TEMPORAL FEED RESTRICTION AND OVERSTOCKING INCREASE COMPETITION FOR FEED IN GROUP-HOUSED DAIRY CATTLE

by

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ABSTRACT

Dairy cows are often overstocked. Some managers are now also using 'slick bunk' management to save on feed costs, but this reduces the time cows have access to feed. Both practices may increase competition and affect feeding behaviour in cows. The aim of this study was to determine the effects of temporal and spatial restrictions on the feeding and competitive behavior of group-housed cows. Using a replicated Latin square design 48 Holstein cows were randomly assigned to groups of 6 cows. Groups were tested as overstocked at the feeder (2:1 cows:feed bin) or not (1:1 cow:bin) and provided feed access for either 14 or 24 h/d. DMI, feeding time and rate were measured for 24 h and 2 h following fresh feed delivery for the last 4 d of the 7 d periods. Displacements were recorded for 2 h after delivery of morning feed (peak feeding period) and 2 h following afternoon milking. DMI tended to decline when temporal access was restricted (27.0 vs. 25.7 ± 0.5 kg/d), but was not affected by overstocking (26.4 ± 1.9, mean ± SD). Temporally restricted cows spent less time feeding (190.9 vs. 207.9 ± 6.1 min). Overstocked cows that were also temporally restricted had greater feeding rates during the day (156 vs. 137 ± 4 g/min) and especially during the peak feeding period (175 vs. 146 ± 4 g/min) compared to cows that were not restricted. In the peak period, overstocked cows had reduced DMI (3.0 vs. 3.4 ± 0.1 kg/h) and feeding times (20.8 vs. 25.8 ± 1.0 min/h) and increased feeding rates (161 vs. 138 ± 4 g/min). Cows with restricted temporal access had greater DMI (3.9 vs. 2.6 ± 0.2 kg/h) and time spent feeding (27.3 vs. 19.2 ± 1.3 min/h) during the peak period, compared with cows that were not restricted. Restricting temporal access in conjunction with overstocking resulted in the greatest increase in daily displacements (15.0 vs. 3.8 ± 1.4 displacements/d); the majority of

these occurred during the peak period. Adequate space and time to access feed is essential to minimize feed bunk competition in indoor group-housing systems.

PREFACE

Lindsay Collings, and Drs. Nuria Chapinal, Dan Weary and Marina von Keyserlingk designed the experiment in collaboration. Lindsay Collings conducted the experiment and collected all the data. Lindsay Collings wrote the manuscript under the supervision of Nuria Chapinal and Drs. Dan Weary and Marina von Keyserlingk. A version of chapter 2 has been submitted for publication and is currently under review. Collings, L. K. M., D. M. Weary, N. Chapinal, M. A. G. von Keyserlingk. 2011. Temporal feed restriction and overstocking increase competition for feed by dairy cattle.

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ADF = acid detergent fibre

CP = crude protein

DIM = days in milk

DM = dry matter

DMI = dry matter intake

NDF = neutral detergent fibre

NE_L = net energy for lactation

NFACC = National Farm Animal Care Council

NRC = National Research Council

SARA = subacute ruminal acidosis

TMR = total mixed ration

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CHAPTER 1: INTRODUCTION

The dairy industry

Over the past few decades, there has been a major shift in the North American dairy industry. There is a trend for fewer but larger farms. In 1993, there were approximately 29,000 dairy farms in Canada, milking an average of 43 cows/farm. By 2010, the number of farms had declined by more than half, with fewer than 13,000 farms milking an average of 76 cows/farm (CDIC, 2011a). Associated with the changes in farm size have been dramatic changes in on-farm management, housing, and feeding practices. Moreover, reductions in labour, land supply, and increased costs have resulted in many farms adopting zero-grazing systems.

When cows are housed intensively indoors, their ability to feed as a group while maintaining preferred space between neighbours while feeding is reduced (Curtis and Houpt, 1983; Estevez et al., 2007). Decades ago, scientists undertaking observational studies reported that when cows are fed indoors, considerable jostling for space occurs and feeding occurs at a faster rate (Schein and Fohrman, 1955). More recent work has verified these findings (Hosseinkhani et al., 2008; Proudfoot et al., 2009). Clearly, housing and management factors that accompany indoor housing systems have created environments that differ greatly from extensive grazing-based systems (Rushen et al., 2008).

Animal welfare

What is animal welfare?

Identifying practical indicators of welfare on commercial dairy farms has received considerable attention in the last decade (Whay et al., 2003; Dawkins, 2004; Rousing et al., 2010; Rushen, 2010). Although some have attempted to argue that maintenance of milk production assures welfare, this concept has been challenged (von Keyserlingk et al., 2009). Improved genetics has led to an increase in milk production per cow, with cows producing on average 2000 kg more milk annually per cow than two decades ago (CDIC, 2011b; Oltenacu and Algers, 2005). Despite these increases in production the industry is plagued by high rates of disease and culling (Fleischer et al., 2001; Zwald et al., 2004), thus, relying exclusively on good biological performance (e.g. high milk yield) does not ensure good overall welfare (von Keyserlingk et al., 2009). Therefore, a broader definition of welfare is needed that highlights more than just biological functioning in cattle.

The concept of animal welfare introduced by Fraser et al. (1997) includes three key components: biological functioning, affective state, and natural living. The biological functioning component focuses on health, reproduction, growth, and maintenance. The affective state component refers to the animals' feelings and emotional state. The natural living component includes the animals' ability to perform behaviours that are considered natural to them. Similarly, Dawkins (2004) argues that the concept of animal welfare involves more than biological functioning and is based on the health, needs, and desires of animals.

Using behaviour to assess welfare

Behaviour is frequently incorporated into animal welfare assessment schemes. Behavioural research is generally non-invasive, and with the development of new technologies such as automated feeders and video cameras, it is relatively non-intrusive (Dawkins, 2004). Recent work has reviewed how an understanding of cattle behaviour can be used as an indicator for health and illness (Weary et al., 2008) and to assess welfare (Rushen et al., 2008).

Rushen et al. (2008) discuss how behavioural observations can be used to assess animal welfare in terms of outcome-based and input-based criteria. The outcome-based or animal-based method uses animal behaviour as an indicator of the state and welfare of the animal. An example of an outcome-based measure is vocal behaviour in dairy cattle (Rushen et al., 2008). The input-based method focuses on factors associated with the environment; behavioural measures can be used to determine how housing and management methods affect how an animal copes with its environment. For example, the use of preference testing allows the animal to choose between two housing systems. Cattle with free access to both outdoor pasture and indoor housing can provide information on when and how much time cows choose to spend in each condition (Legrand et al., 2009). The consequences of behavioural deprivation (i.e.: preventing cows from eating or lying down) have also been used to determine which resources or behaviours cows give priority to (Munksgaard et al., 2005). Clearly, behavioural research has the ability to provide useful information to help further the understanding of the welfare of dairy cattle housed and fed in intensive indoor systems.

