AN ABSTRACT OF THE DISSERTATION OF

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Our objectives were to determine if dietary cation-anion difference (DCAD) and source of anions influence periparturient feed intake and milk production, and to characterize feeding behavior of dairy cattle during the transition period. Diets differed in DCAD (cationic or anionic) and anionic supplement (BioChlor®, Fermenten®, or anionic salts), and were Control (DCAD +20 meq/100 g DM), BioChlor® (DCAD -12 meq/100 g DM), Fermenten® (DCAD -10 meq/100 g DM), and Salts (DCAD -10 meq/100 g DM). Urine pH was lower for cows that consumed an anionic diet prepartum compared to control. Prepartum diet had no effect on prepartum DMI of multiparous or primiparous cows. Postpartum DMI and milk yield for multiparous cows fed anionic diets prepartum was greater compared to control. Postpartum dry matter intake and milk yield of primiparous cows was similar for prepartum diets. Feeding prepartum anionic diets did not affect plasma Ca at or near calving. Postpartum β-hydroxybutyrate and nonesterified fatty acids were lower for primiparous cows fed prepartum anionic diets compared to control. Prepartum and postpartum plasma glucose concentrations were not affected by prepartum diet for all

cows. Plasma cortisol concentrations were similar between parities during the prepartum and postpartum periods. Liver triglyceride differed for parity by day. Parities were similar at 21 d prepartum, but at 0 d and 21 d postpartum, levels were greater for cows. Feeding behavior was not altered by prepartum anionic diets. Prepartum and postpartum feeding rate was greater for multiparous cows, whereas prepartum daily meal time was greater for primiparous cows. Daily meal time, meal duration, feed intake and feed intake per meal decreased prepartum and increased postpartum. Feeding rate did not change prepartum, but decreased during the postpartum period. Results indicate that decreasing the DCAD of the diet during the prepartum period can increase postpartum DMI and milk production of multiparous cows without negatively affecting performance of primiparous cows. In addition, depression in feed intake that occurs around the time of parturition coincides with a decrease in daily meal time. Therefore, strategies that increase feeding time during this critical period may be useful in increasing feed intake.

Effect of Prepartum Anionic Supplementation on Periparturient Feed Intake and Behavior, Health and Milk Production.

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Michael A. DeGroot, Author

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INTRODUCTION

The goal of most dairy producers is to optimize milk production, health, and longevity in a cost-effective manner. On a typical dairy farm, feed costs represent approximately 50 percent of the total cost of milk production. Economically, it is important to maximize feed efficiency, to lower feed costs per unit of milk produced. With high producing cows, successfully implementing management strategies to maximize feed intake will determine how well a balanced diet supports milk production.

The transition period, as defined by Grummer (1995), is the three weeks before and after parturition. The transition period is considered the most traumatic time of the annual cycle of the dairy cow (Keady et al., 2001); determining the cows health, production and reproduction in the subsequent lactation. There are several different factors that can affect the outcome of parturition and in turn the subsequent lactation. Stressors whether environmental, behavioral, or immunologic, play a very important role in the successful transition of dairy cows from the dry period to the subsequent lactation (Drackley et al., 2001). The main goal of any transition program is to keep cows healthy while continuing to increase intake with the least amount of stress possible. Although the greatest organic nutrient imbalances occur immediately postpartum, the greatest fluctuations in organic nutrient metabolism at or immediately before parturition (Grummer, 1995). The magnitude of the fluctuations has a major impact on the amount of stress a cow encounters during the transition period (Grummer, 1995). Several of the metabolic adaptations that occur at parturition are

initiated during late lactation such as the increase in mobilization of fatty acids (Bell, 1995). Parturition in dairy cows is linked with dramatic changes in adipose tissue metabolism from net lipogenesis to lypolysis and release of NEFA into the blood (Bell, 1995). Endocrine changes that initiate lactogenesis also play a role in nutrient metabolism (Bell, 1995). Tissue response to certain hormones can also affect nutrient metabolism during the transition period. Increasing DMI and the nutrient composition of the feed consumed could alter nutrient metabolism and can have a dramatic affect on metabolic disorders seen around the time of calving. However, DMI and the potential dietary contribution to the glucose supply of the cow, increases slower than the demand for glucose after calving; therefore, substantial coordination of metabolism must occur to direct glucose to the mammary gland in support of milk synthesis in the early postpartum cow (Overton, 1998).

Feeding transition dairy cows can be somewhat challenging. When feeding dairy cows there are several factors that can influence the actual feed intake as well as the diet that is actually consumed during this period. Variance exists in every aspect of feeding the dairy cow: forage sampling and analysis, mixing and weighing, dry matter content, amounts and proportions eaten, feeding behavior, requirements across groups, nutrient requirements within groups, and individual cow nutrient requirements (Sniffen et al., 1993).

LITERATURE REVIEW

TRANSITION PERIOD

METABOLIC DISORDERS

It has been well established that the major periparturient disorders that occur are highly correlated (Curtis et al., 1985; Ferguson, 2001; Goff and Horst, 1998; Jordan and Fourdraine, 1993; Wallace et al., 1996). The combined incidence rate for milk fever, dystocia, retained placenta, ketosis, metritis, fatty liver, lameness, and displaced abomasum result in only 50% of all cows calving without any health problems (Ferguson, 2001). Recent work from the University of Illinois (Wallace et al., 1996) examined the relationships between disorders, DMI and milk production. In this study, 48 cows in the university herd were monitored for the first 20 days of lactation. Average daily production was 29.5 kg. Postcalving events monitored were milk fever, retained placenta, metritis, ketosis, displaced abomasum and mastitis. Twenty-four cows had at least one of these events during this period. Dry matter intake of cows with any disorder was significantly lower than those cows with no problems. Cows with any of the above events produced 8952 kg of milk compared with 9424 kg for cows with no disorders. Cows that experienced a displaced abomasum or ketosis had an average milk yield of 8,572 kg of milk. These differences in milk production represent only a fraction of the total economic cost of postcalving disorders. An additional consideration is the interactions that occur between disorders. Curtis and associates (1985) used a path analysis approach to examine these relationships in 31 commercial herds. Cows with milk fever had 4 times more risk of retained placenta and 24 times more ketosis than cows that did not have milk fever.

The risk of complicated ketosis was elevated in cows that had a retained placenta, displaced abomasum or milk fever. Jordan and Fourdraine (1993) surveyed 61 Holstein herds with an average production of 11,071 kg of milk. They reported the following incidence rates: ketosis (3.7%), milk fever (7.2%), displaced abomasum (3.3%), downer cows (1.1%), and retained placenta (9%). These incidence levels imply that high producing herds can have relatively low rates of postcalving disorders.

Approximately one-half of multiparous dairy cows experience moderate to severe fatty liver at calving (Grummer, 1995). Fatty liver occurs when the rate of hepatic triglyceride (TG) synthesis exceeds the rate of TG disappearance through either hydrolysis or secretion via very low-density lipoproteins (VLDL) (Bremmer et al., 2000). Fatty liver causes a decrease in the glucogenic capacity of hepatocytes (Cadorniga-Valino et al., 1997). Fatty liver is associated with an increased incidence of immune suppression (Raabo and Terkildsen, 1960), mastitis (Herdt, 1988), retained placenta (Bruss, 1993; Herdt, 1988), displaced abomasum (Herdt, 1988), and a decrease in reproductive performance (Rayssiguier et al., 1988). Intake of energy is reduced as the cow gets closer to parturition, this results in an increase of fat mobilization and an increase in NEFA concentration in blood as well as a high rate of fatty acid uptake by the liver. Cows that were force fed to maintain adequate dry matter intake during the last three weeks prepartum had reduced plasma NEFA concentration before calving and hepatic triglyceride concentration on the day after calving (Bertics et al., 1992).

DRY MATTER INTAKE

The general concept that is used in the dairy industry in regards to the different rations used from far off dry cows to fresh cows is that nutrient density is increased gradually through all three of these phases. Sudden or abrupt changes in the diet of a cow should be avoided at all costs. Close up rations are a way for the cow to slowly adjust from the increased forage diet of the far off dry period to a diet that is high in concentrates in early lactation. However, there has been evidence that shows that abrupt changes to rations relatively high in concentrate proportions immediately after calving are not detrimental (Hernandez-Urdaneta et al., 1976). Proper nutrition during this transition period can also improve lactational performance (Drackley, 1999).

Dry matter intake provides the framework for a productive, profitable ration. A substantial decrease in dry matter intake occurs in late pregnancy to early lactation. Dry matter intake may decline on average between 20 and 40% during the last three weeks before parturition (Bell, 1995; Grummer, 1995). Intake of dairy cattle after calving is usually less than the energy requirements during the early lactation stage resulting in negative energy balance (Bell, 1995). Glucose needs increase about 2.7 times between late pregnancy and the first few days of lactation (Bell, 1995). Since nutrient requirements of domestic animals with inherently high production capacities often exceed nutrients which can be provided by diet alone, body reserves of these nutrients become critically important, and must be freely mobilized to avoid metabolic failures. The decrease in intake seen around parturition can have an overall effect on the subsequent lactation through decreased milk yield and an increase in metabolic

disorders. Precalving DMI has been positively correlated with the DMI at 21 days in milk (DIM) (Grummer, 1995).

One way to prevent negative energy balance before calving and in the early postpartum period is to increase the energy density of the diet for cows in the last three weeks before parturition. Some recent work has shown that DMI will be increased by increasing the NFC content of the diet in the late prepartum period (Minor et al., 1998; VandeHaar et al., 1999). However, increasing the energy density of the diet has also been proven to decrease feed intake in some situations (NRC, 2001). A recent study done at the university of Wisconsin (Rabelo et al., 2003), exhibited that the greater the energy intake above requirements during the prepartum period the greater the magnitude of drop in DMI as parturition approaches, however, several studies also submit that feeding a higher energy diet in the late prepartum period did not alter postpartum performance in the subsequent lactation (Holcomb et al, 2001; Keady et al., 2001; Mashek and Beede, 2000; VandeHaar et al., 1999).

Minimizing the decrease in DMI or increasing the nutrient density during the final three weeks of gestation can have a dramatic effect on maintaining body reserves as well as increasing nutrient density for fetal growth and milk production. VandeHaar and associates (1999) fed a diet containing 1.6 Mcal of NE_L/kg and 16% crude protein during the last month before parturition and found an improvement in nutrient balance of cattle prepartum and decreases in hepatic lipid content at parturition. Nutrient balance is a function of DMI, nutrient density of the diet, and efficiency of nutrient utilization (Park et al., 2002). It is complicated in the transition cow because of intake depression during the last week prepartum. Nutrient balance

can possibly be achieved by increasing the nutrient density of the diet and total digestive tract efficiency (Park et al., 2002). This is a critical part of the transition period because energy requirements for maintenance and pregnancy of dairy cattle increase 23% during the last month prepartum (Moe and Tyrrell, 1972).

The decrease in DMI has traditionally been interpreted as being caused by physical constraints, but this role is most likely overemphasized. Intake should decline more than 20-40% based on the magnitude of decrease in ruminal capacity in the late gestation cow (Ketelaars and Tolkamp, 1992). Rumen size is a function of body weight, body size, body shape, and competitors for body capacity, such as fetal mass and internal fat (Mertens, 1985). Physical capacity could be a factor limiting dry matter intake of periparturient dairy cows. Factors such as nutrient demand and hormonal status associated with pregnancy and lactation are as important as or more important than ruminal capacity in causing postpartum changes in dry matter intake in beef cows (Stanley et al., 1993).

In early lactation, cows do not consume enough dietary energy to meet the energy requirements of lactation, and, as a result, body fat is utilized for energy. In some cows, excessive amounts of body fat are mobilized and only partially oxidized, resulting in the formation of ketone bodies. These ketoacids build up in the blood and reduce blood pH (Bigner et al., 1996). The depression in dry matter intake in the late dry period and early lactation has been well documented (Bertics et al., 1992; Grant and Albright, 1995; Grummer, 1995; Kertz et al., 1991). Feed intake postcalving doesn't peak until 9 to 13 weeks of lactation (Kertz et al., 1991). Dry matter intake in the first week postcalving is about 65% of maximum dry matter intake (NRC, 2001).

Subsequently, these changes in dry matter intake necessitate adjustments in ration nutrient content and nutrient density. Low dry matter intake in early lactation cows may limit the rate at which concentrate feeding can be increased postcalving. In early lactation, feed intake normally lags behind increased milk yield, resulting in a high-energy deficit or negative energy balance. With a high producing dairy cow, there are several consequences of a negative energy balance such as poor health and decreased fertility. Dairy cows calving in higher body condition have adequate fat reserves to support milk production but often have lower feed intake thus increasing negative energy balance (Pedron et al., 1993). Dietary energy requirement increases as the cow gets closer to calving and begins lactation. The close-up dry cow requires approximately 1.62 Mcal NE_L/kg on a 100% dry basis, in order to maintain body condition and support fetal growth and development (NRC, 2001).

Body condition scoring is an excellent tool for monitoring energy needs and estimating potential DMI (Sniffen et al., 1993). Severely over conditioned cattle may eat less after calving than thinner or correct conditioned cows (Holter et al., 1990; Pedron et al., 1993), but moderate overconditioning has been shown to be non detrimental (Fronk et al., 1980). Feeding practices today include high energy diets during lactation which often extends into the dry period. This action results in cows that are overconditioned at calving or what is known as fat cow syndrome. Fat cow syndrome is defined as cows that are obese and have one or more metabolic disorders at calving (Fronk et al., 1980). Cows with a greater BCS at calving have been associated with decreased DMI (Hayirli et al., 2002). There has been some recent work supporting that drying cows off at a BCS of approximately 3.0 rather than the

traditional scores of 3.5 to 4.0 will increase milk production during early lactation (Contreras et al., 2004).

Feeding Behavior

Dry matter intake of dairy cows is important for overall dairy management. Because of the complexity of factors controlling feed consumption, accurate prediction of daily DMI is difficult (Roseler et al., 1997). Dry matter intake aids in formulating rations that are nutritionally and economically accurate. Measurement of individual DMI is somewhat impossible in a large scale setting where cattle are housed in group pens or on a pasture based system. However, cows that are housed individually or when an individual feed intake monitoring system is used, data can be valuable in determining dry matter intake and feeding behavior. Feeding behavior of transition dairy cattle remains unidentified. Daily individual DMI evaluation requires a sacrifice of model accuracy, and during the time of transition (from late gestation to early lactation), DMI can hardly be evaluated (Roseler, 1997).

Meals are a biologically relevant unit of short term feeding behavior in dairy cattle (Tolkamp et al., 2000). Average daily intake as described by Tolkamp and associates (2000) is the result of the average number of feeding bouts per day and the average size of those bouts. Sniffen and Chase (1987) found that when cows were fed a ration ad libitum at 111% of their NE_L requirement, average meals per day was 12.4. Some further research has indicated that high producing cows consumed 9 to 14 meals per day (Vasilatos and Wanagsness, 1980), and low producing cows consumed 7 to 9 meals per day (Heinrichs and Conrad, 1987). Hunger and appetite are terms that are used to describe an animal's urge to eat. Hunger tends to denote a short term effect, as

might occur between or before meals and the onset of eating, while appetite has implications concerning the amount eaten and the physiological factors contributing to a cessation of eating (Van Soest, 1982).

The satiety concept is defined as the probability of cows starting a meal will not be constant but will increase with time since the last meal. Also, the probability of cows ending a meal increases sharply with meal duration (Tolkamp et al., 2000). Satiety gradually increases during a meal, therefore making it more likely for the cow to stop eating. Satiety seems to be more affected by the amount of feed consumed than by time spent feeding (Van Soest, 1982). Satiety as defined by Van Soest (1982) is the theoretical level needed to balance energy losses and achieve optimal growth, produce milk, and perform work under conditions of a balanced diet. The probability of cows ending a visit to the feed bunk did not change with visit length in some recent work done on feeding behavior (Tolkamp et al., 2000). There are several factors that contribute to the cessation of eating. These include physiological effects such as appetite, the metabolic requirement of the animal, and the quality of feed (Van Soest, 1982).

Control of feed intake and meal patterns may differ by parity and should be considered when grouping cattle (Grant and Albright, 1995). Factors that influence feeding behavior of cattle include: grouping strategy, feeding system, social hierarchy, composition of feedstuffs, and competition for feed and water (Grant and Albright, 2000). Primiparous cows eat slower than multiparous cows (Beauchmemin and Rode, 1994). First lactation heifers fed in separate groups spent 10% -15% more time eating and consumed 0.5 - 2.0 more meals per day (Krohn and Konggaard, 1979). The

majority of feed consumed by a dairy cow is at feed delivery. Approximately 25% of total eating time occurs within the first hour after feeding (Vasilatos and Wangsness, 1980). Feeding behavior of cows at 17 d in milk is very similar to cows that are later in lactation (Dado and Allen, 1994). There is a positive correlation between DMI 1 wk prepartum and DMI 1 wk postpartum (French, 2002). Cow health and environmental temperature can also determine physiological needs and meal patterns (Mertens, 1985).

