Effect of feed presentation on feeding patterns of dairy calves

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ABSTRACT

The objectives of this study were to determine the effect of feed presentation on meal frequency and duration, as well as diurnal feeding patterns of dairy calves, and to assess any longer-term differences in feeding patterns resulting from previous experience. Twenty Holstein bull calves were exposed from wk 1 to 8 of life to 1 of 2 feed presentation treatments: concentrate and chopped grass hay (<2.5 cm) offered at a ratio of 7:3 as a mixture (MIX), or as separate components (COM). Feed was provided *ad libitum*. Calves received 8 L/d of milk replacer (1.2 kg of dry matter), with the amount progressively reduced after 5 wk to facilitate weaning by the end of wk 7. At the beginning of wk 9, all calves received the MIX diet and remained on trial for an additional 3 wk. Feeding behavior was recorded from video for 4 d during wk 6, 8, 9, and 11. In wk 6, calves fed MIX spent more time feeding than calves fed COM (56.7 vs. 46.8 min/d). In wk 8, calves fed MIX spent more time feeding (174.0 vs. 139.1 min/d) and had a lower rate of intake (11.5 vs. 14.7 g/min) compared with calves fed COM. Meal frequency was similar between treatments (12.2 meals/d). Diurnal feeding patterns in wk 8 were also affected by feed presentation, with calves fed MIX spending less time feeding at time of feed delivery and more time feeding throughout the rest of the daylight hours than calves fed COM. Diurnal feeding patterns of hay and concentrate in wk 8 differed for calves fed COM, with more time spent consuming hay at time of feed delivery and less time spent consuming hay throughout the rest of the day. Once calves previously fed COM were transitioned to the MIX diet in wk 9, meal frequency, meal duration, and diurnal feeding patterns were similar between treatments: both treatments spent similar amounts of time feeding (173.9 min/d) and had similar peaks in feeding activity at time of feed delivery, sunrise, and sunset. Provision of hay and concentrate to young calves as a mixed ration,

compared with separate components, increases time spent feeding and results in more evenly distributed diurnal feeding patterns. However, differences in feeding patterns resulting from feed presentation did not persist after 8 wk of age, when all calves were fed a mixed ration.

Key words: dairy calf, feeding pattern, feed presentation

INTRODUCTION

Feeding patterns of dairy cattle are influenced by the manner in which feed is presented. Providing concentrate and forage as separate components encourages rapid intake of the concentrate component at the time of feed delivery before consuming forage in both growing heifers (DeVries and von Keyserlingk, 2009; Greter et al., 2010a) and adult cattle (Maekawa et al., 2002). In contrast, providing concentrate and forage as a TMR to heifers results in increased daily feeding time, lower rates of intake, and longer meals compared with providing these feed types as separate components (DeVries and von Keyserlingk, 2009). Similarly, adult cattle provided a TMR spend more time eating at a lower rate of intake compared with cattle provided forage and concentrate as separate ingredients (Maekawa et al., 2002). Heifers provided a TMR also have more evenly distributed diurnal feeding patterns than heifers provided separate components (DeVries and von Keyserlingk, 2009; Greter et al., 2010a). Evidence suggests that the effect of feed presentation on intake patterns may affect rumen health, given that intake of concentrate without adequate physically effective fiber results in rapid fermentation and decreased rumen pH, increasing the risk of ruminal acidosis (Beauchemin et al., 2002; Krause and Oetzel, 2006). Also, rumen pH decreases following meals, with the extent of the decline increasing with meal size (Allen, 1997; Bach et al., 2007). Thus, feeding patterns exhibited by cattle fed a TMR encourage moderation of rumen fermentation.

When young calves have access to concentrate and forage, these components are commonly presented separately (Vasseur et al., 2010). Intake of concentrate

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provides energy for growth (Hill et al., 2008) and supports the development of rumen papillae (Tamate et al., 1962), whereas intake of hay alongside concentrate improves feed efficiency (Coverdale et al., 2004) and the rumen environment (Suárez et al., 2007; Khan et al., 2011). However, no work to date has examined how the manner in which concentrate and hay are presented—separately or as a mixture—affects the feeding patterns of young calves around the time of weaning.

