Effect of Stocking Density on Feeding Strategies and Health

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Abstract

There are many reasons why overstocking in free-stall housing systems may occur, including an unexpectedly busy calving month, too many replacement heifers, or herd expansion taking place before barn expansion. While overstocking may be a short-term solution to a management challenge, there is a growing body of science that demonstrates that overcrowding results in both behavioral and biological changes that can affect cow health, productivity, and welfare. Overstocking interferes with normal behavioral time budgets of dairy cows, disrupting both feeding and lying activities. Aggressive competitive interactions are also more frequent when cows are crowded at the feed bunk or lying stalls, particularly for socially subordinate animals. More recent work has found that overstocking is associated with increased physiological stress and changes in energy metabolism. This research has dramatically improved our understanding of the ways in which overstocking affects dairy cattle health and welfare and collectively will enable for improved science-based recommendations on how best to manage intensively housed dairy cattle.

Introduction

In the United States, there are no clear national guidelines for recommended space availability in free-stall dairy barns. For instance, the National Dairy FARM (Farmers Assuring Respo nsible Management) Program recommends "stocking rates allow for adequate time per animal for rest, exercise, and feed and water consumption" (National Milk Producers Federation, 2010). In contrast, the Canadian National Farm Animal Care Council in partnership with the Dairy Farmers of Canada established a scientific committee to create a *Code of Practice for the Care and Handling of Dairy Cattle.* This document recommends that lactating dairy cows should be provided one lying stall for every cow in the pen and 60 cm (24 inches) of linear feed bunk space per animal (NFACC, 2009).

A survey conducted in 2007 by the USDA National Animal Health Monitoring Service **(NHAMS)** of free-stall farms reported that 58% of the surveyed farms in the US provided less than 24 inches of feeding space and 43% provided less than one lying stall per animal based on average cow numbers on the farm during the year (USDA, 2010). More recently, stocking rates of high-lactation groups were collected as part of a benchmarking study of free-stall dairy herds in 3 regions of North America: 43 farms from British Columbia, Canada (BC); 39 farms from California, USA (CA); and 40 farms from the northeastern United States (NE-US; including New York, Pennsylvania, and Vermont). Feed bunk stocking density (# of cows per 24 in of feed bunk *100%) was reported to range from 58 to 228% across regions but averaged 116% in BC, 94% in CA, and 142% in NE-US (Figure 1A; von Keyserlingk

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et al., 2012). Stocking density at the lying stalls (# of cows per stall *100%) ranged from 71 to 197% with the majority of the high-producing groups assessed (60%) having densities over 100% (Figure 1B; von Keyserlingk et al., 2012).

The fact that many farms overstock at both the feed bunk and at the lying stalls is worrisome given the breadth of research available on the negative consequences of overstocking on behavior, health, and productivity of cattle. Understanding the various ways in which overstocking affects the welfare of cattle is crucial in order to justify best management practices for intensively housed lactating dairy cows. The aim of this paper is summarize current knowledge of the ways in which overstocking affects feeding strategies and health in Holstein dairy cattle.

Consequences of Overstocking on Behavior

Feeding activity

Cows are social herd animals and prefer to engage in certain activities, like feeding, at the same time (von Keyserlingk and Weary, 2010). Overstocking alters feeding activity by preventing cattle from being able to access the bunk at the same time. Research has shown that cows are particularly motivated to access the feed bunk at the same time during the hours following fresh feed delivery (DeVries and von Keyserlingk, 2005). This is the time of day when feed quality is the greatest as it is fresh and unsorted by the cattle. DeVries et al. (2004) reported that when cows had access to more space at the feed bunk [1.0 m versus 0.5 m per cow (39 vs. 19 inches/cow)], daily feeding activity was higher, particularly during the 90 min following fresh feed delivery. In a follow up study, overstocking at the feed bunk was shown to decrease the proportion of cows feeding during the hours following fresh feed delivery (Huzzey et al., 2006; Figure 2). Interestingly in that study, cows failed to compensate for lost feeding time by spending more time at the bunk during other periods of the day (such as the overnight hours) when bunk attendance was lower (Figure 2). Instead, these cattle had longer inactive (non-feeding) standing times when overcrowded, presumably due to cows waiting to access the feed bunk (Huzzey et al. 2006).

