Effect of feed delivery method on the behavior and growth of dairy heifers

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ABSTRACT

The objective of this study was to determine the effects of feed delivery method on growth, feeding competition, feeding, and sorting behavior of dairy heifers. Thirty-two Holstein heifers (146.2 ± 21.9 d of age) were divided into 8 groups of 4 and exposed to 1 of 2 feed delivery treatments for 13 wk. The treatment rations contained 65% grass/alfalfa haylage and 35% textured concentrate (on a dry matter basis) fed as a 1) total mixed ration (TMR) or 2) top-dressed ration (TDR). Group dry matter intakes were recorded daily throughout the experiment. Feeding behavior, recorded using time-lapse video, and sorting behavior were measured for 7 d during each of wk 1, 5, 9, and 13. Sorting activity was determined through particle size analysis of the fresh feed andorts. The particle size separator separated feed into 4 fractions (long, medium, short, and fine). Sorting of each fraction was calculated as actual intake expressed as a percentage of predicted intake. Heifers were fecal scored for consistency of stool twice weekly using a scale from 1 (liquid) to 4 (solid); heifers were weighed every 2 wk. Neither dry matter intake (7.3 kg/d) nor average daily gain (1.3 kg/d) differed between treatments. Heifers fed the TDR tended to consume less neutral detergent fiber than heifers fed the TMR (4.77 vs. 4.91 kg/d). Heifers fed the TDR sorted against long particles (98.9 vs. 96.0%) and consumed short particles (100.3 vs. 101.1%) to a greater extent than did heifers fed the TMR. Daily feeding time did not differ between treatments (201.0 min/d), but heifers on the TDR did spend more time at the bunk in the 2 h following feed delivery (50.1 vs. 32.0 min/d). Heifers fed the TDR were displaced from the feed bunk more frequently than heifers fed the TMR (17.6 vs. 8.6 times/d), particularly during the 2-h period following feed delivery. Fecal scores were lower for heifers on the TDR (2.7 vs. 3.4). These results suggest that feeding a TMR to replacement dairy heifers may promote a more

even diurnal feeding pattern, minimize feed sorting and feed bunk competition, and promote more solid fecal consistency.

Key words: heifer, feed sorting, feeding behavior, feed delivery method

INTRODUCTION

Raising replacement dairy heifers has one of the highest input production costs and has little benefit to producers until heifers reach lactating age (Hutjens, 2004). Improper management from an early age may contribute to problems with growth and production throughout the life of the animal, further increasing overall costs to the producer (Quigley, 1997).

Much time and effort has been spent on developing efficient feeding management systems for adult dairy cattle. Total mixed ration feeding systems are designed to provide a balanced intake of nutrients to all animals without allowing for individual preferences or sorting (Coppock, 1977). It is now common practice to feed a TMR to all cattle on-farm over the age of 6 mo (DeVries and von Keyserlingk, 2009a). Younger dairy cattle are often provided with a diet composed of a grain concentrate and some form of roughage (Murphy, 2004), presented as separate components or as a top-dressed ration (concentrate spread over roughage). It has been suggested that feeding a TMR to all cattle on-farm would provide a balanced nutrient intake while helping to prevent individual preferences for dietary components and other adverse feeding behaviors from developing (Borland and Kesler, 1979).

DeVries and von Keyserlingk (2009a) demonstrated that growing dairy heifers, when given a choice of ration components or when provided grain concentrate top dressed on hay, rapidly consume the grain concentrate portion of their ration in very few, large meals before consuming the hay portion of their ration. These researchers found that the provision of a TMR increased the distribution of DMI over the course of the day and reduced the amount of sorting against forage and for concentrate. DeVries and von Keyserlingk (2009a) concluded that the provision of a TMR to growing dairy heifers might promote a more balanced intake of nutri-

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ents across the day. These researchers did not consider the longer term effects of these feed delivery methods on the behavior and growth of the heifers or the effect on group-fed heifers.

