

Competition at the feed bunk during transition changes the feeding, standing and social  
behaviour of Holstein dairy cows

by

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## ABSTRACT

Transition dairy cows are vulnerable to negative consequences of depressed feed intake due to a transient state of negative energy balance that predisposes them to disease after calving. Competition has been identified as one factor that can decrease feeding activity in mid-lactation cows, but the effects of competition on the transition cow are less well understood. The objective of this study was to test the effect of a competition on the behaviour and feed intake of transition cows. Standing behaviour, feeding behaviour and dry matter intake (DMI) was monitored from 1 wk before to 2 wk after calving for 110 Holstein dairy cows. Social behaviour was recorded in the week before calving. Cows were assigned to a competitive (2:1 cows:bin) or non-competitive (1:1 cow:bin) treatment at the start of the study. Treatment groups were balanced for parity and baseline feeding data, resulting in 8 primiparous and 10 multiparous cows per treatment. Competition dramatically increased the number of agonistic behaviours between cows at the feeder. Primiparous cows showed no change in either feeding or standing behaviour when fed in a competitive environment; however, they increased their total meal duration and within-meal intervals in the wk -1 before and wk +1 after calving. In wk -1 before calving, competitively fed multiparous cows increased the frequency of visits to the feeder but consumed less feed at each visit, resulting in decreased daily DMI. Throughout the experiment, multiparous cows fed competitively spent less time eating at each visit and ate at a faster rate, particularly during the 2 wk after calving. Multiparous cows on the competitive treatment also increased the time they spent standing (without eating) compared to cows on the non-competitive treatment. Feeding rate was negatively correlated with social status in multiparous cows. In summary, the results of this study indicate that restricting access to the feeder increases agonistic behaviours regardless of parity, and cows of different parity and social status respond differently in terms of feeding and standing behaviour.

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## LIST OF ABBREVIATIONS

**BCS** = body condition score

**BHBA** = beta-hydroxybutyrate

**BW** = body weight

**DM** = dry matter

**DMI** = dry matter intake

**NEB** = negative energy balance

**NEFA** = nonesterfied fatty acid

**PMN** = polymorphonuclear neutrophils

**R<sup>2</sup>** = coefficient of determination

**SD** = standard deviation

**SED** = standard error of the difference between the means

**TAG** = triacylglycerol

**TMR** = total mixed ration

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## CHAPTER 1: INTRODUCTION

In the last 10 years, the volume of milk produced by Canadian dairy producers has increased by 2% (CDIC, 2008). This slight increase in milk production has been coupled with a decrease in the total number of dairy farms, and an increase in the average farm size from 50 cows to close to 70 cows across the nation. In British Columbia, average herd size has increased from 100 to about 115 cows per farm. As herds become larger, producers are forced to use their current space more efficiently or to build larger facilities to maintain a growing number of animals. One way to use space more efficiently is to house animals at a density higher than what the pen was intended to house (i.e. “overstock”). An overstocked pen may have 100 animals, but only enough space for 80 animals to feed, or lay down in a stall, at any given time. Although this may seem enough to give cows as they only need 12 hours a day to lie down, and a few hours to eat, it has been demonstrated that dairy cows tend to synchronize their behaviours, including the time of day they choose to eat and rest (DeVries et al., 2005; Fregonesi et al., 2007).

There is currently no legislation for the amount of feeding and lying space given to dairy cows in Canada. Research has, however, provided some recommended allotments of feeding and lying space for individual animals in a herd. Recommendations for feeding space have been developed using the bunk length allotted to each cow at which intake and milk production of a group of cows in a pen is compromised as an indication of improper space allowance (i.e. Friend et al., 1977; DeVries et al., 2004). If we are to make sound recommendations for feeding space requirements from an animal welfare perspective, it may also be necessary to incorporate the effect of limited feeding space on the health of individual animals within a pen, as good health is one of the central components of positive animal welfare (Fraser et al., 1997).

In order to incorporate good health into the development of proper space recommendations for dairy cows, it is important to firstly identify the period in which cows are most likely to become sick. The most vulnerable period for disease to occur has been well established as the few weeks after calving (Goff and Horst, 1996). It has been estimated that throughout North American dairy farms, 30 to 50% of dairy cows become sick during the weeks after calving (Ferguson, 2001). Several types of diseases have been identified during this period, including metabolic illness such as fatty liver and ketosis, and infectious disease such as mastitis (infection of the udder) and metritis (infection of the uterus). Both metabolic and infectious disease can negatively affect the animal, as well as the producer by causing decreased milk yields (Rajala-Shultz et al., 1999), decreased conception rate and pregnancy rate (LeBlanc et al., 2002) and an increased risk of culling (Grohn et al., 1998).

Due to the impact of disease on dairy cattle and the dairy industry, research has focused on the area of disease physiology for decades. Disease physiology research to date has enabled herd veterinarians to better treat cows with subclinical and clinical signs of disease. Although most disease is diagnosed after calving, cows that are at risk for disease show alterations in behaviour and physiology before calving (i.e. Hammon et al., 2006; Huzzey et al., 2007), demonstrating the need to study both the period directly before calving as well as the period directly after calving, now collectively referred to as “transition” (3 weeks before to 3 weeks after calving, from Grummer et al., 1995).

The interaction between disease physiology and animal management (e.g. space allowance) at transition is an issue yet to be sufficiently addressed in the literature. This review will, firstly, briefly summarize some of the findings from work done on transition cow disease physiology and, secondly, review recent research that has focused on aspects of a transition

cow's environment, including feeding space, social regroupings and stressors that might influence her ability to make a healthy transition to lactation.

### **Disease in dairy cattle: Understanding the physiology**

Dairy cows are genetically selected for a number of traits, including high milk yield. In recent decades milk production per cow has increased, which has followed an increase in the occurrence of disease at transition, and has thus contributed to a general concern over the effect of high milk yield on dairy cow health. However, the data linking the selection of high milk production to disease susceptibility is unclear for most diseases except mastitis (Ingvarstsen et al., 2003). In a recent review, Ingvarstsen et al. (2003) argues for a framework of disease that incorporates genetic selection with immune competence and abnormal body reserve metabolism, rather than high milk yield alone. Research to date on immunity, metabolism and their interaction has contributed to our understanding of the physiological development of transition diseases.

#### Immune competence at transition

In mammals, the immune system plays an integral role in the maintenance of pregnancy as well as the onset of labor. Work with human patients has shown that acquired immunity is suppressed and innate immunity is enhanced throughout pregnancy (Sridama et al., 1982; Molloy et al., 2004). Although the complex interaction between immune components, hormones and cytokines at parturition is still unclear, it is likely that the immune system shifts from a pro-inflammatory to an anti-inflammatory response (via a shift in cytokine production) to allow the maternal immune system to tolerate the presence of the fetus and assist in protecting the fetus against infection (reviewed by Gliether et al., 1979). However, in humans, a mild maternal

inflammatory response is present during labor, and is exaggerated in women with labor difficulties such as preeclampsia (Molloy et al., 2004). In dairy cows, lymphocyte and neutrophil function (i.e. components of acquired immunity) are depressed in the period after calving, but some pro-inflammatory cytokine function, including tumor necrosis factor alpha (TNF- $\alpha$ ) and interleukin 1 (IL-1), is enhanced (Kehrli et al., 1989; Sordillo et al., 1995), likely as an adaptation to expel the placenta and protect the uterus from infection after calving.

Although all cows experience natural fluctuations in lymphocytes and inflammatory cytokines around transition, only a subset of animals develop disease after calving. The variation in disease susceptibility across animals could be in part accounted for by abnormal changes in certain immune components. According to Sordillo et al. (1995), if the natural parturient inflammatory response is not properly regulated after calving, cows can become more susceptible to bacterial infection such as coliform mastitis. Moreover, cows with impaired peripheral blood neutrophil function (PMN, i.e. the first line of cellular immune defense against pathogens) in the period before calving are more at risk for developing retained placenta (Kimura et al., 2002), subclinical endometritis and puerperal metritis after calving (Cai et al., 1994; Hammon et al., 2006).

