Feeding behavior in relation to ovarian cyclicity in cows with no or a short dry period

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ABSTRACT

The objective of this study was to investigate relations between feeding behavior (FB) variables focusing on intake of the basal ration during 3 wk prepartum until 3 wk postpartum, and postpartum onset of luteal activity (OLA) in dairy cows subjected to no (0-d) or a short (30-d) dry period (DP). Feeding behavior of the basal ration intake (concentrate intake excluded) was continuously recorded by computerized feeders for 123 dairy cows and analyzed from 3 wk prepartum to 3 wk postpartum. Cows were subjected to a DP length: 0-d DP (n = 81), or 30-d DP (n = 42). Milk progesterone concentration was determined 3 times per week until 100 DIM to determine OLA, which was classified as early OLA (<21 DIM) and late OLA (≥21 DIM). Relations between FB and OLA class were analyzed using mixed models. During 3 wk prepartum, FB differed between parity class (parity 2 or ≥3 after calving). Cows with a 30-d DP prepartum, regardless of their OLA class, had more visits per meal, higher meal duration, total meal time, total daily feeding time, and lower feed intake and feeding rate compared with cows with 0-d DP. During the first 2 d postpartum, cows with OLA <21 had more visits per day and visits per meal compared with cows with OLA ≥21. During the first 3 wk postpartum, cows within the 30-d DP group with OLA <21 had greater meal size, feed intake, and feeding rate compared with cows with OLA ≥21 of this group. Cows within the 0-d DP group with OLA <21 had higher meal duration, total daily meal time, total daily feeding time, and meal size, but a lower feeding rate compared with cows with OLA ≥21 of this group. Concluding from the current study, cows with OLA <21 had a postpartum FB that reflected a cow with faster recovery from parturition and better adaptation to onset of lactation compared with OLA ≥21. No or a short DP affected prepartum FB, suggesting that prepartum management affects FB. This study provides evidence of different FB between cows with different timing of resumption of ovarian cyclicity.

Key words: feeding behavior, ovarian cyclicity, onset of luteal activity, dry period length, dairy cow

INTRODUCTION

Poor reproductive performance (RP) is one of the most common factors leading to culling of dairy cows (Pinedo et al., 2010; Chiumia et al., 2013). Delayed resumption of ovarian cyclicity, high number of services per conception, and reduced estrous expressions are indicators for impaired RP (Walsh et al., 2011; Fricke et al., 2014; Bruinjé et al., 2017). Both early detection and treatment of reproductive problems are important to improve cow health and decrease economic losses for farmers (Weigel et al., 2003; Inchaitsri et al., 2010; Galvão et al., 2013).

The transition period, which includes the 3 wk prepartum until 3 wk postpartum, is a challenging period for dairy cows that is often accompanied by increased susceptibility to diseases such as metritis, ketosis, and mastitis (Goff and Horst, 1997; Walsh et al., 2007) and reproductive problems (Braga Paiano et al., 2019; Stevenson et al., 2020). This increased susceptibility to diseases is linked to metabolic and infectious challenges around calving. These challenges include a postpartum negative energy balance (NEB) as result of high milk yield (Pushpakumara et al., 2003; Wathes et al., 2007; Churakov et al., 2021), sudden hormonal changes (Taylor et al., 2004; Mikula et al., 2021), and immunosuppression as a result of reduced immune competence and an increased acute phase response after calving (Martinez et al., 2012; Aleri et al., 2016). All these hormonal and metabolic changes consequently affect feeding behavior (FB; van Hoeij et al., 2019; Kuhla, 2020), and RP (Lucy, 2008; Castro et al., 2012; Banuelos and Stevenson, 2021). For example, cows with a better metabolic status had a higher DMI and increased feeding activity compared with cows with a poor metabolic status during the first 4 wk of lactation (van Hoeij et al., 2019). Cows with...
earlier postpartum resumption of cyclicity had lower concentrations of BHB and free fatty acids during the first 2 wk of lactation, indicating a better metabolic status (Banuelos and Stevenson, 2021).

Feeding behavior has previously been associated with postpartum diseases (Huzzey et al., 2007; González et al., 2008; van Dixhoorn et al., 2018), and reproductive indicators such as calving to the first service interval (Hut et al., 2019). Changes in FB and regular diurnal rhythms during the dry period (DP) were associated with postpartum health problems such as mastitis, lameness, and metritis (van Dixhoorn et al., 2018). Daily feeding time in wk 4 prepartum, and wk 3 and 4 postpartum, was negatively related to calving to the first service interval (Hut et al., 2019). These findings illustrate the value of using FB in the health monitoring of dairy cows, but further research is required to improve knowledge about relations between FB and RP.