Greater competition for the concentrate component of a ration, particularly when it is fed separately from forage, has been previously demonstrated in cattle (Hertlin and Frank, 2007; González et al., 2008). Given the consumption patterns of dairy heifers fed a component or top-dressed ration, certain heifers may dominate the feed bunk in a group-feeding situation, particularly during peak feeding times, and consume more concentrate than intended. DeVries and von Keyserlingk (2009a) also speculated that the rapidly consumed, large concentrate meal feeding, or “slug feeding,” exhibited by heifers when fed a top-dressed or a component ration may cause significant postprandial decreases in rumen pH. Slug feeding is widely acknowledged as a negative feeding behavior pattern in adult dairy cows, which may result in SARA (Stone, 2004).

The objective of this study was to determine the effects of exposure to different feed delivery methods on growth as well as on the feeding behavior and feeding competition of prepubertal dairy heifers. Our hypothesis was that heifers fed a TMR would pattern their feeding behavior more evenly throughout the day, engage in less sorting behavior, compete less for their feed, exhibit good rumen health as seen by solid fecal consistency, and gain weight more rapidly than heifers fed a top-dressed ration.

MATERIALS AND METHODS

Animals and Housing

Thirty-two Holstein dairy heifers were used in this study and were acquired, on loan, from a local commercial dairy operation. Heifers were given a broad-spectrum antibiotic (Draxxin, tulathromycin, Pfizer Animal Health, Kirkland, Quebec, Canada) upon arrival to prevent impending respiratory disease due to transport and mixing stresses (Stanton et al., 2010). Heifers were given a 12-d adaptation period following arrival at the research facilities. The heifers were 146.2 ± 21.9 d of age, weighed 165.2 ± 25.1 kg, and measured 102.8 ± 3.8 cm high (mean $\pm$ SD) at the withers at the beginning of the experiment. Heifers weighed 278.4 ± 31.3 kg and measured 117.5 ± 3.2 cm high at the withers at the end of the experiment. Heifers were housed in groups of 4 in 8 pens in the heifer research barn at the University of Guelph, Kemptville Campus (Kemptville, Ontario, Canada) and were managed according to the guidelines set by the Canadian Council on Animal Care

(1993). Use of heifers was approved by the University of Guelph's Animal Care Committee (AUP#08R011). The experiment was conducted between June and September 2008. The pens, located in a naturally ventilated cold barn, consisted of an indoor sawdust-bedded pack area (3.6×10.9 m; width $\times$ depth) and an outdoor concrete run (3.6×16.4 m). Bedding material was replenished as needed. Feed bunks were located along the front of each pack area within each pen and measured 1.35 m in length, allowing for 0.34 m of bunk space per heifer. The heifers were provided ad libitum access to feed. Orts were cleaned out of the feed bunks at 1030 h each day, with new feed delivered once daily at 1200 h. Water was available ad libitum through a water bowl in each pen. Heifers were also given ad libitum access to trace mineral salt blocks (Windsor TM Stock Salt, The Canadian Salt Company Ltd., Pointe-Claire, Quebec, Canada).

Experimental Design and Diets

The number of replicates required per treatment was determined through power analysis (Morris, 1999) for the primary response variables, including feeding and sorting behavior, DMI, and ADG. Estimates of variation for these variables were based on previously reported values (Kertz and Chester-Jones, 2004; DeVries and von Keyserlingk, 2009a). Heifers were divided into 8 groups of 4 that were balanced for age and weight. All heifers were fed a diet consisting of 65% grass/alfalfa haylage and 35% commercial heifer grower textured concentrate (Table 1). This ration was formulated according to the NRC (2001) nutrient recommendations for a nonbred Holstein heifer growing at 1.0 kg/d. During the adaptation period, dietary components were fed separately to prevent sorting behavior. Following the adaptation period, groups were randomly assigned to 1 of 2 treatment diets: 1) TMR or 2) top-dressed ration (TDR), in a completely randomized design. Heifers remained on their respective treatments for 13 wk.

Haylage was delivered each day via a mixer wagon. The necessary amounts of haylage and concentrate were manually weighed out for each pen. For the TMR treatment, the haylage and concentrate were thoroughly mixed on the cement floor in front of each feed bunk for 5 min using a pitchfork. After mixing was complete, feed was placed into the feed bunk. For the TDR, haylage was placed into the feed bunk, and then the concentrate component was spread on top of the forage. The total amount of feed offered was adjusted daily to ensure 5 to 10% Orts per pen. The actual Orts averaged $4.5 \pm 4.1\%$ (mean $\pm$ SD) DM of offered feed over the course of the experiment.