#### Metabolism of body reserves at transition

Several recent reviews have outlined the slew of metabolic changes that occur in dairy cows during the transition period (e.g. Bell, 1995; Goff and Horst, 1996; Ingvarlsen and Anderson, 2000). It is well established that, like immunity, metabolism is naturally altered around parturition. In mammals, metabolic changes during parturition are considered adaptive responses made by the metabolic system to maintain equilibrium (i.e. referred to as “homeorhesis” by Baumen and Currie, 1980). In dairy cows, metabolic changes necessary to

maintain homeorhesis occur as the body moves from late gestation and the provision of nutrients to the fetal calf, to the onset of milk production.

During the last few weeks before parturition (late dry period), energy and nitrogen demands from the fetus are met by placental uptake of maternal glucose and protein (Bell, 1995). The extra energy demand on the cow (i.e. a proposed 30 to 50% increase, depending on the nutrient, Bell, 1995) is partly met by the feed she consumes (i.e. dry matter intake, or “DMI”) and partly met by adaptations made by her metabolic system. Because nutrient intake alone cannot sustain nutrients requirements, cows enter a state of negative energy balance (NEB) at transition, which occurs when energy consumed is less than energy expended for maintenance, growth, pregnancy and milk production. A transient state of NEB is considered natural after calving, and is characterized by the mobilization of energy from body reserves, including fatty acid from adipose tissue, increased glucose production by the liver from amino acids mobilization from muscle tissue, and decreased glucose utilization by tissues (Kunz et al., 1985; Bell, 1995). As fatty acids are mobilized from body reserves, blood concentrations of plasma non-esterfied fatty acids (NEFA) increase, and can subsequently be used as a measurement of energy balance (Pullen et al., 1989).

There is considerable variation between cows in the concentration of plasma metabolites and subsequent disturbances in metabolism (Ingvarsen et al., 2003). Although cows have adopted responses to the transient state of NEB around calving, severe NEB has been linked to the onset of metabolic disease (Collard et al., 2000). For instance, due to their specific metabolism, ruminants collect excess plasma NEFA in their liver. Excess NEFA accumulation in the liver often results in excessive build up of fat triacylglycerols (TAG), especially in over-conditioned cows (McNamara, 2000). Excess TAG accumulation in the liver can result in hepatic lipidosi, also known as “fatty liver” or “fat cow syndrome” (Bauchart et al., 1998). In

addition, clinical ketosis can also occur when glucose demands exceed the gluconeogenesis capacity of the liver, and subsequent lipid metabolism results in high ketone bodies (e.g. BHBA) in the blood, milk and urine (reviewed by Ingvarlsen et al., 2006).

### Infectious disease and metabolic disorders at transition

When a cow's natural alterations in metabolism and immunity are disturbed at transition, she is at greater risk for clinical disease, particularly if she experiences disturbances in both systems. Although thus far discussed as contributing to disease risk separately, components of the immune and metabolic systems interact to increase a cow's disease risk after calving.

Early work by Curtis et al. (1985) found that cows with hypocalcaemia are 5.4 times more likely to contract clinical mastitis than healthy cows, suggesting that metabolic insult may weaken an immune response to infection. Also, fatty liver, which is primarily considered a disorder driven by metabolic imbalance, commonly occurs with altered immunity after calving (Zerbe et al., 2000) as well as some clinical infectious disease (Higgins and Anderson, 1983; Jorritsma et al., 2000). Mounting an immune response to infection can be energetically expensive (Demas, 2004), thus the severity of the NEB at transition could weaken immune-competence (Goff, 2006). For instance, excessive NEFA and the subsequent increase in ketone bodies in the blood have multiple negative effects on immunity, including a weakened ability of leukocytes to multiply (Sato et al., 1995), migrate to the site of infection (Suriyasathaporn et al., 1999) and kill pathogens (Kluciński et al., 1988). Components of metabolism (i.e. NEFA and ketone bodies) have also been linked with the incidence of clinical infectious disease after calving (Hammon et al., 2006).

It is clear that disturbances in a cow's body fat metabolism, excessive NEB and an over-stimulated inflammatory response during transition, may put her at increased risk for one or

more diseases after calving. The second part of this review will discuss the relationship between cow management and behaviour with alterations in metabolism and immunity, and suggest ways in which management practices can be designed to help curb the development of these diseases.

### **Diseases in dairy cattle: Managing cows to prevent disease**

This section will focus on the aspects of an animal's environment, management and behaviour that might influence immunologic and metabolic disturbance around transition. During the transition period, dairy cows are faced with a number of challenges, such as diet changes and social regroupings, that may influence their ability to make a healthy transition into lactation. One of the clearest connections between disease and animal behaviour is the amount of food a cow is able to consume during the transition period, and thus her ability to maintain energy balance. Dry matter intake can be influenced by a number of factors, including the amount of feeding space and social competition at the feeding area. Stressors in an animal's environment may also influence her susceptibility to disease by disturbing natural changes in immunity at transition.

#### Dry matter intake, net energy balance and disease

Optimizing a cow's intake and the quality of her feed have been suggested as the main factors necessary to maintain metabolic and immune stability (Grant and Albright, 1995; Grummer, 1995). However, a drop in DMI in the weeks before calving is common (e.g. Bertics et al., 1992; Hayliri et al. 2002). In an analysis of 16 experiments undertaken at eight Universities, Hayliri et al. (2002) found a 32% decrease in DMI in the final 3 weeks before calving, 89% of which occurred in the week before calving.

According to Drackley et al. (2006), the extent of NEB a cow experiences during early lactation is primarily mediated by her intake, and restricting her intake immediately after calving can put her at greater risk of developing ketosis (Drackley et al., 1991). Suboptimal DMI both before and after calving can also result in an increase of plasma NEFA, which may contribute to the development of fatty liver (Hammon et al., 2006). Although most work to date has focused on optimal intake immediately after calving, recent research has shown that cows that develop metritis or left displaced abomasum in the weeks after calving have lower DMI beginning up to 2 weeks before calving (Shaver, 1997; Hammon et al., 2006; Huzzey et al., 2007).

#### Optimizing dry matter intake at transition

Given the importance of DMI in maintaining energy balance, optimizing transition cow intake has received substantial attention in the literature. The transition period can be broken up into 2 stages of feeding management, a “close-up” period before calving and a “fresh” period directly after calving (NRC, 2001). Research has focused on optimizing intake in both the close-up and fresh periods.

In the early dry period, before entering transition (day -60 to -30 relative to expected calving date, often referred to as the “far-off” period), cows are fed forage with or without a small amount of concentrate (e.g. grain, vitamin and mineral mixture). At approximately 30 days before expected calving date, cows are moved to a higher-concentrate diet (“close-up” diet), and after calving are fed an even higher concentrate diet (“fresh” diet). The goal of most close-up diet formulations is to help maintain DMI in the late dry period, as well as stimulate a rapid increase in DMI immediately after calving (Drackley, 2006). Increasing the energy density of close-up diets has also been recommended to increase DMI after calving by preparing the rumen for the high concentrate diet after calving (Mayer et al., 1986). Bertics et al. (1992) showed that



increasing DMI by force-feeding cows with a rumen cannula (i.e. feeding cows more than they would eat voluntarily) before calving can increase plasma glucose concentrations and decrease TAG accumulation in the liver during the first month of lactation.

The connection between forced increases in DMI, high concentrate close-up diets and reduced disease, however, is not clear. For instance, cows that consume excess energy over the dry period and transition period via increased DMI or energy consumption are at risk for developing fatty liver (McNamara, 2000; Drackley, 2006). Over-feeding in the dry period can result in excess fat accumulation and insulin resistance (Holtenius et al., 2003), and can therefore also contribute to an increased disease risk.

Careful regulation of DMI during the transition period is, thus, vital for cows to make a healthy transition into lactation. Stimulating DMI after calving can reduce the extent of NEB and subsequent disease risk after calving; and both under-consuming or over-consuming before calving may contribute to the development of disease after calving. Identifying the sources of variation in dairy cow feed intake may allow for the design of management practices that reduce this variation and subsequent disease risk.

