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REVIEW: Effects of Zinc Methionine Complex on Milk Production and Somatic Cell Count of Dairy Cows: Twelve-Trial Summary

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Abstract

*The objective of this review was to summarize 12 trials (13 comparisons) evaluating effects of zinc methionine (**ZM**) complex (ZINPRO®; Zinpro Corporation, Eden Prairie, MN) on lactation performance and udder health. Summarized trials were conducted in Washington (2), Colorado (2), New York, Illinois, Arkansas, Missouri, Georgia, Great Britain, Germany, and Israel. In 5 of the trials, ZM provided between 180 and 200 mg of zinc/d per head; in the remaining 7 trials (8 comparisons), ZM supplied 360 to 400 mg of zinc. In all diets, cows received additional zinc from inorganic sources, with the exception of the control diet in one of the Missouri comparisons. For statistical evaluation, each trial was considered as a block, and the treatment least squares mean within a trial was treated as an observation using a mixed model. Cows fed ZM produced more (P<0.01) milk (31.8 vs 30.5 kg/d), energy-corrected milk (31.7 vs 30.4 kg/d), and fat-corrected milk (31.6 vs 30.0 kg/d) than control cows. Milk composition did not differ (P>0.15) between treatment and control cows. Somatic cell count (*__SCC__*; 1000/mL)* was reduced from 294 to 196 (P<0.01) in cows receiving ZM. This summary of 12 dairy trials indicates that ZM increases lactation performance and improves udder health, as a 33.3% reduction in SCC occurred.

(Key Words: Complexed Trace Minerals, Zinc, Lactating Dairy Cows, Somatic Cell Count.)

Introduction

Zinc has been recognized for several decades as indispensable for normal growth and health in animals (NRC, 2001). The recommended level of zinc in diets of lactating dairy cows has been increased recently (NRC, 1989, 2001). It is an essential component of over 300 enzymes covering all six classes of enzymes (Dibley, 2001). Zinc has biological roles that are characterized by catalytic, structural, and regulatory functions (Dibley, 2001). The metabolic action of these systems includes carbohydrate and energy metabolism, protein synthesis, nucleic acid metabolism, epithelial tissue integrity, cell repair and division, vitamin A transport and utilization, and vitamin E absorption (Miller et al., 1988; Dibley, 2001; Hunt and Groff, 1990; Kim et al., 1998; NRC, 2001).

Zinc is also required for maintenance of skin integrity, stabilization of membranes, and activation of the cell-mediated immune system (Miller and Madsen, 1992). Together, stress, a reduction in immune response, and breakdown in skin integrity may deteriorate the natural defense mechanisms of the mammary gland (Miller, 1970). Low zinc status leads to low quality milk with high somatic cell count (SCC) and increased incidence of mastitis (Aguilar and Jordan, 1990; Galton, 1990).

Trace mineral availability is affected by other dietary mineral components such as iron, sulfur, calcium, and heavy metals (NRC, 2001). Research has demonstrated that specific amino acid complexes of trace minerals are more bioavailable (Wedekind et al., 1992; Paripatananont and Lovell, 1995) and have better retention (Nockels et al., 1993) than inorganic sources. Differences in bioavailability between complexed and inorganic sources of trace minerals are not static and are affected by level of an-

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tagonists (Wedekind et al., 1992; Paripatananont and Lovell, 1995) and stress (Nockels et al., 1993). The value of providing complexed zinc has been investigated in 12 research trials under varying management, environmental, and nutritional conditions. The objectives of this review were to summarize 12 trials (13 comparisons) evaluating the feeding of zinc methionine complex (ZM) to dairy cows and to examine levels of ZM supplementation on lactation performance and udder health, as measured by SCC.

Materials and Methods

Data from 12 trials (13 comparisons) were summarized in which lactating dairy cows were supplemented with ZM (ZINPRO®; Zinpro Corporation, Eden Prairie, MN) at a rate to provide a single level within the range of 180 to 400 mg/d of zinc per head. The 12 trials are all known to compare ZM directly with a control diet that contained inorganic zinc as the supplement for lactating dairy cows. The amount of inorganic zinc included in the control diets met or exceeded NRC (1989) recommendations and, in some trials, equaled the amount of zinc supplied by ZM in the treatment diet. In each trial, one level of ZM was compared to a control diet. Trials were included even though feeding management, environmental conditions, and nutritional status might have varied. Research trials summarized were conducted in Washington (Kincaid et al., 1984, 1985), Colorado (Aguilar et al., 1988; Aguilar and Jordan, 1990), New York (Galton, 1990), Illinois (Moore et al., 1989), Arkansas (Kellogg et al., 1989), Missouri (2 comparisons, Jones, 1995), Georgia (Smith et al., 1999), Great Britain (Wealsby, 1985), Germany (Anderson and Leon, 2000), and Israel (Schwimmer and Braun, 2001).