Table 1. Chemical composition and particle size distribution of the experimental ration and components (mean $\pm$ SD)

Composition	Concentrate ¹	Haylage	Ration ^{2,3}
Chemical composition ⁴			
DM (%)	91.8 $\pm$ 0.4	41.9 $\pm$ 2.3	53.3 $\pm$ 4.1
OM (% of DM)	90.5 $\pm$ 1.0	90.7 $\pm$ 1.2	91.5 $\pm$ 0.7
CP (% of DM)	20.2 $\pm$ 1.7	19.7 $\pm$ 1.0	19.4 $\pm$ 0.4
ADF (% of DM)	9.0 $\pm$ 0.5	34.1 $\pm$ 2.1	25.4 $\pm$ 3.0
NDF (% of DM)	20.9 $\pm$ 0.7	42.9 $\pm$ 2.4	35.2 $\pm$ 2.7
NFC (% of DM)	42.9 $\pm$ 2.4	26.3 $\pm$ 2.6	34.9 $\pm$ 3.2
Particle size ⁵ (%)			
Long	—	20.3 $\pm$ 4.2	10.8 $\pm$ 3.6
Medium	—	46.7 $\pm$ 5.6	43.0 $\pm$ 5.3
Short	—	30.3 $\pm$ 2.1	41.0 $\pm$ 5.7
Fine	—	2.8 $\pm$ 0.5	5.2 $\pm$ 1.4

¹Supplied by Rooney Feeds Ltd. (Iroquois, Ontario, Canada), containing (on as-is basis): 34.7% steam-flaked corn, 34.0% whole barley, 15.0% dairy supplement premix (40% protein), 9.0% hi-protein soymeal, 3.5% Monensin pellet, 1.5% molasses, 1.0% dicalcium phosphate, 0.5% calcium carbonate, 0.5% salt, and 0.3% magnesium oxide.

²Containing, on a DM basis, 35% concentrate and 65% grass/alfalfa haylage.

³Chemical composition (DM basis) of long particles was 44.2 $\pm$ 1.5% NDF and 3.1 $\pm$ 0.5% starch, that of medium particles was 33.5 $\pm$ 2.9% NDF and 16.9 $\pm$ 2.3% starch, that of short particles was 32.6 $\pm$ 1.5% NDF and 17.0 $\pm$ 1.8% starch, and that of fine particles was 25.5 $\pm$ 2.3% NDF and 15.6 $\pm$ 3.4% starch.

⁴Values were obtained from chemical analysis of TMR samples. OM = 100 - % ash. NFC = 100 - (% CP + % NDF + % fat + % ash).

⁵Particle size determined by Penn State Particle Separator, which has a 19-mm screen (long), 8-mm screen (medium), 1.18-mm screen (short), and a pan (fine).

Experimental Measurements

Group intakes were recorded daily throughout the study by weighing the amount of feed offered and amount of feed refused. These data were used to calculate daily DMI (kg/d) on a pen basis. Heifers were weighed and measured on the same weekday at the same time every 2 wk to measure weight gain and growth rate (ADG). Additionally, heifers were fecal scored for consistency of feces twice weekly using a scale from 1 (liquid) to 4 (solid; Ireland-Perry and Stallings, 1993).

Feeding and competitive behaviors were monitored using time-lapse video equipment continuously for all 7 d of each recording week: wk 1, 5, 9, and 13 of the study. Heifers were recorded using 1 video camera (Panasonic WV-BP330; Osaka, Japan) per 2 pens, a time-lapse video cassette recorder (Panasonic AG-6740), and a video multiplexer (Panasonic WJ-FS 616). Video cameras were located 3.2 m above the feed bunk between 2 pens. Red lights (100 W), hung adjacent to the cameras, were used to facilitate recording at night. Individual heifers were identified within each pen with unique neck collars.

The amount of time spent feeding during all 7 d of each recording week was scored for individual heifers from video using instantaneous scan sampling every 10 min. For each scan, a heifer was recorded as feeding when its head was completely past the feed rail and over the feed. These scans were then used to calculate

the total time spent feeding by multiplying the number of scans by 10 (Endres et al., 2005). Time spent feeding was then calculated for each heifer for each day of the recording weeks (min/d). Additionally, to detect changes in the diurnal pattern of feed bunk attendance, these scans were used to calculate the percentage of heifers feeding over the course of each 24-h period. Based on these diurnal patterns, we also calculated feeding time for each heifer during the 2-h period (period of peak feeding activity) following delivery of feed, when feeding activity was greatest.

