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Feeding the Dry Cow to Avoid Parturient Paresis

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In the past, dairy producers have regarded the non-lactating or dry period as a time when the dairy cow recuperates from the stresses of her previous lactation and prepares herself for parturition. This kind of thinking usually results in mismanagement of the dry cow since she is seen as an economic drain on the farm. Today this image is changing and through years of research and education the dry period is now considered a vital stage of preparation for the next lactation period. The dry cow should be managed and fed to prepare her for the transition from the low metabolic demand needed during the dry period to the higher metabolic demand of early lactation. If cows are not prepared properly for this transition, periparturient diseases, primarily in the form of metabolic problems, are inevitably going to occur. These problems include: milk fever, retained placenta, dystocia, uterine prolapse, ketosis, fatty liver syndrome, and displaced abomasum.

The dry period is a period, usually during the last trimester of gestation, in which the lactation is ended either abruptly or gradually by discontinuing the cow's daily milking. If a dry period is not allotted, the subsequent lactation will produce only 75% as much milk in the second lactation as a cow that has a minimum of 50 days of non-lactation before parturition. A dry period longer than 70 days, however, results in unnecessary feed costs with no increased milk production.

The non-lactating period is a period of transition where the cow must change her metabolic priorities from tissue deposition, which occurs under a positive energy balance in midgestation, to tissue utilization, occurring under a negative energy balance in early lactation. This transition begins 10 to 20 days prepartum. Along with the transition between energy states, a transition must be made from low calcium demand in the dry period to high calcium demand needed for heavy milk production. This paper will address how to feed and manage the dry cow to reduce the incidence of postparturient hypocalcemia.

Parturient paresis or milk fever is a hypocalcemic disorder that results when the body fails to maintain normal calcium levels in the plasma after the onset of lactation. At parturition a cow's colostrum contains 2.3 grams of calcium per liter. Therefore, a cow producing 10 liters of colostrum has 23 grams of calcium removed with the colostrum. This amount is about 9 times the calcium found in the entire plasma pool (2.5-3.0 grams). This incredible need for calcium causes all dairy cows, except heifers, to experience some degree of hypocalcemia during the first few days after parturition. The fact that most cows do not develop signs of milk fever, even though the majority of them are hypocalcemic, illustrates that milk fever cows have defective calcium homeostatic mechanisms.

In the hypocalcemic state, there are primarily two sources of calcium that can be tapped to increase plasma calcium; bone calcium and ingested calcium. Parathyroid hormone (PTH) and vitamin D are the two substances in the body needed to allow these two stores of calcium to be used. A decrease in plasma calcium causes the parathyroid gland to secrete PTH. PTH, within minutes, acts on the proximal tubules of the kidney to increase renal reabsorption of calcium from the glomerular filtrate. If the hypocalcemia is not corrected by this method, PTH stimulates resorption of calcium from bone by activating osteoclastic activity. The majority of calcium in the bone is in the form of calcium phosphate (CaHPO₄), which is tightly bound to organic bone collagen. When osteoclasts break down the organic bone, CaHPO₄ is released and blood calcium is elevated.

Calcium may be absorbed from the lumen of
the intestines by both passive diffusion or by active transport. The concentration of calcium in the lumen and the demand for calcium in the body determines which type of transport will occur. If the calcium levels in the intestine reach six millimoles and calcium demand is low, as in the dry period, enough calcium can passively diffuse into the extracellular fluid to meet the bodies needs. However, if the calcium demand is high, passive diffusion will not be able to account for this high demand. In these instances active transport, and subsequently Vitamin D, is necessary for enough calcium to be absorbed by the intestinal wall. Vitamin D promotes active transport of calcium through the intestinal wall and into the blood. Vitamin D occurs in two forms. Ergocalciferol (vitamin D2) is found in many forages and cholecalciferol (vitamin D3) is produced in the skin after contact with ultraviolet radiation. 25 hydroxyvitamin D (25-(OH)D) is metabolized by renal mitochondrial 1 alpha hydroxylase to 1,25 dihydroxyvitamin D (1,25(OH)2D), the active form of vitamin D. PTH increases activity of this hydroxylase enzyme. When plasma calcium levels are normal or increased, this enzyme is inactivated and renal metabolism of vitamin D does not occur. When plasma calcium is reduced, PTH increases activation of 1 alpha hydroxylase and 1,25(OH)2D is synthesized. In the blood 1,25(OH)2D contacts its intracellular receptors found in the intestinal mucosa promoting active transport of calcium through the intestinal wall and into capillary beds. The incidence of milk fever on a farm has been shown to be high when dry cows are fed rations supplying over 100 grams of calcium per day. It has been determined that a 500 kg cow needs only 31 grams of dietary calcium to meet daily maintenance and fetal demands in late gestation. With a calcium intake of over 100 grams per day, this calcium requirement can be easily met by passive absorption of calcium through the intestine. Virtually no active transport of dietary calcium through the intestinal wall or bone calcium resorption is needed. Therefore, during the dry period, PTH and vitamin D receptors become quiescent or "go to sleep". Only when severe hypocalcemia takes place in early lactation do the intestinal vitamin D receptors become utilized. During this time if intravenous calcium is not given, these cows cannot mobilize or absorb enough calcium into the blood to prevent terminal hypocalcemia.

