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Altering Source of Organic Trace Minerals Improves Milk Fat in Commercial Dairy

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Abstract

Little research is available directly comparing organic trace mineral sources. Therefore, the objective of this study was to determine effects of altering source of organic trace minerals on lactation and reproductive performance in a commercial dairy herd. Six pens (3 per treatment) received isomineral diets, differing only in supplemental Cu, Mn, and Zn source for 7 months. Supplemental Cu, Mn, and Zn were provided as metal methionine hydroxy analog chelate (MMHAC) or metal complexes of methionine and lysine (MMKC). Monthly milk yield, composition, and reproduction information were collected and analyzed using SAS/STAT software (Version 9.3; SAS Institute Inc., Cary, NC) with repeated measures as appropriate. No significant effects of treatment were observed for reproductive parameters including conception risk at any breeding (29.9 versus 29.4 %; 95% CI 17.0, 47.0, MMKC and MMHAC respectively) and days open (106.8 vs. 107.8; 95% CI 99.9, 114.2). However, a significant treatment by time interaction was observed for milk yield (40.0 versus 39.8 ± 4.1, MMKC and MMHAC respectively; $P = 0.02$), percent fat (3.45 versus 3.51 ± 0.20; $P < 0.01$), and percent solids non-fat (8.77 versus 8.80 ± 0.10; $P = 0.04$). Observed increases in milk fat (12.4 g) suggest additional value for MMHAC because of methionine hydroxy analog ligand. Together this data suggests that differing source of organic trace mineral changes lactation performance, particularly milk fat, over time that may significantly impact dairy farm revenue.

Keywords: Organic trace minerals; Dairy; Performance; Milk fat

Abbreviations: ITM: Inorganic Trace Mineral; MMHAC: Metal Methionine Hydroxy Analog Chelates; MMKC: Metal Methionine and Lysine Complexes; OTM: Organic Trace Mineral

Introduction

Trace minerals such as Zn, Cu, and Mn are essential for health and performance of production animals. Historically, Zn, Cu and Mn have been supplemented using inorganic salts [1]; however, due to the slightly acidic environment in the rumen, inorganic salts tend to dissociate, increasing interactions with antagonists and reducing absorption [2]. Supplementing trace minerals in organic forms reduces dissociation of the trace mineral in the rumen environment due to the organic ligand(s) bound to the mineral, resulting in increased absorption [3,4].

Previous research investigating the effects of metal complexes of methionine and lysine have shown that both mineral sources have greater bioavailability compared to inorganic salts [5,6]. Furthermore, supplementing metal complexes of methionine and lysine has increased milk production and reduced SCC compared to inorganic trace mineral (ITM) supplementation [7-9]. Research in which metal methionine hydroxy analog chelates were supplemented support increased milk yield [10,11], immune function [11,12], and hoof health [11,13]. These responses suggest greater absorption and availability to the animal for metal methionine hydroxy analog chelates compared to inorganic forms [14,15]. With greater availability of organic trace minerals (OTM), regardless of the ligand, increases in lactation performance support organic trace mineral use over ITM use.

Little research has compared the effect of altering the source of OTM. Research looking at the impact of trace mineral supplementation in broilers, observed decreases in plasma lipid hydroperoxide, an indicator of oxidative stress, and increases in intestinal breaking strength with metal methionine hydroxy analog chelates compared to amino acid complexes [1]. Furthermore, metallothionine expression increases with supplementation of metal methionine hydroxy analog chelates compared to amino acid complexes and proteinates in broilers [16]. Together these data support a benefit to supplementation with chelated minerals over other OTM in broilers and highlights the need for comparisons of OTMs in ruminants.

When comparing performance and liver mineral levels of cows supplemented amino acid complexes or metal methionine hydroxy analog chelates, liver copper, as well as milk manganese and fat, were increased with metal methionine hydroxy analog chelates. With the more complex digestive system of ruminants, additional research is needed to verify the benefit of metal methionine hydroxy analog chelates over other OTM. Therefore, the objective of this trial was to evaluate the effects of supplementation with two sources of OTM on lactation and reproductive performance, as well as lameness, in a commercial dairy herd.

