REDUCING BETWEEN-COW VARIATION IN NUTRIENT INTAKE

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INTRODUCTION:

Past research in dairy cattle nutrition has focused almost exclusively on the nutrient aspects of the diet, and has led to many discoveries and improvements in dairy cattle health and production. Despite many advances in the field of ruminant nutrition, however, we are still faced with the challenge of ensuring adequate DMI to maximize production and prevent disease, particularly with lactating dairy cows during the transition period. Many of the cows experiencing decreased DMI the pre-partum period fail to make a successful transition to the post-partum diet. Approximately 50% of cows have one or more adverse health events during transition (Ferguson, 2001), so any practices that can help reduce disease at this time are thus of broad relevance to the dairy industry.

One of the interesting aspects of transition disease is the individual variability of cow susceptibility. Despite subjecting all animals to similar management and diets, we still face a certain percentage of animals succumbing to disease while others remain healthy. There is some data to suggest that this may be in part due to high between-cow variability in DMI, and thus nutrient intake. Drackley (1999) reported that coefficients of variation for DMI during the 1st wk postpartum are in the range of 30 to 40%; whereas, the coefficients of variation for DMI after peak lactation typically range between 6 and 10%. Further, McGuffey et al. (1997) reported that a 1% increase in the variation of DMI in the first 21 DIM was associated with a 4% increase in post-calving incidents (dystocia-related, metabolic, or digestive disorders). Another recent example is that for every 1 kg decrease in DMI during the week before calving, cows were nearly 3 times more likely to be diagnosed with severe metritis at 7 d post partum (Huzzey et al., 2007). Even though we do not yet know the causal relationship between these factors, we do know that ensuring adequate DMI is important to maintaining milk production and health. In the work described by Huzzey et al. (2007), feeding time was positively related to DMI, especially for cows with severe metritis. It follows, therefore, that management and housing practices that allow for increased feed bunk access will positively affect feeding time, and thus improve DMI and possibly reduce disease.

In addition to ensuring consistent nutrient intake through reducing day-to-day variation in DMI, we are also challenged with maintaining consistent nutrient intake within the day. To meet the demands of high producing cattle, we supply them with an energy dense diet in the form of a total mixed ration (TMR). Nocek and Braund (1985) suggested that feeding a TMR is the optimal way to provide the balance of nutrients that ruminants need to maintain a stable and efficient microbial population. Total mixed rations are designed to provide dairy cattle with a consistent supply of nutrients over the course of the day as well as minimize food preferences among animals, which help prevent over consumption of grain that may increase the risk for acidosis.

Even when providing feed as a TMR cows have been shown to preferentially sort for the grain component of a TMR and discriminate against the longer forage components. This type of sorting behaviour results in an increase in the fibre content of the remaining feed (Leonardi and Armentano, 2003). Sorting of the diet can lead to the cows consuming an inconsistent ration, as suggested by Stone (2004). Recent research has shown that those cows at high risk for acidosis, sorting against long fibre particles was associated with lower rumen pH (DeVries et al., in press). This is particularly troublesome for early lactation cows, where greater sorting of a higher concentrate, lower fiber diet, coupled with rapidly increasing DMI (Kertz et al., 1991), will exacerbate the intake of highly fermentable carbohydrates and refusal of physically effective fiber, and thus increase the risk of ruminal acidosis. This in turn may result in inconsistent feed intake, poor feed efficiency, reduced feed digestibility and protein synthesis, and increased incidence of diseases. Alternatively, sorting of the TMR can reduce the nutritive value of the TMR remaining in the feed bunk, particularly in the later hours past the time of feed delivery (DeVries et al., 2005). This may be detrimental for those cows that do not have access to feed at the time when it is delivered. In such cases, these cows may not be able to maintain adequate nutrient intake to maintain high levels of milk production (Krause and Oetzel, 2006). It follows, therefore, that strategies to reduce feed sorting, and promote equal feed bunk access by all cows, will decrease the compositional variation in feed eaten by dairy cows.

