Transition Cow Grouping Strategy: Effects on Cow Health

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Introduction

The period from three weeks before to three weeks after parturition in dairy cows, also known as the transition period, is characterized by significant changes in hormonal profile, feed intake, nutrient requirements, metabolism, and energy balance. These changes are known to dramatically affect immune function. Consequently, cows are at greater risk of health disorders and mortality during early lactation. In the last week of gestation, concentrations of progesterone decrease as concentrations of cortisol, estradiol, prostaglandin $F_{2\alpha}$, and prolactin increase (Stevenson, 2007). These changes are important for onset of colostrum production and preparation for parturition. Cortisol, the key hormone that triggers parturition (Akers, 2002), is known to alter neutrophil morphology and functionality (Burton and Kehrli, 1995a; Burton et al., 1995b; Burton et al., 2005). At the same time that dramatic hormonal changes are occurring, feed intake in the last 14 d before parturition decreases by approximately 50%, reaching its nadir on the day before parturition (Grummer et al., 2004). Although feed intake starts to increase immediately after parturition, it is not sufficient to meet nutrient requirements for the rapidly increasing milk yield. Thus, cows suffer from negative energy balance for up to 8 to 12 weeks after parturition and must utilize body energy reserves to meet nutrient requirements for milk production. At the same time that decline in feed intake starts to occur, a decoupling of the somatotropic axis occurs that results in elevated concentrations of growth hormone (GH) and reduced circulating concentrations of insulin and insulin-like growth factor-1 (IGF-1), because of down regulation of expression of GH receptor 1-alfa (Rhoads et al., 2004; Lucy, 2008). Furthermore, around the time of parturition cows undergo a state of insulin resistance in which glucose receptor dependent uptake of glucose by muscle and adipose tissue is reduced and GH-induced lipolysis is increased. These are considered homeorhetic changes to assure that cows continue to produce milk during periods of scarce nutrient availability. The combination of reduced feed intake, negative energy balance, increased GH concentration, and insulin resistance result in elevated plasma concentrations of non-esterified fatty acids (NEFA). Exposure of cows to severe and prolonged negative energy balance and extremely elevated concentrations of NEFA predispose cows to hepatic lipidosis (Grummer et al., 2004), compromised liver function, incomplete oxidation of NEFA, and elevated concentrations of ketone bodies [e.g. beta-hydroxy butirate (BHBA)] (Grummer et al., 2004).

Elevated plasma NEFA concentration is associated with reduced neutrophil function (Klucinski et al., 1988; Rukkwamsuk et al., 1999; Hammon et al., 2006) and reduced feed intake during the prepartum period is associated with reduced peripartum neutrophil activity (phagocytosis and oxidative burst) and increased likelihood of metritis postpartum (Hammon et al., 2006). Furthermore, postpartum hepatic lipidosis has been associated with increased length of bacterial shedding from mastitic cows (Hill et al., 1985) and prepartum increase in fat mobilization and serum lipoprotein metabolism resulted in increased risk of metritis and retained fetal membranes (Kaneene et al., 1997). Increasing prepartum and postpartum NEFA plasma concentrations were associated with increased risk of retained fetal membranes, metritis, clinical ketosis, and displacement of abomasum (DA; Ospina et al., 2010). Accentuated negative energy balance accompanied by increased BHBA plasma concentrations during early postpartum also has been associated with increased risk of metritis and DA (Ospina et al., 2010), endometritis (Reist et al.; 2003), and other peripartum diseases (Erb and Grohn, 1988; Grohn et al., 1989; Correa et al., 1993). Therefore, situations of stress, limited availability of and/or access to feed and water during the transition period are likely to exacerbate the negative energy balance and further compromise immune function and increase the risk for postpartum diseases.