Social organization

To understand how management factors affect the welfare and feeding behaviour of dairy cattle, it is important to understand how the dynamics of living in a group or herd can affect the behaviour of individuals. Several species including cattle live and thrive in large social groups. Individuals within social groups benefit from reduced predation risk, social learning and companionship, social thermoregulation, and reduced vigilance allowing for more time to forage or rest (reviewed by Estevez et al., 2007). However, living in groups, particularly when combined with limited space or other resources can have disadvantages as well.

In group-housed animals, the behaviour of one individual is dependent on the other individuals in the group (Bolhuis and Giraldeau, 2005). Hierarchies typically develop when social animals, such as dairy cattle, are housed in groups (Schein and Fohrman, 1955; Fraser and Broom, 1997). Although the formation of groups is usually associated with increased aggression as social hierarchies become established, overall aggression usually declines once the groups have been stable for a period of time (Mazur, 1973; Beilharz and Zeeb, 1982). Historically, individuals within the hierarchy have been classified as dominant or subordinate, with dominance defined as "a priority of access . . . that one animal has over another" (van Kreveld, 1970). In small to medium-sized flocks of chickens, a linear or near-linear dominance hierarchy is established after only a few interactions between individuals (Mazur, 1973). However, recent work on dairy cattle shows that social hierarchies are not linear (Val-Laillet et al., 2008a).

In an effort to understand the complex social dominance structures seen in groups of cows, researchers have attempted to assign dominance ranks to individuals. When studying feeding behaviour for example, the number of feed bunk displacements (when one cow physically butts or pushes another cow out of the feeding area) has been used to assign a social rank to an individual within the group. For each displacement, one cow is the actor (the cow initiating contact with another cow) and one cow is the reactor (the cow receiving the contact). Social rank (e.g. dominance and subordinace) is then calculated as the proportion of times the cow initiated a displacement compared to the total number of displacements she was involved in. Variations in this calculation have been reported in the literature, for example, DeVries et al. (2004) and Huzzey et al. (2006) calculated an "index of success" suggested by Mendl et al. (1992). The index of success is based on the number of cows that an individual was able to displace compared to the sum of the number of cows the individual was able to displace and the cows that were able to displace her. Proudfoot et al. (2009) used an "index of displacement" created by Galindo and Broom (2000) based on the number of times an individual displaced others compared to the number of total displacements she was involved in.

There is still some debate, however, on how to assign social rank to dairy cows and what inferences can be made from these ranks. For instance, Val-Laillet et al. (2008a) discussed social dominance in dairy cows based on competitive success of displacements and found that dominance relationships were not linear, unidirectional, or transitive. Additionally, dominance ranks based on mathematical formulas (e.g. the "index of displacement") may potentially mask useful direct information (e.g. the total number of displacements an individual was involved in). For example, a cow that dominated 1 of 2 displacements and a cow that dominated 10 of 20 displacements will be regarded as equally dominant even though the latter cow was involved in 10 times as many interactions. Reporting the total number of displacements occurring in the pen may provide a more practical and realistic understanding of the level of competition in a group of dairy cows.

Competition

Competition can be defined as "the situation where individuals seek to obtain the same resource" (Fraser and Broom, 1997), particularly a resource in limited supply. On pasture, cows do not usually compete for space to eat (Schein and Fohrman, 1955), but rather for preferred areas and qualities of forage. Forage is usually spread across a vast area making it hard for one cow to protect more than a small section of grass (Metz and Wierenga, 1987). Moreover, cows that are less competitive are able to retreat or escape from physical interactions and threats and find forage elsewhere (Curtis and Houpt, 1983). As early as the 1950s, reports suggested that when housed indoors, cows butt and push other cows in order to gain access to the feed bunk (Schein and Fohrman, 1955). It was predicted by Schein and Fohrman (1955) that the cows that were displaced more often when feeding would suffer the most when fed indoors by not having equal opportunity to gain access to feed, and recent studies now provide experimental evidence in support of this prediction (Olofsson, 1999; DeVries et al., 2004; Huzzey et al., 2006).

How an animal responds to competition is based, in part, on the individual's motivation to secure access to the resource and the individual's existing relationships with other herd members (Beliharz and Zeeb, 1982). For example, the effects of a competitive feeding situation on the behaviour of individuals will be determined by the individual's motivation to find and consume feed and its behaviour towards other animals in the group. Not surprising, competition is increased when resources such as feed are clumped or limited (Estevez et al., 2007) and cows on pasture with access to limited forage consume feed at a faster rate (Benham, 1982; Fraser and Broom, 1997). Similarly, changes in feeding rate (Proudfoot et al., 2009) and in dry matter intake (DMI) (Nielsen, 1999; Olofsson, 1999) occur when cows housed indoors are forced to feed in a competitive situation. Moreover, a cow's preference to eat with the herd in a competitive situation may outweigh her desire to eat at her preferred eating rate, forcing her to modify her feeding rate (Nielsen, 1999; Olofsson, 1999; Proudfoot et al., 2009).

Recent evidence also suggests that competition is specific to the resource being pursued. For example, cows that were involved in a large number of feed bunk displacements did not necessarily participate in a large number of displacements to access lying stalls or a mechanical brush (Val-Laillet et al., 2008b). This study also reported that in groups of 12 cows provided with one lying stall per cow, 0.6 m of feed bunk space per cow, and one mechanical brush, over 85% of the displacements took place at the feed bunk, providing evidence that feed is indeed a valuable resource. Thus, it is not surprising that there has been tremendous interest in the past decade in improving the understanding of the factors contributing to the variation in feeding behaviour of group-housed cows.

Feeding behaviour in dairy cattle

Cattle are social animals and coordinate their behaviours, including feeding, as a group. Social facilitation is thought to play a major role in initiating the herd to begin feeding (Cutis and Houpt, 1983). On pasture cattle are crepuscular feeders with the majority of the 4 to 9 hours of grazing time taking place between dawn and dusk (Hafez and Boissou, 1975). This diurnal feeding pattern is primarily based on daylight, but is influenced in part by factors such as temperature, weather, and forage quality and availability (Ray and Roubicek, 1971; Ruckebusch and Bueno, 1978).