Furthermore, feeding experiences early in life may influence development of feeding behavior in young ruminants, affecting feed preferences (Nolte et al., 1990) and feeding motor skills (Arnold and Maller, 1977; Provenza and Balph, 1987). Interestingly, Greter et al. (2010b) found that weaned heifers previously exposed to a top-dressed ration (grain concentrate placed on top of forage) spent more time feeding in response to fresh feed delivery after transition to a TMR compared with heifers previously fed the TMR. Greter et al. (2010b) speculated that this effect reflected the persistence of feeding patterns learned while heifers were fed the top-dressed ration. These results suggest that if feeding patterns of dairy calves are influenced by feed presentation, the potential may exist for differences in feeding patterns to persist once all animals are later provided a mixed ration.

Therefore, the objectives of this study were to assess the effect of feed presentation (hay and concentrate provided as separate components or a mixed ration) on the feeding patterns of dairy calves during the milk feeding stage and around the time of weaning, and to assess whether any differences in feeding patterns persist after transition to a common mixed ration. Our first hypothesis was that providing a mixed ration may result in more evenly distributed diurnal patterns of feeding behavior and a reduced response to feed delivery compared with providing separate feed components. Second, we hypothesized that prior exposure to feed types as separate components may result in longer-term differences in feeding patterns upon transition to the mixed ration compared with calves previously exposed to the mixed ration.

MATERIALS AND METHODS

Animals and Housing

This study was completed concurrently with another study (Miller-Cushon et al., 2013), in which the effect of feed presentation on the development of feed sorting behavior was assessed. Thus, calf management is described in detail by Miller-Cushon et al. (2013). In brief, 20 male Holstein calves were used in this study. Calves were housed within individual pens (1.2 × 1.8 m;

width × depth) at the University of Guelph Kemptville Campus Dairy Education and Research Centre (Kemptville, ON, Canada) and were managed according to the standard operating procedures of this research station, in accordance with guidelines set by the Canadian Council on Animal Care (2009). The front of each pen had 2 openings for access to feed pails (diameter = 25.4 cm, height = 23.0 cm, capacity = 8 L) mounted on the outside. For the first 7 wk of life, all calves were fed milk replacer (Shur-Gain High Performance Milk Replacer; Nutreco Canada Inc., Guelph, ON, Canada) via an artificial teat (Peach Teats, Skellerup Industries Ltd., New Zealand). All calves were fed twice daily at 0800 and 1600 h a fixed amount of 8 L/d (1.2 kg of DM) for the first 4 wk. Calves were weaned by reducing the amount of milk replacer offered to 6 L/d (0.9 kg of DM) during wk 5, 4 L/d (0.6 kg of DM) during wk 6, and incrementally reduced during wk 7 (in d 1 to 4, calves were offered 3 L/d and in d 5 to 7, calves were offered 2 L/d).

Experimental Design and Treatments

Upon enrollment in the study, calves were randomly assigned to 1 of 2 feed presentation treatments. The treatment diets were (1) concentrate and chopped hay (<2.5 cm) offered at a ratio of 7:3 as a mixture (**MIX**), and (2) concentrate and chopped hay (<2.5 cm) offered at a ratio of 7:3 as separate components (**COM**). These diets were provided ad libitum. Actual orts were similar between treatments: in wk 8, 17.0 ± 3.1% of offered DM ($P = 0.4$). For calves fed COM, concentrate orts were 12.2 ± 5.2% of offered concentrate DM (mean ± SD) and hay orts were 25.5 ± 8.5% of offered hay DM. The front of each pen had 2 openings for access to feed pails (diameter = 25.4 cm, height = 23.0 cm, capacity = 8 L) mounted on the outside. Calves remained on their respective feed presentation treatments throughout the milk-feeding stage (wk 1 to 7) and for 1 wk following removal of milk (wk 8).