Proper nutritional management of the dry cow is very important in preventing parturient paresis. Milk fever can be nearly eliminated if the one week prepartum dry cow ration is limited in calcium to less than 20 grams a day for one week prepartum. This diet is much lower in calcium than the NRC recommended daily requirement so calcium homeostatic mechanisms are activated before parturition and milk fever is avoided. Placing cows on a low calcium diet prevents milk fever by increasing renal production of 1,25(OH)2D without increasing vitamin D receptor activity. A diet deficient in calcium should only be fed one week before parturition. Lengthy feeding of a ration this low in calcium will exhaust calcium stores and the incidence of parturient paresis will increase significantly. Use of this tactic will prevent many of the problems associated with hypocalcemia, however, diets this low in calcium are very difficult to formulate. Many farms, especially in the midwest, use home grown forages. Most of these forages, particularly ones containing alfalfa, are high in calcium making it difficult, if not impossible, to formulate a ration with less than 20 grams of calcium available per day. Another theory recommends feeding low levels of phosphorus to reduce the incidence of parturient paresis and problems associated with it. Studies have shown that low phosphorus levels (<20 grams per day) fed with high calcium levels (>85 grams per day) virtually eliminated parturient paresis. It is thought that low levels of phosphorus in the ration result in increased intestinal binding of 1,25-(OH)2D which results in increased intestinal absorption of calcium. However, limiting phosphorus is as impractical in many situations as limiting calcium since both grain and forages are significantly high in phosphorus. A more practical method must be used to prevent milk fever from occurring. A more reliable nutritional management technique has come to the forefront of parturient paresis prevention in recent years. This technique supplements anions in the dry cow ration three to five weeks prepartum. The physiological mechanism that results from this supplementation and accounts for the reduced incidence of milk fever is very complex and highly unknown.

Anions are negatively charged ions and cations are positively charged ions. In the body, as in all solutions, electrical neutrality needs to be maintained and, therefore, a balance must be preserved between the anions and cations.
When the anions outnumber the cations in the blood, H⁺ concentration must increase in order to maintain neutrality. When the H⁺ concentration is higher than that of water an acidotic state results with a pH of less than 7.0. If cations outnumber anions in the blood, H⁺ concentration is reduced and an alkalotic state results with a pH greater than 7.0. Although this explanation is quite simplified it tells us that if more anions than cations are taken into the blood an acidosis is created. This will be a key concept in understanding the use of anionic salts in preventing milk fever.

The ions most important in the acid/base balance are the cations: sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), and the anions chloride (Cl⁻), sulfur (S⁻²), and phosphorus (P⁻³). Nutritionists use an equation to determine the cation/anion difference in a given ration expressing the difference in milliequivalents. The equation: meq(Na⁺ + K⁺) - (Cl⁻ + S⁻²) is the accepted equation, however, it does have limitations. 4 This equation is simplified in that it only recognizes ions that are most easily absorbed by the intestines. The ability of ions to affect the acid base balance in the body is determined by efficiency of intestinal absorption. Na⁺, K⁺, and Cl⁻ have intestinal absorption rates exceeding 90%, while S⁻² has only a 60% absorption rate. Calcium, Mg²⁺, and P⁻³ all have lower absorption rates and, therefore, are not considered in this equation. 9

The anion/cation difference in the dry cow ration has been shown to be extremely influential on the incidence of milk fever. Most prepartum rations are primarily based on forages. Most forages are high in cations, especially K⁺, and dry cow diets that are high in cations have been found to induce parturient paresis. 7 Studies have shown that cows fed high cation diets significantly reduce plasma 1,25(OH)₂D levels and bone calcium resorption activity. 7 The kidneys and the bones become refractory to PTH when an alkalotic state is made with a highly cationic diet. If anions are added to the ration, or cations are removed, a negative cation/anion difference is made and the incidence of milk fever is reduced. 8