The average number of cows assigned to the studies was 56, with the smallest study allocating 16 cows and the largest study allocating 98 cows (Table 1). Recombinant bovine somatotropin was not administered in any of the studies. All studies, except the Missouri trials, included all multipa-

TABLE 1. Characteristics of individual trials evaluating zinc methionine complex.

Item	Cows assigned[a] (no.)	Parity of cows	Treatment period and duration (d)	Times milked (/d)
Washington[b]	80	Multiparous, primiparous	Lactation, 329 d	2
Washington[c]	30	Multiparous	Dry period and lactation, 126 d	2
Colorado[d]	76	Multiparous	Lactation, 126 d	3
Great Britain[e]	96	Multiparous, primiparous	Lactation, 170 d	2
Illinois[f]	36	Multiparous	Lactation, 365 d	2
New York[g]	58	Multiparous, primiparous	Lactation, 120 d	2
Colorado[h]	76	Multiparous	Lactation, 126 d	3
Arkansas[i]	40	Multiparous, primiparous	Lactation, 140 d	2
Israel[j]	98	Multiparous, primiparous	Lactation, 126 d	3
Missouri[k]	16	Primiparous	Lactation, 80 d	2
Missouri[k]	16	Primiparous	Lactation, 80 d	2
Germany[l]	79[m]	Multiparous	Dry period and lactation, 183 d	2
Georgia[n]	36	Multiparous, primiparous	Dry period and lactation, 240 d	2

[a]Animals were equally divided between treatments unless otherwise noted.
[b]Washington State University, Kincaid et al. (1984).
[c]Washington State University, Kincaid et al. (1985).
[d]Colorado State University, Aguilar et al. (1988).
[e]Great Britain, Wealsby (1985).
[f]Illinois State University, Moore et al. (1989).
[g]Cornell University, Galton (1990).
[h]Colorado State University, Aguilar et al. (1990).
[i]University of Arkansas, Kellogg et al. (1989).
[j]Kibbutz Gat, Israel; Schwimmer and Braun (2001).
[k]University of Missouri, Jones (1995).
[l]Kroepelin, Germany; Anderson and Leon (2000).
[m]There were 37 control animals, and 42 animals received the treatment diet.
[n]University of Georgia, Smith et al. (1999).

rous or both multiparous and primiparous cows (Table 1). Average duration of the treatment period was 170 d and included the prefresh period in one Washington trial and the whole dry period in the German and Georgia trials. Cows in the Colorado and Israel studies were milked three times daily (Table 1). All studies were conducted in moderate to high producing dairy herds (24.2 to 38.9 kg/d milk production). Studies conducted in the United States and Israel contained Holstein-Friesian dairy cows; the British trial contained British Friesian cows.

Ingredient composition of 7 of the 12 trials is reported in Table 2. Exact ingredient composition of trial diets was not reported in one Colorado trial or in the New York, Great Britain, Israeli, and Missouri studies. Diets were composed of normally occurring ingredients and were indicative of those commonly found in the dairy industry. Total zinc content of the diets fed in 9 of the 12 trials is reported in Table 3, as three trials only reported supplemental zinc, not total dietary intake. In five of the trials, ZM supplied 180 to 200 mg of zinc/d per head; in the remaining seven studies, ZM supplied 360 to 400 mg of zinc/d per head. The objective of each trial was to supplement ZM in addition to inorganic zinc fed in the diet typically used in that herd. The control diet in one of the Missouri comparisons, the German study, the New York study, and one of the Colorado studies did not meet current NRC (2001) recommendations for zinc, but exceeded earlier recommendations for zinc by the NRC (1978, 1989). Both control and treatment diets in the Illinois study were below current NRC (2001) recommendations for zinc. All other diets met or exceeded NRC (2001) recommendations for zinc. It should be noted that all studies were formulated using earlier NRC (1978 or 1989) zinc recommendations and, therefore, would have been below NRC (2001) recommendations. Zinc requirements using NRC (2001) recommendations were calculated for a lactating dairy cow, 42 mo of age, second lactation, 658 kg BW, 680 kg mature BW, 110 d in milk, 31.7 kg daily milk yield, 3.48% milk fat, 2.91% milk true protein, 22.6 kg DMI, and default environ-

TABLE 2. Ingredient composition (kg DM/d per head) of diets fed in studies evaluating zinc methionine complex[a].

