Trace Minerals in the Dry Period – Boosting Cow and Calf Health

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Take Home Messages

- Trace minerals such as chromium, copper, iron, manganese, and selenium have important roles in the immune system.
- Maintaining adequate trace mineral status during the dry period is an important component required to minimize the occurrence of dairy cow health disorders during the periparturient period.
- The trace mineral status of newborn calves is dependent on placental transfer of trace minerals and colostrum trace mineral concentrations. Therefore, adequate feeding of trace minerals to the cow during gestation is important for the health of calves.

Introduction

Cows experience a significant amount of metabolic and physiological changes that stress their immune system around the time of parturition. Trace minerals play a key role in supporting immune function, and therefore maintaining adequate trace mineral status during the dry period is an important component in achieving cow health during the periparturient period. Minimizing health disorders during this time is economically advantageous as transition cow diseases are costly, not only in terms of treatment costs, but also as a result of the subsequent decrease in lactation performance and reproduction, the increased risk for additional health disorders, and decreased market value and productive life (Campbell and Miller, 1998). Trace mineral status during the dry period is also important for calf health. Calves rely on placental transfer of trace minerals from the dam to meet requirements for proper fetal growth, and trace mineral status of the dam can affect colostrum quality, including trace mineral concentrations, somatic cell count (SCC) and immunoglobulin levels (Quigley and Drewry, 1998). The primary intent of this paper is to provide a summary of research findings regarding the impact of trace mineral supplementation during the dry period on cow and calf health. Minerals primarily discussed include chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), selenium (Se) and Zinc (Zn).

▪ Trace Minerals and Immunity – Transition Period

During the transition period, approximately 3 weeks prior to calving until 3 weeks post-calving, immune function is weakened and dairy cows have a decreased capacity to fight disease (Waldron, 2010). Factors suggested to be responsible for this immunosuppression include oxidative stress, non-esterified fatty acids, ketones, negative energy balance, and calcium status (Sordillo, 2009; Waldron, 2010).

The primary mechanism in which trace minerals impact immune status is via a role as antioxidant nutrients decreasing oxidative stress. More specifically, trace minerals are an integral part of the animal’s capability to prevent free radicals such as superoxide, hydrogen peroxide, hydroxyl radical and fatty acid radicals which are toxic to cells from accumulating in the cell and causing oxidative cell damage or death. Free radicals are continuously produced in the body as they are a byproduct of normal cell metabolism. They are also produced as a response to infection, serving as a method for neutrophils to kill bacterial pathogens. During the transition period, cows experience increased free radical production. Factors exacerbating free radical production during this time include heat stress, disease challenge and high production (Castillo et al., 2005; Gaál et al, 2006; Petit, 2009; Abd Ellah, 2010). If the amount of free radicals produced exceeds the antioxidant capacity of the animal, oxidative stress occurs. The resultant impact on health status, because free radicals are especially harmful to immune cells, can include an impaired immune response and increased susceptibility of the animal to infection. Health disorders associated with oxidative stress include mastitis, retained fetal membranes and udder edema (Weiss, 2005a; Bowman et al., 2008).

Trace minerals with an antioxidant function include selenium (Se), copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe). While some nutrients have a role in directly quenching free radicals, these trace minerals have an indirect role in which they are required components of a variety of antioxidant enzymes (Waldron, 2010). For example, enzymatic antioxidants such as superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase are considered to be an important defense system against free radical accumulation; superoxide dismutase converts superoxide to hydrogen peroxide while GSH-Px and catalase convert hydrogen peroxide to water. Superoxide dismutase is Cu, Mn and Zn dependent, GSH-Px is Se dependent and catalase is Fe dependent (Bowman et al., 2008; McDowell et al., 2007; Weiss, 2005a).