Shortening and omitting the DP reduced the severity of postpartum NEB and improved RP (Chen et al., 2015), indicated by improved resumption of ovarian cyclicity and an increased conception rate (Gümen et al., 2005; Watters et al., 2009; Ma et al., 2020). Ma et al. (2020) found that earlier onset of luteal activity (OLA) was associated with a better metabolic status, indicated by a greater concentration of glucose, IGF-1, and insulin, and a lower concentration of NEFA and BHB during the first 7 wk of lactation in cows subjected to a short (30-d) or no (0-d) DP. Cows with a short or without a DP also showed different behavior around calving (Kok et al., 2017), as cows without a DP had a higher postpartum feed intake and longer lying time both pre- and postpartum compared with cows with a short DP. Although shortening and especially omitting the DP is not common practice in commercial dairy farming, investigation of the effects of no or a short DP of 30 d (n = 42) was associated with a better metabolic status, indicated by a greater concentration of glucose, IGF-1, and insulin, and a lower concentration of NEFA and BHB during the first 7 wk of lactation in cows subjected to a short (30-d) or no (0-d) DP. Cows with a short or without a DP also showed different behavior around calving (Kok et al., 2017), as cows without a DP had a higher postpartum feed intake and longer lying time both pre- and postpartum compared with cows with a short DP. Although shortening and especially omitting the DP is not common practice in commercial dairy farming, investigation of the effects of no or a short DP on FB and ovarian cyclicity can contribute to a better understanding of the consequences of different metabolic statuses on FB and ovarian cyclicity in dairy cows.

The above-mentioned findings suggested that FB is related to ovarian cyclicity, and that DP length may affect this relation. A better understanding of the relations between FB, ovarian cyclicity, and DP length can contribute to both early detection and early treatment of delayed resumption of cyclicity, thereby reducing reproductive problems and decreasing economic losses for farmers. Therefore, the aim of this study was to investigate relations between FB variables focusing on intake of the basal ration during 3 wk prepartum until 3 wk postpartum, and postpartum OLA in dairy cows subjected to a 0-d or 30-d DP.

MATERIALS AND METHODS

Experimental Setup, Animals, and Housing

The Institutional Animal Care and Use Committee of Wageningen University & Research approved the experimental protocol in compliance with the Dutch law on Animal Experimentation as described earlier (protocol number 2014125; van Hoeij et al., 2017). The experiment was performed from January 27, 2014, until May 9, 2016. The experiment was designed to study the effect of DP length and ration on energy balance (EB) and metabolic status (van Hoeij et al., 2017). A total of 123 dairy cows were used for the experiment. Sample size was based on previous studies with a similar experimental design (Sorensen and Knight, 2002; Gümen et al., 2005; Rastani et al., 2005; Marett et al., 2011; van Kneusel et al., 2014). Cows were included in the experiment at an average rate of 3 cows per week, based on the availability of cows in late gestation. Inclusion criteria were an expected calving interval shorter than 490 d, a daily milk yield of >16 kg, and no (sub)clinical mastitis (a cell count >250,000 cells/mL) at 90 d before expected calving. Treatment groups were balanced for parity (2 or ≥3 after calving), expected calving date, and milk production in the previous lactation. This was done by grouping cows that were most similar in these factors together in groups of 6, and randomly assigning the cows of each group to no DP (n = 81), or a short DP of 30 d (n = 42). Almost twice as many cows were assigned to the no DP treatment because of an additional contrast in concentrate allowance from 22 DIM. This study only focuses on FB until 21 DIM, hence the cows with a 0-d DP are treated as 1 group, as feed provision is the same for all 0-d DP cows in the analyzed period.

All cows were housed in a freestall barn with a concrete slatted floor in the alleys, and rubber mattresses covered with sawdust in the cubicles. Stocking density was 1 cow per cubicle and no more than 2 cows per feeding bin. Dry and lactating cows were housed separately. Lactating cows were milked twice daily (0600 and 1800 h) in a milking parlor. Cows with a 30-d DP were milked once daily from 4 d before drying off. The lactating herd consisted of both cows with a 0-d and 30-d DP, and all cows were treated similarly during and after calving (expect for feed provision which is further described below).

All treatments of disease during the experiment were recorded by farm staff according to farm protocols (Dairy Campus, Lelystad, the Netherlands). Disease treatments were registered daily based on treatments for disease, including milk fever, retained placenta,
endometritis, cystic ovaries, mastitis, claw disorders, fever, ketosis, displaced abomasum, and other diseases.

**Feed Provision**

Feed composition was reported earlier in van Hoeij et al. (2017). In short, during the DP, cows with a 30-d DP received a DP ration that consisted of grass silage (48%), maize silage (19%), wheat straw (25%), rapeseed meal (8%; DM basis), and vitamins and minerals (estimated net energy: 5.4 MJ/kg of DM). Prepartum, cows with a 0-d DP received a lactation diet that consisted of grass silage (45%), maize silage (35%), wheat straw (2%), soybean meal (8%), and sugar beet pulp (10%; DM basis), and vitamins and minerals (estimated net energy: 6.4 MJ/kg of DM; basal ration). Postpartum, all cows received the same basal ration up to 49 DIM. The basal ration was provided in roughage intake control (RIC) feeders. Feed was mixed once a day around 1000 h and was delivered twice a day around 1000 and 1700 h. Between 2345 and 0000 h, the RIC feeder was not accessible for cows as recorded data were saved. Concentrate was provided separately from the basal ration in individual concentrate feeders (Manus VC5, DeLaval). Peripartum, all cows received the same dietary energy level of concentrate: 1 kg of concentrate from 10 d before expected calving date and from 4 DIM concentrate supply increased stepwise for all DP lengths with 0.3 until 6.7 kg per d at 22 DIM.

**Reproduction Protocol**

Cows were inseminated after a voluntary waiting period of 50 d, and inseminations continued until 170 DIM. Artificial insemination was conducted once a day during the morning, and at least 12 h after estrous was detected by Lely Qwes-HR activity tags (Lely). Cows remained in the herd for insemination. Every 4 wk, pregnancy checks were performed on cows that were inseminated over 30 d ago using ultrasound.