Although cattle housed indoors in group-housed environments, if provided sufficient space, feed together (DeVries et al., 2003b), the crepuscular nature of their feeding pattern is less obvious with daily feeding times ranging from 3 to 6 hours (Grant and Albright, 2001).

Indoor-housing systems rely on "fence line feeding" systems (Albright, 1993) that provide access to a total mixed ration (TMR) along a linear feed bunk. The feed is normally delivered on the ground along a tombstone that allows cattle to maintain a natural grazing position (Albright, 1993). This type of feeding system allows producers to deliver feed to a large group of cows at one time and prevents the cows from walking and defecating on the feed. However, this feeding system usually requires cows to stand very close together while feeding, resulting in high levels of competition (Metz and Wierenga, 1987). Understanding how feeding behaviour is affected by feed bunk design and feeding management is key when designing feeding environments for group-housed dairy cattle.

Feed bunk design

Design and structure

In freestall systems, cows are commonly fed at a linear feed bunk with either a post and rail or headlocker design (see Huzzey et al., 2006 for description). These designs allow cows to access feed, but minimize feed wastage and fecal contamination. Unfortunately, this design prevents the natural tendency of cows to slowly move forward as they graze (Metz and Wierenga, 1987). Although the post and rail system allows cows to stretch their necks and move side-to-side, it has been criticized as it puts tremendous pressure on the neck of the cow pushing the rail (Kielland et al., 2010). Additionally, the lack of any side-to-side barriers in the post and rail system allows cows to easily displace adjacent cows (Endres et al., 2005). Conversely, the headlock system is more constraining of movement, but does provide a physical barrier between cows, reducing displacements at the feed bunk (Huzzey et al., 2006). Less competitive cows in particular benefit from headlockers, showing the greatest increases in time spent feeding, likely due to being displaced less often by more competitive cows (Endres et al., 2005; DeVries and von Keyserlingk, 2006).

Feed bunk space

Each cow should be provided at least 0.6 m of linear feed bunk space (Grant and Albright, 2001; NFACC, 2009). However, despite this recommendation feed bunk space on farms across the United States varies greatly (0.45 m, Endres and Espejo, 2010; 0.52 to 0.56 m, Caraviello et al., 2006). For example, one study reported that 92% of the high-producing groups surveyed had less than the recommended 0.6 m/cow (Endres and Espejo, 2010). This discrepancy between evidence-based guidelines and actual practice likely has an impact on the feeding behaviour of cows in indoor housing systems.

When pens are overstocked it reduces the amount of feed bunk space available per cow, which increases competition. Although competitively fed cows show reduced DMI during peak feeding periods (following feed delivery), they attempt to compensate by increasing DMI in the hours following (Hosseinkhani et al., 2008). Unfortunately this compensatory behaviour likely affects the type of feed consumed as feed quality declines over the course of the day as a consequence of sorting for particular components of the diet (DeVries et al., 2005). Interestingly, competition at the feed bunk had no affect on DMI, feeding rate, or feeding time in primiparous cows in the week before or after calving (Proudfoot et al., 2009), but DMI tends to be affected by competition in multiparous cows in the week before calving (Proudfoot et al., 2009). Overall, in multiparous lactating cows, competition does not affect daily DMI or feeding time, but does result in an increase in feeding rate (Olofsson, 1999; Proudfoot et al., 2009). The least competitive cows show the greatest increases in feeding rate and reductions in DMI as a result of reduced feed bunk space (Olofsson, 1999; Proudfoot et al., 2009). For both primi and multiparous cows, increasing feed bunk space above 0.6 m/cow reduces competitive displacements and allows for increased feeding activity especially in peak feeding hours (DeVries et al., 2004; DeVries and von Keyserlingk, 2006). Clearly, there are benefits of providing cows with at least the recommended amount of space with the least competitive cows showing the greatest increases in time spent feeding.

The amount of feeding space needed per cow is also affected by the stage of lactation, with the transition cow being most vulnerable as reductions in DMI can affect health status post partum (see Huzzey et al., 2007; Goldhawk et al., 2009). The transition period, beginning approximately 3 wk before calving and ending 3 wk after calving, is a demanding time for the cow. During this time she will experience multiple dietary changes and social regroupings as well as parturition and the onset of lactation. All cows will experience negative energy balance in the weeks following calving as initially her ability to consume nutrients fails to meet the need to support lactation. Feed bunk space recommendations during the transition period are higher than those recommended for mid-lactation cows (0.6 to 0.76 m/cow, Shaver, 1993; NFACC, 2009).

The amount of space needed over the course of the day also changes, as it is a function of feed availability and the diurnal pattern of when cows eat. Therefore, feed bunk space recommendations should be based on the space required per cow during the busiest feeding periods to ensure all cows have space to feed. Space requirements may also be a function of management factors, as feed bunk management has been shown to impact feeding behaviour and competition in dairy cattle.

Feed bunk management and feeding regime

When and how often to feed

Cows are stimulated to eat when they return from the milking parlour, when fresh feed is delivered, and through social facilitation. DeVries and von Keyserlingk (2005) determined that the delivery of fresh feed has the greatest impact on increasing feeding activity, and although cows housed indoors try to maintain natural diurnal feeding patterns, they will shift their diurnal feeding pattern around the delivery of fresh feed (DeVries and von Keyserlingk, 2005). When the frequency of feeding increased from one to two or two to four feedings per day, DeVries et al. (2005) recorded spikes in feeding activity after each feeding resulting in an overall increase in daily feeding time. Moreover, despite the fact that increased feeding frequency had no affect on feed bunk competition, less competitive cows showed the greatest reduction in displacements when feeding frequency was increased. Furthermore, DeVries et al. (2005) indicated that cows had increased feed sorting behaviour when fed only once per day compared to two times daily. Feeding more than once per day provides benefits for the less competitive cows. These cows generally do not gain access to the feed bunk until after the peak feeding periods, and due to the sorting behaviour of other cows, they consume lower quality feed (DeVries et al., 2005).

When cows sort for short particles, including grains (DeVries et al., 2008), it often results in the remaining feed being pushed away from the feed bunk. Many producers “push up” the feed as a means of counteracting the pushing away of feed by the cows, but also as a means of increasing feeding time. Although, push up plays a role in ensuring feed is accessible to the cows there is no evidence that it increases feeding activity (DeVries et al., 2003b).

