

Management of Late Lactation and Overweight Dry Cows

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SUMMARY

The period from 3 wk before to 3 wk 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. In this manuscript we will discuss situations that accentuate immune suppression and predispose cows to health disorders. We will also evaluate how to improve health of transition cows through management in order to reduce health disorders.

INTRODUCTION

In the last weeks of gestation, significant changes in concentrations of cortisol, progesterone, estradiol, prostaglandin $F_{2\alpha}$, and prolactin occur (Stevenson, 2007). These changes in hormone concentrations occur mainly in response to increased production of monoamine oxidase by the fetus, an enzyme that breaks-down serotonin. The reduction in serotonin concentrations results in increases in corticotropic releasing factor and adrenocorticotrophic hormone concentrations in fetal circulation. Consequently, cortisol secretion by the fetus' adrenal gland increases. Cortisol up-regulates the expression of 17- α hydroxylase, an enzyme that increases secretion of estradiol in the placenta to the detriment of progesterone production. Simultaneously, an increase in prolactin and prostaglandin $F_{2\alpha}$

concentration is observed. These changes are important for onset of colostrum production and preparation for parturition (Akers, 2002). Although increases in concentration of estradiol and prostaglandin $F_{2\alpha}$ in the uterus increase blood flow to the uterus and theoretically the influx of immune cells, cortisol suppresses immune response because it down regulates the neutrophil expression of L-selectin and CD18, adhesion molecules involved in the trafficking of neutrophils from the endothelium to the site of infection (Burton and Kehrli, 1995; Burton et al., 1995; Burton et al., 2005). Cortisol is also produced in adverse conditions (e.g. transport, overstocking) that result in stress and circulating concentrations of cortisol have been used as an indicator of stress (Nanda et al., 1990). Therefore, conditions during the prepartum period that increase stress are expected to increase cortisol concentrations, and consequently, further suppress immune function of peripartum cows.

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 rapidly increasing milk yield. Thus, cows suffer from negative energy balance (**NEB**) for up to 8 to 12 wk after parturition and must utilize body energy reserves to meet nutrient requirements for milk

production. Therefore, during the transition period cows go from a state of homeostasis to a state of homeorhesis, "orchestrated or coordinated changes in metabolism of body tissues necessary to support a dominant physiological state (Bauman and Currie, 1980)." For peripartum cows, increasing milk production is the dominant physiological state as the utilization of nutrients by the mammary gland of high producing dairy cows exceeds that of the rest of the body in the first trimester of lactation (Bauman, 2000).

Some of the homeorhetic changes observed in peripartum dairy cows are discussed below. Before the decrease in feed intake prepartum starts, cows have low circulating concentrations of growth hormone (**GH**) and high circulating concentrations of insulin and insulin-like growth factor-I (**IGF-I**). Once feed intake starts to decrease and NEB occurs, GH concentration increases and insulin and IGF-I concentrations decrease indicating a decoupling of the somatotropic-IGF-I axis because the liver, under the influence of GH, is the main source of circulating IGF-I (Rhoads et al., 2004; Lucy, 2008). This occurs because during NEB the expression of GH receptor (**GHR**), particularly GHR1 α , is decreased (McCarthy et al., 2009). As cows return to positive energy balance hepatic expression of GHR1 α increases and hepatic IGF-I production starts to increase (Lucy, 2008).

Insulin-like growth factor-I is a fundamental factor that stimulates growth, differentiation, and functionality of several different cell types. For example, IGF-I is likely to affect innate immunity of peripartum cows because it regulates functionality (i.e. superoxide anion production, oxidative burst, and degranulation) of neutrophils, the primary

defense line against infections (i.e. metritis and mastitis). Further, circulating concentrations of neutrophils and production of antibodies (i.e. IgG, IgM, and IgA) are significantly increased in GH-deficient humans and mice after GH-induced increase in concentrations of IGF-I (Kimata and Yoshida, 1994; Ibanez et al., 2005; Sohmiya et al., 2005). Pigs that were treated with IGF-I stimulating compounds and were subjected to simultaneous weaning and transport had greater count and concentrations of neutrophil in the blood than non-treated pigs (Kojima et al., 2008). Thus, exacerbation of NEB during the peripartum period is likely to affect innate and humoral immunity because cows would be exposed to extended periods of time with reduced IGF-I concentration.