Following the period of feed presentation exposure in wk 1 to 8, all calves were offered the MIX diet for an additional 3 wk (wk 9 to 11) to assess the longer-term effects of prior exposure to different feed presentations.

On the days on which behavior was recorded from video, feed intake was determined by weighing the quantity of feed provided and the amount of feed refused. For determination of DMI on these days, fresh feed was sampled weekly and individual orts from each calf were sampled twice weekly (on d 1 and 4), just before removal and delivery of fresh feed. For calves fed COM, weekly samples were taken of both concentrate and hay in wk 1 to 8. Samples taken for DM analysis were oven-dried at 55°C for 48 h.

Behavioral Observations and Calculations

Behavior of calves was recorded throughout the study using 8 color video cameras (Day/Night Camera, model no. WV-CP504; Panasonic, Osaka, Japan) fitted with an F0.95/2.8- to 8-mm lens (Fujinon CCTV lens, Fuji, Tokyo, Japan). Cameras were connected to a digital video recorder (Digital Disk Recorder, model no. WJ-HD616K, Panasonic) set to record at 7.5 images/s. Cameras were positioned above the pens such that each individual pen was fully visible from one of the cameras (placed approximately 2 m in front of the pens and 4 m from the pen floor). Four red lights (100 W) were spaced evenly between cameras and placed on a timer to provide enough light to record during nighttime hours.

Calves were observed individually for the first 4 d of wk 6 (during the milk-feeding stage, while exposed to their respective feed presentation treatments), wk 8 (after milk weaning, while exposed to their respective feed presentation treatments), and wk 9 and 11 (when all calves were consuming the MIX ration). In all weeks, instantaneous scans were performed at intervals of 30 s (as validated previously by Miller-Cushon and DeVries, 2011) for solid feed intake (defined as taking place when a calf's head was lowered in the feed bucket). For COM calves in wk 6 and 8, it was noted whether they were feeding from the bucket offering hay or concentrate. Data obtained from instantaneous recording were used to approximate behavior throughout the day by assigning a 30-s block of time to the time point of each scan when the calf was feeding, as validated and described by Miller-Cushon and DeVries (2011). On the days on which behavior was recorded from video, feed intake was determined by weighing the quantity of feed provided and the amount of feed refused. For determination of DMI on the calves on these days, fresh feed was sampled weekly and individual orts from each calf were sampled twice weekly (on d 1 and 4), just before removal and delivery of fresh feed.

Meal analysis was performed on the 4 d of feeding time data collected for individual calves in each observation week. Meal criteria (minimum duration of a time interval between meals) were determined for individual calves in each week using a software package (MIX 3.1.3; MacDonald and Green, 1988). The nonfeeding time intervals between recorded periods of time spent feeding were $\log_{10}$ -transformed, and their frequency distribution was approximated using 2 normal distributions. As described in detail by DeVries et al. (2003), the meal criterion was chosen as the time point at which the curve of one normal distribution intersected the second normal distribution, with nonfeeding time intervals shorter in duration than the point of intersection oc-

curing within meals and those longer in duration than the point of intersection occurring between meals. For calves fed COM in wk 6 and 8, meals often consisted of feeding from both feed buckets. Thus, meal analysis was performed for combined hay and concentrate feeding times for COM calves. However, DMI and feeding time were summarized separately for hay and concentrate, and rate of intake (intake/feeding time) was calculated separately for each feed component. Across all calves, solid feed meal criteria averaged 17.2 ± 3.8 min (mean $\pm$ SD) throughout the study and were similar between treatments ($P = 0.8$) and over time ($P = 0.2$).

Meal criteria determined for each calf in each recorded week were used to calculate daily meal frequency and total daily meal duration. Daily meal frequency was determined by counting the number of intervals between visits to the feed pail (or teat) that exceeded the meal criterion calculated for each calf. Total daily meal duration was calculated as the sum of all recorded feeding time (total daily feeding time) and all nonfeeding time periods shorter than the meal criterion. Data from meal analysis (total daily feeding time, daily meal frequency, total daily meal duration) were also used, in combination with values for daily intake corresponding to observation days, to generate values for average meal duration (total daily meal duration/meal frequency) and rate of intake (intake/feeding time).