**Measurements**

**Feeding Behavior.** Feeding behavior of basal ration intake was continuously recorded by RIC feeders. During every visit to a feeding bin, the cows’ identity, start and end time (hh:mm:ss), and start and end weight of the feed in the feeding bin to the nearest 0.1 kg were recorded. Feeding behavior was previously reported by Kok et al. (2017).

**Determination of Onset of Luteal Activity.** Onset of luteal activity was analyzed and previously reported by Ma et al. (2020). Briefly, milk samples were taken 3 times a week during morning milking from day of parturition until 100 DIM. Milk progesterone concentration was measured by using an enzyme immunoassay (Ridgeway Science Ltd.) as described by Roelofs et al. (2006). The intraassay and interassay coefficients of variation were 4.4 and 16.7%. Onset of luteal activity was defined as 2 or more successive milk samples with a milk progesterone concentration of 4 ng/mL or higher. Cows were classified into OLA class based on days to OLA (<21, ≥21 DIM; using the cut-off value of previous research; Chen et al., 2015; Ma et al., 2020). Descriptive statistics and distribution of OLA per DP length and parity class (2 or ≥3 after calving) are shown in Table 1.

**Data Processing and Statistical Analysis**

The RIC data set consisted of records of 123 cows. Five cows were excluded from analysis due to incomplete OLA data. Visits with a feeding rate of >2 kg per minute were discarded (0.4% of records), as well as visits with a duration longer than 3 and a feeding rate below 0.02 kg/min (0.1% of records). Visits to the feeder were clustered into meals using a meal criterion of 18.0 min prepartum and 20.9 min postpartum (i.e., visits of the same cow that were less time than the meal criterion apart) were combined into the same meal [as calculated by Kok et al. (2017)]. In this way, deter-
mined feeding variables based on basal ration intake were meals per day, number of visits per meal, meal duration, total daily meal time, and meal size. Also, daily feed intake, daily feeding time, feeding rate, and number of visits per day were determined.

All statistical analyses were performed using SAS (University Edition 2.8.1 9.4 M6; SAS institute Inc.). Daily RIC data were analyzed for 3 wk prepartum, 3 wk postpartum, and the first 2 d postpartum. To evaluate normality of residuals, a normality test (PROC UNIVARIATE) was performed where skewness between −1 and 1, and kurtosis between −2 and 2, were used as criteria for normality. Statistical models are described below. All models were analyzed using backward elimination with a stay-in P-value of <0.05 in the type 3 tests of fixed effects. Tukey’s studentized range tests were performed to investigate between-group differences where P < 0.05 was considered a significant difference. Values were shown as least squares means and the largest standard error of the mean of the presented groups.

To evaluate relations between OLA and FB during 3 wk before day of calving (in case of early calving, only data of the available time period was included), and 3 wk after day of calving, a mixed model (PROC MIXED) was used. The dependent variable was one of the feeding variables. Independent variables were OLA class (OLA <21 or ≥21 DIM), DP length (30-d DP or 0-d DP), parity (2 or ≥3 after calving), and their 2-way interactions. Also, similar analyses were carried out for the first calendar day, first 3 calendar days, and first week after calving. The lowest P-values were found for the first 2 calendar days postpartum, and this model was therefore used for further evaluation.

RESULTS

Relations Between Prepartum Feeding Behavior and Onset of Luteal Activity

For prepartum FB, interactions with OLA and DP length (7 out of 9 variables) and OLA and parity class (5 out of 9 variables) were found often (Table 2). All prepartum FB was affected by DP length, either independently, or in interaction with parity class or OLA class. Within the 30-d DP group, cows with OLA <21 had fewer visits per meal, a shorter meal duration, total daily meal time, and total daily feeding time, and higher feed intake, and feeding rate compared with cows with OLA ≥21. Within the 0-d DP group, cows with OLA <21 had a higher number of visits per meal and visits per day, longer meal duration, total daily meal time and total daily feeding time, and lower feeding rate compared with cows with OLA ≥21.

We observed an interaction effect with OLA class and parity class for the number of visits per meal and the number of visits per day. Within the group of cows with parity 2 at calving, cows with OLA <21 had a higher number of visits per meal and visits per day compared with cows with OLA ≥21 (Figure 1a, b). In parity ≥3, cows with OLA <21 had a higher number of visits per meal and visits per day compared with cows with OLA ≥21. Cows of parity 2 had more visits per day, higher meal duration, total daily meal time, total daily feeding time, feed intake, and lower feeding rate compared with cows of parity ≥3.

Relations Between Feeding Behavior During the First 2 d Postpartum and Onset of Luteal Activity

Cumulative feeding variables during the first 2 d postpartum were analyzed to investigate the relation between early postpartum FB and OLA (Table 3).
Cows with OLA <21 had a higher number of visits per meal and cumulative number of visits during the first 2 d postpartum than cows with OLA ≥21. Cows of parity 2 had a higher number of visits per meal, cumulative meal duration, cumulative total meal time, and cumulative total number of visits during the first 2 d postpartum than cows of parity ≥3.

