Technical Report 31

Controlling Milk Fever and Hypocalcemia in Dairy Cattle: Use of Dietary Cation-Anion Difference (DCAD) in Formulating Dry Cow Rations

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SUMMARY

Calcium metabolism of close-up dry cows and fresh cows is critical for reducing incidence of metabolic disorders. Anionic salts fed to the close-up group can reduce the incidence of milk fever, displaced abomasum, and subclinical hypocalcemia in early postpartum dairy cattle. Dairies experiencing a high incidence of milk fever or displaced abomasum would likely benefit from use of anionic salts. In addition, dairies that feed high-potassium forages, such as alfalfa hay, to dry cows may benefit from supplementing with anionic salts. Anionic salts must be used with caution, however, because they are unpalatable and can reduce dry matter intake. They should only be fed to close-up dry cows. Controlled feeding, precise ration formulation using the DCAD concept, and monitoring of urine pH are necessary to achieve success using anionic salts.

Controlling Milk Fever and Hypocalcemia in Dairy Cattle: Use of Dietary Cation-Anion Difference (DCAD) in Formulating Dry Cow Rations

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The most critical time in the life of a dairy cow is the first few days postpartum. The cow's metabolism is under severe stress as she transitions to lactation. To meet requirements for milk production, her body has a high nutrient demand. This early lactation period is when she is most susceptible to some diseases and metabolic disorders. Fresh cows commonly experience milk fever, retained placenta, displaced abomasum, and mastitis. A smooth transition from the dry pen to the fresh pen is critical to achieving high peaks and high production throughout the lactation.

Hypocalcemia (low blood calcium) resulting from inadequate calcium metabolism is common among fresh cows, and can lead to milk fever and other health disorders. This paper focuses on approaches to alleviate hypocalcemia and milk fever in fresh cows, particularly dietary manipulations during the close-up dry period. The close-up period is defined as the period from 3 weeks prepartum until parturition.

MILK FEVER

Milk fever, also known as parturient paresis, is a well-known metabolic disorder that occurs at or near calving, particularly in high producing cows. A fairly common problem, it's estimated to occur at the rate of 5-10% nationwide (Horst, 1986). Recently, the economic loss associated with milk fever was estimated at $334 per occurrence (Guard, 1996), including cost of treatment and loss in milk production. Incidence tends to increase with age and is higher in Jerseys compared to Holsteins. Cows that recover from milk fever are less productive and more susceptible to other health disorders such as ketosis, mastitis, retained placenta, displaced abomasum, and uterine prolapse.

Milk fever results from severe hypocalcemia. Most cows experience subclinical hypocalcemia after parturition, but some experience severe hypocalcemia that leads to milk fever. Normal blood calcium is 8-12 mg/dl. When blood calcium is reduced to 7.5 and 5 mg/dl, abomasal motility is reduced 30 and 70%, respectively (Daniel, 1983). This is due to the vital role of calcium in muscle contraction. Reduced abomasal motility from low blood calcium can lead to displaced abomasum.

During the dry period, calcium needs are minimal, but after parturition large amounts of calcium are exported into milk. This sudden calcium drain must be countered by increased calcium absorption from the gut or calcium resorption (mobilization) from bone. Bone is the primary source of calcium when absorption from the gut is less than required, because bone contains nearly all of the calcium stores in the body. Absorption of calcium in the gut occurs primarily in the small intestine and is facilitated by 1,25 dihydroxyvitamin D3. Calcium resorption from bone is influenced by 1,25 dihydroxyvitamin D3, parathyroid hormone, and blood calcium. As blood calcium drops, parathyroid hormone is released to enhance calcium resorption from bone. Hypocalcemia results when mechanisms of calcium absorption and resorption are insufficient to meet calcium demands. If untreated, most cows with milk fever die within a day.

Methods for treating milk fever involve elevating blood calcium. For down cows, treatment normally consists of 8-10 g intravenous calcium. Due to the role of the vitamin D metabolite 1,25 dihydroxyvitamin D3 in calcium absorption and resorption, some have recommended supplementing large quantities of vitamin D orally before calving to alleviate hypocalcemia and milk fever. Recent work (Goff et al., 1986, 1989) has suggested intravenous or intramuscular injection of parathyroid hormone may reduce incidence of milk fever. Calcium gels have been used successfully to administer supplemental calcium in hopes of elevating blood calcium. The gels are typically $CaCl_2$ or calcium propionate. $CaCl_2$ can cause ulceration of the mouth and digestive tract, induce severe metabolic acidosis, and reduce dry matter intake. Calcium propionate has the advantage of containing propionate, a readily available energy source for the cow.

LOW-CALCIUM DIETS TO PREVENT MILK FEVER

Traditionally, it was thought that feeding a low-calcium diet during the dry period would prevent milk fever. The goal was for cows to consume less than 50 g per day of calcium. To reduce calcium intake, high-calcium forages such as alfalfa were eliminated from the diet. Forages such as corn silage and grass hay were routinely used in dry cow diets to reduce calcium intake. This presents a problem for many western dairy producers who use alfalfa hay as a forage base for dry and lactating cow rations.