In this paper we will describe management and housing factors that will encourage feed bunk access, reduce feed sorting, and thus reduce the variation in nutrient intake in dairy cattle. First, we will describe factors that control the feeding behavior patterns of group-housed dairy cows. Next, we will review studies showing how feeding management and feed bunk design can be altered in ways that reduce competition at the feed bunk, thereby allowing for increased access to feed for all animals. Finally, we will discuss how feed sorting can be managed.

FEEDING BEHAVIOR PATTERNS:

It has typically been accepted that dairy cattle exhibit a diurnal feeding pattern where the majority of feeding activity occurs during the day, particularly around sunrise and sunset (Albright, 1993). However, this observation is almost exclusively based on the feeding patterns exhibited by grazing cattle. To gain a better understanding of how management factors influence dairy cattle behavior, we examined the normal feeding pattern of group-housed lactating cows fed a TMR ad libitum (DeVries et al., 2003). In this study we found that cows consumed an average of 7.3 meals/d and had an approximate daily meal time of 6 h/d. We also found that the diurnal feeding pattern was mostly influenced by the time of feed delivery, feed push-up and milking. Further, it was clear that the most dramatic peaks in feeding activity occur around the time of feed delivery and the return from the milking parlor.

To follow up on this, we set out in an experiment to determine which of these management practices is the primary factor stimulating dairy cattle to go to the feed bunk (DeVries and von Keyserlingk, 2005). We tested this objective by separating feed delivery and milking times by 6 h. When animals were fed 6 h post milking, they increased their total daily feeding time by 12.5%. This change was predominantly driven by a small decrease in feeding time during the first hour post-milking and a very large increase in feeding time during the first hour immediately following the delivery of fresh feed (Figure 1). These results indicate that the management practice of feed delivery acts as the primary influence on the daily feeding pattern of lactating dairy cows and not, as previously thought, the time of day.

FEEDING BUNK MANAGEMENT:

One of the most common feeding management practices believed to stimulate feeding activity is feed push-up. When fed a TMR, dairy cows have a natural tendency to continually sort through the feed and toss it forward where it is no longer within reach. This is particularly problematic when feed is delivered via a feed alley and, thus, producers commonly push the feed closer to the cows in between feedings to ensure that cows have continuous feed access. In an observational study Menzi and Chase (1994) noted that the number of cows feeding increased after feed push up, however they concluded that feed push ups had “minor and brief effects” in comparison to milking on the feed bunk attendance. In a more recent study, we tested the stimulatory effect of feed push-up by increasing the number of push ups during the late evening and early morning (DeVries et al., 2003). In that study we found that the addition of extra feed push ups did little to increase feeding activity. However, push up does play a vital role in ensuring that feed is accessible when cows want to eat.

As mentioned above, delivery of fresh feed is clearly an important factor in stimulating cows to eat. Thus, the frequency of feed delivery should influence the feeding patterns of lactating dairy cows. To test this prediction, we conducted a study to determine whether increasing frequency of feed delivery affects the behavior of group-housed dairy cows (DeVries et al., 2005). In this study, we compared the delivery of feed once per day (1x), twice per day (2x), and four times per day (4x). Increasing the frequency of feed provision increased total daily feeding time, as well as increased the distribution of feeding time throughout the day, indicating that cows had more equal access to feed throughout the day when provided feed more frequently. Frequency of feed delivery had no effect on the daily lying time of the cows or the total number of aggressive interactions at the feed bunk. However, we did find that subordinate cows were not displaced as frequently when fed more often, indicating that these cows would have greater access to feed, and particularly fresh feed, when the frequency of feed delivery is high.

FEED BUNK DESIGN:

One of the specific objectives of cattle housing is to provide a comfortable environment that will allow cows to meet their behavioral and physiological needs (Phillips, 2001). There are several aspects of the feeding environment that have the potential to influence the ability of cows to access feed, including the amount of available feed bunk space per animal and the physical design of the feeding area.