In one study hydroxyproline was used as a marker of activity of PTH because hydroxyproline is released when osteoclastic activity and bone resorption is taking place. When cows were fed a negative cation/anion difference the serum levels of hydroxyproline increased. 8 Reports have also shown that cows fed anionic diets have higher plasma Ca²⁺ concentration and higher 1,25(OH)₂D concentration. 8 It does not appear that increased renal calcium conservation is the cause of the increased Ca²⁺ concentration in the blood since urinary calcium is increased in cows fed anions. 8 Therefore, it appears that adding anions to the diet restores the ability of tissues to respond to PTH. The kidneys respond by generating more 1,25(OH)₂D and the bone responds by increasing osteoclastic activity and bone resorption. 7

In light of all these facts, anion supplementation in the feed is a very effective method to reduce the milk fever incidence in a herd. Calcium restriction and anionic supplementation should not be used together, however. When calcium was restricted and anions were fed prepartum, the incidence of milk fever went up. 11 The reason for this is unknown. When anions are fed, the calcium intake should be maintained at high levels of 120 to 150 grams per day.

The best sources for anions are anionic or acidifying salts. A salt is considered acidogenic only if the anion is preferentially absorbed over the cation. 8 For example, NaCl is not an acidifier because Na⁺ is absorbed just as efficiently as the anion Cl⁻. On the other hand CaCl₂ is considered an anionic salt because Cl⁻ is absorbed much more efficiently than Ca²⁺. The salt used in each ration is determined by palatability, availability, cost, and the feeding system used. Some commonly used salts are magnesium sulfate (MgSO₄·7H₂O), calcium sulfate (CaSO₄·2H₂O), calcium chloride (CaCl₂·2H₂O), ammonium chloride (NH₄Cl), and ammonium sulfate ((NH₄)₂SO₄). These salts, along with others, are generally available at feed mills. The cost of feeding these at the suggested levels for the recommended three to five weeks prior to parturition is $5 to $8 per cow. 11 The estimated cost of each salt is listed in Table 1. 3 This cost is minimal when considering the increased production, decreased veterinary care, and decreased incidence of milk fever and it's related diseases.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Cost/100 (eqv)</th>
<th>Na %</th>
<th>Ca %</th>
<th>Mg %</th>
<th>S %</th>
<th>Cl %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Sulfate</td>
<td>39.4</td>
<td>7.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium Chloride</td>
<td>20.7</td>
<td>11.2</td>
<td>34.96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium Sulfate</td>
<td>9.8</td>
<td>9.76</td>
<td>13.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Chloride</td>
<td>4.4</td>
<td>26.2</td>
<td>66.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>3.6</td>
<td>27.2</td>
<td>48.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Sulfate</td>
<td>2.6</td>
<td>21.2</td>
<td>24.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Sulfate</td>
<td>1.9</td>
<td>23.2</td>
<td>18.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1

Iowa State University Veterinarian
Formulating a diet including anions is relatively easy. Dr. Jesse Goff has outlined steps in adjusting the cation/anion difference in a dry cow ration. The cation/anion difference (CAD) should be brought down to 0 meq or less to reduce the incidence of milk fever. If greater than 300 meq of anions per kilogram of diet must be added, dry matter intake is reduced significantly and fatty liver syndrome is the possible consequence. Therefore, the dry cow diet CAD should be no greater than +200 meq/kg for anionic salt supplementation to be considered. The K+ level in alfalfa generally determines the CAD of the ration because it varies tremendously.

With this in mind, the first step in adjusting the dry cow diet is to have the diet analyzed for Na+, K+, Cl-, S²-, Ca²⁺, Mg²⁺, and P⁻³. The CAD should be determined from this by using Table 2 as will be illustrated later in the text. If the CAD is greater than +200 meq a feedstuff lower in K+ should be substituted for the forage that is being used at the present.

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Weight(g)</th>
<th>Equivalent Weight(g)</th>
<th>Factor To Convert From% To meq/kg diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>23.0</td>
<td>23.00</td>
<td>435</td>
</tr>
<tr>
<td>K⁺</td>
<td>39.1</td>
<td>39.10</td>
<td>256</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>40.1</td>
<td>20.05</td>
<td>499</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>24.3</td>
<td>12.20</td>
<td>823</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>35.5</td>
<td>35.50</td>
<td>282</td>
</tr>
<tr>
<td>S⁻</td>
<td>32.1</td>
<td>16.50</td>
<td>624</td>
</tr>
<tr>
<td>P⁻</td>
<td>31.0</td>
<td>10.33</td>
<td>968</td>
</tr>
</tbody>
</table>

The second step is to take any added sources of cations out of the diet. Sodium bicarbonate and calcium carbonate, which are both used commonly in prepartum diets are cationic salts and they should be removed. NaCl blocks should also be removed.

