The behavioral and physiological consequences of overstocking dairy cattle

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Abstract

Overstocked group pens continue to be a challenge for many dairy producers. There are many reasons why overstocking may occur, including an unexpectedly busy calving month, too many replacement heifers, or herd expansion before barn expansion. While overstocking may be a short-term solution to a management challenge, a growing body of science demonstrates that overcrowding results in both behavioral and physiological changes that could compromise future performance, productivity and animal welfare. Overstocking interferes with normal behavioral time budgets of dairy cows, disrupting both feeding and lying activity. 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 research has found that overstocking can affect physiological processes, including energy metabolism and glucocorticoid secretion. This research has dramatically improved our understanding of the ways in which overstocking affects dairy cattle health and welfare, and collectively will enable improved science-based recommendations on how best to manage intensively housed dairy cattle.

Key words: dairy cattle, stocking density, overstocking, behavior, welfare

Résumé

Les enclos collectifs surpeuplés demeurent un défi pour de nombreux producteurs laitiers. Il existe plusieurs raisons pour lesquelles il peut y avoir surpeuplement, comme un mois où les vêlages sont nombreux de façon inattendue, un trop grand nombre de génisses de remplacement, ou une expansion du troupeau qui précède l'agrandissement de l'étable. Bien que le surpeuplement puisse permettre de solutionner à court terme un problème de gestion, les données scientifiques démontrent de plus en plus que le surpeuplement entraîne des changements comportementaux et physiologiques susceptibles de compromettre le rendement, la productivité et le bien-être des animaux à long terme. Le surpeuplement nuit au budget-temps normal sur le plan du comportement des vaches laitières, perturbant à la fois l'alimentation et la période de repos. Les interactions concurrentielles agressives sont également plus fréquentes quand les vaches sont plus nombreuses à la mangeoire ou dans les logettes, particulièrement pour les animaux socialement subordonnés. Des recherches plus récentes ont permis de constater que le surpeuplement peut nuire aux processus physiologiques, notamment au métabolisme de l'énergie et à la sécrétion de glucocorticoïdes. Ces recherches ont radicalement amélioré notre compréhension des façons dont le surpeuplement agit sur la santé et le bien-être du bétail et, collectivement, elles permettent de formuler de meilleures recommandations scientifiquement fondées sur la meilleure façon de gérer les bovins laitiers dans des exploitations intensives.

Introduction

The recently published Canadian Code of Practice for Dairy Cattle suggests that lactating dairy cows should be provided one lying stall for every cow in the pen and 24 inches (60 cm) of linear feed bunk space per animal.[5] Despite these recommendations overstocking is still common, particularly in the United States, where survey data of free-stall farms showed that 58% of farms surveyed provided less than the recommended 24 inches of feeding space. Also, 43% provided less than the recommended lying stall availability based on average cow numbers on the farm during the year.[7]

The fact that many farms fail to provide the minimum requirements is worrisome given the breadth of research available on the negative consequences of overstocking on the health and productivity of cattle. For example, average daily gain of growing beef heifers was shown to decline when space availability in the pen was reduced to 1.5 m^2 per individual despite feed bunk space being held constant at 23 inches (59 cm) per heifer.[12] Other work has reported that reduced lying stall availability is an important risk factor for reduced milk yield.[2] Although decreased feed bunk space has been associated with a decreased probability of pregnancy by 150 days-in-milk (DIM) and an increased risk of health disorders such as displaced abomasum[3,4], other authors have failed to show an association between feed bunk space availability and subsequent milk yield.[2,26] The

failure to consistently show reductions in milk yield when feed bunk space is limited has likely contributed 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, and as such few animal welfare experts consider milk yield to be a useful measure in on-farm welfare assessments of dairy cattle.[27,29]

Clearly, for best management practices to be adopted when intensively housing lactating dairy cows a thorough understanding of the ways in which overstocking affects both behavior, physiology, health, and productivity is needed.