Feeding competition, recorded as displacements from the feed bunk while feeding, was measured on d 2, 4, and 6 of each recording week. A displacement was noted when a butt or a push from the actor (instigator) resulted in the complete withdrawal of the reactor's head from beneath the feed rail (DeVries et al., 2004). These observations were used to calculate the number of times each heifer was displaced from the feed bunk each day. Further, these data were used to calculate, according to DeVries et al. (2004), an agonistic interaction success rate (**AISR**) for each individual heifer. The AISR was calculated as follows: number of individuals subdominant to focal heifer/number of individuals dominant to focal heifer + number of individuals subdominant to focal heifer $\times$ 100%.

During each of the recording weeks, when feeding behavior was monitored, standing and lying behavior were also measured. Daily lying times of individual heifers

were obtained via electronic data loggers (Hobo Pendant G Data Logger, Onset Computer Corp., Pocasset, MA). These small devices were attached to the hind leg of each heifer using veterinary bandaging (Vetrap Bandaging Tape, 3M, St. Paul, MN) and measured the orientation of the leg at 1-min intervals. These data were summarized to calculate the average lying time and the average number of lying bouts for each heifer.

Feed Sampling and Analysis

A representative sample of the ration was collected for particle size separation at the time of feed delivery each day during the recording weeks. Orts samples, for particle size separation, were taken from each feed bunk at the end of each recording day when the feed bunks were cleaned out. Samples of the TMR and Orts from each pen were taken twice weekly throughout the experiment for DM and chemical analysis. Samples of the dietary components were also taken once a week for DM and chemical analysis. Duplicate samples of forage components were taken during the recording weeks for particle size separation. All samples were immediately frozen at -20°C until they were further analyzed.

Samples for particle size separation were separated using the 3-screen (19, 8, and 1.18 mm) Penn State Particle Separator (**PSPS**; Kononoff et al., 2003). Samples were separated into 4 fractions: long (>19 mm), medium ($<19, >8$ mm), short ($<8, >1.18$ mm), and fine (<1.18 mm) particles. After separation, the DM of each separated fraction was determined by oven drying at 55°C for 48 h.

Dry matter content of samples taken for chemical analysis was determined by drying samples in a forced-air oven at 55°C for 48 h. These samples, plus the dried TMR particle fractions, were then ground to pass through a 1-mm screen (Wiley mill, Arthur H. Thomas Co., Philadelphia, PA). The ground samples were then sent to Cumberland Valley Analytical Services Inc. (Maugansville, MD) for analysis of DM (135°C ; AOAC, 2000; method 930.15), ash (535°C ; AOAC, 2000; method 942.05), ADF (AOAC, 2000; method 973.18), NDF with heat-stable α -amylase and sodium sulfite (Van Soest et al., 1991), CP ($\text{N} \times 6.25$) (AOAC 2000; method 990.03; Leco FP-528 Nitrogen Analyzer, Leco, St. Joseph, MI), and starch (Holm et al., 1986).

Calculations and Statistical Analysis

Sorting was calculated as the actual DMI of each fraction of PSPS expressed as a percentage of the predicted DMI of that fraction (Leonardi and Armentano, 2003). The actual intake of each individual fraction was calculated as the difference between the DM amount of each

fraction in the offered feed and that in the refused feed. The predicted intake for each individual fraction was calculated as the product of the DMI of the total diet multiplied by the DM percentage of that fraction in the offered diet. Values equal to 100% indicate no sorting, $<100\%$ indicate selective refusals (sorting against), and $>100\%$ indicate preferential consumption (sorting for).

For analyses of treatment effects, the pen was considered the experimental unit. The DMI and sorting behavior data were calculated on a pen basis and averaged by week for the entire experiment. Growth (ADG) was averaged on a pen basis by 2-wk period for the entire experiment. Pen variance in ADG (**ADG_v**) was calculated by averaging, per pen, the absolute difference between individual heifer ADG and pen mean ADG. Feeding, competitive, and lying behavior data were averaged across heifers within each pen and days to create one observation per recording week per pen. Data for feed bunk attendance (% of heifers feeding) were summarized by hour for each pen on each treatment.