Ruminants have evolved to substitute glucose by volatile fatty acids (i.e. propionate, butyrate, and acetate) and their derivative ketoacids as respiratory and lipogenic fuels (Bauman and Currie, 1980). Nonetheless, glucose remains essential for normal brain and liver function and for production of lactose in the mammary gland, the latter being the most important osmotic solute of milk production. During early lactation and NEB, insulin-dependent uptake of glucose by tissues other than the mammary gland (i.e. muscle and adipose tissue) is reduced, in part because of increased GH concentrations, assuring that glucose is available for production of copious amounts of lactose and milk (Bauman, 2000; Lucy, 2008).

In situations in which cows are exposed to severe and prolonged NEB large amounts of body reserves (i.e. glycogen, lipids, and amino acids) are mobilized to provide the necessary substrate for milk production (Grummer et al., 2004). A consequence of extreme adipose tissue mobilization during

the peripartum period is the increasing circulating concentration of non-esterified fatty acids (**NEFA**), which predisposes cows to hepatic lipidosis (Grummer et al., 2004). Consequently, concentrations of ketone bodies [e.g. beta-hydroxybutyrate (**BHBA**)] may also increase because of compromised liver function and incomplete oxidation of NEFA (Grummer et al., 2004).

Amount of feed intake is inversely associated with plasma NEFA concentrations, and the latter affects neutrophil function (Klucinski et al., 1988; Rukkamsuk et al., 1999; Hammon et al., 2006). Hammon et al. (2006) demonstrated that cows that had reduced feed intake during the prepartum period had reduced neutrophil activity (phagocytosis and oxidative burst) during the peripartum period and were more likely to develop metritis postpartum. This seems to be a consequence of the onset of colostrum/milk production and the simultaneous insufficient feed intake peripartum because cows that were mastectomized 4 mo before parturition had greater expression of L-selectin prepartum, greater leukocyte count postpartum, and greater neutrophil killing activity postpartum than cows with intact mammary glands (Kimura et al., 1999).

Compromised immune function due to altered metabolic status predisposes cows to infectious diseases (i.e. metritis, endometritis, and mastitis). 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). In a recent large study, Ospina et al. (2010) demonstrated that increasing prepartum and postpartum NEFA plasma concentrations

were associated with increased risk of retained fetal membranes, metritis, clinical ketosis, and displacement of abomasum. Accentuated NEB accompanied by increased BHBA plasma concentrations during early postpartum also has been associated with increased risk of peripartum diseases (Erb and Grohn, 1988; Grohn et al., 1989; Correa et al., 1993). For example, higher milk acetone concentrations were associated with increased risk of endometritis (Reist et al.; 2003) and increasing BHBA plasma concentration was associated with increased risk of metritis and displacement of abomasum (Ospina et al., 2010).

OBESE COWS, IMMUNE FUNCTION, AND HEALTH

A critical factor affecting immune function of peripartum dairy cows is dry matter intake (**DMI**) and the consequences of reduced DMI. Hayirli et al. (2002) gathered data from 16 experiments and evaluated diet and animal factors that affected DMI in the last 21 d of gestation. Dietary factors evaluated were net energy for lactation, rumen undegradable protein, rumen degradable protein, neutral detergent fiber, acid detergent fiber, non-fiber carbohydrate, ether extract, and ash. Animal factors evaluated were proximity to calving, parity (heifer vs cow) and body condition score (**BCS**) at dry-off (thin = 2.8, moderate = 3.6, obese = 4.4). According to Hayirli et al. (2002), variability in DMI in the last 21 d of gestation was mainly due to proximity to calving (56.1 %), neutral detergent fiber (15.3 %), parity (10 %), and BCS (9.7 %). Obese cows had reduced DMI throughout the last 21 d of gestation and had a more pronounced decrease in DMI in the last 7 d of gestation compared with thin and moderate cows (Hayirli et al., 2002).