Feeding time and dry matter intake

Changes in these feed patterns likely explain why average daily feeding time is generally found to be lower when cows are overstocked at the feed bunk (Olofsson, 1999; DeVries et al., 2004; Huzzey et al., 2006; Proudfoot et al., 2009). These lower feeding times do not necessarily translate to lower daily dry matter intake **(DMI)**, as multiparous cows appear to be able to compensate (at least to some degree) by increasing their feeding rate when overstocked at the feed bunk (Olofsson, 1999; Proudfoot et al., 2009). However, high feeding rates may lead to complications associated with slug feeding, like acidosis, particularly if overstocking is combined with a poorly formulated or highly sortable TMR rations (DeVries et al., 2008) and thus a potential risk factor for sole ulcers (Proudfoot et al., 2010). However, DMI increases in responses to overstocking are not consistent. For example, multiparous cows that were overstocked during the week before calving tended to consume nearly 4.4 lb/day less DM compared to cows that were not forced to compete for access to the feed bunk (Proudfoot et al., 2009).

Social behavior at the feed bunk

Aggressive competitive displacements at the feed bunk are increased at high stocking densities, likely because cows must stand closer together in order to obtain feed (DeVries et al., 2004; Huzzey et al., 2006; Proudfoot et al., 2009). Feeding rate during periods of overstocking have also been shown to be correlated with displacement success; cows that are displaced frequently but have difficulty displacing others have the highest feeding rates (Proudfoot et al., 2009). These apparent low ranking cows also have the greatest improvements in feeding activity, particularly during the 90-min period following fresh feed delivery, when provided with additional space at the feed bunk (DeVries et al., 2004).

Interactions between lying and feeding activity

Stocking rate (cow:stall ratio) at the lying stalls affects resting time budgets and also indirectly affects feeding activity. Fregonosi et al. (2007) reported that when cows were housed at a stocking rate of 150% (12 cows: 8 stalls), they spent 1.7 h/day less time lying down compared to when they were housed at a 100% stocking rate (8 cows: 8 stalls). These results are consistent with earlier studies that have also found decreased lying times in response to reduced stall availability (Friend et. al., 1977; Friend et al., 1979; Wierenga and Hopster, 1990). During periods of overstocking, lying behavior appears to be most affected during peak resting times, which included the overnight hours and mid-day (Figure 3; Fregonosi et al., 2007). Shorter resting times during periods of overstocking result in cows having to spend more time standing, often on the hard concrete surfaces in the pen alleys; this is a concern as long standing times on hard surfaces is a known risk factor for lameness (Cook and Nordlund, 2009).

Lying time is highly valued by cattle and there also can be unintended consequences on feeding activity if lying opportunities are restricted. For instance, repeated studies have shown that cows will sacrifice feeding time in order to lie down when both resources are limited (Metz, 1985; Munksgaard et al., 2005). Similarly, rather than going up to the feed bunk to feed following milking, cows that were overstocked at the lying stalls (150 % stocking rate) laid down about 13 min sooner than cows that were not overstocked (Fregonesi et al., 2007). These results suggest that when resting space is limited, cows will scramble to obtain a resting location as soon as they become available and forfeit eating.

Consequences of Overstocking on Health and Functioning

By far, the majority of research exploring the consequences of overstocking have focused on the behavioral changes associated with reduced space availability. However, more recent work has shown that overstocking increases cows risk for health problems, low milk yield, and poor reproductive performance.

Disease, milk, and reproduction

In a large study that followed 1170 multiparous cows on 67 high-producing dairy herds, Cameron et al. (1998) reported that if each individual cow was provided with < 30 cm (12 in) of bunk space or 30 to 60 cm (12 to 24 in) of bunk space with restricted feed availability (not ad-libitum) during late gestation, they were of increased risk of displaced abomasum after calving.

