P-values.

	Control period	-0.02 until -0.04	*p*-Value
Group 6 (n=41)	18.3 ± 12.1	18.1 ± 14.4	0.895
Group 8 (n=49)	33.0 ± 14.5	30.6 ± 19.5	0.196

Table 5. Eating behaviour during the last two hours before calving (-0.04 until -0.06 hours) compared to the control period (day -2 to -6). Means (±S.D.) and P-values.

	Control period	-0.04 until -0.06	*p*-Value
Group 6 (n=41)	9.6 ± 7.6	12.8 ± 10.7	0.139
Group 8 (n=49)	32.8 ± 13.5	31.8 ± 18.5	0.250

DISCUSSION

Usefulness

This study found significant changes on the last day before calving in number of meals, average length of meals and average length of period between meals. Eating duration per day and per two hours did not show any significant difference prior to the moment of birth. In the validation study of the device used in this study, Ipema found differences between parity groups (Ipema 2015). In contrast, in this study such differences were not found. Ipema used a total of 60 cows in his study containing 22 heifers, 19 second parity cows and 29 older cows. In our study data of 359 cows was assessed, which decreases the influence of individual variation. The study of Miedema et al. (2011) found no significant changes in eating duration on the last day before calving compared to the control period, they did find changes during the last six hours prior to calving, however, variation between cows was high (Miedema, Cockram et al. 2011). in our study data was used per two hours and no significance was found in the last three 2hr blocks before calving, but variances between cows were high in our study as well. Jensen et al.(2012) found that cows were eating and drinking less during the last six hours before calving (Jensen 2012). This is in contrast with the results of our study in which no difference was found. Jensen used 38 cows for his study, whereas in our study almost ten times more cows were assessed. After determining meals and meal lengths derived from these data, significant differences between the day before calving and the control period become visible. The method used to determine meals did not lead to major differences with data found in other studies. For instance, DeVries et al. (2003) found an average meal length of 47.1 minutes and total eating time of 332.3 minutes with an average of 7.3 meals taken daily in lactating dairy cows (DeVries, Von Keyserlingk et al. 2003b).

For the use of prediction of calving, stand-alone parameters need to be combined in order to search for an algorithm which could be implemented in the daily use of dairy farmers. Ouellet et al. (2015) combined several parameters such as ruminating time, lying bouts, lying time and mean vaginal temperature in order to predict calving time; only two cows could be predicted correctly. 14 Cows calved before the predicted date (3.0±1.5 days) and 16 cows calved after the predicted date (3.1±1.7 days) (Ouellet, Vasseur et al. 2015). Earlier Streyl et al.(2011) investigated the establishment of standard procedure in predicting calving time in cattle. Although this study was done under clinical conditions, they combined progesterone rapid blood tests with clinical signs and behaviour in order to rule out calving in the next 12 hours (Streyl, Sauter-Louis et al. 2011). Our results do not seem to be suitable for this approach since no differences were found using the two hour data. In conclusion, our results are not fit to make predictions regarding calving time.

Influence of parity

Significant differences in parity groups were found only for heifers in the numbers of meals per day. Heifers consumed less meals (-1.04 ± 0.22), although variation is high. This difference could be explained by competition at the feeding bunk with other more dominant cows. Heifers are still in a growing stage during their first lactation. Therefore they are smaller and experience a lower hierarchal position within the herd(Grant, Albright 2001).Wehrend et al.(2006) investigated the influence of parity during the first stage of parturition and did not find behavioural differences between heifers and older cows (Wehrend, Hofmann et al. 2006). In the present study results show heifers consumed significantly less meals than multiparous cows, average meal length and periods between meals did not differ from the multiparous cows. Likewise to this study, no differences in parity were found in eating behaviour in other studies. For example, Proudfoot et al.(2009) evaluated competition at the feed bunk. However more competition was shown in heifers, this did not have an effect on the number of meals and dry matter intake (DMI)(Proudfoot, Veira et al. 2009). Lobeck-Luchterhand et al.(2015) investigated eating behaviour in the transition period in relation with stocking density. In this study parity and social rank interacted with the daily eating time (Lobeck-Luchterhand, Silva et al. 2015). This is different than the results found in our study, but Lobeck-Luchterhand did not mix heifers and older cows in their study, which does happens in the farm environment in which the present study is performed. As cows in this study came from 14 different farm in the Netherlands, the possibility of major variances between farms existed, however none where found between the farms in this study.

