Feeding and Lameness Relationships

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Laminitis is an inflammation in the hoof area causing disrupted blood flow to the corium. Inflammation of the laminae can compromise blood supply and nutrient delivery to the keratin-producing cells that affects horn tissue quality. Several potential causes of laminitis can be found in research reports and field observations.

- Excessive rumen fermentable carbohydrates can lead to volatile fatty acids that can lead to higher levels of lactic acid (strong acid dropping rumen pH) and an increase in rumen fluid osmolality.

- Blood histamine is increased after the death of gram-negative bacteria releasing endotoxin-causing blood pooling in the claw. Coliform bacteria may thrive releasing endotoxins and amides. Protein degradation in the rumen also could contribute histamine production.

- Rumen acidosis produces a toxin with activates a metalloproteinase (MMP) that breakdown bonds between the epidermis of the hoof wall and soft tissue in the corium leading to sole ulcers and white line abscesses.

- A lack of fat cushion that is a complex structure composed of adipose tissue located under the distal phalanx. This structure reduces compression of the corium tissue.

Subacute rumen acidosis (SARA) continues to be a factor in hoof disorders as it can lead to laminitis (Hutjens, 2008). Factors that can lower rumen pH below 6 include high levels of rumen fermentable starch and sugars , unsaturated fatty acids (PUFA), high dry matter intakes shifting rate of passage and availability of nutrients, slug feeding of grain (over 2.2 to 3.2 kg of dry matter per meal), forages lower in natural buffering capacity (such as corn silage), forages that are processed too short reducing cud chewing (less than 18 mm), wet rations (over 55 percent moisture), high quality pasture (lack of functional fiber), empty feed bunks (over two hours resulting in engorgement of feed), and feed sorting (allows dairy cows to consume high levels of fermentable carbohydrates). A suboptimal transition program can lead to rumen acidosis and risks as dry cows consuming high fiber rations are moved to rations containing higher levels of grain and less forage. This can lead to hoof disorders observed 100 days after calving.

Related feeding factors, feed related factors, and recommended nutrient levels to minimize the hoof risk are summarized are listed below. More than one feeding factor may contribute to a herd hoof problem.

Starch and sugar leads to greater dry matter intake and increase in VFA production. These carbohydrates can shift fermentation from fiber digestion and increase levels of propionic and lactic acids. Grain particle size (finely ground less than 500 microns), grain processing (steam flaking or high moisture grain over 28 percent moisture), and starch source (wheat grain vs. corn grain) impact the rate of rumen fermentation. Sugars have faster rates of rumen fermentation (found in high quality pasture for example). Suggested starch levels in the total ration dry matter is 24 to 28 percent starch and 5 to 7 percent sugar in the total ration dry matter.

Protein quality and quantity can affect hoof hardness. High levels of degradable protein and total protein may lead to rumen fermentation products that can affect foot health. Balance rations based on metabolizable protein requirements using a rumen modelling program to avoid excessive nitrogen while meeting amino acid needs for milk yield.

Physically effective fiber maintains a rumen forage raft to optimize rate of passage and normal rumination (over 450 to 600 minutes of cud chewing activity per day). Rumen pH should be maintained above 6.0 related to saliva production rich in sodium bicarbonate (rumen buffer at a pka 6.25). Two kilograms of forage particles over 25 millimeters in length, 21 percent forage NDF, or 19 to 21 percent effective NDF are suggested minimum levels. Rumination collars can measure on-farm cow cud chewing time and Penn State particle box to evaluate feed particle size can be effective tools to use on dairy farms to evaluate effective fiber. Milk fat test may not be an effective tool to evaluate physically effective fiber.

Unsaturated fats and oils can reduce fiber digestion, shift VFA patterns, or lower rumen pH depressing fiber digesting bacteria. Unsaturated fatty acid can be changed to CLA (conjugated linoleic acids) forms of the fatty acid lowering milk fat test. Limit added vegetable oil to 2.5 percent as oilseeds, free oil (not contained in the oil seed cell) to 225 gram per cow per day, and/or fish oil to 50 grams per day. Feeding rumen inert fat sources reduce rumen fermentation changes. Total levels of PUFA should be under 500 grams per cow per day**.** Keep total ration ether extract below six percent of the ration dry matter.