#### Sources of variation in the DMI of transition cows

A number of sources of variation in transition cow DMI have been identified in the literature, including physiological changes associated with parturition, individual cow factors, properties of the diet and management practices. For instance, the drop in DMI that cows experience in the weeks before calving is considered to be an adaptation of the cow's endocrine system to parturition (reviewed by Ingvarsten, 1999). Both plasma insulin and estrogen peak around the time of calving, and both hormones have been shown to depress feed intake (Grummer et al., 1990; Bradford et al., 2007). Natural changes in lipid metabolism around

parturition also signal an innate drive to increase or decrease body fat through intake, depending on weight at parturition, to maintain a target level of body fat in early lactation (reviewed by Friggens, 2003). Aside from hormonal signals associated with depressed intake, the size of the calf in late gestation can also influence a cow's feeding behaviour; as the calf gets larger, the space available in the abdomen for the rumen gets smaller, causing cows to eat less as a consequence (Stanley et. al., 1993).

Individual cow factors and diet can also influence a cow's feed intake around transition. After evaluating the effect of cow and diet factors on DMI in the pre-partum period, Hayirli et al. (2002) found that 19.7% and 24.3% of the variation in DMI in the week before calving was explained by cow factors (parity and body condition) and dietary factors (rumen undegradable protein, neutral detergent fiber and ether extract), respectively. Specifically, older cows and cows with lower BCS ate more than younger cows and cows with higher BCS.

Alternatively, Grant and Albright (2001) suggest that the provision of feed may be more important for a cow to eat when she wants to eat, and maintain adequate DMI, than animal factors and the nutrient content of the diet alone. Specifically, the authors suggest that feed accessibility, regrouping of animals and competition for feeding space can all influence the amount of feed mid-lactation cows consume. Although there is limited work available on the feeding behaviour of transition cows, work on mid-lactation cows has revealed that stocking density and competition at the feed bunk can markedly influence the time cows spend at the feed bunk (DeVries et al., 2004), the amount of feed they consume and the rate at which they consume it (Olofsson, 1999). In a number of early studies testing the effect of overstocking on time spent feeding, no change in feeding time occurred until cows were severely overstocked (e.g. Friend et al., 1977; Collis et al., 1980). However, recent research suggests that a moderate

increase in feeding space per cow can increase feeding time (DeVries et al., 2004; Huzzey et al., 2006).

Changes in feeding behaviour in response to limited feeding space are closely tied with aggressive behaviour of cows at the feeder. Dairy cows tend to synchronize their behaviours, and thus attempt to feed as a group during “peak” feeding times when fresh feed is delivered or directly after milking (DeVries and von Keyserling, 2005). It follows that at high stocking densities, cows have limited space to feed and this can increase social pressure, aggressive behaviour and competition at the feed bunk. Aggressive behaviour is commonly measured as “displacements” at the feeder, where one cow (i.e. the “actor”) physically pushes another cow (i.e. the “reactor”) away from the feed bunk. This idea has been demonstrated by a study by DeVries and von Keyserlingk (2006), where physical partitions installed between cows that significantly impaired a cow’s ability to displace other cows, markedly increasing the feeding time of cows in the pen.

Most work to date testing the effect of overstocking and competition on feed intake has been unable to directly measure the DMI of individual animals in a pen, and thus it has been difficult to make the connection between competition and subsequent disease risk by reduced intake. In one study, Olofsson (1999) found that cows increase their intake in response to competition by increasing the rate at which they consumed feed. However, this same study found that an increased proportion of feed intake occurred at night when cows were housed competitively (Olofsson, 1999). A shift in diurnal feeding patterns of some animals have also been a consequence of competition in beef cows (Stricklin and Gonyou, 1981), as well as finishing pigs (Georgesson and Svendsen, 2002). Cows that eat at night are consuming feed long after it was delivered and are, therefore, at risk of consuming less nutritious feed, as the cows

with first access to feed will sort through the TMR for the most nutritious particles (Kononoff et al., 2003).

Grant and Albright (2001) also identified social regroupings as a factor in the feeding behaviour of dairy cows. In commercial dairy herds, cows are commonly housed in pens based on their stage of lactation and diet. During transition, cows change diets at least twice (far-off to close-up, close-up to fresh), and thus are regrouped at least twice in a short time period. In the few days after a cow enters a new social group, her social behaviour is dramatically altered (von Keyserlingk et al., 2008). Moving lactating cows between pens can increase both physical and nonphysical agonistic behaviours (Kondo et al., 1990). Although the relationship between social changes associated with regrouping, intake and health has not been extensively studied in dairy cows, a study with mid-lactation ewes showed that regrouping resulted in altered immune responses and short-term effects on production performance, but had no effect on DMI or disease incidence (Sevi et al., 2001). Disease incidence, however, is greatest around parturition, making this period the most vulnerable to any alterations in immunity due to regrouping.

#### Environmental stress and immunity

A cow's susceptibility to disease may be heavily influenced by the amount of feed she consumes during transition – but other factors of a cow's environment may also influence her immune system's ability to defend against disease after calving. For instance, there has been recent interest in the relationship between the stressors in an animal's environment and its immunity (reviewed by Padgett and Glaser, 2003). For the purpose of this review, stress will be considered as Moberg (2001) defined it: “the physical response elicited when an animal's homeostatic balance is threatened”. A “stressor” is the stimulus that leads to a physiological stress response. Physiological reactions to stressors include endocrine changes associated with

stimulation of the hypothalamic-pituitary-adrenal axis, stimulation of norepinephrine from the sympathetic nervous system and production of pro-inflammatory cytokines (Moberg, 2001).

A host of potential stressors affect transition dairy cows, including excess heat and cold, social stress associated with overstocking at the feed bunk and lying stalls and social regrouping, uncomfortable lying stalls or flooring, diet changes and infectious challenges. Potential responses to stressors at transition may include decreases in DMI, diversion of scarce nutrients away from milk synthesis and maintenance, interference with lactogenic hormones, increases in body fat mobilization and decreased milk yield in early lactation (Drackley, 2006; Collier et al., 1982).

Although little work has been done with dairy cows, evidence from mice, monkeys and humans suggest that social stress may influence the body's ability to defend against disease. For instance, overcrowding and subsequent aggression is often used as a model for social stress in mice, and has been associated with impaired immunity in a number of studies (i.e. reviewed by Bartolomucci et al., 2007). In humans, stressors that increase inflammatory responses during human pregnancy contribute to premature labor and labor difficulties (Molloy et al., 2004).

Physiological changes associated with social stress and immune activity can also cause decreases in feed intake, which can compound to influence the immunologic and metabolic status of transition cows. For instance, decreased feed intake is a common "sickness behaviour" associated with an inflammatory response to a pathogen, as well as social stress (Hart, 1988). In humans, social stress has been linked to decreased feeding behaviour and postpartum fatigue, and this change is thought to be driven by pro-inflammatory cytokines (Coussons-Read et al., 2005; Corwin, 2003). Interestingly, postpartum depression (the symptoms of which include decreased feeding behaviours), is also associated with increased social stress and excessive labor-induced increases in pro-inflammatory cytokines (reviewed by Kronfol and Remick, 2000).

### Individual ‘coping style’ and cow health

It is important to consider that environmental stressors will likely impact individual cows within a group in different ways. There has been much interest in the usefulness of individual responses to environmental stressors as indicators of an animal’s ability to adaptively “cope” with the stressor. Research with humans, rodents and some farm animals have attempted to classify animals based on behavioural responses to stimuli into distinct ‘coping styles’ (see Koolhaas et al., 1999 for a review). An animal’s coping style is a consistent set of behavioural and physiological responses to an environmental stressor, is consistent over time, and is likely based on a combination of genetics and past experience. However, the classification of animals into distinctive ‘coping styles’ is not without debate (Jensen et al., 1995).