METABOLIC ADAPTATIONS

Plasma Metabolites

Parturition and transition from gestation to lactation are under homeorhetic control (Hayirli et al., 2002). The increase in plasma NEFA normally seen around parturition is due to a decrease in DMI before calving as well as an increase in lipolytic hormones at calving (Grummer, 1993). Energy balance may be estimated from plasma NEFA concentrations, which are closely related to energy balance in ruminants (Kunz, et al. 1985). Within the liver, NEFA have one of three fates; 1) NEFA can be completely oxidized to CO_2 to provide energy for the liver, 2) NEFA can be partially oxidized to produce ketone bodies that are released into the blood to serve as fuels for other tissues, or 3) NEFA can be reconverted back to triglycerides which are the form of fat storage in the cow (Young et al., 1990). Hepatic uptake of NEFA is positively correlated to plasma concentration (Bell, 1980). Increased NEFA concentrations before calving are associated with an increase in displaced abomasum, retained placenta, ketosis, and mastitis postpartum (Cameron et al., 1998). The greater the magnitude of negative energy balance, the larger the amount of NEFA that are

released to meet the requirements of the cow. Therefore, the concentration of NEFA in blood reflects the degree of adipose tissue mobilization (Pullen et al., 1989). NEFA are utilized to contribute up to 40% of the milk fat produced during the first days of lactation (Bell, 1995). Normal values of NEFA at parturition should be between 0.7 and 0.9 mEq/L (Kaneene et al., 1997).

Dairy cattle requirements for glucose and metabolizable energy increase two to three-fold from 21d before to 21d after parturition (Drackley et al., 2001). Metabolic patterns of well fed, late gestation ruminants are defined by an increase in hepatic gluconeogenesis, reduced glucose utilization in peripheral tissues, a moderate increase in mobilization of NEFA from adipose tissue, as well as increases in utilization of NEFA and 3-hydroxybutyrate (Bell, 1995). Recent studies in humans and dogs have indicated a role for the kidney in post absorptive glucose homeostasis. Renal release of glucose, like that of the liver, is regulated by insulin (Cersosimo et al., 1999, 1994), and counter regulatory hormones (Meyer et al., 1999). Renal uptake of glucose has been shown to increase during hyperglycemia as well (Cersosimo et al., 1997; Dzurik and Chorvathova, 1972). Uptake of glucose by liver, muscle, brain, and kidney could account for at least 90% of the disposal of an ingested glucose load in humans (Meyer et al., 2001). Most of the carbohydrate fraction of the diet is fermented in the rumen and very little glucose is actually absorbed directly from the digestive tract. Because of this, cows rely almost exclusively on gluconeogenesis from propionate, body fat and amino acids in the liver to meet their glucose requirements (Overton, 1998). Insulin can indirectly affect liver glucose production not only through an effect on fat but also through inhibition of glucagon secretion. Glucagon potently stimulates

glycogenolysis; therefore, an insulin-mediated reduction in plasma glucagon would provide an indirect means of inhibiting hepatic glucose production in dogs (Edgerton et al., 2001). Some work done in nonlactating nonpregnant Jersey cows (Bigner et al., 1996) concluded that plasma glucose concentrations were highest, and plasma insulin concentrations were lowest, during metabolic acidosis (ie. feeding anionic salts).

Blood calcium drops to subnormal levels immediately before and during parturition, and the decrease in available body calcium may eventually continue below the levels of normal, optimal function, resulting in pathologic milk fever or parturient paresis (Larsen et al., 2001). Peripartum plasma calcium levels in cows fed anionic salts from 21 d prepartum until calving are higher than in cows fed diets with a positive dietary cation-anion difference (Joyce et al., 1997; Melendez et al., 2002). Phosphorus and calcium levels are correlated to each other. Normal phosphorus levels should be between 4 and 8 mg/dl in adult animals (Goff, 1999b).

There is a negative association between blood calcium and glucose in parturient cows (Blum et al., 1972). The increase in blood glucose at parturition is a result of decreased insulin. Infusion of calcium in hypocalcemic cows has increased the plasma levels of insulin (Blum et al., 1973), which suggests that physiological concentrations of calcium are required for glucose stimulation of insulin secretion from β-cells in the pancreas (Capen and Rosol, 1989).

During times of stress the neuroendocrine system responds by secreting pituitary hormones such as cortisol in an attempt to restore homeostasis (Buckingham et al., 1997). Cortisol is an endogenous glucocorticoid that delivers its hormonal message to cells via cytoplasmic glucocorticoid receptors. Glucocorticoid receptor

expression is down regulated in periparturient dairy cows when there is also an elevated blood cortisol level as seen in times of stress or calving (Preisler et al., 2000). Any changes in the neuroendocrine system can have dramatic effects on metabolism, production, reproduction lactation and behavior. Hypocalcemia leads to an increase in the secretion of cortisol, which could be a factor in retained placenta (Goff, 1999a). Cortisol-activated glucocorticoid receptors modulate cellular responses to stress by translocating from the cytosol to the nucleus and enhancing or repressing the transcription of target genes (Preisler et al., 2000).

Liver Metabolism and Gluconeogenesis

Gluconeogenesis occurs primarily in the liver and is intrinsic to meeting the metabolic requirements of the periparturient cow. Energy requirements of the gravid uterus determine the response of the liver, rather than any metabolic adaptations preceding parturition and lactation (Freetley and Ferrell, 2000). The liver is responsible for approximately 85% of gluconeogenesis with the remaining 15% occurring in the kidneys (Katz and Bergman, 1969). Anything that compromises overall liver function and the ability of the liver of the transition cow to synthesize glucose will be detrimental to metabolic health and subsequent performance of the cow during early lactation (Overton, 1998). Approximately 46% of the maternal supply of glucose is taken up by the uterus during the dry period, while 2.7 times the amount of the glucose production required for the gravid uterus is associated with lactation in the postpartum cow (Bell, 1995). A decrease in glucose production as well as an increase in fatty acid mobilization can lead to severe metabolic disorders and a decrease in health and production of the transition dairy cow.

Reynolds and associates (2003), suggest that even in late gestation, diet intake is the primary determinant of splanchnic tissue metabolism. Liver size does not change during the transition period; however, oxygen uptake which is an indicator of metabolic activity doubles in the early postpartum cow when compared to the late dry period (Reynolds et al., 2000).

Maximal contributions of various glucogenic substrates to liver glucose release at 11d postcalving include lactate which accounts for 20.9% of glucose release (Reynolds et al., 2000), propionate contributes approximately 52.9% during the first three weeks postpartum (Lomax and Baird, 1983; Reynolds et al., 1988), glycerol supplies 9.6% at 11d postcalving (Pullen et al., 1989) and amino acids calculated by difference account for 16.5% of the glucose supply. Lactate utilization for gluconeogenesis primarily represents recycling of carbon because most circulating lactate is formed either during catabolism of glucose by peripheral tissues or by partial catabolism of propionate by the ruminal epithelium (Overton, 1998). Propionate is the primary foundation for which hepatic gluconeogenesis occurs and is produced during ruminal and hindgut fermentation.

Ammonia is produced in two different pathways in ruminants during the degradation of protein in the rumen and in the catabolism of amino acids in the tissues (Zhu et al., 2000). Large excesses of ammonia from excess dietary nitrogen intake, imbalances in RDP and RUP, or imbalances in amino acids, along with metabolic situations (e.g., fatty liver) that may compromise the ability of the liver to synthesize urea, may cause a decrease in the ability of the liver to synthesize glucose from propionate (Overton et al., 1999). Fat infiltration during early lactation impairs the

ability of the liver to detoxify ammonia to urea (Strang et al., 1998). There is a positive correlation between liver triglyceride, plasma ammonia, and glutamine percent in dairy cows. This correlation suggests that hepatic triglyceride accumulation as often seen in periparturient cows might inhibit ureagenesis, thereby increasing ammonia concentration at the perivenous hepatocytes where glutamine synthesis occurs and increasing ammonia concentration in blood leaving the liver (Zhu et al., 2000).

Immune Function

Stress as defined by Moberg (1985), is the impacts of external stimuli (physiological, environmental, psychological) that challenge homeostasis. The central nervous system and the neuroendocrine system are directly related to and have the capability to directly affect the immune system of animals (Neveu, 1997). Impaired immune function during the periparturient period contributes to the increased susceptibility of the cow to infectious disease around the time of calving (Kimura et al., 1999). Work done by Kimura and associates (1999) found that T-cell populations reached nadir levels at calving and did not return to precalving levels until 2 weeks after calving. They suggest that T-cell populations may contribute to the immunosuppression seen in dairy cows around calving. Function of the immune system is decreased or depressed during the transition period and normally begins approximately three weeks before calving, is lowest at parturition, and continues until three weeks after calving (Mallard et. al, 1998). Negative energy balance may be a contributing factor to the depression in immune function that is seen (Morrow, 1976).

Trace minerals such as selenium, copper and zinc as well as vitamins A and E can enhance immune function.

MILK FEVER

At or near calving, most cows experience some degree of hypocalcemia or milk fever (Goff et al., 1987; Horst et al., 1997). Clinical signs of milk fever are not often seen until calcium is approximately 4 mg/100 ml (Goff and Horst, 1997). In a recent study of plasma calcium, 10 to 50 % of periparturient Holsteins remained subclinically hypocalcemic (plasma calcium < 7.5 mg/100 ml) for up to 10 d after calving (Goff et al., 1996). Clinical hypocalcemia increases in likelihood with increasing age of the cow. Clinical hypocalcemia or milk fever affects up to 9% of dairy cows (Goff et al., 1987; Joyce et al., 1997). Guard (1996) estimated the average cost per milk fever case to be $334. In addition, cows with milk fever are also susceptible to secondary disorders, such as ketosis, mastitis, retained placenta, and displaced abomasums (Curtis et al., 1983). Cows with subclinical hypocalcemia were 4.8 times more likely to have left abomasal displacement mainly because the cows go off feed, regardless of whether they developed clinical signs of milk fever (Jordan and Fourdraine, 1993).

CALCIUM HOMEOSTASIS

The onset of lactation places a sudden demand on the Ca homeostatic mechanisms of the dairy cow. A cow producing just 9.98 kg of colostrum (2.3 g of Ca/kg) will lose 23g of Ca in a single milking (Bertics et al., 1992). This is about nine times as much Ca as is present in the entire plasma Ca pool of the cow. Calcium lost

from the plasma pool must be replaced by increasing intestinal Ca absorption and bone Ca resorption. Intestinal Ca absorption efficiency decreases with age in cows. Acidic diets increase the proportion of dietary Ca absorbed from the intestines and increase the rate of mobilization of Ca from the bone. It appears that dietary acid-base effects are as important as dietary Ca in the pathogenesis of parturient paresis. Because Ca has a role in smooth muscle function, hypocalcemia at calving is a predisposing factor for dystocia, prolapsed uterus, retained placenta, and early metritis.

The primary sources of Ca in mammals are diet and bone (DeLuca, 1984). Calcium regulating hormones parathyroid hormone and 1,25-dihydroxyvitamin D control and bone resorption of Ca. However, absorption of intestinal Ca is controlled by 1,25-dihydroxyvitamin D alone. Parathyroid hormone is secreted by the parathyroid gland and 1,25-dihydroxyvitamin D is secreted by the kidney (Horst et al., 1994). Parathyroid hormone and 1,25-dihydroxyvitamin D concentrations were higher in cows that were diagnosed with milk fever (Mayer et al., 1969). Metabolic alkalosis has been shown to disrupt the receptors of parathyroid hormone on target tissues. Diets high in cations, especially Na and K cause blood pH to increase, resulting in a state of mild metabolic alkalosis (Goff et al., 2004). This in turn reduces the ability of the periparturient cow to maintain Ca homeostasis at or near calving by reducing tissue responsiveness to parathyroid hormone (Goff and Horst, 1997; Phillippo et al., 1994). Which in turn decreases the concentration of 1,25-dihydroxyvitamin D. Low DCAD diets ($\leq$ -5 meq/100 g diet DM) through addition of anions, increases target tissue responsiveness to parathyroid hormone by preventing mild metabolic alkalosis (Horst et al., 1997).

ACID-BASE HOMEOSTASIS

Homeostasis is defined as the condition of relative uniformity, which results from the adjustments of living things to changes in their environment (Hale and Meinhardt, 1979). Acid-base homeostasis is a very critical part of dairy cattle nutrition. Fixed ions, those that are neither produced nor destroyed by metabolism, are a major determinant of metabolic acid-base status. The normal acid-base status of a healthy cow is a mild state of metabolic alkalosis (Bigner et al., 1996). Several mineral elements, Na, K, P, Ca, Cl, Mg, and S, are involved in the process of acid-base homeostasis.

The acidity of a solution is determined by its concentration of hydrogen ions, and when the concentration is expressed in moles per liter the acidity is written [H+]. The concentration of hydrogen ions in pure water is about 10^7 moles per liter. By convention, a solution having a concentration higher than 10^7 moles per liter is called an acid solution, and one having a lower concentration is called an alkaline solution. The pH of blood is maintained within very narrow limits (pH 7.31 to 7.53 in the cow) by the acid-base homeostatic mechanisms of the body. Blood pH values outside this range are generally incompatible with life. Highly acidic or basic conditions alter the conformation of cellular proteins, especially those on the surface of the cell. This compromises the cell membrane, allowing an influx of extracellular ions and fluids, swelling, and eventually killing the cell (Vagnoni and Oetzel, 1998). Less severe alterations in pH can affect cellular enzyme activity and the structure of hormone receptors, decreasing productivity of animals and/or their resistance to metabolic disease.

Acidified or alkaline diets are used to cause a change in the acid-base balance of the cow so that homeostatic mechanisms can buffer the blood and a normal blood pH is maintained (Hale and Meinhardt, 1979). Acids are buffered by carbonates (HCO_3), phosphates (PO_4), proteins, hemoglobin, and respired carbon dioxide (CO_2) or excreted as titratable acid. Bases are utilized in the synthesis of urea, excreted as HCO_3, titrated in blood or respired as CO_2 (Atkinson and Camien, 1982). Bone is a very critical part of acid-base homeostasis. Bone contains a large reserve of base (carbonates), which is exchanged for phosphates during acidosis (Lemann and Lennon, 1972). Bone also participates directly in buffering acute and chronic acid or base loads by releasing carbonates and phosphates during acidosis and absorbing carbonates during alkalosis (Burnell, 1971).

Minerals Involved in Acid Base-Homeostasis

The four primary mineral elements considered in cation-anion balancing are sodium (Na^+), potassium (K^+), chlorine (Cl^-) and sulfur (S^{2-}). These four ions generally are thought to be the most important strong ions in determining the effects of diet on systemic acid-base balance.

Sodium, K, and Cl are closely related metabolically and they all serve a vital function in regulating and balancing physiological processes in the dairy cow. In ruminants, K and Na are absorbed primarily from the small intestine, but some absorption of K also takes place in the rumen within the epithelial cells. Chlorine is absorbed chiefly in the small intestine. The main functions of Na appear to be connected with the regulation of osmotic pressure, maintenance of acid-base balance, and together with K and Cl, it plays an important role in water metabolism as well.

Sodium and Cl are elements provided by salt, but they are also found to some extent in most feeds. Low salt intake is one of the most common problems in the diet of dairy cows. Lack of salt impairs acid-base balance.

Sulfur is necessary for the synthesis of essential amino acids by rumen microbes. The most critical S requirement in dairy cattle is for optimal rumen microbial growth. Sulfur supplementation is important in rations containing high levels of nonprotein nitrogen because several sulfur-containing amino acids must be made by rumen microbes, notably, cysteine, cystine, and methionine. Oxidation of methionine and cysteine causes sulfur to also exist in tissues as the sulfate anion, which influences the acid-base balance status of the cow (NRC, 2001). Low S intake results in an induced protein deficiency, and excessive intake damages liver tissue and function.