Materials and Methods

Study design and treatments

This study occurred over 7 months and served as a prospective split herd side-by-side comparison-controlled trial. A total of 6 pens of lactating cows from a commercial dairy in California were enrolled in the study. All pens received the same isomineral diets during the study period with the difference of the organic source of Zn, Cu and Mn. Three pens were supplied metal methionine hydroxy analog chelate (MMHAC) as a source of supplemental Zn, Cu, and Mn (MINTREX®, Novus International, St Charles, MO). The other three pens were supplied metal complexes of methionine and lysine (MMKC) as a source of supplemental Zn, Cu, and Mn (4-PLEX®C, MANPRO 160 and ZINPRO 120, Zinpro Corporation, Eden Prairie, MN). As MMKC provided cobalt glucoheptonate, cobalt glucoheptonate was added at the same inclusion level to MMHAC.

Animal management

A total of 3,575 cows were enrolled in the study across a total of 6 pens over the 7-month experiment. Cows of similar days in milk and production were housed together, when feasible, to allow for a similar average lactation number and days in milk for both treatment groups. Pen inventory was reviewed biweekly to ensure cow movements between pens-maintained treatment assignment over the duration of the study. For the duration of the study, animals were cared for according to standard site practices and cows deemed to require veterinary attention or treatment outside of veterinary care (i.e. mastitis etc.) were handled according to established site standard operating procedures. These practices and procedures agreed with principles presented in Guide for the Care and Use of Agricultural Animals in Research and Testing.

Diets and feed preparation

Diets were formulated to be isomineral and differed only in the source of organic Zn, Cu, and Mn (Table 1). Mineral premixes containing the different sources of OTM were prepared in larger batches at a commercial feed mill. Feedstuffs were combined daily and cows were feed a TMR twice daily. Premixes and TMR were sampled once a month during the study period (n=7) [17] and analyzed for nutrient and mineral composition using AOAC International (2000, 2006) approved methods at a commercial laboratory (Cumberland Valley Analytical Services, Hagerstown, MD).

Animal Measures and Data Management

Animal records (monthly DHIA lactation performance, reproduction, and culling) to encompass the 7 months of the trial were collected from the farm's record system (Dairy Comp 305; Valley Agricultural Software, Tulare, CA). Cows were followed until the end of the study period, end of current lactation, movement to another non-study pen (i.e. low production) or removed from the herd based on whichever comes first. Lactation performance measures included milk yield, fat, solids non-fat, and SCC. Milk SCC was log transformed to normalize the data to linear SCC. Additionally, SCC was categorized by level of SCC into 1 of 9 categories (1 = 0 to 125,000cells/mL; 2 = 125,001 to 250,000cells/mL; 3 = 250,001 to 375,000cells/mL; 4 = 375,001 to 500,000cells/mL; 5 = 500,001 to 625,000cells/mL; 6 = 625,001 to 750,000cells/mL; 7 = 750,001 to 875,000cells/mL; 8 = 875,001 to 1,000,000cells/mL; and 9 = > 1,000,001cells/mL) to allow for analysis of differences in distribution between category.

Table 1: Composition of TMR used during the experimental period.

	% of diet DM	
Feedstuff	MMKC[1]	MMHAC[1]
Corn silage	15.2	15.2
Corn, rolled	13.5	13.5
Citrus pulp	11.8	11.8
Alfalfa hay	10.3	10.3
Almond hulls	9.23	9.23
Wheat, mill run	7.31	7.31
Cottonseed, delinted	7.27	7.27
Distillers grains, dried	6.63	6.63
Wheat silage	6.21	6.21
Soybean meal	5.1	5.1
Alfalfa haylage	3.92	3.92
Molasses	1.91	1.91
Mineral Pre-mix[2]	1.62	1.62

[1]Treatments include metal methionine and lysine complexes (MMKC) and metal methionine hydroxy analog chelates (MMHAC).

[2]MMKC mineral pre-mix contained 42.5% calcium carbonate, 33.4% sodium bicarbonate, 7.09% magnesium oxide, 6.41% rice bran, 4.92 % vitamin and trace mineral pre-mix, 2.82% yeast culture, 1.43% metal methionine and lysine complexes, 1.01% fat blend, 0.22% biotin (2%), and 0.20% agolin. MMHAC mineral pre-mix contained 43.1% calcium carbonate, 33.4% sodium bicarbonate, 7.08% magnesium oxide, 6.40% rice bran, 4.92 % vitamin and trace mineral pre-mix, 2.82% yeast culture, 1.01% fat blend, 0.46% zinc methionine hydroxy analog chelate, 0.31% manganese methionine hydroxy analog chelate, 0.22% biotin (2%), 0.20% agolin, 0.02% zinc methionine hydroxy analog chelate, and 0.02% cobalt glucoheptonate.

