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Characterizing changes in activity and feeding behaviour of housed, lactating dairy cows during behavioural and silent oestrus

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Highlights

- Activity was increased on the day of behavioural oestrus
- Resting time, lying bouts and feeding behaviours were reduced on the day of behavioural oestrus
- Only feeding duration was reduced on the day of silent oestrus

Abstract

The normal time budgets of dairy cows are influenced by oestrus, with cows spending less time resting and eating but more time walking. Previous studies have shown that cows spend approximately 21% less time feeding where the day of oestrus is assumed to be the day of successful artificial insemination. The objective of the present study was to determine whether the number of steps, lying time, lying bouts, dry matter intake (**DMI**), feeding duration and the number of visits to feed were affected by behavioural and silent oestrus in lactating dairy cows. Thirty Holstein Friesian cows were housed in a free-stall barn with 34 cubicles and were continuously monitored by four video cameras. Milk samples were collected on Monday, Wednesday and Friday afternoon and analysed for progesterone concentration by enzyme immunoassay. Steps, lying time and lying bouts were measured using IceQubes (IceRobotics Ltd., Edinburgh, UK) from three days before (3DB) to three days after (3DA) oestrus. Daily feed intakes and feeding duration were recorded by a Roughage Intake Control (RIC) system (Insentec B. V., Marknesse, Netherlands) over the same period.

Of the 40 *behavioural* oestrus events, standing behaviour was observed in 50% of events. On the day of *behavioural* oestrus the number of steps were increased significantly ($P < 0.001$) compared to 3DB and 3DA oestrus, whilst the percentage of lying time, lying bouts, DMI, feeding duration and the number of visits to feed were reduced ($P < 0.001$) compared to 3DB and 3DA oestrus. On the predicted day of *silent* oestrus, the duration of feeding was reduced ($P < 0.03$) only when compared to one day before and one day after oestrus.

In conclusion, although the number of steps were increased, lying time, lying bouts, DM intake and feeding duration were reduced by behavioural oestrus, and only feeding duration was significantly lowered during silent oestrus. Technologies that facilitate the on-farm measurement of feeding duration could potentially be used to help farmers detect silent oestrus in their cattle.

Keywords: Dairy cows; Time budgets; Behavioural oestrus; Silent oestrus; Activity

1. Introduction

The normal time budget of a Holstein dairy cow fed a total mixed ration (**TMR**) and in free-stall housing is 3 to 5 h/d eating, with an average 14 feeding bouts per day, 12 to 14 h/d lying time, 2 to 3 h/d social interaction, 7 to 10 h/d rumination during both standing and lying time, 0.5 h/d drinking and 2.3 to 3.5 h/d spent outside of the yard for milking and other management practices (Grant and Albright, 2000).

In mammals, oestrus is a behavioural sign that ensures that the female is ready to be mated close to the time of ovulation. Mounting behaviour with standing to be mounted is the definitive sign of oestrus (Roelofs *et al*., 2010). However, over the past 30 to 50 years, the incidence of mounting behaviour has decreased from 80% to 50% in dairy cows (Dobson *et al*., 2008) and over the last 50 years the duration of oestrus in dairy cattle has also declined from 18 to 8 h (Dolecheck *et al*., 2015). Oestrus is the period of maximum sexual activity, it has been shown to range from 2-30 h (Hanzen, 2000). Standing oestrus is often defined as true oestrus, when the cow makes no effort to escape when mounted by other cows and is defined as "the interval between the first and last standing events" (Hurnik *et al*., 1975). Other signs of oestrus include mounting of other cows, increased activity and mucus discharge from the vulva (Sveberg *et al*., 2011). While standing to be mounted is considered as the primary behavioural sign of oestrus, other behaviours such as ano-genital sniffing, restlessness, bellowing, chin resting, head mounting, and an attempt to mount are considered secondary signs (Gordon, 2011).

The cows' normal time budget can be influenced by oestrus (Yaniz *et al*., 2006). During oestrus, the activity of dairy cows increases about 2 to 4 times compared to non-oestrus cows (Kiddy, 1977). In addition, during the period from 72 to 16 h before standing oestrus, dairy cow activity increases linearly with further increases during the 16 h before standing oestrus (Arney *et al*., 1994). In dairy cows ovulation occurs from 8 to 30 h after the onset of increased activity (Hocky *et al*., 2010). With the availability of activity monitoring on commercial dairy farms, restlessness has become an important indicator of oestrus (Diskin and Sreenan, 2000).