We observed an interaction between parity class and OLA class for cumulative feed intake during the first 2 d postpartum (Figure 2a). Cows of parity ≥3 with OLA ≥21 had lower cumulative feed intake during the first 2 d postpartum compared with cows of parity ≥3 with OLA <21 and all cows of parity 2. We observed an interaction between parity class and DP length for cumulative feeding time (Figure 2b), and did not result in significant post hoc comparisons. Irrespective of DP length, cows with parity 2 had a higher cumulative feeding time compared with cows with of parity ≥3.

Cumulative feed intake and feeding rate during the first 2 d postpartum was greater in cows with a 0-d DP than a 30-d DP (74.6 vs. 66.5 kg/2 d, and 283 vs. 252 g/min feeding, respectively).

### Relations Between Postpartum Feeding Behavior and Onset of Luteal Activity

During the first 3 wk of lactation, an interaction effect of DP length × OLA was found for most feeding variables (Table 4). Within the 30-d DP group, cows with OLA <21 had higher meal size, feed intake, and feeding rate compared with cows with OLA ≥21. Within the 0-d DP group, cows with OLA <21 had longer meal duration, total daily meal time, total daily feeding time, and meal size but a lower feeding rate compared with cows with OLA ≥21. Average milk yield during the first 3 wk of lactation was higher for OLA ≥21. Average milk production with OLA >21 was lower compared with OLA <21. Average milk production with OLA ≥21 was higher for OLA ≥21. Average milk production with OLA <21 was lower compared with OLA ≥21. No correlations were found with milk production with milk yield (Table 5).

### Table 2. Relations between feeding behavior and onset of luteal activity (OLA) during 3 wk before calving after no or a short dry period (DP), and per parity (P) in 118 dairy cows in 1 farm

<table>
<thead>
<tr>
<th>Item</th>
<th>30-d DP</th>
<th>0-d DP</th>
<th>SEM</th>
<th>Parity</th>
<th>SEM</th>
<th>OLA</th>
<th>P</th>
<th>DP</th>
<th>DP × P</th>
<th>DP × OLA</th>
<th>P × OLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLA (d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cows (n)</td>
<td>19 &lt;21</td>
<td>21 ≥21</td>
<td>47</td>
<td>31</td>
<td>61</td>
<td>57</td>
<td>0.07</td>
<td>0.12</td>
<td>0.87</td>
<td>&lt;0.01</td>
<td>NM</td>
</tr>
<tr>
<td>Meals per day</td>
<td>5.1b</td>
<td>5.4a</td>
<td>4.6b</td>
<td>4.3d</td>
<td>0.11</td>
<td>5.5b</td>
<td>4.1d</td>
<td>0.08</td>
<td>0.91</td>
<td>&lt;0.01</td>
<td>NM</td>
</tr>
<tr>
<td>Meal duration (min/meal)</td>
<td>45.6b</td>
<td>50a</td>
<td>34.9</td>
<td>31.4b</td>
<td>0.88</td>
<td>45.1b</td>
<td>36.1b</td>
<td>0.59</td>
<td>0.47</td>
<td>&lt;0.01</td>
<td>NM</td>
</tr>
<tr>
<td>Total meal time (min/d)</td>
<td>285b</td>
<td>305a</td>
<td>249</td>
<td>227</td>
<td>3.5</td>
<td>292b</td>
<td>240b</td>
<td>2.4</td>
<td>0.79</td>
<td>&lt;0.01</td>
<td>NM</td>
</tr>
<tr>
<td>Visits per day</td>
<td>32.8b</td>
<td>33.6a</td>
<td>33.6</td>
<td>31.3</td>
<td>0.64</td>
<td>37.3b</td>
<td>28.3b</td>
<td>2.6</td>
<td>0.21</td>
<td>&lt;0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Total feeding time (min/d)</td>
<td>239b</td>
<td>250a</td>
<td>202</td>
<td>184</td>
<td>3.0</td>
<td>240b</td>
<td>197b</td>
<td>2.0</td>
<td>0.19</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Meal size (kg/meal)</td>
<td>4.9</td>
<td>4.9</td>
<td>0.06</td>
<td></td>
<td>0.80</td>
<td>0.47</td>
<td>&lt;0.01</td>
<td>NM</td>
<td>NM</td>
<td>NM</td>
<td>NM</td>
</tr>
<tr>
<td>Feed intake (kg/d)</td>
<td>27.9b</td>
<td>26.4d</td>
<td>38.5a</td>
<td>39.4a</td>
<td>0.39</td>
<td>33.5b</td>
<td>32.6b</td>
<td>0.26</td>
<td>0.26</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Feeding rate (g/min feeding)</td>
<td>125b</td>
<td>113d</td>
<td>203</td>
<td>228</td>
<td>2.5</td>
<td>152b</td>
<td>182b</td>
<td>1.7</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

**Note:** Values with different superscripts in the same row differ (P < 0.05).

1OLA was defined as 2 or more successive milk samples with milk progesterone concentration of 4 ng/mL or higher during 100 DIM.
2Least squares means ± maximum SEM.
3DP lengths were 0-d DP; 30-d DP.
4Least squares means for meals per day and meal size are not shown because DP × OLA interaction effects were not retained in the final model after backward selection.
5Feed intake refers to fresh feed intake from the basal ration (concentrate intake not included).
6NM = not in model.
day and visits per meal, and higher feed intake and feeding rate. The proportion of cows of parity $\geq 3$ with OLA $\geq 21$ treated for a postpartum disease was higher compared with all cows of parity 2 and cows of parity $\geq 3$ with OLA $<21$.