The percent of animals in each pen was calculated for each category for later analysis. Milk production and composition analysis were limited to observations collected from 60 to 500 DIM to remain within the linear portion of the lactation curve. For reproduction, date of first breeding, date of conception, and pregnancy result were used only from cows housed in study pens at the time of first breeding to determine risk and days to conception. For cows with more than one conception recorded (e.g. due to embryo loss/abortion), the 1st conception date was

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used (after examination of the individual records for validation). Reproduction parameters were calculated for cows between 60 to 500 DIM and those bred for the first and subsequent times during the study period within their assigned pen. Lameness and lying time were assessed every 2 months (n=3) using the methods of Flower & Weary & Ito [18,19] respectively. Lameness was defined as cows scoring greater or equal to 3, while severe lameness was defined as cows scoring greater or equal to 4. Stocking density was also recorded at each assessment. For all cows in the study, the removal date (culling or death) was retrieved to determine risk and days to culling.

As this study was conducted allowing for natural movement of cows within a farm, to maintain independence between experimental units (pens) only observations collected within one pen were utilized for cows listed in multiple pens over the study period. As such, the number of milk production records for each cow within each pen was calculated. Each cow was assigned to the pen with the max number of observations and only observations within the assigned pen were included into the analysis. In case of ties, the pen where the cow was in first was considered. For single events (e.g. conception and culling risk) only events observed in the assigned pen were considered unless otherwise specified.

Statistical analysis

In the current study, treatments were randomized to pens; therefore, the experimental unit was pen (6 pens in total with 3 pens per treatment) and cows within pen constituted sampling units. Data were analyzed using the SAS/STAT software (Version 9.3; SAS Institute Inc., Cary, NC). Milk production data were analyzed using the mixed procedure with repeated measure analysis where the time variable consisted of days post-trial initiation. The repeated measure model included treatment, time and their interaction as fixed effects. Pen within treatment was included in the model as a random effect. Cow within treatment was the subject of the repeated statement and compound symmetry was used as the covariance structure. To evaluate differences in distribution of SCC between treatments, a Kolmogorov-Smirnov test was preformed using NPAR1WAY procedure. Conception and culling risk, number of breeding times and days open were analyzed using the GLIMMIX procedure.

Distributions implemented were Binomial, Poisson and log-Normal for conception and culling risk, breeding count and days open, respectively. Pen within treatment was included in the model as a random effect. The effect of treatment on survival time (time to conceive, time to die, or being sold) was modelled using the Cox proportional hazards regression using the PHREG procedure available within SAS/STAT software using a robust sandwich estimator and accounting for the intra-pen dependence. The repeated measure model included treatment, time and their interaction as fixed effects, pen within treatment was included in the model as a random effect, and cow within treatment as the subject of the repeated statement with a compound symmetry covariance structure. Significance was declared at $P < 0.05$ and tendency was declared at $0.05 \le P < 0.10$.

Results and Discussion

Lactation performance

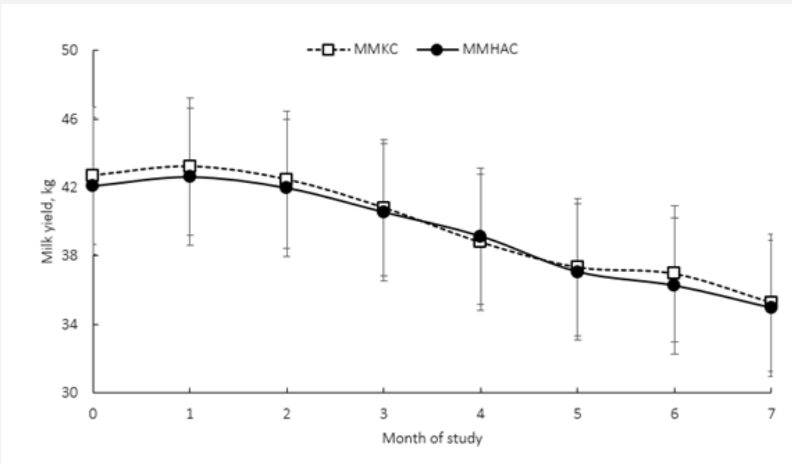

Figure 1: Effect of altering source of organic trace minerals (MMKC compared to MMHAC) on milk production (kg/d) of a commercial dairy herd. MMKC (□) stands for metal methionine and lysine complexes; MMHAC (●) stands for metal methionine hydroxy analog chelates. Effect of treatment (P = 0.98) was not significant. However, a significant time by treatment interaction (P = 0.02) was observed.