How much to feed

Dairy cows are typically provided with a TMR formulated to meet a cow's changing nutrient requirements as she moves through her lactation cycle. High-producing Holstein cows will consume an average of 23 kg/d DM (Dado and Allen, 1994; however, there is variation in time spent feeding and DMI between primi and multiparous cows as well as variation within-cow throughout her lactation (Munksgaard et al., 2005; DeVries et al., 2003a). This can make it difficult for a producer to ensure that each cow in a group is consuming the required amount of DMI to support her unique nutritional requirements. As feed is one of the largest operating costs on-farm, feed wastage is also a concern (Barmore, 2002) and producers usually aim to have minimal leftovers (refusals) in the bunk by the next feeding. Although it is recommended that cows be fed for 5% refusals (Albright, 1993) to ensure feed is available 24 h/d, not all producers feed for 5% refusals (Silva-del-Río et al., 2010), potentially creating situations where cows are unable to access feed.

Feeding for a slick bunk

Feeding for a slick bunk, or aiming for 0% refusals, has become common practice in beef production systems. It has been argued that this practice reduces costs associated with leftover feed and it has been suggested that reducing the amount of feed provided can increase the efficiency of feed use (Hicks et al., 1990; Hoffman et al., 2006). The slick bunk practice is now becoming more common in dairy systems. A recent survey of 120 California producers found that 50% fed for less than 2% refusals (Silva-del-Río et al., 2010).

In beef feedlot systems, cattle are housed and fed in groups where individuals are of very similar age and body weight (Krause and Oetzel, 2006). In dairy systems, groups are less uniform and more dynamic, with primi and multiparous and early and later lactation cows often housed together. The exact nutritional demands are dependent on the composition of the group (average parity and DIM), and as this changes, it follows that the amount of TMR required by the group will change. This makes it difficult to manage a feed bunk for low refusals (Krause and Oetzel, 2006) and if dairy cows are fed to a slick bunk, questions arise as to how well the less competitive cows are able to cope.

To date no research has determined the effects of feeding to a slick bunk or restricting feed access time in group-housed dairy cows. Work focusing on individually fed cows has shown that temporal feed restriction results in feeding behaviour changes. After 12-h of feed restriction, Munksgaard et al. (2005) saw increased feeding rates and reduced feeding time compared to cows provided with feed 24 h/d. Erdman et al. (1989) provided cows housed in tie-stalls access to feed for 8, 12, 16, or 20 h/d. Feeding time did not change, but DMI decreased as feed access time was reduced. Research examining group-housed cows placed on pasture overnight and subjected to restricted TMR access, showed that daily DMI and feeding time were not affected, but an increase in competitive interactions was noted after TMR access was reinstated (Chapinal et al., 2010a,b). Therefore, if group-housed cows are fed to a slick bunk, and are exposed to long periods with no access to feed it would follow that feeding and social behaviour are likely affected. Moreover, in a situation where competition is already increased due to overstocking, the effects of temporal feed restriction may be magnified.

Objectives

The purpose of this thesis was to determine how management factors affect the feeding behaviour of group-housed dairy cattle in an effort to improve the feeding practices used for freestall-housed cows. Specifically, the objectives of this study were to examine the separate and combined effects of feed bunk overstocking and temporal feed restriction on the feeding and social behaviour of group-housed mid-lactation dairy cattle.

CHAPTER 2: TEMPORAL FEED RESTRICTION AND OVERSTOCKING INCREASE COMPETITION FOR FEED IN DAIRY CATTLE [1]

Introduction

Feeding behaviour in freestall-housed dairy cows is affected by feed bunk design (DeVries and von Keyserlingk, 2006; Huzzey et al., 2006) and feeding management, including feed bunk stocking density (Huzzey et al., 2006; Proudfoot et al., 2009) and fresh feed availability (DeVries et al., 2005). Feeding behaviour is highly synchronized (Hafez and Boissou, 1975) and peaks immediately following the delivery of fresh feed and after milking (DeVries and von Keyserlingk, 2005). High producing cows spend on average 3 to 6 h/d feeding, consuming approximately 23 kg/d DM in 9 to 14 meals/d (Dado and Allen, 1994; Grant and Albright, 2000; Munksgaard et al., 2005).

The effects on feeding behaviour of overstocking at the feed bunk, either through a reduction in space or an increase in the number of cows, have received considerable attention over the last decade. At increased stocking densities cows increase direct competitive behaviour through increased displacements at the feed bunk (Proudfoot et al., 2009), and compete indirectly by increasing their feeding rates (Olofsson, 1999). Subordinate cows tend to be most affected, showing the greatest increases in feeding rate and reductions in DMI (Olofsson, 1999; Grant and Albright, 2001; Proudfoot et al., 2009). Interestingly, the effects of increased stocking density at the feed bunk on DMI, feeding time, and feeding rate are less

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for primiparous cows (Proudfoot et al., 2009), perhaps because they typically consume less than multiparous cows.

Current industry practice is to provide cows with at least 0.6 m/cow of bunk space (NFACC, 2009) and to provide 5% excess feed (in relation to estimated requirements) to ensure access to feed 24 h/d (Albright, 1993; Grant and Albright, 2001; NFACC, 2009). However, some authors have suggested that feed efficiency can be improved by reducing the amount of feed provided (Hicks et al., 1990; Hoffman et al., 2006), and a recent survey shows that a growing number of dairy producers are aiming for 0% orts, or a "slick bunk" (Silva-del-Río et al., 2010). In effect, slick bunk management results in some periods of the day when cows have little or no access to suitable feed, imposing a temporal restriction on feed availability.

Little is known about the effects of temporal restrictions in feed access. Munksgaard et al. (2005) studied the effects of reducing feed access to only 12 h/d on the lying and feeding behaviour of individually housed cows. Cows restricted from feed had lower feeding times and higher feeding rates, and only slightly lower DMI. In a tie-stall environment, Erdman et al. (1989) tested the effects of providing feed for 8, 12, 16 or 20 h/d, and found lower DMI but no change in feeding time with reduced feed access time. Chapinal et al. (2010a,b) examined the effects of overnight access to pasture, which included denying access to TMR during the night, and found no effect on milk production, TMR intake, or feeding time. However, cows that were denied access to TMR overnight compensated by spending more time feeding in the first 3 h after re-gaining access to TMR and displacing other cows from the feed bunk during this period (Chapinal et al., 2010b).

These effects of temporal restriction are similar to the effect of increased stocking density, perhaps because both factors can reduce cow access to feed. It thus seems likely that the effects of temporal restrictions may accentuate any effects of feed bunk overstocking on the feeding and social behaviour of dairy cows. The aim of this experiment was to determine the effects of temporal and spatial restriction separately, and together, on the feeding and social behaviour of group-housed lactating cows.