Feeding behavior data obtained from video were also used to generate diurnal patterns of feeding activity in each week. Time spent feeding or engaged in a meal was summed by hour for each calf, day, and week. For calves fed COM in wk 6 and wk 8, diurnal patterns were also generated for hay and concentrate feeding time by summarizing feeding time separately for each feed component.

Statistical Analyses

One calf (on COM treatment) was removed from the study during wk 6 for health reasons unrelated to the study; thus, data from only 9 COM calves was analyzed in wk 7 to 11.

All data were summarized for each calf in each week in which data were collected and analyzed separately by time period: milk feeding stage (wk 6), postweaning while on respective feed presentation treatments (wk 8), and postweaning while offered the common MIX ration (wk 9 and wk 11). Data were analyzed using the MIXED procedure of SAS (SAS Institute, 2003). In wk 6 and wk 8, the model included the fixed effects of treatment and the random effect of calf within treatment. Data from weeks in which all calves were offered the MIX ration (wk 9 and wk 11) were analyzed treating week as a repeated measure. The model

included the fixed effects of week, treatment, and week $\times$ treatment interaction, and the random effect of calf within treatment. Compound symmetry was selected as the variance-covariance matrix structure on the basis of best fit according to Schwarz's Bayesian information criterion. For calves fed COM, the difference in rate of intake and feeding time between feed components was analyzed within calf using dependent group *t*-tests (SAS Institute, 2003).

For analyses of diurnal patterns of feeding activity, data were summarized by calculating the mean hourly total of feeding time for each calf and hour across the 4 d of observation in each week. Data were analyzed separately in each week using the MIXED procedure of SAS (SAS Institute, 2003), treating hour as a repeated measure. The model included the fixed effects of hour, treatment, and hour $\times$ treatment interaction, and the random effect of calf within treatment. The autoregressive model was selected as the variance-covariance matrix structure for diurnal pattern data on the basis of best fit according to Schwarz's Bayesian information criterion. For calves fed COM in wk 6 and 8, diurnal patterns of hay feeding time and concentrate feeding time were analyzed similarly, with a model including the fixed effects of hour, feed type, and hour $\times$ feed type interaction.

Assumptions of normality and homogeneity of variance were verified by plotting residuals from the model against predicted values. All values reported are least squares means. Significance was declared at $P \leq 0.05$, and trends reported if $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

Several recent studies have investigated the effect of manner of presentation of concentrate and forage on the performance and feeding behavior of weaned heifers around 5 to 7 mo of age (DeVries and von Keyserlingk, 2009; Greter et al., 2010a,b). The calves in the present study were exposed to different feed presentations as their initial exposure to solid feed; thus, it was unclear

whether they would respond similarly to older more experienced animals.

Before weaning, intake was similar between treatments ($P = 0.67$), but calves fed COM spent less time feeding than calves fed MIX ($P = 0.04$; Table 1). Feed presentation did not affect meal frequency or duration in wk 6 ($P > 0.19$; Table 1). Overall rate of intake was similar between treatments in wk 6 ($P = 0.30$; Table 1). Diurnal patterns of feeding time in wk 6 (Figure 1a) were subject to a treatment effect ($P < 0.001$), due to calves fed MIX having greater daily feeding time (Table 1). However, no treatment $\times$ hour interaction ($P = 0.25$) was observed, with calves fed MIX and COM exhibiting peaks in activity at similar times of day (Figure 1a). The subtle effect of feed presentation on feeding patterns in the week before weaning is perhaps not surprising, due to the low solid feed intake before weaning (Table 1). Solid feed intake before weaning depends on the quantity of milk provided (Appleby, 2001; Terré et al., 2007). Thus, the effect of feed presentation on preweaning solid feed intake patterns may be more pronounced when calves are offered less milk than that provided in the present study.