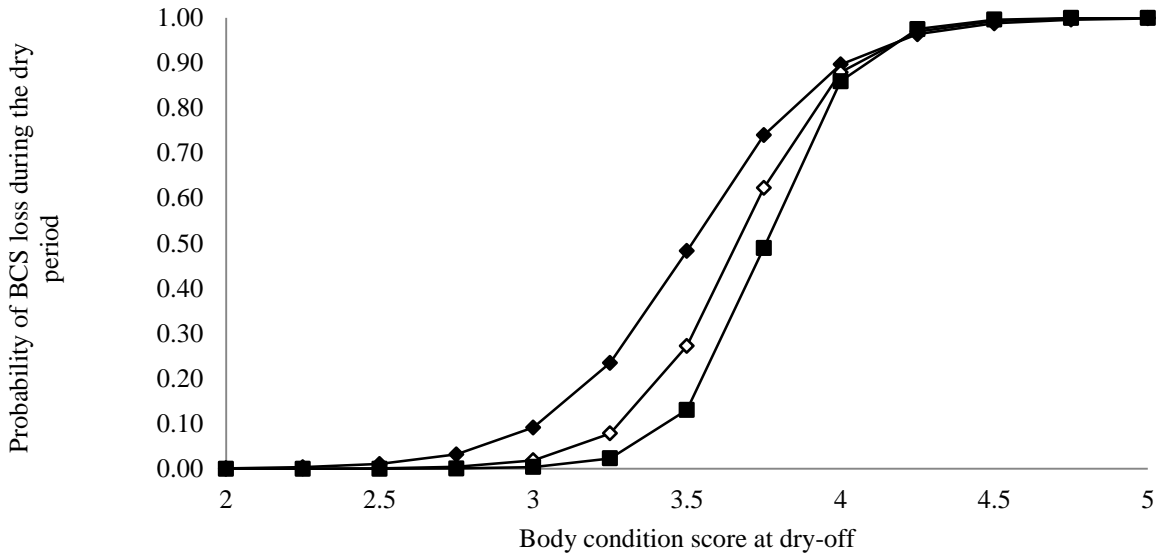


Figure 1. Probability of BCS loss during the dry period according to BCS at dry-off and length of the dry period (◆ = 30 d; ◇ = 60 d; ■ = 90 d).

Actually, the decrease in DMI in the last 3 wk of gestation was 40 % in obese cows, but only 29 % for thin and moderate cows (Hayirli et al., 2002).

In a large retrospective experiment we demonstrated that the probability of cows losing BCS during the dry period is

dependent on BCS at dry-off, sex of the calf, twins, number of days in the dry period, and season (Mendonça and Chebel, unpublished data). As observed in figure 1, when BCS at dry-off exceeded 3.25 the probability of BCS loss during the dry period increased significantly and the probability of BCS loss during the dry period was nearly 100 % for

Table 1. Association between body condition score (BCS) change during the dry period and risk of postpartum diseases.