Materials and methods

Animals, housing, and diet

Forty-eight multiparous lactating Holstein dairy cows were enrolled in this experiment. All animals were housed at the University of British Columbia Dairy Education and Research Centre (Agassiz, BC, Canada) and were cared for according to the guidelines of the Canadian Council on Animal Care (2009) and the National Farm Animal Care Council (NFAAC, 2009). Cows on all treatments had ad libitum access to water, and were milked twice daily at approximately 0600 h and 1700 h. Cows were fed a TMR balanced according to the NRC (2001) recommendations. The TMR was fed at approximately 615 and 930 h. Samples of TMR were collected twice weekly (from the top, middle, and bottom of feed bins to get a representative sample) and frozen for storage in sealed plastic bags at -18°C. Thawed samples were dried using a forced air oven at 60°C for 48 h to determine DM. To calculate nutrient composition, samples were sent for analysis to Cumberland Valley Analytical Services, Inc. (Maugansville, MD; Cumberland Valley Analytical Services, 2009). The TMR consisted of 27.2% corn silage, 16.7% grass silage, 8.5% alfalfa, and 47.7% mineral and concentrate mix on a DM basis (DM: 56 ± 2.5%, CP: 16.8 ± 0.5% DM, ADF: 21.8 ± 0.2% DM, NDF: 35.9 ± 0.8% DM, and NE_L: 1.64 ± 0.01 Mcal/kg).

Experimental treatments and design

Each of the 4 experimental pens contained 6 electronic feed bins and 1 electronic drinker (Insentec, Marknesse, Holland); cows had free access to all feed bins within a pen. Each pen had rubber flooring and contained 2 rows of 6 lying stalls each fitted with mattresses (Pasture Mat, Promat Inc., Woodstock, Ontario, Canada) and bedded with approximately 5 cm of washed river-sand. Stalls were raked twice daily while cows were away from the pen during milking, and fresh sand was added once a week. Lying stalls were blocked according to treatment to maintain a cow to stall ratio of 1:1.

Cows were randomly assigned to groups of 6, balanced by parity (3.1 ± 1.2, mean ± SD, range from 2 to 6 lactations), projected 305-d milk production (12,603.3 ± 1,656.5 kg), and DIM (204.2 ± 40.7 d). Each group was exposed to each of the 4 treatments for 1 wk, with treatment order assigned using a randomized 4-by-4 Latin square. Two replications involving different focal cows were completed to give a total of 8 groups.

The four treatments were as follows: 1) **100%-24h:** 100% feed bunk stocking density, 24 h access to feed, 2) **100%-14h:** 100% feed bunk stocking density, 14 h access to feed (0600 h to 2000 h), 3) **200%-24h:** 200% feed bunk stocking density, 24 h access to feed and, 4) **200%-14h:** 200% feed bunk stocking density, 14 h access to feed (0600 h to 2000 h).

To create the densities of cows at the feed barrier (100% or 200%), a group of 6 multiparous non-experimental (filler) cows were added to or removed from groups of 6 focal cows. On the 100% treatments, 6 cows fed from 6 bins (1:1 cow:bin), on the 200%

treatments, 12 cows fed from 6 bins (2:1). To create the 2 temporal feed access treatments, the feeding system was programmed to allow cows access to the feed bins for 14 h or 24 h/d.

The first 3 d of each treatment week were considered as an acclimation period in an attempt to minimize any carryover effects from the previous treatment. Data was collected on the last 4 d of the treatment week.

Feeding and social behaviour

DMI was continuously monitored using the Insentec feeding system (Insentec, Marknesse, Holland) previously validated by Chapinal et al. (2007). In summary, the Insentec system recorded the duration of each visit to the feed bins as well as the amount of TMR consumed by the cow. For each visit to the feed bins, feeding rate was calculated using the amount consumed and time spent at the feeder. Social behaviour was recorded using a video camera (WVCW504SP Dome, Panasonic and WV-BP330, Panasonic, Osaka, Japan) placed 6 m over the feed bunk, connected to a digital recording system (GeoVision, Inc., Irvine, California). Each cow was marked (L'Oreal Paris Perfect Blondissima and Clairol nice'n easy 124 Natural Blue Black) with a unique alphanumeric symbol for identification purposes. Preliminary analyses based on data from 10 d indicated that continuous recording of displacements from the feed bins for 2 h following the first feeding and 2 h following the afternoon milking explained the majority of the variation associated with displacements recorded over a full 24 h ($R^2 = 0.96$; $P < 0.001$). Displacements were recorded during the last 4 d of each treatment week. A displacement was defined as a butt or a push from a focal cow "actor" that resulted in the complete withdrawal of the head of the "reactor" (either a focal or filler cow) from the feed bin. Intra-observer and inter-observer reliability for number of displacements recorded was $R^2 = 1.0$ and $R^2 = 0.98$, respectively ($P < 0.002$).

Lying behaviour

Standing and lying behaviour were recorded using an activity data logger (HOBO Pendant G, Onset, Cape Cod, Massachusetts) fitted to one hind leg of each cow. Each minute, the data logger recorded the position of the leg as either standing or lying (Ledgerwood et al., 2010). This data was used to determine daily lying time as well as the frequency and duration of lying bouts. Daily non-feeding standing time was calculated by subtracting the time spent feeding from the time spent standing.

Milk production

On each experimental day, milk production was recorded for each cow at the morning and afternoon milking. These 2 values were summed to provide 1 daily value per cow (kg/d).

Statistical Analysis

One cow was diagnosed as lame and removed from the experiment. To maintain stocking density, a filler cow took the place of the lame cow when she was removed from the pen. The remaining 47 cows were used in the analysis.

Statistical analyses were conducted using SAS (version 9.2, SAS Institute, 2009). Each group of focal cows was considered the experimental unit (n = 8 groups). Feeding behaviour data from the Insentec system was screened for outliers using PROC UNIVARIATE (SAS Institute, 2009). Based on feeding rate, of the 33,095 feeding events, 1.6% were identified as extreme outliers (more than 3 times the interquartile range below the first quartile or above the third quartile) and were thus removed. Using PROC UNIVARIATE, no extreme outliers were detected in the social or lying behaviour measures. For each group, data were averaged across the 4 d and the 6 focal cows of each group to provide 1 value per group per treatment, expressed on a per day and per cow basis (average DMI/d/cow) or a per hour per cow basis (average DMI/h/cow).