Reduced space availability has been shown to result in increased aggressive behavior in cattle (Kondo et al., 1989). When feed bunk space is limited, increases in aggressive behavior are thought to limit the ability of some cows to access feed at times when feeding motivation is high, particularly after the delivery of fresh feed. We set out to determine if increased space availability at the feed bunk (40 vs. 20 inches/cow) improves access to feed and reduces social competition (DeVries et al., 2004). When cows had access to more feed bunk space there was at least 60% more space between animals and 57% fewer aggressive interactions while feeding. These changes in spacing and aggressive behavior in turn allowed cows to increase feeding activity throughout the day. The increase in feeding activity was especially noticeable during the 90 minutes after fresh feed was provided. During this period, cows at the 40 inches/cow stocking density increased their time at the feeder by 24%, and this effect was strongest for subordinate animals.

In addition to the amount of available feed bunk space, the physical design of the feeding area can influence feeding behavior. One of the most obvious features of the feeding area is the physical barrier that separates the cow and the feed. Different feed barriers are all designed with the intention of allowing cows equal access to feed, however, some designs can limit the cows' ability to freely access feed and increase the frequency of aggressive interactions at the feed bunk. Many producers believe that a feed line barrier that provides some sort of separation between cows (e.g. headlocks) will reduce competition and improve feed access. To test this hypothesis, we completed an experiment comparing a post-and-rail versus a headlock feed line barrier on the feeding and social behavior of dairy cows (Endres et al., 2005). Average daily feeding time did not differ when cows had access to feed via headlocks (271.7 ± 3.8 min d-1) compared to the post and rail barrier (277.8 ± 3.8 min d-1). However, during periods of peak feeding activity (90 min after fresh feed delivery) cows that had lower feeding times relative to group mates when using the post-and-rail barrier showed more similar feeding times to group mates when using the headlock barrier. There were also 21% fewer displacements at the feed bunk when cows accessed feed by the headlock barrier compared to the post-and-rail barrier. These results suggest that using a headlock barrier reduces aggression at the feed bunk and improves access to feed for socially subordinate cows during peak feeding periods.

To determine how the amount of available feed bunk space and the physical design of the feeding area interact with one another, we followed up on our previous studies with a trial that examined how stocking density at the feed bunk affects the feeding and social behavior of dairy cows and if this was also affected by the type of feed barrier used (Huzzey et al., 2006). Although, daily feeding times were higher (Figure 2) and the duration of inactive standing in the feeding area was lower when using a post-and-rail compared to a headlock feed barrier we noted a significant reduction in aggressive behavior with the headlock barrier compared to the post and rail barrier. As well, regardless of barrier type, feeding time decreased and inactive standing increased as stocking density at the feed bunk increased. Cows were displaced more often from the feeding area when the stocking density was increased, and this effect was greater for cows using the post-and-rail feed barrier. Further, we found that subordinate cows were displaced more often with the post-and-rail barrier design, particularly at high stocking densities. From these results, we can conclude that overstocking the feed bunk will decrease time spent at the feed bunk and increase competition, resulting in poor feed access. Further, the use of a barrier that provides some physical separation between adjacent cows, such as a headlock feed barrier, can be used to further reduce competition at the feed bunk. A less aggressive environment at the feed bunk may also have long term health benefits, as it has been suggested that cows engaged in high number of aggressive interactions at the feed bunk may be at risk for hoof health problems (Leonard et al., 1998).

In the two studies on feed barrier design (Endres et al., 2005; Huzzey et al., 2006) the use of a headlock reduced the incidence of displacements at the feed bunk, but did not completely eliminate aggressive behavior, indicating that the neck division does not provide full protection. Researchers in other species have demonstrated in that providing partitions that separate the bodies of adjacent animals can have profound effects on reducing competition and allowing animals to feed for longer periods. For this reason, we were interested if the addition of partitions (feed stalls) between the bodies of adjacent cows provides additional protection while feeding and allows for improved access to feed (DeVries and von Keyserlingk, 2006). When animals had access to more space, particularly with the feed stalls, there were far fewer displacements while feeding (Figure 3). Further, subordinate cows benefited the most from this reduction in displacements. Reduced aggression at the feed bunk allowed cows to increase their daily feeding time and reduce the time they spent standing in the feeding area while not feeding.