During oestrus, the time spent lying by dairy cows decreased as a result of increased activity and restlessness (Jónsson *et al*., 2011) driven by increased secretion of oestradiol

(Sumiyoshi *et al*., 2014) from the developing ovulatory follicle (Allrich, 1994). According to Dolecheck *et al*. (2015) oestrus-synchronised cows spent less time lying than non-oestrus cows (10.19 vs 24.82 min/h, respectively) when IceQubes were used to monitor activity and Reith et al. (2014) found that dairy cows drank 15.3% less water during oestrus. In a study where the day of AI was assumed to be the day of oestrus (rather than observing for oestrus behaviour), Halli *et al*. (2015) found that cows spent approximately 21% less time feeding on the day of oestrus in comparison to other days of the oestrous cycle (2.82 vs. 3.54 h/d, respectively), but it was unclear whether the cows were synchronised or naturally cycling. In addition, Reith and Hoy (2012) showed that rumination was reduced on the day of oestrus from 7.2 to 5.9 h/d.

However, 35 % of cows show no obvious behavioural signs of oestrus and are defined as showing silent oestrus (Palmer *et al*., 2010). This means that despite the use of oestrus detection aids such as activity monitors, judging the correct time for AI in naturally cycling cows is difficult. The present study was designed to investigate whether the activity and feeding behaviour of lactating Holstein Friesian cows undergoing spontaneous oestrus cycle is affected by behavioural and silent oestrus.

2. Materials and methods

The experiment was undertaken between June and August 2016 at the dairy unit of Harper Adams University, Newport, Shropshire, TF10 8NB, UK. The Harper Adams University Research Ethics Committee approved the research protocol.

2.1. Experimental animal, housing and management

Thirty Holstein-Friesian cows (parity 2.5 ± 1.1) with initial body weight of 637.0 ± 60.0 kg and daily milk yield of 35.8 ± 1.8 kg/d, were used at Harper Adams University dairy unit. At the start of the study the cows were 29 ± 6.3 days in milk and 2.9 ± 0.28 body condition score (Scale 1-5; AHDB Dairy, 2014). The average locomotion score (Scale 1-5; as described by Chapinal *et al*., 2009) of the selected cows was 2.0 ± 0.58. Cows were housed in a covered yard with 34 cubicles (2.7 x 1.2 m, with 3 cm thick rubber mattresses) and two grooved concrete passageways (6 x 50 m) giving approximately 10.8 m^2 area per cow. The cubicles were bedded with sawdust three times per week. The passageways were scrapped by an automatic scraper 4-5 times per day. Study cows were milked twice a day from approximately 05:00 and 16:30 through a 40-point internal rotary milking parlour (Wesfalia, GEA Milking System, Germany). Milking took approximately 30-40 minutes for the group.

Cows were fed from 30 Roughage Intake Control (RIC) system bins and intake recorded using an automated feed recording system (1.0 x 0.9 x 0.8 m; RIC, Insentec B. V. Marknesse, the Netherlands). They were moved into the study area on 6th June 2016 and data were collected until 19th August 2016. All the cows used in the study were trained to feed through RIC bins over a one week period in order to ensure that each cow could access feed without assistance. Approximately 65 kg (fresh weight) of a total mixed ration (TMR) (see Table 1) was provided daily at approximately 08:30, sufficient for *ad libitum* availability. Refused feed was removed three times per week on Monday, Wednesday and Friday morning at 08:00 and the RIC bins were cleaned before fresh feed was allocated. Water was provided *ad libitum* from three water troughs. Feed samples were collected directly from the RIC bins daily at feeding time and immediately oven dried overnight at 105°C to constant weight (AOAC, 2012; 934.01) for determination of dry matter (DM). The nutrient content of the ration composed of DM (39.5%), ME (11.8 MJ/kgDM), CP (17.6% DM) and NDF (36.4% DM).

2.2. Data collection

2.2.1. Video recording of oestrus behaviours

The cows were monitored to detect spontaneous behavioural oestrus using four video cameras (Voltek, KT&C Co Ltd, Seoul, South Korea) for approximately 19.46 ± 1.7 h/d. The four cameras were placed at about 5.25 m above the trial cubicles and passageways to give a clear view of the area in which cows were housed. The cameras were connected to an external hard drive video recorder (Sentient 960H, England, UK). Cows were clearly identified by numbers from 1 to 30 on both sides of the cow and an individual combination of coloured tape on each cow (Kerbrat and Disenhaus, 2004). Video recordings were retrospectively reviewed to determine the time and intensity of oestrus. The scores of Van Eerdenburg *et al*. (2002) (Table 2) were allocated and recorded each time a sign of oestrus was observed on the video recording. The total number of points scored in a day indicated oestrus intensity.