■ Trace Mineral Requirements – Dry Period

In the 2001 dairy NRC, recommended intake levels for Cu, iodine (I), Fe, Mn and Zn were determined by summing absorbed mineral requirements for maintenance, growth, production and pregnancy. Total absorbed requirements were then divided by an estimated mineral absorption coefficient, which is influenced by chemical form of the mineral and the anticipated presence of dietary antagonists that decrease mineral absorption. Then, based on predicted dry matter intake (DMI), the needed dietary mineral concentration (mg/kg) can be determined. While animals require amounts of trace minerals, most often our expression of requirements is as a concentration (mg/kg or ppm). Due to decreased DMI for close-up compared to far-off dry cows, close-up diets should be formulated to contain a higher concentration of trace minerals than far-off dry cow diets. Recommended dietary levels of cobalt (Co) and Se were not based on the previously discussed methodology. Cobalt is recommended to be fed at 0.11 mg/kg diet DM and the FDA restricts Se supplementation to a maximum of 0.3 mg/kg diet DM for dry and lactating cows (NRC, 2001). Refer to Table 1 for an example of trace mineral requirements (daily intake and dietary concentration) for dry and pre-fresh cows based on the specified cow parameters. A requirement for Cr has not been established. However, as of 2009, the only allowable Cr supplement for dairy cattle diets is chromium propionate which can be fed at levels up to 0.50 mg/kg diet DM (FDA, 2009).

Table 1. Example of trace mineral requirements during the far-off and pre-fresh dry cow periods according to NRC (2001)

Item	**Dry Cow (Far-off)[1]**		**Pre-Fresh (Primiparous)[2]**		**Pre-Fresh (Multiparous)[2]**	
DMI, kg/d:	14.4		10.0		12.0	
	Trace Mineral					
	Intake, mg/d	**Diet[3], mg/kg DM**	Intake, mg/d	**Diet[3] mg/kg DM**	Intake, mg/d	**Diet[3], mg/kg DM**
Cobalt		0.11		0.11		0.11
Copper[4]	173	12.0	170	17.0	178	14.8
Iodine[5]	5.8	0.4	4.2	0.42	5.5	0.46
Iron	187	13.0	276	27.6	178	14.8
Mn[6]	230	16.0	233	23.3	247	20.5
Selenium		0.3		0.3		0.3
Zinc	302	21.0	318	31.8	301	25.1

Adapted from Socha et al., (2006)

[1] Trace mineral requirements were based on the following cow parameters= Holstein cow: BW, with conceptus 730 kg, mature BW without conceptus 680 kg, body condition score (BCS) = 3.3, 57 months of age, 240 d pregnant, calf weight = 45 kg, gaining 0.68 kg with conceptus.

[2] Trace mineral requirements were based on the following cow parameters= Holstein cow: 270 d pregnant, mature BW 680 kg, BCS = 3.3. Primiparous: BW = 625 kg with conceptus gaining 0.95 kg. Multiparous: BW = 751 kg with conceptus .

[3] Dietary trace mineral concentration (ppm diet DM) = mineral intake (mg/d) ÷ total dry matter intake.

[4] High dietary levels of molybdenum, sulfur and iron can interfere with Copper (Cu) absorption increasing Cu intake requirements.

[5] High dietary levels of goitrogenic substances or nitrates increase iodine intake requirements.

[6] Mangense (Mn).

▪ Trace Mineral Content of Feedstuffs

Table 2 provides the average Cu, Fe, Mn, Se, and Zn content of some forages and byproducts typically fed to dairy cows. As indicated by Spears (2010), little is known regarding the Cr content of dairy feedstuffs and therefore, Cr concentration is not included in the table. Li et al., (2005) reported a range in Cr content from 0.33 mg/kg DM for corn grain to 0.91 mg/kg DM for alfalfa haylage based on 54 dairy farms in Wisconsin.

Table 2. Copper (Cu), iron (Fe), manganese (Mn), selenium (Se) and zinc (Zn) content of feed ingredients commonly fed to dairy cows

	Cu		Fe		Mn		Se		Zn	
	Avg	**SD[1]**	**Avg**	**SD[1]**	**Avg**	**SD[1]**	**Avg**	**SD[1]**	**Avg**	**SD[1]**
Forages										
Corn silage	6	7	104	109	36	19	0.04	0.02	24	8
Grass hay	9	6	156	157	72	52			31	30
Legume hay	9	4	286	270	35	13	.20	0.18	24	19
Straw	6	4	172	113	67	81			16	7
Grain										
Barley	.35	.28	70	60	22	12	.11	.09	38	30
Corn	3	4	54	53	11	24	.07	.05	27	20
Wheat	5	3	72	55	42	17	.28	.37	40	13
Byproducts										
Beet pulp	11	6	642	269	62	30	.14	.09	22	9
Canola meal			296	251	62	12	1.1	.99	61	7
DDGS[2]	8	7	178	82	27	15	.39	.44	65	19
Soybean meal, 48%	16	4	206	124	40	12	.13	.19	58	17

Data from NRC (2001)

[1] Standard deviation (SD). Generally, 68% of the values are ± 1 SD from the mean and 95% of the values are ± 2 SD from the mean. For example, if the average Copper (Cu) content was 10 mg/kg with a SD of 2.0. A ± 1 SD means 68% of all samples analyzed had a Cu content between 8 mg/kg (10.0-2.0) and 12 mg/kg (10.0 + 2.0).

