Nutritional Intervention to Improve the Calcium and Energetic Status of High Producing Transition Dairy Cattle

Mark A. Froetschel, The University of Georgia, Athens Georgia

SUMMARY

The high producing dairy cow makes major metabolic adjustments in the transition phase in order to support a profitable lactation. During transition dairy cow adjusts its metabolism to mobilize calcium from skeletal reserves and energy from adipose reserves. These adjustments are needed in a timely fashion for the cow to up-regulate intake capacity and meet nutrient requirements for peak milk production in early lactation. Periparturient disease is a consequence of the cow not adequately adjusting its metabolism during transition. Special attention to dry cow nutrition, especially during the close-up period, can facilitate metabolic adjustment. Formulating close-up rations with a negative dietary cation-anion difference is a proven approach to stimulate the fresh cow's ability to mobilize and maintain circulating levels of calcium a key physiological regulator. Muscle contractility, endocrine signaling and tissue metabolism are critical physiological functions of circulating calcium in transition cows that can be compromised in transition cows leading to perparturient disease and reduced productivity. Maintaining constant concentrations of circulating calcium is a highly regulated homeostatic process and critically important for many physiological functions. Circulating calcium is important for: 1) strength of reticulo-ruminal muscle contractions required for rumen microbial processing of feed, passage rate of reticulo-ruminal digesta and enhancing intake capacity, 2) mobilization and processing of adipose tissue net energy of lactation and milk fat synthesis in early lactation, 3) metabolic coordination of lipolysis and gluconeogenesis to prevent ketosis 4) rate of attaining energy balance in early lactation to support peak milk production and reproduction. Preliminary research findings suggest feeding anionic salts prepartum to promote circulating calcium postpartum will allow the early lactation cow to utilize much higher levels of dietary fat from rumen protected sources than previously thought without compromising caloric intake. This strategy could potentially prove useful for improving energy balance of fresh cows, reproduction status and lactation performance.

Developments in transition cow nutrition

Major advances in transition cow nutrition were made in the decade prior to the 2001 edition of the National Research Council publication Nutrient Requirements of Dairy cattle (Bell, 1995; Grummer; 1995). This led to establishment of the first NRC close-up cow nutrient requirements. Now group feeding close-up dairy cows a specialized ration is an established practice. Close-up cow rations should be formulated for the cow to meet its macro-nutrient requirements, net energy of lactation (NE_L) and metabolizable protein (MP), for maintenance, gestation and developmental needs. It is well recognized (Dairy NRC, 1989) to feed far-away dry cows to maintain proper body condition. The 2001 dairy NRC recommends that close-up cows should be fed a greater concentration of NE_L and metabolizable protein to developmental requirements, digestive capacity and to compensate for reduced intake. More recent findings suggest that the close-up cow should be fed slightly below their NE_L and MP requirements to avoid peri-parturient disease (Janovik and Drackley 2011). It is becoming apparent that properly setting the level of effective fiber (% NDF and forage particle size) is critical to control NE_L and MP intake. Different feed sources of NE_L (starch, fiber, fat) and MP (UIP and RUP) appear to be equally effective at supplying NE_L and MP as long as their inclusion rate allows the cow to consume the prescribed NE_L and MP intake to be in or slightly below its macro-nutrient balance.

The practice of feeding anionic salts to influence electrolyte balance and health of transition dairy cattle is well established (Moore et al 2000; DeGroot et al 2010). Feeding a negative dietary cation-anion difference to multiparous cows in the close-up period can greatly facilitate transition to peak milk production in early lactation. The cost benefits of feeding anionic salts to close-up cows is related to improved milk yield, animal health and reproduction. Improved calcium status in early lactation is critical for proper rumen motility and digestive function (Froetschel et al, 2004). Maximal rumen digestive function is required for the cow to up-regulate intake in early lactation. It is recommended to set the dietary cation-anion difference in a prepartum transition cow diet at -10 milliequivalents/ 100 g of DM using anionic salt supplements. This can be calculated by subtracting the sum of the percentage concentrations of sodium and potassium from the sum of the percentage concentrations of chloride and sulfur in the complete ration. Other salts (calcium, magnesium, phosphorus) and certain nutrients (crude protein, readily fermentable carbohydrates) can affect DCAD. However the equation based on the difference between percentage concentrations of cations (sodium and potassium) and anions (chloride and sulfur) is effective at formulating the proper DCAD as confirmed by urine pH measurements. Cows fed an anionic salt ration set at or below-10 milliequivalents/ 100 g DM DCAD prepartum should have a urine pH < 6.0 within a day of feeding. It is recommended that anionic salt rations be fed for at least two weeks prepartum to receive their postpartum benefit. After calving, cows should be changed immediately to an early lactation ration formulated from 100-300 milliequivalents /100 g DM. Feeding less than 20 milliequivalents/100 g DM will inhibit dry matter intake and prolong negative energy balance due to metabolic acidosis especially with higher starch rations (Apper-Boussard et al 2010; Block, 2010).