Benus (1991) was the first to describe two very different coping styles to an aversive stimulus in rodents: passive and active. Cows housed in a group environment have also been classified as either passive or active based on their responses to a limited resource, and these responses remained consistent over time (Hopster, 1998). Coping styles in dairy cattle are often measured based on the number of aggressive engagements (i.e. displacements) counted at the feed bunk, and are classified as “dominant” or “submissive” based on a number of criteria and indices (see Val-Laillet et al., 2007 for a review), such as their social hierarchy in a stable group of pen-mates (e.g. Landau's Linearity Index, Landau, 1951), or the proportion of engagements they initialize relative to their overall total number of aggressive engagements (i.e. Galindo-Broom Index, Galindo and Broom, 2000).

In dairy cows, measurements of ‘submissiveness’ at the feed bunk has the strongest correlation with parity and body weight, where younger and smaller animals tend to be classified as submissive more often than older cows using various indices (Schein and Fohrman, 1955;

Dickson et al., 1970; Phillips and Rind, 2002). Primiparous cows are, therefore, often considered to suffer the most in new social environments and it is often recommended that they be separated from multiparous cows (Grant and Albright, 1995; NRC, 2001; Cook and Nordlund, 2004). However, there is little evidence to support the conclusion that primiparous animals suffer in terms of health and production when forced to compete with multiparous cows.

Mid-lactation cows classified as “dominant” or “submissive” based on various definitions have been found to react differently to a competitive feeding environment. Nielson (1995), for instance, found that dairy cows classified as submissive at the feed bunk are the most likely to increase their rate of feed intake in response to competition. Manson and Appleby (1990) found that under space constraints, submissive cows spent less time eating and had lower daily DMI than cows considered dominant. Olofsson (1999) showed that as social constraints increase at the feed bunk, the divergence between DMI of submissive and dominant animals grows, and other studies have shown that increasing feed bunk space provides the greatest improvements in the feeding time of submissive cows (Phillips and Rind, 2002; DeVries et al., 2004).

Although it is clear that mid-lactation cows of differing social classification alter their feeding behaviour differently when faced with a competitive feeding environment, it is unclear how a cow’s coping style may contribute to her susceptibility to disease. Evidence from pigs suggests that active and passive responders differ in their neuroendocrine and immune responses to a stressor (Hessing et al., 1994). In one study of cynomolgus monkeys, the monkeys with the lowest social rank in a group, and the highest frequency of submissive behaviours, were more susceptible to respiratory disease than monkeys classified as dominant (Cohen et al., 1997).

## **Objective**

It is clear that when a transition dairy cow's immune status is compromised, or body reserve metabolism is disturbed, she is at risk for developing one or more diseases after calving. Although a cow's metabolic and immune systems are naturally altered around parturition, severe deviations from these natural changes can result in clinical disease. Any factor that might contribute to severe alterations in metabolism or immunity around transition can, therefore, increase a cow's risk for developing disease.

Dry matter intake plays a major role in maintaining energy balance and health throughout the transition period, and management factors including regrouping and overstocking at the feed bunk can alter a cow's ability to consume an optimal amount of feed. Although work with lactating cows suggests that DMI and feeding behaviour can be altered by grouping and feeding strategy, no work has focused on the effect of a competitive feeding environment on transition cows. Thus, the objectives of my research are to: 1) determine the effect of a competitive feeding environment on the DMI, feeding and social behaviour of cows from 3 weeks before to 3 weeks after calving and, 2) determine the relationship between social behaviour and feeding behaviour in transition dairy cows.

## **Hypothesis**

It was hypothesized that transition dairy cows will increase their feeding rate and aggressive interactions at the feed bunk, and may be compromised in terms of DMI, in response to a competitive feeding environment. It was also hypothesized that cows classified as submissive at the feed bunk will show the most dramatic increases in feeding rate, and decreases in feed intake during this period.



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## CHAPTER 2: COMPETITION AT THE FEED BUNK DURING TRANSITION CHANGES THE FEEDING, STANDING AND SOCIAL BEHAVIOUR OF HOLSTEIN DAIRY COWS<sup>1</sup>

### **Introduction**

It has been estimated that between 30 and 50% of cows experience one or more infectious or metabolic disease in the first few weeks after calving (Goff and Horst, 1997; Ferguson, 2001). Susceptibility to disease after calving is thought to be linked to alterations in immunity and body fat metabolism, both of which are influenced by a state of negative energy balance (NEB) (Goff, 2006; Ingvarsten, 2006). A brief period of NEB is common around calving; the extra energy demands by the fetal calf in late gestation, and mammary glands at the onset of lactation, exceed energy intake even for cows that remain healthy after calving (Bell, 1995). Excessive NEB, however, is thought to contribute to the onset of clinical disease and compromised reproduction (Collard et al., 2000; Drackley, 2006).

A combination of dry matter intake (DMI) and feed composition contribute to total energy intake, and therefore the extent of NEB (Drackley, 2006). A number of studies report a decline in DMI in the week before calving (e.g. Bertics et al., 1992, Hayliri et al., 2002) and low DMI during transition has been linked to disease after calving (Huzzey et al. 2007). For instance, cows that are restricted from maintaining adequate energy intakes immediately after calving are more prone to ketosis (de Boer et al., 1985). Cows that consume less in the prepartum period are also most at risk of displaced abomasum and puerperal metritis after calving (Shaver, 1997; Huzzey et al., 2007, respectively). Despite decades of research on factors affecting energy intake during the transition period (reviewed by Ingvarsten, 2006), disease incidence remains high.

Recent research on mid-lactation cows has identified management factors, such as design

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of the feed barrier and grouping strategy, that affect feed bunk access and feeding activity (DeVries et al., 2004; Huzzey et al., 2006). For instance, in free-stall housing systems where cows are given limited feeding space, competition at the feed bunk can markedly affect feeding activity (DeVries et al., 2004; Huzzey et al., 2006). Management strategies that reduce competition can increase feeding activity, particularly for cows considered submissive at the feed bunk (DeVries et al., 2004). Competition has also been related to increases in standing time, as cows wait by the feeder to gain access to feed (Olofsson, 1999; Huzzey et al., 2006). Excessive standing time has been linked to lameness, and transition cows may be most at risk from the effects of excessive standing times as most lameness cases develop in the months after calving (Bergsten and Frank, 1996).

No work to date has identified the effect of competition on transition dairy cow behaviour and intake. The objective of the current study was to determine the effect of a competitive feeding environment on the social, standing, and feeding behaviour of cows during the weeks around calving.

## **Materials and Methods**

### Animals, experimental design and diet

Thirty four primiparous and 76 multiparous (Parity =  $2.8 \pm 0.2$ , mean  $\pm$  SD) Holstein dairy cows housed in 5 experimental pens at the University of British Columbia's Dairy Education and Research Centre (Agassiz, BC, Canada) were used in this study. Animals were cared for according to the guidelines of the Canadian Council on Animal Care (1993). Each experimental pen was equipped with 6 electronic feed intake bins (INSENTEC, Marknesse, The Netherlands). Cows entered a baseline pen 23 d before expected calving date, and 18 d before expected calving were moved to one of two prepartum pens where they remained until calving.

At signs of imminent calving (i.e. udder enlargement, milk let-down, relaxation of tail ligament), cows were moved to an individual maternity pen where they were kept for a maximum of 24 h after calving. Following parturition, cows were moved into one of two postpartum pens where they remained until 18 DIM. The baseline pen housed 6 cows, and the prepartum and postpartum pens housed 9 cows per pen throughout the experimental period.

Cows in the prepartum and maternity pens were fed a close-up TMR of 21.3% corn silage, 42.8% alfalfa hay, and 35.9% concentrate and mineral mix on a DM basis. Cows in the postpartum pens were switched to TMR formulated for high producing cows which consisted of 21.3 % grass silage, 14.7 % corn silage, 12.3 % alfalfa hay, and 51.7 % concentrate and mineral mix on a DM basis. Cows were fed twice daily at approximately 0800 h and 1600 h. Representative samples of the prepartum and postpartum TMR were taken 3 times per week and pooled monthly. Samples were dried at 60 °C for 48 h to determine DM.

### Behavioural data collection

Feeding behaviour was measured using an INSENTEC feed intake system (see Chapinel et al., 2007) that recorded the duration and amount of feed consumed during every visit to a feeder. These measurements were then used to calculate feeding rate per visit (i.e. intake per visit/feeding time per visit), daily feed intake and daily feeding time.