As solid feed intake increased in the week after weaning (wk 8), feed presentation had a greater effect on feeding patterns (Table 1). Calves fed COM spent less time feeding ($P = 0.01$) and had a greater overall rate of intake ($P = 0.04$). Calves fed COM also tended to have shorter meals than calves fed MIX ($P = 0.09$). Providing a TMR compared with separate components has also been found to increase daily feeding time in adult cattle and weaned heifers (Maekawa et al., 2002; DeVries and von Keyserlingk, 2009) and to tend to increase meal duration in heifers (DeVries and von Keyserlingk, 2009). Similar results of feed presentation on the feeding behavior of ruminants have been reported in "cafeteria" feeding systems, in which a greater variety of feed types is provided: Görgülü et al. (2008) reported that goats provided 6 feed types as separate components had shorter meals and greater intake rates than animals provided the ingredients as

Table 1. Effect of feed presentation treatments on intake and meal characteristics in the week before (wk 6) and the week after (wk 8) weaning^{1,2}

Item	Week 6				Week 8			
	MIX	COM	SE	<i>P</i> -value	MIX	COM	SE	<i>P</i> -value
DMI (kg/d)	0.45	0.38	0.061	0.67	1.99	1.91	0.14	0.71
Feeding time (min/d)	56.7	46.8	5.6	0.04	174.0	139.1	8.6	0.01
Meal frequency (no./d)	10.5	11.7	0.73	0.26	11.6	12.7	0.86	0.35
Meal duration (min)	13.3	11.2	1.14	0.19	25.6	21.0	1.9	0.09
Rate of intake (g/min)	7.7	8.2	0.86	0.30	11.5	14.7	1.07	0.04

¹Data are averaged by week for each calf per treatment (n = 10 for MIX, n = 10 for COM in wk 6 and n = 9 for COM in wk 8).

²MIX = calves provided a mixture of 70% concentrate and 30% chopped hay; COM = calves provided concentrate and chopped hay in separate buckets.

Figure 1. Diurnal patterns of total feeding time of calves provided concentrate and chopped hay as a mixture (MIX) or as separate components (COM) in (a) the week before weaning (wk 6) and (b) the first week after weaning (wk 8). Feeding time is summarized by hour, with data averaged across 4 d of observation/week for each calf per treatment ($n = 10$ for MIX and $n = 9$ for COM).

a TMR, whereas providing 4 separate feed ingredients to lambs increased their rates of intake compared with a single diet composed of the same ingredients (Keskin et al., 2004). Feed presentation did not affect growth of the calves in the present study (Miller-Cushon et al., 2013), similar to results reported in weaned heifers (Greter et al., 2010a).

Considering feeding behavior data for concentrate and hay separately revealed that calves fed COM spent more time consuming hay than concentrate in wk 6 (30.8 vs. 16.0 min/d; SE = 2.5, $P = 0.0013$) and a similar amount of time consuming hay and concentrate in wk 8 (69.8 min/d; SE = 6.3, $P = 0.32$). The change in proportion of time spent consuming the separate feed components corresponds to an increase in concentrate intake relative to hay intake in wk 8 (approximately

80% of DMI) compared with wk 6 (approximately 60% of DMI), as described by Miller-Cushon et al. (2013). Calves fed COM consumed 0.12 ± 0.05 (mean $\pm$ SE) kg/d of hay and 0.28 ± 0.17 kg/d of concentrate in wk 6 and 0.35 ± 0.08 kg/d of hay and 1.74 ± 0.31 kg/d of concentrate in wk 8. It follows that concentrate was consumed at a greater rate of intake than hay in both wk 6 (19.0 vs. 4.2 g/min; SE = 1.5, $P < 0.001$) and wk 8 (23.2 vs. 6.2 g/min; SE = 1.9, $P < 0.001$).