Other elements that are important in the acid-base status of the cow include Ca, Mg, and P. Calcium and P are the chief elements of the skeleton; 99% of the Ca and about 80% of the P found in the body are located in the bones and teeth. Calcium ions are principally absorbed in the proximal (upper and middle) part of the small intestine, and their absorption can be enhanced by ensuring an adequate supply of vitamin D in the diet at the same time. The excretion of Ca takes place via the large intestine and the kidneys, and the amount excreted fluctuates strongly. Calcium can have a large effect on rumen metabolism, production, skeletal growth, and reproduction. Calcium metabolism is affected by changes in acid-base balance (Barzel, 1981). An animal may draw upon its bones for limited amounts of Ca and P. Daily body turnover of calcium changes from approximately 10 g in nonlactating cows to greater than 30 g in

lactating cows (Horst et al., 1997). Calcium plays a role in smooth muscle function and hypocalcemia around the time of calving can cause an increase in prolapsed uterus, metritis, retained placenta, and dystocia (Grohn et al., 1989). Phosphorus is absorbed mainly in the lower part of the small intestine. As in the case of Ca, it is difficult to assess the actual amount of phosphorus absorbed because it can be affected by a number of factors. It has been proven, however, that the intake of vitamin D and the correct ratio of Ca to P both improve Ca absorption (Barzel, 1981). Phosphorus is very important for normal rumen metabolism, reproduction, skeletal growth, and production. Prolonged consumption of high P diets may cause metabolic problems due to disorders associated with Ca absorption and metabolism such as hypocalcemia.

About 60% of the body's Mg is found in the skeleton. The remaining 40% is scattered throughout the body fluids (Miller, 1979). Magnesium activates many enzyme systems, particularly those concerned with the carbohydrate metabolism. It is essential in maintaining normal rumen fermentation, skeletal growth, production, reproduction, and health. Depressed fiber digestibility and impaired reproduction usually occur when rations are not balanced for magnesium.

DIETARY STRATEGIES TO PREVENT MILK FEVER

Dietary Calcium

Calcium restriction during the prepartum period will significantly reduce the incidence of parturient paresis because of its increase in net bone resorption as well as the increases in efficiency of bone resorption (Vagg and Payne, 1970). Ca restriction during the prepartum period has been used in the prevention of hypocalcemia (Goings et al., 1974) Metabolic acidosis during the close up period causes an increase in

mobilization of calcium from the bone; in contrast high dietary potassium concentrations and a positive DCAD abolish this process (Horst et al., 1997). Calcium restriction has numerous disadvantages also, particularly in that it requires restricted legume forage utilization in favor of utilizing corn silage, corn or other cereal grains. This may result in excessive fattening during the prepartum period, sudden changes in forage feeding after freshening, and increased incidence of abomasal displacements (Oetzel et al., 1991).

Removal of Cations

Although decreasing DCAD through removal of cations is effective in preventing hypocalcemia (Goff and Horst, 1997), this generally precludes the use of farm-grown forages high in K. Diets that are cationic induce a state of metabolic alkalosis which can decrease absorption of Ca from the gut and resorption of Ca from the bone. Metabolic alkalosis in periparturient dairy cattle can have an effect on liver metabolism also. Triglyceride accumulation in the liver has been shown to decrease the capacity of the liver to detoxify ammonia to urea (Strang et al., 1998; Zhu et al., 1997). This could also affect the gluconeogenic capacity of the liver from propionate and other substrates (Overton et al., 1999).Ureagenesis is used to remove bicarbonate from the blood and in turn reducing blood pH (Bean and Atkinson, 1984). Inhibition of urea synthesis by fatty liver might pose a threat of alkalosis to periparturient dairy cattle even in the absence of direct ammonia toxicity (Zhu et al. 2000). High blood pH reduces calcium mobilization from bone and reduces blood calcium levels (Barzel and Jowsey, 1969; Phillipo et al., 1994). Because of this when there is decreased urea synthesis there might also be alkalosis and reduced blood calcium.

DCAD

Due to difficulty in formulating very low Ca diets, recent interest has been focused on decreasing the dietary cation-anion difference (DCAD; milliequivalents [(Na + K) – (Cl + S)]/100 g DM) during the last 3 to 4 wk of gestation (Block, 1984; Goff and Horst, 1997; Horst et al., 1997). The difference between the amounts of absorbable anions and cations in a diet determines the acid-base status of the cow as well as the pH of blood (Stewart, 1983; Tucker et al., 1988). This difference is referred to as the DCAD of a diet. Terms used to describe variations in these expressions have included anion-cation balance, fixed cation-anion balance, dietary fixed ion balance, dietary cation-anion balance, dietary electrolyte balance, dietary cation-anion difference, and strong ion difference (Oetzel et al., 1991). Urine pH is used as an index of body acid-base status and is a valuable tool when monitoring the effects of DCAD diets in the prepartum close up period (Jardon, 1995).

Various authors have used different expressions and terminology in describing the potential of a diet to affect systemic acid-base balance, but the formula (Na + K) – (Cl + S), expressed as either milliequivalent per 100 grams of feed on a dry matter basis, or as milliequivalent consumed daily is the most commonly used equation (Oetzel et al., 1991). The equivalent weight, which is molecular weight divided by the valence, of the minerals is used to calculate the DCAD of the diet. An example of a diet that contains 0.16% Na, 1.22% K, 0.98% Cl and 0.37% S is calculated as follows:

General Equation:

DCAD (meq/100 g DM) =

[(% Na in DM/. 023) + (% K in DM/.039)]- [(% Cl in DM/.035) + (% S in DM/.016)]

Example:

DCAD (meq/100 g DM) =

[(0.16% Na/0.023) + (1.22% K/0.039)]-[(0.98% Cl/0.035) + (0.37% S/0.016)]

= (6.95 Na + 31.28 K) – (28.00 Cl + 14.38 S)

= (38.23) – (51.12) = -12.89

= **- 12.89 meq/100g diet DM**

This is a typical DCAD for a close-up prepartum diet. A typical prepartum diet would have more negatively charged anions when compared to positively charged cations and therefore a negative DCAD would result.

Sodium and K are often absorbed from the gastrointestinal tract in exchange for the secretion of a proton and Cl is often absorbed in exchange for the secretion of a bicarbonate ion to maintain a normal blood pH. Any alteration in the relative amounts of Na, K, and Cl absorbed from the gastrointestinal tract could affect the acid-base status of the animal by making the blood too acidic or basic (Miller, 1979). Sulfur is also used in this equation, but is more complex due to the effects that protein metabolism may have on S-related systemic acid generation.

A negatively balanced DCAD ration is used in prepartum dry cows to reduce the incidence of milk fever, whereas a positively balanced ration is utilized by lactating cows for increased levels of milk production. Acid-base imbalance causes disorders in Ca metabolism also, and may relate to the etiology of hypocalcemia in dairy cattle. Whereas alkalosis causes Ca accretion into the bone, acidosis causes Ca

mobilization from the bone (Barzel and Jowsey, 1969). In ruminants, acid-base imbalance alters Ca absorption from the gastrointestinal tract as well as from bone and thus influences the amount of Ca in the exchangeable Ca pool. The onset of lactation places a sudden demand on the Ca homeostatic mechanisms of the dairy cow. Acidic diets increase the proportion of dietary Ca absorbed from the intestines and increase the rate of mobilization of Ca from the bone. It appears that dietary acid-base effects are as important as dietary Ca in the pathogenesis of parturient paresis. Therefore, the role of acid-base balance and DCAD are crucial for milk production, calcium availability and homeostasis in the periparturient animal.

The other alternative to lower the DCAD of prepartum diets is to feed anionic salts. Anionic salts are defined as salts that are higher in the negatively charged fixed anions, Cl and S, relative to the positively charged cations, Na and K (Gant et al., 1998). Some common anionic salts used include $CaSO_4$, NH_4Cl, $MgSO_4$, and CaCl (Joyce et al., 1997). Anionic salts can be very unpalatable to the cow and therefore could cause a decrease in dry matter intake as parturition approaches (Goff and Horst, 1998); however, cows fed an anionic salt diet versus a non anionic salt diet consumed more dry matter postpartum (Joyce et el., 1997). Feeding a negative DCAD diet during the close up stage to primiparous cows has been shown to have detrimental effects on dry matter intake and an increase in liver triglycerides (Moore et al., 2000).

Anionic salts increase absorption of Ca through the gastrointestinal tract and increase bone mobilization of Ca because of their acidifying properties (Vagg and Payne, 1970). Improvements in Ca homeostasis from dietary anionic salts are thought to be mediated by the onset of acidosis. Metabolic acidosis during the close up period

causes an increase in mobilization of calcium from the bone; in contrast high dietary potassium concentrations and a positive DCAD abolish this process (Horst et al., 1997).

Feeding increasing amounts of anionic salts during the prepartum period will decrease the blood and urine pH of the cow. The lower pH levels associated with feeding anionic diets my cause impaired energy metabolism (Burhans and Bell, 1998). If pH levels fall too low there could be a decrease in gluconeogenesis due to metabolic acidosis (Kashiwagura et al., 1984), and or impaired uptake of glucogenic substrates (Boon et al., 1996).

Several studies have shown improved Ca metabolism by decreasing DCAD through feeding anionic salts (Joyce et al., 1997; Moore et al., 2000). However, only one study (Block, 1984) has shown a positive milk yield response (7%) for cows fed anionic salts prepartum. In addition, anionic salts can have a negative effect on prepartum DMI (Joyce et al., 1997; Moore et al., 2000). Reduction in prepartum DMI due to the addition of anions is often attributed to decreased palatability, but may represent a response to metabolic acidosis induced by anionic salts (Vagnoni and Oetzel, 1998). Regardless of the exact mechanism whereby anionic diets elicit their negative effect on prepartum DMI, decreasing DMI may be counterproductive.

THE EFFECT OF ANIONIC SUPPLEMENT ON INTAKE, PRODUCTION AND BLOOD METABOLITES

INTRODUCTION

The transition period, as defined by Grummer (1995), is the three weeks before and after parturition. The transition period is considered the most traumatic time of the annual cycle of the dairy cow (Keady et al., 2001); determining the cows health, production and reproduction in the subsequent lactation. At or near calving, most cows experience some degree of hypocalcemia (Horst et al., 1997). Clinical hypocalcemia or milk fever affects up to 9% of dairy cows (Goff et al., 1987). Guard (1996) estimated the average cost per milk fever case to be $334. In addition, cows with milk fever are also susceptible to secondary disorders, such as ketosis, mastitis, retained placenta, and displaced abomasums (Curtis et al., 1983).

Several nutritional strategies have been used in the prevention of hypocalcemia, including Ca restriction during the prepartum period (Goings et al., 1974) and decreasing the dietary cation-anion difference (DCAD; milliequivalents [(Na + K) – (Cl + S)]/100 g DM) during the last 3 to 4 wk of gestation (Block, 1984; Goff and Horst, 1997b). Due to difficulty in formulating very low Ca diets, recent interest has focused on DCAD (Horst et al., 1997). Although decreasing DCAD through removal of cations is effective in preventing hypocalcemia (Goff and Horst, 1997a), this generally precludes the use of farm-grown forages high in K. The other alternative to lower the DCAD of prepartum diets is to feed anionic salts ($MgSO_4$, $MgCl_2$, NH_4Cl, $(NH_4)_2SO_4$, $CaCl_2$, and $CaSO_4$).

Diets high in cations, especially Na and K cause blood pH to increase, resulting in a state of milk metabolic acidosis (Goff et al., 2004). This in turn reduces

the ability of the periparturient cow to maintain Ca homeostasis at or near calving by reducing tissue responsiveness to parathyroid hormone (Goff and Horst, 1997b; Phillippo et al., 1994). Low DCAD diets (≤ -5 meq/100 g diet DM) through addition of anions, increases target tissue responsivness to parathyroid hormone by preventing mild metabolic alkalosis (Horst et al., 1997).

Several studies have shown improved Ca metabolism by decreasing DCAD through feeding anionic salts (Joyce et al., 1997; Moore et al., 2000). However, only one study (Block, 1984) has shown a positive milk yield response (7%) for cows fed anionic salts prepartum. In addition, anionic salts can have a negative effect on prepartum DMI (Joyce et al., 1997; Moore et al., 2000). Reduction in prepartum DMI due to the addition of anions is often attributed to decreased palatability, but may represent a response to metabolic acidosis induced by anionic salts (Vagnoni and Oetzel, 1998). Regardless of the exact mechanism whereby anionic diets elicit their negative effect on prepartum DMI, decreasing DMI may be counterproductive.

The present study was conducted to determine if prepartum DCAD (+20 or -10 meq/100 g DM) and source of anions (feed grade anionic salts or commercial acidified by-products) affect peripartum DMI, Ca homeostasis, and milk production in the subsequent lactation.

MATERIALS AND METHODS

Animals and Diets

The Oregon State University Institutional Animal Care and Use Committee approved all procedures involving animals. Thirty-five multiparous and 19 primiparous Holstein cows were selected from the Oregon State University Dairy Center, blocked by expected calving date and assigned at random to one of four prepartum dietary treatments beginning four weeks prior to expected calving date. The experimental design was a randomized incomplete block with factorial arrangement of treatment. Main effects were parity and prepartum diet. Data was collected beginning 21 d prepartum and ended 21 d postpartum. Cows were group housed in a freestall barn and fed individually using Calan® gates (American Calan, Northwood, NH).

Prepartum diets differed in DCAD (cationic or anionic) and anionic supplement (BioChlor® (Church & Dwight Co. Inc., Princeton, NJ), Fermenten® (Church & Dwight Co. Inc., Princeton, NJ), or fertilizer grade anionic salts), and were Control (DCAD +20 meq/100 g DM; n= 9 cows and n= 4 heifers), BioChlor® (DCAD -10 meq/100 g DM; n= 9 cows and n= 5 heifers), Fermenten® (DCAD -10 meq/100 g DM; n= 8 cows and n= 5 heifers), and Salts (DCAD -10 meq/100 g DM; n= 9 cows and n= 5 heifers. Dietary cation anion difference was calculated using the following equation: [(% Na in DM/. 023) + (% K in DM/.039)]- [(% Cl in DM/.035) + (% S in DM/.016)]. Due to variability of ingredient mineral composition, average DCAD was +22, -12, -11, and -10 meq/100 g DM for Control, BioChlor®, Fermenten®, and Salts, respectively.

Average number of lactations for multiparous cows was 2.78, 2.89, 3.00, and 3.11 for control, BioChlor®, Fermenten®, and anionic salts diets respectively. Average number of days cows were on prepartum diet were 29, 31, 29, and 30 for all cows on control, BioChlor®, Fermenten®, and anionic salts diets respectively. There were 7 cows that did not finish the trial: 3 on BioChlor® diet (displaced abomasum, stillborn twins, and intestinal blockage); 2 on control diet (displaced abomasum and 18 d overdue); and 2 on Fermenten® diet (under conditioned and lameness). These cows were removed from the trial at or soon after calving. Data from these 7 cows were not included in analysis and animals were replaced with other cows. Cows not on treatment for at least 14 d before parturition were also excluded from the data set and replaced as soon as possible. Four cows had twins (two on control, one on Fermenten®, and one cow on anionic salts), and were included in the data set because these cows responded similarly to the treatments when compared to cows that had a single birth.

Ingredients were sampled weekly, dried to static weight at 55°C in a forced air oven, and ground through a 1-mm screen in a Thomas Wiley Mill (Thomas Scientific, USA). Weekly ingredient samples were composited monthly and analyzed by Cumberland Valley Analytical Services Inc (Maugansville, MD). Nutrient composition of forages, concentrates, and mineral/vitamin premixes are shown in Tables 1, 2 and 3, respectively. Prepartum and postpartum diets were formulated using the CPM Dairy (version 2.0) ration evaluator. Ingredient and nutrient composition of diets is shown in Tables 4 and 5, respectively. Prepartum diets were formulated to be isonitrogenous and contained approximately 1.60 Mcal NE_L/kg DM. For prepartum

diets, forages and concentrates were weighed and blended in a Uebler Mixing Cart (Uebler Manufacturing, Vernon, NY). Anionic supplementation was discontinued at calving. All cows received a common TMR postpartum that was mixed and delivered by the Oregon State University Dairy staff. Postpartum diet was formulated for approximately 17% crude protein and 1.79 Mcal NE_L/kg DM. Cows were fed twice daily, with approximately 67 and 33 % of daily feed allowance offered at 0700 and 1300 h, respectively. Feed offered and refused was recorded daily at the morning feeding.

Table 1. Chemical composition of forages (DM basis).