Regrouping of dairy cows is used in dairy operations to maintain homogenous groups in terms of gestation stage to optimize nutritional management. Thus, in many dairy operations cows are housed as a group from approximately 230 to 250 d of gestation in so called “dry cow pens” and as another group from 251 d of gestation to parturition in so called “close-up cow pens”. Every week, cows from the dry-cow pen are moved to the close-up cow pen, which results in weekly disruption of social interactions and for many cows disruption of social interactions in the last days before parturition. Constant regrouping of cows changes the hierarchical order among them, forcing cows to reestablish social relationships through physical and nonphysical interactions and exacerbating aggressive and submissive behaviors (von Keyserlingk et al., 2008). Furthermore, because dry-cows and close-up cows are not producing milk, their management is often taken for granted resulting in overstocked pens, insufficient water and feed availability, and exposure to adverse weather conditions (i.e. heat stress). These managerial inadequacies that increase and prolong the negative energy balance during the peripartum transform the normal homeorhetic changes into metabolic diseases (i.e. excessively elevated fat mobilization, hepatic lipidosis, and ketosis) further suppressing immune function of dairy cows and predisposing them to health disorders, and compromised productive, reproductive, and economic performances.

Stocking density prepartum and its effects on behavior, feed intake, and immune function

Cows are social animals and as such are highly susceptible to social interactions and hierarchical order. Situations of limited space or access to feed exacerbate aggressive and submissive behaviors. Two small but elegant studies conducted in research facilities of the University of British Columbia in Canada demonstrated the effects of overstocking of prepartum cows on behavior and feed intake. According to one of these studies, cows housed in pens in which the ratio of cows to feeding bin was 2:1 had altered behavior compared with cows housed in pens with cow to feeding bin ratio of 1:1 (Hosseinkhani et al., 2008). Similarly, the second study demonstrated that cows housed in pens with 30 cm/cow of feed bunk space had altered behavior compared with cows housed in pens with 60 cm/cow of feed bunk space (Proudfoot et al., 2009). These altered behaviors included increased rate of feed intake, fewer meals per day, increased feed sorting, decreased overall feed intake, increased standing time, and increased rate of displacement from the feeding area (Hosseinkhani et al., 2008; Proudfoot et al., 2009). The consequences of stocking density for dominant and submissive cows are likely to be distinct. Dominant cows are predisposed to ruminal acidosis when they have increased rate of feed intake, fewer meals per day, and increased feed sorting. On the other hand, submissive cows are more likely to have metabolic diseases such as hepatic lipidosis and ketosis because of reduced feed intake and to develop lameness because of increased standing time and displacement rate. Therefore, overstocking of pens of prepartum cows, a common problem in dairy operations of all sizes, predisposes all cows to inadequate nutrient intake prepartum and consequently compromised immune function.

We are unaware of studies with dairy cows that have evaluated the effects of stocking density on immune parameters during the periparturient period. Dairy ewes, however, that were housed in high stocking density (1.5 m^2/ewe) conditions during the peripartum period up to mid-lactation had reduced anti-ovalbumin IgG concentration in response to an ovalbumin challenge compared with ewes housed in low stocking density (3 m^2/ewe) conditions (Carporese et al., 2009). Furthermore, ewes that were housed in high stocking density conditions tended to have greater number of aggressive interactions and had reduced milk yield and increased milk somatic cell count (Carporese et al., 2009). Therefore, increased stocking density is likely to affect immune function of dairy cows as well.

Regrouping frequency and its effects on behavior, feed intake, and milk yield

The effects of regrouping frequency of cows on behavior, feed intake, and health has been less studies and has yielded more contradictory results. In small studies also conducted in Canada cows were demonstrated to have reduced feeding time, greater rate of displacement from the feed bunk and stalls, and reduced milk yield on the days following regrouping (von Keyserlingk et al., 2008). Although the question has not yet been definitively answered, cows may require 3 to 14 days after regrouping to reestablish social stability to pre-regrouping levels (Grant and Albright, 1995). This could be a significant problem for close-up cows because weekly entry of new cows in the close-up could result in social disruption and stress on the last days of gestation, compromising further dry matter intake (DMI) and immune parameters.

Coonen et al. (2011) evaluated dry matter intake, plasma NEFA concentration, and 30-d milk yield of close-up cows (14 to 28 d before expected calving date) that were housed in stable (no new cows entering the close-up pen) or dynamic pen (new cows entering the close-up pen twice weekly). The pens were relatively small (10 cows per pen) and the total number of cows used in the experiment was 85. Cows were observed twice weekly for 1 h after feed delivery to evaluate social disruption in the feed bunk. In this small study no differences in feed bunk displacement rate, DMI, NEFA concentrations during the peripartum, and milk yield between 'stable' and 'dynamic' grouping systems were observed (Table 1). It is likely that the lack of difference in displacement rate from the feed bunk in this study was a consequence of the monitoring schedule used, but the lack of difference DMI, NEFA concentration, and milk yield are novel and important to evaluate in larger studies.