Items, AOR (95% CI)*	BCS change				P – value
	Gain (n = 1,384)	No change (n = 3,852)	-0.25 to -0.5 unit (n = 3,551)	≤ -0.75 unit (n = 202)	
Stillbirth	0.9 (0.6, 1.2)	Ref.	1.4 (1.1, 1.7)	1.3 (0.7, 2.5)	<0.01
Retained fetal membrane	0.9 (0.6, 1.2)	Ref.	1.64 (1.3, 2.1)	2.3 (1.3, 3.9)	< 0.01
Metritis	0.8 (0.7, 1.0)	Ref.	1.3 (1.2, 1.5)	1.9 (1.4, 2.8)	< 0.01
Digestive diseases	1.0 (0.7, 1.5)	Ref.	2.0 (1.5, 2.6)	4.3 (2.6, 7.1)	< 0.01
Culled cows < 60 DIM	1.0 (0.8, 1.4)	Ref.	1.7 (1.4, 2.0)	3.7 (2.4, 5.6)	< 0.01

*AOR = adjusted odds ratio; 95 % CI = 95 % confidence interval.

cows with BCS ≥ 4 at dry-off. Furthermore, BCS loss increased the incidence of postpartum diseases (Table 1; Mendonça and Chebel, unpublished data). Lacereta et al. (2005) demonstrated that obese cows (BCS ≥ 3.5 at 30 d before calving) had greater NEFA plasma concentrations on d 3 and 7 after calving compared with thin and moderate cows. Furthermore, peripheral mononuclear cells of obese cows had reduced production of IgM on d 14 and 35 after calving and secreted less IFN- γ 7 d before calving compared with thin cows; demonstrating that the immune system of obese cows was hampered during the peripartum period (Lacereta et al., 2005). Therefore, elevated BCS at dry-off is expected to cause reduced DMI and BCS loss during the dry period, predisposing cows to immunosuppression and increased incidence of periparturient diseases. The main factors that impacted BCS at dry-off were parity, interval from calving to

pregnancy, and milk yield (Mendonça and Chebel, unpublished data). As expected, reduced milk yield and longer interval from calving to pregnancy reduced the probability of cows going dry with BCS ≤ 3.25 (Figure 2). Therefore, in order to minimize the number of cows that enter the dry period with elevated BCS, aggressive reproductive management to maximize the likelihood of pregnancy within the first 100 d postpartum must be in place. In herds with poor reproductive performance; however, it is expected that a large percentage of cows entering the dry period will have elevated BCS.

Because cows that lose BCS during the dry period have reduced IGF-1 concentration (Chebel et al., unpublished data), which is an important growth and differentiation factor for immune cells, we hypothesized that treatment of obese cows