Item	Corn Silage	Alfalfa Hay	Oat Hay	Grass Silage
CP, %	8.54	21.5	6.79	9.76
ADICP[1], %	0.96	1.20	0.93	1.02
NDICP[2], %	1.52	2.12	1.61	1.70
Soluble Protein, %	4.35	8.72	1.95	5.70
NE_L, Mcal/kg[3]	1.58	1.33	1.30	1.36
NDF, %	43.6	34.2	57.7	54.7
ADF, %	27.2	27.8	37.5	35.9
NFC, %	39.6	30.2	25.5	23.9
Crude Fat, %	3.28	2.22	2.20	3.13
Lignin,	3.13	5.8	4.44	3.94
Ca, %	0.23	1.43	0.28	0.37
P, %	0.20	0.29	0.19	0.29
Mg, %	0.19	0.38	0.12	0.17
K, %	1.06	3.23	1.86	2.43
Na, %	0.02	0.20	0.11	0.08
S, %	0.13	0.32	0.13	0.18
Cl, %	0.31	0.64	0.50	0.59
Fe, ppm	321	626	143	825
Zn, ppm	36.5	18.4	25.7	37.9
Cu, ppm	6.27	9.08	4.27	9.67
Mn, ppm	49.8	53.0	67.2	149
	11.2	53.4	30.2	37.8

[1]Acid detergent insoluble crude protein.
[2]Neutral detergent insoluble crude protein.
[3]Calculated using the equation of Weiss et al. (1992).
[4]DCAD = (Na + K) – (Cl +S).

Table 2. Chemical composition of concentrates (DM basis).

Item	Corn/Barley[1]	SBM/DDG[1]	DDG[2]	WCS[3]	BioChlor	Fermenten	Protein Mix
CP, %	10.3	41.2	30.1	24.6	49.1	52.5	48.8
ADICP[4], %	1.06	4.29	4.65	1.75	0.63	0.57	1.81
NDICP[5], %	1.60	5.80	8.10	2.25	2.48	2.43	3.78
Soluble Protein, %	1.47	6.63	4.74	5.73	38.3	39.9	33.1
NE_L, Mcal/kg[6]	2.07	1.91	2.00	2.09	1.70	1.84	1.85
NDF, %	15.6	25.5	42.8	47.1	22.6	19.1	30.8
ADF, %	6.71	14.5	19.9	36.7	7.88	6.4	11.9
NFC, %	69.8	25.0	13.8	4.61	19.6	22.6	14.0
Crude Fat, %	3.60	7.46	13.9	21.1	2.77	2.97	5.73
Lignin, %	1.36	3.54	4.74	11.5	2.33	1.78	3.29
Ca, %	0.04	0.32	0.57	0.16	0.17	0.13	0.18
P, %	0.30	0.80	0.86	0.76	0.73	0.70	0.74
Mg, %	0.12	0.37	0.41	0.43	0.30	0.28	0.34
K, %	0.43	1.75	1.10	1.23	1.11	1.04	1.01
Na, %	0.02	0.52	0.61	0.05	1.15	0.30	0.07
S, %	0.14	0.16	0.73	0.28	2.49	6.97	0.32
Cl, %	0.12	0.19	0.58	0.10	8.57	0.53	0.22
Fe, ppm	49.8	155	132	95.5	101	95.1	106
Zn, ppm	28.3	70.0	241	45.8	62.6	54.7	84.3
Cu, ppm	3.91	12.8	25.4	10.6	6.58	6.42	10.7
Mn, ppm	12.2	41.3	73.9	20.1	79.1	96.2	74.5
DCAD[7], meq/100 g	-0.24	52.1	-7.21	13.4	-319	-410	2.73

[1]Rolled corn/barley and soybean meal/dried distillers grain, 1:1 ratio on an as-fed basis.
[2]Dried distillers grain.
[3]Whole cotton seed.
[4]Acid detergent insoluble crude protein.
[5]Neutral detergent insoluble crude protein.
[6]Calculated using the equation of Weiss et al. (1992).
[7]DCAD = (Na + K) – (Cl +S).

Table 3. Chemical composition of vitamin and mineral mixes (DM basis).

	Prepartum				
Item	Control	BioChlor	Fermenten	Salts	Postpartum
Ca, %	19.8	19.8	20.0	18.3	9.93
P, %	4.00	2.75	4.00	3.61	1.99
Mg, %	0.49	0.16	0.50	0.45	1.99
K, %	1.75	0.23	1.60	1.56	1.54
S, %	0.24	0.23	0.34	5.90	0.99
Na, %	3.75	0.02	2.75	3.50	9.12
Cl, %	---	---	---	19.3	0
Co, ppm	1.65	3.30	1.65	1.65	3.97
Cu, ppm	393	720	730	645	397
Fe, ppm	3044	2625	3039	2800	0
Mn, ppm	180	300	180	201	1589
Zn, ppm	695	702	745	636	1589
Se, ppm	6.00	7.00	6.80	5.60	11.9
Vitamin A, KIU/kg	185	185	185	170	127
Vitamin D, KIU/kg	55.1	55.0	55.1	50.0	39.4
Vitamin E, IU/kg	2475	2479	2480	2255	876
DCAD[1], meq/100 g	193	-7.59	139	-720	374

[1]DCAD = (Na + K) – (Cl +S).

Table 4. Ingredient composition of diets (DM basis).

	Prepartum				
Ingredient	Control	BioChlor	Fermenten	Salts	Postpartum
Corn Silage, %	33.8	34.1	33.8	33.5	17.7
Grass Silage, %	---	---	---	---	17.0
Alfalfa Hay, %	14.3	14.4	14.3	14.2	18.5
Oat Hay, %	14.7	14.8	14.7	14.6	---
Rolled Corn/Barley[1], %	22.8	23.1	22.9	22.6	27.4
SBM/DDG[1], %	2.0	1.6	2.0	2.3	7.7
Dried Distillers Grain, %	0.6	---	0.6	0.8	---
Whole Cottonseed, %	---	---	---	---	9.2
BioChlor, %	---	8.7	---	---	---
Fermenten, %	---	---	7.5	---	---
Protein Mix[2], %	8.6	---	1.0	8.5	---
BioChlor Min/Vit, %	---	3.3	---	---	---
Control Min/Vit, %	3.2	---	---	---	---
Fermenten Min/Vit, %	---	---	3.2	---	---
Salts Min/Vit, %	---	---	---	3.5	---
Lactating Min/Vit, %	---	---	---	---	2.5

[1]Rolled corn/barley and soybean meal/dried distillers grain, 1:1 ratio on an as-fed basis.
[2]Contains 9.3% ground corn, 54.7% wheat middlings, 21.5% dried distillers grain, 4.8% SBM, and 9.7% urea on a DM basis.

Table 5. Chemical composition of diets (DM basis).

	Prepartum				
Item	Control	BioChlor	Fermenten	Salts	Postpartum
CP %	14.7	14.7	14.9	14.7	15.5
Soluble Protein, %	43.3	46.5	46.0	43.1	31.0
NE_L, Mcal/kg[1]	1.61	1.59	1.59	1.59	1.59
NDF, %	35.7	35.0	34.6	35.6	34.0
NFC, %	39.7	40.3	39.8	39.5	38.3
Crude Fat, %	3.45	3.12	3.18	3.49	5.10
Ca, %	0.99	1.00	1.00	1.00	0.66
P, %	0.42	0.37	0.42	0.42	0.40
Mg, %	0.22	0.20	0.21	0.22	0.28
K, %	1.38	1.34	1.37	1.37	1.60
Na, %	0.19	0.16	0.18	0.19	0.30
S, %	0.20	0.38	0.71	0.40	0.25
Cl, %	0.32	1.05	0.35	1.00	0.33
Fe, ppm	341	329	341	341	347
Zn, ppm	57.8	54.9	57.0	58.1	73.4
Cu, ppm	19.0	29.3	29.5	29.1	17.4
Mn, ppm	50.5	54.7	52.2	51.7	92.1
DCAD[2], meq/100 g	22.1	-12.1	-11.3	-9.82	29.1

[1]Calculated using the equation of Weiss et al. (1992).
[2]DCAD = (Na + K) – (Cl +S).

Plasma Sampling and Analysis

Plasma samples were collected by venipuncture on -21, -14, -11, -9, -7, -5, -3, -2, -1, 0, 1, 7, 14, and 21 d relative to parturition. Samples taken on 0 d were within 2 h of parturition and 1 d samples were taken 24 h after parturition. Blood was collected in tubes (Becton Dickson, Franklin Lanes, NJ) containing K EDTA, Na heparin, or Na heparin plus NaFl and put on ice immediately after collection. Plasma was separated after centrifugation at 1600 x *g* for 15 min at 5°C, and frozen at -80°C until analysis. Sampling time (approximately 1300 h) corresponded to approximately 5 h after morning feeding.

A subsample was used for analysis which included -21, -14, -9, -7, -5, -3, -1, 0, 1, 7, 14, and 21 d relative to parturition for BHBA, NEFA, total calcium, glucose, and phosphorus. A subsample was used for analysis which included -21, -14, -7, -5, -3, -1, 0, 1, 7, 14, and 21 d relative to parturition for cortisol. Plasma collected from K EDTA additive tubes was analyzed for β-hydroxybutyrate (Procedure 2440, Stanbio Laboratory, Boerne, TX) and nonesterified fatty acids (NEFA-C, WAKO Pure Chemical Industries, Richmond, VA). Plasma from Na heparin plus NaFl tubes was analyzed for glucose (Procedure No. 1070, Stanbio Laboratory, Boerne, TX). Plasma from Na heparin tubes was analyzed for total calcium (Procedure No. 0150, Stanbio Laboratory, Boerne, TX), phosphorus (Procedure No. 0830; Stanbio Laboratory, Boerne, TX), and cortisol (DSL-10-2000; Diagnostic Systems Laboratories, Oxon, UK). All spectrophotometric measurements were conducted using a BIO-TEK (Winooski, VT) EL-309 microplate autoreader.

Liver samples were obtained by percutaneous trochar biopsy (Veenhuizen et al., 1991) from each cow on -21 d, within 2 d postpartum, and 21 d relative to parturition, immediately frozen, and stored at -80°C until analysis. Liver biopsies were performed at approximately 1330 h. Liver sample size was approximately 3 grams. Based on observations, liver biopsy did not result in decreased milk production or feed intake. Liver triglyceride content was determined using the procedure described by Piepenbrink et al. (2004) and a commercial kit (Procedure No. 2200; Stanbio Laboratory, Boerne, TX).

Body weight and body condition score were measured weekly. Body condition score was assigned using a 5-point scale (1 = thin, 5 = fat; Wildman et al., 1982) by two individuals. Midstream urine samples were obtained at the time of blood sampling by manual stimulation of the vulva and analyzed for pH immediately after collection with a pH meter (Corning model 20 pH meter; Corning Life Sciences, Acton, MA). Energy balance was calculated for all cows using BW and NRC (2001) equations for NE_L requirement. Cows were milked twice daily and milk production was recorded daily. Milk was analyzed for fat, protein and SCC on two consecutive milkings each week by Willamette Valley DHIA (Salem, OR).

Statistical Analysis

Data were analyzed as repeated measures using the Proc Mixed procedure in SAS (SAS User's Guide, 2001). Cow within block by parity by treatment was defined as the subject. For equally spaced repeated measures, AR(1) covariance structure was used. Akaike's information criteria was used to select the best covariance structure from one of three spatial structures [SP (POW) (spatial power law), SP (GAU)

(Gaussian), and SP (SPH) (spherical)] for unequally spaced repeated measures. Prepartum and postpartum data were analyzed separately. For all variables, cows and heifers were analyzed together to test parity and parity by diet interactions (Moore et al., 2000). Model used was $Y_{ijklm} = \mu + B_i + P_j + T_k + PT_{jk} + C_{(ijk)l} + D_m + DP_{jm} + e_{ijklm}$ where μ= overall mean, B_i = ith block (1,2,...9), P_j = jth parity (multiparous or primiparous), T_k = kth treatment (control, BioChlor®, Fermenten®, and salts), $C_{(ijk)l}$ = lth cow within the ith block, the jth parity, and the kth treatment, D_m = mth day or week (repeated measure), and e = residual error. Urine pH, prepartum and postpartum cortisol, and prepartum and postpartum calcium were significant for parity by prepartum diet interactions. All other data was then analyzed separately to view diet effects (Moore et al., 2000). All other results will be shown separately for cows and heifers. Results in tables are reported as least squares means. Preplanned contrast was control versus anionic supplements. Dry matter intake data by day were compared by orthogonal contrasts: linear, quadratic, and cubic. Significance was declared at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

RESLUTS AND DISCUSSION

Body Weight, Body Condition Score and Urine pH

Diet and parity means for body weight, BCS, and urine pH are shown in Table 6. Body weight was not different between prepartum diets ($P < 0.71$) during the prepartum period. As expected, prepartum and postpartum BW was greater for multiparous compared to primiparous cows. Body weight from wk 3 prior to parturition to wk 1 prior to parturition increased ($P < 0.08$) from 704 to 711 kg, respectively, for primiparous and multiparous combined. Body weight during the

postpartum period was similar ($P < 0.99$) between diets for all cows. Postpartum body weight decreased ($P < 0.01$) from 644 kg wk 1 to 606 kg wk 3 for all cows.

Prepartum BCS was similar for prepartum diets ($P < 0.62$) and was 3.56. Cows were in the suggested range of body condition score, which is 3.50. Body condition score during the postpartum period was similar between prepartum diets ($P < 0.68$) and parity ($P < 0.62$). Body condition score decreased ($P < 0.01$) from 3.44 wk 1 to 3.30 wk3 postpartum.

Parity by diet interaction was significant ($P < 0.01$) for urine pH. Heifers receiving Fermenten® had lower pH (6.24 vs. 6.80; $P < 0.01$) compared to cows fed Fermenten®. Likewise, heifers fed salts tended (6.55 vs. 6.77; $P < 0.08$) to have lower urine pH compared to cows receiving salts. Within either BioChlor® or control diets, parities responded similarly. Anionic diets were effective in reducing urine pH below the 6.5 threshold recommended for Holsteins (Moore et al., 2000). However, urine pH less than 6.0 would indicate excessive anion supplementation (Moore et al., 2000) as seen in the BioChlor® diet.

Dry Matter Intake, Milk Yield and Composition, and Energy Balance

Prepartum diet means for dry matter intake, milk production and composition, and energy balance are shown in Table 7. Prepartum diet did not affect prepartum DMI of cows or heifers. Horst et al. (1994) reported that addition of >300 meq of anions/kg diet may reduce intake. BioChlor®, Fermenten®, and salts diets were supplemented with 275, 312, and 257 meq anions/kg DM, respectively. Therefore, anionic supplementation in the current experiment was near or below the threshold

Table 6. Effect of prepartum diet and parity on body weight, body condition score and urine pH.

	Prepartum Diet						Parity Treatment			
Item	Control	BioChlor	Fermenten	Salts	SEM	$P <$	Multiparous	Primiparous	SEM	$P <$
Body weight prepartum, kg	727	714	690	695	25.8	0.71	793	620	18.8	0.01
Body weight postpartum, kg	625	629	622	622	23.2	0.99	697	551	16.6	0.01
BCS prepartum	3.59	3.64	3.52	3.51	0.08	0.62	3.59	3.54	0.06	0.52
BCS postpartum	3.34	3.43	3.37	3.35	0.07	0.68	3.35	3.39	0.05	0.62
Urine pH, prepartum	8.03	5.93	6.52	6.66	0.06	‡	6.89	6.68	0.04	‡

‡Parity by treatment interaction ($P < 0.01$)

where DMI would be negatively affected. Joyce et al. (1997) reported depressed DMI in multiparous cows supplemented 471 meq anions/kg DM, whereas Moore et al. (2000) showed no decline in DMI for multiparous cows supplemented 329 meq anions/kg DM. However, prepartum DMI was lower for heifers supplemented 329 meq anions/kg DM. Prepartum DMI differed by day ($P < 0.01$) for all cows, decreasing linearly and quadratically from 14.5 to 9.9 kg from -21 d to -1 d relative to parturition, respectively. Parities differed ($P < 0.01$) during the prepartum period with cows consuming 14.2 kg DM/d and heifers consuming 11.9 kg DM/d. Prepartum DMI of heifers is similar to a data set compiled by Hayirli et al. (2002); however cows in that experiment consumed 1.85 kg DM/d less on average than the cows in the current study. Parity by day or prepartum diet by day interactions were not significant for prepartum DMI.

