



The Role of Trace Minerals in Bovine Claw Horn Quality and Lameness

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Abstract

The nutrition program of the dairy can have a significant impact on the incidence of laminitis. Providing cows with adequate amounts of fiber, the proper amounts of rumen fermentable carbohydrates and the proper quantity and quality of protein can minimize incidence of lameness. Meeting the micronutrient requirements of the dairy cow requires not only knowledge of the animal's requirements, but also factors affecting the availability of micronutrients. Feeding vitamins including biotin and complexed trace minerals that are research proven are means to minimize the risk of animals developing subclinical micronutrient deficiencies that compromise claw integrity.

Modern dairy production in Iran looking for new scopes of increasing milk production, decreasing culling rate, improving fertility and other dairy indices. A growing pattern of milk production in Iranian dairy industries is obvious through past three years as most industrial dairy farms got the average production of more than 31 liters/cow/day and higher that is the case in other countries as well. Milk yields per cow in United States increased annually as reported by the USDA National Agricultural Statistics Service. Average production per cow in the United States reported in 1975 was 5180 kg as compared to 7105 kg in 1988.

Much of this increase in milk production is due to better nutrition and feeding, overall management practices and the genetic improvement of the cow population. Advances in technology and research have had major impacts on dairy management practices and performance of dairy cattle. With higher levels of milk production, there is a continuing

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increase in the requirements for energy, protein, fiber, minerals and vitamins. Also, just as important as the nutritional needs of high producing cows are the various management strategies needed to achieve and maintain those higher levels of milk production. In short, the many scientific discoveries and advances in technology that are continually taking place are exciting and challenging to those managing dairy farms today. Total management becomes the objective when striving for efficiency and profitability. This is accomplished by understanding the different phases of lactation and how to cope with each phase in order to maximize performance.

Proper feeding and good balanced rations remains the cornerstone of a successful dairy operation. Milk yield per cow and the cost of feed to produce milk have by far the greatest influence on profitability in a dairy operation. If a dairy is to be successful, the dairymen must continually strive to adopt practices that allow the greatest output of milk at the most economical cost. Successful dairying in the future will depend on high levels of milk production, culling for low production, controlling feed costs, and using good replacements. Regarding to increasing the price of foodstuffs beside other dairy facilities, balancing the cost benefit equation of the dairy farms is more difficult than previous years and producers should get benefit from modern science and technologies to improve the efficiency of the management and husbandry process. Constant relation of the nutritional disorders has been reported repeatedly as is the case in most dairy farms in Iran. High concentrate ratios (up to 18 kg a day) make SARA (subacute ruminal acidosis) besides all of its complications an important condition. Also heat stress occurs in most parts of Iran as reduction in production indices is a constant finding after hot summer months. Good Nutritional program beside other management practices not only can increase milk production but also minimize some conditions and with providing sufficient nutritional elements and minerals, fulfill physiological demands of the body for high production.

Growing production made so many problems including increasing rate of culling, digital disorders, decreasing fertility rate of the herds and obstetrics indices that make the owners to look for new technologies and strategies for preventing these conditions. List of the main causes of dairy cattle culling in the world, shows that lameness has the third place after infertility and mastitis. This ranking in Iran is somehow different in certain areas with different management and climatic conditions. As still some infectious diseases like paratuberculosis and leucosis are at the top of the list but except infectious diseases, in Iran like other countries lameness following infertility and mastitis got the third place in the list of culling causes.

Lameness is a multifactorial disease, as nutrition, environment and management play a role in its pathogenesis. A successful control program should target all risk factors that have been reviewed previously²¹⁻²⁶.

Proper mineral and vitamin supplementation in dairy cattle feeding programs is essential to animal health and performance. Optimum feeding of the animal means that the individual nutrients such as vitamins and minerals must be supplied in the right quantities and proportions, since interactions between individual substances may influence their availability and utilization. The functional integrity of hoof horn essentially depends on a proper differentiation, i.e., keratinization of hoof epidermal cells. Keratinization of hoof epidermis is controlled and modulated by a variety of bioactive molecules and hormones. This process is dependent on an appropriate supply of nutrients, including vitamins,

minerals, and trace elements. Regulation and control of differentiation and nutrient flow to the epidermal cells play a central role in determining the quality and, consequently, the functional integrity of hoof horn. Decreasing nutrient supply to keratinizing epidermal cells leads to horn production of inferior quality and increased susceptibility to chemical, physical, or microbial damage from the environment. A growing body of evidence suggests that hormones, vitamins, minerals, and trace elements play critical roles in the normal development of claw horn and correct keratin formation³⁸.