The MIXED procedure in SAS was used to test the effects of overstocking, feed restriction, and the interaction between these effects, for feeding behaviour variables (DMI, kg/d, kg/h; feeding time, min/d, min/h; feeding rate, g/min, frequency of visits, n/d, n/h), social behaviour (displacements initiated/d; displacements initiated/h), lying behaviour (lying time, h/d; frequency of lying bouts, n/d; non-feeding standing time, h/d), and milk production (kg/d). Group was considered a random effect in the model and variance components covariance structure was used. Specific contrast statements were used when an interaction was detected between the main effects. Contrast statements were used to test differences between densities for each feed access time, and differences between different feed access times for each stocking density. The LSMEANS function in the MIXED procedure was used to determine least squares means and standard errors. Tendencies are reported at $P < 0.1$ and significant results at $P < 0.05$ for all tests.

Results

Feeding behaviour

Over a 24-h period, groups of cows that were overstocked at the feeder had similar daily DMI and number of visits to the feeder in comparison to non-overstocked cows, but the overstocked cows tended to spend less time feeding (Table 1). Groups that were unable to access feed at night tended to have lower DMI compared to unrestricted cows, spent less time eating, with fewer visits to the feed bins. There were no other differences among treatments in these response variables.

There was an interaction (P < 0.0001) between overstocking and temporal restriction on feeding rate. Feeding rate was highest when overstocking and temporal restriction were combined. Indeed, rates during the combined treatment were higher than when cows were overstocked without temporal restriction (P < 0.0001) and higher than when cows were temporal restricted without overstocking (P < 0.0001). There were no other differences among treatments in feeding rate.

The effects of competitive feeding and temporal restriction were most noticeable during the 2 h after morning feeding. DMI and visits to the feeder were greater during this period for cows that were temporally restricted. Overstocked cows had reduced DMI, but had greater feeding rates and tended to visit the feeder more often. There was an interaction (P = 0.04) between overstocking and temporal restriction on feeding time during this 2-h feeding period. Cows that were both overstocked and feed restricted spent less time feeding than those that were feed restricted but not overstocked (P < 0.0001). When cows were temporally restricted they spent more time feeding than cows that were not restricted when stocked at 100% (P < 0.0001) and 200% (P = 0.001). There was no effect of overstocking (P = 0.09) when there was no temporal restriction in feed access.

The diurnal pattern of DMI was affected by both stocking density and temporal restriction (Figure 1). The largest peak in feeding activity was 2 h after the delivery of morning feed, with a smaller peak in the afternoon following milking. Cows restricted from feeding overnight showed the greatest peak in DMI during the morning period. Cows that had access to feed 24/d consumed between 0 and 0.5 kg/h DM overnight.

Social behaviour

There was an interaction between treatments for daily displacements and displacements during the 2 h after morning feeding ($P < 0.01$ in both cases). Combining overstocking and temporal feed restriction resulted in a greater number of displacements initiated per cow compared to overstocking alone (24-h period, $P < 0.0001$; 2-h period, $P < 0.0001$). For both periods, overstocking resulted in a greater number of displacements with (24-h period, $P < 0.0001$; 2-h period, $P < 0.0001$) and without (24-h period, $P = 0.02$; 2-h period, $P = 0.04$) temporal restriction in feed access. There was no effect of temporal restriction when cows were stocked at 100%, for either daily displacements or displacements during the 2 h after morning feeding.

Lying behaviour

Feed restriction and stocking density at the feed bunk had no effect on daily lying time, frequency of lying bouts, or non-feeding standing time.

Milk production

There were no treatment differences in milk production. Cows produced on average 36.5 ± 2.6 kg/d (mean $\pm$ SD) for the duration of the experiment.

Discussion

This study was the first to examine the effects of temporal restriction in access to feed on the behaviour of a stable group of lactating dairy cows, and the first to test how this restriction interacts with the effect of overstocking. The results show that both management practices negatively affect feeding and social behaviour, and that the 2 factors interact such that the combination is especially problematic.

Overstocked groups consumed 11% less feed than groups that were not overstocked, during the 2 h following fresh feed delivery when cows are highly motivated to feed (DeVries and von Keyserlingk, 2005). The overstocked cows compensated for the reduction in feed intake by increasing DMI in the hours following, resulting in similar DMI over a 24-h period. Hosseinkhani et al. (2008) also reported reduced DMI for overstocked cows during peak feeding periods and greater DMI in the hours following.

Previous studies on close-up cows (Hosseinkhani et al., 2008) and fresh cows (Proudfoot et al., 2009) reported an increase in daily feeding rate when overstocked. In the current study we found increased feed consumption rates for overstocked cows during the 2-h period after morning feeding.

During the 2 h after they were first allowed access to feed in the morning, feed restricted cows consumed 50% more DM (1.3 kg/h more) than non-restricted cows. Temporally restricted cows that were also overstocked ate at a faster rate. Earlier work showed that feeding rate increased after the delivery of fresh feed (DeVries and von Keyserlingk, 2005) and was greater in animals that were more motivated to feed (Nielson, 1999). Non-restricted cows consumed less DM during the peak feeding period, but with the opportunity to eat overnight, they were able to spread their DMI more evenly throughout the 24-h period and consumed the same amount of DM/d as the restricted cows.

A potential concern with restricting feed is the spike in DMI when feed is first provided (Stone, 2004). In the current study some groups consumed on average more than 8 kg/cow DM in the 2 h after the morning feeding. Measures of rumen function were not included in the current study, but we encourage future research to assess the effects of temporal restrictions in feed access on rumen pH and subacute ruminal acidosis as these responses are associated with periods of slug feeding (Owens et al., 1998; Krause and Oetzel, 2006).

Consistent with previous literature, overstocking and restricting feed access time caused increases in the number of displacements at the feed bunk, especially during the peak morning period (Huzzey et al., 2006; Proudfoot et al., 2009; Chapinal et al., 2010b). Feed restricted cows were highly motivated to eat, as they needed to consume their daily TMR in a shorter period. When cows were not overstocked all animals were able to eat simultaneously, perhaps explaining why there was less effect of the temporal restriction on displacements at the 100% stocking level. When temporal feed restriction was combined with overstocking we noted a doubling in the number of displacements relative to the other treatments. These results indicate that slick bunk management may be especially problematic when combined with overstocking at the feed bunk.

In the current study we noted no differences in daily lying times or in daily non-feeding standing time, consistent with the recent findings of Chapinal et al. (2010b), but others have reported that lying time was reduced with overstocking, with this difference driven by more time standing in the feeding area waiting to access feed (Huzzey et al., 2006;

Proudfoot et al., 2009). The variability in this response across studies may be due in part to the high among-cow variability in standing and lying behaviours (Ito et al., 2009).

