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Review Article

MASTITIS PREVENTION—A NUTRITIONAL APPROACH

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Mastitis is the disease that causes heavy loss to dairy farmers. Proper balanced ration can effectively reduce the occurrence of mastitis. Micronutrients are identified that can prevent mastitis. Balanced energy and protein content is one of the most important principle that had to be followed during dairy cattle feeding. Certain micronutrients that affect udder health include Vitamin E, A, C, Selenium, Copper, Zinc and Manganese. So this article reviews the functions and the mechanism through which these nutrients prevent the incidence of mastitis.

Keywords: Mastitis, Vitamin E, Selenium, Dietary cation anion balance

INTRODUCTION

Mastitis is the inflammation of cow's mammary gland usually caused by bacteria entering the teat canal and moving to the udder. Bovine mastitis continues to cause the biggest economic impact to the dairy industry even though intensive research and prevention measures have been carried out for years to control. Mastitis causes 53 billion dollars annual loss globally (Javaid *et al.,* 2009). Mastitis can be classified based on many criteria. Most common classification divides mastitis mainly into two forms- clinical and subclinical forms. Among them subclinical form causes the greatest loss. Subclinical form has 15-20 times more occurrence compared to that of clinical mastitis. Detection of subclinical form of mastitis is difficult. It causes about 26% of total cost of all dairy cattle diseases. The loss produced by mastitis is about twice of that of caused by both infertility and reproductive disorders. Good nutrition can reduce the occurrence of mastitis.

MASTITIS LOSS

Loss due to mastitis to dairy farmers occurs because of drop in milk production, discarded milk, decrease in value of sales, cost of medicines, veterinary aid and also of extra work. Drop in milk production causes 76% loss to farmers. Discarded milk causes 12% loss. Mastitis also changes milk composition, shortens the productive life of affected cows (Janzen, 1970). The losses are the potential revenues not earned, while the control costs are actual expenditures related to treatments, preventive measures, and additional labour used by them (McInereny *et al.,* 1992). Another thing is less

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mastitis means less risk of antibiotic contamination of milk.

MASTITIS AND NUTRITION

Nutrition and its effect on mastitis is not that much clear as that of the relationship between nutrition and fertility in cows. Then also lot of works was carried out to find out the influence of nutrition on the occurrence of mastitis. Mastitis marks an increase in somatic cell count in milk. Nutrition affects the incidence of clinical mastitis and cell counts in different ways. Milk leakage occurs due to excess nutrition and over production provide perfect environment for bacteria to enter the teats and cause infection. So high producers are in the threat of mastitis. Deficiency of minerals like sodium, potassium causes oedema that also increases the bacterial penetration which finally leads to mastitic infection. Exposure of teats to faecal contamination due to poor beddings in the cow shed causes an increase in the occurrence of disease. Nutrition exerts its most significant role regarding mastitis prevention through its effect on immunity. Antioxidant nutrients can prevent the occurrence of mastitis. This article mainly covers the role of antioxidant nutrients on immunity and prevention of mastitis.

NUTRIENTS FOR CONTROL

Energy and Protein

At the time of calving, cow is in requirement of high energy and at the time of peak production the animal will be under negative energy balance. Dry matter intake of the animal will not match with the draining of energy from the body at the time of peak production. Fat store in the body will be utilized for production of energy as an immediate source. As a result, large amount of ketone bodies will be produced and in circulation. Ketone bodies like acetone, acetoacetate and beta hydroxyl butyrate provide energy to the peripheral tissues, when carbohydrate levels are limited. When the ketone body level increase in circulation, condition called ketosis will develop. In subclinical ketosis, the animal won't show any signs of the disorder but the condition was developed due to presence of ketone bodies in circulation for a prolonged time.

Occurrences of ketosis and mastitis infection are closely related. Ability of cow to resist intra mammary infection reduced in ketotic condition (Leslie *et al.,* 2000; and Suryasathaporn *et al.,* 2000). Phagocytic capacity of macrophages and polymorpho nuclear cells get reduced during ketosis. Capacity of blood leucocytes to migrate to the site of infection also got reduced. According to Duffield (2000), ketotic cows are 1.7 times more susceptible to have an elevated somatic cell counts compared to the non ketotic cows. Leslie *et al.* (2000) through their works churned out the association between ketosis, mastitis occurrence and somatic cell count level. They observed that 15.1% of ketotic cows developed mastitis and only 10.1% of non ketotic cows develop mastitis. They also observed elevated level of somatic cell count in ketotic cows compared to non ketotic ones.