[2] Dried distillers grains with soluble (DDGS).

The trace mineral content of feeds is quite variable, as indicated by the large standard deviation relative to the average within each feedstuff (Table 2). Factors affecting trace mineral content of forages include harvest method, soil type, and species while mineral content of byproduct feeds is primarily influenced by the processing method used (NRC, 2001). Due to this variation, utilizing published average values for trace mineral content of dietary feedstuffs would not provide an accurate estimation of the trace mineral content of most homegrown and purchased feeds in diets. An alternative is to routinely analyze all feeds utilized in the diet for trace mineral content and alter amounts of supplemental trace minerals fed. However routine analysis expenses can exceed the cost of trace mineral supplementation and altering diets for trace mineral adequacy would be logistically difficult. Another option is to disregard trace minerals supplied by homegrown and purchased feed grains in the diet and supplement trace minerals at NRC (2001) requirement levels. This is a common and generally acceptable practice in industry because the safety margin between requirement and toxicity level for most trace minerals is relatively large. However, trace minerals fed beyond requirements may alter the absorption of other trace minerals and in locations where homegrown forages and feeds are unusually high in a trace mineral such as Cu and Se, toxicity could be of potential concern (Socha et al., 2006). Increasing trace mineral supplementation above NRC (2001) requirements during the dry period has been suggested by Socha et al. (2006) for Co, Mn, and Zn. They recommend disregarding trace minerals supplied by homegrown and purchased feed grains in the diet and adding Co at 0.8 to 1.2 mg/kg diet DM, Mn at 55 to 75 mg/kg diet DM and Zinc at 75 to 85 mg/kg diet DM with 25 mg Co/d, 200 mg Mn/d and 360 mg Zn/d provided from an organic source.

▪ Trace Mineral Content of Water

Based on mineral analysis of 3,618 water samples taken from dairy farms throughout the United States, minerals in water can significantly contribute to the mineral requirements of dairy cows (Socha et al., 2003). Table 3 provides average and maximum mineral values and estimated daily mineral intakes (average and maximum) for the average dairy cow drinking 108 liters of water per day. Macro- and trace mineral concentrations are provided in this table as excess macro-mineral intake can decrease absorption of trace minerals.

Table 3. Average and range in mineral content of water (n=3651) and estimated daily intake of minerals from water based on average and maximum mineral levels.

	Mineral concentration, ppm		**Daily mineral intake from water**	
Mineral	Average	Maximum	Average[1]	Maximum[2]
Macro minerals				
Calcium	65	590	7 g	64 g
Chloride	59	727	6 g	78 g
Magnesium	24	682	3 g	74 g
Potassium	4	33	.4 g	4 g
Sulfur	27	1197	3 g	129 g
Trace minerals				
Copper	0.07	11	8 mg	1 g
Iron	0.79	123	85 mg	13 g
Manganese	0.17	12.7	18 mg	1 g

Socha et al., (2003)

[1] Mineral intake based on intake of 108 liters water/day x the average mineral concentration.

[2] Mineral intake based on intake of 108 liter water/day water x maximum mineral concentration.

▪ Trace Mineral Research – Periparturient Period

The following section will provide a brief summary of the role of each mineral in immunity followed by a research summary that highlights studies that have evaluated the affect of trace mineral supplementation during the dry cow period on cow and calf health.

Zinc (Zn)

Zinc has a number of roles in the immune system. It is a required component of the antioxidant enzyme superoxide dismutase and is needed for the synthesis of metallothionein, which may scavenge free radicals (Spears and Weiss, 2008). Zinc is required to maintain epithelial tissue integrity and for keratin formation which provide a physiological barrier to infection (Socha et al., 2005; O'Rourke, 2009) and Zn can impact immune status via a role in cell proliferation. Cells deficient in Zn have decreased ability to proliferate, and immune cell response requires rapid cell proliferation (Spears and Weiss, 2008; Forsberg, 2010).