In a recent study (Silva et al., 2012a) the hypothesis that constant disturbance of social order prepartum by weekly introducing new cows in a close-up pen was tested in a large dairy herd (6,400 lactating cows). Cows (254 ± 7 d of gestation) were paired by gestation length and assigned randomly to an All-In-All-Out (AIAO) or control treatments. In the AIAO (n = 259) treatment, groups of 44 cows were moved into a pen where they remained for 5 wk, whereas in the control treatment (n = 308) approximately 10 cows were moved into a pen weekly to maintain stocking density of 100% and 92% relative to stalls and headlocks, respectively. Cows in the AIAO treatment that had not calved by 5 wk remained in the same pen until calving but new cows were added to the pen to achieve 100% stocking density relative to stalls. Pens were identical in size (44 stalls and 48 headlocks) and design and each of the pens received each treatment a total of 3 times, totaling 6 replicates. Video recording cameras were placed above the feed lane for determination of feed bunk displacement activity (Lobeck et al., 2012). Displacement from the feed bunk was measured, in both pens, during 3 h on the day cows were moved to the close-up pen (-30 d before expected calving date) at 13:00 ± 1:00 and following fresh feed delivery (05:00 ± 1:00) 1, 2, 3 and 7 d after cows were moved to control close-up pen. Displacement rate was calculated as daily displacements divided by the number of cows in the pen to account for stocking density. Cows were examined at enrollment, calving, and 28 and 56 DIM for body condition score (BCS; 1 = emaciated to 5 = obese) and lameness and at 1, 4, 7, 10, and 14 DIM for retained fetal membranes (RFM) and metritis. Cows were observed daily for DA and mastitis until 60 DIM. Blood was sampled weekly from all cows from 21 d before expected calving date to 21 DIM for determination of non-esterified fatty acid (NEFA) concentration. Blood was sampled weekly from 14 d before expected calving date to 14 DIM from a subgroup of cows (n = 34/treatment) to determine neutrophil phagocytosis (PHAGO), oxidative burst (OXID), expression of CD18 and L-selectin, and for hematology. Milk production and components were measured monthly and energy corrected milk yield was calculated for the first 3 tests. Cows were examined by ultrasound for detection of corpus luteum (CL) at 39 ± 3 and 56 ± 3 DIM. Cows were presynchronized with three injections of prostaglandin $F_{2\alpha}$ at 41 ± 3, 55 ± 3, and 69 ± 3 DIM, and those observed in estrus after 55 DIM were inseminated, whereas cows not observed in estrus were enrolled in an Ovsynch56 protocol at 81 ± 3 DIM. Pregnancy exam was conducted 38 ± 3 and 66 ± 3 d after AI.

In figure 1 we observe that the average stocking density of the control pen varied between 100 and 69.5%, whereas the average stocking density in the AIAO pen varied between 100 and 7.3% (Silva et al., 2012a). There were 17 AIAO cows that did not calve within 5 wk and had to be mixed with other cows. The average interval between mixing of these cows and calving was 4.1 ± 0.6 d. The data referent to these cows is discussed later in this manuscript (Silva et al., 2012b).