Researchers in Wisconsin collected reproduction and management data from 153 farms, collectively representing 16,000 cows, to identify management practices that increase cows' risk for decreased fertility. Increased stocking density at the feed bunk was found to be one of the most detrimental risk factors. Specifically, farms with less than 14 inches (36 cm) of linear bunk space per cow had a greater percentage of non-pregnant cows at 150 DIM, while the probability of pregnancy increased linearly as bunk space increased from 12 to 24 in/cow (Caraviell et al., 2006).

Researchers in Spain measured the milk yield of over 3000 cows on 47 commercial dairy herds that fed the same TMR ration that had been mixed at a central location. This study reported a strong negative correlation between stocking density in the lying stall with milk yield; the higher the ratio of cows to stalls, the lower the average daily milk yield for each animal (Bach et al., 2008). On the other hand, reduced feed bunk space has not been linked to lower milk yield (Bach et al., 2008; Proudfoot et al., 2009). The failure to consistently show reductions in milk yield when feed bunk space is limited has likely been a contributing factor to the continued practice of overstocking. However, the maintenance of milk production alone should not be used to justify a management practice as the relationship between milk production and animal welfare is complex. As such, few animal welfare experts consider milk yield to be a useful measure in on-farm welfare assessments of dairy cattle (Whay et al., 2003; von Keyserlingk et al., 2009).

Physiological health

Very few studies have investigated the physiological consequence of overstocking. Understanding this relationship, including its interaction with behavior, however, is likely a key factor to understanding how overstocking affects overall welfare. Research conduced over 30 years ago reported greater physiological stress (increased cortisol production) in cows that were overstocked at the feed bunk (10 in/per cow) and lying stalls (2 cows per 1 lying stall) compared to cows that were not crowded (Friend et al., 1977; Friend et al., 1979). These earlier findings are supported by more recent research that showed when cows were overstocked at the lying stalls, those with the lowest feeding times had higher cortisol production during an adrenocorticotropic hormone test - evidence of increased sensitivity to stress (Gonzalez et al., 2003). However, until recently, the effects of increased cortisol production during overstocking on health and performance had not been investigated further.

Physiological changes in response to overstocking likely occur as cows try to cope with an environment where access to resources is limited, but this can have unintended consequences on other biological processes. For example, increased cortisol production can alter energy metabolism. Glucocorticoids (e.g. cortisol) regulate fat break down and storage as well as glucose production by the liver, thereby influencing plasma nonesterified fatty acid **(NEFA)** and glucose concentrations (Parker et al., 2004). During short-term stress, these functions can be very useful for increasing energy availability to allow the animal to respond to a stressor. However, persistently elevated cortisol concentration due to long-term or chronic stressors (which overstocking may represent) can begin to negatively affect animal health. For example, excess glucocorticoid production has been associated with insulin resistance (Andrews and Walker 1999).

Recent work conducted at Cornell University attempted to answer the question: Is overstocking a physiological stressor capable of altering aspects of energy metabolism? To address this question, 4 groups of 10 late gestation non-lactating dairy cattle (4 heifers and 6 cows) were exposed to both a control (100% Stocking Rate: 1 lying stall/cow and 27 in feed bunk/cow) and overstocked (200% Stocking Rate: 0.5 lying stalls/cow and 13.6 in feed bunk/cow) treatment for 14 days each. Group DMI was recorded and feeding and social behavior were monitored using video recordings of the feed bunk. Blood and fecal samples were collected throughout each treatment to measure biomarkers of energy balance (e.g., NEFA) and stress (fecal cortisol metabolites) and a glucose tolerance test **(GTT)** was conducted on all cows during each treatment to more specifically examine the effects of overcrowding on energy metabolism (Huzzey et al., 2012a; Huzzey et al., 2012b).