Copper is needed for synthesis and maintenance of elastic tissue such as tendons. Copper can affect the claw by increasing the production of a copper enzyme, thiol oxidase, increasing hoof hardness through disulfate bonds in keratin. Immunity and antioxidant activity by superoxide dismutase need copper for cell membrane protection. Cattle deficient in copper were more susceptible to heel, foot rot, and sole abscesses. Suggested level of total copper in the ration dry matter is 10 to 15 ppm (one third from organic copper sources and two thirds from inorganic copper sources). If molybdenum is over 1 ppm, higher levels of supplemental copper will be needed***.***

Manganese is needed for normal bone density and joint structure. It is required for chondroitin sulfate synthesis in its role in joint cartilage. Manganese has a role as a superoxide scavenger decreasing free radical leading to oxidative damage. Suggested level of manganese is 40 to 60 ppm with one third from organic sources.

Sulfur is needed for sulfur containing amino acids synthesized by rumen bacteria (requires a ratio of 10 to 12 parts nitrogen to one part sulfur), vitamins (biotin and thiamine), and chondroitin sulfate. Harder hooves have been reported with added sulfur by strengthening associated protein bond. Suggested levels of total sulfur is 0.25 to 0.28 percent in the total ration dry matter.

Zinc is a component of over 300 enzyme systems and improves claw integrity through wound healing, epithelium maintenance, and keratin synthesis and maturation. Synthesis of collagen, keratin, and related protein-keratin compound require zinc for enzyme function. Pasture zinc levels vary with lowest levels in the spring lush growth period. Recommended zinc levels in the total ration dry matter is 40 to 60 ppm (one-third organic zinc sources).

Calcium, phosphorous, and vitamin D contribute to bone formation and skeleton soundness. Suggested ration levels for calcium vary from 0.65 to 0.80 percent, phosphorous guidelines are 0.38 percent and 25000 to 35,000 IU of added vitamin D in the total ration dry matter.

Vitamin A is important for epithelial skin and bone health. A deficiency can result in inflammation of the coronary band of the hoof. Suggested supplemental levels of vitamin A range from 75,000 to 100,000 IU per cow per day.

Biotin is needed for keratin formation and claw horn development leading to foot disorders during deficiencies in cattle and horses. Biotin can increase milk yield by 2.0 to 2.5 kg. Milk production increases were not related to hoof improvement due to the immediate milk response. The mechanism for higher milk yield may be related to its metabolic vitamin B function while added biotin requires 6 to 12 months to observe a hoof response. The recommended level of biotin is 20 mg per day.

Feed additives

Sodium bicarbonate, sodium sesquicarbonate, and/or potassium carbonate are rumen buffers that maintain an optimal rumen pH. Potassium carbonate is used during heat stress to maintain feed intake and replace lost potassium. Suggested levels of sodium bicarbonate or sodium sesquicarbonate are 0.75 to 1 percent of total ration dry matter. Potassium and sodium buffers are added to raise the dietary cation-anion balance to a positive 400+ meq/kg during heat stress.

Direct fed microbial (DFM) or probiotics include yeast products and live bacteria that can reduce lactic acid levels in the rumen, increase fiber digestion, and/or stabilize the rumen environment. Check DFM products for controlled research results as numerous commercial products are available with different bacterial combinations.

Monensin reduces lactic acid levels in the rumen while lowering ketosis risk in transition cows that can maintain feed intake and meet nutrient needs. Monensin can also lead to smaller and more meals per day that reduces shifts in the rumen environment based on feedlot data.

Body condition scores are positive associated with digital cushion thickness (DCT) which can provide cushion to the hoof support structure. Cows with the highest DCT score/thickness had 15 percent lower lameness score compared to the lowest DCT scored cows. The DCT continued to drop after parturition reaching a nadir at 120 days after calving. Dairy managers need to monitor changes in BCS after calving minimizing BCS losses to less than 0.5 point (on a 1 to 5 scale).

Transition ration feeding program can cause a buildup of VFA and lactic acid as rations are shifted to higher fermentable carbohydrates. Changing rumen bacteria and reduced rumen VFA absorption can be risks. Stepping up ration nutrient concentration from far off to close up ration to fresh cow ration and to high group rations may allow rumen environment adaptation. Greater risk occurs when higher dry matter intakes occur after calving.