**DISCUSSION**

During the last 3 wk prepartum, FB differed between cows with a short or without a DP, irrespective of their OLA class. Cows with a 30-d DP, regardless of their OLA class, had more visits per meal, higher meal duration, total meal time, total daily feeding time, and lower feed intake and feeding rate compared with cows with 0-d DP. The lower feeding rate was likely explained by the DP ration that these dry cows were provided, which contained a large proportion of straw. The lower feed intake may be explained by the lower energy requirements and provision of high amounts of voluminous straw in dry cows in the 30-d DP group compared with the lactating cows in the 0-d DP group (Kok et al., 2017). The higher total meal time and total daily feeding time in cows with a 30-d DP may be related to the fact that these cows do not spend time being milked and moving to the milking parlor. In line with this, Kok et al. (2017) found that cows with a 30-d DP had a lower number of steps per day during the 4 wk before calving compared with cows with a 0-d DP, indicating lower walking activity.

Within the 30-d DP group, cows with early OLA had a higher prepartum feed intake with fewer visits per meal, lower meal duration, total meal time and, total daily feeding time, and higher feeding rate compared with cows with late OLA. Cows with early OLA compared with cows with late OLA thus were capable of eating more in less time already during the prepartum period, possibly indicating a higher feed intake capacity and adaptation to the DP diet (Kok et al., 2017). However, it should be noted that too high feed intake during the prepartum period should be avoided to prevent metabolic diseases as a result of over-conditioning (Janovick et al., 2011; Roche et al., 2013), especially because cows with early OLA had a lower milk yield compared with cows with late OLA. Within the 0-d DP group, prepartum feed intake did not differ between OLA classes. However, these cows with early OLA had a higher number of visits per meal, higher meal duration, total daily meal time, and total daily feeding time, and lower feeding rate compared with cows with late OLA. Hence, fast adaptation to the DP diet by cows with a 30-d DP and high prepartum feeding motivation in cows with a 0-d DP may be hypothesized to favor OLA.

During the first 2 d postpartum, cows with early OLA had more visits per day and visits per meal compared with cows with late OLA. These results could indicate a faster recovery from parturition and quicker adaptation to a new lactation in cows with early OLA compared with cows with late OLA. Cows of parity $\geq 3$ with early OLA had higher feed intake compared with cows with parity $\geq 3$ with late OLA. In line with this, cows suffering from postpartum health disorders or delayed OLA often suffer from a severe NEB during early lactation (Beam and Butler, 1997; de Vries and Veerkamp, 2000), which was also associated with a severe decline in feed intake after calving (Wankhade et al., 2017). Similarly, cows suffering from postpartum hypocalcemia had lower feed intake during the first 2 d postpartum compared with healthy cows (Goff and Horst, 1997), and cows suffering from subclinical ketosis during the transition period had lower feed intake during the first week postpartum compared with healthy cows (Goldhawk et al., 2009). Hence, decreased feed intake in the older cows in the first week postpartum may be an indicator for delayed OLA. Except for feed intake and feeding rate, DP length did not affect FB in the first 2 d postpartum. This suggests that FB during the first 2 d postpartum is greatly affected by parturition, irrespective of DP length and the prepartum ration. This is in line with previous research (Huzzey et al., 2007; Proudfoot et al., 2009; Schirmann et al., 2013), which reported great changes in FB around parturition. Overall, it may be hypothesized from the current study that cows with earlier resumption of ovarian cyclicity have a higher feeding motivation as a result of a faster recovery from parturition and better adaptation to the lactation diet. Focusing on easy accessibility of fresh feed directly after parturition is may potentially be an important factor in increasing feeding motivation after parturition in all cows.

During the first 3 wk of lactation, omitting or shortening the DP greatly affected the relation between FB and OLA. Within the 30-d DP group, cows with early OLA had larger meal size, greater feed intake, and feeding rate postpartum compared with cows with late OLA. This could indicate greater feed intake capacity through more prepartum feed intake, and a faster adaptation to the lactation diet or onset of lactation (Kok et al., 2017). Within the 0-d DP group, cows with early OLA had a longer meal duration, total daily meal time, total daily feeding time and a larger meal size, and a lower feeding rate compared with cows with late OLA. This indicates that cows with early OLA of both DP groups show a higher feeding motivation through spending more time feeding. This pattern was already present during the prepartum period. This was in line
with Banuelos and Stevenson (2021) who reported that cows with early ovulation were more active and had more eating time during the first 3 wk of lactation. From the current study, it may be hypothesized that FB during the entire peripartum period is associated with OLA. Irrespective of OLA class, feeding rate was lower in cows with 30-d DP compared with 0-d DP, which indicates better adaptation to a new lactation in cows with 0-d DP (Kok et al., 2017). The higher total daily feeding time in cows with 0-d DP with early OLA was in line with Hut et al. (2019). In this earlier study, a lower mean feeding time in wk 3 postpartum resulted in an increased calving to the first service interval. Additionally, out of several feeding characteristics, feeding time was often affected in relation to disorders such as subclinical ketosis, metritis, and lameness (González et al., 2008). However, in the current study no difference was found for feeding time between OLA classes in the 30-d DP group. Hence, the effect of DP length and transition management on the relation between feeding time and RP requires more investigation.