During the overstocked period, group DMI was on average 2.2 lb/day greater than during the control period, but total daily feeding time did not differ between the 2 treatments, suggesting that cows compensated by increasing their feeding rate during the overstocked period. Despite higher DMI during the overstocked period, average NEFA and glucose concentrations were also higher during this time; these results contradicted expected blood profiles based on the observed higher intake. The results also indicated that overstocking was associated with slightly slower glucose clearance from circulation and decreased insulin production following a large intravenous dose of glucose during the GTT. These changes in the way glucose is metabolized in the body could explain the higher concentrations of NEFA and glucose in the blood, despite higher intake. Some of these changes in metabolism could have been influenced by stress, the resulting changes in cortisol production as there was also a tendency for higher concentrations of fecal cortisol metabolites (11,17-dioxoandrostanes) during the overstocked period (Huzzey et al., 2012a).

Interactions between behavior and physiology

Research has shown that cows that are most frequently displaced from the feed bunk have the highest feeding rates during overstocking (DeVries et al., 2004), suggesting that these may also be the animals that have the greatest difficulty coping with overcrowding. The results of the overstocking study undertaken by Huzzey et al. (2012a,b) provided the first evidence that cattle that have little success in competitive interactions at the feed bunk when housed in overstocking situations show the greatest physiological responses to this stressor (Huzzey et al., 2012b). Low-success cows (displaced more than they could displace others) had the highest concentrations of fecal cortisol metabolites and plasma NEFA (Figure 4). Interestingly, the low-success group consisted almost entirely of heifers. This information combined with the work of Proudfoot et al. (2009) collectively suggest that grouping these younger, arguably more vulnerable, animals with the older multiparous cows in an overcrowded environment provides additional previously unknown behavioral and physiological challenges (Huzzey et al., 2012b).

Managing Overstocking

To achieve best management practices, we strongly encourage producers to strive to achieve stocking rates that include providing cattle with 1 lying stall per cow and at least 2 feet (60 cm) of linear bunk space per cow (equivalent to 1 head-lock per cow). When stocking rates exceed these recommendations, there may be management related strategies that can be used to minimize the impact of crowding on behavior and health.

Avoid high-risk periods

Clearly, avoiding overstocking during times when cows are particularly vulnerable, such as during the transition period a time when they experience numerous physiological and management changes, is a key first step to maximizing health and welfare and ultimately farm income. Increased NEFA concentration during the weeks around calving (e.g. $\geq$ 0.3 mEq/L during the 2-wk period before calving) have been associated with an increased risk of disease, reduced milk yield, and compromised reproductive performance (Ospina et al., 2010a; Ospina et al., 2010b). Therefore, management practices known to be associated with higher plasma NEFA, like overstocking, should be avoided during these high-risk periods. Alternative grouping strategies during periods of overstocking, such as separating primiparous and multiparous cows, may also be beneficial; however, more research is needed to fully understand how best to manage these different groups of cows.

Feed barriers

Researchers have also discovered that certain feed bunk designs may help reduce displacement frequency during periods of overstocking. Providing physical separation between the necks of cattle, as with a head-lock feed barrier (Huzzey et al., 2006), or between the bodies of cattle, as with specially designed feeding stalls

(DeVries and von Keyserlingk, 2006), has been shown to decrease displacement frequency during periods of overstocking when compared with more open feed barrier designs (e.g. post-rail feed barrier). Cattle at the feed bunk commonly displace other feeding animals by swinging their head or bodies in such a way that it makes contact with the adjacent cow, causing that cow to step away from the bunk. Providing physical separation between the bodies of feeding cows likely makes this behavior in particular more difficult to perform (Figure 5).

Ensure consistent TMR quality

Avoiding variation in TMR quality along the length of the feed bunk may also be important, particularly in overcrowded groups. Recent research has shown that dairy heifers are highly motivated to find the highest quality (most energy dense) feed locations along the bunk and will actively compete for access to these spots. In that study, despite heifers having ample space to feed (8 headlocks for 2 heifers), competitive displacements were 3 times greater when TMR quality along the bunk was non-uniformly distributed compared to when in was uniform in quality along the entire bunk length (Huzzey et al., 2013). Although not yet experimentally tested, it could be predicted that the behavioral consequence of variable TMR quality in an overstocked group, including adult cows, would be even more dramatic.