Visits to the feeder are usually grouped in time to form ‘meals’ and meal-based measures are often considered more biologically relevant than individual visits to the feeder (Tolkamp et al., 2000). A meal consists of both the time a cow has her head in the feed bin and the intervals between feeding visits within a meal. The meal criterion is the minimum time interval away from the feeder such that the next visit is considered a new meal, and was identified using discontinuities in the distribution of intervals using the mixed distribution method described by

DeVries et al. (2003). A pooled meal criterion of 16.7 min for the prepartum period and 20.1 min for the postpartum periods were established. This meal criterion was used to calculate the meal-based measures (i.e. meal size, meal duration and duration of within-meal intervals).

To record standing behaviour, each cow was fitted with a modified datalogger (Gemini Dataloggers Ltd., Chichester, UK) on the hind leg that recorded leg orientation (horizontal or vertical) at 1 min intervals. Data were collected from the logger once a week at milking and used to calculate daily standing time and daily lying time. Daily idle standing time (i.e. the time cows spent standing without eating) was calculated as the difference between daily standing time and feeding time recorded from the feeding system.

Displacements at the feed bins were recorded using video from 2 cameras (Panasonic WV-BP330, Panasonic, Osaka, Japan) mounted 6 m above the feed bins in each of the prepartum pens, a time-lapse videocassette recorder (Panasonic AG-6540), and a video multiplexer (Panasonic WJ-FS 216). Displacements were recorded during the 3 h following the twice daily delivery fresh feed for 4 d (beginning at  $d -11 \pm 3$  d, mean  $\pm$  SD). A displacement was recorded when a butt or a push from the “Actor” resulted in the complete withdrawal of another cow’s head (the “Reactor”) from the feed bin. A social status score was established by dividing the frequency of Actor instigations by the total frequency of displacements the cow was involved in (see Galindo and Broom, 2000).

#### Treatments and cow participation

To collect baseline data, cows were given exclusive access to one bin for approximately 5 d before calving ( $d -23 \pm 4$  to  $d -18 \pm 4$  pre-partum, mean  $\pm$  SD). Data from d 3 and 4 of the baseline period were used to establish baseline feeding behaviour measurements for each cow.

Cows were assigned treatment upon entry into the prepartum pen. Cows in the noncompetitive treatment (n = 34) were trained to eat from a single feed bin; two cows (paired according to expected calving date) were assigned to eat from a specific bin in the competitive treatment (n = 76). After calving, cows in the competitive group were paired with the same cow as in the prepartum pen if they calved within 1 d of each other, or with a cow from another pair if the calving dates were separated by more than 1 d.

To generate only one experimental unit from each pair in the competitive treatment, only the first cow of each pair to calve was used for data analysis, resulting in 18 cows in the competitive treatment. Following formation of the competitive treatment, a noncompetitive group was selected on the basis of similarity in parity and prepartum feeding measures. Cows with clinical health problems (e.g. milk fever, retained placenta or puerperal metritis) after calving were not included in either treatment group.

### Statistical analysis

The cow was considered the experimental unit in all statistical tests. The PROC UNIVARIATE procedure in SAS (2003, version 9.1) was used to screen the distributions of feeding time, DMI and feeding rate per visit for normality and the presence of outliers. Observations identified as extreme outliers (i.e. more than 3 times outside the inter-quartile range) were removed. Due to differences in actual and expected calving dates, complete feeding data were only available between -9 d and +18 d relative to calving. Day -1, d 0 and d +1 were removed prior to analysis as cows were moved to the maternity pen during this period. Day -2 pre-partum was also removed due to high between-cow variation. For all feeding and standing variables, data were summarized to create one observation per day for each cow. Days were then averaged into the following weekly periods: wk -1 (d -9 to d -3), wk +1 (d +2 to d +8) wk +2 (d

+9 to d +18). Social data obtained during the prepartum period were averaged over 4 d for each cow to create one value per cow.

We observed interactions between parity (categorized as primiparous versus multiparous) and treatment for most of the recorded behaviours, so differences between treatments were tested separately for primiparous and multiparous cows. The PROC MIXED procedure in SAS was used to test the fixed effect of treatment on feeding, standing and social behaviour variables for each parity category and experimental period. Pen was included in the model as a random effect. Least square means and standard errors were determined using the LSMEANS statement in PROC MIXED.

We expected that social status at the feeder would help account for between cow differences in how feeding behaviour responds to competition. Specifically, we predicted that for cows fed in the competitive environment, social status at the feeder would be positively related to daily DMI, and negatively related to feeding rate and inactive standing time. We did not expect these relationships for cows fed in the non-competitive environment, as our measure of “social status” for cows fed noncompetitively was much less meaningful (these cows had nothing to gain by displacing other cows, as they had unrestricted access to their own feeder). Therefore, the regression analysis (PROC GLM procedure in SAS) was only done for cows in the competitive treatment, testing the relationship between social status and feeding variables with pen included in the model as a class variable.

## **Results**

### Social behaviour

Competitively fed cows had a higher frequency of displacements at the feed bins in wk - 1 compared to noncompetitively fed cows (Figure 2.1). Competitively fed primiparous cows

were involved in over 3 times more displacements per day than their non competitively fed counterparts (25 vs. 7 no./d, SED = 2.2,  $P < 0.001$ ); multiparous cows fed competitively were involved in just over twice as many displacements per day compared to noncompetitively fed cows (24 vs. 10 no./d, SED = 3.8,  $P = 0.02$ ). Although competition increased the number of displacements of both primiparous and multiparous cows, this increase was driven by actor instigations made by competitively fed multiparous cows, and by both actor and reactor frequencies in primiparous cows.

#### Feeding behaviour: short-term and daily variables

Although competitively fed primiparous cows were involved in more displacements at the feed bins than the noncompetitive primiparous cows, these displacements did not affect the frequency of feeder visits, time at the feeder, the amount consumed during each visit, and total daily feeding time for these cows (Table 2.1).

In contrast, competition tended to increase the frequency of daily visits multiparous cows made to the feeder during wk -1 (Table 2.1). During visits in the week prior to calving competitively fed multiparous cows spent 28% less time eating than noncompetitive multiparous cows, resulting in lower DMI per visit and a minor increase in feeding rate. In the week after calving (wk +1), competition had no effect on the number of visits to the feeder by the multiparous cows, yet multiparous cows fed competitively continued to spend less time eating per visit to the feeder during this period. By the second week after calving (wk +2), DMI of competitively fed cows were similar to non-competitive cows, but feeding times were shorter resulting in a 35% higher feeding rate in the competitively fed cows.

When individual visits were summarized by day, competitively fed multiparous cows tended to eat less than the non-competitive cows during wk -1 and +1. By wk +2, both groups of

multiparous cows were consuming similar amounts. The daily feeding time of multiparous cows was not different during wk -1, but tended to be lower in competitively fed cows during wk +1 and +2.

#### Feeding behaviour: meals

Before calving, primiparous cows fed competitively had longer meals than those fed noncompetitively; this increase was driven by longer intervals within meals (i.e. the time spent between feeding bouts within a single meal; Table 2.2) and not by the time spent feeding (Table 2.1). During wk +1, meal duration tended to be longer in competitively fed primiparous cows compared to non-competitive primiparous cows, but this effect was not present by wk +2.

In wk -1, competitively fed multiparous cows tended to increase the duration of their within-meal intervals, and this trend continued until wk +2. Unlike for primiparous cows, feeding multiparous cows competitively had no effect on the total duration of meals. However, within meal intervals were higher in competitively fed than non-competitively fed multiparous cows.

#### Standing behaviour

Under a competitive feeding environment, we predicted that cows would increase the time they spend standing waiting to gain access to the feeder (i.e. reflected in their idle standing time), and thus reduce the time they spend lying. However, competition had no effect on the idle standing or lying time of primiparous cows (Figure 2.2). In contrast, competition did affect the standing behaviour of multiparous cows (Figure 2.2). Although we observed no differences in daily feeding time in wk -1, there was a tendency for competitively fed multiparous cows to spend more time standing idly during this period. By wk +1, competitively fed multiparous

cows spent about 2.8 h more time standing idly than their non-competitively fed counterparts. A higher idle standing time was accompanied by a decrease in lying time in competitively fed multiparous cows (494 min/d vs. 641 min/d, SED = 41,  $P < 0.01$ ). By wk +2, competitively fed multiparous cows did not differ from non-competitively fed multiparous cows in inactive standing time or lying time.