Dry matter intake during the postpartum period was significantly different for multiparous cows. Multiparous cows fed an anionic prepartum diet had greater DMI postpartum compared to the control diet (19.5 vs. 17.4 kg DM/d; $P < 0.01$). Likewise, postpartum DMI was greater for primiparous cows fed an anionic prepartum diet compared to control (14.2 vs. 12.8 kg DM/d; $P < 0.04$). Feeding an anionic diet prepartum does not decrease postpartum DMI (Goff and Horst, 1998b; Gulay et al., 2004) or has shown to increase postpartum DMI (Joyce et al., 1997). Multiparous cows consumed more dry matter postpartum compared to primiparous cows (17.5 vs. 13.71 kg DM/d; $P < 0.01$). Dry matter intake increased (linear, quadratic, cubic; $P < 0.01$) for all cows from 9.7 kg DM/d on the day of calving to 38.9 kg DM/d. Parity by day or prepartum diet by day interactions were not significant for postpartum DMI.

Table 7. Effect of prepartum diet and parity on dry matter intake, milk yield and composition, and energy balance[1].

Item	Dietary Treatment				SEM	P[2]<
	Control	BioChlor	Fermenten	Salts		
Cows						
Prepartum DMI, kg/d	14.4	14.4	14.3	14.2	0.60	0.91
Postpartum DMI, kg/d	17.4	19.4	20.1	19.1	0.52	0.01
Milk, kg/d	36.6	44.0	43.5	42.0	2.11	0.01
Fat, %	4.74	4.58	4.58	4.59	0.23	0.58
Fat, kg/d	1.78	1.98	1.96	1.90	0.12	0.27
3.5% FCM[3], kg/d	45.6	51.1	50.4	49.1	2.60	0.15
Protein, %	3.67	3.38	3.58	3.69	0.16	0.54
Protein, kg/d	1.39	1.46	1.52	1.51	0.08	0.29
Energy Balance Prepartum Mcal/d	4.04	3.80	2.58	3.87	1.40	0.70
Energy Balance Postpartum Mcal/d	-11.1	-11.3	-11.2	-11.3	2.22	0.96
Heifers						
Prepartum DMI, kg/d	11.8	11.3	11.9	12.5	0.37	0.79
Postpartum DMI, kg/d	12.8	13.3	14.7	14.7	0.40	0.04
Milk, kg/d	29.6	28.3	28.2	31.6	1.92	0.91
Fat, %	4.76	4.58	4.09	4.00	0.19	0.05
Fat, kg/d	1.41	1.29	1.14	1.28	0.09	0.15
3.5% FCM[3], kg/d	35.8	33.2	30.7	34.4	2.25	0.30
Protein, %	3.50	3.39	3.56	3.54	0.11	0.99
Protein, kg/d	1.04	0.94	0.99	1.08	0.06	0.62
Energy Balance Prepartum Mcal/d	0.97	1.34	2.77	2.98	0.82	0.20
Energy Balance Postpartum Mcal/d	-10.1	-7.81	-4.32	-7.57	1.57	0.09

[1]Results shown are least square means from separate analyses for cows and heifers. In an analysis of both cows and heifers, cows were different ($P < 0.01$) from heifers for all variables except fat and protein percent, and prepartum energy balance.
[2]Control versus anionic treatments (BioChlor®, Fermenten®, Salts).
[3]3.5% FCM = Fat-corrected milk = 0.4324*(kg milk) + 16.2162*(kg fat).

Milk production was greater for multiparous cows fed anionic prepartum diets versus control (43.1 vs. 36.6 kg/d; $P < 0.01$). This increase was due to the significant increase in DMI during the postpartum period for anionic prepartum diets versus control. Prepartum diet did not affect milk production of primiparous cows (29.4 kg/d; $P < 0.91$). Parity by day interaction was significant ($P < 0.01$) for milk production with multiparous cows increasing at a faster rate compared to primiparous cows (data not shown). Prepartum diet by day interaction was not significant for milk production.

Fat percentage and yield, protein percentage and yield, as well as 3.5% FCM were similar for all diets in multiparous cows and all diets in primiparous cows. Primiparous cows fed anionic diets prepartum tended ($P < 0.06$) to have a lower fat percentage when compared to heifers fed the control diet prepartum. Fat percentage decreased ($P < 0.01$) for all cows by week from 4.95% wk 1 postpartum to 4.20% wk 3. Likewise, protein percentage decreased ($P < 0.01$) by week for all cows from 4.07% wk 1 postpartum to 3.11% wk 3 postpartum. Butterfat yield increased ($P < 0.01$) by week for multiparous cows from 1.83 to 1.98 kg/d from wk 1 to wk 3 postpartum. There was no difference ($P < 0.76$) by week in butterfat yield for primiparous cows. Protein yield did not differ ($P < 0.43$) by week for primiparous or multiparous cows. 3.5 % fat corrected milk increased ($P < 0.01$) by week for multiparous cows from 45.2 wk 1 to 51.2 kg/d wk 3 postpartum. Prepartum diet by day interaction was not significant for 3.5 % FCM, fat and protein yield.

Energy balance was similar for all diets during the pre- and postpartum periods for multiparous cows. Energy balance was also similar for heifers during the prepartum period; however energy balance for the postpartum period tended ($P <$

0.09) to be different for anionic diets versus control. The majority of this difference was from the Fermenten® diet. Parity by week interaction was significant ($P < 0.01$) for prepartum energy balance when cows and heifers were analyzed together (Figure 1). Multiparous cows started the trial in higher energy balance than primiparous cows; however prepartum energy balance was similar by wk 2 prepartum. Parity by week or prepartum diet by week interactions were not significant for prepartum energy balance. However, parity by week interaction was significant ($P < 0.03$) for the postpartum period.

Plasma Metabolites

Prepartum diet means are shown in Table 8 for plasma metabolites measured. Prepartum diet did not affect prepartum or postpartum plasma glucose. Prepartum plasma glucose concentrations were unaffected by prepartum diet, but were affected by day and parity. Plasma glucose concentrations during the prepartum period decreased as parturition approached then increased the day before calving ($P < 0.01$). Glucose concentrations prepartum were higher in heifers versus cows (76.4 vs. 67.4 mg/dL; $P < 0.01$). Prepartum diet by day interaction was not significant for plasma glucose. Postpartum glucose concentrations differed for parity by day ($P < 0.01$). Postpartum glucose concentrations decreased in multiparous cows, but not in primiparous cows.

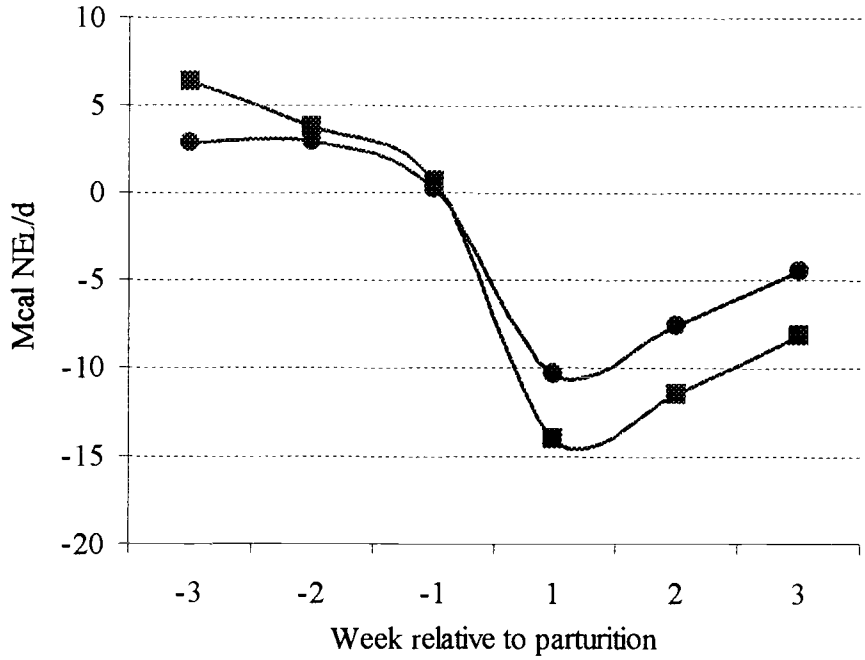

Figure 1. Energy balance of cows (-■-) and heifers (-●-) during the transition period. Prepartum and postpartum data were analyzed separately. Parity by week interaction significant ($P < 0.01$) for prepartum period.

Prepartum plasma P tended ($P < 0.08$) to be greater for multiparous cows fed an anionic diet prepartum. Prepartum plasma phosphorus concentrations were affected by day with concentrations decreasing from 21 d prepartum to 1 d prior to parturition (6.6 to 5.4 mg/dL; $P < 0.01$). Prepartum and postpartum plasma phosphorus levels were similar between parities. Postpartum phosphorus concentrations were affected by day ($P < 0.01$) with concentrations increasing from the day of calving to 21 d postpartum. Diet had no effect on postpartum phosphorus concentrations. Parity by day or prepartum diet by day interactions were not significant for prepartum and postpartum plasma P concentrations.

Prepartum BHBA concentrations were lower in heifers than in cows (5.82 versus 4.84 mg/dL; $P < 0.01$). Prepartum diet did not affect prepartum BHBA concentrations. Prepartum BHBA increased ($P < 0.01$) from 21 d prepartum to 1 d prepartum for all cows. Postpartum BHBA was lower for both multiparous ($P < 0.06$) and primiparous ($P < 0.01$) cows fed anionic diets prepartum compared to control. Postpartum BHBA concentrations were affected by day ($P < 0.01$) for all cows, peaking at d 7 postpartum and decreasing through 21 d postpartum. There was a parity difference in postpartum BHBA with cows having concentrations of 8.58 mg/dL and heifers 5.39 mg/dL ($P < 0.02$). Parity by day or prepartum diet by day interactions were not significant for prepartum and postpartum plasma BHBA concentrations.

Prepartum NEFA concentrations were different between parity (268 and 73 μmol/L for cows and heifers respectively; $P < 0.01$). Prepartum NEFA levels increased ($P < 0.01$) from 80 μmol/L to 340 μmol/L, from 21 d to 1 d prepartum, respectively. Prepartum diet had no affect on prepartum NEFA concentrations for cows and heifers. There was a decrease in postpartum NEFA concentration for primiparous cows fed an anionic diet prepartum versus control ($P < 0.01$). Dry matter intake and NEFA concentrations have been shown to be inversely related during the postpartum period (Overton and Waldron, 2004) and this would explain the increase in postpartum DMI of primiparous cows fed anionic diets prepartum. Parity also affected postpartum NEFA levels with multiparous cows having greater ($P < 0.01$) concentrations (638 μmol/L) than primiparous cows (360 μmol/L) throughout the postpartum period. Postpartum NEFA levels decreased from the day of parturition to 21 d postpartum ($P < 0.01$). Other studies have shown that NEFA concentrations

Table 8. Effect of prepartum diet on pre-and postpartum glucose, phosphorus, BHBA, NEFA and Liver triglyceride[1].

	Dietary Treatment					
Item	Control	BioChlor	Fermenten	Salts	SEM	P[2]<
Cows						
Prepartum glucose, mg/dL	67.6	70.6	65.3	66.3	1.6	0.92
Postpartum glucose, mg/dL	69.4	72.2	67.3	66.0	2.2	0.72
Prepartum phosphorus, mg/dL	5.87	6.19	6.81	6.09	0.23	0.08
Postpartum phosphorus, mg/dL	4.05	4.00	4.50	3.96	0.20	0.65
Prepartum BHBA, mg/dL	6.42	5.30	5.91	5.61	0.41	0.10
Postpartum BHBA, mg/dL	11.3	8.98	6.07	8.00	1.5	0.06
Prepartum NEFA, µmol/L	369	238	280	186	72	0.12
Postpartum NEFA, µmol /L	697	597	625	632	59	0.25
Liver TAG, % wet weight	5.58	5.11	4.52	6.70	0.74	0.87
Heifers						
Prepartum glucose, mg/dL	75.5	74.5	72.2	71.0	1.9	0.22
Postpartum glucose, mg/dL	71.4	72.2	69.1	72.2	2.5	0.96
Prepartum phosphorus, mg/dL	5.56	5.85	5.97	5.47	0.33	0.62
Postpartum phosphorus, mg/dL	4.11	3.66	4.02	4.39	0.24	0.77
Prepartum BHBA, mg/dL	5.49	5.05	5.20	5.51	0.30	0.53
Postpartum BHBA, mg/dL	7.92	6.20	4.40	5.66	0.58	0.01
Prepartum NEFA, µmol/L	204	157	121	118	32	0.09
Postpartum NEFA, µmol /L	635	460	377	383	60	0.01
Liver TAG, % wet weight	3.78	3.77	3.66	2.97	0.62	0.68

[1]Results shown are least square means from separate analyses for cows and heifers. In an analysis of both cows and heifers, cows were different from heifers for all variables ($P < 0.01$) except prepartum and postpartum phosphorus and liver TAG.
[2]Control versus anionic treatments (BioChlor, Fermenten, Salts)

begin increasing approximately 5 d before calving, peak at or around calving and begin to decrease 3 to 5 d postpartum (Goff et al., 1996; Grummer, 1993; Studer et al.,1993). Results of the current research are in agreement with these recent studies. Parity by day or prepartum diet by day interactions were not significant for prepartum and postpartum plasma NEFA concentrations.

Liver triglyceride (% wet weight) differed for parity by day ($P < 0.03$). Parities were similar at 21 d prepartum, but liver TAG was greater for multiparous cows the day of parturition (5.92 vs. 2.95 % wet weight for multiparous and primiparous cows, respectively) and 21 d postpartum (7.94 vs. 3.58 % wet weight for multiparous and primiparous cows, respectively) (Figure 2). Liver TAG concentrations have been correlated with circulating NEFA concentrations (Studer et al., 1993). For multiparous cows, greater plasma NEFA during both the prepartum and postpartum periods compared to primiparous cows lead to differences in liver TAG. Prepartum diet had no affect on liver TAG during the transition period. Prepartum diet by day interaction was not significant for the transition period.

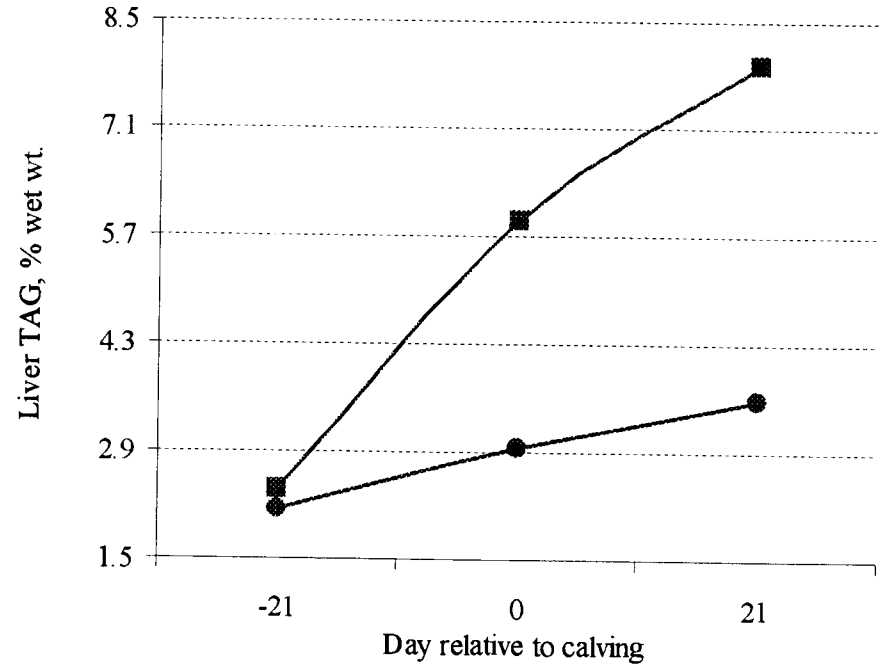

Figure 2. Liver triglyceride (TAG; % wet weight) for multiparous (-■-) and primiparous (-●-) cows during the transition period. Parity by day interaction was significant ($P < 0.01$); primiparous cows had lower liver triglyceride the day of parturition and 21 d postpartum.

Plasma Ca concentrations for the prepartum (11.0 vs. 9.2 mg/dL for primiparous and multiparous, respectively) and postpartum (11.3 vs. 8.7 mg/dL for primiparous and multiparous, respectively) periods were greater for primiparous cows versus multiparous cows ($P < 0.01$). Dietary treatment had no effect on prepartum plasma Ca concentration for cows or heifers. However, parity did not respond similarly to prepartum diet (parity by diet interaction; $P < 0.01$). This interaction was due to the magnitude of difference between multiparous and primiparous cows fed salts diet (Figure 3). Prepartum plasma Ca was not different by day for cows or heifers. Parity or diet by day interactions was not significant.