Behavioral Consequences of Overstocking

The majority of research to date has explored the effects of overstocking on behavior, particularly lying, feeding, and social behavior. This research has found that all of these behaviors are affected during periods of overcrowding. Further, the magnitude of these behavioral effects appears to depend upon which resource is crowded (i.e. feed bunk or lying stalls) and how extreme the overcrowding is.

Feeding behavior

Overstocking alters the feeding time budget of dairy cattle. One study showed that when cows had access to more space at the feed bunk (3.3 ft versus 1.6 ft; 1.0 m versus 0.5 m per cow), daily feeding activity was higher, particularly during the 90 minutes following fresh feed delivery.[8] The time following fresh feed delivery is a period when feed quality is highest and when cows are highly motivated to approach the feed bunk to eat.[9] 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 (Figure 1), regardless of what type of feed barrier was used (i.e. a post-rail or a head-lock feed barrier).[17] Cows failed to compensate for lost feeding time by eating more during other periods of the day (such as the overnight hours) when bunk attendance was lower (Figure 1), but rather had longer inactive (non-feeding) standing times when overcrowded, presumably due to cows waiting to access the feed bunk.[17] These observations were not surprising, given that cattle are herd animals and will synchronize their behavior when housed within the same pen. [28]

Changes in these feed patterns likely explain why daily feeding times are generally found to be lower when cows are overstocked at the feed bunk.[8,17,22,26] These lower feeding times do not necessarily translate to lower daily dry matter intake (DMI) as cows, particularly multiparous cows, increase their feeding rate when overstocked at the feed bunk.[22,26] High feeding rates may lead to

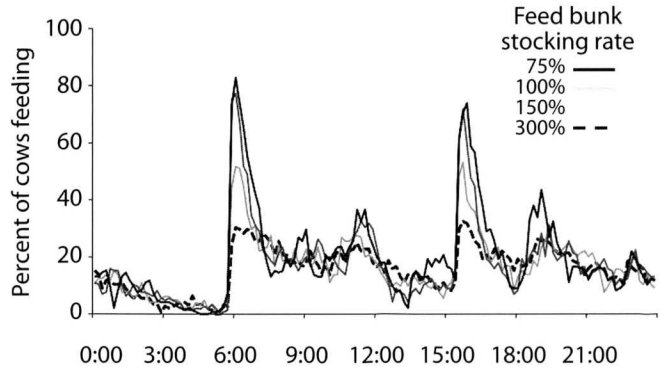

Figure 1. Diurnal variation in feeding time over a 24-hour period. Stocking levels were achieved by manipulating access to the feed bunk. Pattern was the same for cows feeding at a headlock (HL) and post-rail (PR) feed barrier. Stocking rates were as follows: 300%: three cows/HL or 0.69 ft (0.21 m) of PR space/cow; 150%: 1.5 cows/HL or 1.35 ft (0.41 m) of PR space/cow; 100%: one cow/HL or 2 ft (0.61 m) of PR space/cow; and 75%: 0.75 cows/HL or 2.65 ft (0.81 m) of PR space/cow. Figure redrawn from Huzzey JM, DeVries TJ, Valois P, von Keyserlingk MAG. Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle. *J Dairy Sci* 2006;89:126-133.

complications associated with slug feeding, particularly if overstocking is combined with a poorly formulated or highly sortable total mixed ration (TMR).[11] However, in some cases DMI has been found to decline as a consequence of overcrowding; multiparous cows that were overstocked during the week before calving tended to consume nearly 4.4 lb (2 kg) less DM per day.[26]

Standing behavior

Similar to feeding time budgets, resting time budgets are also affected when cows are overcrowded at the lying stalls. Cows that were housed at a stocking rate of 150% (1.5 lying stalls per cow) spent 1.7 hours per day less time lying down, compared to when they were housed at a 100% stocking rate (one cow per stall).[13] These results are consistent with earlier studies that have also found decreased lying times in response to reduced stall availability.[14,15,30] During periods of overstocking, lying behavior appears to be most affected during peak resting times, which includes the overnight hours and mid-day (Figure 2).[13]