Although there is increased interest in evaluating the impact of Zn supplementation during the dry period on cow and calf health, to date, data is very limited. Research by Campbell and Miller (1998) showed improvements in reproductive performance but no impact on the incidence of retained fetal placenta when cows were fed a high Fe diet and supplemented with either 0 or 800 mg Zn/d (400 mg from Zn methionine and 400 mg from Zn sulfate). The control diet (0 mg added Zn/d) however, was already high in Zn providing approximately 1100 mg Zn/d, which is approximately 3 times greater than NRC recommended levels. Zinc supplementation did decrease days to first estrus and resulted in a tendency for fewer days to first artificial insemination. While reproductive efficiency is not a direct measurement of immune function, the authors speculated that decreased oxidative stress could impact the uterine environment and therefore reproductive measures.

According to Enjalbert (2009), while placental transfer of Zn to the calf during gestation is efficient, Zn stores are relatively less available than Cu stores which results in a greater deficiency risk for Zn compared to Cu in calves. A severe Zn deficiency in calves and lambs has been shown to decrease immune status, however when cattle are fed typical diets, a marginal deficiency is more likely to occur and a marginal Zn deficiency does not appear to have a significant impact on immune status of ruminants (Spears and Weiss, 2008).

Enhanced maternal Zn supplementation in swine and poultry has been shown to improve gut development and health of offspring (Socha et al., 2006). Caine et al. (2001) fed sows an additional 250 ppm Zn from a Zn amino acid complex, starting on day 80 of gestation until farrowing, and found improvements in intestinal development and immune function as indicated by increased intestinal villous height and intraepithelial lymphocytes, respectively. In a number of poultry studies, feeding higher levels of Zn in breeder diets has been shown to increase immunity of progeny (Kidd et al., 1992ab, 2000; Stahl et al., 1989).

Dairy cow research in this area is lacking. Recently however Golombeski (PhD Thesis, 2010) evaluated the impact of feeding additional Zn from Zn methionine to dairy cows from 60 days prior to calving until calving on intestinal development of offspring and colostrum content. Twice the level of Zn supplementation during the dry period (~3300 vs. 1650 mg Zn/d) resulted in no difference in calf intestinal development, measured as crypt depth and villus height, at birth or two weeks of age. There was also no impact of Zn supplementation level on colostrum Zn, IgG or IgM concentration. In this study, all cows were fed Zn at levels significantly higher than NRC (2001) recommendations and a limited number of calves (3-4 per treatment) were evaluated for intestinal development at each time point. Additional dairy cow studies are needed to ascertain the impact of maternal Zn supplementation on dairy calf gut development and health.

Iron (Fe)

While iron is a required component for the antioxidant enzyme catalase, it is generally not or minimally supplemented in dairy cow diets and research evaluating Fe supplementation during the dry period is minimal. As speculated by Weiss et al., (2010) this is likely because feedstuffs can contain a significant amount of Fe and therefore most diets would appear to meet Fe requirements without supplementation. However, if soil contamination is a major source of Fe in the diet, the Fe is largely unavailable to the animal (Hansen and Spears, 2009). This is because Fe in soil is generally bound to chelating agents and exists in the ferric form, which is considered less bioavailable than ferrous Fe (Weiss et al., 2010). A small amount of Fe supplementation during the dry period may be beneficial because while DMI declines during the close-up period, Fe needed for the conceptus and maternal blood volume increases. Additionally, research suggests Fe status may decline in late gestation (Weiss et al., 2010). Supplementing more than 250 mg Fe/kg DM from Fe sulfate however is not suggested as this has been shown to increase oxidative stress, and decrease Cu status, health, production, intake and fiber digestion (Weiss et al., 2010).

Recently, Weiss et al. (2010) fed 0 or 30 mg/kg DM supplemental Fe from a Fe amino complex to dairy cows starting approximately 60 days prior to calving until 63 days in milk. Unsupplemented diets contained 313 and 336 mg Fe/kg DM during the dry and prefresh periods, respectively. They found supplementing dairy cows with additional organic Fe slightly reduced SCC

(114,000 vs. 94,000 cell/ml) compared to unsupplemented cows with no difference in milk yield, milk composition or DMI between treatments. Blood measures of Fe status were also similar between treatments and there was no indication of reduced Fe status during this study. This would suggest the Fe available in the unsupplemented diet was sufficient to meet requirements and therefore a limited response to feeding additional Fe would be expected.

Copper (Cu)

Copper is a required component of the antioxidant enzymes superoxide dismutase (SOD) and ceruloplasmin. As mentioned, SOD converts superoxide to hydrogen peroxide. Ceruloplasmin prevents oxidation and peroxidation of tissues during the oxidation of ferric iron (Fe^{+3}) to ferrous iron (Fe^{+2}) and may have a role scavenging superoxide radicals (Spears and Weiss, 2008).