Based on these results, we could conclude that the provision of more feed bunk space, particularly when combined with feed stalls, will improve access to feed and reduce competition at the feed bunk, particularly for subordinate cows. This could help reduce the between-cow variation in the composition of ration consumed by preventing subordinate cows from being forced to access the bunk only after dominant cows have sorted the feed.

MANAGING FEED SORTING:

To date, the majority of the research on feed sorting in dairy cattle has focused on changing the composition of the TMR, particularly the forage components. Leonardi and Armentano (2003) studied the effects on feed sorting of different quantities (20 or 40%), qualities (low or high), and lengths of alfalfa hay (chopped or long), without changing the proportion of concentrate in the diet. They found that cows increased their sorting (discrimination against long particles) with more hay and with longer hay, while the quality of hay had no effect. These authors also noted large variation in the amount of sorting that individual cows performed. Similar effects of particle size have been demonstrated by other researchers. Kononoff and Heinrichs (2003) found that more sorting against long particles occurred in a TMR with long corn silage particle size. Leonardi et al. (2005b) also found that cows increased their sorting behaviour with diets with increasing particle size of oat silage. Alternatively, Kononoff et al. (2003) found that the amount of feed sorting could be reduced by reducing the particle size of corn silage. Similarly to that, Onetti et al. (2004) found that decreasing the particle size of alfalfa hay (compared to long particles size) increases the amount of fibre (NDF) intake, indicating that cows were not able to sort as much with shorter particle sizes and, hence, they consumed more fibre. Ebling and Kung (2004) reported that cows fed unprocessed corn silage (as 42% of a TMR) sorted more against longer particles than those fed processed corn silage. Finally, increasing the concentrate to forage ration in a TMR has recently been shown to increase the amount of sorting against long particles, and for shorter particles (DeVries et al., 2007).

Beyond changing forage characteristics or content, sorting can be influenced by other factors. It is commonly believed that adding water to dry TMRs will help bind particles together and make it harder for dairy cattle to sort out finer particles. This hypothesis was tested in an experiment by Leonardi et al. (2005a), who showed a reduction in the amount of feed sorting (against long particles) when water was added to a dry diet (80% DM). One caution when reviewing these data is that even the 'wet' diet in this study was drier (64% DM) than a typical lactating dairy cow diet. It is, therefore, unknown how the addition of water affects the sorting of these wetter diets; more research is needed in this area.

Beyond dietary factors, several feed management type recommendations to control feed sorting, including increasing the frequency of feeding and push-up, availability of bunk space, and bunk access time have been made (Shaver, 2002). To date, the effects of frequency of feed delivery and competition and the feed bunk have been studied. In our research on effects of frequency of feed delivery (DeVries et al., 2005), we noted that the NDF content of the TMR present in the feed bunk increased throughout the day, indicating that sorting of the feed had occurred. Further, we found that increasing the frequency of feed delivery from 1x to 2x reduced the sorting of the TMR, but no additional benefits were gained when feed was delivered 4x. These changes in NDF resulted in changes in the forage to concentrate ratio over the course of the day, particularly for the 1x treatment. Initially, the TMR had a forage to concentrate ratio of 49:51 (DM basis), however, the remaining orts for the 1x and 2x treatments had a calculated ratio of 63:37 and 55:45, respectively (Figure 4). Cook et al. (2004) suggested that consumption patterns rather than total feed intake appear to be important in the development of sub-acute ruminal acidosis. Increasing the frequency of feed delivery results in less feed sorting, more equal access to freshly delivered feed and a more even distribution of feeding time over the course of the day (DeVries et al., 2005) and, therefore, has the potential to reduce the variation in diet quality consumed by the cows and reduce the risk of SARA.