Item	WSU[b,c]	WSU[b]	CSU[d]	IL[e]	UA[f]	G[g]	UGA[h]
Corn silage	1.0		2.4	5.1	2.8	8.8	11.3
Alfalfa hay	4.0	4.0	7.0	1.0			
Orchardgrass hay					3.6		
Ryegrass/clover green chop	6.3						
Fescue/wheat pasture					2		
Alfalfa haylage				4.1			
Grass haylage		6.7				1.6	
Sorghum silage							7.7
Wheat hay							3.6
Cottonseed hulls					0.4		
Grain mixture					10[i]		
Corn, ground or steam flaked			4.1	6.7	1.3		2.9
Barley	3.7	4.8					
Oats				2.0	0.3		
Soybean hulls			4.2				1.9
Corn gluten feed							2.1
Wheat bran/mill run	4.0	5.1	1.2				
Bread crumbs			2.4				
Soybean meal (48% CP)	0.7	0.9		1.2	0.4	1.7	0.7
Cottonseed, fuzzy			4.0		2.3		2.3
Beet pulp, pressed						1.7	
Wheat						1.7	
Brewer's grains						0.9	
Canola meal, coarse extract						1.2	
RUP blend[j]							1.3
Soybean meal, treated							0.9
Minerals/vitamins/fat/molasses	0.9	1.2	0.7	0.4	0.1		0.3
Protein/vitamin/mineral mix						2.5	

[a]Exact ingredient composition of diets fed in one Colorado trial (Aguilar et al., 1990) and of the diets fed in the New York (Galton, 1990), Great Britain (Wealsby, 1985), Israeli (Schwimmer and Braun, 2001), and Missouri (Jones, 1995) studies was unavailable.

[b]WSU = Washington State University; Kincaid et al. (1984, 1985).

[c]Forage sources varied by season from alfalfa hay (76 d) to green chop (182 d) to corn silage and alfalfa hay (66 d); Kincaid et al. (1985).

[d]CSU = Colorado State University; Aguilar et al. (1990).

[e]IL =Illinois State University; Moore et al. (1989).

[f]UA = University of Arkansas; Kellogg et al. (1989).

[g]G = Kroepelin, Germany; Anderson and Leon (2000).

[h]UGA = University of Georgia; Smith et al. (1999). Lactating phase diets included forage DM provided by corn silage (11.3 kg/d) for 0 to 90 d of lactation; whereas, sorghum silage plus wheat hay (7.7 and 3.6 kg DM/d) provided the forage for 90 to 180 d of lactation.

[i]Grain mixture consisted of 60.5% corn, 15% oats, 21% soybean meal (49% CP), 20% cottonseed hulls, 1% salt, 1% limestone, and 0.5% magnesium oxide.

[j]RUP blend = Ruminally undegraded protein mix consisting of menhaden fish meal, corn gluten meal, and extruded soybean meal (SoyPLUS®; Ralston, IA). Each source provided equal CP.

TABLE 3. Zinc content of diets fed in studies evaluating zinc methionine (ZM) complex.

Trial	Control	ZM
Washington[a]	50	71
Washington[b]	93	93
Illinois[c,d]	28	35
Colorado[c,e]	40	58
Arkansas[f]	49	62
Israel[c,g]	43	57
Missouri[h]	31	48
Missouri[h]	48	48
Germany[i]	35	53
Georgia[j]	177	174

[a]Washington State University, Kincaid et al. (1984).

[b]Washington State University, Kincaid et al. (1985).

[c]Calculated using book values for trace mineral content of feedstuffs.

[d]Illinois State University, Moore, et al. (1989).

[e]Colorado State University, Aguilar et al. (1990).

[f]University of Arkansas, Kellogg et al. (1989).

[g]Kibbutz Gat, Israel; Schwimmer and Braun (2001).

[h]University of Missouri, Jones (1995).

[i]Kroepelin, Germany; Anderson, and Leon (2000).

[j]University of Georgia, Smith et al. (1999).