Diurnal feeding patterns in wk 8 (Figure 1b) were subject to a treatment $\times$ hour interaction ($P < 0.001$). Compared with calves fed MIX, calves fed COM spent slightly more time feeding after feed delivery (0900 h) and less time feeding during the rest of the daylight hours. Feeding patterns, as well as greater daily feeding times of calves fed MIX, are similar to previously

reported effects of providing a TMR to weaned heifers (DeVries and von Keyserlingk, 2009; Greter et al., 2010a) and adult cattle (Maekawa et al., 2002). In these studies, differences in diurnal feeding patterns were explained by the observed rapid intake of the concentrate component at time of feed delivery, before consumption of forage, by animals fed separate components or a top-dressed ration compared with a TMR (DeVries and von Keyserlingk, 2009). In contrast to these results, calves fed COM in the present study spent more time consuming hay than concentrate at time of feed delivery and less time consuming hay throughout the rest of the day (feed type $\times$ hour interaction, $P < 0.001$; Figure 2). This indicates that the differences in diurnal feeding patterns compared with calves fed MIX were not driven by motivation to consume concentrate, as observed in older animals.

It is unclear why time spent consuming hay, relative to concentrate, fluctuated over the course of the day (Figure 2), given that the calves had continuous access to both feed types. The much greater rate of intake of concentrate compared with hay (23.2 vs. 6.2 g/d) and the greater time spent consuming concentrate except at time of feed delivery (Figure 2) indicated that calves consumed primarily concentrate for several hours of the day. Interestingly, differences in diurnal intake of hay relative to concentrate similar to the present results were reported in goats by Senn et al. (1990). In their study, goats provided hay and concentrate ad libitum consumed more hay during daylight and at the time when feed was replenished and consumed more concentrate during the night. Based on correlations of meal size with postmeal interval, those authors suggested

that hay intake was triggered by external stimuli, such as feed delivery, but that concentrate intake was regulated by internal satiety signals (Senn et al., 1990). It is also possible that the unbalanced intake of nutrients over the course of the day in the present study may have negatively affected the rumen environment, which, in turn, influenced feeding patterns. The level of forage in the diet affects saliva production and rumen pH (Allen, 1997; Khan et al., 2011), and adult cattle have been found to select in favor of long forage particles to attenuate low rumen pH (DeVries et al., 2008). Although rumen pH was not measured in the present study, it could be speculated that preference for hay at the time of feed delivery was a functional response to a bout of low rumen pH caused by concentrate intake.

It is likely that the diurnal feeding patterns observed in the present study would be influenced by changes in feed characteristics. For example, there is evidence that calves respond differently to different types of hay: Castells et al. (2012) reported that offering ryegrass hay, which was provided in the present study, increased concentrate intake compared with calves not offered a forage source, whereas offering alfalfa hay decreased concentrate intake. Thus, the type of hay provided is likely to affect feeding patterns. In addition, composition of the concentrate may affect feeding patterns, as rumen environment and intake are affected by starch source (Khan et al., 2008) and starch content (Suárez et al., 2006) of the diet.

Contrary to our hypothesis, feeding patterns were similar across treatments once all calves were provided the mixed ration in wk 9 (Table 2). Previous exposure to different feed presentations had no effect on

Figure 2. Diurnal feeding patterns separated by feed component of calves provided concentrate and chopped hay as separate components (COM). Feeding time for concentrate and hay are summarized by hour, with data averaged across 4 d of observation for each calf ($n = 9$) in wk 8 (the first week after weaning).

Figure 3. Diurnal feeding patterns of calves previously provided concentrate and chopped hay as a mixture (MIX) or as separate components (COM), once transitioned to the common MIX ration. Feeding time is summarized by hour, with data averaged across 8 d of observation (4 d in wk 9 and 4 d in wk 11) for each calf per treatment ($n = 10$ for MIX and $n = 9$ for COM).