2.2.2. Cow's activity and feed intake

To monitor cow activity, IceQubes (IceRobotics Ltd., Edinburgh, UK) were attached to the back left leg of each cow using a Velcro hook and loop strap (Dolecheck *et al*., 2015). The IceQube is a 3-axis accelerometer which reports cow activity summarised in 15 minute blocks (Dolecheck *et al.,* 2015). These generate data to show *the number of steps taken*, *lying time* and *lying bouts* for each cow, every day. Daily TMR intake was recorded by the RIC system. Dry matter intake was calculated as TMR intake (fresh weight; kg/d) x dry matter of TMR. Total daily feeding duration and the number of feeding bouts were also recorded by the RIC system.

2.3. Milk progesterone assay

Oestrus periods were identified by measuring the concentration of progesterone in whole milk. Milk samples (40 ml) were collected from each cow 3 times per week on Monday, Wednesday and Friday afternoon. Immediately after sampling one preservative tablet (Broad Spectrum Microtabs II, Advanced Instrument, INC. USA; containing 8 mg Bronopol and 0.30 mg Natamycin) was added to each milk sample. Sample pots were inverted to mix until the tablet was dissolved. The samples were stored in a refrigerator at 4ºC until the progesterone assay which was completed within one week of collection. Milk samples were brought to room temperature and mixed well before analysis using an enzyme immunoassay (Ridgeway Science Ltd., Rodmore Mill Farm, Alvington, Gloucestershire, UK). A cow was considered in oestrus when milk progesterone concentrations were <3 ng/ml for two to three days before a period when progesterone rose to >5 ng/ml for at least 5 days (Isobe *et al*., 2004).

2.4. Definition of behavioural and silent oestrus

Each oestrus identified by the progesterone profile was classified as a behavioural or silent oestrus. A cow was defined to be in *behavioural oestrus* when the sum of the points scored for oestrus behaviour observed by the video recording exceeded 100 (Van Eerdenburg *et al*., 2002). A cow was considered to be in *silent oestrus* when the cow did not display any behavioural signs of oestrus or the oestrus score was < 100 points at or around the day of oestrus as defined by her milk progesterone profile (Van Eerdenburg et al., 2002).

2.5. Duration of oestrus

The duration of oestrus recorded by the camera was defined as the interval between the time that cows showed the first signs of oestrus and the time that the last signs of oestrus were observed. Oestrus duration based on accelerometer data was defined as an increase in walking activity and the number of steps taken increased to > 80% above the mean number for the preceding three days followed by a decrease to < 80% in the following two days. The periods between the two thresholds was considered as the duration of oestrus (Lopez-Gatius, *et al*., 2008).

2.6. Data-set construction

Data from 61 oestrus events were collected during the study period. The six parameters analysed were *the number of steps taken by cows each day*, *time spent lying (h/d)*, *number of lying bouts per day*, *DM intake (kg/d)*, *feeding duration (h/d)* and *number of visits to feed per day*. Prior to statistical analysis, the data for all parameters were summarized to one value per day using Microsoft Excel. A day was defined as the period from midnight to midnight. The day of oestrus was defined as day (**0**) and compared with three days before (-3, -2 and -1; 3DB) and three days after (+1, +2 and +3; 3DA). Fresh TMR intakes (kg/d) intakes were converted into DM intake (kg DM/d) based on the DM content of the TMR (39.5%).

2.7. Statistical analyses

Statistical analyses were performed using the Genstat statistical software package (Genstat V 17th edition, VSN international Ltd, UK). The datasets were analysed by repeated measures ANOVA to compare between groups (*behavioural* and *silent oestrus*) days before and after oestrus and the group x day interaction. Factorial one way ANOVA was used to compare *behavioural* and *silent* oestrus. Differences were reported as significant at $P < 0.05$ and trends were reported when P was between < 0.1 and > 0.05. Linear regression analysis was used to determine the relationship between the number of steps taken per day and dry matter intake (kg DM/d) on the day of behavioural oestrus.