Ongoing nutrition research with feeding transition dairy cattle

Feeding ruminal-inert fat to early lactation cows

Ruminal-inert sources of fat were developed with the potential application of solving problems associated with negative energy balance of early lactation dairy cow. Although, ruminal-inert fat can improve ration energy density and increase caloric intake of high producing cows without compromising rumen microbial fermentative digestion, its use must be carefully restricted in fresh cows. Feeding levels > 3% inhibits caloric intake likely through a direct effect on inhibition of reticulo-rumen motility and rumen fill (Kumar et al. 2004). Feeding recommendations (manufacturers and nutritionists) for feeding ruminal-inert fat to transition and fresh cows are set at less than 2% of dry matter intake to keep total ration fat below 5% (Block, 2010) . However, concerns regarding physiological effects supplementing fat to transition and fresh cows on incidence of periparturient disease and intake has led some nutritionists to recommend against using supplemental fat until after peak lactation. A glucogenic diet facilitated the rate early lactating cows reached energy balance as compared to lipogenic diet (van Knegsel et al 2007). At current prices supplemental fat has limited usefulness as a cost-effective source of calories in mid to late lactation. However, if higher levels of supplemental fat could be fed in early lactation, and alleviate negative energy balance, improve reproductive efficiency and reduce days open it could be cost effective.

Ruminally inert (RI) fat in the form of calcium salts of fatty acids (~1 to 3%) is effective at improving caloric intake as required for milk production of high producing cows (Garcia-Bojalil et al. 1998). An RI fat product containing more unsaturated fatty acids (18:1 and 18:2, Megalac-R, Church and Dwight Co., Inc. Princeton, NJ), has application for alleviating the impact of negative energy balance on reproduction efficiency and providing specific unsaturated fatty acids that improve fertility (Staples et al. 1998). Specific fatty acids in transition rations are being proven to enhance metabolic health and reducing economic losses due to milk fever, dystocia, retained placenta, ketosis and displaced abomasums, lowered production and reproductive efficiency (Overton and Waldron, 2004). Furthermore, RI fat products have a greater application for dairies located in warmer climates as lactating dairy cattle fed diets that contain RI fat will benefit from both a lower heat increment and increasing ration energy density without decreasing the roughage concentrate ratio. However, there is concern that at higher levels of RI fat supplementation (>3%) an associated depression in intake may compromise the effectiveness of the RI fat products to improve energy balance (Choi and Palmquist, 1996).

A number of interacting physiological factors have been implicated as responsible for supplemental fat (>3%) depressing caloric intake. Unsaturated fatty acids appear to have a greater inhibitory effect on DMI (Allen 2000, Harvatine and Allen, 2006). Intake regulation in transition cows has particularly important ramifications as it alleviates negative energy balance and perparturient disease in early lactation and positively impacts lactational performance and reproduction. During transition, digestive and metabolic capacity increase substantially as related to gastrointestinal tract and the liver mass. In addition there is substantial mobilization of energy and protein reserves in adipose and muscle tissue. This physiological state is characterized by higher circulating levels of non-esterified fatty acids, ketone bodies (aceto-acetate, acetone and β-hydroxy butyrate), blood urea nitrogen and lower levels of glucose and amino acids. Mobilization of endogenous adipose tissue and its demand on hepatic gluconeogenesis may limit the cow from using additional fatty acids supplied in the diet.