Analyzed nutrient composition of the treatment rations agreed with calculated composition (Table 2) and were in close approximation to one another. Milk yield (P = 0.98) and fat corrected milk (P = 0.99) were not significantly altered by OTM source (Table 3). When the interaction of treatment and time was evaluated, a significant interaction was observed for milk yield (P = 0.02, Figure 1) with milk yield being greater (0.37 kg/d) for MMKC over time. Previous research comparing supplementation with ITM to those with MMHAC also observed no differences in milk yield. However, a meta-analysis suggested an increase in

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milk yield by 0.93 kg/d when trace minerals are supplemented as amino acid complexes compared to ITM. These changes in milk volume may be linked to changes in milk components observed in this trial.

Table 2: Nutrient analysis of mineral mix and TMR used during the experimental period.

	Mineral Mix[1]		TMR[2]	
Values	**MMKC[3]**	**MMHAC[3]**	**MMKC**	**MMHAC**
Dry Matter, %	89.4 ± 3.4	87.8 ± 1.3	57.5 ± 0.9	59.6 ± 6.8
Crude Protein, % DM			17.9 ± 0.9	17.9 ± 1.1
ADF, % DM			22.1 ± 2.1	21.9 ± 1.8
aNDF, % DM			31.0 ± 1.4	30.9 ± 1.3
Ash, % DM	82.9 ± 1.0	83.2 ± 0.9	8.0 ± 0.5	8.5 ± 0.6
Ca, % DM	19.5 ± 0.9	20.6 ± 0.6	0.78 ± 0.08	0.84 ± 0.10
P, % DM	0.19 ± 0.01	0.21 ± 0.03	0.46 ± 0.03	0.47 ± 0.02
Mg, % DM	4.13 ± 0.35	3.59 ± 0.62	0.33 ± 0.01	0.33 ± 0.02
K, % DM	0.45 ± 0.11	0.41 ± 0.13	1.70 ± 0.06	1.74 ± 0.11
Na, % DM	10.7 ± 0.4	10.9 ± 0.37	0.24 ±0.03	0.23 ± 0.02
Fe, ppm	1299 ± 144	1353 ± 168	461 ± 101	492 ± 99
Mn, ppm	1768 ± 374	1511 ± 127	77.4 ± 12.3	74.0 ± 8.1
Zn, ppm	2655 ± 226	2720 ± 504	79.6 ± 7.6	78.0 ± 5.2
Cu, ppm	760 ± 147	730 ± 34	20.4 ± 2.2	21.1 ± 1.9
NEL, mcal/kg			1.67 ± 0.02	1.65 ± 0.02
NFC, % DM			43.2 ± 1.5	42.7 ± 2.7

[1]n = 6 samples/treatment; values presented are means with associated standard deviation.

[2]n = 7 samples/treatment; values presented are means with associated standard deviation.

[3]Treatments include metal methionine and lysine complexes (MMKC) and metal methionine hydroxy analog chelates (MMHAC).

Altering source of OTM did not change milk fat percent (P = 0.88) and solids non-fat percent (P = 0.78); however, both parameters were significantly altered (P < 0.01) by time (Table 3). This resulted in significant interaction between treatment and time for milk fat percent (P < 0.01; Figure 2) and solids non-fat percent (P = 0.04; Figure 3). In fact, when combining reduction in milk yield with increases in milk fat percent observed with MMHAC, there is still a benefit of MMHAC to have greater milk fat yield by 12.4 g per day (1366.8 g of milk fat for MMKC and 1379.2g of milk fat for MMHAC). This increase suggests that changes in milk yield were most likely due to altered nutrient partitioning to support greater milk fat synthesis with MMHAC over time. Previous research with amino acid complexes, including MMKC, observed increases in fat yield when compared to ITM [20]. Other research observed increased milk fat with feeding of MMHAC ligand [21,22], suggesting there is ample research to support increasing milk fat with MMHAC supplementation.