Conclusion

Overstocking results in behavioral and physiological changes that may increase a cow's risk for health disorders, low milk yield, or poor reproductive performance. Ensuring cows have the recommended 2 feet (260 cm) of linear feed bunk space and 1 lying stall per animal should be the aim of every dairy producer. The research summarized in this review provides useful insights that can be used to inform management strategies aimed at improving dairy cattle welfare during periods of overstocking.

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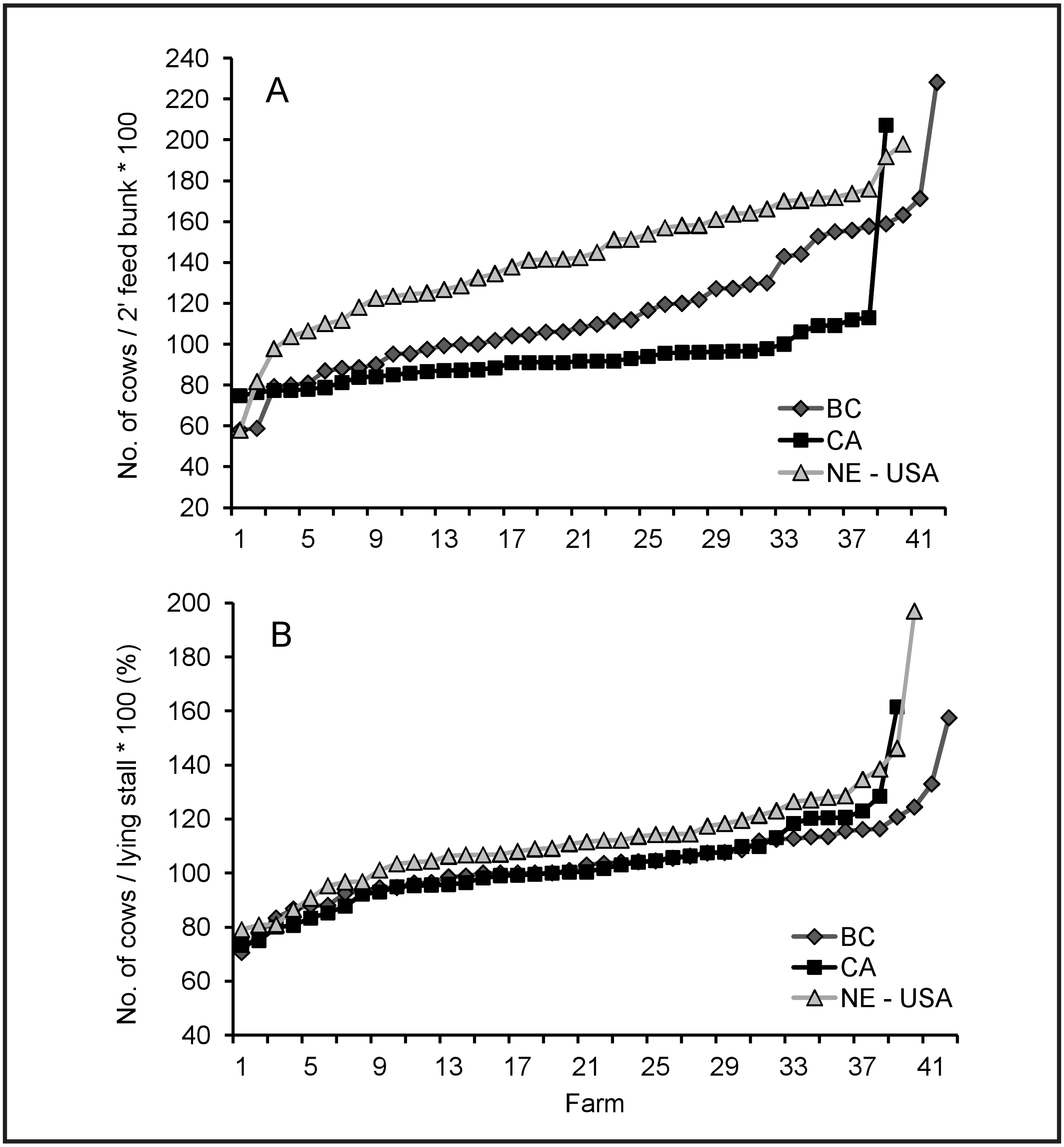