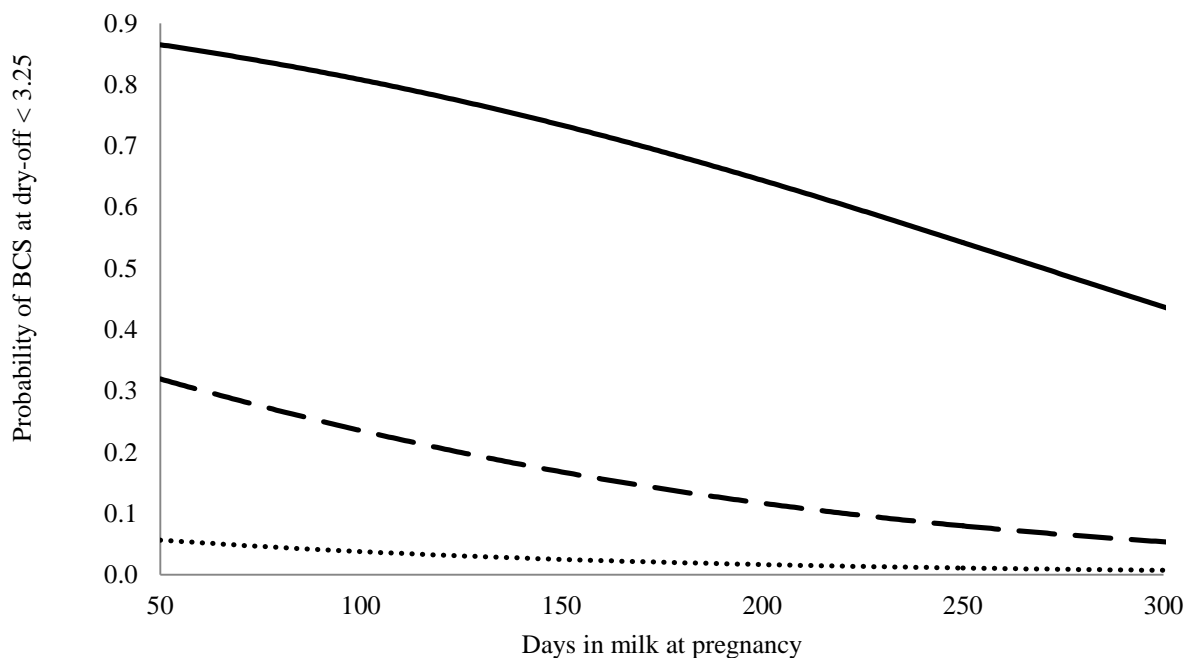


Figure 2. Probability of BCS at dry-off ≤ 3.25 according to days in milk at pregnancy and milk yield (solid line = 49,200 lb; dashed line = 27,000 lb; dotted line = 9,460 lb; Mendonça and Chebel, unpublished data).

with recombinant bovine somatotropin (**rbST**) hormone would improve immune function. In a pilot experiment, obese cows ($BCS \geq 3.75$) are being treated weekly with 0, 12.5, or 17.9 mg/d of rbST from 21 d before to 21 d after calving (Silva et al., unpublished data). According to the preliminary data of this pilot experiment being conducted in our lab, the intensities of phagocytosis and oxidative burst (parameters related to function of cells that are part of the innate immune system) are increased in approximately 40 % of the cows during the prepartum period (Silva et al., unpublished data). If these promising preliminary results are confirmed at the end of the experiment, it may be possible to improve innate immune response of obese cows with weekly treatment with rbST from 21 d before to 21 d after calving.

PREPARTUM GROUPING MANAGEMENT AND TRANSITION COW HEALTH

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 re-establish 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 NEB during the peripartum period 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 performance. The selection of cows for high milk yield has also resulted in significant homeorhetic alterations that predispose them to immune suppression and more diseases postpartum exacerbate these same managerial inadequacies.

Cows are social animals and as such are highly susceptible to social interactions and hierarchical order. Once housed within a group, dominant cows display physical and non-physical aggressive behavior towards submissive cows. Situations that exacerbate these deleterious interactions among dominant and submissive cows have the potential to affect health and performance. Although group performance is the most commonly used parameter to evaluate management and protocols, often evaluation of averages masks the poor performance of subordinate cows in particular. Therefore, management should be focused to provide all cows with sufficient feed, water, and resting space to minimize the expression of subordinate behaviors.

Table 2. Performance of primiparous when grouped separately from multiparous cows (Adapted from Grant and Albright, 1995).

Item	Multiparous and Primiparous	Primiparous Only
Eating time, min/d	184	205
Eating bouts / d	5.9	6.4
Concentrate intake, kg/d	10.1	11.6
Silage intake, kg/d	7.7	8.6
Lying time, min/d	424	461
Resting periods/d	5.3	6.3
Milk yield, kg/130d	2,383	2,590
Milk fat, %	3.92	3.97

SEPARATION OF PREPARTUM HEIFERS AND COWS

Smaller cows are in general more submissive than larger cows. Consequently, when prepartum heifers are housed together with mature cows they are more likely to expressive submissive behavior. In a study in which prepartum heifers were housed with mature cows during the prepartum period or were housed alone, heifers housed with mature cows had reduced feed intake and decreased resting time during the prepartum period followed by reduced milk yield compared with heifers housed alone (Table 2). Therefore, we recommend that primiparous cows be housed separately from mature cows from at least 21 d before to 21 d after calving. If this is not possible, prepartum and postpartum pens should have a stocking density of < 80 %.