Studies have also demonstrated that cows place a higher priority on securing a lying space compared to a feeding place; for instance, cows will sacrifice feeding time in order to lie down when both resources are limited.[20,21] Overstocking also influences latency to lie down after milking; when cows had fewer free-stalls available latency to lie down following milking was shorter (13

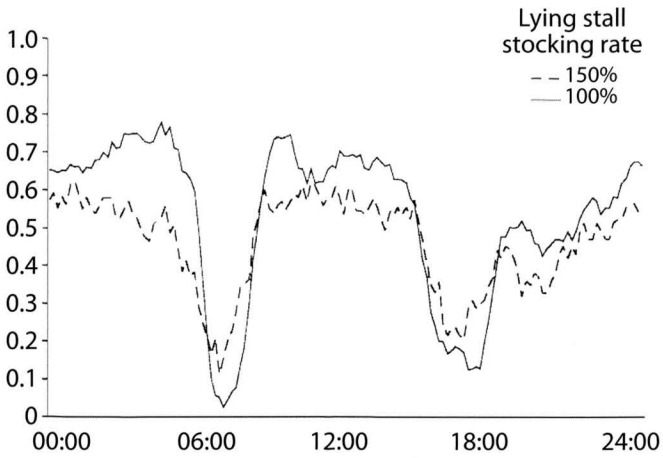

Figure 2. Diurnal variation in lying time over a 24-hour period. Stocking levels were achieved by manipulating access to the free-stalls (150%: 1.5 cows/stall; 100%: one cow/ stall). Figure redrawn from Fregonesi JA, Tucker CB, Weary DM. Overstocking reduces lying time in dairy cows. *J Dairy Sci* 2007;90:3349-3354.

minutes less when housed at a 150% free-stall stocking rate compared to the 100% stocking rate treatment).[13] 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.

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.[6]

Social behavior

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.[8,17,26] Feeding rate during periods of overstocking has also been shown to be correlated with displacement success; cows that are displaced frequently but have difficulty displacing others have the highest feeding rates.[26] These low ranking cows also have the greatest improvements in feeding activity, particularly during the 90-minute period following fresh feed delivery, when provided with additional space at the feed bunk.[8]

Researchers have also found that certain feed bunk designs may help reduce displacement frequency during periods of overstocking.[10,17] Providing physical separation between the necks of cattle, as with a head-lock feed barrier, or between the bodies of cattle, as with specially designed feeding stalls, has been shown to decrease displacement frequency during periods of overstocking when compared with more open feed barrier designs, such as a post-rail feed barrier.[10,17]

Physiological Consequences of Overstocking

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 health and performance. Early work has shown that when cows are regrouped into a pen that is overstocked at the feed bunk (9.8 inches (25 cm) per cow) and lying stalls (1 stall per 2 cows) they have a greater cortisol response to adrenocorticotropic hormone (ACTH) challenge compared to cows that are not regrouped or overcrowded.[14,15] Other researchers have reported that cows having the lowest feeding times in a pen that was overstocked at the lying stalls (1 stall per 2 cows) had the greatest cortisol responses at 60 and 90 minutes following an ACTH challenge.[16] This work suggests that there may be alterations in adrenal function in response to the stress of overstocking. Changes in stress physiology may be a reflection of the physiological adaptations that occur as cows try to cope with an overcrowded environment. Moreover, higher circulating plasma cortisol concentration may also influence other physiological processes.

Glucocorticoids are important regulators of energy metabolism. They help to raise circulating glucose concentrations by increasing hepatic gluconeogenesis and inhibiting peripheral tissue uptake of glucose. Glucocorticoids also contribute to the regulation of lipolysis and lipogenesis, and facilitate increased plasma nonesterified fatty acid (NEFA) concentrations.[25] Excess glucocorticoid production has also been associated with insulin resistance.[1] To date, no work has explored how adrenal activity and energy metabolism of dairy cattle change in response to the stress associated with overstocking.