In addition, intake sensitivity to supplemental fat by cows in early lactation may be related to the endocrine regulation involving lipostatic and gastric controls. Leptin, an adipose tissue hormone, discovered in 1995, acts to inhibit caloric intake and increase metabolic rate of animals with increased fat stores. Leptin increases the animal's sensitivity to the gastric hormone cholecystokinin thereby reducing reticulo-rumen digesta passage and enhancing the negative impact of dietary fiber on intake due to greater reticulo-ruminal fill and distension. At present, supplemental fat has to be precisely allocated in early lactation (< 3 %) to allow the cow to cope with negative energy balance and not overwhelm its metabolic and digestive capacity to effectively utilize lipid as a source of metabolic energy. The sensitivity of fresh cows to ruminally inert fat with regard to caloric intake may be due to circulating concentrations of leptin that are higher in cattle with more body condition. Leptin increases the sensitivity of the animal to cholecystokinin, an important gastrointestinal hormone involved in regulating reticulo-rumen motility and rumen processing of feed (Kumar et al 2004). Circulating concentrations of leptin are related to body fat (body condition) and stage of lactation in dairy cows (Kumar et al 2003). Leptin may be responsible for intake regulation and sensitivity to incremental levels of dietary fat during early lactation. Janovik et al (2011) found that feeding an increased concentrate diet increased circulating leptin concentrations prepartum and this was associated with greater incidence of periparturient disease problems even though leptin was not increased postpartum.

Impact of calcium status on utilization of rumen inert fat in transition dairy cattle

A study was undertaken to determine the relationship between circulating concentrations of leptin and feeding behavior of fresh cows fed either 0, 3, or 6 % supplemental rumen inert fat (Megalac-R®) (Kumar et al 2003). All the cows in this study were fed anionic salts prepartum 2 weeks prepartum. Dry matter intake was correlated (r^2 0.23, $P < 0.01$) with serum leptin during first 8 weeks of lactation. Serum leptin increased ($P < 0.01$) by 7.2 % (4.54 vs. 4.87 ± 0.07 ng/ml) in cows post-calving (measured at weekly intervals) as compared to 2 d pre-calving. Leptin decreased by approximately 15% due to higher levels of fat in the diet. Milk production decreased (linear, $P < 0.01$) 6.7 to 19%, due to dietary fat. However, dry matter intake increased (quadratic, $P < 0.05$) from 1.5 to 7.0% with feeding dietary fat. This stimulatory effect of fat on intake was opposite from that reported in the literature and thought to be possibly attributable to feeding anionic salts pre-partum. Another treatment group of cattle were added to the study, that were not fed anionic salts prepartum. These cows had reduced dry matter intake and greater incidence of periparturient disease as compared to cows fed 0% fat.

These preliminary findings just discussed indicate that calcium status is crucial for the transition cow to effectively utilize higher levels of supplemental ruminally inert fat. Dry matter intake was not depressed in fresh cows of cows fed up to 6% ruminally inert fat (Megalac-R) after being fed anionic salts. This level of ruminally inert fat was fed at levels that substantially exceeded manufacturer's and nutritionist recommendations. This level of fat supplementation was used to better understand the relationship between leptin and intake sensitivity of fresh cows to dietary fat. Milk fat was measured on composite milk samples taken during week one and week eight. Increased caloric intake was related to trends for increased milk fat in cattle fed DCAD pre-partum. Also, it appeared that cattle fed DCAD and high fat diets retained more body weight. Changes in blood metabolites (glucose, calcium, blood urea N and hormones (insulin and leptin) imply that anionic salts pre-partum influence calcium and metabolic energy regulation postpartum.

Table 1. Pre-partum anionic salts and post-partum rumen inert (RI) fat (Megalac-R) on performance and blood metabolites of transition dairy cattle during the first eight weeks of lactation.[1]

Prepartum treatment	Anionic salts	Anionic salts	Anionic salts	Control	
Postpartum treatment	0 % RI fat	3% RI fat	6% RI fat	6% RI fat	
Result					SE
DMI (lb)[a,b,c]	49.6	51.6	50.5	43.8	2.0
DMI (%BW) [a,b,c]	3.97	3.95	3.95	3.24	.19
Milk (lb) [a,b]	97.9	91.5	79.4	80.9	2.9
Milk fat (%)	3.73	3.59	4.07	3.72	.33

[1] Values are least square means estimated from 4 animals per treatment during the first eight weeks of lactation.