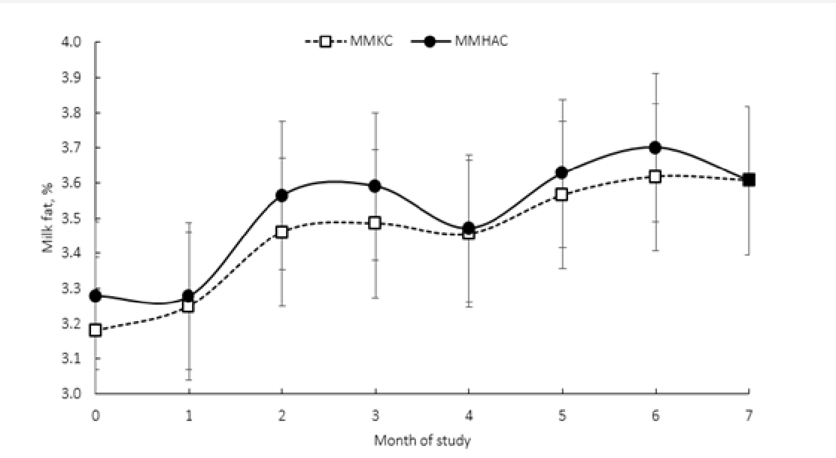

Figure 2: Effect of altering source of organic trace minerals (MMKC compared to MMHAC) on milk fat (%) of a commercial dairy herd. MMKC (□) stands for metal methionine and lysine complexes; MMHAC (●) stands for metal methionine hydroxy analog chelates. Effect of treatment (P = 0.88) was not significant. However, a significant time by treatment interaction (P > 0.01) was observed.

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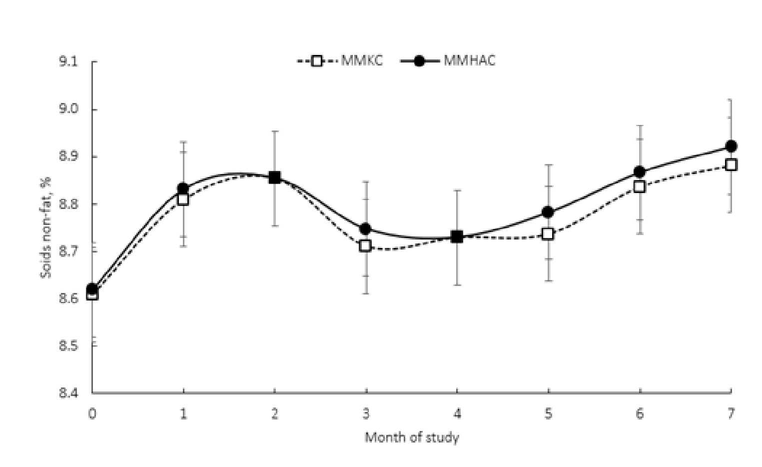

Figure 3: Effect of altering source of organic trace minerals (MMKC compared to MMHAC) on milk solids non-fat (%) of a commercial dairy herd. MMKC (□) stands for metal methionine and lysine complexes; MMHAC (●) stands for metal methionine hydroxy analog chelates. Effect of treatment (P = 0.87) was not significant. However, there a significant time by treatment interaction (P = 0.04).

This observed increase in milk fat may be multi-faceted as recent research shows a role for 2-hydroxy-4-(methylthio) butanoate to modify biohydrogenation pathways in the rumen in favor of increasing milk fat [23-25]. Moreover, a recent meta-analysis supports the benefits of supplementing 2-hydroxy-4-(methylthio) butanoate, the ligand associated with MMHAC, to increase milk fat yield by 45g/d [26]. Together this data supports that there is additional value to the methionine hydroxy analog ligand associated with MMHAC supplementation than the lysine and methionine ligands associated with MMKC supplementation.

Table 3: Effect of altering source of organic trace mineral on lactation performance of a commercial dairy herd.

		Treatment[1]			*P* – value	
Outcome[2]	**MMKC**	**MMHAC**	**SEM**	**Treatment**	**Time**	**Treatment x Time**
Milk yield, kg	40	39.8	4.1	0.98	< 0.01	0.02
Fat corrected milk, kg	39.5	39.6	3.8	0.99	< 0.01	0.13
Fat, %	3.45	3.51	0.2	0.88	< 0.01	< 0.01
Solids non-fat, %	8.77	8.8	0.1	0.78	< 0.01	0.04
Linear score, SCC	4.5	4.52	0.33	0.97	< 0.01	0.14

[1]Treatments include metal methionine and lysine complexes (MMKC) and metal methionine hydroxy analog chelates (MMHAC).