### Relationship between social and feeding variables

We found no relationship between social status and daily DMI for multiparous or primiparous cows. However, we did observe a strong negative relationship between feeding rate and social status ( $R^2 = 0.82$ ,  $P < 0.001$ ) in the competitively fed multiparous cows (Figure 2.3). No relationship was found between the social status of competitively fed primiparous cows and any feeding behaviour.

### **Discussion**

Recommendations for bunk space per cow are varied. Early work with mid-lactation cows suggested that cows can be housed with as little as 0.2 m of feed bunk space/cow without negatively affecting the DMI or milk production of the pen (Friend et al., 1977; Collis et al., 1980). More recently, recommendations for feeding space have increased to approximately 0.6 m/cow as we begin to understand the consequences of competition on individual animals within the pen (Grant and Albright, 2001). Although we know of no previous work that has looked specifically at the effects of competition at the feed bunk on transition cow behaviour, between 0.61 and 0.76 m of linear feed bunk space per cow has been recommended for transition dairy cows (Shaver, 1993). If the electronic feeding system used in this trial were considered equivalent to linear bunk space, then the amount of feeding space given to a cow fed on the



competitive and noncompetitive treatments provided approximately 0.3 m/ and 0.6 m/feeding space per cow, respectively.

Limiting access to feed bins or a feed bunk has been shown to increase agonistic behaviour (i.e. measured as displacements) at the feeder in a number of studies (Olofsson, 1999; DeVries et al, 2004; Huzzey et al, 2006). Our work is the first to show that the effects of competition on aggression in close-up dry cows is similar to that observed in mid-lactation cows overstocked at feed bins (4 cows:1 bin, Olofsson, 1999), as well as overstocked at a post-and-rail feeding barrier (0.21 m/cow, Huzzey et al., 2006).

For every displacement recorded at the feed bins in this study, there was one actor and one reactor; therefore, if all animals in the experiment were included in the analysis there would be a 1:1 actor:reactor ratio. In the present study the total number of reactors was greater than actors for both primiparous and multiparous cows. This imbalance was expected as we predicted that both primiparous and multiparous non-competitive cows would rarely instigate an aggressive interaction. By design, at any given time in the experiment the number of competitive cows outnumbered the non-competitive cows 6:3 in each pen. However, in the final analyses only one cow from each matched-pair was used thus creating an imbalanced actor:reactor ratio.

One of the primary aims of this study was to determine how the social status of a cow affected her behavioural responses within a competitive feeding environment. To our knowledge this is the first study to show that feeding rate was strongly related to social status in multiparous cows. Similar to previous work with mid lactation cows, multiparous cows during transition adapted to increased competition at the feeder by increasing their feeding rate at each visit (Harb et al., 1985; Olofsson, 1999). Factors affecting feeding rate have been discussed (i.e. see Nielson, 1999 for a review), and include increased motivation to feed and increased social pressure at the feeding area.

Most (82%) of the variation in feeding rate in the multiparous cows used in the current study was explained by social status, as cows of lower social status (i.e. were displaced from the feeder more often than they displaced another cow) ate the fastest. This finding complements DeVries et al. (2004), who reported that subordinate cows showed the greatest reductions in feeding time when feeder space was restricted. An increased feeding rate is likely an adaptation to a competitive feeding environment in animals that are less able to compete directly with more dominant animals and, thus, indirectly alter their behaviour to maintain DMI. The literature on social competition in animals distinguishes between indirect ("scramble") and direct ("interference") behaviours in response to a limited resource (Giraldeau and Caraco, 2000). In this case, the cows that are less likely to compete for feed using aggressive "interference" are more likely to increase their "scramble" behaviour by eating quickly when they obtain access to the feeder.

Although we expected primiparous cows to alter their feeding rate in response to competition based on previous work (i.e. Schein and Fohrman, 1955; Phillips and Rind, 2002), we were unable to detect differences in rate between treatment groups. In growing sows, feeding rate increases over time and these changes are likely as a result of age-dependent changes in body size (Nielsen et al., 1995). In ruminants, it has been suggested that certain body traits change over time, such as the capacity of the mouth to take larger bites (Illius and Gordon, 1987), which may account for the similar feeding rates between primiparous treatment groups as well as a difference in feeding rate between multiparous and primiparous cows reported by others (i.e. see Kertz et al., 1991).

Despite a high feeding rate throughout transition, multiparous cows on the competitive treatment failed to maintain similar intakes of non-competitively fed cows in the week before calving. The lower DMI observed in competitively fed cows was driven by smaller and shorter

individual visits to the feeder. Surprisingly, this difference in intake was not reflected in meal-based measures, as cows in both treatments ate the same number of meals of equal size. Our finding is in contrast to that of Hosseinkhani et al. (2008) who reported no change in DMI in response to competition when dry cows were fed using a similar feeding system to monitor feeding behaviour. The difference between studies could be due, in part, to analyzing multiparous and primiparous cows separately in the current study.

In a within-cow trial testing the effect of competition on mid lactation cows, Olofsson (1999) noted an increase in DMI in a highly competitive feeding environment driven by a higher rate of intake. Although the current study was the first to report decreased DMI in response to competition in dairy cows, growing and finishing pigs penned in small groups will eat less than those housed individually (Gonyou et al., 1992). Nielson (1999) argues that, within a social context, sows may be compromising their intake in exchange for synchronizing feeding behaviour with pen-mates. It is well established that feeding activity in a pen of dairy cows is highest after fresh feed delivery and return from milking (DeVries et al., 2004). It is possible that higher energy demands associated with lactation (Bell, 1995) may provide competitively fed cows a greater motivation to increase their energy intake, as well as increase synchronization of their behaviour (i.e. feeding after the return from milking, DeVries et al., 2004).

Dairy cows are known to decrease their daily DMI as calving approaches. Hayliri et al. (2002), for instance, recorded an 89% drop in intake in the week before calving compared to previous week. The decline in DMI in the days before calving is highly variable between cows, and considerable research has identified factors that likely contribute to the decline. For instance, Hayirli et al (2002) found that 19.7% and 24.3% of the variation in DMI in the week before calving was explained by cow factors (parity and body condition) and dietary factors, respectively. However, in the current study, all cows were fed the same diets throughout

transition, groups were balanced for pre-partum BCS, and data were analyzed separately for primiparous and multiparous cows, eliminating variation due to feed and animal factors. A reduction in DMI in competitively fed multiparous cows was, therefore, likely a consequence of their feeding environment.

Although cows with severe illness were removed from this dataset, the multiparous cows in the competitive treatment may have been at risk for developing sub-clinical disease that may have gone undetected by the farm manager or herd veterinarian. According to Drackley et al. (2006), the extent of NEB experienced by a cow during early lactation is primarily mediated by DMI, and cows that experience prolonged NEB and lower intakes may be at increased risk for developing disease after calving (Shaver, 1997; Huzzey et al., 2007). The wk -1 intake recorded for non-competitive cows in this trial was similar to those reported by Huzzey et al. (2007) for healthy cows fed from the same feeding system, suggesting that competitively fed cows in this trial may have been consuming a suboptimal amount of feed.

Aside from changes in intake, Olofsson (1999) also found a decrease in total feeding time and increase in idle standing time in response to a competitive feeding environment. An increase in total standing time and idle standing time as a result of competition has also been found in studies testing the effect of an overstocked feeding area on mid-lactation cows (Huzzey et al., 2006; DeVries et al., 2006). In the current study, multiparous cows decreased their daily feeding time, and decreased their daily lying time in the period directly after calving. The remainder of the time was spent standing idly (i.e. not eating). Although it is unclear where the standing occurred (i.e. alley or stall), previous work suggests that these cows were likely standing in the feeding area, waiting to gain access to the feeder (Galindo and Broom, 2000; Huzzey et al., 2006). It is unclear why these differences in idle standing time between groups were the greatest during the week directly after calving; however, one explanation for differences may be due to

the effect of a new partner; reestablishing dominance with a new pair may influence the time a cow spends standing at the feeding area. Of the 10 multiparous cows in the competitive group, only 2 cows in the competitive group had the same partner after calving.