In cows with a 30-d DP, postpartum feed intake and meal size were higher in cows with early OLA compared with cows with late OLA. It may be hypothesized that OLA was mostly favored by higher energy availability through higher feed intake, rather than by differences in other FB variables. This may indicate that OLA is mostly favored by a positive EB during early lacta-

### Table 3. Relations between cumulative feeding variables, and onset of luteal activity (OLA) during the first 2 d postpartum per parity (P) in 118 dairy cows in 1 farm

<table>
<thead>
<tr>
<th>Item</th>
<th>OLA</th>
<th>Parity</th>
<th>SEM</th>
<th>OLA</th>
<th>Parity</th>
<th>SEM</th>
<th>P-value</th>
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<tbody>
<tr>
<td>Cows (n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meals (per 2 d)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits per meal</td>
<td>6.5b</td>
<td>6.5b</td>
<td>0.33</td>
<td>7.1a</td>
<td>7.1a</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Meal duration (min/meal)</td>
<td>41.4</td>
<td>43.9a</td>
<td>2.0</td>
<td>35.6b</td>
<td>35.6b</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Total meal time (min/2 d)</td>
<td>409</td>
<td>434a</td>
<td>20.1</td>
<td>348b</td>
<td>348b</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>Visits (per 2 d)</td>
<td>66.0a</td>
<td>70.7a</td>
<td>3.7</td>
<td>50.8b</td>
<td>50.8b</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Total feeding time (min/2 d)</td>
<td>286</td>
<td>314a</td>
<td>12.2</td>
<td>239b</td>
<td>239b</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>Meal size (kg/meal)</td>
<td>7.4</td>
<td>7.4</td>
<td>0.33</td>
<td>7.4</td>
<td>7.4</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Feed intake (kg/2 d)</td>
<td>72.4</td>
<td>75.6b</td>
<td>2.7</td>
<td>65.5b</td>
<td>65.5b</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Feeding rate (g/min feeding)</td>
<td>266</td>
<td>249a</td>
<td>9.5</td>
<td>290b</td>
<td>290b</td>
<td>9.4</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 1. Interaction of different parity classes (par 2 = parity 2; par ≥3 = parity ≥3) and onset of luteal activity (OLA) classes (OLA <21 d = dark blue and OLA ≥21 d = light blue) during the 3 wk before expected calving date for (A) visits per meal and (B) visits per day. Values represent least squares means ± maximum SEM. Values with different letters (a–d) differ ($P < 0.05$).
tion. In line with this, cows with higher DMI and a more positive EB during the first 4 wk of lactation were more likely to have an earlier postpartum resumption of cyclicity (Patton et al., 2007), and the calving to ovulation interval was the shortest with highest DMI during the first 11 wk of lactation (Lucy et al., 1992). Within the group of cows with 0-d DP, no difference between postpartum feed intake was found between the different OLA classes. This was in line with prepartum feed intake. These findings indicate that energy availability is likely not a limiting factor in OLA in cows without a DP. However, previous research showed that 0-d DP cows were more prone to prepartum fattening due to low milk yield but continuation of the lactation diet (Chen et al., 2015; Ma et al., 2020). Hence, prepartum energy intake should not exceed the energy requirements for milk yield and maintenance to prevent the impairing effect of fattening on fertility (Watters et al., 2009; Ma et al., 2020).

Not only energy intake, but also energy output through milk yield differed between OLA classes and DP. Mean milk yield during the first 3 wk of lactation was higher in cows with 30-d DP than cows with 0-d DP, and lower in cows with early than cows with late OLA. Early OLA was previously associated with lower milk yield (Mackey et al., 2007; Garmo et al., 2009), which was in line with the current study. Patton et al. (2007) did not find any effects of milk yield on fertility. Lower milk yield in cows with a 0-d DP compared with cows with a 30-d DP was previously found, and associated with a more positive EB (van Knegsel et al., 2014) and a better metabolic status (van Hoeij et al., 2019). A better metabolic status was associated with less days to OLA (Ma et al., 2020). Overall, relations between milk yield and feed intake with fertility are not fully clear, but a neutral EB is suggested to be most favorable for fertility.

The number of visits per day and visits per meal were affected by parity, both pre- and postpartum. Prepartum, cows of parity 2 had more visits per meal and visits per day compared with older cows. This was in line with Neave et al. (2017), who reported that this was caused by the fact that younger cows experienced more displacements from the RIC feeders by older cows. This is likely related to the fact that older cows are typically more dominant compared with younger cows, as dominance increases with age and cow size (Val-Laillet et al., 2008). Within the group of parity 2, cows with early OLA had more visits per meal and visits per day compared with cows with later OLA. It was hypothesized that cows with early OLA may have been more motivated to feed, as these cows were associated with a better metabolic status compared with cows with later OLA (Ma et al., 2020). A better metabolic status with less fatty acid oxidation consequently stimulates appetite in these cows (Allen, 2020). These cows are therefore more likely to revisit the feeder after displacement after calving. This was in line with a previous study where metritic cows were after calving more often displaced from the feeding bunk and consumed fewer meals per day compared with healthy cows (Neave et al., 2018). In this study, 1 RIC feeder per 2 cows was available, resulting in a relatively high stocking density per RIC feeder. Decreasing stocking density at the feeding bunk was found to decrease number of displacements from the feeding bin, especially in lower-ranked cows (Huzzey et al., 2006). A lower stocking density per RIC feeder will likely affect the results of the current study. It should be noted that in the RIC feeder only the basal ration was provided, separate from the