3. Results

3.1. The duration of oestrus and scores of behavioural activity

Using the milk progesterone profiles, 61 spontaneous oestrus events were detected for all cows during the study period. Of the 61 oestrus events detected, 40 were defined as *behavioural* (65.5%) and 21 defined as *silent* (34.5%) oestrus. The percentage of *silent* oestrus at the first, second and third oestrus post-partum were 44.8%, 27.3% and 20.0% respectively in the present study. The percentage of cows standing to be mounted during *behavioural* oestrus was 50%.

The average duration of *behavioural* oestrus (determined from video recordings) was 9.1 ± 3.1 h and the duration of oestrus based on the number of steps recorded by IceQubes was 12.9 ± 2.5 h. The number of points scored during *behavioural* oestrus determined from the camera recordings were between 225 and 2921 points. However, during *silent* oestrus the number of points scored were between 0 and 32 points.

3.2. Oestrus activity

On the day of *behavioural* oestrus the number of the steps (2095 ± 217 steps; mean ± SEM) were higher ($F_{6,354} = 32.2$, $P < 0.001$) compared to 3DB (849 ± 60 steps) and 3DA (971 ± 61 steps) while on the day of *silent* oestrus the number of steps (984 ± 73.5 steps) were not significantly different in comparison to 3DB (891 ± 63 steps) and 3DA (849 ± 50 steps). From factorial one way ANOVA, cows took significantly more steps during *behavioural* oestrus ($F_{1,39}$ = 13.2, $P < 0.001$) compared to *silent* oestrus. There was a significant interaction ($F_{6,354}$ = 5.6, $P < 0.001$) between oestrus expression and day of oestrus on the number of steps taken (Figure1, A). In addition, there was a significant ($F_{1,39}$ = 31.9, $P < 0.001$) positive correlation between the number of points scored and the number of steps taken (y= 0.348x + 486; $P < 0.001$; $r^2 = 0.32$) during *behavioural* oestrus.

Lying time and the number of lying bouts (7.1 ± 0.3 h/d and 9.1 ± 0.5 bouts, respectively) were reduced ($F_{6,354}$ = 17.2, $P < 0.001$) on the day of *behavioural* oestrus in comparison to 3DB (10.0 ± 0.3 h/d and 13.0 ± 0.7 bouts, respectively) and 3DA (10.1 ± 0.3 h/d and 12.7± 0.8 bouts, respectively). However, lying times (9.3 ± 0.5 h/d) and the number of lying bouts (13.0 ± 1.1) bouts were not significantly affected by the day of *silent* oestrus compared to 3DB (10.0 ± 0.4 h/d and 14.0 ± 1.2 bouts, respectively) and 3DA (10.4 ± 0.4 h/d and 13.7 ± 1.3 bouts, respectively). Furthermore, from a factorial one way (ANOVA), lying times were lower ($F_{1,39}$ = 17.2, $P < 0.001$) on the day of *behavioural* oestrus compared to *silent* oestrus and the number of lying bouts were also lower ($F_{1,39}$ = 17.2, $P < 0.001$) on the day of *behavioural* oestrus compared to *silent* oestrus. With regard to lying time, there was a significant oestrus x day interaction ($F_{6,354}$ = 5.6, $P < 0.001$) with lying time significantly reduced during *behavioural* oestrus but not *silent* oestrus (Figure 1, B). Similarly, the number of lying bouts was reduced during *behavioural* oestrus but not during *silent* oestrus as well as there being an interaction between oestrus expression and day ($F_{6,354}$ = 3.3, $P < 0.006$) (Figure 1, C).

3.3. Feeding behaviour

Dry matter intakes were significantly ($F_{6,354}$ = 12.0, $P < 0.001$) lower on the day of *behavioural* oestrus (19.8 ± 0.41 kg/d) in comparison to 3DB (22.4 ± 0.5 kg/d) and 3DA (22.6 ± 0.5 kg/d). There was a significant ($F_{1,39}$ = 31.9, $P < 0.001$) negative correlation between the number of steps taken and DMI (y= -0.0014 + 22.46; $P < 0.001$; $r^2 = 0.46$) during *behavioural* oestrus. However, DMI was not significantly lower on the day of *silent* oestrus compared to other days. There was also no interaction between oestrous expression and day (Table 3).