Preliminary screening of the data revealed that all dependent variables were normally distributed. To test whether sorting of the experimental diets occurred, data for each PSPS fraction was tested for a difference from 100 using *t*-tests within the MIXED procedure of SAS (SAS Institute, 2003). To test for the effect of treatment, all data were analyzed using the MIXED procedure (SAS Institute, 2003), treating week as a repeated measure. The model included the fixed effects of treatment and week, and the random effect of pen within treatment. The variance-covariance error structure was first-order autoregressive, variance components, or first-order heterogeneous autoregressive, depending upon the best fit according to Schwarz's Bayesian information criterion. To test for effect of treatment on feed bunk attendance patterns, these data were analyzed using the MIXED procedure (SAS Institute, 2003), treating hour as a repeated measure. The model included the fixed effects of treatment and hour and the random effect of pen within treatment. The variance-covariance error structure was first-order autoregressive, according to the best fit with Schwarz's Bayesian information criterion. All values reported are least squares means.

To test the hypothesis that socially subordinate heifers would be most affected in their response to the treatments, measures of growth, feeding time, and fecal score were regressed within treatment on the heifer's AISR using the regression procedure (SAS Institute, 2003). Only those statistically significant models are shown. For all analyses, significance was declared at $P \leq 0.05$, and a trend was reported if $0.05 < P \leq 0.10$.

Table 2. Intake and behavior measures from growing dairy heifers on experimental treatments¹

Item	Treatment ²		SE	P-value
	TMR	TDR		
Feeding time (min/d)	199.7	202.3	6.3	0.8
Peak feeding time ³ (min/d)	32.0	50.1	1.1	<0.001
Displacements (no./d)	8.6	17.6	1.0	<0.001
Peak displacements ³ (no./d)	1.9	6.5	0.6	<0.001
Lying time (h/d)	14.3	14.2	0.2	0.8
Lying bouts (no./d)	14.6	14.3	0.2	0.4
Fecal score	3.4	2.7	0.08	<0.001
DMI (kg/d)	7.36	7.29	0.07	0.4
NDF intake (kg/d)	2.61	2.53	0.02	0.03
ADG (kg/d)	1.27	1.25	0.03	0.6
ADGv ⁴ (kg/d)	0.20	0.26	0.03	0.1

¹Data are averaged across 4 pens (4 heifers/pen) on each treatment.

²On a DM basis, 35% concentrate fed top-dressed (TDR) on or mixed with (TMR) 65% grass/alfalfa haylage.

³Peak feeding activity period = 2-h period immediately following feed delivery.

⁴ADGv = pen variance of average daily gain; ADGv was calculated by averaging, per pen, the absolute difference between individual heifer ADG and pen mean ADG.

RESULTS

Analysis of the diurnal feed bunk attendance of heifers showed a treatment by hour interaction ($SE = 0.3$, $P < 0.001$; Figure 1), with an increased percentage of heifers fed the TDR present at the feed bunk during the 2 h after feed delivery (period of peak feeding activity). Although there was no difference in daily feeding time between treatments, heifers fed a TDR spent more time at the feed bunk during the period of peak feeding activity (Table 2). The AISR was negatively correlated with feeding time ($y = -0.4x + 217.3$; $R^2 = 0.27$, $P = 0.04$) and tended to be negatively correlated with peak feeding time ($y = -0.1x + 36.2$; $R^2 = 0.23$, $P = 0.06$) for heifers fed the TMR, whereas there was no relation-

Figure 1. Percentage of heifers present at the feed bunk over a 24-h period (percentage for each 10-min interval during the day) for 2 treatments: 1) TMR and 2) top-dressed ration (TDR). Data were averaged across 28 d for 4 pens (4 heifers/pen) per treatment.

ship between AISR and feeding time ($P = 0.6$) or peak feeding time ($P = 0.9$) for heifers fed the TDR.

The number of displacements, as measured by the number of times a heifer was physically displaced from the feed bunk, was higher for heifers fed the TDR than for those fed the TMR across the day, especially during periods of peak feeding activity (Table 2). Daily lying time and the number of lying bouts of heifers were unaffected by treatment (Table 2).