Based on a limited number of studies, maintaining adequate Cu status during the periparturient period appears to be beneficial in terms of increasing resistance to mastitis in dairy cows. Torre et al., (1996) reported decreased killing of *S. aureus* for neutrophils collected from heifers fed a diet containing Cu at 6-7 mg/kg diet DM compared to those collected from heifers fed a diet supplemented to 20 mg/kg of Cu in the diet DM. Scaletti et al. (2003) fed diets similar to Torre et al. (1996) starting at 60 days prior to calving. Upon challenging these heifers with *Esherichia coli* in one quarter of the udder at 34 days in milk, they found feeding the additional Cu decreased clinical scores 24 h post-infusion (3.2 vs. 4.1) and peak rectal temperature (40.0 vs. 40.8°C). An optimal Cu supplementation level for mastitis resistance has not been established and the impact of Cu on the incidence of other health disorders has not been evaluated.

Neonatal calves rely on liver stores accumulated during gestation for Cu. A moderate Cu deficiency in dairy cows would be expected to have limited effect on Cu status and therefore, immune status of calves because the fetus has priority over the dam for Cu (Enjalbert, 2009). Research in beef cows showed no difference in plasma erythrocyte superoxide dismutase activity approximately 1, 3 and 7 weeks following birth of calves born to marginally deficient cows supplemented with Cu at 0 mg/kg diet DM, 10 mg/kg diet DM for 5 months, 30 mg/kg for 5 months or 120 mg/kg for 10 days prior to calving (Enjalbert et al., 2002). There was also no difference in plasma Cu concentration, however as indicated by the authors, liver Cu stores are a better indicator of an animal's Cu status than plasma. Copper status may have an impact on colostrum immunoglobulin concentration, however research is currently too limited to be definitive.

Chromium (Cr)

While the other trace minerals discussed in this paper impact immunity through a role in the antioxidant system, Cr differs and is thought to impact immune status via a role in insulin signaling (Spears and Weiss, 2008). Stress has been shown to result in increased urinary excretion of Cr (Burton et al., 1996) and according to Yari et al. (2010) supplementing Cr in dairy cow diets appears to be most beneficial, in terms of resulting in a positive physiological or production response, during times of stress. It is therefore not surprising that Cr research in dairy cows has focused on the transition cow period. For a comprehensive review of the impact of Cr in dairy cow diets on production, reproduction and health refer to Spears (2010).

Although not clinically verified in the literature, research suggests Cr supplementation during the periparturient period could decrease the risk of ketosis. Studies in beef and dairy have indicated Cr supplementation may increase insulin sensitivity and decrease fat mobilization during the periparturient period (Spears, 2010). Decreased plasma β-hydroxybutyrate and liver triglyceride concentrations postpartum have also been reported for dairy cows fed supplemental Cr from Cr picolinate at 0.8 ppm compared to control cows (Besong, 1996). In a dairy herd experiencing a very high incidence rate for retained placenta, topdressing 3.5 mg/day of Cr from Cr picolinate, starting approximately 9 weeks prior to calving, significantly reduced the occurrence of retained placentas from 56 to 16% (Villalobos-F et al., 1997). In contrast, Cr supplementation has not been shown to impact mammary gland health. Chang et al. (1996) reported no impact of Cr supplementation (0.5 ppm) starting 6 weeks prior to calving on milk SCC or bacterial colonies from calving until 56 DIM.

Manganese (Mn)

Along with Zn and Cu, Mn is a required component of superoxide dismutase and has an important antioxidant role. Manganese has been shown to increase macrophage killing ability and as macrophages help protect the mammary gland against intramammary gland infection, it has been speculated that Mn may have a role in mastitis prevention (Tomlinson et al., 2008). However, we were unable to find any published research evaluating the impact of Mn supplementation during the dry period on cow or calf health.

Selenium (Se)

Selenium is a required component of gluthathione perioxidases and thioredoxin reductases (Andrieu, 2008) and appears to have the largest trace mineral role in the antioxidant system.