The following part is extracted from a review by Michael Socha et al. from Zinpro Corporation³⁶.

Relationship Between Trace Minerals and Claw Integrity

Iodine: Among the signs of a subclinical iodine deficiency is a suppressed immune system resulting in increased incidence of foot rot and respiratory diseases³². There have been several studies conducted that showed a benefit of feeding iodine in the form of ethylenediamine dihydriodide (EDDI) in excess of the nutritional requirement to prevent foot rot¹⁹. Only 8.3% of calves on pasture fed a salt mixture containing EDDI had foot rot, while 20.8% of calves receiving a salt mixture without EDDI had foot rot¹⁶. When cattle were inoculated intradermally in the interdigital space with a mixture of *Fusobacterium necrophorum* and *Bacteriodes melanigenicus* to induce acute foot rot, cattle receiving 12.5-200 mg/animal/day of EDDI had less lameness than control cattle.

A series of studies addressing iodine supplementation in feedlot diets have concluded³¹: 1) iodine has direct antibacterial properties, but achieving this level would be toxic to cattle; 2) serum iodine concentrations of 60-80 µg/dl are thought to be prophylactic; and 3) cellular immune response is improved by feeding EDDI and iodate.

Feeding 0.11 mg/kg BW/d of EDDI has been found to be correlated with serum iodine concentrations of 20-80 µg/dl and found to be effective in preventing foot rot in cattle¹⁷. However, the maximum legal limit for EDDI in the United States is 10 mg/head/d. The required dietary content of iodine for dairy cattle ranges between 0.3 and 0.9 ppm, depending upon stage of the life cycle²⁸. Soybean, rapeseed and canola increase iodine requirements of the animal as they contain goitrogenic compounds that reduce iodine availability³². High dietary nitrate also inhibits uptake of iodine by the animal³².

Selenium: It has been reported that placental retention, metritis and mastitis predisposes dairy cows to foot problems. Feeding vitamin E and selenium have long been associated with reducing incidence of retained placentas and uterine infections. However dairy producers need to be aware that over supplementation of selenium can also result in increased incidence of lameness. Symptoms of chronic selenium toxicity include lameness, sore feet, deformed claws and loss of hair from the tail³².

A study conducted at the University of Nebraska illustrates the effect of oversupplementing selenium on incidence of foot problems. In the study, only 28% of cows fed no supplemental vitamins and 30% of cows receiving supplemental vitamins A, D and E had severe claw problems¹⁴. In contrast, 48 and 69% of cows receiving 50 mg of injectable selenium with and without supplemental vitamins A, D and E, respectively, had severe claw problems¹⁴. The maximum legal limit for selenium supplementation in the United States is 0.3 ppm²⁸. Calcium, copper, zinc and sulfur reduce the absorption of selenium deficiency³².

Zinc: Zinc is an essential component of numerous enzyme systems. The metabolic actions of these systems include carbohydrate and energy metabolism, protein synthesis, nucleic acid metabolism, epithelial tissue integrity, cell repair and division, and vitamin A transport and utilization²⁸. In addition, it plays a major role in the immune system and certain reproductive hormones²⁰.

It is theorized that zinc improves claw integrity by speeding wound healing, increasing rate of epithelial tissue repair and maintaining cellular integrity. Zinc is also required for the synthesis and maturation of keratin³⁵.

On dairies with high incidence of foot problems, cows fed 2 to 3 g/d of zinc sulfate for 70 days had fewer claw problems than cows not receiving supplemental zinc⁴⁰. In contrast, sheep fed rations containing zinc sulfate for up to six months did show a reduction in claw problems⁷. The lack of a consistent response to feeding inorganic zinc can be attributed to antagonists present in the diet reducing the bioavailability of inorganic zinc. Complexed sources of zinc such as zinc methionine have been proven to be more bioavailable than zinc from inorganic sources⁴¹.