To address this gap in the literature, a detailed study was carried out at the Cornell University Teaching and Research Dairy Center.[18,19] Forty pregnant, non-lactating Holstein dairy cows (16 heifers and 24 multiparous cows (mean parity ± SD; 1.38 ± 0.65)) were housed in a two-row, free-stall barn in groups of 10. Groups were balanced based on parity (four heifers and six multiparous cows per group) and previous 305ME among multiparous cows. In sets of two, all four groups were exposed to two 14-day stocking density treatments using a crossover experimental design (i.e. replicated crossover). The stocking density treatments were defined as follows: 1) control (100% stocking rate): one lying stall per cow and 2.2 feet (0.67 m) linear feed bunk (FB) space per cow, and 2) overstocked (200% stocking rate): two cows per lying stall and 1.1 foot (0.34 m) linear FB space per cow. On days 1, 3, 5, 7, 9, and 11 of each 14-day treatment period, blood and fecal samples were collected from each cow for the determination of plasma NEFA, glucose, insulin, and fecal cortisol metabolite (11,17-dioxoandrostane; 11,17-DOA) concentrations. A

glucose tolerance test (GTT) and ACTH challenge were conducted on days 13 and 14, respectively, of each treatment period to further explore the effects of overstocking on energy metabolism and stress physiology. Group DMI was recorded and feeding and social behavior were monitored using video recordings of the feed bunk.

Energy metabolism and stress physiology

During the overstocked period, group DMI was on average 2.2 lb (1 kg) per day greater than during the control period, but total daily feeding time did not differ between the two treatments, suggesting that cows compensated by increasing their feeding rate during the overstocked period. These results are consistent with the results of others who also report increased feeding rate at an overstocked feed bunk.[26] Despite this increase in DMI, average NEFA and glucose concentrations were higher during the overstocked period, possibly suggesting increased mobilization of energy reserves. Overstocking was associated with a slightly slower glucose clearance from circulation as evidenced by a greater area under the curve (AUC) estimate for the glucose response curves resulting from the GTT (2882 vs. 2657 ± 165 mg/dL x 180 min; Figure 3A), but a more attenuated insulin response (insulin AUC = 5258 vs 6692 ± 1104 µIU/mL x 180 min for the overstocked and control periods, respectively; Figure 3B). These results provide the first evidence that overstocking is capable of altering energy metabolism, and thus may have long-term unintended consequences to the cow but more work is needed to ascertain these effects. Changes in glucose uptake may be mediated by alterations in pancreatic secretion of insulin or peripheral tissue responses to insulin.[18]

The role of stress hormones (i.e. cortisol) in mediating these changes in energy metabolism are still unclear, as overstocking did not influence the amount of cortisol secretion from the adrenal gland following ACTH stimulation. However, concentrations of 11,17-DOA tended to be greater during the overstocked period, suggesting that overall daily cortisol secretion might have been higher during overstocking.[18]

Although this study was completed during the early dry period, it could be hypothesized that physiological disturbances would have been even more pronounced if overstocking had occurred during more physiologically sensitive periods, such as the transition period. Increased NEFA concentration during the weeks around calving (e.g. ≥ 0.3 mEq/L during the two-week period before calving) have been associated with an increased risk of disease, reduced milk yield, and compromised reproductive performance.[23,24]

Interactions between behavior and physiology

As discussed previously, level of success during competitive interactions at the overstocked feed bunk