Figure 1. Stocking density at the feed bunk (A) and the lying stalls (B) in high-production groups on farms in British Columbia (BC; n =42), California (CA; n-39), and the northeastern United States (NE-US; n=40). Farms are sorted from lowest to highest stocking density (von Keyserlingk et al., 2012).

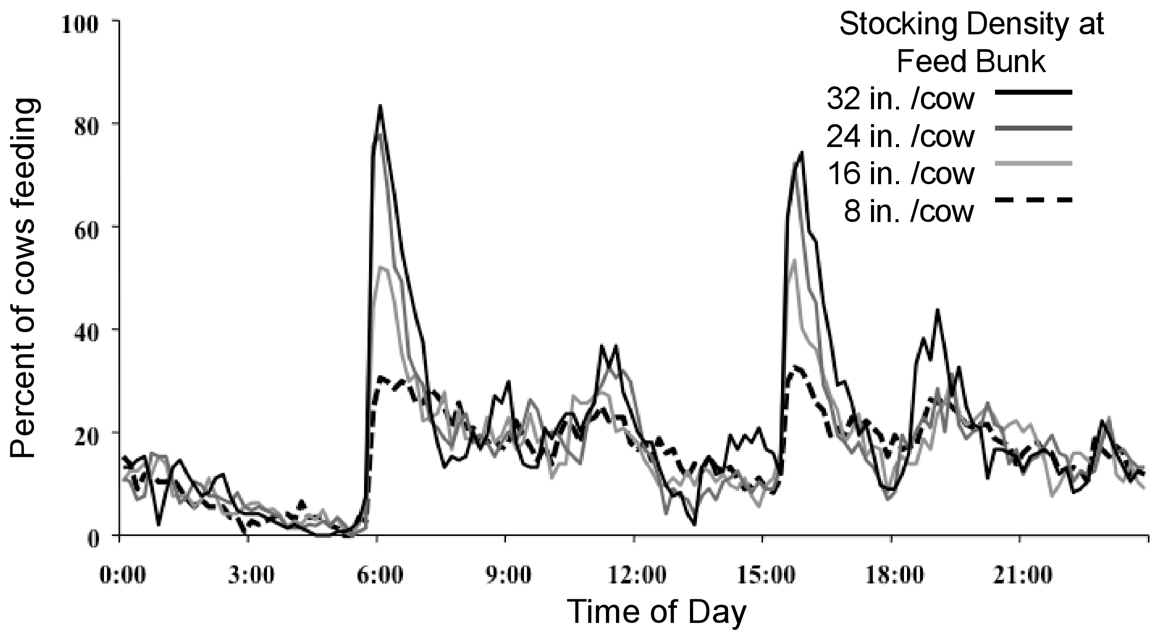

Figure 2. Pattern of feeding activity during a 24-h period for dairy cattle at 4 stocking densities at the feed bunk. Data presented are for cows at a post-rail feed barrier; however, the pattern is the same for cows feeding at a headlock (HL) with corresponding stocking densities: 3, 1.5, 1, and 0.75 cows/HL (Huzzey et al., 2006).