The occurrence of *behavioural* oestrus significantly ($F_{6,354}$ = 9.2, P < 0.001) reduced the mean duration of feeding (2.4 ± 0.09 h/d) in comparison to 3DB (3.4 ± 0.17 h/d) and 3DA (3.2 ± 0.12 h/d). Duration of feeding (2.9 ± 0.15 h/d) was also significantly (P < 0.03) reduced during *silent* oestrus when compared to one day before (3.4 ± 0.2 h/d) and one day after (3.6 ± 0.2 h/d) the predicted day of oestrus. There was a tendency for an interaction between oestrous expression and day ($F_{6,354}$ = 2.1, P = 0.06) effect on feeding duration (Table 3).

The mean number of visits to the RIC feed bin during *behavioural* oestrus was less (25.3 ± 1.26 visits/d; $F_{6,354}$ = 9.5, P < 0.01) compared with 3DB and 3DA oestrus. However, there were no significant differences between the day of *silent* oestrus (29.0 ± 1.71 visits/d) in comparison to other days. There was also no significant interaction between oestrus expression and day with regard to the number of visits to feed. Analysing the number of visits to feed with regard to oestrous expression, there was also no significant difference ($F_{1,59}$ = 1.0, P = 0.318) between *behavioural* and *silent* oestrus (Table 3).

4. Discussion

4.1. Oestrus duration and observed oestrus activity

Previously, the duration of standing oestrus in dairy cows has been considered to be 18 h (Valenza *et al*., 2012). The average duration of oestrus measured using the video camera in the present study was 9.1 ± 3.1 h. However this was 2 hours longer than the duration reported by Sveberg *et al*. (2011) of (7.1 ± 1.4 h) in oestrus detected by video recording of 22 Holstein-Friesian cows housed on an outdoor wood chip-pad. Based on the number of steps recorded by the IceQubes, the duration of oestrus in the present study was (12.9 ± 2.5 h) very similar to that seen in the study of Roelofs *et al*. (2005) which found that the duration of oestrus detected by pedometer lasted for 12.3 h, while a study by Silper *et al*. (2015), reported longer oestrus in 12 month old Holstein heifers (14.3 ± 4.1 h) using neck mounted accelerometers. However, the duration of oestrous activity in the present study was 3.2 h shorter than that reported by Valenza *et al*. (2012) of 16.1 (± 4.7 h) also using an activity monitoring system. The present study found that the duration of oestrus determined by activity monitor was 3 h longer than that detected by observation. The difference between the duration of oestrus activity in high yielding dairy cows may be due to the disconnection of secondary signs of oestrus behaviour detected by activity monitors (restlessness) and standing oestrus (Valenza *et al*. (2012). Our finding is supported by a reported increase in activity, detected by pedometers in dairy cows, 1 to 3 h before the onset starting of standing oestrus (Sveberg *et al*., 2011).

In the present study, standing behaviour was observed in 50% of those cows expressing behavioural oestrus. Similarly, Van Eerdenburg *et al*. (2002) detected 50% of standing oestrus events in Holstein Frisian cows. However, Kerbrat and Disenhaus (2004) observed standing events by video camera in 32% of Holstein cows housed in a loose housing system with a concrete floor. The results of the present study indicate that there is great variability between cows in the total points scored with between 225 and 2921 points during *behavioural* oestrus and the number of steps taken during oestrus (754 to 6008 steps). The results of the current study agree with those reported by Van Eerdenburg *et al*. (1996) who continuously monitored cows and another study conducted on Holstein cows by Kerbrat and Disenhaus (2004) who reported the total number of behavioural signs (rather than points score) which ranged from 27 to 239 signs. As expected, the oestrus scores of the present study were higher than the scores (approximately 50 -1000 points) reported by Van Eerdenburg *et al*. (2000) who observed cows during two time periods of about 30 min in the morning at 5:00 before milking and 30 min in the afternoon at 17:00.

In dairy cows, oestrus often takes place without clear changes in behaviour (Kyle *et al*., 1992). Indeed this was the case in 44.8% of first post-partum oestruses observed in the present study. Low expression of oestrus behaviour at the first oestrus post-partum in lactating dairy cows is thought to be an effect of high concentrations of oestradiol from foetal origin during late gestation, which induces refractoriness of the hypothalamus to oestradiol (Kyle *et al*., 1992). Other studies suggested this may also be caused by lower frequency of LH pulses as a result of negative energy balance in early lactation (Lucy, 2001) which results in lower oestradiol synthesis (Butler, 2000; Isobe *et al*., 2004) by the pre-ovulatory follicle and decreased the sensitivity of the hypothalamus to oestradiol which leads to a high incidence of *silent* oestrus.