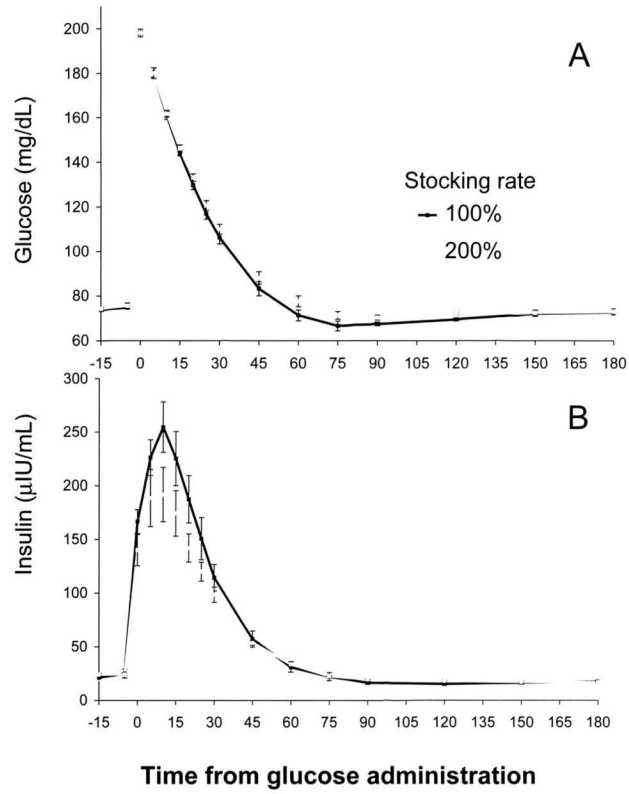

Figure 3. Effects of overcrowding on glucose (A), insulin (B) (arithmetic mean ± SE) response to an intravenous glucose tolerance test. Figure redrawn from Huzzey JM, Nydam DV, Grant RJ, Overton TR. The effects of overstocking Holstein dairy cattle during the dry period on cortisol secretion and energy metabolism. *J Dairy Sci* In Press, 2012.

are associated with specific behavioral observations. For example, cattle that are frequently displaced from the feed bunk have the highest feeding rates during overstocking and have the greatest improvements in feeding activity when given more space.[8,26] These cattle may be considered the socially subordinate individuals (e.g. low success) in the groups, and thus may have the most difficulty coping with in overstocked situations. The results of the overstocking study conducted at Cornell University now provide evidence that low success cattle also have greater physiological responses to overstocking.[19]

Level of success during competitive interactions at the feed bunk was determined by first assigning each cow a Competition Index (CIndex) score.[19] This score was calculated by dividing the number of times a cow displaced another cow from the feed bunk by the total number of interactions she was involved in (times displaced plus times she displaced others). For each cow, the CIndex score could vary from 0 to 1; an index value

of 0 would indicate that a cow was never successful at displacing another individual but was displaced by others; whereas, an index value of 1 reflects a cow that successfully displaced others but was never displaced by others. These index values were used to categorize cows into three subgroups according to their level of success during competitive interactions at the feed bunk: low success (LS: CI < 0.40), medium success (MS: 0.40 < CI ≤ 0.60), and high success (HS: CI > 0.60).[19]

Although there were no differences in daily feeding time, time to approach the feed bunk following fresh feed delivery (Figure 4), or total number of displacements between the three CIndex groups, the LS cows had the highest concentrations of 11,17-DOA and NEFA (Figure 4). This latter result provides the first evidence suggesting that the LS cows had greater stress-loads, and thus greater physiological alterations, as a consequence of having to cope in the overstocked environment.[19] During the GTT, glucose response curves were similar across all three CIndex categories; however, the peak insulin response by the LS cows was 130 μIU/mL greater than the peak HS response, indicating that the LS cows likely had either reduced tissue responses to insulin or increased pancreatic responses to glucose. Interestingly, the LS group consisted almost entirely of heifers, suggesting that grouping these younger, arguably more vulnerable, animals with the older multiparous cows in an overcrowded environment provides additional previously unknown physiological challenges.[19]

Conclusions

Adequate feed bunk and stall space for each individual cow within the pen is essential for optimizing feeding and resting activity and promoting proper biological functioning. Overstocking results in behavioral and physiological changes that may increase a cow's risk for health disorders, low milk yield or poor reproductive performance. The research summarized in this review provides useful insights that can be used to inform management strategies aimed at improving cattle welfare during overstocking. For example, finding ways to