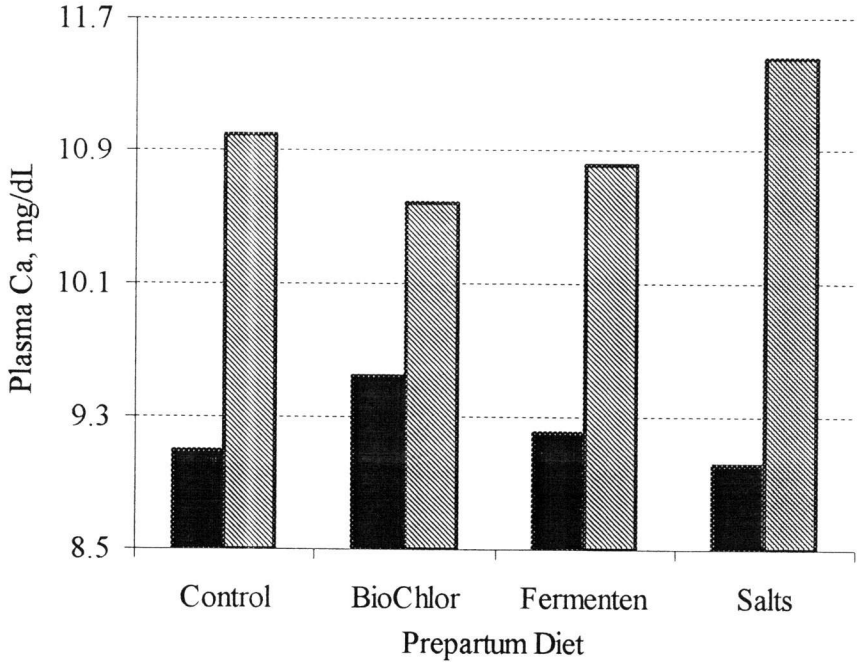

Figure 3. Prepartum plasma Ca for multiparous (-■-) and primiparous (-\-) cows during the transition period. Parity by diet interaction was significant ($P < 0.01$).

An interaction ($P < 0.01$) between parity and prepartum diet was also shown during the postpartum period for plamsa Ca concentrations (Figure 4). Concentrations of postpartum plasma Ca for primiparous cows were similar across prepartum diet. This interaction was due to the magnitude of the difference between primiparous and multiparous cows. Parity by day interaction was significant due to multiparous cows not acting similarly to primiparous cows during the postpartum period ($P < 0.01$). Plasma Ca concentrations for primiparous cows increased until 21 d postpartum where levels decreased. However, multiparous cows postpartum plasma Ca concentrations increased from the day of parturition through 21 d postpartum. Prepartum diet by day interaction was not significant. The use of anionic salts during the prepartum period has repeatedly been shown to prevent hypocalcemia in multiparous cows at or near

calving (Block, 1984; Horst et al., 1997; Joyce et al., 1997). Our results are similar to those of Moore et al. (2000), which showed no improvement in postpartum Ca metabolism of primiparous cows when supplemented with an anionic diet prepartum. Plasma Ca concentrations were similar on 0 d and 1 d postpartum between multiparous cows fed the control or anionic diets prepartum (Figure 5). One reason for this could be the amount of calcium found in the prepartum diets and the time that these cows spent on those diets prepartum. There were only 2 cows (1 cow on Control and one cow on Fermenten® diet prepartum) showing signs of clinical hypocalcemia around calving.

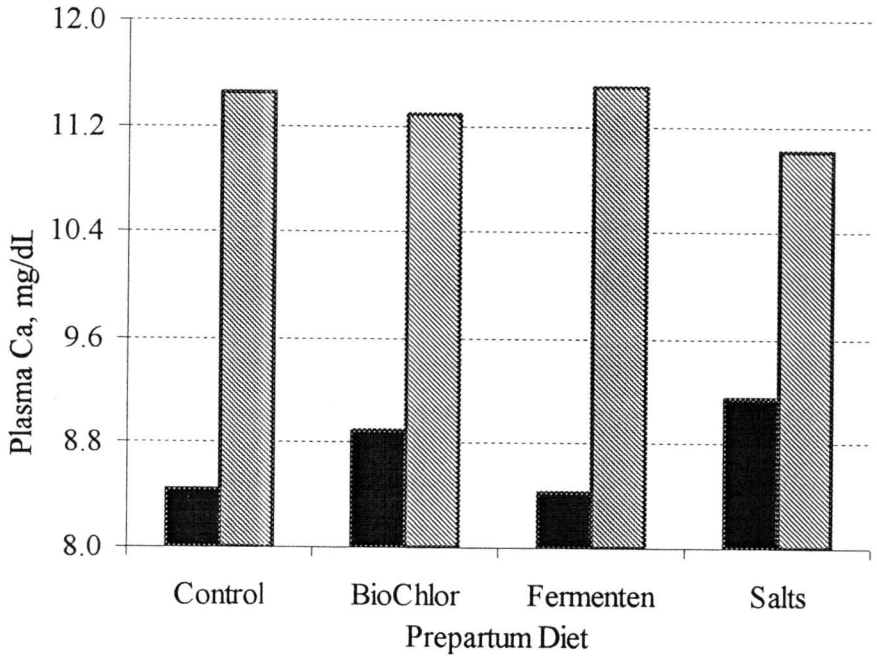

Figure 4. Postpartum plasma Ca for multiparous (-■-) and primiparous (-\-) cows during the transition period. Parity by diet interaction was significant ($P < 0.01$).

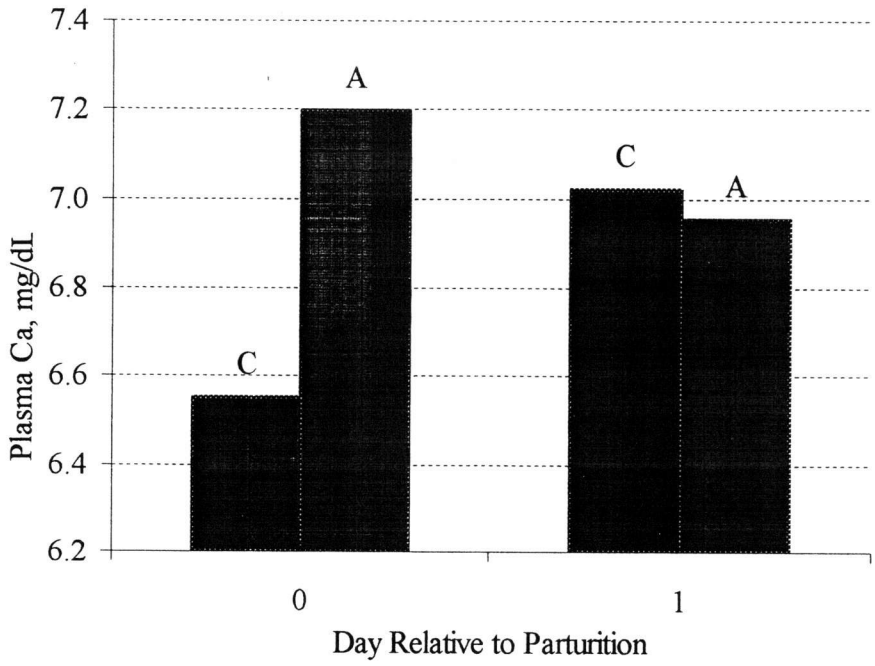

Figure 5. Effect of prepartum diet on plasma Ca concentrations on the day of parturition and 1 d postpartum. C = Control diet fed prepartum. A = Anionic diet fed prepartum. Prepartum diet was not significant for d 0 or d 1 plasma Ca concentrations.

Prepartum plasma cortisol concentrations were different for parity by treatment ($P < 0.05$) (Figure 6). Heifers fed the Fermenten® diet during the prepartum period had lower ($P < 0.05$) concentrations than cows fed the same diet. Likewise, heifers fed salts diet during the prepartum period had decreased ($P < 0.09$) plasma cortisol concentrations compared to cows fed the same diet. Parity had no effect for all cows on BioChlor® and Control whereas cows on the Fermenten® and Salts diet had greater concentrations of prepartum cortisol compared to primiparous cows on the same diets. There was a trend for a parity by day interaction for prepartum cortisol concentration ($P < 0.09$). Prepartum cortisol concentrations increased as parturition approached. Diet by day interaction was not significant.

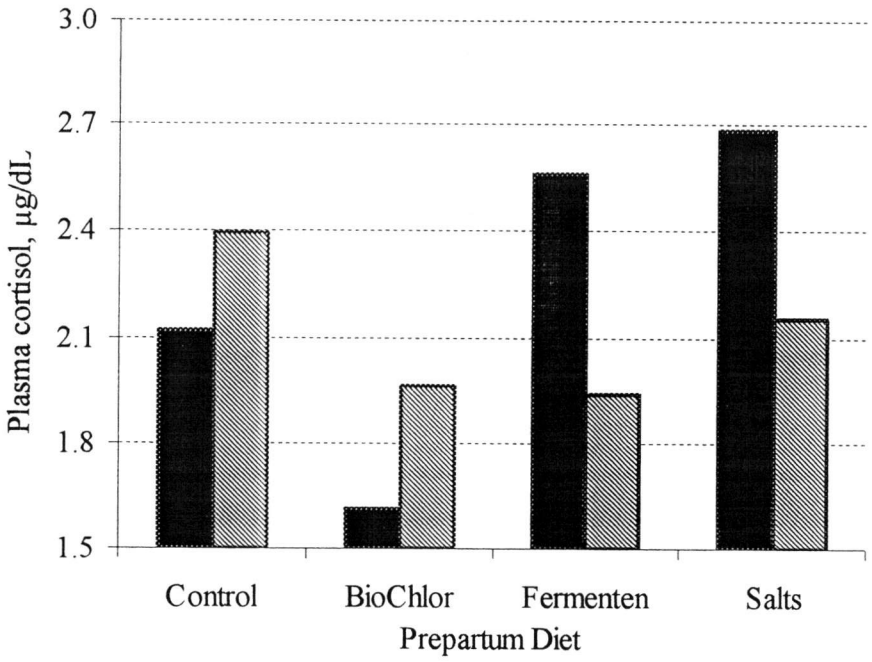

Figure 6. Prepartum plasma cortisol concentrations for multiparous (-■-) and primiparous (-\-) cows. Parity by diet interaction was significant ($P < 0.01$).

Parity by diet interaction ($P < 0.05$) was shown for postpartum cortisol concentration (Figure 7). There was a trend for BioChlor® ($P < 0.06$) and Salts ($P < 0.07$) diets to have an effect on postpartum plasma cortisol concentrations. Primiparous cows on BioChlor® (2.32 µg/dL) and control (2.40 µg/dL) diets had greater concentrations of cortisol postpartum compared to cows fed the same diets (1.60 and 2.18 µg/dL for multiparous cows on BioChlor® and control diets respectively). In contrast, primiparous cows on Fermenten® (1.89 µg/dL) and salts (1.96 µg/dL) diets had lower postpartum concentrations of cortisol compared to the cows fed the same diets (2.18 and 2.65 µg/dL for multiparous cows fed Fermenten® and salts respectively). Parity or diet by day was not significant for postpartum cortisol concentrations.

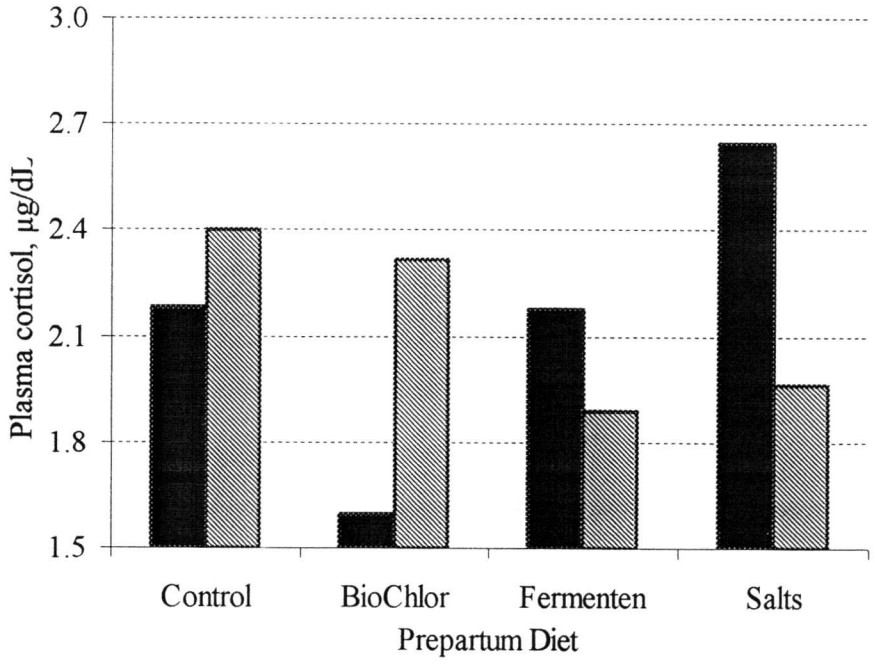

Figure 7 Postpartum plasma cortisol concentrations for multiparous (-■-) and primiparous (-\-) cows. Parity by diet interaction was significant ($P < 0.01$).

CONCLUSIONS

Anionic supplements were effective in acidifying prepartum diets based on urine pH, which is an indicator of acid-base status. Prepartum anionic diets were not detrimental to prepartum dry matter intake and did not decrease postpartum performance of primiparous cows. Feeding anionic diets prepartum increased postpartum DMI of both primiparous and multiparous cows and increased milk yield of multiparous cows. However, prepartum anionic diets did not increase plasma Ca of multiparous cows at calving. Based on the current research, cows and heifers can be grouped together during the prepartum period of the transition period and fed an anionic diet without negatively affecting prepartum DMI and postpartum performance.

FEEDING BEHAVIOR OF PRIMIPAROUS AND MULTIPAROUS HOLSTEINS DURING THE PERIPARTURIENT PERIOD

INTRODUCTION

Feed intake is regulated and limited by the requirements of the animal's physiology and metabolism. Psychogenic regulation of DMI involves the cow's behavioral responses to inhibitory or stimulatory factors in the feed or feeding environment separate from the diet's energy or fill value (Mertens, 1994). Palatability, social interactions, and learning behavior are integral components of psychogenic modulation of intake (Grant and Albright, 1995). Daily feed intake comprises the number of meals eaten daily, the length of each meal, and the rate of eating (Grant and Albright, 1995). High producing dairy cows achieve greater intake by increasing meal size and spending less time eating and ruminating per unit of intake (Grant and Albright, 1995).

Periparturient DMI depression has been well established (Bell, 1995; Grummer, 1995). Feed intake decreases 25% the last week of gestation and is depressed 40% the first week of lactation (NRC, 2001). The factor(s) causing feed intake depression during the transition period are not clearly understood, but may include elevated nonesterified fatty acids and changes in endocrine status (Grummer, 1995). This decline in DMI can affect productivity and health of the dairy cow in the subsequent lactation. In addition, there is a positive correlation between DMI 1 wk prepartum and DMI 1 wk postpartum (French, 2002).

Feeding behavior of dairy cows in early to late lactation is well characterized (Dado and Allen, 1993; DeVries et al, 2003; Tolkamp et al., 2000). However, feeding behavior of transition dairy cattle remains unidentified. Therefore, the objectives of

the current research were to 1) characterize the feeding behavior of multiparous and primiparous cattle during the transition period, and 2) determine if changes in feeding behavior observed during the periparturient period are associated with DMI depression.

MATERIALS AND METHODS

Animals, Diets and Environment

For animals and diets refer to Material and Methods of the previous chapter. Cows were fed individually via Calan® doors. Behind each door was a feed tub (99 L) that rested on an electronic scale. Electronic scales (Ohaus® Champ SQ, Pine Brook, NJ) had a 100 kg capacity and were equipped with RS232 bi-directional interface. Scales were connected to a computer via null modem cables and a software program (Collect 4.0, Labtronics, Ontario Canada) collected date, time, and weight. Scales were set to auto send data when stable after motion.

Meal Criteria

Meal criteria were calculated to determine if a visit to the feed bunk was part of the previous meal, part of the next meal, or formed a meal in itself. Meal criteria were calculated using the log-frequency (log denotes natural logarithm throughout this paper) distribution of the interval lengths between scale weigh events for each cow. Because the scale system recorded events after scale movement, this resulted in a plurality of weigh events within a visit, which were less than 20 s. This distorted the frequency distribution in such a way that it could not be modeled statistically. Therefore, weigh event intervals less than 3 log s (20 s) were removed before analysis.