In a recent study we also set out to investigate how feed sorting is affected by competition for access to the feed bunk. Thirty-six dry Holstein cows, consuming a close-up TMR diet, were assigned to one of 2 treatments: 1) noncompetitive (1 cow/feed bin) or 2) competitive (2 cows/feed bin). Feeding behavior, DMI, and sorting behavior were monitored on 4 separate days during weeks 2 and 3 before the expected calving dates of the cows. Regardless of treatment, the cows sorted against long particles and for short particles. Interestingly, there was a tendency for more sorting for short particles during the first 4 h after feed delivery. Competition at the feed bunk dramatically increased the feeding rate of the cows throughout the day (Figure 5). The competitively-fed cows also had fewer meals per day, and tended to have larger and longer meals. Competition also changed the distribution of DMI over the course of the day, resulting in higher intakes during the later hours after feed delivery after much of the feed sorting had already occurred (Figure 6). These results suggest that increased competition at the feed bunk promotes feeding behavior patterns that will likely increase the between-cow variation in composition of TMR consumed.

CONCLUSIONS:

This proceedings chapter summarizes a number of studies that we have undertaken that collectively provide us with a basic understanding of how feed bunk management and design can be manipulated to reduce competition, improve feed access, and reduce feeding sorting. Collectively, this information can be used to reduce between-cow variation in DMI and the actual composition of feed consumed. Future research must now determine the long-term implications of increased feed access and reduced competition at the feed bunk on the dry matter intake, milk production, and health of lactating dairy cows, particularly those in early lactation.

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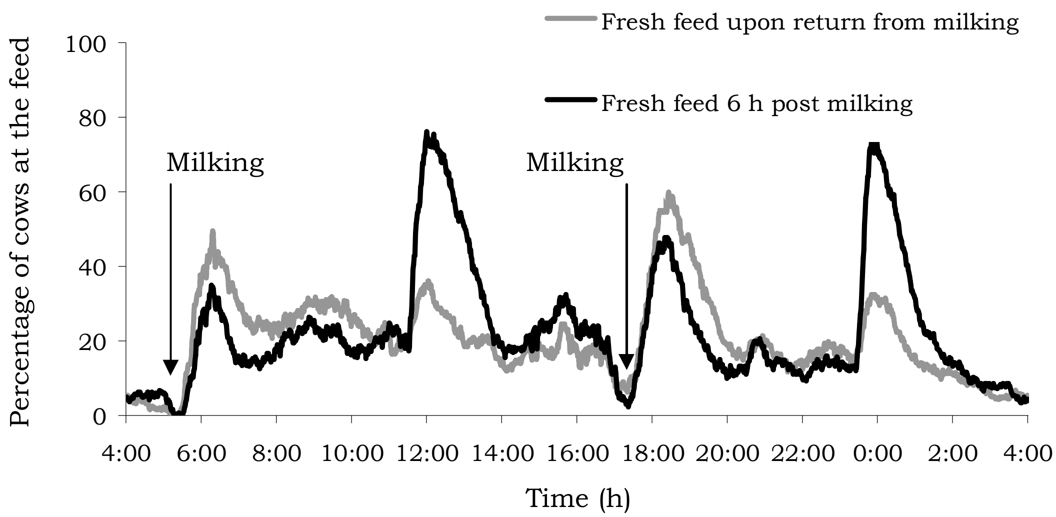

Figure 1. Feed bunk attendance when cows were provided with fresh feed upon the return from milking and when provided fresh feed 6 h post milking (from DeVries and von Keyserlingk, 2005).