A greater number of displacements was observed in the control treatment than in the AIAO treatment (22.0 ± 1.0 vs. 10.4 ± 1.0; $P < 0.01$; Lobeck et al., 2012). Similarly, displacement rate was greater for the control than AIAO treatment (0.54 ± 0.03 vs. 0.31 ± 0.03; $P < 0.001$; Lobeck et al., 2012). Treatment did not affect BCS ($P > 0.59$) or lameness ($P > 0.35$) at any interval of the study (Silva et al., 2012a). Glucose (59.2 ± 1.3 mg/dl; $P = 0.28$) and NEFA (227.2 ± 3.2 mol/L; $P = 0.17$) concentrations were not affected by treatment (Silva et al., 2012a). Percentage of neutrophil positive for OXID ($P = 0.91$) and PHAGO ($P = 0.98$) and intensity of OXID ($P = 0.94$) and PHAGO ($P = 0.91$) were not different between treatments. In addition, percentages of neutrophil expressing CD18 ($P = 0.17$) or L-Selectin ($P = 0.83$) were not different between treatments (Silva et al., 2012c). Number of leukocytes ($P = 0.64$), neutrophils ($P = 0.33$), and lymphocytes ($P = 0.80$) were not affected by treatment (Silva et al., 2012c). Similarly, treatment had no effect on incidence of RFM ($P = 0.84$), metritis ($P = 0.35$), acute metritis ($P = 0.54$), DA ($P = 0.92$), and mastitis ($P = 0.47$; Table 1; Silva et al., 2012b). Treatment had no effect on milk yield (33.1 ± 0.3 kg/d, $P = 0.82$), energy corrected milk (37.2 ± 0.3 kg/d, $P = 0.66$), and linear somatic cell score (2.9 ± 0.1, $P = 0.28$; Silva et al., 2012b). Percentage of cows with a CL on d 39 ($P = 0.17$) and 56 ($P = 0.96$) and percentage of cows pregnant after first AI ($P = 0.47$) were not affected by treatment (Silva et al., 2012b).

Among AIAO cows, those that did not calve within 35 d after enrollment and had an additional change in group a few days before calving (average 4.1 ± 0.6 d) had similar incidence of health disorders and reproductive performance compared with those that calved within 35 d after enrollment and were only regrouped once, at enrollment. Furthermore, cows with additional regrouping a few days prepartum had greater yield of ECM than those that did not have additional regrouping (39.1 ± 2.4 vs 32.3 ± 1.4 kg/d; $P < 0.01$).

According to the current experiment, even though in commercial herds where size of close-up pens is expected to be larger than in research facilities, weekly entry of new cows in a close-up pen is expected to cause more agonistic interactions in the feed bunk than stable pen. In the current experiment, however, the increased rate of displacement from the feed bunk did not result in compromised innate immune function or metabolic parameters.

Correspondingly to these findings, increased social disturbance in the control treatment did not result in greater incidence of diseases or reduced reproductive and productive performances. It is interesting that even AIAO cows that underwent group change within 4.1 ± 0.6 d prepartum no significant increase in incidence of disease or reduction in reproductive performance were observed. From the current experiment and from the experiment by Coonen et al. (2011) we conclude that conventional prepartum grouping strategy (i.e. weekly entry of new cows to the close-up pen) does not affect health of cows. These are important findings because the average stocking density of the control pen was 87%, whereas in the AIAO pen it was 73% (Silva et al., 2012a). Therefore, in a herd with 1,000 lactating dairy cows, with 110 calving per month, and a close-up period of 28 d, the dairy would need 126 stalls if a conventional system is implemented and 150 stalls if an AIAO system is implemented. If the cost of a stall is approximately $ 5,000, the additional cost to build the close-up pen for an AIAO system would be approximately $ 120,000.

Conclusions and recommendations

Cows exposed to conditions that limit feed intake prepartum (i.e. overstocking or lack of water) are at greater risk of immune suppression and metabolic diseases peripartum and health disorders postpartum. Furthermore, because a positive correlation exists between prepartum and postpartum feed intake (Grummer et al., 2004), conditions that limit feed intake prepartum are likely to have a profound effect on productivity of dairy cows and economic sustainability of dairy operations. Weekly prepartum regrouping affects behavior of dairy cows, particular in the feed bunk in the hours following feeding. Weekly prepartum regrouping of dairy cows, however, does not seem to be associated with immune and metabolic parameters peripartum and health postpartum. Furthermore, because 'All-In-All-Out' or 'stable' prepartum grouping strategy results in reduced average stocking density compared with a conventional system (weekly entrance of new cows in the close-up pen), the cost to build facilities for an 'All-In-All-Out' system would be significantly greater than the cost to build close-up pens for conventional systems.

The current recommendations indicate that stocking density during the prepartum should be 1 cow per stall and at least 27 inches of linear feed bunk space per cow in pens with headlocks and 30 inches of linear feed bunk space per cow in pens without headlocks. Another very important, and often overlooked, requirement of prepartum cows is water availability. Current recommendations indicate that there should be at least 3 inches of linear space of water trough/cow and 20 cows/water trough.