Proper management and dietary practices can bring changes in this condition. Prevent cows from becoming too fat in late lactation and dry period. Minimum of 14 Mcal of Net energy of lactation per day is required. Avoid large decrease in DMI during prepartum period. Lactating animal diet should contain 30-35% NDF and 30-40% concentrates with good forage. Promote a rapid increase in energy intake post calving (Starch 22-25% and 5% total fat improves DMI) (Weiss, 2005). Flax seed instead of soybeans improved neutrophil response in transition cows (Lessard *et al.,* 2004). Supplementation of glutamine (300 g/day) showed beneficial effects on immune function (Doepel *et al*., 2006).

Micronutrients

Micronutrients that affect udder health include Vitamin E, A, C, Selenium, Copper, Zinc and Manganese.

Vitamin E

Vitamin E is a lipid soluble antioxidant that protects against lipid peroxidation initiated by free radicals and has been shown to play an important role in immune response and health of dairy cows (Spears and Weiss, 2008). Various researches show how vitamin E may be involved in the body's defense against mastitis.

Polymorphonuclear neutrophils and macrophages in the blood are immune bodies that can engulf the bacteria. When these cells engulf bacteria, it causes release of free radicals. These free radicals are highly reactive and can cause destruction of body cells. Free radicals itself can damage macrophages and polymorphonuclear neutrophils. So antioxidant nutrients can prevent these free radicals from creating destruction. Adequate vitamin E levels in the polymorphonuclear neutrophils allow a more active and more prolonged effect of a cow's natural immune system on invading bacteria.

Blood levels of vitamin E decrease as parturition approaches and remain low for several days postpartum (Weiss *et al.,* 1994). Allison and Laven (2000) concluded that the supplementation of Vitamin E decreases incidence and duration of clinical mastitis in dairy cows. Studies have shown that Vitamin E is directly associated with neutrophil function in dairy cows by enhancing neutrophil function, improving the killing ability of blood neutrophils during the periparturient period (Hogan *et al.,* 1992). In addition, vitamin E supplementation during the transition period prevented a decline in neutrophil superoxide anion production, interleukin-1 (IL-1) production, and MHC-II expression by blood monocytes after parturition; as well as prevented a decrease in chemotactic responsiveness of neutrophils beginning 2 wk prior to and continuing for 4 wk after parturition (Politis *et al.,* 1995 and 1996). Vitamin E at 1000 IU/cow/day should be supplemented to dry pregnant cows atleast 30 days before parturition to 30 days of lactation to reduce incidence of mastitis (Kaur *et al*., 2002).

Vitamin E reduces circulating cortisol levels, as well as prostaglandin concentration in teat ends. Since high prostaglandin concentrations relax smooth muscle tissue and this affect the closure of teat ends result in higher entry of bacteria through the teat ends. So this is another mechanism of Vitamin E through which it affect mastitis occurrence.

Daubinger and Preisinger (1990) found that Vitamin E supplementation on different farms reduced the somatic cell count. Weiss *et al.* (1990) showed consistent, negative correlations between dietary vitamin E supplementation and the incidence of clinical mastitis and also increased levels of dietary supplemental vitamin E were associated with reduced somatic cell counts in all of the herds.

According to the NRC (2001) recommendations, during last 60 days of gestation dry cows should be provided with 80 IU/kg DMI. Lactating cows should be given with 20 IU/kg DMI. Plasma concentrations of greater than 3.5 to 4 mg/ml of alpha-tocopherol are considered adequate as evidenced by the relationship between intracellular kill of bacteria by neutrophils and plasma E concentrations (Hogan *et al*., 1993).