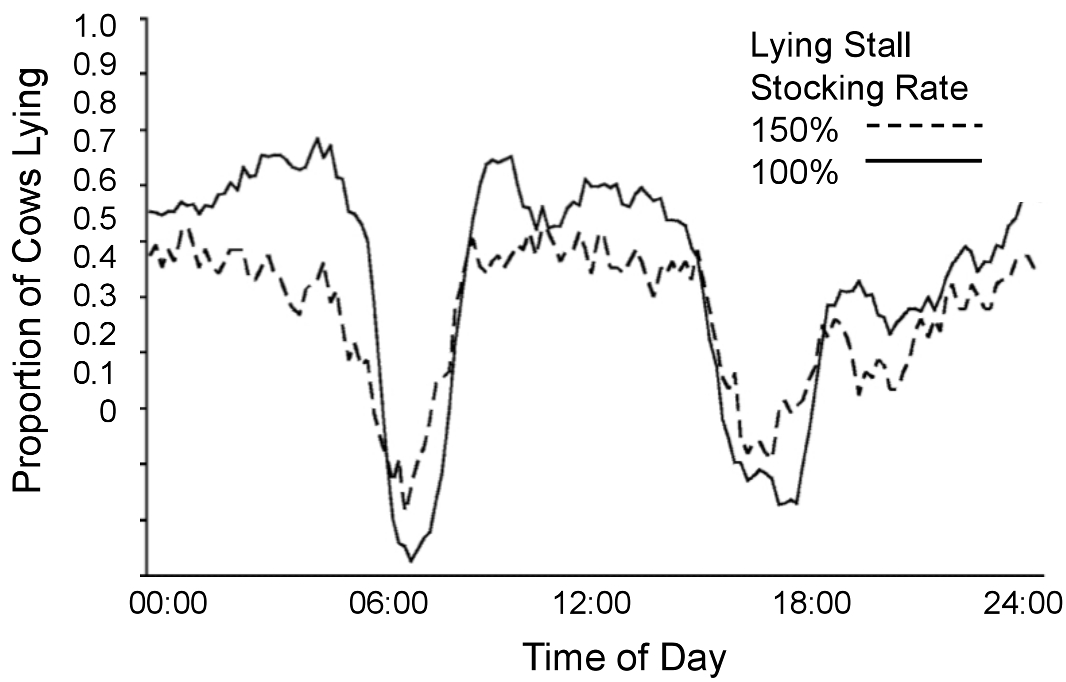

Figure 3. Pattern of feeding activity during a 24-h period for dairy cattle at 2 stocking densities at the lying stalls: 150% = 1.5 cows /stall; 100% = 1 cow /stall. Cows were milked and fresh feed was delivered at 06:00 and approximately 15:30 h (Fregonosi et al., 2009).

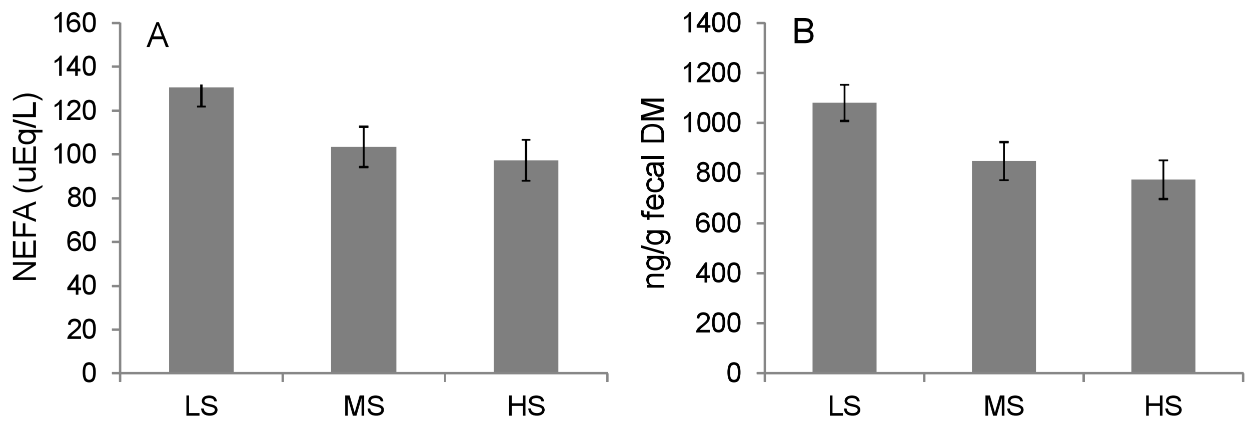

Figure 4. Average (±SE) plasma NEFA (A) and fecal cortisol metabolite (B) concentration for cows that differed in their success at competitive interactions at an overstocked feed bunk. *Low success (LS):* cow is displaced more often than she can displace others; *Moderate Success (MS)*: cow is displaced about as frequently as she can displace others; and *High Success (HS)*: cow displaces others more than she is displaced (Huzzey et al., 2012b).