4.2. Oestrus activity detected by activity monitor

Overall, 65.5% of the spontaneous oestruses identified in the present study were associated with behavioural signs detected by video recording and the percentage of oestrus detected by accelerometer was 52.5%. This was within the range 51 to 87% found by Roelofs *et al*. (2005) using pedometers for oestrus detection. The results of the present study also agree with the previously reported 52% detection rate in cubicle housed Holstein-Friesian cows studied by Palmer *et al*. (2010). At-Taras and Spahr (2001) detected approximately 54% of oestrus by visual observation. Conversely, this finding was lower than the 70% of oestrus events detected recorded by Fricke *et al*. (2014) in oestrus-synchronized Holstein cows using an activity monitor attached to the neck (Heatime, SCR Engineer Ltd, Netanya, Israel). This high detection rate may be related to the high number of cows in oestrus at the same time (Gilmore *et al*., 2011).

Restlessness is one of the most important secondary indicators of oestrus in cattle (Firk *et al*., 2002). In the current study, on the day of behavioural oestrus, the number of steps was increased by 146.8%, while during silent oestrus, step count was only 10% higher. Similarly, Sakaguchi *et al*. (2007) recorded a 100% increase in the number of steps on the day of behavioural oestrus using radiotelemetric pedometers on grazing dairy Holstein heifers in Japan. Using pedometers, ultrasound and visual observation, Roelofs *et al*. (2005) recorded a 5.5 fold increase in the number of steps taken on the day of visually observed oestrus. Environmental conditions, the type of housing and management conditions may affect the extent of walking activity (Lopez-Gatius *et al*., 2005; Yaniz *et al*., 2006).

Alongside the increase in activity, on the day of *behavioural* oestrus in the present study, cows spent significantly less time lying down (32.2%) and had 28.3% fewer lying bouts during spontaneous oestrous events. On the day of behavioural oestrus, continuously observed

Friesian cows housed in cubicles were also found to spend less time lying down (approximately 5 h/d) and more time standing than non-oestrus cows (Esslemont and Bryant, 1976).

A recent study at the University of Kentucky conducted by Dolecheck *et al*. (2015) using oestrus-synchronised Holstein cows, found a 50% decrease in lying time and also a reduction in lying bouts (56.0%) during oestrus. The greater reduction in lying behaviour may be because oestrus synchronization meant there are more cows in oestrus at the same time (Hurnik *et al*., 1975) resulting in greater restlessness and activity on the day of behavioural oestrus (Roelofs *et al*., 2005; Jónsson *et al*., 2011).

4.3. Feeding behaviour

In the present study, cows consumed approximately 22 kg DMI/d during a normal days, similar to other published studies of early lactation cows: e.g. Dado and Allen (1994) reported average DMI/d of 22.8 kg during a normal day. However, on the day of *behavioural* oestrus, the increase in activity observed was associated with a 12% reduction in DMI. Furthermore, both feeding duration and the number of visits to feed per day were lower on the day of *behavioural* oestrus compare to 3DB and 3DA. These data suggest that increased activity at oestrus diverts cows from their normal time budget with more steps replacing both feeding and resting time (Walker *et al*., 2008). This is exacerbated in more active cows which had a greater reduction in DMI demonstrated by the negative correlation between the number of steps taken and DMI during the day of behavioural oestrus. Other studies of Holstein-Friesian cows have shown reduced DMI on the day of AI (14.6%; Reith *et al*., 2014, 10.3%; Halli *et al*., 2015). Cows spent a similar amount of time feeding (2.8 h/d) but had many more visits to the feed troughs (46.2 visits/d) than in the present study (Halli *et al*., 2015). This may be because Halli *et al*. (2015) only determined feeding behaviours in relation to AI rather than behavioural oestrus.