Selenium

Selenium is an essential component of the enzymes glutathione peroxidase and thioredoxin reductase located in the cytosol of the cells; which function in preventing oxidative stress. In addition, Se is also considered to have a protective effect on phagocytic cells from autoxidative damage during the respiratory burst (Mustacich and Powis, 2000). Leakage of free radicals from the phagolysosomes, or failure to detoxify these products, could affect the microbicidal and metabolic functions of phagocytic cells. It has been stated that Se concentration in colostrum is 4 times higher than in milk. Grasso *et al.* (1990) have demonstrated that neutrophils, from cows supplemented with Se, killed mastitis pathogens more efficiently compared to cows not fed with supplemental Se. Erskine *et al.* (1989), in a similar study, showed that cows supplemented with Se and challenged with *Escherichia coli* had a faster influx of neutrophils to the site of the infection compared with non-supplemented cows. Reduction in SCC noticed (Malbe *et al.,* 1995) by Se supplementation. But no clinical evidence for the improvement of udder health beyond a supplemental level of 0.3 ppm Se (Weiss, 2002). Whole blood concentrations of Se should be at least 0.2 mg/ml but should not exceed 1 mg/ml (Weiss *et al*., 1990).

Studies had shown that supplementation of Vitamin E and Selenium together reduced the number of clinical cases of mastitis (Smith *et al.,* 1987). It improves the milk quality by decreasing the somatic cell count and also reduces the oxidative flavor problems. Supplementation of Se and vitamin E to dry cows reduced the duration of mastitis and incidence of clinical mastitis, with vitamin E alone being a good supplementation in preventing mastitis in early lactation (Weiss *et al.,* 1997; and Smith *et al.,* 1984).

Selenium can be supplemented at the rate of 0.3 ppm. Selenium occurs mainly in two forms, i.e., organic form and inorganic form. Organic Selenium exists as selenium yeast and inorganic form exists as Sodium selenite and Sodium selenate. Organic Selenium found to have better absorbtion and bioavailability compared to inorganic ones.

Vitamin A and Beta Carotene

Vitamin A is necessary for all cellular division and differentiation (Herdt and Stowe, 1991), and plays a key role in inhibition of keratinization. Deficiency of vitamin A results in hyperkeratinization of the secretory epithelium and this stiffening of epithelium increases the chance of infectious organisms to enter through this and finally increasing the susceptibility to diseases (Reddy and Frey, 1990).

Beta-carotene, a precursor of vitamin A, functions as an antioxidant reducing superoxide formation within the phagocyte (Sordillo *et al.,* 1997). Vitamin A is also related to immunity and mastitis. Vitamin A and beta carotene have stimulatory effects on immune cells (Daniel *et al*., 1991).

Chew *et al.* (1993) studied the effect of Vitamin A and beta carotene on somatic cell count in cows by giving three types of diet (low Vitamin A – 53,000 IU/d, High Vitamin A – 1,73,000 IU/d and Vitamin A + beta carotene diet – 53,000 IU/d + 300 mg/day). He found that Vitamin A + beta carotene supplementation found to have more effect compared to low and high Vitamin A diet in reducing the somatic cell count.

According to NRC (2001), dry and lactating cow's diet should contain 110 IU/kg bwt/day and growing dairy animals with 80 IU/kg bwt/day. Supplementation needed in case of high levels of concentrates, low level of green forages, high level of poor quality forages. Supplementation of beta carotene is needed only when cows are in low beta carotene status.

Copper

Copper forms part of many enzymes and thus plays an important role in immunity. Copper is a component of the enzyme ceruloplasmin, which is synthesized in the liver that assists in iron absorption and transport. Ceruloplasmin is an antioxidant protein that prevents copper from participating in oxidation reactions. Cu is also an important part of superoxide dismutase, which converts superoxide to hydrogen peroxide and thus protects cells from the toxic effects of oxygen metabolites released during phagocytosis. Both functions may be important in reducing the incidence of mastitis during the periparturient period. Bactericidal capacity of polymorphonuclear cells got reduced on copper deficiency (Xin *et al.,* 1991). Copper supplemented to heifers starting 60 d pre-calving and continuing to 30 d postpartum decreases the severity of *Escherichia coli* induced mastitis cases (Rourke, 2009).

Copper sulfate and copper proteinates are the recommended sources for copper supplementation.

Zinc

Zinc plays an important role in maintaining health and integrity of skin due to its role in cellular repair and replacement, and by increasing the speed of wound healing. In addition to this healing effect, it has been suggested that Zn reduces somatic cell count due to its role in keratin formation. Zinc plays a critical role in function and effectiveness of some immune components. Zinc has an antioxidant role by being part of a group of elements that induces the synthesis of metallothionein, which binds to free radicals. As a component of the enzyme superoxide dismutase, it can stabilize cell membrane structures. Zinc deficiency affects formation of T and B lymphocytes and also phagocytes. Zinc is necessary for the hepatic synthesis of retinol-binding protein, which transports vitamin A in the blood (Gropper *et al.,* 2005). Zn levels in dairy cows decrease at parturition due to a decrease in DMI, transfer of Zn to colostrum, increased stress at this time, and return to baseline levels within 3-5 d postpartum.