Several studies have shown that zinc methionine improves claw integrity. In a yearlong study conducted at Illinois State University, cows fed zinc from zinc methionine had fewer cases of heel cracks, interdigital dermatitis and laminitis than cows not fed zinc methionine (Table 2)²⁷. Also, incidence of foot rot, sole ulcers and white line disease tended to be reduced²⁷.

Researchers at Kansas State University found that feeding zinc methionine also improved claw quality of crossbred steers grazing native grass⁵. Of cattle receiving 216 mg per day of zinc from zinc methionine, 2.45% had foot rot while 5.38% of cattle not receiving zinc methionine had foot rot⁵. The reduction in foot rot may have partially contributed to higher average daily gain for cattle fed zinc methionine (2.80 lb. vs. 2.71 lb.)⁵.

At the University of Missouri, sheep fed 80 mg per day of zinc from zinc methionine had a reduction in mean lesion scores per foot⁴. Feet were scored for lesions on a scale of 0 to 3, with 0 being no lesions and 3 being undermining of the wall⁴. Sheep fed zinc methionine had a 43% improvement in foot lesion scores, while control sheep had no change in foot lesion scores from start to finish of the trial⁴.

The required dietary content of zinc for dairy cattle ranges between 18 and 73 ppm, depending upon stage of the lifecycle²⁸. Copper, cadmium, calcium and iron reduce zinc absorption and interfere with zinc metabolism³².

Copper: Copper's role in the production of a healthy claw horn is related to the copper enzyme, thiol oxidase³⁵. Thiol oxidase increases the structural strength of horn by cross-linking adjoining keratin filaments³⁵. In addition, strength of connective tissues such as tendons and laminae is dependent on copper. The copper containing enzyme, lysyl oxidase forms the cross linkages between collagen fibers, thus giving connective tissue strength³⁵.

It is interesting to note that recently researchers have reported that connective tissue suspending the pedal bone in the claw capsule taken from cows nearing parturition has more elasticity than similar tissue collected in other stages of lactation³⁷. Increased elasticity allows greater movement of the pedal bone in the claw capsule, increasing compression of corium, resulting in increased sole and white line hemorrhages and ultimately white line and sole ulcers. Researchers theorized that the increased elasticity

of connective tissue suspending the pedal bone is due to the hormone, relaxin, which softens connective tissue allowing expulsion of the calf³⁷.

Another occurring during the prepartum period is maternal transfer of copper to the developing fetus. This process can result in the dam depleting her copper stores³². The question is; does depletion of the dam's copper reserves result in formation of connective tissue that is not as extensively cross-linked, resulting in greater elasticity of the tissue.

Cattle suffering from a subclinical copper deficiency are more susceptible to heel cracks, foot rot and sole abscesses³². The required dietary content of copper for dairy cattle ranges between 9 and 16 ppm, depending upon stage of the life cycle²⁸. Copper's availability is greatly diminished by sulfur and molybdenum as they form an insoluble complex that renders copper unavailable to the animal²⁰. Zinc and iron also reduce the availability of copper to the animal³². Producers who utilize by-products (i.e. corn gluten products, etc.) need to be aware of possible antagonists and adjust their copper levels appropriately.

Table 2. Claw evaluation scores of lactating dairy cows fed zinc methionine²¹

Claw Attribute	Start		Finish	
	Zinc Methionine	Control	Zinc Methionine	Control
Texture	2.62	2.61	2.11	** 3.11
Heel cracks	1.90	1.76	1.58	* 2.50
Laminitis	2.81	2.86	1.65	+ 2.44
Ulcers	1.71	1.38	1.24	1.61
White line disease	1.42	1.00	1.65	1.78
Interdigital dermatitis	1.76	1.76	1.06	** 1.94

** P<0.01, * P<0.05, + P<0.10, Scoring 1-5, 1 = perfect, 2 = good, 3 = fair, 4 = poor, 5 = severe

Manganese: Manganese plays a role in a number of enzyme systems and is required for cartilage and collagen formation and bone growth²⁰. In addition, it plays an important role in reproduction²⁸. Animals suffering from a clinical manganese deficiency will exhibit skeletal abnormalities, crooked legs and shortening of tendons as noted by knuckling over of feet²⁰. Manganese helps minimize feet problems by maintaining proper leg formation.