As far as we are aware, the present study is the first to report feeding behaviour during *silent* oestrus in dairy cows. Interestingly, while behavioural measures were not changed during the predicted time of *silent* oestrus in the current study, DMI and number of visits to the RIC bins were numerically lower in comparison to 3DB and 3DA oestrus. In addition feeding duration was significantly reduced compared to one day before and one day after oestrus. This finding indicates that cows deemed in *silent* oestrus may show subtle changes to their behavioural repertoire that are not apparent using commercial oestrus detection regimes. Alternatively, oestradiol has been shown to suppress feed intake (Ingvartsen and Andersen, 2000) and an increase in oestradiol concentration at silent oestrus may be sufficient to reduce feed intake but not sufficiently adequate to increase oestrus activity. On the day of oestrus, the higher physical activity and restlessness in dairy cows may replace feeding behaviour (DMI, feeding duration and number of visits to feed) (Hurnik *et al*., 1975; Kiddy, 1977). In the present study there was a negative relationship between the number of steps and DMI. In comparison to non-oestrus cows, during oestrus, cows spent more time walking and consequently less time resting and eating (Hurnik *et al*., 1975). Conversely, Lukas *et al*. (2008) found that cows consumed more feed on the day of oestrus, while De Silva *et al*. (1981) reported no change in feed intake on the day oestrus.

5. Conclusion

During the day of behavioural oestrus, high yielding dairy cows in cubicle housing spend more time walking, less time lying down and a reduced number of lying bouts, but none of these parameters were affected during silent oestrus. In addition, on the day of behavioural oestrus, DM intake, feeding duration and number of visits to feed were reduced. On the day of silent oestrus, only feeding duration was reduced. Technologies that facilitate the on-farm measurement of feeding duration could potentially be used to help farmers detect silent oestrus in their cattle. Where behavioural oestrus is expressed there is considerable variation in the extent of activity, but the reasons for this remain to be elucidated. It remains to be determined why these differences are seen but one factor worthy of investigation maybe circulating oestradiol concentrations.

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Table 1. Dietary composition of the trial ration.

Ingredient	**g/kg DM**	**kg DM/hd**
Maize silage	342.2	7.2
Lucerne	161.60	3.4
Blend	200.57	4.22
Soda wheat	113.12	2.38
Sweet starch	73.19	1.54
Soya hulls	53.23	1.12
Spey syrup	26.62	0.56
Megalac	7.13	0.15
Butterfat extra	7.13	0.15
Dairy minerals	7.13	0.15
Salt	3.33	0.07
Acid buff	3.80	0.08
Saccharomyces cerevisiae	0.95	0.02
Total	1000	21.04

(Profeed Nutrition Consultancy, UK, 2016)

Table 2. Scoring scale for observed signs of oestrous.

Oestrous signs	**Score**
Flehmen	3
Mucous discharge from vulva	3
Cow restlessness	5
Sniffing the vulva of another cow	10
Mounting but not standing	10
Resting the chin on the back of another cow	15
Mounting or attempt to mount other cows	35
Mounting or attempt to mount head side other cows	45
Standing heat	100

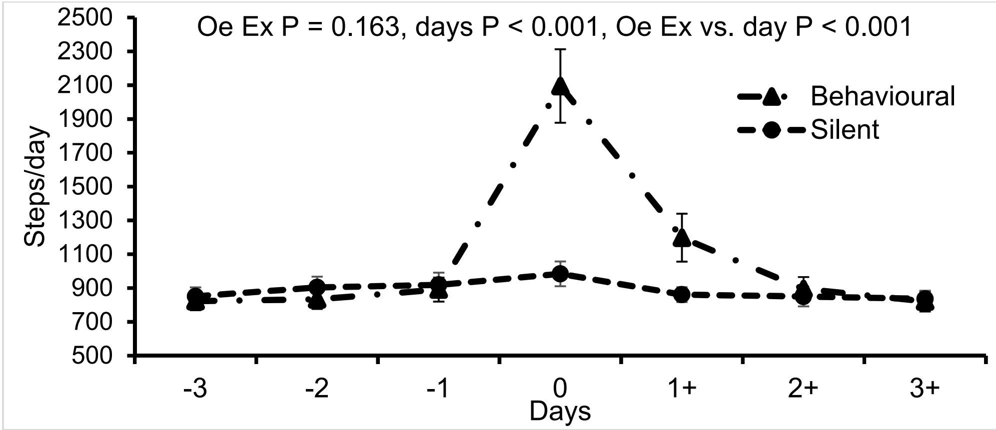
Van Eerdenburg *et al*., 2002.

Table 3. Means of dry matter intake (gkDM/d), feeding duration (h/d) and the number of visiting to feed/d, 3 days before, on the day of oestrus (0) and 3 days after oestrus, during behavioural (n = 40) and silent (n = 21) oestrus.