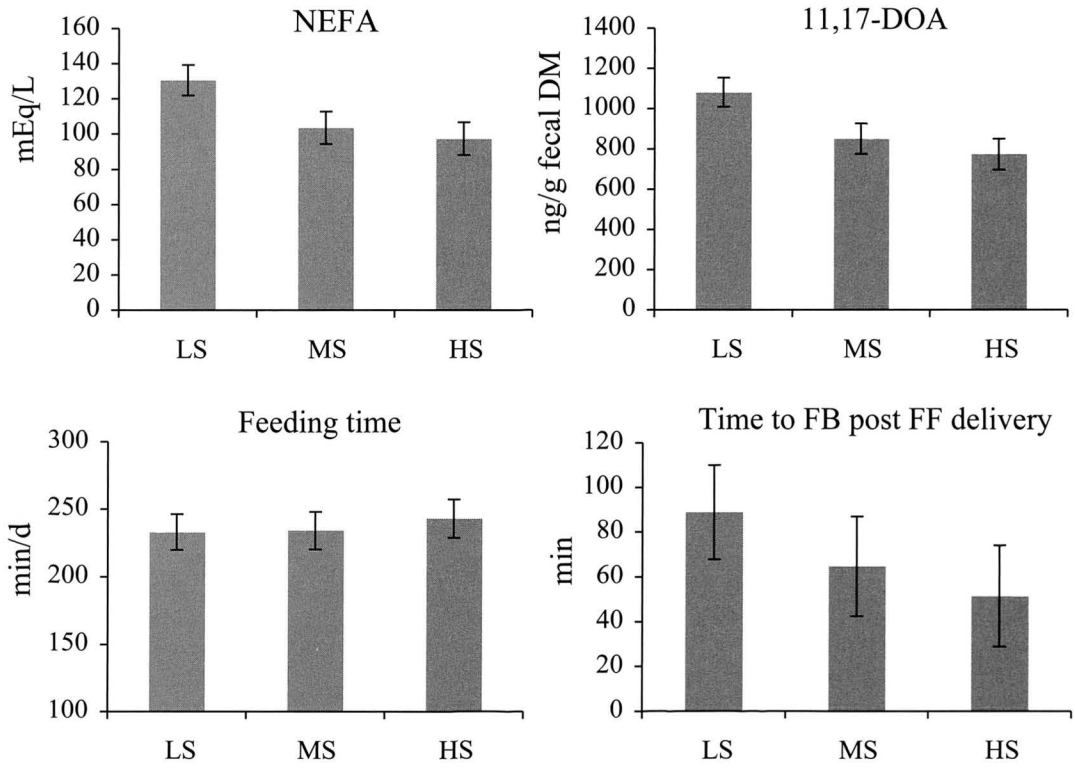

Figure 4. Least squares means (± SE) plasma NEFA, fecal cortisol metabolite (11,17-DOA), daily feeding time and time to approach the feed bunk (FB) following fresh feed (FF) delivery of cows grouped into three categories based on their competition index (CI) score: high success group (HS: CI ≥ 0.6), medium success group (MS: 0.4 ≥ CI < 0.06), and low success group (LS: CI < 0.4). Figure is redrawn from Huzzey JM, Grant RJ, Overton TR. Short communication: Relationship between competitive success during displacements at an overstocked feed bunk and measures of physiology and behavior in Holstein dairy cattle. *J Dairy Sci* In Press, 2012.

reduce displacement frequency during overcrowding, such as using headlock feed barriers or feeding partitions that reduce aggression, are effective strategies that are available to producers. 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.

Ensuring cows have the recommended 2 feet (60 cm) of liner feed bunk space and one lying stall per animal should be the aim of every dairy producer. Clearly, avoiding overstocking during times when cows are particularly vulnerable, such as during the transition period when they are also going through numerous physiological and management changes, is a key first step to maximizing health and welfare, and ultimately farm income.

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