[2]n = 3,575.

Table 4: Effect of altering source of organic trace mineral on distribution of somatic cell count of a commercial dairy herd.

	Treatment[1]		SE	*P*-value
SCC Level	**MMKC**	**MMHAC**		
Less than 125,000cells/mL	63.1	62.51	10.32	0.97
125,001 - 250,000cells/mL	21.53	21.77	5.35	0.97
250,001 - 375,000cells/mL	6.77	7.36	2.22	0.85
375,001 - 500,000cells/mL	2.97	3.23	1.11	0.87
500,001 - 625,000cells/mL	1.5	1.6	0.57	0.9
625,001 - 750,000cells/mL	0.78	0.97	0.34	0.71
750,001 - 875,000cells/mL	0.68	0.6	0.23	0.81
875,001 - 1,000,000cells/mL	0.51	0.44	0.11	0.65
Greater than 1,000,000cells/mL	2.15	1.52	0.61	0.48

[1]Treatments include metal methionine and lysine complexes (MMKC) and metal methionine hydroxy analog chelates (MMHAC).

Somatic cell score did not differ between OTM source (P = 0.97) nor was there a significant interaction of treatment and time (P = 0.14; Table 3). When the level category of SCC was considered, no differences were observed in the percent of animals in each category of SCC level between treatments (P ≥ 0.48; Table 4). Furthermore, there was no observed difference in the distribution of SCC levels between treatments (P = 0.70; data not shown). Previous reports on the effect of trace minerals on SCC have varied. Comparison of ITM to amino acid complexes resulted in a significant decrease (54%) in SCC. Conversely, trials comparing use of amino acid complexes, as well as metal chelates of methionine hydroxy analog, have observed no differences in SCC [27]. Previous research suggests that the ability of OTM, such as Zn, to reduce SCC depends upon initial SCC being high [28]. With 84.6% (MMKC) and 84.3% (MMHAC) of cows having a SCC less than 250,000 cells/mL, there was most likely not a role for Zn and other OTMs to improve SCC. Lack of changes between the treatment groups of the current trial may suggest that udder health was optimized for the herd used in this trial, limiting the ability of trace minerals to reduce SCC.

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Reproductive Performance

Table 5: Effect of altering source of organic trace mineral on reproductive performance of a commercial dairy herd.

	Treatment[1]		P-value
Outcome[2]	MMKC	MMHAC	
Conception risk at 1st breeding, %	36.2 (17.7, 59.9)	34.0 (16.3, 57.7)	0.8
Conception risk at any breeding, %	29.9 (17.0, 47.0)	29.4 (16.6, 46.4)	0.92
Breeding events	2.3 (1.9, 2.9)	2.4 (1.9, 2.9)	0.86
Days open for pregnant cows	87.0 (81.5, 92.8)	89.0 (83.4, 94.9)	0.39
Days open for all cows	106.8 (99.9, 114.2)	107.8 (100.9, 115.2)	0.72

[1]Treatments include metal methionine and lysine complexes (MMKC) and metal methionine hydroxy analog chelates (MMHAC).

[2]Analysis includes cows bred only during the study period and n = 1,799; data presented as means with associated 95% confidence interval.

No significant treatment effects were observed in any of the reproduction parameters assessed (Table 5). Conception risk (P ≥ 0.80), days open (P ≥ 0.39), and number of breeding events (P = 0.86) did not differ between treatments. First service conception risk (36.2% for MMKC and 34.0% for MMHAC) and overall conception risk (29.9% for MMKC and 29.4% for MMHAC) were high compared to other herds in California. Previous research reported first service conception risk of 30.8% and an overall conception rate of 26.4 % in a large Central Valley dairy [29], while Cassell & McAllister [30] reported a 22% first service conception rate for Holstein dairy cows in California. Together these number suggest that the herd used for the current trial had maximized reproductive function due to conception rates being greater than other reported values for large herds in California.