Excessive standing time is a major risk factor for developing lameness conditions such as claw horn lesions (Greenough and Vermunt, 1991). Although avoiding excessive standing times at all stages of lactation is important to avoid hoof injuries, the period around calving may be especially sensitive for the development of hoof pathologies, as claw horn lesions (which are delayed clinical signs of horn-disruption by approximately 8-12 weeks) are most commonly identified in the few months after calving (Bergsten and Frank, 1996).

## **Conclusions**

It has been well established that reducing feeding space per cow increases competition for feed and agonistic behaviours, as well as alters some feeding behaviours in cows with relatively consistent energetic demands in mid-lactation. This was the first study to report the negative impact of reduced feeding space on the feed intake of transition dairy cows. Future work is needed to establish the effect of reduced intake on disease susceptibility and immunity after calving. Competition at the feeder during transition also increased the feeding rate, aggressiveness and idle standing time of multiparous cows, but had little effect on primiparous cows.

**Table 2.1.** The effect of competition on daily feeding visits and short-term feeding variables (i.e. per visit to the feeder) for primiparous and multiparous Holstein dairy cows from wk -1 before calving to wk +2 after calving. Feed intake is reported on a DM basis.

	Wk -1				Wk +1				Wk +2			
	NC <sup>1</sup>	C <sup>2</sup>	SED	P	NC <sup>1</sup>	C <sup>2</sup>	SED	P	NC <sup>1</sup>	C <sup>2</sup>	SED	P
<b>Primiparous (n=16)</b>												
Visits (no./d)	46	47	3	0.81	33	35	3	0.57	33	33	4	0.86
Visit intake (g/visit)	290	260	20	0.47	450	410	60	0.65	530	470	80	0.60
Visit feed time (min/visit)	4.7	4.8	0.4	0.90	4.8	4.6	0.5	0.79	6.2	6.0	0.7	0.86
Feed rate per visit (g/min)	69	73	9	0.73	99	102	6	0.72	87	87	5	0.98
Daily intake (kg/d)	12.2	12.2	0.5	0.95	12.8	13.8	0.7	0.37	14.4	14.8	0.74	0.74
Daily feed time (min/d)	199	216	13	0.34	138	154	7	0.13	173	187	10	0.36
<b>Multiparous (n=20)</b>												
Visits (no./d)	32	43	4	0.10	23	27	3	0.37	24	31	5	0.31
Visit intake (g/visit)	510	380	50	0.08	710	610	60	0.17	750	660	110	0.40
Visit feed time (min/visit)	5.8	4.2	0.5	0.03	7.0	5.3	0.7	0.05	8.0	6.0	0.9	0.07
Feed rate per visit (g/min)	95	118	10	0.10	116	138	10	0.14	105	142	11	0.02
Daily intake (kg/d)	15.1	13.4	0.6	0.06	15.7	13.9	0.8	0.11	16.3	15.6	0.9	0.59
Daily feed time (min/d)	179	154	12	0.16	150	124	9.1	0.06	173	144	11	0.10

<sup>1</sup>NC = non-competitive treatment

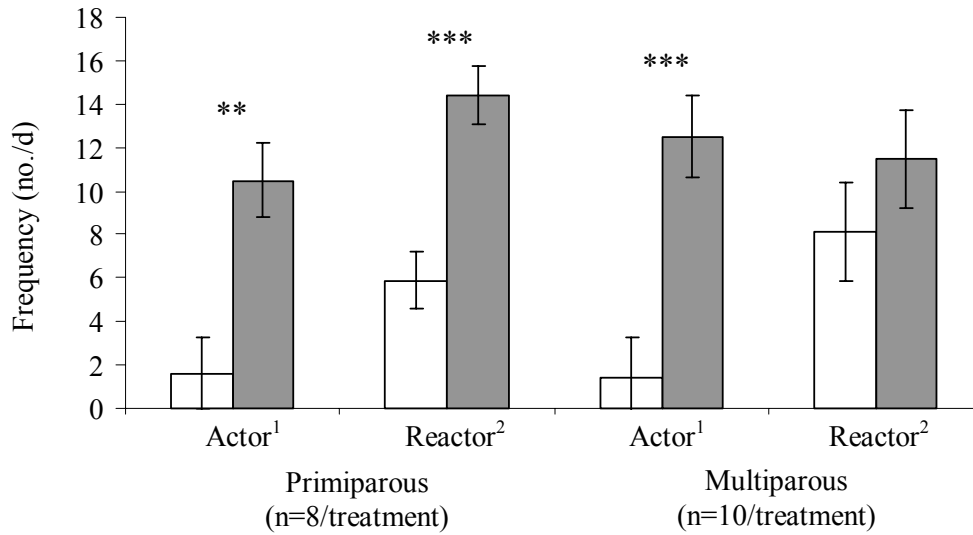
<sup>2</sup>C = competitive treatment

**Table 2.2.** The effect of competition on meal-based variables for primiparous and multiparous Holstein dairy cows from wk -1 before calving to wk +2 after calving. Meal criterion was established as 16.7 min in wk -1 and 20.1 min for wk +1 and wk +2 for both parity groups. Feed intake is reported on a DM basis.

	Wk -1				Wk +1				Wk +2			
	NC <sup>1</sup>	C <sup>2</sup>	SED	P	NC <sup>1</sup>	C <sup>2</sup>	SED	P	NC <sup>1</sup>	C <sup>2</sup>	SED	P
<b>Primiparous (n=16)</b>												
Meal frequency (no./d)	11	11	0.7	0.33	10	9	0.5	0.80	9	9	0.5	0.82
Meal time (min/meal)	24.0	28.0	1.5	0.04	19.8	24.4	1.7	0.07	25.1	28.6	1.9	0.21
Meal size (kg/meal)	1.1	1.2	0.1	0.48	1.4	1.5	0.1	0.21	1.7	1.7	0.1	0.77
Within meal interval (min/meal)	6.0	7.8	0.8	0.05	5.1	7.1	0.9	0.12	5.3	7.2	0.8	0.13
<b>Multiparous (n=20)</b>												
Meal frequency (no./d)	10	10	0.6	0.97	9	10	0.5	0.74	8	8	0.4	0.80
Meal time (min/meal)	25.2	25.8	2.2	0.85	20.6	18.7	1.1	0.24	25.9	24.8	1.9	0.70
Meal size (kg/meal)	1.7	1.5	0.1	0.25	1.7	1.5	0.1	0.10	2.0	1.9	0.1	0.59
Within meal interval (min/meal)	6.1	8.9	1.1	0.11	3.9	5.2	0.5	0.11	4.6	7.1	1.0	0.10