Cows are crepuscular feeders, consuming most of their daily intake between dawn and dusk (Hafez and Boissou, 1975). Results from the present study and from DeVries and von Keyserlingk (2006) suggest that cows will adjust their diurnal feeding pattern based on management factors such as competition at the feed area due to overstocking or feed restriction. Although overstocked cows are able to compensate for reduced DMI during the peak feeding period by eating in the hours following, competition may be detrimental to individual cows. DeVries et al. (2005) and Huzzey et al. (2006) stated the effects of competition at the feed bunk were greatest for subordinate cows. Further, DeVries et al. (2005) reported that the quality of TMR drops throughout the day due to sorting, so in non-peak feeding times, when less competitive cows are able to access the feed, the TMR available is likely of lower quality than that originally delivered.

This study focused on the short-term effects of reduced feeding space and reduced feed access time. In a commercial setting, cows may be subjected to these environmental constraints for long periods of time, which may lead to more detrimental effects, or may provide cows the opportunity to compensate thus reducing the effects described here. The period of feed restriction in this study (10 h restricted/d) was most likely longer than cows would typically experience when fed to a slick bunk. However, on-farm documentation of the amount of time cows do not have access to feed when fed for a slick bunk does not exist, and is likely variable across farms. Further research should explore the effects of various feed restriction times on feeding and competitive behaviour.

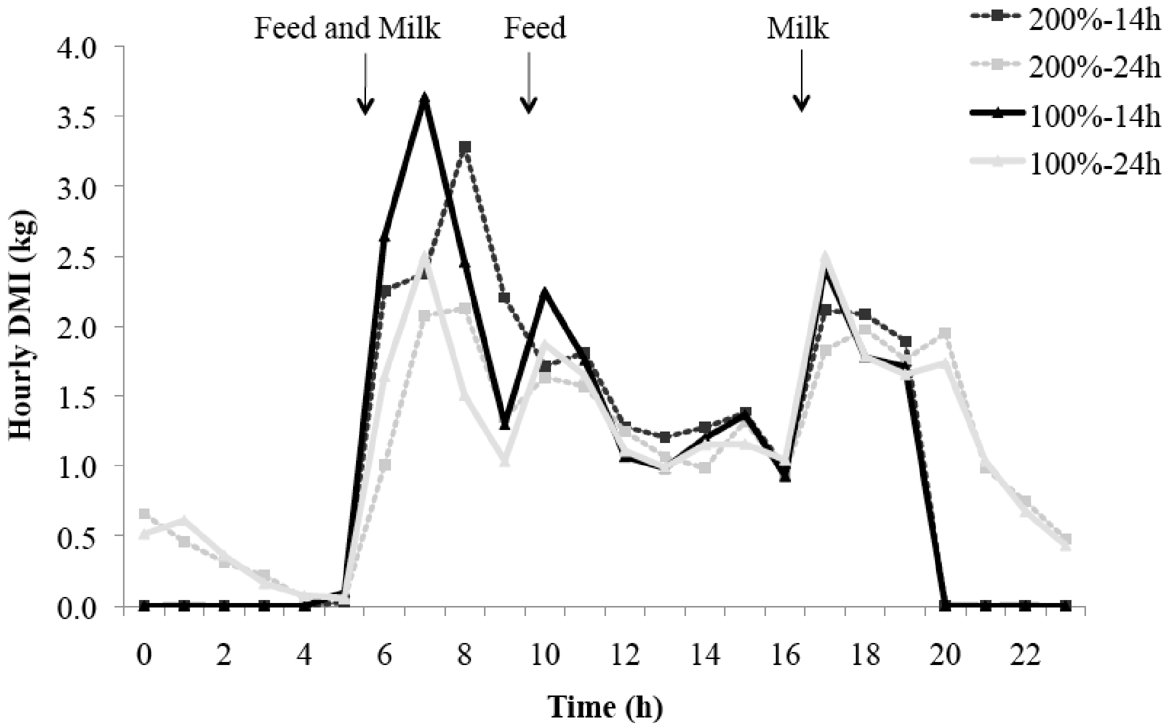
Conclusion

Overstocking at the feed bunk and temporal feed restriction increased competition at the feed bunk and changed feeding behaviour, especially during peak feeding periods. The results from this study indicate that combining overstocking with a period of feed restriction may be especially problematic in terms of competitive and feeding behaviour for lactating dairy cows.

Table 2.1. Mean responses for 8 groups of cows, each tested under 4 treatments, least-squared SEM, and the P values for main effects (stocking density and feed access time) and interaction. Means are shown separately for observations throughout the day and for the 2 h after fresh feed was delivered in the morning.

	Treatment					*P*-value		
Variables	100%-24h	100%-14h	200%-24h	200%-14h	SEM	Density	Access	Density X Access
Daily average								
DMI (kg/d)	27.2	25.6	26.8	25.9	0.6	0.92	0.06	0.57
Feeding time (min/d)	211.0	199.0	204.8	182.9	7.2	0.05	0.005	0.36
Feeding rate (g/min)	135	133	137	156	4	<0.0001	<0.0001	<0.0001
Frequency of visits (no./d)	44.1	40.0	47.2	42.1	2.7	0.1	0.006	0.73
Lying time (h/d)	10.3	10.9	10.8	10.3	0.4	0.87	0.84	0.10
Frequency of lying bouts (no./d)	8.4	8.5	8.4	8.0	0.5	0.26	0.60	0.36
Non-feeding standing time (h/d)	10.2	9.8	9.8	10.7	0.4	0.57	0.60	0.10
Displacements initiated (no./d)	3.8	5.7	7.4	15.0	1.4	<0.0001	0.0002	0.01
2 h after morning feed delivery								
DMI (kg/h)	2.7	4.1	2.4	3.7	0.2	0.02	<0.0001	0.52
Feeding time (min/h)	20.6	31.0	17.9	23.6	1.3	0.0001	<0.0001	0.04
Feeding rate (g/min)	139	137	146	175	4	<0.0001	<0.0001	<0.0001
Frequency of visits (no./h)	4.7	6.2	4.9	7.1	0.5	0.08	<0.0001	0.29
Displacements initiated (no./h)	1.1	2.0	2.4	5.6	0.6	<0.0001	<0.0001	0.01

Figure 2.1. The diurnal pattern of hourly DMI (kg) averaged for 8 groups of cows for each stocking density (100 and 200%) and feed access treatment (14 and 24 h/d). For the temporally restricted feed access treatment feed bins were programmed to prevent access between 20:00 and 6:00.