Selenium deficiency decreases the activity and lifespan of neutrophils, macrophages, and lymphocytes (Hefnawy et al., 2010). As a result, Se status has a significant impact on cow health. As reviewed by Spears and Weiss (2008), research has shown supplementing Se-deficient dairy cow diets with Se pre-partum can decrease the incidence of retained placenta and decrease the incidence and severity of mastitis. Due to the legal limitations of Se in dairy cow diets, a significant amount of dairy research has compared supplementation of inorganic Se to Se-yeast. According to Weiss (2005b), because of a lack of clinical data, the health effect of inorganic versus Se-yeast is unclear. However, studies have shown increased transfer of Se from cows to calves when cows are supplemented with Se-yeast compared to inorganic Se during the dry period. This is in agreement with more recent research by Koenig and Beuchemin (2009) in which adequate Se diets were supplemented with 0.3 mg/kg diet DM Se yeast or sodium selenite. In this study, cows were fed supplemental Se approximately 60 days prior to calving until 60 DIM. Total dietary Se concentration was 0.78 and 0.64 mg/kg diet DM during the dry and close-up periods, respectively. Cows receiving the Se-yeast treatment had higher serum Se concentration from 30 days prior to calving to calving and their calves had higher serum Se concentrations at 24 h of age. Increased Se status did not however translate into increased health status; there was no difference in colostrum or calf serum IgG and IgM concentrations or milk SCC between treatments.

▪ Maternal Trace Mineral Status and Calf Health

The trace mineral status of newborn calves is dependent on placental transfer of trace minerals and colostrum trace mineral concentrations. Therefore, maternal trace mineral status can have a significant impact on the health status of calves. Enjalbert (2009) summarized the available data on Cu, Zn, and Se maternal status and calf health as follows.

Studies have primarily evaluated the impact of maternal trace mineral status on biological markers of immune status rather than disease incidence and the majority of work has been conducted in beef rather than dairy herds. Selenium supplementation to Se-deficient diets of beef cows has resulted in increased colostrum and calf serum IgG concentrations. However, Cu and Zn data evaluating the relationship between maternal trace mineral status and immunoglobulin transfer to the calf is lacking. Based on a retrospective study in which data was collected from 997 dairy herds and 1083 beef cow herds in France and Belgium (Enjalbert et al., 2006), deficient Cu, Zn or Se herd status has been identified as a risk factor for one or more calf health disorders (perinatal mortality, diarrhea, vaccination failure, myopathy, or heart failure). In this study, a herd deficient in Se put calves at a greater risk for health disorders than Cu or Zn deficient herds.

■ Colostrum Somatic Cell Count (SCC) and Calf Health

Research has shown mammary infections and high SCC can negatively impact colostrum quality, calf health and performance. Maunsell et al. (1998) reported cows with persistent mammary infections produced less colostrum, and colostrum with less protein, less fat and a higher SCC. Cows with a transient mammary infection produced colostrum with lower protein content and a higher SCC. Ferdowski Nia et al. (2009), classified colostrum SCC as low, medium or high. They found no impact of SCC on colostrum IgG concentration, however there was a trend (P=0.10) for decreased calf serum IgG concentration 3-h following birth as colostrum SCC concentration increased. Colostrum fat concentration also decreased linearly as colostrum SCC increased. Although SCC had a limited impact on colostrum quality, calf performance and health was affected. Increasing colostrum SCC linearly decreased average daily gain from 0.19 to 0.08 kg BW/day during the first month of life and overall from 0.49 to 0.40 kg BW/day during the first 60 days of life. Fecal scouring days were also increased with feeding higher SCC colostrum at birth.

This data does not provide a direct link between maternal trace mineral status and calf health. However Se, Cu and Zn status have the known potential to impact udder health in dairy cows (O'Rouke, 2009) and therefore it does provide indirect evidence that the trace mineral status of dairy cows during gestation can impact progeny health.

■ Summary

While large trace mineral deficiencies result in specific diseases, current feeding practices for dairy cows make any major trace mineral deficiencies unlikely unless a high level of dietary antagonists are present. Moderate trace mineral deficiencies are more likely to occur, especially during the transition period, affecting the health of both cows and calves. A moderate deficiency in a trace mineral with a role in immune function such as Cu, Cr, Fe, Mn, Se, and Zn compromises the immune system, increasing the risk for health disorders that can result in significant economic loss for a producer. Trace mineral status during the dry period is also important for calf health as the trace mineral status of newborn dairy calves is dependent on placental transfer of trace minerals and colostrum trace mineral concentration. Research has shown an impact of trace mineral status on biological markers of immune status. However, additional studies involving large numbers of animals are needed to fully determine the effect trace mineral status during the dry period has on disease incidence of cows, colostrum quality and calf health.

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