There was a treatment by week interaction for the sorting of long ($P = 0.04$; Figure 2), medium ($P = 0.02$), and short ($P = 0.03$) particles. Heifers sorted against long particles (>19 mm) to a greater extent when fed the TDR compared with when fed the TMR (Table 3). When provided the TMR, heifers did not sort for or against medium particles, whereas on the TDR, heifers sorted against medium particles (Table 3). Heifers consumed more of the short particles when fed the TDR as compared with when fed the TMR (Table 3). Heifers on the TMR sorted against fine particles, whereas heifers on the TDR sorted for fine particles (Table 3).

Heifers fed the TDR had lower fecal scores than those fed the TMR (Table 2), with lower fecal scores indicating loose stool. However, fecal scores of heifers fed the TMR tended to be positively correlated with AISR ($y = 0.01x + 3.2$; $R^2 = 0.24$, $P = 0.06$), whereas there was no relationship between fecal score and AISR for heifers on the TDR ($P = 0.4$). Even though DMI did not differ between treatments, heifers fed the TDR consumed less NDF than heifers fed the TMR (Table 2). Average daily gain and ADGv were similar between treatments (Table 2). However, the ADG of heifers on the TDR was positively correlated with AISR ($y = 0.002x + 1.2$; $R^2 = 0.33$, $P = 0.02$), whereas there was no relationship

Table 3. Effect of experimental treatments on the sorting (%) of long, medium, short, and fine particles by growing dairy heifers¹

Particle size ²	Treatment ³		SE	P-value
	TMR	TDR		
Long	98.9*	96.0*	0.5	0.006
Medium	100.1	99.4*	0.1	0.002
Short	100.3*	101.1*	0.1	0.004
Fine	97.5*	101.2*	0.4	<0.001

¹Sorting % = $100 \times (\text{particle size } n \text{ DM intake} / \text{particle size } n \text{ predicted intake})$, where n = long, medium, short, or fine particle fraction. Sorting values equal to 100% indicate no sorting; <100% indicate selective refusals (sorting against); and >100% indicate preferential consumption (sorting for). Data are averaged across 28 d for 4 pens (4 heifers/pen) on each treatment.

²Particle size determined by Penn State Particle Separator, which has a 19-mm screen (long), 8-mm screen (medium), 1.18-mm screen (short), and a pan (fine).

³On a DM basis, 35% concentrate fed top-dressed (TDR) on or mixed with (TMR) 65% grass/alfalfa haylage.

*Difference ($P < 0.05$) in sorting values from 100%.

between ADG and AISR in heifers fed the TMR ($P = 0.2$).

DISCUSSION

There was a peak in feeding activity by heifers on both treatments immediately following feed delivery. This feeding pattern is typical for both young and adult dairy cattle (DeVries et al., 2003; DeVries and von Keyserlingk, 2005, 2009a). Daily feeding time was similar between treatments, as was daily lying time. In support of our hypothesis, we found that heifers fed

the TDR spent over 60% more time at the feed bunk during the 2-h period of peak feeding activity following feed delivery. This translated into there being 15% more heifers, on average, at the feed bunk during this period. DeVries and von Keyserlingk (2009a) recently found that heifers fed a TDR consumed greater DM during the period of peak feeding activity following feed delivery compared with heifers fed a TMR. Additionally, this intake pattern was found to be similar to that of the choice-fed heifers, with all concentrate consumed in 2 meals or fewer during this time period (DeVries and von Keyserlingk, 2009a). Based on these results, those researchers speculated that heifers fed a TDR also consumed the concentrate component of their diet, in a slug-feeding pattern, before consuming their forage. It is possible, then, that heifers fed the TDR in the present experiment were also consuming more during peak feeding periods than heifers fed a TMR, likely because of the consumption of the concentrate component of the ration apart from the forage. Data from Quigley et al. (1992) also support the hypothesis that these heifers may have been slug feeding during peak feeding time because calves in that study exhibited similar behavior when fed calf starter and hay separately. This slug-feeding pattern is not surprising because the concentrate component of the ration was much more easily accessible in the TDR than in the TMR. Slug feeding is often described as a negative feeding behavior pattern in adult dairy cows, which may result in SARA (Stone, 2004). Additionally, Quigley et al. (1992) found that there were postprandial decreases in rumen pH in the calves following the slug-feeding incidents. It could be hypothesized that such feeding patterns are learned early in life, as a result of factors such as feed delivery method, and may persist as the animal matures. Further research to address this hypothesis is encouraged.