Circadian rhythm

The two hour data was assesed since significance was found in other results on the last day before calving, such as number of meals, meal length and length of periods without meals. The eating behaviour was investigated for a circadian rhythm before by DeVries et al., (2003), showing a similar pattern as the rhythm found in this study: most of the eating was done during daytime and the peaks tended to have similar times (DeVries, Von Keyserlingk et al. 2003a).The pattern found in this study agrees with those found by DeVries and with the pattern found by Schirmann et al. (2012) (Schirmann, Chapinal et al. 2012), which showed that most eating took place during daylight. So when evaluating differences in eating behaviour is investigated for prediction of parturition, this circadian patterns has to be taken in to account. The circadian pattern is important for further study and placing measurements in perspective of time. It is clear these steps had to be taken in order to attempt calving predictions and clearly more research is needed. Other studies show similar circadian patterns in pre-partum dairy cows for other behaviours, such as lying time (Bekkedam 2016) and step-activity (Frieling 2016). Combining these data may lead to results of interest and therefore deserve further research.

Variations in cows and farms

Variations between the farms included in this study exist. With respect to eating behaviour, the moment of eating is one of management aspects influencing the eating data. Also the type of food may influence eating behaviour. In a study performed by Dado et al., 1994 30% more non digestible fibres (NDF) in the diet showed a decrease in total eating time of 77 minutes per day (Dado, Allen 1994). Differences between stocking densities could be present: a higher stocking density could lead to more competition at the feeding bunk. On top of that, further differentiation should be made between conventional milking farms and farms using automated milking systems (AMS), since cows milked in automated milking systems do not have to wait to be milked and therefore have more time to eat and/or rest. Cows within farms show individual variation as well, therefore data has to be analysed by comparing each individual cow with itself.

CONCLUSION

It is clear that, prior to calving, eating behaviour of the cow starts to alter until calving is present. Significant changes on daily basis were found in the number of meals consumed per day, the average length of meals and the length of period without meals. When two hour data, used to monitor changes in behaviour, no changes were found compared to control periods. Therefore, eating behaviour alone will not be enough to predict exact calving time. Eating time in combination with other behavioural parameters could be more suitable to predict the exact moment of calving The circadian rhythm has to be taken into account when predictions are done. Therefore more research has to be done in order to implement eating behaviour measurements in parturition prediction models. Overall, it is questionable if eating behaviour is a necessary parameter in this algorithm.

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REFERENCES

BEKKEDAM, N.B., 2016. *Changes in lying behavior of pre-partum dairy cows.* Utrecht University, Faculty of Veterinary Medicine, Department of Farm Animal Health.

BICALHO, R., GALVAO, K., CHEONG, S., GILBERT, R., WARNICK, L. and GUARD, C., 2007. Effect of stillbirths on dam survival and reproduction performance in Holstein dairy cows. *Journal of dairy science,* **90**(6), pp. 2797-2803.

BRZOZOWSKA, A., ŁUKASZEWICZ, M., SENDER, G., KOLASIŃSKA, D. and OPRZĄDEK, J., 2014. Locomotor activity of dairy cows in relation to season and lactation. *Applied Animal Behaviour Science,* **156**, pp. 6-11.

BÜCHEL, S. and SUNDRUM, A., 2014. Short communication: Decrease in rumination time as an indicator of the onset of calving. *Journal of dairy science,* **97**(5), pp. 3120-3127.

DADO, R. and ALLEN, M., 1994. Variation in and relationships among feeding, chewing, and drinking variables for lactating dairy cows. *Journal of dairy science,* **77**(1), pp. 132-144.

DEVRIES, T., VON KEYSERLINGK, M. and BEAUCHEMIN, K., 2003a. Short communication: Diurnal feeding pattern of lactating dairy cows. *Journal of dairy science,* **86**(12), pp. 4079-4082.

DEVRIES, T., VON KEYSERLINGK, M., WEARY, D. and BEAUCHEMIN, K., 2003b. Measuring the feeding behavior of lactating dairy cows in early to peak lactation. *Journal of dairy science,* **86**(10), pp. 3354-3361.

FRIELING, W.J.H., 2016. *Usefulness of step-activity in predicting calving time in dairy cows.* Utrecht: Utrecht University, Faculty of Veterinary Medicine, Department of Animal Health.

GEORG, H., BEINTMANN, S., SCHWALM, A. and UDE, G., 2008. Evaluation of heart rate, lying behaviour and activity measurement to predict calving of dairy cows, *Agricultural and biosystems engineering for a sustainable world. International Conference on Agricultural Engineering, Hersonissos*, 23-25 June, 2008 2008, European Society of Agricultural Engineers (AgEng).