DMI, daily time spent feeding, meal frequency, meal duration, or rate of intake ($P > 0.63$; Table 2). Time spent feeding was similar between wk 9 and 11 ($P = 0.46$), but rate of intake increased ($P < 0.001$; Table 2). Meal frequency tended to increase ($P = 0.07$; Table 2). Diurnal feeding patterns were also similar ($P > 0.57$) between calves previously exposed to MIX and calves previously exposed to COM (Figure 3). Interestingly, differences between treatments in the extent of feed sorting in wk 9 and wk 11 were reported by Miller-Cushon et al. (2013). Although it might be expected that feed sorting would influence rate of intake and, consequently, feeding time, differences in the extent of feed sorting did not correspond to differences in feeding patterns in the present study. Alternatively, a relationship may exist between the extent of feed sorting and feeding time in cases where the provided ration is more

difficult to sort (e.g., a wetter TMR; Leonardi et al., 2005). Further research is encouraged to investigate the link between feed sorting and feeding patterns.

In contrast to the present results, Greter et al. (2010b) reported that heifers previously provided forage and concentrate as separate components maintained differences in diurnal feeding patterns, spending more time feeding in response to feed delivery for 7 wk following transition to a novel TMR. Given that the longer-term effects reported by Greter et al. (2010b) were only noticeable in the peak feeding period after feed delivery, it is perhaps not surprising that no longer-term effect was reported in the present study. As discussed above, although calves fed COM spent slightly more time feeding at time of feed delivery compared with MIX (Figure 1b) and exhibited diurnal variation in time spent consuming hay relative to concentrate (Figure

Table 2. Effect of prior exposure to different feed presentations on meal characteristics once all calves were provided the mixed ration^{1,2}

Item	Week 9		Week 11		SE	<i>P</i> -value ³		
	MIX	COM	MIX	COM		W	T	W × T
DMI (kg/d)	2.6	2.5	3.9	3.9	0.17	<0.001	0.91	0.98
Feeding time (min/d)	171.9	180.5	170.2	172.8	0.43	0.46	0.63	0.64
Meal frequency (no./d)	12.8	13.3	14.2	13.5	0.78	0.07	0.90	0.17
Meal duration (min)	21.9	21.4	19.4	20.5	1.6	0.15	0.89	0.49
Rate of intake (g/min)	14.9	14.9	23.3	23.8	1.54	<0.001	0.88	0.81

¹Data are averaged by week for each calf per treatment ($n = 10$ for MIX and $n = 9$ for COM).

²MIX = calves provided mixed ration containing 70% concentrate and 30% chopped hay in wk 1–8 of life; COM = calves provided concentrate and chopped hay in separate buckets in wk 1–8 of life.

³W = week on treatment; T = treatment (MIX or COM); W × T = interaction of week and treatment.

2), they did not respond to feed delivery by rapidly consuming the concentrate component, as described in heifers (DeVries and von Keyserlingk, 2009). Further, the persistence of feeding patterns described by Greter et al. (2010b) may have been influenced by the interaction of feed presentation and social factors: calves in the present study were housed individually, whereas heifers in the study conducted by Greter et al. (2010b) were housed in groups of 4. Greter et al. (2010b) reported that greater competition at the bunk persisted in heifers previously provided a top-dressed ration after transition to a TMR. Rate of intake increases in response to competition for food (Nielsen, 1999), suggesting that differences in feeding patterns may be partially mediated by differences in the previously established competitive social environment within the pen. Further research should, thus, investigate whether prior exposure to feed presentation during the preweaning stage results in any longer-term differences in feeding patterns when calves are group-housed rather than housed individually.

CONCLUSIONS

Providing hay and concentrate to young calves as a mixed ration, compared with separate ingredients, increased the time spent feeding before weaning. In the week after weaning, feed presentation influenced feeding behavior to a greater extent, with calves provided the mixed ration having greater daily feeding time, lower rate of intake, and slightly more evenly distributed diurnal feeding patterns. In calves provided separate components, diurnal feeding patterns of concentrate and hay differed, with calves spending more time consuming hay than concentrate at time of feed delivery and more time consuming concentrate throughout the rest of the day. Prior exposure to different feed presentations did not have a longer-term effect on feeding patterns once all calves were provided the mixed ration, suggesting that feed presentation alone does not play a role in development of persistent characteristic feeding patterns, at least for calves housed individually.

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