Figure 2. Interaction of different parity classes (par 2 = parity 2; par ≥3 = parity ≥3) and onset of luteal activity (OLA) classes (OLA <21 d = dark blue and OLA ≥21 d = light blue) during the first 2 d postpartum for (A) cumulative feed intake and (B) total feeding time. Values represent least squares means ± maximum SEM. Values with different letters (a,b) differ (P < 0.05).
Table 4. Relations between feeding behavior and onset of luteal activity (OLA)\(^1\) during the first 3 wk after calving after no or a short dry period (DP) per parity (P) in 118 dairy cows in 1 farm\(^2\)\(^3\)

<table>
<thead>
<tr>
<th>Item(^4)^(^5)</th>
<th>DP length</th>
<th>Parity</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30-d DP</td>
<td>0-d DP</td>
<td>2</td>
</tr>
<tr>
<td>OLA (d)</td>
<td>&lt;21</td>
<td>&gt;21</td>
<td></td>
</tr>
<tr>
<td>Cows (n)</td>
<td>19</td>
<td>21</td>
<td>47</td>
</tr>
<tr>
<td>Meals per day(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits per meal(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meal duration(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total meal time(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits per day(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total feeding time(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meal size (kg/meal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed intake (kg/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeding rate (g/min feeding)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average milk yield(^7)^(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion of cows treated for disease(^7)^(^8) (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(a\)-d Values with different superscripts in the same row differ \((P < 0.05)\).

1OLA was defined as 2 or more successive milk samples with milk progesterone concentration of 4 ng/mL or higher during 100 DIM.

2Least squares means ± maximum SEM.

3DP lengths were 0-d DP; 30-d DP.

4Least squares means for meals per day, visits per meal, and visits per day are not shown because DP × OLA interaction effects were not retained in the final model after backward selection.

5Feed intake refers to fresh feed intake from the basal ration (concentrate intake not included).

6Interactions between P × OLA are shown in Figure 3.

7For variables where no DP × OLA interaction is present, the DP effect is shown here: meals per day: 8.4 per day (30-d DP) vs. 8.9 per day (0-d DP); visits per meal: 3.4 per day (30-d DP) vs. 3.6 per day (0-d DP); visits per day: 28.9 per day (30-d DP) vs. 31.3 per day (0-d DP); average milk yield: 34.6 kg/d (30-d DP) vs. 31.6 kg/d (0-d DP); proportion of cows treated for disease: 66.6% (30-d DP) vs. 42.9% (0-d DP).

8For variables where no DP × OLA interaction is present, the OLA effect is shown here: meals per day: 8.6 per day (OLA <21) vs. 8.6 per day (OLA ≥21); visits per meal: 3.8 per day (OLA <21) vs. 3.3 per day (OLA ≥21); visits per day: 31.9 per day (OLA <21) vs. 28.1 per day (OLA ≥21); average milk yield: 29.8 kg/d (OLA <21) vs. 36.4 kg/d (OLA ≥21); proportion of cows treated for disease: 57.5% (OLA <21) vs. 52.5% (OLA ≥21).

9NM = not in model.
concentrate. Additional analysis of concentrate intake behavior can contribute to a more detailed description of FB patterns in the current study.

Dry period length affected postpartum visits per meal and visits per day, as both feeding variables were lower in cows with 30-d DP than 0-d DP. An explanation may be that cows with a 30-d DP are reintroduced in the herd after an absence of 30 d, which increases feeding competition compared with cows with a 0-d DP who only leave the herd around parturition. This may lead to a reduced motivation to visit the feeding bin or revisit the bin after replacement in cows with 30-d DP, thereby reducing their number of visits per day and visits per meal. This hypothesis is similar to results found in a previous study, where cows exposed to a more unpredictable and competitive environment had a reduction in the number of visits to the feed bin (Proudfoot et al., 2018). Next to that, the change from a DP ration to a lactation ration and onset of lactation requires adaptation (Kok et al., 2017), which is reflected in their FB, including visit frequency. It should be noted that the proportion of cows treated for a postpartum disease was higher for cows with a 30-d DP compared with cows with a 0-d DP, which is likely reflected in the postpartum FB. Further analysis of the effects of disease on FB and OLA is beyond the scope of this study, but it is valuable in better understanding underlying mechanisms.

The current study only includes cows with a 0-d or 30-d DP, whereas the effect of a standard DP length of 6 to 8 wk on OLA was not investigated. A standard DP is accompanied with a more severe NEB and higher milk yield during early lactation, compared with a 0-d DP, with cows with a 30-d DP being intermediate (van Knegsel et al., 2014). Also, cows with a standard DP are often subjected to 2 different DP rations, and are regrouped more often compared with cows with 30-d DP. Although both a standard and 30-d DP involve a DP, farm managements differ and are not fully comparable. However, as both a standard and 30-d DP involve cessation of lactation, a DP, and diet changes, it may be speculated that cows with a standard DP show FB comparable with cows with a 30-d DP. Previous studies compared postpartum feed intake in cows with a standard and short, but no differences between the 2 groups were found (Rastani et al., 2005; van Knegsel et al., 2014). However, a standard or short DP had different effects on milk production and metabolite profiles in subsequent lactation (Rastani et al., 2005). Feed intake may be similar for cows with a short and standard DP, but more research toward the effects of the different DP lengths on metabolic processes and milk yield may give insight in the consequences on RP of the different DP lengths.