TABLE 4. Effect on lactation performance of supplementing lactating dairy diets with zinc methionine (ZM) complex.[a]

	Milk production		ECM[b] production		FCM[c] production	
Trial	Control	ZM	Control	ZM	Control	ZM
	(kg)					
Washington[d]	27.4	28.9	28.2	29.9	27.9	29.8
Washington[d]	35.4	36.6	34.0	36.9	33.7	37.1
Colorado[e]	36.0	38.1	36.7	37.6	36.4	37.3
Great Britain[d]	24.2	25.2	24.5	25.7	24.5	25.8
Illinois[d]	26.9	27.0	26.6	26.2	26.4	26.2
New York[e]	—	—	—	—	—	—
Colorado[d]	35.4	37.9	36.2	38.6	36.0	38.2
Arkansas[e]	26.5	28.1	26.6	27.9	26.3	27.6
Israel[e]	37.4	38.9	33.3	34.5	32.0	33.4
Missouri[e]	26.7	27.2	26.6	27.3	26.7	27.2
Missouri[e]	27.1	27.2	27.9	27.3	27.9	27.2
Germany[e]	—	—	—	—	—	—
Georgia[e]	28.5	30.1	30.6	32.9	28.7	33.9

[a]12 trials; 13 comparisons.

[b]ECM = Energy-corrected milk (3.5% fat; 3.2% protein).

[c]FCM = Fat-corrected milk (3.5% fat).

[d]Treatment diet provided between 180 and 200 mg Zn/d per head from ZM complex.

[e]Treatment diet provided between 360 and 400 mg Zn/d per head from ZM complex.

mental conditions. Dry matter intake was not evaluated because cows were group fed, and DMI were not reported.

Production and udder health measures were not reported in all studies. Data from the New York and German studies included only SCC. The Arkansas and Georgia studies did not report SCC.

Statistical analysis was conducted by designating the trial by treatment least square means as the experimental unit, thereby giving equal weight to each individual study. Experimental units were blocked on trial and tested using the residual block by treatment effect as the error term. Thus, effects included in the model were block, a random effect, treatment, and fixed effect, and all were analyzed using the PROC MIXED procedure of SAS (Littell et al., 1996; Kellogg et al., 2003). Significant treatment effects were noted at $P \leq 0.05$, and trends for treatment effects were noted at $P > 0.05$ and $P \leq 0.15$.

Results and Discussion

Summary of All 12 Trials. Individual trial performance results are presented in Tables 4, 5, and 6. Cows fed ZM produced, on average, more total milk ($P < 0.001$) than cows supplemented with only inorganic zinc sources (31.8 vs 30.5 kg; Table 7). This 1.3-kg increase in milk production translates to a 4.26% improvement over unsupplemented animals. Percentage improvement in milk production ranged from 0.37 to >7.06% in the 11 comparisons reporting milk production. Milk production response was independent of level of production as milk production increased even in high producing herds. In the two Colorado studies (Aguilar et al., 1988; Aguilar and Jordan, 1990), milk yield was increased from 36.0 to 38.1 and from 35.4 to 37.9 kg/d per cow, respectively, for cows receiving ZM.

Milk composition with regard to percentage of fat and protein was not significantly affected by ZM supplementation (Table 7). Production of energy-corrected milk (**ECM**) and 3.5% fat-corrected milk (**FCM**) were increased ($P < 0.01$) by 1.3 and 1.6 kg, respectively, for cows on the ZM-supplemented treatments. Cows fed ZM also produced more kilograms of total milk fat and protein ($P < 0.05$) than unsupplemented cows.

Increases in milk production and components can be partially attributed to improved udder health. Somatic cell count (1000/mL) was reduced from 294 to 196 ($P = 0.001$) by the addition of ZM to the lactation

TABLE 5. Effect on milk component production of supplementing lactating dairy diets with zinc methionine (ZM) complex[a].

	Fat production		Protein production	
Trial	Control	ZM	Control	ZM
	(kg/d)			
Washington[b]	0.99	1.06	0.89	0.93
Washington[b]	1.14	1.31	1.07	1.10
Colorado[c]	1.28	1.28	1.15	1.19
Great Britain[b]	0.87	0.92	0.74	0.78
Illinois[b]	0.91	0.89	0.83	0.81
New York[b]	—	—	—	—
Colorado[b]	1.27	1.35	1.12	1.22
Arkansas[b]	0.91	0.95	0.85	0.89
Israel[c]	0.98	1.02	1.17	1.19
Missouri[c]	0.93	0.95	0.80	0.84
Missouri[c]	1.00	0.95	0.84	0.84
Germany[c]	—	—	—	—
Georgia[c]	1.20	1.30	0.91	0.94

[a]12 trials; 13 comparisons.