[a]P<.05, DCAD VS No DCAD

[b]P<.05, DCAD with RI fat (3% and 6%) VS No DCAD with RI fat (6%)

[c]P<.05, DCAD with RI fat (6%) VS No DCAD with RI fat (6%)

A subsequent experiment was conducted to gain further support for the interaction between feeding anionic salts prepartum upon feeding rumen inert fat postpartum on performance, energetics and circulating metabolites of early lactating cows (Norat-Collazo et al 2008). Twelve multiparous Holstein dairy cows, were assigned tone of four treatment groups that were equalized based on their mature equivalent milk production. Cows were fed either a control or anionic salt diet (Biochlor®: Church and Dwight Co. Inc., Princeton, NJ) prepartum and a control or ruminal inert fat supplemented diet postpartum in 2 X 2 factorial designed experiment. Total mixed rations, fed prepartum with and without anionic salts, were composed of 75% wheat silage, and formulated to contain 1.55 Mcal/kg of $NE_{L,}$ 15% CP and 52 % NDF (adjusted concentrate sources 30% discount) on a DM basis. The anionic salt prepartum ration contained 9.3 % Biochlor® and was estimated to provide a dietary DCAD of -14 milliequivalents/100g DM; whereas, the control diet contained a 9.3% mixture of soybean meal, corn gluten feed and soyhulls and estimated to provide a DCAD of + 13.8 milliequivalents/100g DM. Transition cows were moved from dry cow pasture to a free-stall facility and trained to use Calan gates® (American Calan Inc., Northwood, NH)t 2-3 weeks prior to calving. Urine samples were collected from each cow on day 10, 5 and 1 before their calving date and measured for pH.

Postpartum total mixed rations contained either 0 or 5.3% ruminal inert fat (Megalac-R® Church and Dwight Co. Inc., Princeton, NJ). Postpartum rations contained either 3.5% or 7.6% fat and 1.65 and 1.9 Mcal/NE_L. Postpartum rations varied in fat and energy content they were similar roughage concentrate ratio (42-46% roughage from wheat silage), % NDF (34.8 and 37.8% adjusted for concentrate sources), CP (18.5%) and undegradable intake protein (44.3% of CP).

Although a minimal number of cows were used in this follow-up experiment, the results obtained do lend support to the concept that improving calcium mobilization in transition cows by feeding anionic salts enhances the fresh cow's ability to utilize dietary fat in early lactation. There was an interaction between prepartum DCAD and postpartum fat feeding for milk production that occurred in early lactation ($P < 0.01$). Cattle fed anionic salts prepartum and ruminal inert fat postpartum produced as much as 28.6% more milk from week eight to twelve in as compared to controls (Figure 1). It appears that the fresh cow required several weeks to adjust to dietary treatments. Cows fed anionic salts had 13.8 to 15.2% lower DMI in the first two weeks of lactation but then increased their intake after seven weeks. Although cattle fed HF diets consumed 9.8-16.3% less dry matter two weeks after parturition (week 2-11) the cows fed anionic salts prepartum were able to maintain their intake of NE_L.

Differences in circulating concentrations of insulin and metabolites of early lactating cows fed anionic salts prepartum and rumen inert fat postpartum hint at an underlying mechanism that may be responsible for cows with improved calcium status to better utilize rumen inert fat. Cows fed rumen inert fat had 24.8 to 32% ($P < 0.01$) increased circulating concentrations of insulin at 4 and 8 weeks postpartum indicating insulin insensitivity or lowered responsiveness. Feeding anionic salts improved insulin activity or responsiveness although its effects diminished in a few weeks into lactation. The cows fed supplemental fat became more insulin resistant as early lactation progressed. Insulin resistance may be important for the early lactating cow to coordinate lipolysis and gluconeogenesis along with utilizing preformed absorbed dietary lipid for lactation. Non-esterified fatty acids were decreased by feeding anionic salts prepartum but increased by feeding ruminal inert fat. It appears that mobilization of calcium during transition influences insulin sensitivity and adipose mobilization in a positive manner. Cows fed control diets prepartum and fat postpartum had the greatest concentrations of NEFA at week eight postpartum indicating that mobilizing calcium in transition cows by feeding anionic salts facilitates the cow’s ability to utilize higher levels of supplemental fat in early lactation.