### Table 5. Descriptive statistics of milk yield and feeding behavior, and Pearson correlations coefficients with milk yield of 118 dairy cows in 1 farm

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Milk yield (kg/d)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPCM(^1) (kg/d)</td>
<td>32.2 (7.2)</td>
<td>-0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>Meals per day</td>
<td>8.6 (1.2)</td>
<td>-0.07</td>
<td>0.44</td>
</tr>
<tr>
<td>Visits per meal</td>
<td>3.6 (1.1)</td>
<td>0.03</td>
<td>0.75</td>
</tr>
<tr>
<td>Meal duration (min/meal)</td>
<td>27.0 (6.4)</td>
<td>-0.05</td>
<td>0.60</td>
</tr>
<tr>
<td>Total meal time (min/d)</td>
<td>221 (53.7)</td>
<td>-0.12</td>
<td>0.18</td>
</tr>
<tr>
<td>Visits per day</td>
<td>30.5 (10.3)</td>
<td>0.008</td>
<td>0.93</td>
</tr>
<tr>
<td>Total feeding time (min/d)</td>
<td>171 (39.5)</td>
<td>0.20</td>
<td>0.03</td>
</tr>
<tr>
<td>Meal size (kg/meal)</td>
<td>4.6 (0.90)</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>Feed intake (kg/d)</td>
<td>37.2 (6.7)</td>
<td>0.07</td>
<td>0.46</td>
</tr>
<tr>
<td>Feeding rate (g/min feeding)</td>
<td>230 (52.9)</td>
<td>-0.12</td>
<td>0.18</td>
</tr>
</tbody>
</table>

1Feed intake refers to fresh feed intake from the basal ration (concentrate intake not included).
2Pearson correlation coefficients are given, together with a P-value (significant when P < 0.05).
3FPCM = fat- and protein-corrected milk.

### Table 6. Descriptive statistics of disease treatment (%) during the first 7 wk of lactation per dry period (DP) group and onset of luteal activity (OLA)\(^1\) class in 118 dairy cows in 1 farm

<table>
<thead>
<tr>
<th>OLA class</th>
<th>30-d DP</th>
<th>0-d DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow (n)</td>
<td>&lt;21</td>
<td>≥21</td>
</tr>
<tr>
<td>Disease treatment</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Leg problems</td>
<td>78.9</td>
<td>57.1</td>
</tr>
<tr>
<td>Retained placenta</td>
<td>21.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Endometritis</td>
<td>10.5</td>
<td>14.2</td>
</tr>
<tr>
<td>Milk fever</td>
<td>47.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Other(^2)</td>
<td>5.2</td>
<td>9.5</td>
</tr>
</tbody>
</table>

1OLA was defined as 2 or more successive milk samples with milk progesterone concentration of 4 ng/mL or higher during 100 DIM.
2DP lengths were 0-d DP; 30-d DP.
3Other = fever, ketosis, displaced abomasum, and cystic ovaries.
This study suggests that FB can be used as an indicator of impaired ovarian cyclicity in dairy cows. Irrespective of the presence of on-farm sensor-based FB monitoring, detection of deviating FB can be used to monitor cow health. These observations potentially can affect decisions on reproduction management of farmers. Daily assessment of ruminal fill (Schneider et al., 2022) and ruminating behavior (Soriani et al., 2012; Calamari et al., 2014) allows for visually monitoring FB. Next to monitoring of individual behavior, a farmer can also affect FB of its herd, as adequate feeding management is important for an adequate feeding pattern of the cow. Regular feed push-ups and frequent provision of fresh feed are important to ensure constant availability of high quality feed, thereby maintaining good ruminal health, adequate nutrient uptake, and decreasing feeding competition (DeVries et al., 2003; King et al., 2016).

Figure 3. Interaction of different parity classes at calving (par 2 = parity 2; par ≥3 = parity ≥3) and onset of luteal activity (OLA) classes (OLA <21 d = dark blue and OLA ≥21 d = light blue) during the first 3 wk postpartum for (A) meals per day, (B) visits per meal, (C) meal duration (min/meal), (D) feed intake (kg/d), (E) feeding rate (g/min feeding), and (F) proportion of cows treated for disease. Values represent least squares means ± maximum SEM. Values with different letters (a–d) differ ($P < 0.05$).
Cows with early OLA, irrespective of the subjection to no or a short DP, had higher feed intake during the first 3 wk of lactation compared with cows with late OLA. In addition, cows with early OLA had more visits per day and visits per meal during 2 d postpartum compared with late OLA. The more active feed intake behavior for cows with an early OLA postpartum could indicate a faster recovery from calving and a better adaptation to the lactation diet. Cows with a 30-d DP, regardless of their OLA class, prepartum had more visits per meal, higher meal duration, total meal time, total daily feeding time and lower feed intake and feeding rate compared with cows with 0-d DP. This highlights the effect of a DP on FB. Both pre- and postpartum, parity affected FB, as younger cows experienced a higher level of displacement by older cows, indicated by more visits to the feeder.

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