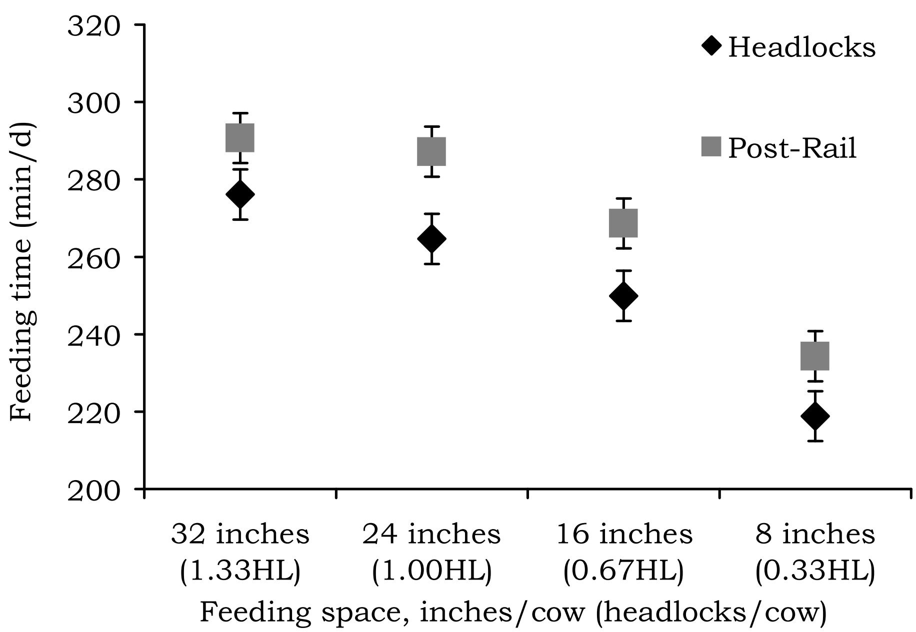

Figure 2. Daily feeding time per cow at 4 different stocking density treatments when provided either a headlock or a post-and-rail feed barrier (from Huzzey et al., 2006).

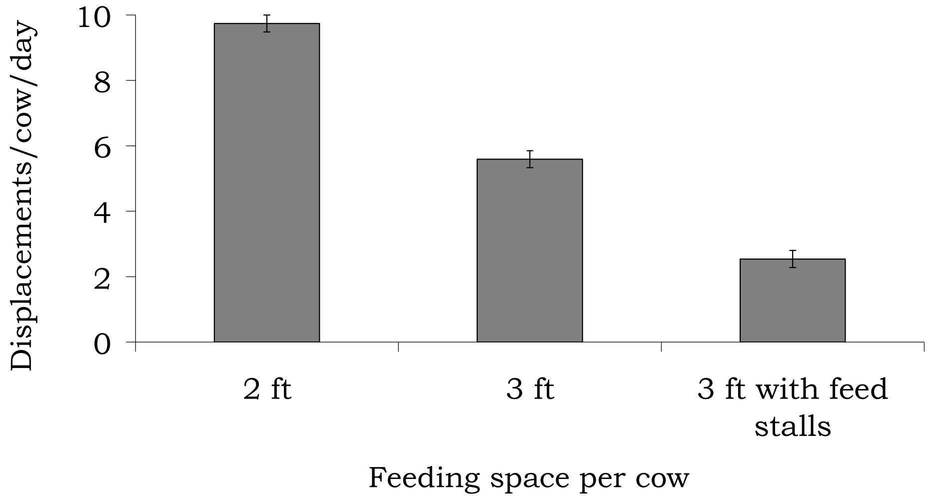

Figure 3. Daily number of displacements per cow at three different levels of feed bunk space (adapted from DeVries and von Keyserlingk, 2006).