Recommendations of Zinc for lactating cow were 1000-1400 mg/day (NRC, 2001). Common sources of Zinc include Zinc oxide and Zinc sulfate.

Manganese

Manganese is a component of superoxide dismutase enzyme. It is having high tolerance limit. For lactating cow they can be given in the dose of 30-40 ppm.

Vitamin C

Mastitis decreases plasma Vitamin C concentrations in dairy cows (Weiss *et al.,* 2004; Kleczkowski *et al.,* 2005; and Ranjan *et al.,* 2005). Some researchers investigated the efficacy of parenteral Vitamin C administration as a potential mastitis treatment. Vitamin C treatment reduced the severity of acute mammary inflammation, which was induced by intramammary infusion of endotoxin (Chaiyotwittayakun *et al.,* 2002). Another experiment showed that subcutaneous injection of ascorbic acid (25 mg/kg BW) stimulated the recovery from clinical mastitis in cows treated with antimicrobials (Naresh *et al.,* 2002). Dietary supplementation with ascorbyl-2-

Table 1: Antioxidant Systems of Mammalian Cells

Component (Location in Cell)	Nutrients Involved	Function
Superoxide dismutase (Cytosol)	Copper and Zinc	An enzyme that converts superoxide to hydrogen peroxide
Superoxide dismutase (Mitochondria)	Manganese and Zinc	An enzyme that converts superoxide to hydrogen peroxide
Ceruloplasmin	Copper	An antioxidant protein, may prevent copper, from participating in oxidation reactions
Glutathione peroxidase (Cytosol)	Selenium	An enzyme that converts hydrogen peroxide to water
Catalase	Iron	An enzyme (primarily in liver) that converts hydrogen peroxide to water
Alpha-tocopherol (Membranes)	Vitamin E	Breaks fatty acid peroxidation chain reactions

Source: Modified from Weiss (2002)

polyphosphate (30 g/d) decreased milk somatic cell count in dairy cows with mastitis induced by the endotoxin challenge but did not improve neutrophil function in blood (Weiss and Hogan, 2007).

ANION CATION BALANCE

Dietary cation anion balance (DCAB) system is the method of feeding system used in dairy cows for the prevention of milk fever. It is the method of balancing the minerals in feed so as to create an acidic condition in the blood so that it prevents the mobilization of calcium from bones. DCAB is obtained by substracting the anions from the cations. The value of DCAD is easy to calculate as only two cations (sodium Na^+ and potassium, K^+) and two anions (chloride, Cl^- and sulfate, SO_4^-) are used. The equation is milliequivalents (Na^+ and K^+) - (Cl^-+ SO_4^-) per kilogram of dry matter. Negative DCAB ration can prevent the occurrence of milk fever.

Cows with milk fever are much more likely to get clinical mastitis than cows without milk fever (Weiss, 2005). Hypocalcaemia prevents teat sphincter from closing both before and after milking. Lying down of animal for more time in bed during milk fever increases the chance of bacterial entry to teats. Higher cortisol also suppress immune function and reduces monocyte functioning. No incidence of mastitis in cows fed anionic diet as compared to 14.3% in cationic diets (Kumar and Kaur, 2005).

KEYS FOR IMPROVING MAMMARY HEALTH THROUGH NUTRITION

- Feed and manage late-lactation and dry cows to maintain proper body condition
- Prevent hypocalcaemia
- Supplement vitamins and trace minerals in diet or grain mix
- Be aware of differences in bioavailability

CONCLUSION

Nutrition can influence the cow's resistance to mastitis. However, it does not influence the exposure of teat ends to pathogens. Mastitis control begins with implementation of the five-point control programme as well as providing a clean dry environment for cows. Ensuring that the cow has adequate energy, minerals and vitamins for optimal milk production is essential for the maintenance of udder health and immune status. However, it should be noted that if mastitis control practices are poor then these will outweigh any potential influence of energy balance, mineral or vitamin status. A holistic approach to mastitis control should be taken and nutritional management is but one part of the control programme.

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