The required dietary content of manganese for dairy cattle ranges between 13 and 40 ppm, depending upon stage of the life cycle²⁸. Calcium, potassium, iron, magnesium, phosphorus and cobalt reduce the availability of manganese²⁰.

Cobalt: The primary physiological role of cobalt is the formation of vitamin B₁₂ in the rumen²⁰. A vitamin B₁₂ deficiency impairs protein and energy metabolism, resulting in lameness. The recommended dietary content of cobalt for lactating dairy cattle is 0.11 ppm²⁸. Manganese, zinc, iodine and monensin may reduce cobalt availability.

Factors Affecting Trace Mineral Availability

Effect of Feeding a Combination of Trace Minerals on Claw Health

As noted above, trace minerals in addition to zinc have an important in maintaining healthy feet. Thus, it is not surprising that feeding a combination of complexed zinc, manganese, copper and cobalt (4-Plex), results in a further reduction in claw disorders when compared to feeding only complexed zinc or no complexed trace minerals. Results from a study conducted in Central New York with approximately 3000 cows indicates that feeding combination of complexed zinc, manganese, copper and cobalt, instead of only ZINPRO zinc methionine or no organic trace minerals reduced incidence of double soling (4.0 vs. 9.8%), white line separation (28.9 vs. 43.9%), sole hemorrhages (64.1 vs. 72.5%) and ultimately, sole ulceration (13.2 vs. 14.8%)²⁸. Supplementation with 4-Plex also reduced incidence of digital dermatitis (8.3 vs. 12.4%) and tended to reduce incidence of dorsal wall ridges (10.4 vs. 11.7%)³⁰.

Florida researchers found that replacing inorganic zinc, copper, manganese and cobalt with similar amounts of these trace minerals from complexed sources (Availa-4) also resulted in a reduction in claw lesions¹. Cows fed a combination of complexed zinc, manganese, copper and cobalt tended to have fewer incidence of claw disorders than cows fed inorganic trace minerals at 75 d postpartum (23.6 vs. 34.1%) and numerically lower incidence at 250 d postpartum (10.0 vs. 17.7%)¹. At 75 d postpartum, complexed trace minerals reduced incidence of white line disease (9.5 vs. 14.6%) and tended to reduce incidence of heel erosion (15.8 vs. 12.2%)¹. In addition, if cows exhibited white line disease or heel erosion, the severity was lessened with the addition of complexed trace minerals to the diet as noted by the reduction in the claw lesion index (numbers of zones of the claw that contained a lesion multiplied by the average severity score for the lesion) (1.3 vs. 2.6, 6.7 vs. 8.9, respectively)¹. At 250 d postpartum, cows fed complexed zinc, manganese, copper and cobalt had less white line disease (4.9 vs. 8.8%) and tended to have less sole ulcers (5.9 vs. 6.7%) and foot rot (0.0 vs. 1.6%)¹. Claw lesion indexes for cows fed complexed trace minerals tended to be lower for both white line disease (1.7 vs. 2.7) and sole ulcers (2.5 vs. 4.2)¹. These results indicate that feeding a combination of complexed zinc, manganese, copper and cobalt reduced incidents of claw disorders. If cows did develop a claw lesion, feeding complexed trace minerals reduced the severity of the lesion.

Effect of Feeding Complexed Trace Minerals to Replacement Dairy Heifers

Wisconsin researchers found that almost 3 out of 4 heifers had a claw lesion at 12 months of age. Heifers with claw lesions at 12 months of age were 27.7 times more likely to have claw lesions in early lactation, as compared with heifers that did not have a claw lesion at 12 months. Adding complexed trace minerals (Availa-4) to growing heifer diets did not reduce incidence of claw lesions during the rearing phase. However, adding complexed trace minerals to growing heifer diets resulted in decreased incidence and severity of claw lesions in early lactation as indicated by a reduction in the claw lesion incidence and severity index for white line separation (4.9 vs. 7.5) and a trend for a reduction in the claw lesion incidence and severity index for overall claw lesions (4.9 vs.

7.5 5.5 vs. 6.6) and sole ulcers (0.1 vs. 0.5) over all claw lesions.

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