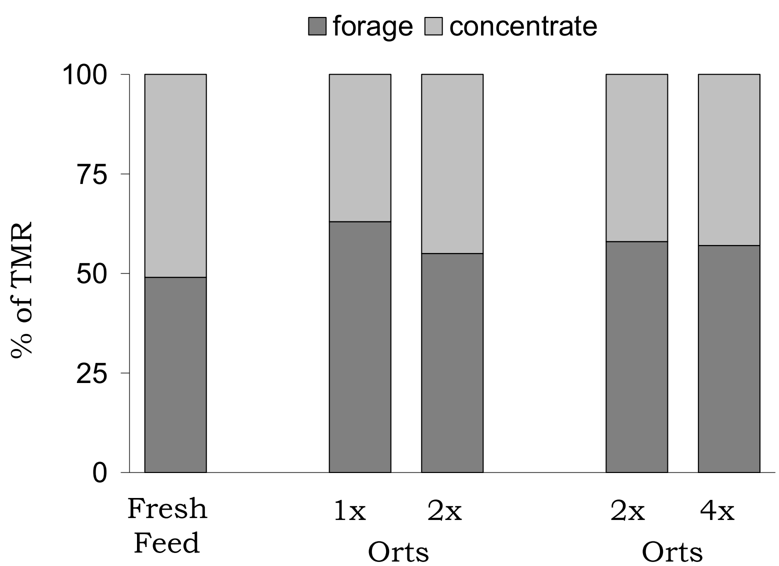

Figure 4. Forage to concentrate ratio of the initial total mixed ration (TMR) and orts estimated from the initial neutral detergent fiber (NDF) content values for the TMR and the final NDF content of the orts (adapted from DeVries et al., 2005).

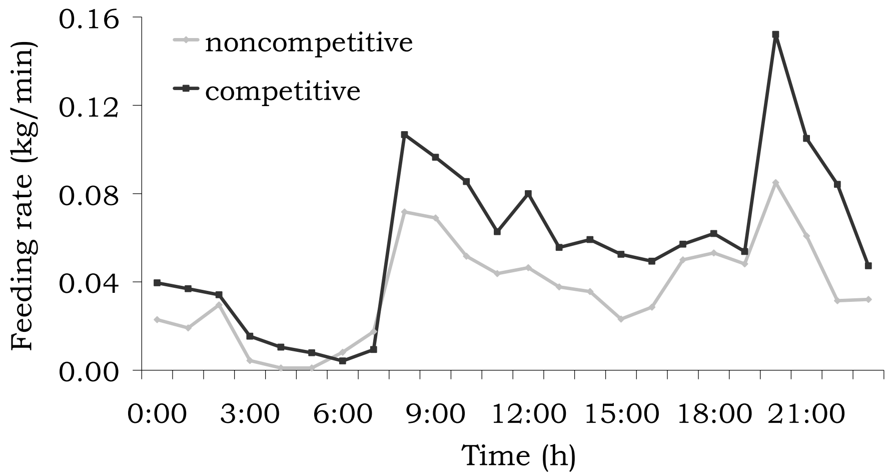

Figure 5. Average hourly feeding rate (kg/min) for cows fed noncompetitively (1 cow/feed bin) or competitively (2 cows/feed bin) (from Hosseinkhani et al., 2008).

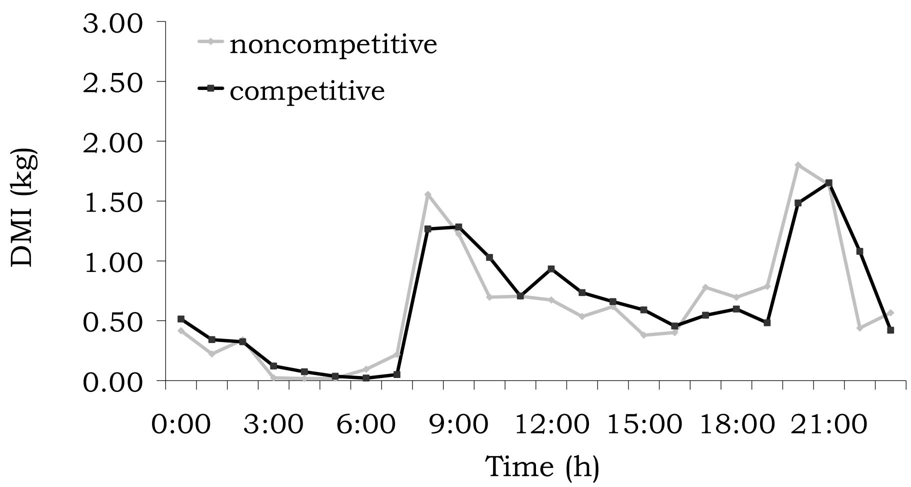

Figure 6. Average hourly dry matter intake (DMI; kg) for cows fed noncompetitively (1 cow/feed bin) or competitively (2 cows/feed bin) (from Hosseinkhani et al., 2008).