The negative correlation between AISR and feeding time and the tendency for a negative correlation between AISR and peak feeding time for heifers fed the TMR indicate that dominant heifers spent less time feeding during peak feeding activity and throughout the day than subordinate heifers. Alternatively, access to feed in heifers fed the TDR was unaffected by dominance status. This suggests that there may have been a strong desire to consume the concentrate component of the diet, forcing the subordinate heifers to try to out-compete the dominant heifers to consume the concentrate. It is not surprising, therefore, that heifers fed the TDR exhibited more than twice the number of displacements at the feed bunk per day compared with those fed the TMR, further supporting our hypothesis. This translated into heifers fed the TDR being displaced over 3 times more than heifers fed the TMR during the period of peak feeding activity. In fact, heifers fed the

Figure 2. Sorting activity [$100 \times (\text{long particle intake} / \text{long particle predicted intake})$] of heifers on a TMR or a top-dressed ration (TDR) for long particles (>19 mm). Data were averaged across the 7 d of each week with 4 pens (4 heifers/pen) per treatment. Sorting values equal to 100% indicate no sorting, <100% indicate selective refusals (sorting against), and >100% indicate preferential consumption (sorting for).

TDR performed a greater percentage (37%) of their daily displacements during this period than heifers fed the TMR (22%). This finding provides further evidence that access to the concentrate component of the ration increases the competition level in the pen. Greater competition for concentrate, when it is fed separately from forage, has been previously demonstrated in cattle (Herlin and Frank, 2007; González et al., 2008). Furthermore, feeding competition has been shown to cause heifers to consume fewer meals per day, which are larger and longer in duration (DeVries and von Keyserlingk, 2009b). Although meal data were not measured in this study, it could be assumed that heifers fed the TDR were consuming feed in an intake pattern similar to that of the competitively fed heifers in the DeVries and von Keyserlingk (2009b) study. As a result, the heifers fed the TDR would be consuming large grain meals immediately following feed delivery and fewer overall meals throughout the day. The increased competition observed in the heifers fed the TDR could have a negative long-lasting effect if this behavior persists. Proudfoot et al. (2009) recently demonstrated that feeding competition in transition dairy cows negatively affects feeding and standing behavior, resulting in lower DMI, and potentially increases the risk of lameness or other disease. Further research is, therefore, needed to determine the long-term persistence of such competitive behavior on production and performance of the heifers as they reach breeding and lactating age.

The lack of difference in DMI between treatments is consistent with the results of DeVries and von Keyserlingk (2009a) from their study considering short-term effects of various feed delivery methods. It is important to note that, although there was no difference in DMI, there were differences in diet selection between treatments, suggesting that heifers were consuming different proportions of nutrients. Heifers fed the TDR sorted against long forage particles to a greater extent than heifers fed the TMR for much of the length of the experiment. As a result, the amount of NDF consumed was less for those heifers fed the TDR. Overall, heifers fed the TDR consumed the short particles to a greater extent than heifers fed the TMR. Given that the short fraction of the ration consisted mainly of the concentrate component, this provides further evidence that top dressing increased the accessibility of that fraction of the ration. The slug-feeding pattern seen following feed delivery as well as the greater selection against long forage particles and increased consumption of the concentrate portion of the ration by heifers fed the TDR may result in problems with rumen fermentation, as such feeding patterns have been related to reduced rumen pH in adult dairy cattle (DeVries et al., 2008). Although heifers fed the TDR sorted for fine particles,

and heifers fed the TMR sorted against fine particles, it is unlikely that there was any biological significance of this sorting, because fine particles represented only about 5% of the ration.