[b]Treatment diet provided between 180 and 200 mg Zn/d per head from ZM complex.

[c]Treatment diet provided between 360 and 400 mg Zn/d per head from ZM complex.

TABLE 6. Effect on milk composition and somatic cell count (SCC) of supplementing lactating dairy diets with zinc methionine (ZM) complex[a].

	Fat		Protein		SCC	
Trial	Control	ZM	Control	ZM	Control	ZM
	(%)				($\times 10^3$/mL)	
Washington[b]	3.62	3.67	3.27	3.20	231	136
Washington[b]	3.21	3.58	3.01	3.01	218	176
Colorado[c]	3.56	3.37	3.19	3.11	560	282
Great Britain[b]	3.59	3.64	3.08	3.08	497	390
Illinois[b]	3.40	3.30	3.10	3.00	243	228
New York[b]	—	—	—	—	242	115
Colorado[b]	3.60	3.55	3.18	3.22	250	195
Arkansas[b]	3.44	3.38	3.21	3.17	—	—
Israel[b]	2.62	2.62	3.13	3.07	410	333
Missouri[c]	3.50	3.50	3.00	3.10	228	46
Missouri[c]	3.70	3.50	3.10	3.10	131	46
Germany[c]	—	—	—	—	95	81
Georgia[c]	4.00	4.20	3.20	3.10	—	—

[a]12 trials; 13 comparisons.

[b]Treatment diet provided between 180 and 200 mg Zn/d per head from ZM complex.

[c]Treatment diet provided between 360 and 400 mg Zn/d per head from ZM complex.

diets. Thus reduction translates to a 33.3% reduction in SCC. Dibley (2001) reported that zinc plays an integral role in immune function by activating T-lymphocyte responsiveness, thus impacting the effectiveness of somatic cells within the mammary gland.

Level of Supplementation. In seven of the trials, ZM was supplemented at 360 to 400 mg of zinc/d per head. Several of the earlier trials (Kincaid et al., 1984, 1985; Wealsby, 1985; Moore, 1989; Aguilar and Jordan, 1990) evaluated ZM at the level of 180 to 200 mg zinc/d per head. Results from seven studies conducted at 360 to 400 mg of zinc from ZM are reported in Table 8. Supplementing lactating dairy cows with the greater level of ZM resulted in an increase of 1.2 kg of milk (32.4 *vs* 31.2 kg) ($P<0.005$), a 3.8% improvement. This ZM treatment level also improved total kilograms of ECM and milk protein ($P\leq0.05$). There was a trend ($P\leq0.11$) for improvement in 3.5% FCM production when cows were supplemented with 360 to 400 mg of zinc from ZM.

The magnitude of SCC reduction was enhanced when cows were supplemented at the greater level of ZM. Somatic cell count (1000/mL) was reduced by 42.6% (from 298 to 171 cells) with the elevated ZM treatments. There are several plausible means by which increasing zinc status reduces SCC. Zinc is important in maintenance of health and integrity of epithelial tissue, such as skin (teats) and mammary tissue, because of its role in cell division and protein synthesis (Cook-Mills and Fraker, 1993). Zinc deficiencies have been shown to reduce cellular and humoral immune responses (Cook-Mills and Fraker, 1993). Reduced immune function, resulting from a zinc deficiency, is attributed to decreased cell-mediated immune response and natural killer cell activity, atrophy of the spleen and thymus, and decreased T-dependent and independent antibody-mediated responses (Wirth et al., 1984). Possibly, an additional

TABLE 7. Effect of supplementing lactating dairy diets with 180 to 400 mg Zn/d per head of zinc methionine (ZM) complex.