GRANT, R. and ALBRIGHT, J., 2001. Effect of animal grouping on feeding behavior and intake of dairy cattle. *Journal of dairy science,* **84**, pp. E156-E163.

HUZZEY, J.M., KEYSERLINGK, M. A. G. VON and WEARY, D.M., 2005. Changes in feeding, drinking, and standing behavior of dairy cows during the transition period. *Journal of dairy science,* **88**(7), pp. 2454-2461.

IPEMA, B., 2015. Application of a neck-collar mounted sensor for recording feeding and grazing behaviour. *12th Conference Construction, Engineering and Environment in Livestock Farming,* .

JENSEN, M.B., 2012. Behaviour around the time of calving in dairy cows. *Applied Animal Behaviour Science,* **139**(3/4), pp. 195-202. 23 ref.

KINDAHL, H., KORNMATITSUK, B. and GUSTAFSSON, H., 2004. The cow in endocrine focus before and after calving. *Reproduction in domestic animals,* **39**(4), pp. 217-221.

LOBECK-LUCHTERHAND, K., SILVA, P., CHEBEL, R. and ENDRES, M., 2015. Effect of stocking density on social, feeding, and lying behavior of prepartum dairy animals. *Journal of dairy science,* **98**(1), pp. 240-249.

MALTZ, E. and ANTLER, A., 2008. Detecting calving time of dairy cows by analyzing activity and feeding behaviour in computer controlled self-feeders management, *Central theme, technology for all: sharing the knowledge for development. Proceedings of the International Conference of Agricultural Engineering, XXXVII Brazilian Congress of Agricultural Engineering, International Livestock Environment Symposium - ILES VIII, Iguassu Falls City*, 31st August to 4th September, 2008 2008, International Commission of Agricultural Engineering (CIGR), Institut fur Landtechnik.

MIEDEMA, H.M., COCKRAM, M.S., DWYER, C.M. and MACRAE, A.I., 2011. Changes in the behaviour of dairy cows during the 24h before normal calving compared with behaviour during late pregnancy. *Applied Animal Behaviour Science,* **131**(1), pp. 8-14.

NORRING, M., HÄGGMAN, J., SIMOJOKI, H., TAMMINEN, P., WINCKLER, C. and PASTELL, M., 2014. Short communication: Lameness impairs feeding behavior of dairy cows. *Journal of dairy science,* **97**(7), pp. 4317-4321.

OUELLET, V., VASSEUR, E., HEUWIESER, W., BURFEIND, O., MALDAGUE, X. and CHARBONNEAU, É, 2015. Evaluation of calving indicators measured by automated monitoring devices to predict the onset of calving in Holstein dairy cows. *Journal of dairy science,* .

PROUDFOOT, K.L., VEIRA, D.M., WEARY, D.M. and KEYSERLINGK, M.A.G., 2009. Competition at the feed bunk changes the feeding, standing, and social behavior of transition dairy cows. *Journal of dairy science,* **92**(7), pp. 3116-3123.

SAINT-DIZIER, M. and CHASTANT-MAILLARD, S., 2015. Methods and on-farm devices to predict calving time in cattle. *The Veterinary Journal,* .

SCHIRMANN, K., CHAPINAL, N., WEARY, D., HEUWIESER, W. and VON KEYSERLINGK, M., 2012. Rumination and its relationship to feeding and lying behavior in Holstein dairy cows. *Journal of dairy science,* **95**(6), pp. 3212-3217.

STREYL, D., SAUTER-LOUIS, C., BRAUNERT, A., LANGE, D., WEBER, F. and ZERBE, H., 2011. Establishment of a standard operating procedure for predicting the time of calving in cattle. *Journal of veterinary science,* **12**(2), pp. 177-185.

VAN AKEN, T.J.M., 2015. *Validation of the 'Nedap SmartTag'.* Utrecht: University Utrecht, department of Farm Animal Health.

VERGARA, C., DÖPFER, D., COOK, N., NORDLUND, K., MCART, J., NYDAM, D. and OETZEL, G., 2014. Risk factors for postpartum problems in dairy cows: Explanatory and predictive modeling. *Journal of dairy science,* **97**(7), pp. 4127-4140.

WEHREND, A., HOFMANN, E., FAILING, K. and BOSTEDT, H., 2006. Behaviour during the first stage of labour in cattle: influence of parity and dystocia. *Applied Animal Behaviour Science,* **100**(3/4), pp. 164-170. 17 ref.

WOOD, C.E., 1999. Control of parturition in ruminants. *Journal of reproduction and fertility.Supplement,* **54**, pp. 115-126.