Contrary to our hypothesis, the difference in sorting between treatments disappeared by the end of the experiment. The treatment by week interaction for sorting of long, medium, and short particles indicated greater treatment differences during the first week of the experiment. Of particular note was a 6% difference (91.4 vs. 96.8%) between treatments in sorting of long particles during the first week of treatment (Figure 2). These sorting differences between treatments decreased over time as the heifers became accustomed to the feed delivery methods. By the final recording week, there was very little sorting of long particles (98.3 vs. 99.1%) observed on either treatment. This acclimation is of particular interest, because it suggests that the heifers may have adjusted their sorting patterns over time, while remaining consistent in their feeding patterns. This would suggest that feeding patterns developed early on are more likely to be retained, whereas sorting patterns are more flexible over time. Future research in this area should focus on determining what factors may influence this flexibility in sorting behavior.

As heifers fed the TDR competed more for feed, spent more time feeding immediately following feed delivery, selected against longer forage particles and consumed shorter concentrate particles to a greater extent, and had lower NDF intake, it is not surprising that these heifers also had looser stools, as indicated by lower fecal scores throughout the experiment, compared with heifers fed the TMR. Researchers have shown that cattle rapidly consuming concentrate are likely to experience more SARA because of postprandial decreases in rumen pH (Østergaard and Grohn, 2000; González et al., 2008). It is possible that the young dairy heifers in the present study experienced similar effects on rumen pH. Heifers fed the TDR may have experienced an increase in rumen osmolality following the rapid consumption of starch and greater refusal of effective fiber and, thus, increased water movement into the rumen, resulting in diarrhea (lower fecal scores; Kleen et al., 2003). Previous research has shown that loose stool can be used as an indicator of problems with rumen or digestive health and may be used as an indicator of reduced pH (Nocek, 1997; Krause and Oetzel, 2006). Heifers consuming the TMR, conversely, consumed a more balanced diet overall, which would likely contribute to improved digestive health (Coppock, 1977; Borland and Kesler, 1979) and welfare. The positive correlation between AISR and fecal score for the heifers fed a TMR indicates that the more dominant heifers exhibited more solid feces and, thus, may have had better rumen health than

subordinate heifers. Furthermore, the lack of relationship between fecal score and AISR for heifers fed the TDR suggests that all heifers were affected by this feed delivery method, regardless of social status. This may be because of the intake of an unbalanced diet by all heifers within these groups. Unfortunately, the composition of the diet consumed throughout the day was not measured and, therefore, we cannot be certain of what these heifers were consuming following feed delivery. Moreover, it was not possible to measure rumen pH in this study, which could have provided more concrete evidence of SARA. Thus, further research is needed to determine the effect of feed delivery method on rumen pH, and any possible occurrence of SARA, as well as the actual composition of the ration consumed throughout the day.

Despite the ration being formulated according to NRC (2001) recommendations for a nonpregnant replacement Holstein heifer, heifers in this study consumed more feed than predicted (7.3 vs. 6.2 kg/d), resulting in higher energy intake than predicted (18.8 vs. 14.5 Mcal/d). As such, higher ADG than predicted was maintained throughout the trial (1.3 vs. 1.0 kg/d). It was recently summarized by Hoffman et al. (2008) that heifers typically consume 1.0% of their BW in NDF. According to this formula, heifers in the present study should have been consuming, on average, 2.2 kg/d of NDF. The heifers in our study consumed NDF in excess of this amount (1.16% of their BW in NDF), thus contributing to the higher than predicted ADG. Contrary to our hypothesis, there was no difference in ADG or ADGv between treatments. Recent evidence has suggested that lactating dairy cattle affected with SARA are able to maintain similar milk production as unaffected cows (O'Grady et al., 2008). As such, these animals seem able to adapt to metabolic or production challenges and balance resources accordingly. It is possible, therefore, that heifers fed the TDR were able to react in a similar manner and were able to gain, on average, as efficiently as heifers fed the TMR. There was, however, a positive correlation between AISR and ADG in heifers fed the TDR, suggesting that socially dominant heifers gained more than submissive heifers. This is possibly because of higher intake of the concentrate component of the diet as well as fewer displacements from the feed bunk seen in dominant heifers.

CONCLUSIONS

Feed delivery method affects the feeding, sorting, and competitive behaviors of growing dairy heifers. Heifers fed the TDR consumed less NDF, showed greater feed bunk competition, and displayed more liquid fecal consistency. Feeding a TMR to replacement dairy heifers

promoted a more even diurnal feeding pattern, minimized sorting and competitive behaviors, and resulted in more solid fecal consistency. Further research is needed to determine when these behaviors develop and how long they may persist in the life of the animal.

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