Item	n[a]	Control	ZM	SEM	P=
Milk, kg/d	10	30.5	31.8	1.6	0.0001
ECM[b], kg/d	10	30.4	31.7	1.5	0.003
3.5% FCM[c], kg/d	10	30.0	31.6	1.5	0.008
Fat, kg/d	10	1.06	1.10	0.05	0.03
Protein, kg/d	10	0.96	0.99	0.05	0.003
Fat, %	10	3.47	3.48	0.12	0.90
Protein, %	10	3.14	3.11	0.02	0.17
SCC[d], $\times 10^3$/mL	10	294	196	41	0.001

[a]Number of trials in which parameter was measured.
[b]ECM = Energy-corrected milk (3.5% fat; 3.2% protein).
[c]FCM = Fat-corrected milk (3.5% fat).
[d]SCC = Somatic cell count.

mode of action for zinc-reducing SCC is related to zinc's role in keratin formation. Zinc is required for the incorporation of cystine into keratin (Moynahan, 1981). The keratin lining of the teat canal entraps bacteria and prevents their upward movement into the mammary gland (Cross and Parker, 1981; Nickerson, 1985, 1990). Approximately 40% of the keratin lining in teat canals of Holstein dairy cattle is removed during the milking process, thus requiring continuous regeneration. Capuco et al. (1992) estimated that approximately 1.3 mg of keratin must be regenerated during the inter-milking period. Results from the study conducted at the University of Missouri lend credence to the theory that reduced SCC is due to increased keratin synthesis and improved immune function (Jones, 1995). These researchers initially collected more keratin from teat canals of cows fed ZM than from cows fed an equivalent amount of zinc in the form of zinc oxide. However, because of the time required to regenerate keratin, there was no difference in amount of keratin collected from cows at subsequent collections. When cows in that same study were challenged with *Escherichia coli*, cows fed ZM recovered more quickly from the bout with E. coli mastitis than cows fed zinc oxide, as evidenced in numerically greater milk production and DMI for cows fed ZM (Jones, 1995). Prior to the bacterial infection, cows fed ZM produced a similar level of milk as cows fed zinc oxide, but tended to produce milk with a lesser SCC (Jones, 1995). Galton (1990) reported that cows supplemented with ZM had a similar number of incidents of intramammary infections, but the severity and duration were reduced as noted by reduced linear SCC. Swelling of the mammary gland increases stress and potential for additional mammary infections. Although not reporting somatic cell scores, Campbell and Miller (1998) indicated that first lactation heifers had less udder edema when supplemented with an additional 800 mg zinc, 400 mg per head from ZM, during late gestation.

TABLE 8. Effect of supplementing lactating dairy diets with ≥360 mg zinc from zinc methionine (ZM) complex.

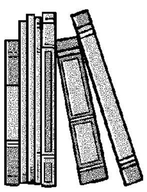
Item	n[a]	Control	ZM	SE	P=
Milk, kg/d	5	31.2	32.4	2.4	0.005
ECM[b], kg/d	5	31.0	32.0	1.9	0.04
3.5% FCM[c], kg/d	5	30.3	31.7	1.9	0.11
Fat, kg/d	5	1.07	1.09	0.08	0.26
Protein, kg/d	5	0.98	1.01	0.07	0.05
Fat, %	5	3.45	3.41	0.23	0.51
Protein, %	5	3.15	3.12	0.03	0.35
SCC[d], $\times 10^3$/mL	5	298	171	70	0.012

[a]Number of trials in which parameter was measured.
[b]ECM = Energy-corrected milk (3.5% fat; 3.2% protein).
[c]FCM = Fat-corrected milk (3.5% fat).
[d]SCC = Somatic cell count.

Claw (Hoof) Integrity. Improvements in lactation performance can be partially attributed to reduced SCC, but may also be due to improved claw integrity of hoof tissue. Growth, wear, and quality of cow's claws (hooves) were measured precisely in the Illinois State University trial (Moore, 1989). Claw growth and wear were similar between treatment and control animals, but cows fed ZM had improved ($P<0.05$) visual claw (hoof) scores compared with control animals. Visual claw scores included texture of the claws, incidence of heel cracks, interdigital dermatitis, and foot rot. Condition scores of the claws were also improved in ZM-supplemented cows, over control animals, in the British trial (Wealsby, 1985). Similar results in improving claw integrity have been reported in beef cattle. The ZM improved claw quality of crossbred steers grazing native grass (Brazle, 1993). Of cattle receiving 216 mg/d zinc from ZM in this study, 2.45% had foot rot, and 5.38% of cattle not receiving ZM had foot rot.

Implications

This summary of 12 trials (13 comparisons) indicates that ZM improves lactation performance and production of milk components and reduces milk SCC in lactating dairy cows. Reduction in SCC was enhanced when ZM was fed to provide ≥360 mg zinc/d per head. Supplementation of dairy cows with ZM positively influences claw integrity and, thus, may have affected lactation performance. Improvements in lactation performance, reduction in SCC, and improvements in claw integrity were produced under varying management, housing, nutritional, and environmental conditions.



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