The third step is to add calcium sulfate (CaSO₄·2H₂O) to the diet. Add enough to achieve a dietary sulfur of 0.45% or until the calcium supplied is 140 g/day. If 0.45% sulfur cannot be reached using CaSO₄ then use magnesium sulfate (MgSO₄·7H₂O) to increase the sulfur and use calcium chloride (CaCl₂·2H₂O) to bring calcium to 140 g/day. Calcium chloride, however, seems to be very irritating to the respiratory tracts of workers in feed mills. If a better way to handle the salt is not achieved, feed mills may stop supplying it and a different source of calcium, such a limestone, may need to be used to increase the calcium levels.

The fourth step is to add ammonium chloride (NH₄Cl) to reduce CAD to -100 meq/kg of diet. This salt is chosen because the chloride is well absorbed by the gastrointestinal tract and the NH₄⁺ is either metabolized or is trapped in the rumen. The ammonia salts are not very palatable so they are eaten best if given in a TMR or given with distillers grains.

The final step is to keep phosphorus intake low, or 30 to 60 g/day. Even though phosphorus is an anion, it has been shown to inhibit the ability of the cow to produce 1,25(OH)₂D. A good way to monitor whether the diet that has been formulated is working is to monitor the pH of the urine. If a CAD of 0 or less is achieved the urine pH may decrease to between 6.0 and 7.3 and the incidence of milk fever should be reduced.

EXAMPLE OF DRY COW RATION FORMULATION: 75% alfalfa and 25% corn silage ration. Assume 9 kg/day dry matter intake. Feed analysis for ions is done on dry matter basis and fed as a total mixed ration. (ex: alfalfa at 0.15% Na⁺ is 75% of the total ration, therefore, (0.15%)(75%)= 0.11% of Na⁺ in ration contributed by alfalfa. Corn silage at 0.03% Na⁺ is 25% of the total ration, therefore, (0.03%)(25%)= 0.0075% of Na⁺ in ration contributed by corn silage. Total Na⁺ in the ration is then 0.12%. (0.11% + 0.0075%). These calculations are continued in Table 3.

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<table>
<thead>
<tr>
<th>% in feed</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Cl</th>
<th>S</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>alfalfa</td>
<td>0.1</td>
<td>1.93</td>
<td>1.51</td>
<td>0.30</td>
<td>0.76</td>
<td>0.35</td>
<td>0.26</td>
</tr>
<tr>
<td>corn silage</td>
<td>0.03</td>
<td>1.15</td>
<td>0.35</td>
<td>0.23</td>
<td>0.18</td>
<td>0.12</td>
<td>0.28</td>
</tr>
<tr>
<td>total ration</td>
<td>0.12</td>
<td>1.73</td>
<td>1.22</td>
<td>0.28</td>
<td>0.61</td>
<td>0.29</td>
<td>0.26</td>
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<tr>
<td>conversion factor</td>
<td>435</td>
<td>256</td>
<td>499</td>
<td>823</td>
<td>282</td>
<td>624</td>
<td>645</td>
</tr>
<tr>
<td>meq/kg diet</td>
<td>52.2</td>
<td>442.9</td>
<td>608.8</td>
<td>230.4</td>
<td>172.0</td>
<td>181.0</td>
<td>167.7</td>
</tr>
</tbody>
</table>

STEP I: The CAD is figured by the equation 
(Na⁺ + K⁺) - (Cl⁻ + S²⁻): (52.2 + 442.9) - (172 + 181) = +142.1 meq/kg diet.

This is not greater than +200 meq/kg so this herd can be helped by adding anionic salts.

STEP 2: The herd is not on any other sources of cations such as sodium bicarbonate or NaCl, however, if the ration did
contain these salts they should be removed.

STEP 3: Add CaSO\(_4\) \(2\)H\(_2\)O to bring sulfur content to .45% from .29%.