Heat stress can lead to a drop in rumen pH values by 0.2 point (for example from 6.0 to 5.8 units) as experience respiratory acidosis and a drop in blood carbon dioxide and bicarbonate. Cow related factors include lower and variable dry matter intake due to heat stress, a decrease in rumination as cows may be panting, more sorting of feed, and shift of blood flow to the surface area of the cow for heat transfer. Dairy managers may also shift ration ingredients increasing concentrate feeding, lower forage and fiber levels, and added fats/oils that can affect rumen fermentation. Increased the DCAD to over +400 meq/kg of ration dry matter can be effective.

References.

Bicalho, R.C. 2011. Lameness in dairy cattle: a debilitating disease or a disease of debilitated cattle? Western Dairy Management Conference Proceedings. pp. 73-82.

Hutjens, M.F. 2008. Feeding Guide. W.D.Hoard Book Company. ISBN 0-932147-53-4. Fort Atkinson, WI. 3rd edition.

Hutjens, M.F. 2004. Feeding for productive live. Four State Dairy Nutr. and Mgmt Conf. Proc. pp. 128-134.

Larson, C., D. Tomlinson, M. Brainine, C. Mulling, D Dorpfer, and T. Edwards. 2014. Cattle lameness—identification, prevention, and control of claw lesions. Zinpro Corporation. 1st edition. ISBN: 978-0-692-21409-1.

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. National Academy Press. Washington, D.C.

Santos, J.E. and M.W. Overton. Diet, feeding practices, and housing can reduce lameness in dairy cattle. pp. 145-161.

Schearer, J.K., M.F. Hutjens, and M.I. Endres. 2017. Minimizing lameness. In Large Dairy Herd Management. 3rd ed. E-book.

Shaver, R. D. 2005. Feeding to minimize acidosis and laminitis in dairy cows. Western Dairy Management Conference Proceeding. pp. 157-16

Table 1. Illinois nutrient recommendations for dairy cows in different stages of lactation and gestation.

	Dry Cow Early	Dry Cow Close-up	Fresh 0 to 21d	Milk Cows Early 22 to 80d	Milk Cows Middle 80 to 200d	Milk Cows Late >200d
DMI (lbs)	30	22	>35	53	48	44
Crude Protein(CP)%	12	Cows 12 – 13 Heifers 14 – 15	19	18	16	14
Metabolizable Protein (%)	6.0	8.0	13.8	11.6	10.2	9.2
*RDP:% of CP (DM)	70 (8.4)	60 (10)	60 (11.4)	62 (11.2)	64 (10.2)	68 (9.5)
RUP:% of CP (DM)	30 (3.6)	40 (5)	40 (7.6)	38 (6.8)	36 (5.8)	32 (4.5)
SIP:% of CP(DM)	35 (4.2)	30 (4.5)	30 (5.7)	31 (5.60	32 (5.10	34 (4.8)
TDN%	60	67	75	77	75	67
NE_L(Mcal/lb)	0.63	0.69	0.78	0.80	0.78	0.69
Ether Extract %	2	3	4	5.0	5	3
ADF%	30	24	21	19	21	24
NDF%	40	35	30	28	30	32
Starch%	12	15	24	25	22	19
Major Minerals in % of DM						
Calcium (Ca)	0.60	0.7 (*1.0)	1. 0	0.90	0.70	0.60
Phosphorous (P)	0.26	0.30	0.40	0.38	0.36	0.32
Magnesium (Mg)	0.16	0.4	0.33	0.30	0.25	0.20
Potassium (K)	0.65	0.65	1.00	1.00	0.90	0.90
Sodium (Na)	0.10	0.05	0.33	0.30	0.20	0.20
Chlorine (Cl)	0.15	0.15 (*0.8)	0.28	0.25	0.25	0.25
Sulfur (S)	0.16	0.2 (*0.4)	0.25	0.25	0.22	0.22
**When anionic salts are used: mineral/anionic salts (%)*						
Vitamins in IU per Day						
Vitamin A	100,000	100,000	100,000	100,000	50,000	50,000
Vitamin D	25,000	30,000	30,000	25,000	20,000	20,000
Vitamin E	1,000	2,000	2,000	1,000	600	400

a. Trace minerals: iron (150 ppm), cobalt (0.1 ppm), copper (15 ppm), manganese (60 ppm), zinc (60 ppm), iodine (0.6 ppm), and selenium (0.3 ppm).
b. Ratio of minerals in total ration: zinc to copper 4:1, iron to copper 40:1, potassium to magnesium 4.5:1, copper to molybdenum 6:1, potassium to sodium 3:1, nitrogen to sulfur 11:1