<sup>1</sup>NC = non-competitive treatment

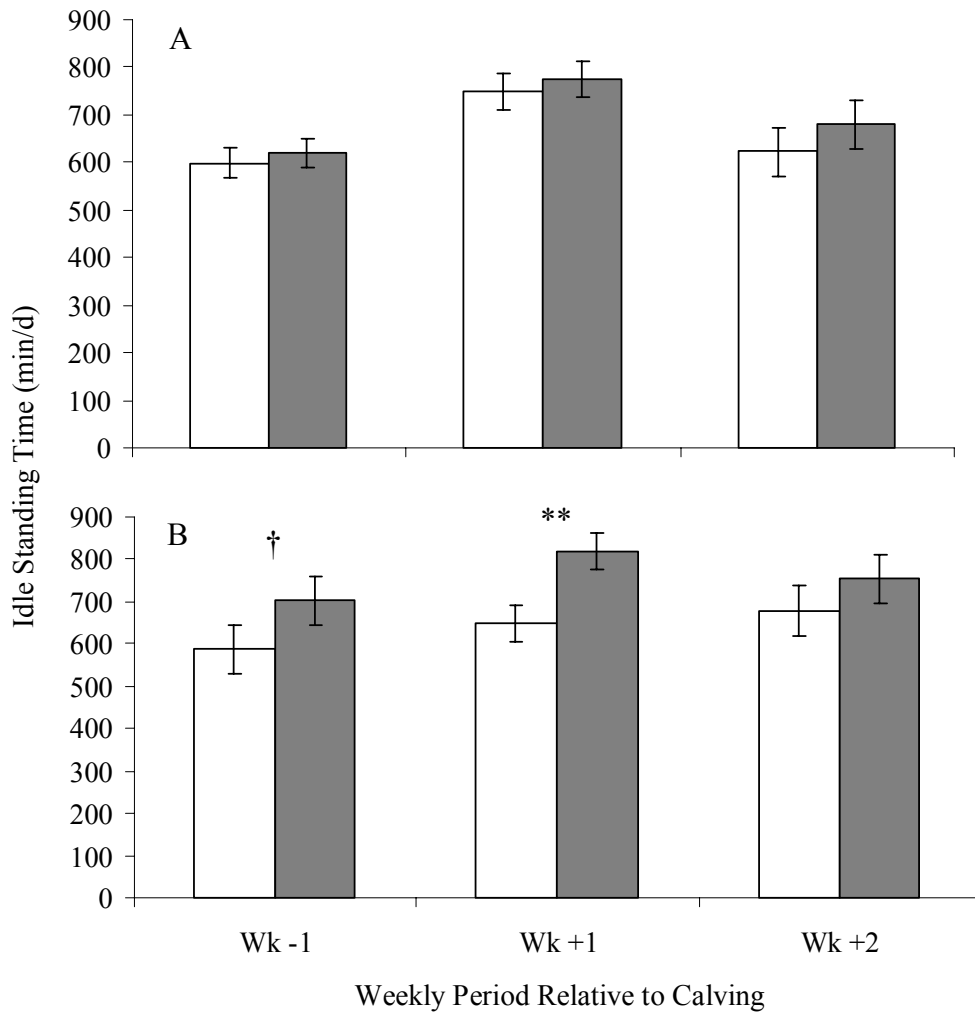
<sup>2</sup>C = competitive treatment



<sup>1</sup>Actor = displaced the Reactor cow at the feed bin  
<sup>2</sup>Reactor = was displaced at the feed bin by the Actor  
\*\*\*  $P < 0.001$   
\*\*  $P < 0.01$

**Figure 2.1.** The effect of competition on the frequency of agonistic behaviour at the feed bins for primiparous and multiparous Holstein dairy cows fed competitively (grey) and non-competitively (white) during wk -1 before calving (LS means  $\pm$  LS SED).

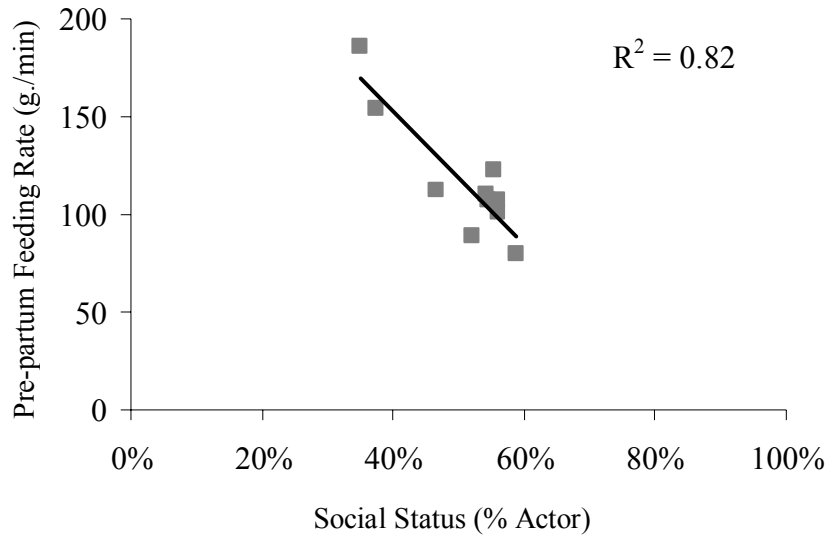




\*\*  $P = 0.01$

†  $P = 0.10$

**Figure 2.2.** Idle standing time (min/d) of (A) primiparous and (B) multiparous Holstein dairy cows fed competitively (grey) and non-competitively (white) from wk -1 before calving to wk +2 after calving (LS means  $\pm$  LS SED).



**Figure 2.3.** The relationship between feeding rate and social status for competitively fed multiparous Holstein dairy cows (n=10) during wk -1 before calving. Social status was calculated as the frequency of actor instigations divided by the total frequency of recorded displacements.

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### CHAPTER 3: GENERAL CONCLUSIONS

In a recent review, Leblanc et al. (2006) commented that “the single biggest advance in dairy health in the last 25 years has been the paradigm shift from treatment of clinical illness to disease prevention.” Prevention, however, requires a more holistic approach to transition cow disease than studying disease physiology alone; one that also takes into consideration a cow’s social environment, the way she is housed and managed, and her individual response to stressors.

As the dairy industry continues to increase in efficiency and herd size, a reduction in the amount of space allotted to individual cows at the feeder is a likely outcome. Although work has established that reduced feeding space can affect the behaviour and intake of mid-lactation cows (DeVries et al., 2004), there is a much greater need to study these effects during the transition period when cows are most at risk for disease. Moreover, studying the possible consequences of reduced feeding space is an important component of disease prevention, as changing a cow’s environment may contribute to her risk for becoming ill. It was, therefore, the purpose of this master’s thesis to take the first steps to approach disease prevention by measuring the effect of reduced feeding space on transition dairy cow behaviour.

One important outcome of my study was the slight reduction in the intake of multiparous cows in the week before calving as a result of competition. To date, technology has limited our ability to collect sensitive individual measurements of DMI and, therefore, represents a major gap in our understanding of the effect of competition on the individual behaviour and DMI of cows housed in a group environment. In the current study, the INSENTEC feeding system allowed for sensitive measurement of feeding behaviour in individual animals housed in a group pen.

One of the most surprising outcomes of this study was the strong effect that competition had on the idle standing time of multiparous transition cows directly after calving. Like other

transition diseases, lameness can cause both poor welfare (due to pain associated with hoof injuries) as well as a decreased productivity (such as reduced milk yield and reproduction complications; reviewed by Fourichon et al., 2000). Further research is now required to demonstrate that the increased standing time resulting from competition predisposes cows to lameness.

Another novel finding of this study was the strong relationship between social status and feeding rate in multiparous cows. This was the first work to show that a transition cow's social status can affect her feeding response to competition. Extensive research in rodents, and some work with farm animals has suggested that a coping style may reflect an animal's capacity to adapt to a given environment, and thus, their vulnerability to stress-related changes in cardiovascular health, immunity and susceptibility to disease (Koolhaas et al., 1999). Cows submissive at the feed bunk in the current study altered their feeding behaviour in response to social competition, but it remains unclear how the psychosocial implications of low social status and increased rate of intake may affect cows in terms of their ability to avoid health complications at transition.

### **Future Research**

A major gap in the literature regarding transition cow disease is the relationship between various responses to environmental stressors and their association with health. Although this study was the first to identify the effect of competition on dairy cow behaviour, more work is needed to determine the effect of overstocking and these changes in behaviour on direct measures of dairy cow health. Specifically, future work should focus on the effect of competition and individual coping style on components of the immune and metabolic systems known to

contribute to disease risk during transition, such as exaggerated inflammation and excessive negative energy balance.

Future work should also focus on using the information we gain from studying the relationship between behaviour and health to develop methods of assessing the various housing systems commonly used for transition cows in the dairy industry today. For instance, if idle standing time during transition is found to be a major risk for lameness after calving, measuring the idle standing time of transition cows under different housing conditions will give us an indication of the lameness risk associated with each housing practice. Ultimately, the aim of this line of research is to give dairy producers science-based recommendations for housing their transition cows in such a way that limits the various environmental and management factors that put cows at physical, immunological or metabolic risk for developing clinical disease and lameness after calving.



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