4.5 g/kg - 2.9 g/kg = 1.6 g/kg diet

Therefore, add 1.6 grams s-2 per kilogram of diet. CaSO\(_4\) \(2\)H\(_2\)O is 18.6% S\(^-2\) so adding 8.6 grams CaSO\(_4\) per kg diet will add 1.6 grams of S\(^-2\).

\[
\text{8.6 grams CaSO}_4 / \text{kg diet} \\
\text{(18.6% S}^-^2\text{)(X g CaSO}_4\text{)} = 1.6 \text{ g S}^-^2\text{/kg} \\
X = 8.6 \text{ grams CaSO}_4 / \text{kg diet} \]

CaSO\(_4\) \(2\)H\(_2\)O is 23.2% calcium so we have added 2 g Ca\(^{2+}\)/kg.

\[
\text{(8.6 g CaSO}_4\text{)(23.2% Ca}^{2+}\text{)} = 2 \text{ grams calcium} \\
\text{This raises calcium from 1.22% to 1.42%. If dry matter intake is 9 kg/day, the 1.42% calcium supplies 127 grams of calcium per day. We need to bring the diet to 140 grams Ca}\^{2+}/\text{day so we need to add 13 g Ca}^{2+}/\text{day or 1.4 g Ca}^{2+}/\text{kg of diet. CaCl}_2 \text{ 2H}_2\text{O is 27.2% calcium, therefore, we need to add 5.1 g/kg of CaCl}_2 \text{ 2H}_2\text{O to the diet. This is 1.55% Ca}^{2+}.} \\
\text{(27.2% Ca}^{2+}\text{)(X g CaCl}_2\text{/kg)= 1.4 grams Ca}^{2+}/\text{kg} \\
X = 5.1 \text{ g CaCl}_2 / \text{kg diet} \]

Since 48.3% of the CaCl\(_2\) 2H\(_2\)O is Cl\(^-\) then we are adding 2.46 grams of Cl\(^-\) per kg of diet.

\[
\text{(5.1 g CaCl}_2/\text{kg})(0.483)=2.46 \text{ g Cl}^-/\text{kg diet} \\
\text{Adding 2.46 grams of Cl/kg of diet changes the dietary Cl}^- from 0.61 to 0.86, therefore the new CAD is as follows in Table 4.}

<table>
<thead>
<tr>
<th></th>
<th>% in feed</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Cl</th>
<th>S</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion Factor X</td>
<td>435</td>
<td>256</td>
<td>499</td>
<td>823</td>
<td>282</td>
<td>624</td>
<td>645</td>
<td></td>
</tr>
<tr>
<td>meq/kg diet</td>
<td>52.2</td>
<td>442.9</td>
<td>773.0</td>
<td>230.4</td>
<td>242.5</td>
<td>281.0</td>
<td>167.7</td>
<td></td>
</tr>
</tbody>
</table>

CAD = -25.6 meq/kg diet

STEP 4: Using NH\(_4\)Cl we now add 71.6 meq Cl\(^-\)/kg diet to bring CAD to -100 meq/kg diet.

Adding 71.6 meq Cl\(^-\)/kg increases the dietary Cl\(^-\) by 0.25% or 2.5 g/kg.

\[
\text{(71.6 meq/kg/282= 0.25% or 2.5 g Cl}^-/\text{kg}) \\
\text{282= conversion factor for Cl}^- \\
\text{Therefore, since NH}_4\text{Cl is 66% Cl}^- \text{we need to add 3.9 g NH}_4\text{Cl/kg of diet to make the} \]

CAD - 100 meq/kg diet.

\[
\text{(66% Cl}^-)(X \text{ g NH}_4\text{Cl/kg)=2.5 g Cl}^-/\text{kg} \]

\[
X = 3.8 \text{ g NH}_4\text{Cl/kg diet} \]

STEP 5: The phosphorus levels in this ration are lower than suggested at 23.4 g/ day, so it will not reduce the 1.25(CH)_3D production. This level should be sufficient for the herd.

SUMMARY: This diet requires 8.6 g CaSO\(_4\)-2H\(_2\)O/kg, 5.1 g CaCl\(_2\)-2H\(_2\)O/kg, and 3.9 g (NH\(_4\))Cl/kg diet to bring the CAD to a suggested -100meq level. This addition of anions should not harm dry matter intake significantly because only 242 meq had to be added.

We have demonstrated dry cow feeding strategies to prevent milk fever. Since limiting Ca\(^{2+}\) and P\(^{3-}\) is very difficult to do in the dry cow ration, supplementation of anionic salts seems to be the most practical method of achieving lower incidence of milk fever. Since this feeding technique is relatively new, difficulties in the plan may come up and some adjustments may have to be made to perfect the technique. However, feeding anionic salts seems to be the trend of the future and with salt costs as low as they presently are, dairy farmers stand to benefit economically from this new discovery in parburiert pareisis prevention.

References


"Pepper" - Deb Sime

"Bo" meets the "Great Pumpkin" - Alicia Konsella