Calcium requirements for the dry cow are minimal (41 grams/day for a 1400 lb cow; NRC, 1989), being necessary only for maintenance and fetal skeletal development. Therefore, the dry cow has very little need for calcium beyond dietary intake. If calcium requirements are met through the diet, metabolic processes for mobilizing calcium from bone will not occur. Upon parturition and onset of lactation, there is an immediate demand for large amounts of calcium in colostrum. Intake of calcium from the diet will not meet this sudden demand, particularly because dry matter intake normally declines near parturition. Therefore, calcium must be mobilized from bone to meet calcium needs. However, if calcium intake from the diet was sufficient to meet requirements during the dry period, then mechanisms responsible for calcium mobilization are not in place. In other words, a cow that does not mobilize calcium during the dry period will have difficulty doing so when the need arrives at parturition.

Normally a day or so is required for calcium mobilization mechanisms to become effective. Often by this time, hypocalcemia and possibly milk fever already have occurred. Underfeeding calcium during the dry period promotes calcium mobilization from bone, ensuring that the metabolic processes are in place when parturition occurs. In addition, calcium absorption from the small intestine is proportionately higher when calcium intake is lower. Thus, a low-calcium diet will promote more efficient absorption of calcium from the small intestine. Enhanced calcium mobilization from bone and efficient calcium uptake from the small intestine are two reasons why milk fever may be prevented by feeding a low-calcium diet during the dry period.

Although low-calcium diets have traditionally been recommended to prevent milk fever, there are some practical problems to this approach. One is that alfalfa is the forage of choice for a large number of dairy producers. Because alfalfa is high in calcium, dairy producers must secure another forage for the dry cows. Another problem is that low-calcium diets may be difficult to achieve—even with low-calcium forages. Research has shown that dry cow diets that provided less than 10 grams/day calcium were most effective at preventing milk fever, but diets with this little calcium are very difficult to formulate.

Potassium

High-potassium forages have more recently been implicated in causing milk fever. Alfalfa, long considered suspect in causing milk fever because of high calcium levels, also has high potassium levels. In hindsight, high potassium levels may have been the cause of milk fever associated with alfalfa-based dry cow diets. Grass hay can have lower levels, but over-fertilizing with potassium on hay fields increases both soil and hay potassium levels. High soil potassium often occurs in fields where manure has been applied for many years. Some have recommended harvesting forage separately for dry cows from fields where soil potassium levels are not high. Also, potassium levels drop as forage matures. Although quality also declines as the forage matures, relatively mature forages of average quality are well suited for dry cows.

CONTROLLING MILK FEVER WITH ANIONIC SALTS

Anionic salts are simply minerals that have a high proportion of anions. Anions are ions that are negatively charged, and cations are ions that are positively charged. Living tissues maintain a balance of anions and cations to maintain neutrality. Thus, the net sum of anions and cations in a feed should be near neutral. However, certain cations and anions have a large effect on metabolic processes in the body. In particular, the cations sodium and potassium, and the anions chloride and sulfur are considered major influences on acid-base status in the body.

We can quantify the major cations and anions in the diet by calculating the difference between them—the dietary cation-anion difference (DCAD). Calculation of

DCAD is normally expressed using milliequivalents of the major cations and anions as follows:

(sodium + potassium) – (chloride + sulfur).

A negative DCAD diet contains more equivalents of anions than cations, a zero DCAD diet contains equal equivalents, and a positive DCAD diet contains more cation equivalents. To calculate DCAD in milli-equivalents per 100 g ration dry matter for a diet, the following formula is used:

[(% sodium/0.023) + (% potassium/0.039)] –
[(% chloride/0.0355) + (% sulfur/0.016)]

The purpose in determining DCAD is to estimate the influence of a diet on acid-base status of the animal. The theory is that an anionic diet (a negative DCAD) will induce metabolic acidosis and a lower blood pH. This scenario results in elevated blood calcium, although the mechanisms are not completely understood. Horst et al. (1997) suggest that metabolic acidosis increases tissue responsiveness to parathyroid hormone, thus increasing calcium resorption from bone. Horst et al. also suggest that parathyroid hormone receptors in bone are less functional at high blood pH.

Researchers from Michigan State University recommended a DCAD of -10 to -15 milliequivalents per 100 g dry matter for close-up dry cows (Davidson et al, 1995). Horst et al. (1997) summarized six studies involving anionic salts and concluded that milk fever prevention is highest when DCAD is -5 to -10 milliequivalents per 100 g dry matter.

However, a more desired approach may be to monitor urine pH of close-up dry cows to assess the impact of diet on their acid-base status. The desired effect of feeding anionic salts is to decrease blood pH, which reportedly increases blood calcium. Urine pH will drop with blood pH, therefore urine pH is an indicator of blood pH. Thus, an anionic diet should result in a lower urine pH than a cationic diet.

Table 1 illustrates the relationship between DCAD and urine pH of close-up dry cows. The desired situation is a negative DCAD diet that induces mild metabolic acidosis, normal blood calcium, and results in a urine pH between 6.5 and 5.5 in close-up cows. Horst et al. (1997) concurred, suggesting a pH between 6.2 and 5.5.