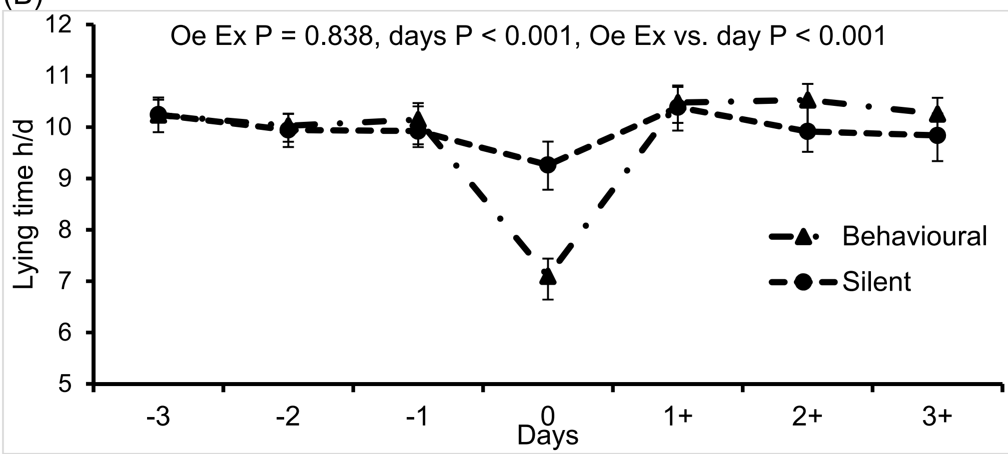
Feeding behaviour	Oe EX	Time/Day							SED	P-value		
		-3	-2	-1	0	1+	2+	3+		Oe Ex	Days	Oe Ex vs. days
Dry matter intake kg/d	B	22.5	22.1	22.5	19.8	22.5	22.5	22.7	0.906	0.314	<0.001	0.371
	S	21.9	21.8	21.6	20.5	21.8	21.8	22.0				
Feeding duration h/d	B	3. 5	3.4	3.3	2.4	3.2	3.2	3.3	0.180	0.306	<0.001	0.06
	S	3.1	3.4	3.4	2.9	3.6	3.4	3.4				
Number of visits to feed/d	B	29.2	28.8	27.2	25.3	27.8	28.3	28.3	3.754	0.318	<0.01	0.588
	S	29.6	29.9	29	27.1	30.5	30.6	30.8				

Oe Ex = Oestrus Expression, B = Behavioural oestrous and S = Silent oestrus, 0 = day of oestrus, SED = standard errors of differences

(A)



(B)



(C)

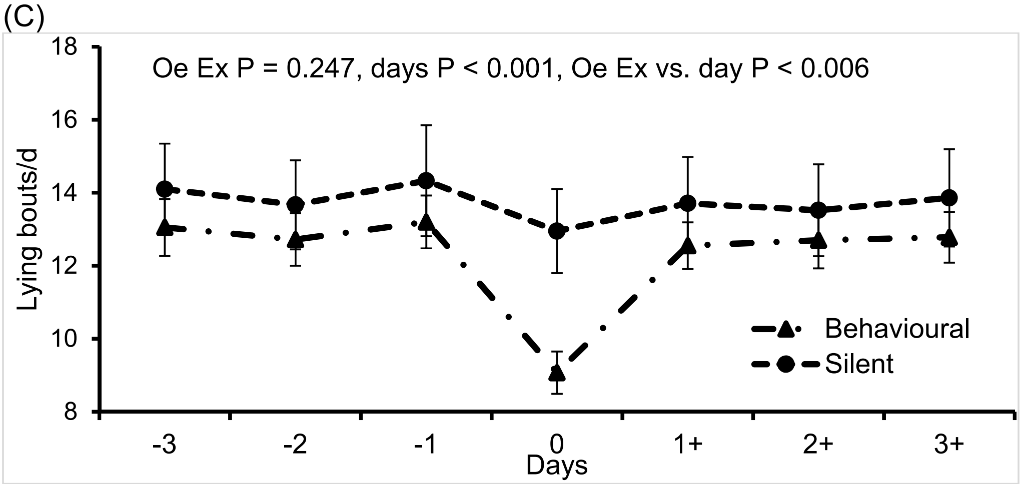


Figure 1. Effect of oestrus on number of steps (A), lying time (B) and number of lying bouts (C), 3 days before, on day of oestrus (0) and 3 days after and during silent (n=21) and behavioural (n=40) oestrus. Oe Ex = Oestrus Expression, 0=day of oestrus.