STOCKING DENSITY PREPARTUM AND ITS EFFECTS ON BEHAVIOR, FEED INTAKE, AND IMMUNE FUNCTION

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. Because cows have allelomimetic behavior, characterized by cows doing the same activity at the same time, it is fundamental during the prepartum period to assure that space is available for all cows to eat at the same time without the expression of aggressive and submissive behaviors.

A study conducted in Italy evaluated the humoral immunity and productive performance of dairy ewes that were housed in high or low stocking density conditions from late gestation to mid-lactation (Carporese et al., 2009). Ewes that were housed in high stocking density conditions had reduced anti-ovalbumin IgG concentration in response to an ovalbumin challenge compared with ewes housed in low stocking density conditions (Carporese et al., 2009). Further, ewes that were housed in high stocking density conditions tended to have a greater number of aggressive interactions and had reduced milk yield and increased milk somatic cell count (Carporese et al., 2009).

In a recent experiment (Dresch et al., unpublished data), we housed prepartum Jersey to 100 % stocking density of headlocks (109 % stocking density of stalls; **100D**) or 80 % stockings density of headlocks (87 % stocking density of stalls; **80D**). New cows entered the prepartum pen twice weekly to try to maintain a stocking density close to the desired. Cows were examined for retained fetal membranes, metritis, and endometritis. Body condition and locomotion scores were collected at 28 d before expected calving date, on the day of calving, and 28 and 56 d after calving. To date, data regarding removal from the herd and milk yield up to 60 DIM have been

collected. Furthermore, blood was sampled weekly from 14 d before to 14 d after calving to evaluate innate immune function.

Stocking densities were 74.0 and 94.3 % (± 0.3) of headlocks and 80.7 and 102.8 % (± 0.4) of stalls for 80D and 100D, respectively (Dresch et al., unpublished data). There was no effect of treatment on incidence of stillbirth (80D = 3.9 vs 100D = 3.4 %; $P = 0.50$), retained placenta (80D = 4.4 vs 100D = 7.4 %; $P = 0.13$), and endometritis (80D = 7.4 vs 100D = 7.1%; $P = 0.65$). There was a tendency ($P = 0.10$) for incidence of metritis to be greater for 80D (21.5 %) than 100D (13.9 %). Treatment did not affect percentages of cows with locomotion score > 2 at 35 ($P = 0.94$) and 56 ($P = 0.77$) DIM. Body condition score was not affected by treatment (80D = 2.97 ± 0.02 vs 100D = 2.97 ± 0.01 ; $P = 0.91$). Percentage of cows removed from the herd within 60 DIM (80D = 4.4 vs 100D = 3.0 %; $P = 0.42$) and yield of energy corrected milk (80D = 27.56 ± 1.52 vs 100D = 27.98 ± 1.50 kg/d; $P = 0.85$) were not affected by treatment. Treatment did not affect percentage of polymorphonuclear leukocytes (**PMNL**) positive for phagocytosis ($P = 0.71$), intensity of phagocytosis ($P = 0.79$), percentage of PMNL positive for oxidative burst ($P = 0.84$), intensity of oxidative burst ($P = 0.84$), percentage of PMNL positive for CD18 (80D = 98.8 ± 0.3 vs 100D = 99.5 ± 0.3 %; $P = 0.12$), intensity of CD18 expression ($P = 0.47$), percentage of PMNL positive for L-selectin ($P = 0.93$), and intensity of L-selectin expression ($P = 0.66$). Therefore, we conclude that prepartum management that attempts to maintain stocking density of 100 % of headlocks and 110 % of stalls does not compromise immune function or incidence of postpartum diseases (Dresch et al., unpublished data).

Current recommendations indicate that stocking density during the prepartum period should be 1 cow per headlock and at least 76 cm of linear feed bunk space per cow. Even in herds in which prepartum cows are housed in good pasture conditions, prepartum cows should have sufficient access to the feed bunk to assure that the whole group is ingesting the proper amount of feed and nutrients.