Urine pH can be monitored on the farm using pH paper or a pH meter. If urine pH is greater than 7.0, consider using anionic salts. If anionic salts are being used, urine pH can be monitored to determine their effectiveness or to prevent problems from too much anionic salt. Urine pH less than 5.5 indicates that anionic salt intake is excessive and should be reduced. Too much anionic salt can cause reduced feed intake, displaced abomasum, and kidney overload.

A ration formulated using typical forages and concentrates will always have a positive DCAD. Adding anionic salts (such as magnesium sulfate, calcium sulfate, ammonium sulfate, calcium chloride, ammonium chloride, and magnesium chloride) are the only means of achieving a negative DCAD. Only use anionic salts for close-up dry cows. Heifers should not receive anionic salts (Moore et al., 1997). In heifers, the potential drop in dry matter intake with anionic salt feeding is of greater concern than the possible benefits. Springing heifers normally have fewer problems with milk fever and hypocalcemia, so anionic salts are probably not beneficial for them. Moore et al. (1997) reported that Holstein heifers in their study were not hypocalcemic.

Although supplementing close-up dry cow diets with anionic salts can reduce the incidence of milk fever, there are potential problems that need to be considered. The problems are two-fold. First, anionic salts are expensive, significantly increasing feed costs per day for the close-up group. Second, they are very unpalatable and can reduce dry matter intake. Field reports indicate some herds have had serious health problems when fed anionic salts. In severe cases, animals died when anionic salts were misfed. The reasons for the deaths probably relate to reduced dry matter intake from feeding too much anionic salt. Significant reductions in dry matter intake near parturition can predispose animals to metabolic disorders such as displaced abomasum, milk fever, and ketosis. Dry matter intake normally declines as parturition nears, so anionic salts can further drop dry matter intake to the point where metabolic disorders arise.

Because problems can occur when anionic salts are fed, it's necessary to closely monitor the close-up pen and precisely control the feeding. A total mixed ration should be used to ensure adequate, but not excessive, intake of anionic salts. The diet should be fed free-choice with animals having access to feed throughout the day. A pre-mix of anionic salts and added calcium with a carrier such as soybean meal or ground corn is ideal. A pre-mix avoids improper mixing of anionic salts and allows changes in anionic salt content of the diet.

Feeding of anionic salts is not recommended in cases where dry matter intake is not measured or where consumption of anionic salts cannot be monitored. Anionic salts may be appropriate in herds experiencing problems with metabolic disorders such as milk fever, retained placentas, abomasal displacements, etc. Only close-up dry cows should be fed anionic salts, which necessitates at minimum two dry cow groups. Also, as previously mentioned, springing heifers should be separated from cows and fed a diet without anionic salts.

USING DCAD TO FORMULATE DIETS FOR CLOSE-UP DRY COWS

1. The first step in calculating DCAD is to have a macromineral analysis for all feeds in the diet. Wet chemistry techniques are recommended for accurate mineral analysis.

2. Select forages that are low in potassium. This will result in a lower DCAD, thus reducing the amount of anionic salts necessary to achieve desired effects.

3. Calculate DCAD using the formula presented in this paper (page 3).

4. If anionic salts are to be supplemented, start with magnesium sulfate, because it's the most palatable. Add until total magnesium is 0.4% of dry matter. Next, add calcium sulfate and/or ammonium sulfate until sulfur is 0.4 to 0.5% of dry matter. Last, add calcium chloride and/or ammonium chloride until DCAD is -5 to -15 milliequivalents per 100 g dry matter.

5. Elevate the calcium to 1.5 to 1.8% of dry matter. Negative DCAD diets increase urinary calcium excretion, so more dietary calcium is necessary to meet requirements.

6. After a week of feeding anionic salts, monitor the urine pH of close-up dry cows. If pH is above 7.0, more anionic salts can be added. If pH is 6.5 to 5.5 and dry matter intake is acceptable, then continue with the current diet. However, if pH is less than 5.5 or dry matter intake has significantly declined, remove some of the anionic salts.

When selecting anionic salts, consider the source. Some sources may have a higher bioavailability, thus increasing the likelihood of sufficient mineral absorption. Do not use sodium chloride and potassium chloride because they contribute both anions (sodium or potassium) and cations (chloride), so their effect is neutralized. When using ammonium salts, check non-protein nitrogen levels to avoid ammonia toxicity. Minimize ammonium salt in diets with more than 70-75% of its protein in the degradable form.

Table 1. Relationship of DCAD and urine pH to acid-base status of close-up dry cows and to calcium status of fresh cows (Davidson et al, 1995).

Close-up ration DCAD	Urine pH of close-up dry cows	Acid-base status of close-up dry cows	Calcium status of fresh cows
Positive	8.0 to 7.0	Alkalosis	Low blood calcium
Negative	6.5 to 5.5	Mild metabolic acidosis	Normal blood calcium
Negative	Below 5.5	Kidney overload	—

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