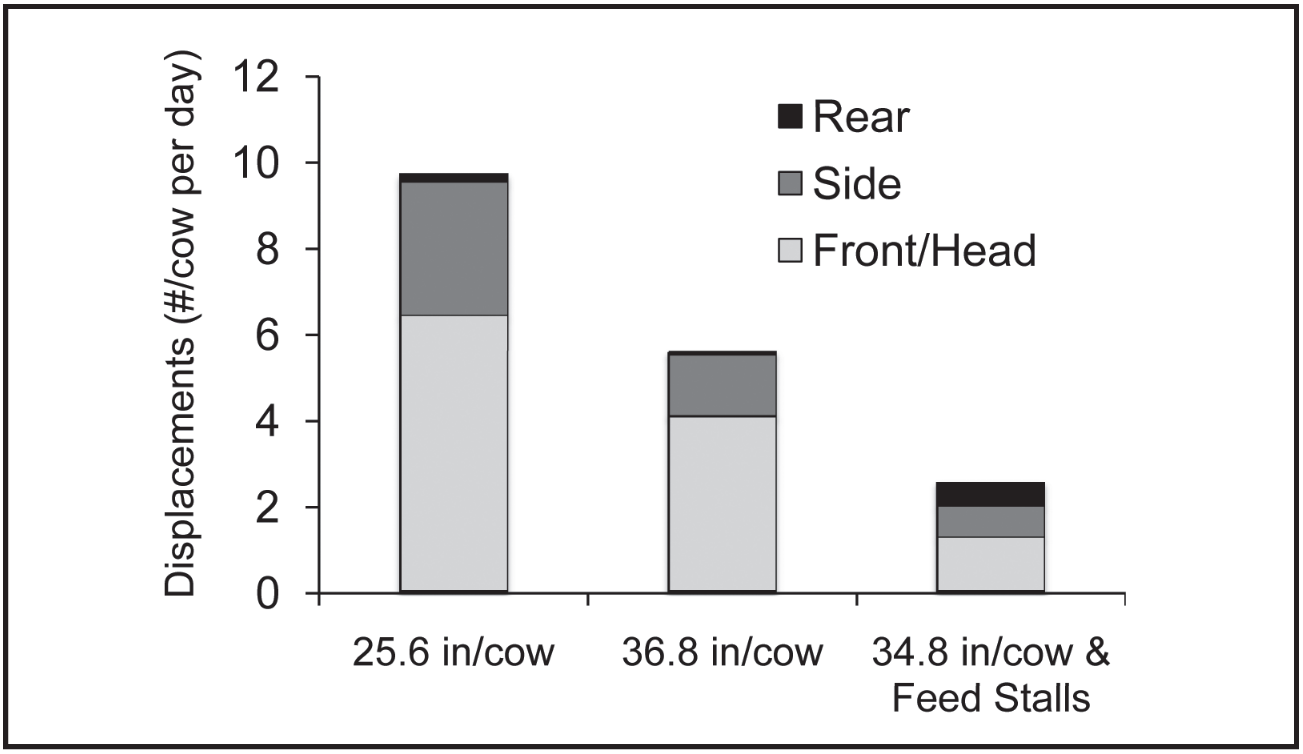

Figure 5. The effect of stocking density and provision of feed stalls (photo) on displacement frequency at the feed bunk. Displacements were either initiated by contact at the rear, side, or front/head of the cow being displaced (DeVries and von Keyserlingk, 2006).