Table 2. Pre-partum anionic salts (Biochlor® 9.3% of DM) and post-partum rumen inert (RI) fat treatments (Megalac-R 5.3% of DM) on performance and blood metabolites of transition dairy cattle during the first eight weeks of lactation.[1]

Prepartum treatment	Anionic salts	Control	Anionic salts	Control	
Postpartum treatment	5.3 % RI fat	5.3% RI fat	Control	Control	
Result					SE
Prepartum Urine pH[a]	5.71	6.96	5.91	7.04	.16
DMI (lb)	55.3	50.6	58.4	63.0	5.4
NE_L Intake Mcal	47.7	43.6	43.7	47.1	4.4
Milk (lb)	77.7	67.0	74.9	74.1	5.4
Milk fat (%)	3.66	3.64	3.64	3.55	.04

[1] Values are least square means estimated from 3 animals per treatment during the first twelve weeks of lactation.
[a]P<.05, Anionic salts VS control diet

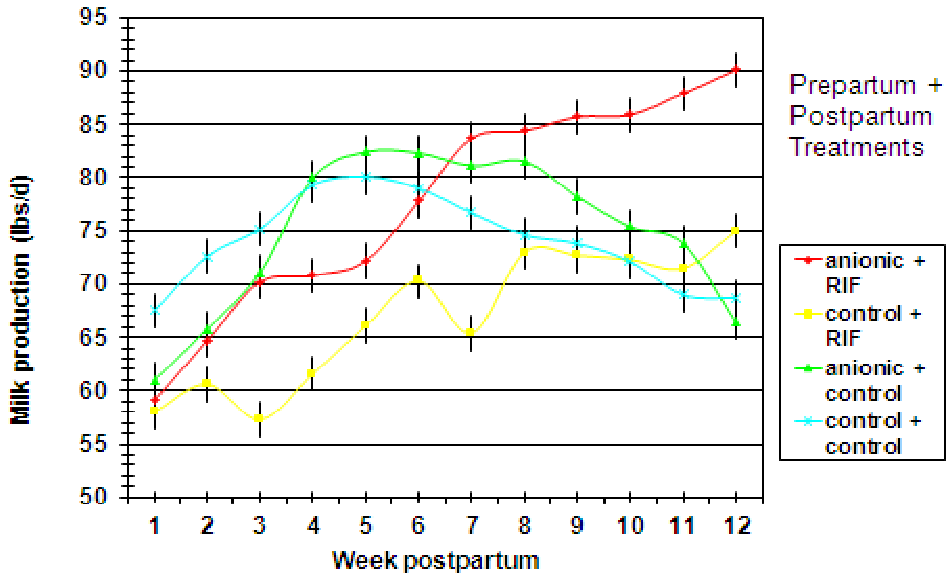

Figure 1. Effect of feeding anionic salt diets prepartum and rumen inert fat (RIF) feeding postpartum on milk production of lactating dairy cows. Each point represents least square means from intake of three cows averaged over a seven day period.

CONCLUSION

Specialized nutrition of the transition cow has developed substantially in the last 20 years. Carefully formulating the close-up prepartum diet facilitates the performance, health and reproductive efficiency of early lactation cows. Our research suggests that early lactation cows fed anionic salts can utilize higher levels of dietary rumen inert fat in early lactation. Higher circulating calcium allows early lactating cows to metabolize more fat from adipose and dietary sources without compromising caloric intake facilitating the cow to attain positive energy balance sooner in lactation. These results were obtained in studies with a minimum number of experimental animals and need to be confirmed with a much larger number of observations. Furthermore, the value of this technology partly involves the impact of positive energy balance on reproduction thus necessitating even more animal observations than feeding/performance trials. The potential economic advantage of improved milk production, reduced periparturient health disorders and lesser days open all need to be accounted for to justify supplement costs and to refine the application of using prepartum anionic salts to facilitate increased rumen inert fat supplementation in early lactation high producing dairy cattle.

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