With reproductive function optimized in this study, and the integral roles Cu, Zn, and Mn play in reproductive function, treatment means suggest that the maximized reproductive function of this herd limits the sensitivity of reproductive performance to be an indicator of bioavailability of the high quality OTM evaluated. In fact, most reported changes in reproductive performance are observed under deficiency conditions or with large differences in quality of trace mineral. When MMHAC completely replaced ITM in a 305-d lactation trial, cows supplemented MMHAC had greater odds of conceiving at earlier services [31]. Furthermore, in a commercial dairy trial where MMHAC partially replaced ITM, conception rate at first and second service were significantly greater for cows supplemented MMHAC for at least 30 d. A meta-analysis for MMKC supplementation in dairy cows supports a 13.5-day reduction in days open and fewer services per conception when compared to ITM supplementation. Together these data suggest that both OTM sources provide the required level of mineral to maintain reproductive performance, while suggesting that less drastic changes in bioavailability of high quality OTM are not reflected in situations, like the herd used for the current study, where reproductive function is maximized.

Lameness

Table 6: Effect of altering source of organic trace mineral lameness, stocking density, lying behavior, and culling risk of a commercial dairy herd.

	Treatment[1]			*P* – value		
Outcome	MMKC	MMHAC	SEM	Treatment	Time	Treatment x Time
Lame cows[2], %	10.8	9.6	1.4	0.57	0.01	0.84
Severely lame cows[3], %	0.42	0.13	0.14	0.22	0.39	0.55
Stocking density, %	103	103	1	0.73	0.23	0.99
Lying time, h/d	10.5	10.77	0.68	0.8	0.02	0.9
Culling risk[4], %	9.4 (4.3, 19.5)	11.3 (5.2, 22.7)	.	0.67	.	.

[1]Treatments include metal methionine and lysine complexes (MMKC) and metal methionine hydroxy analog chelates (MMHAC).

[2]As determined by Novus C.O.W.S. assessments; values represent cows scoring 3 or greater using methods of Flower and Weary (2006).

[3]As determined by Novus C.O.W.S. assessments; values represent cows scoring 4 or greater using methods of Flower and Weary (2006).

[4]n = 3,684; data presented as mean with associated 95% confidence interval.

No significant treatment effects were observed for lameness (P = 0.57), severe lameness (P = 0.22), or culling risk (P = 0.67; Table 6). Lameness was significantly altered by time (P = 0.01), while severe lameness was not altered by time (P = 0.39). The interaction between treatment and time was not significant for lameness (P = 0.84) or severe lameness (P = 0.55). With lameness being a multifactorial issue, lying time and stocking density were measured at the same time lameness was assessed. Altering source of OTM did not alter lying time (P = 0.80) nor did stocking density differ (P = 0.73) between treatments. Lameness prevalence varies by region, with a reported average of 30% in California dairies, and severe lameness being lower, with an average of 2% in California [32]. Comparing reported averages of lameness to those observed in the current trial (less than 11%) suggests that management was optimal for hoof health in this herd.

Furthermore, failure to see differences between the two treatments suggests both sources provided adequate mineral nutrition allowing for structural integrity to be maximized. This maximization makes lameness an insensitive marker for differences in bioavailability of the high-quality trace mineral sources utilized in the current study. Previous research suggests Cu and Zn are imperative for hoof formation, with the hard keratin found in hooves having greater concentrations of the

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two minerals than soft keratin located in other tissues [33]. Work comparing MMHAC inclusion to that of ITM inclusion in dairy rations support a benefit of greater quality minerals to reduce lameness over time, while MMKC has been shown to reduce heel erosion compared to ITM [34]. Together, these data indicate that cows were supplied the needed trace minerals from both treatments to maintain a high level of structural integrity resulting in low levels of lameness and severe lameness [35-37].

Implications

The high level of reproductive performance and udder health, as well as low prevalence of lameness made it difficult to detect differences between MMHAC and MMKC in this 7-month trial. This suggests that when these parameters are optimized, they are not suitable indicators of bioavailability differences between high quality OTM. However, an additional benefit is realized with MMHAC due to improvements in milk fat. This increase in milk fat speaks to the methionine analog component of the product, as well as the rumen effect, of the HMTBa ligand associated with MMHAC. This suggests that when MMHAC is provided, cows realize not only the value of the mineral, but also a biological value for the associated ligand. Finally, the significant increase in milk fat due to MMHAC translates to a meaningful improvement in profit in today's dairy farms, even with the small increase in milk yield from MMKC.

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