Meal criteria were calculated by fitting a mixture of two normal distributions to the distributions of log-transformed weigh event intervals as described by Tolkamp et al. (1998, 1999, 2000). The model was: $y_{log(t)}=p*(1/(\sigma_1\sqrt{2\pi}))*exp(-(log(t)-\mu_1)^2/2\sigma_1^2)+(1-p)*(1/(\sigma_2\sqrt{2\pi}))*exp(-(log(t)-\mu_2)^2/2\sigma_2^2)$, where $y_{log(t)}$ = probability density at log(t), p = proportion of intervals belonging to the first distribution, σ_1 and σ_2 = standard deviations of the first and second distribution, log(t) = natural logarithm of interval length (expressed in seconds), μ_1 and μ_2 = mean log(interval length) of the first and second distribution. Mean interval lengths of the populations of intervals were back transformed from model parameters as mean = $exp(\mu + 0.5\sigma^2)$. Meal criteria were then estimated as the interval length where the two distributions intersected. Individual meal criteria were calculated for each cow and were used to calculate meal frequency (meals/d), total daily meal-time (min/d), meal duration (min/meal), DMI (kg/d), DMI per meal, and feeding rate (g DM/min). These measures were calculated by macros written in Microsoft® Excel. Meal frequency was calculated by summing the first meal and the number of intervals that exceeded the meal criteria. Meal duration was calculated as the time from the first weigh event until, but not including, a weigh event that exceeded the meal criteria. Total daily meal-time was the sum of these meal durations. Dry matter intake per meal was calculated as feed disappearance from the first weigh event until the last weigh event of a meal. Feeding rate was simply daily DMI in g divided by total daily meal-time. During calculation of behavior parameters from the raw data, >0.35 kg feed (as-fed basis) disappearance during a meal was specified in order for the visit to be considered a feeding meal. Therefore, the system

only measured time spent feeding at the bunk for meals that have >0.35 kg feed (as-fed basis) disappearance.

Statistical Analysis

Data were analyzed as repeated measures using the Proc Mixed procedure in SAS (SAS User's Guide, 2001). Cow within block by parity by treatment was defined as the subject. First order autoregressive covariance structure was used. Model used was $Y_{ijklm} = \mu + B_i + P_j + T_k + PT_{jk} + C_{(ijk)l} + D_m + DP_{jm} + e_{ijklm}$ where μ = overall mean, B_i = ith block (1,2,...9), P_j = jth parity (multiparous or primiparous), T_k = kth treatment (control, BioChlor®, Fermenten®, and salts), $C_{(ijk)l}$ = lth cow within the ith block, the jth parity, and the kth treatment, D_m = mth day (repeated measure), and e = error. Prepartum and postpartum data were analyzed separately. Trend analysis was conducted using orthogonal contrasts (linear, quadratic, and cubic) to determine if feeding behavior parameters differed over the prepartum and postpartum periods. Significance was declared at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

RESULTS

Meal Criteria

Parameter estimates used in the calculation of meal criteria are shown in Table 9. During the prepartum period all parameter estimates, except μ_1 did not differ for prepartum diet. Prepartum diet by parity interaction was significant ($P < 0.03$) for μ_1. Heifers fed the salts treatment had a larger μ_1 compared to cows on the same diet; 3.54 and 3.31 respectively. Otherwise, prepartum mean of the first distribution was similar for cows and heifers. For parity, all parameter estimates were similar except σ_1, which

was larger for heifers compared to cows (0.44 vs 0.39 for heifers and cows, respectively; $P < 0.02$). Parameter estimates did not differ by week during the prepartum period. Prepartum meal criteria did not differ for parities. There was a significant ($P < 0.04$) difference in meal criteria for prepartum diets with BioChlor® being greater than control. Although meal criterion differed between prepartum diets, the difference was relatively small (68 s) and a pooled meal criterion of 4.57 min was used in calculating feeding behavior parameters.

During the postpartum period all parameter estimates were similar for prepartum diet as well as parity (Table 9). The proportion of intervals in the first distribution increased ($P < 0.01$) for all cows by week during the postpartum period, increasing from 0.86 1 wk postpartum to 0.90 3 wk postpartum. Postpartum standard deviation for the first distribution decreased ($P < 0.02$) by week from 0.33 during the first wk after parturition to 0.31 by three wk after parturition. Meal criteria during the postpartum period did not differ for parity or prepartum diet. Therefore, meal criteria were pooled and 4.86 min was used for all cows during postpartum period.

Prepartum Feeding Behavior

Parity by prepartum diet interaction was significant for meals per day ($P < 0.01$; Table 11). For the control diet, cows had more meals per day compared to heifers, whereas heifers had fewer meals per day than cows for the salts diet. Meals per day were similar for heifers compared to cows within either the BioChlor® or Fermenten® diets. Meals per day was similar from 21 to 2 d prepartum, but tended ($P < 0.06$) to decline the day prior to parturition as shown in Figure 8.

Daily meal-time was greater ($P < 0.01$) for heifers compared to cows and tended ($P < 0.06$) to be less for BioChlor® compared to other prepartum diets (Table 11). There was a linear ($P < 0.01$) and quadratic ($P < 0.01$) effect by day for daily meal-time with all cows decreasing from 198 min at 21 d prior to parturition to 121 min 1 d prior to parturition (Figure 9). Heifers and cows responded differently to prepartum diet for meal duration (parity by prepartum diet interaction; $P < 0.01$; Table 11). Meal duration was longer for heifers compared to cows within the control diet, whereas meal duration was shorter for heifers compared to cows within the Fermenten® diet. There was a linear ($P < 0.01$) and a cubic ($P < 0.05$) decrease in prepartum meal duration from d 21 prior to parturition to the day before calving, 20.0 and 13.3 min, respectively (Figure 10).

As expected, DMI was greater ($P < 0.01$) for cows compared to heifers and prepartum diet did not affect DMI. Prepartum DMI decreased linearly and quadratically ($P < 0.01$) from 21 to 1 d prepartum as shown in Figure 11. Parity by prepartum diet interaction was significant for DMI per meal ($P < 0.01$; Table 10). Control heifers and cows consumed similar amount of DM per meal. However, heifers on an anionic diet (BioChlor®, Fermenten®, or Salts) consumed less DM per meal compared to cows. Dry matter intake per meal is simply daily DMI divided by number of meals per day. There was a linear decrease ($P < 0.01$) in DMI per meal from 21 d (1.40 kg) prior to calving to 1 d (0.98 kg) before parturition as shown in Figure 12.

Feeding rate during the prepartum period differed for parity ($P < 0.01$), prepartum diet ($P < 0.06$), and day ($P < 0.01$). Feeding rate for cows was 94 g DM/min compared to 59 g DM/min for heifers. Feeding rate tended ($P < 0.06$) to be

greater for BioChlor® compared to control, with all cows fed BioChlor® consuming 13 g DM/min more than all cows on control. Feeding rate increased numerically from 75 g DM/min 21 d prepartum to 88 g DM/min the day before parturition as shown in Figure 13.

Postpartum Feeding Behavior

Postpartum number of meals per day was similar for cows and heifers for all prepartum diets except salts, where cows had fewer meals per day compared to heifers (parity by prepartum diet interaction; $P < 0.01$; Table 12). The effect of day was significant (cubic; $P < 0.01$) for all cows (Figure 8). Number of meals the day of calving was 8.4, increased to 12.8 on d 3 postpartum, then decreased to approximately 10.9 by d 11 postpartum.

Prepartum diet and parity effects on daily meal-time, meal duration, DMI, and feeding rate are shown in Table 13. Daily meal-time duration was not different ($P < 0.14$) between parities with all cows averaging 195 min per day. Comparing the effect of prepartum diet on postpartum daily meal-time showed that all cows on anionic treatments during the prepartum period spent more ($P < 0.02$) time at the feed bunk when compared to all cows on the control diet, 200 versus 178 min/d, respectively. Total daily meal-time increased in a linear ($P < 0.01$), quadratic ($P < 0.01$), and cubic ($P < 0.04$) manner from parturition to 21d postpartum. On day 0 all cows spent an average of 97.6 min at the feed bunk; whereas by d 21 postpartum all cows averaged 240 min/d at the feed bunk. The effect of day on daily meal-time is shown in Figure 9. There was no difference in parity ($P < 0.13$) or prepartum diet ($P < 0.48$) for postpartum meal duration. Postpartum meal duration increased linearly ($P < 0.01$),

quadratically ($P < 0.02$), and cubically ($P < 0.01$) from 11.5 min/meal the day of calving to 23.0 min/meal 21 d after calving (Figure 10).

Dry matter intake was greater ($P < 0.01$) for cows compared to heifers (Table 13. Postpartum DMI was greater ($P < 0.05$) for all cows fed anionic diet prepartum compared to all cows fed control diet prepartum. The effect of day relative to parturition on DMI for all cows is shown in Figure 11. Dry matter intake increased linearly and quadratically ($P < 0.01$). Dry matter intake per meal was greater for cows than heifers for anionic prepartum diets except control, where DMI per meal was similar for cows and heifers (parity by prepartum diet interaction; $P < 0.01$; Table 12). Dry matter intake per meal increased (linear, quadratic, cubic; $P < 0.01$) from the day of calving to 21 d postpartum as shown in Figure 12.

Postpartum feeding rate was not different ($P < 0.32$) between prepartum diets with all cows consuming 90 g DM/min. Parity affected ($P < 0.01$) feeding rate from calving until three weeks after calving with cows consuming more DM per min than heifers. There was also a day effect ($P < 0.01$) for feeding rate during the postpartum period (Figure 13) with all cows having the greatest feeding rate at calving (107 g/min) and decreasing linearly ($P < 0.01$) to 21 d postpartum (84.8 g DM/min).

Table 9. Least square means of individual parameter estimates of the mixture of two normal distributions model for prepartum diet and parity during the pre- and postpartum periods.

Item	Prepartum Diet[1]					Parity		
	BioChlor	Control	Fermenten	Salts	*P*<	Cows	Heifers	*P*<
p[2]	0.94	0.94	0.95	0.94	0.07	0.94	0.94	0.34
μ_1 prepartum[3]	3.38	3.32	3.43	3.43	‡	3.35	3.43	‡
μ_2 prepartum[3]	8.54	8.44	8.56	8.58	0.59	8.56	8.50	0.43
σ_1 prepartum[4]	0.45	0.38	0.41	0.42	0.17	0.39	0.44	0.02
σ_2 prepartum[4]	0.56	0.56	0.58	0.55	0.71	0.56	0.57	0.68
Meal criteria prepartum, min[5]	5.18[a]	4.04[b]	4.33[ab]	4.76[ab]	0.04	4.31	4.84	0.10
p[2]	0.90	0.89	0.88	0.88	0.74	0.88	0.90	0.24
μ_1 postpartum[3]	3.49	3.42	3.46	3.45	0.69	3.43	3.48	0.19
μ_2 postpartum[3]	6.80	6.59	6.63	6.56	0.67	6.61	6.68	0.66
σ_1 postpartum[4]	0.34	0.31	0.32	0.31	0.65	0.31	0.33	0.28
σ_2 postpartum[4]	1.80	1.91	1.80	1.85	0.49	1.85	1.83	0.72
Meal criteria postpartum, min	5.02	4.65	4.79	4.67	0.71	4.71	4.86	0.60

‡Parity by treatment interaction ($P < 0.01$)
[1]Prepartum diet LS Means include heifers and cows combined
[2]p = proportion of intervals belonging to the first distribution
[3]μ_1 and μ_2 = mean interval length of the first and second distribution in log seconds
[4]σ_1 and σ_2= standard deviation of the first and second distribution in log seconds
[5]Means within a row for prepartum diet with different superscripts differ.

Table 10. Effect of parity and prepartum diet on meal frequency, meal duration, and DMI per meal during the prepartum period[1].

	Control		BioChlor		Fermenten		Salts		
Item	Cows	Heifers	Cows	Heifers	Cows	Heifers	Cows	Heifers	SEM
Meals per day	12.0[a]	9.3[b]	11.1	11.5	10.3	10.4	10.2[a]	12.7[b]	0.45
Meal duration, min/meal	14.3[a]	23.4[b]	14.6	15.3	16.6[a]	20.8[b]	17.3	16.3	0.91
DMI per meal, kg	1.23	1.32	1.31[a]	1.00[b]	1.47[a]	1.18[b]	1.48[a]	0.97[b]	0.07

[1]Parity by treatment least means within a row and prepartum diet with different superscripts differ ($P < 0.01$).

Table 11. Effect of prepartum diet and parity on daily meal-time, DMI, and feeding rate during the prepartum period.

	Prepartum Diet						Parity			
Item	Control	BioChlor	Fermenten	Salts	SEM	$P <$	Multiparous	Primiparous	SEM	$P <$
Daily meal-time, min/d	186	162	183	181	7	0.06	163	193	5	0.01
Dry matter intake, kg/d	13.0	12.9	12.9	13.5	0.4	0.70	14.2	11.9	0.3	0.01
Feeding rate, g DM/min	70.3	84.1	75.3	75.2	3.3	0.06	93.6	59.1	2.3	0.01

Table 12. Effect of parity and prepartum diet on meal frequency and DMI per meal during the postpartum period[1].

	Control		BioChlor		Fermenten		Salts		
Item	Cows	Heifers	Cows	Heifers	Cows	Heifers	Cows	Heifers	SEM
Meals per day	11.4	9.8	11.0	10.6	11.8	11.2	10.6[a]	12.7[b]	0.45
DMI per meal, kg	1.52	1.40	1.78[a]	1.37[b]	1.73[a]	1.39[b]	1.87[a]	1.20[b]	0.07

[1]Parity by treatment least means within a row and prepartum diet with different superscripts differ ($P < 0.01$).

Table 13. Effect of prepartum diet and parity on daily meal-time, meal duration, DMI, and feeding rate during the postpartum period.

	Prepartum Diet						Parity			
Item	Control	BioChlor	Fermenten	Salts	SEM	$P <$	Multiparous	Primiparous	SEM	$P <$
Daily meal-time, min/d	178	193	211	197	7	0.02	189	200	5	0.15
Meal duration, min/meal	17.4	18.3	19.0	17.8	0.8	0.48	17.5	18.8	0.5	0.13
Dry matter intake, kg/d	15.9	16.9	17.8	17.2	0.5	0.05	18.7	15.2	0.3	0.01
Feeding rate, g DM/min	91.8	92.0	85.6	91.2	2.9	0.32	104	76	2	0.01

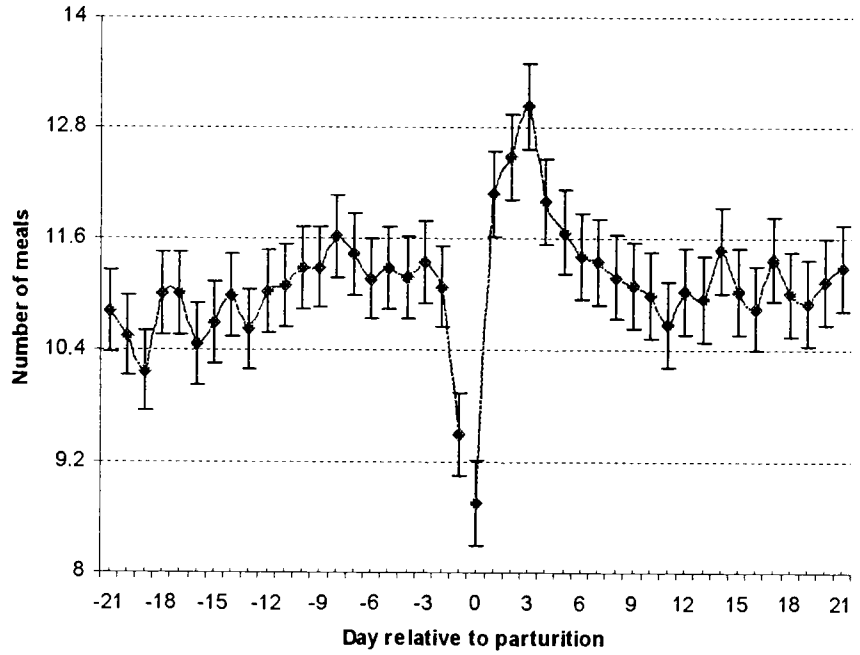

Figure 8. The effect of day relative to parturition on meals per day of all cows. Day effect was not significant prepartum and was significant (cubic; $P < 0.01$) postpartum. Data represent least square means and vertical bars are SE (SE=0.46).