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Table 1. Effects of stable and dynamic prepartum housing systems on feed bunk displacement, dry matter intake (DMI), plasma concentration of non-esterified fatty acids (NEFA), and milk yield [Adapted from Coonen et al. (2011)].

	Housing		
Variables	Stable	Dynamic	*P*-value
Feed bunk displacements	1.17 ± 0.52	1.69 ± 0.77	0.39
DMI postpartum, kg/d	25.5 ± 1.6	25.7 ± 1.0	0.53
NEFA, mEq/L			
> d -15	0.21 ± 0.04	0.18 ± 0.04	0.69
d -9 to -14	0.28 ± 0.04	0.21 ± 0.04	0.32
d -3 to -6	0.36 ± 0.04	0.32 ± 0.04	0.63
Lactation first 30 DIM			
Milk yield, kg/d	34.6 ± 1.4	36.9 ± 3.4	0.32
Fat, %	4.59 ± 0.16	4.54 ± 0.33	0.88
Protein, %	3.33 ± 0.12	3.39 ± 0.14	0.62

Table 2. Effects of a conventional and All-In-All-Out prepartum grouping systems on plasma concentration of non-esterified fatty acids (NEFA), incidence of postpartum diseases, culling, yield of energy corrected milk (ECM), resumption of cyclicity, estrous expression, and pregnancy to first postpartum AI [Adapted from Silva et al. (2012a), Silva et al. (2012b), and Silva et al. (2012c)].

Conventional AIAO	(n=308)	(n=259)	*P*-value
NEFA from 21 d before to 21 d after calving, mol/L	80.4 ± 8.2	62.9 ± 8.5	0.17
NEFA > 100 mol/L (21 d before calving), %	62.7	55.8	0.19
NEFA > 130 mol/L (7 d before calving), %	25.4	25.5	0.99
Retained fetal membranes, %	10.9	11.6	0.84
Metritis, %	16.7	19.8	0.35
Displacement of abomasum, %	3.2	1.7	0.92
Mastitis, %	13.8	11.3	0.47
Culling within 60 DIM, %	9.1	8.9	0.94
90-d ECM, kg/d	37.5 ± 0.4	36.8 ± 0.4	0.66
Cyclic by 53 DIM	90.1	90.2	0.96
Cows inseminated in estrus, %	93	91	0.52
Pregnant 63 d after first AI, %	36.3	40.0	0.47

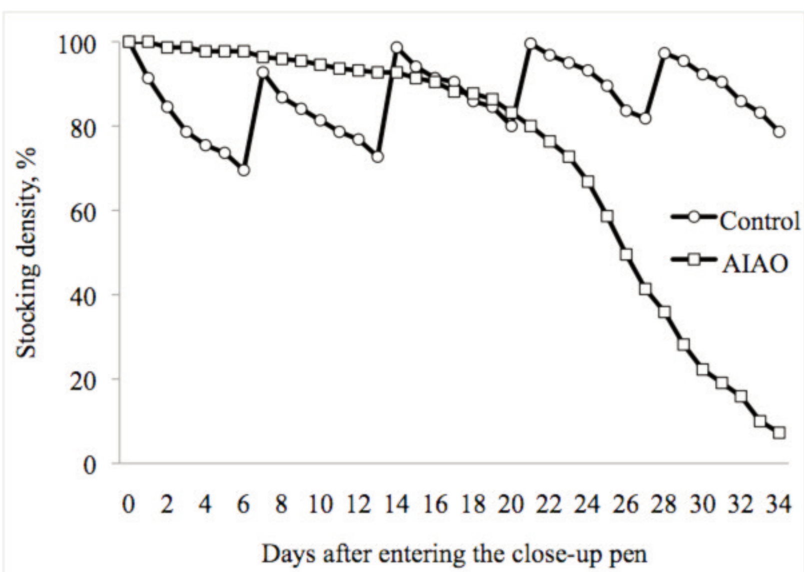

Figure 1. Stocking density of prepartum pens with conventional or All-In-All-Out grouping strategy (Silva et al., 2012a).