An issue that is often overlooked in overstocked and non-overstocked conditions is the amount of water and access to water available to prepartum and postpartum cows. In general, we recommend that a minimum 10 cm of linear water trough space is available per cow and at least 2 water troughs per group to assure that cows have sufficient access to water.

EFFECTS OF REGROUPING FREQUENCY ON BEHAVIOR, FEED INTAKE, AND MILK YIELD

The effects of regrouping frequency of cows on behavior, feed intake, and health has been less studied 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 d 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 into the close-up pen could result in social disruption and stress on the last days of gestation, compromising further DMI and immune parameters.

Coonen et al. (2011) evaluated DMI, 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* pens (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. In this small study no differences between *stable* and *dynamic* grouping systems in feed bunk displacement rate, DMI ($P = 0.53$), NEFA concentrations during the peripartum ($P > 0.32$), and milk yield ($P = 0.32$) in the first 30 DIM were observed (Table 2). The observations that DMI, NEFA concentration, and milk yield did not differ are novel and suggest that larger experiments are necessary.

In a recent study (Silva et al., 2012a) the hypothesis that constant disturbance of social order prepartum by weekly introductions of 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 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_{2α} 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.

The average stocking density of the control pen was 87 % (69.5 to 100 %);

whereas in the AIAO pen the average stocking density was 73 % (7.3 to 100 %; Silva et al., 2012a). There were 18 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 was used for statistical analysis and 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 μmol/L; P = 0.17) concentrations were not affected by treatment (Silva et al., 2012a).

Innate and humoral immune parameters were not affected by prepartum grouping strategy. 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 = 0.82), metritis (P = 0.37), acute metritis (P = 0.22), DA (P = 0.38), and mastitis (P = 0.45; 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; $n = 18$) 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; $P < 0.01$).

Weekly entry of new cows in a close-up pen is expected to cause more agonistic interactions in the feed bunk than a stable pen (Lobeck et al., 2012). The increased rate of displacement from the feed bunk did not affect innate immune function, metabolic parameters, incidence of diseases, and reproductive and productive performances. It is interesting that even for AIAO cows that underwent a group change within 4.1 ± 0.6 d prepartum, no significant increases in incidence of disease or reduction in reproductive performance were observed. Behavioral change is one of the four biological responses to stress (neuroendocrine, immune, autonomic). Stressors that only cause a transient change in behavior, but have no effects on other responses to stress, seem to have little importance to biological function of cows.

CONCLUSIONS

Transition cows are predisposed to immunosuppression because of changes in endocrine and metabolic parameters during

the periparturient period. Poor productive and reproductive performance result in greater BCS at dry-off, which in turn increases the likelihood of periparturient diseases because obese cows have suppressed DMI, altered metabolic parameters, and immunosuppression. Dairy herds should have very aggressive reproductive management to maximize the percentage of cows that becomes pregnant within 100 DIM and reduce the percentage of cows that enter the dry period with $BCS > 3.25$. Preliminary data from a pilot experiment suggest that it could be possible to improve innate immune function of obese cows with weekly treatments of 17.9 mg/d of rbST. These results, however, need to be confirmed and more research needs to be conducted to ascertain that improvement in immune parameters will result in reduce likelihood of obese peripartum diseases.

Prepartum cows and heifers should be housed separately when possible to reduce agonistic interactions and to assure that submissive animals (usually heifers) have proper access to water, feed, and resting space. A recently proposed system to reduce regrouping of prepartum cows (AIAO system) has not resulted in improvements in metabolic, immune, health or productive parameters; even though it reduced the rate of agonistic interaction in the feed bunk. This indicates that regrouping of prepartum cows results in transient disruption of social interactions but it is insufficient to alter neuroendocrine and immune functions sufficiently to compromise biological function.

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