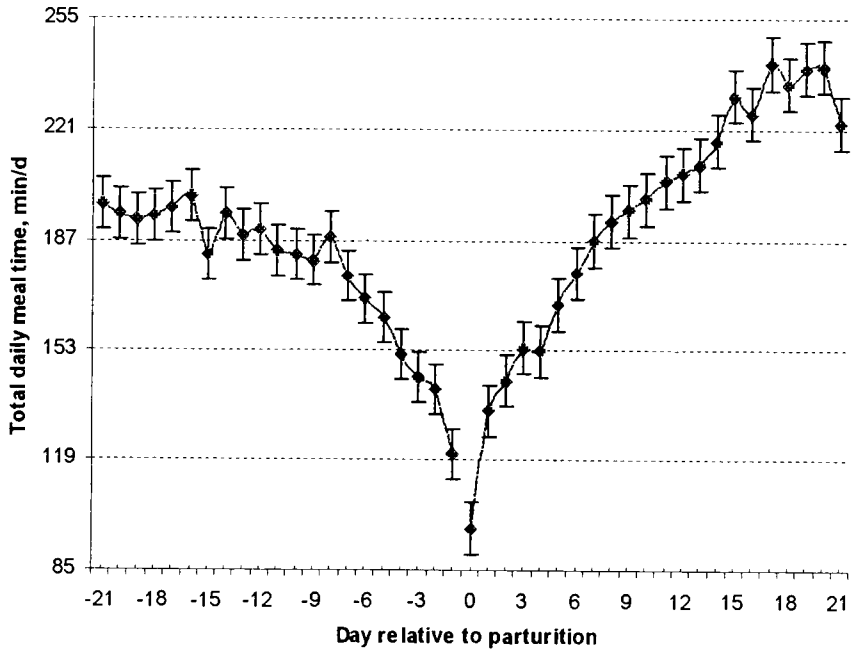

Figure 9. The effect of day relative to parturition on daily meal-time (min/d) for all cows. Day effect was significant (linear, quadratic; $P < 0.01$) prepartum and was significant (linear, quadratic, cubic; $P < 0.05$) postpartum. Data represent least square means and vertical bars are SE (SE=7.9).

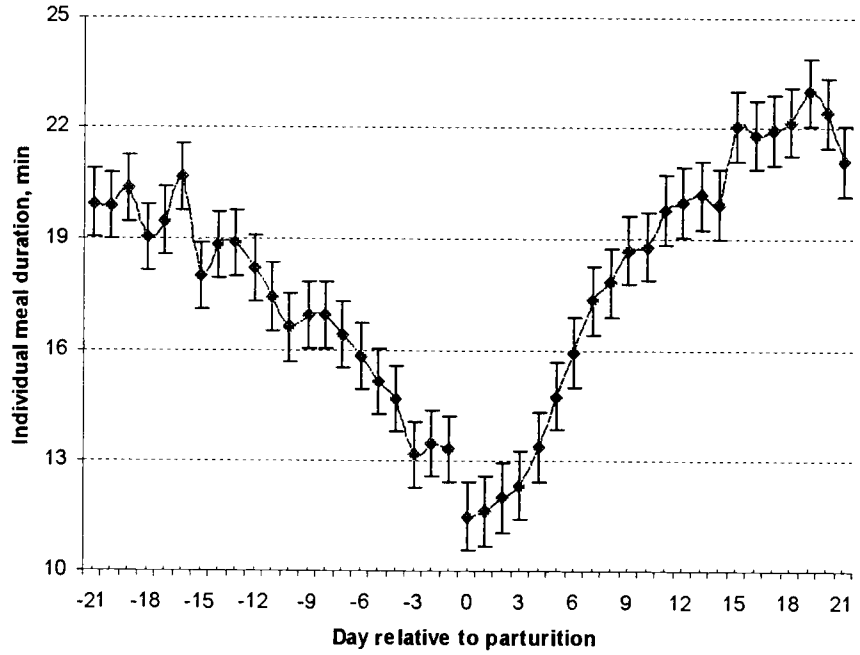

Figure 10. The effect of day relative to parturition on meal duration (min/meal) for all cows. Day effect was significant (linear, cubic; $P < 0.05$) prepartum and was significant (linear, quadratic, cubic; $P < 0.05$) postpartum. Data represent least square means and vertical bars are SE (SE=0.9).

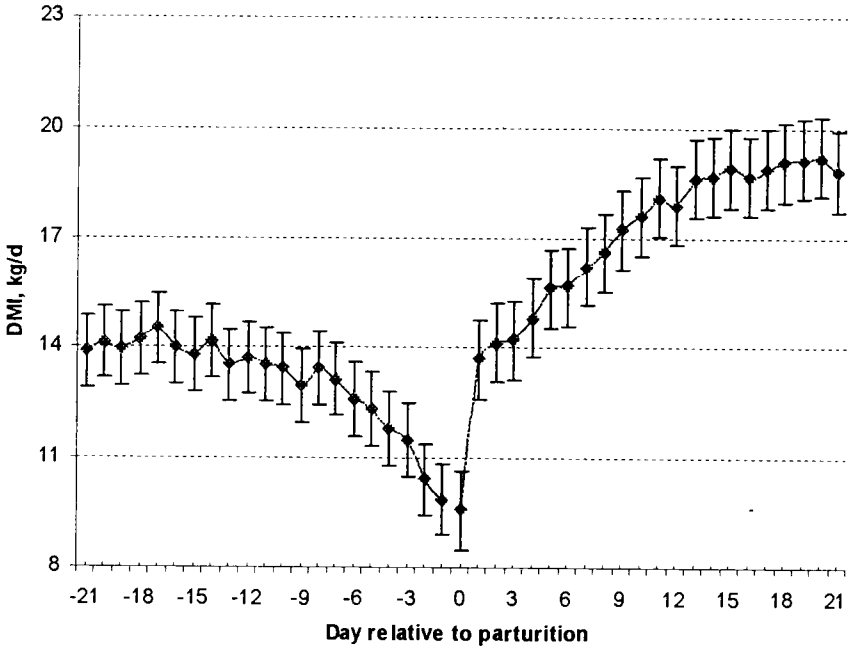

Figure 11. The effect of day relative to parturition on DMI (kg/d) for all cows. Day effect was significant (linear, quadratic; $P < 0.01$) prepartum and was significant (linear, quadratic; $P < 0.01$) postpartum. Data represent least square means and vertical bars are SE (SE=0.5).

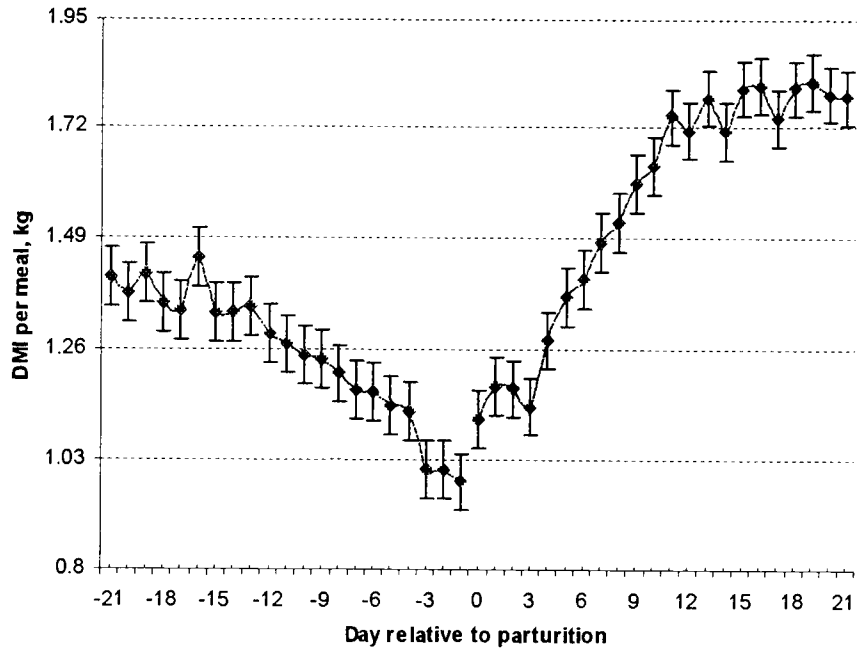

Figure 12. The effect of day relative to parturition on DMI per meal (kg) for all cows. Day effect was significant (linear; $P < 0.01$) prepartum and was significant (linear, quadratic; cubic; $P < 0.01$) postpartum. Data represent least square means and vertical bars are SE (SE=2.7).

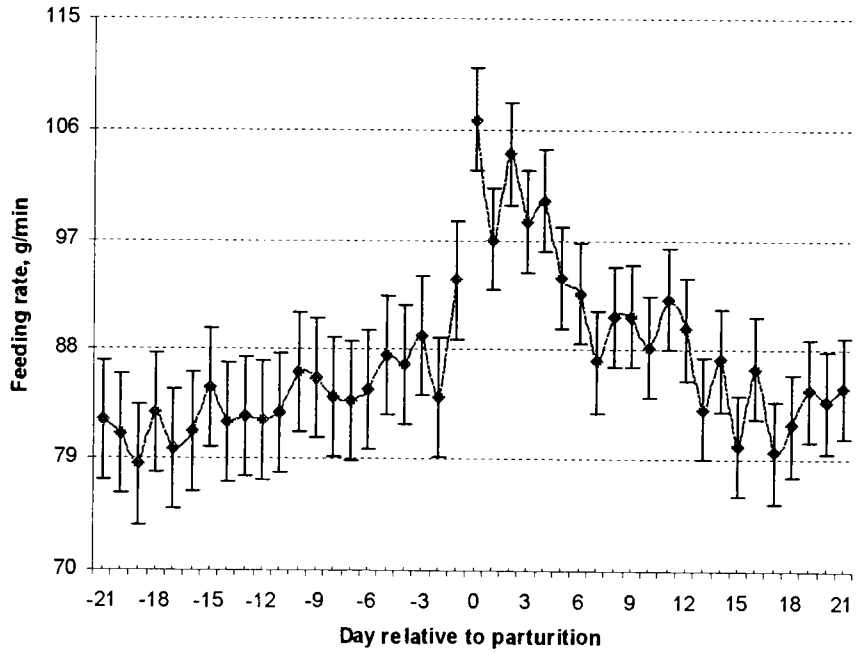

Figure 13. The effect of day relative to parturition on feeding rate (g DM/min) for all cows. Day effect was not significant prepartum and was significant (linear; $P < 0.01$) postpartum. Data represent least square means and vertical bars are SE (SE=3.9).

DISCUSSION

Although parity by prepartum diet interaction was significant for meals per day, meal duration, and DMI per meal, anionic supplementation did affect prepartum feeding behavior. Heifers fed salts consumed more meals per day prepartum compared to cows fed the same diet, which may be interpreted as salts are unpalatable for heifers. However, this same difference in meal per day occurred during the postpartum period when cows and heifers were consuming a common ration. Therefore, parity difference within the salts diet was likely due to animals assigned to this diet rather than an effect of diet.

Prepartum DMI per meal was less for heifers on an anionic diet prepartum compared to cows, whereas DMI per meal was similar for control cows and heifers. Dry matter intake per meal is simply daily DMI divided by number of meals. Daily DMI was less for heifers and number of meals per day was similar, at least for BioChlor® and Fermenten® diets. Therefore, DMI per meal would be expected to be less for heifers. The interaction occurred due to the control diet, where DMI per meal was similar for cows and heifers. This was due to heifers consuming 2.7 fewer meals per day compared to cows.

Number of meals per day was similar during the prepartum period except on d 1 prior to parturition where all cows consumed approximately 1.5 meals less than other days, which in retrospect indicated that parturition was imminent. Dry matter intake decreased 37% from 21 d to 1 d prepartum, which is consistent with previous reports (NRC, 2001). Interestingly, daily meal-time decreased 38% during this same period. Both DMI and daily meal-time decreased linearly and quadratically as

parturition approached. Therefore, prepartum DMI depression can be directly attributed to increasingly less time spent at the feed bunk as parturition approaches. Since prepartum DMI and daily meal-time decreased in synchrony, feeding rate did not change over the prepartum period.

As expected, DMI was greater for cows compared to heifers during the prepartum period. In addition, heifers spent more time at the feed bunk, which lead to heifers consuming 35 g less DM per min compared to cows. This may have implications in prepartum grouping strategies, since heifers need more access time to feed. In this experiment, if heifers were given access to feed 163 min/d (daily meal-time for cows) predicted DMI would have been 9.7 kg/d; assuming this limited access would not alter feeding rate.

Postpartum number of meals per day was similar between parities for prepartum diets Control, BioChlor® and Fermenten®. However, cows fed the Salts diet prepartum consumed fewer meals per day compared to heifers fed the same diet prepartum, which was similar to prepartum findings. Due to this difference parity by prepartum diet was significant for postpartum number of meals per day. This interaction was most likely due to the differences in animals, not the prepartum diet fed.

Postpartum DMI per meal was similar for control cows and heifers, but greater for cows compared to heifers fed anionic diets prepartum. Except for the salts diet, postpartum number of meal per day were similar for cows and heifers and since DMI was lower for heifers, DMI per meal would be expected to be lower for heifers. The lack of difference in DMI per day between cows and heifers fed the control diet

prepartum was due to numerically fewer meals per day for heifers and statistically lower DMI for control cows compared to anionic diets.

As expected, postpartum DMI was greater for cows compared to heifers. However, because daily meal-time was similar between parities, the difference in postpartum DMI was due to a decrease in feeding rate for heifers. Feeding rate of cows was 28 g DM/min more than heifers. Although feeding rate was lower for heifers when expressed as g DM per min, feeding rate was similar when expressed as g DM per 100 kg BW (13.8 and 14.9 g DM/100 kg BW for heifers and cows, respectively).

Prepartum anionic diets did not negatively affect postpartum daily meal-time, meal duration, DMI, or feeding rate. In fact, cows and heifers that received an anionic diet prepartum spent more time (22 min/d) feeding at the feed bunk and consumed more (1.4 kg DM/d) feed. Less time spent at the feed bunk for control cows and heifers lead to the decrease in DMI, since feeding rate was similar for prepartum diets.

Number of meals per day were lowest the d of calving and increased by 4 meal/d by d 4 postpartum. This change during the first few days after calving is attributed to the calving event. Postpartum DMI increased 2-fold from parturition to 21 d postpartum. Likewise, daily meal-time increased 2.5-fold during the first 3 wk after calving. When considering that feeding rate decreased linearly during the postpartum period; the increase in DMI was due to an increase in time spent at the feed bunk. Postpartum DMI depression, especially the first wk postpartum can be directly attributed to time spent at the feed bunk.

CONCLUSIONS

Feeding anionic diets prepartum did not negatively affect prepartum or postpartum feeding behavior. The negative effect of anions on DMI and presumably palatability were not observed in this experiment. Cows and heifers fed anionic diets during the prepartum period spent more time eating postpartum, which lead to greater DMI.

Notable differences in the feeding behavior of cows and heifers occurred during both the pre- and postpartum periods. Daily meal-time was greater for heifers and feeding rate was lower, which resulted in lower DMI for heifers compared to cows. The lower feeding rate for heifers also continues into the postpartum period. An understanding the behavioral differences between cows and heifers can be used to develop strategies for these animals.

The depression in DMI commonly observed during the periparturient period coincides with changes in daily meal-time and DMI per meal. An initial concept would be an increase in daily meal-time or meal duration may lead to improvements in DMI. However, discovery and ultimately mitigation of the factor(s) that is causing DMI depression is the most plausible strategy at this point.

CONCLUSIONS

A goal of dairy producers is to maximize milk production and dry matter, while minimizing metabolic disorders during the transition period. Feeding anionic diets during the close-up or prefresh period is a dietary strategy that is available to assist in attaining this goal. Decreasing the DCAD of the close-up diet increased feed intake and milk production in multiparous cows during the postpartum period. However, prepartum anionic diets did not improve plasma Ca soon after parturition as commonly reported with the use of anions. Therefore, the increase in milk yield and postpartum DMI may be other than an improvement in Ca homeostasis. Importantly, anionic diets did not adversely affect primiparous heifers, which comprise one-third on the dry cow herd. In fact, feeding heifers anionic diets prepartum increased feed intake and decreased circulating concentrations of BHBA and NEFA. In the end, the decision of feeding anionic diets to commingled prefresh cow and heifer pens must consider the cost and benefit, since modern dairy herds often exceed 40% first lactation animals.

Feeding behavior during the periparturient period can have a dramatic influence on DMI. The depression in DMI during the periparturient period is actually a depression in daily-meal time and meal duration. The key to maximizing DMI during this period will be accomplished by devising strategies to get cattle to the feed bunk more often and/or for longer periods of time. Corrective measures may range from altering cow behavior through the feeding program on dairies to preventative measures that focus on altering the metabolic status of the dairy cow. In the end, maximizing the amount of time that cows spend at the feed bunk will ultimately

determine how well dairymen attain the goals that have been set for the transition period.

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