CHAPTER 3: CONCLUSION

Implications

The focus of this thesis was to determine how overstocking at the feed bunk and reduced feed access time affect the feeding behaviour and welfare of lactating dairy cows. The effects of treatment were determined by collecting behavioural data and then comparing these results to the findings published in the peer-reviewed literature.

The effects of overstocking at the feed bunk have been shown repeatedly. For example, studies undertaken by previous members of UBC's Animal Welfare Program involved assigning 2 cows to the same individual feed bin, forcing cows to compete for access to the food resource (Hosseinkhani et al., 2008; Proudfoot et al., 2009). In contrast, I elected to allow all cows access to all bins, arguably a more accurate representation of the effects of overstocking at the feed bunk on a commercial farm. To further reflect industry practices (Silva-del-Río et al., 2010), I also elected to investigate the effects of limiting feed access time.

Temporally restricted cows had higher DMI during the 2-h peak feeding period after re-gaining access to feed. This corresponds to previous work, which suggested that cows fed amounts that resulted in only 1-3% refusals will consume all the available feed increasing the likelihood that slug feeding will occur when fresh feed is delivered (Stone, 2004). Consuming a large amount of concentrates in a short amount of time, or slug feeding, can have dramatic consequences to the health of the animal as it has been associated with large drops in rumen pH, potentially increasing the incidence of subacute ruminal acidosis (SARA) (Owens et al., 1998; Krause and Oetzel, 2006). Consequences of SARA include depressed

DMI (Nocek, 1997; Brown et al., 2000), reduced milk production (Krause and Oetzel, 2005), and hoof problems such as laminitis (Nocek, 1997).

The results of my study indicate that feeding to a slick bunk where cows did not have access to feed for 10 h/d increased the level of slug feeding, potentially putting the cows at risk of the negative health implications outlined above thus reducing their welfare. In an effort to reduce slug feeding and the risks of SARA, the findings of my work, together with previously published studies, indicate that feeding management practices should aim for 5% refusals.

Providing adequate access to feed provides cows with the opportunity to consume smaller meals (Grant and Albright, 2000; Stone, 2004). Additionally, when dairy cows are overstocked at the feed bunk or temporally restricted from feed access they are forced to alter their feeding behaviour. Reducing feed bunk space also limits the extent to which all animals in the group can feed together, a behaviour well established in cattle (Hafez and Boissou, 1975). When housed on pasture, aggressive social interactions are relatively infrequent (Curtis and Houpt, 1983; Metz and Wierenga, 1987) which is not the case in freestall-housed cows, even when provided 0.6 m of linear feed bunk space per animal (NFACC, 2009). Housing cows indoors affects both feeding and social behaviour (Schein and Fohrman, 1955; Metz and Wierenga, 1987; Rushen et al., 2008), and imposing space and time constraints exacerbates these effects. As suggested by Stricklin and Kautz-Scanavy (1984), well-managed production systems should aim to minimize the impediments that cause disturbances to the natural diurnal patterns of cattle behaviour.

Overall, the findings of my work have helped clarify the effects of competition due to overstocking at the feed bunk, and introduced the idea that restricting feed access time affects the behaviour of group-housed cows. A combination of these treatments leads to the greatest increase in competition. To improve the welfare of group-housed dairy cows, cows should be able to execute their crepuscular feeding nature while being fed as a group, which requires environments that minimize competition at the feed bunk.

Limitations and future research

On-farm situations

In this study, the effects of overstocking and reducing feed access time were assessed in stable groups. However, on most commercial farms, cattle are housed in dynamic groups as individuals enter and leave the group due to their lactation stage. The common practice of regrouping can lead to increased competition; cows moving to a new pen have reduced DMI and feeding rates (Schirmann et al., 2011) likely due to being displaced more often (von Keyserlingk et al., 2008). When cows are regrouped into a less than optimum feeding environment (e.g. reduced feeding space or time given to access feed) I would predict that the effects of competition on feeding and social behaviour would be even greater than that observed in the present study.

The level of feed bunk overstocking (200%) and feed access time (14 h/d) used in this study were greater than that typical on commercial dairy operations. However, feed bunk stocking levels of 125 or 150% are not uncommon (Endres and Espejo, 2010), and result in increased competition. For example, Huzzey et al. (2006) found that the effects of feed bunk overstocking on feeding behaviour and competitive displacements increased as feed bunk space was reduced in 0.2 m increments from 0.81 to 0.21 m/cow. Additionally, when slick bunk feeding management practices are implemented on farms, the time when cows do not have access to suitable feed has not been documented, and thus I predict this period to be variable across farms. Therefore, although the levels of overstocking and temporal feed restriction were higher than on-farm averages, the data from this study provides valuable information on how these factors increase competition and affect dairy cattle feeding behaviour.

Behaviour of individuals

When making welfare assessments on-farm or for groups of animals, it is important to consider the state of all individuals, instead of only considering group averages (Fraser, 2003). Thus one of the potential limitations of this study was the use of group averages to detect treatment effects. Treatments were applied to the pen, and group was considered the experimental unit; changes within each group were then analyzed following exposure of all groups to all treatments. As changes within specific individuals were not analyzed or reported, the effect of treatment on individual cows may have been masked by group averages. Previous work in this area has concluded that less competitive cows are affected the most by competition (DeVries and von Keyserlingk, 2006; Huzzey et al., 2006; Proudfoot et al., 2009), and therefore benefit the most from increased feed bunk space or time to access feed. The goal of improving the lives of individual cows by minimizing the impacts of indoor systems should not be forgotten when managing the group. Group-housed cows should be managed and fed in ways that improve the welfare of both the herd and all individuals within the herd.

Conclusion

The amount of feed bunk space required per cow is a function of feed availability and cattle feeding patterns over the course of the day (Grant and Albright, 1995). Industry recommendations currently suggest providing at least 0.6 m/cow of linear feed bunk space for mid-lactation cows (NFACC, 2009), and feeding 5% in excess of requirements to ensure access to feed 24 h/d (Albright, 1993). However, it is clear that these recommendations are not always followed (Endres and Espejo, 2010; Silva-del-Río et al., 2010). The results from this thesis show that reducing the space or time dairy cattle have to access feed, especially in combination, increases competition at the feed bunk and affects feeding behaviour. Both factors likely reduce dairy cattle welfare for the reasons expressed above. Adhering to recommended standards for feed space and feed access time helps to ensure that cows have adequate space and time to access fresh feed, providing indoor-housed cows with the opportunity to feed in a more natural way.

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