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A Comparison of MIN-AD® to MgO and Limestone in Peripartum Nutrition

Introduction

Recent research has linked subclinical hypocalcemia, which impacts 11-25% of first lactation heifers and 42-60% of multiparous cows, with increased risk of displaced abomasum and ketosis, diminished immune function, lower feed intake, and decreases in milk production and reproductive performance. To help prevent low blood Ca, it has become common practice to feed higher concentrations of dietary Mg prepartum (0.45-0.50% of DM), as Mg contributes to the homeostatic pathway regulating blood Ca. With this in mind, theoretically, feeding higher concentrations of Mg postpartum to increase blood Mg levels may increase the rate of postpartum Ca recovery.

Previous transition cow research has shown that replacing supplemental MgO and limestone with MIN-AD results in similar serum levels of Mg and Ca in close-up cows. In a study involving early lactation cows, DMI and milk production increased when MIN-AD partially replaced MgO and limestone in the diet (MIN-AD Technical Bulletin D-7 and D-6).

This trial was conducted at Cornell University by Dr. Tom Overton and Brittany Leno to determine the effects of feeding MIN-AD in the peripartum period, and different dietary levels of Mg postpartum, on plasma mineral status, performance, and aspects of energy metabolism in transition dairy cows.

Experimental Design

Between May and July of 2015, 47 multiparous Holstein cows were enrolled in a 2 X 2 factorial design experiment starting at -28 d prior to expected parturition. Cows were fed a control diet for one week. At -21 d to parturition, cows were randomly assigned to one of two source treatments in which supplemental dietary Ca and Mg were provided primarily through a common source, MgO and limestone (CS), or MIN-AD (MA). Randomization was restricted to balance for parity group and previous 305 d ME milk production.

At the first feeding postpartum, cows within each source treatment were further randomized to receive diets formulated for either low Mg (LM = 0.30% of DM) or high Mg (HM = 0.45% of DM). This resulted in 4 treatment groups: CS-LM, CS-HM, MA-LM, and MA-HM. Cows were followed through 42 DIM.

Cows were fed once daily with individual feed intake measured by weighing feed delivered and refused. To allow for ad libitum intake, cows were fed for a targeted refusal rate of 10%. All rations were composed of a base TMR containing forages, a base grain mix, and

a small inclusion rate grain mix; the latter of which was unique to each treatment group. The small inclusion rate grain mix contained the majority of the supplemental minerals as well as ingredients to offset the higher inclusion rate of MA compared to CS. Ingredient composition and analyzed diet composition of all pre- and postpartum treatment diets are presented in Tables 1 and 2.

Feed ingredient and TMR samples were collected weekly to determine DM. Weekly DM values were used to adjust as-fed inclusion rates of all ingredients. At the end of the experiment, composited TMR, forage, and grain samples were analyzed for DM, CP, ADF, NDF, starch, sugar, ether extract, minerals, chloride, and sulfur. Values for NEL of TMR composite samples were calculated according to NRC (2001).

Cows were observed daily for health disorders. Body weights (BW) and BCS were measured on a weekly basis from -28 d prepartum through 42 d postpartum.

Table 1. Ingredient composition of prepartum and postpartum diets

	Prepartum Diet		Postpartum Diet			
Ingredient, % of DM	CS	MA	CS-LM	CS-HM	MA-LM	MA-HM
Brown mid-rib corn silage	37.59	37.59	38.00	38.00	38.00	38.00
Alfalfa hay	-	-	7.60	7.60	7.60	7.60
Wheat straw	23.23	23.23	6.21	6.21	6.21	6.21
Ground shelled corn	2.29	2.29	17.10	17.10	17.10	17.10
Wheat midds	6.54	6.54	4.71	4.71	4.71	4.71
Citrus pulp	4.31	4.31	4.75	4.75	4.75	4.75
Soybean hulls	6.50	6.50	2.13	2.13	2.13	2.13
Canola meal	3.33	3.33	3.80	3.80	3.80	3.80
Corn gluten feed	1.67	1.67	2.37	2.37	2.37	2.37
Distillers grains, ethanol	1.10	0.62	1.29	1.02	1.13	0.58
Amino Plus	2.32	2.32	5.70	5.70	5.70	5.70
Gemini Protein	1.99	1.99	2.28	2.28	2.28	2.28
Energy Booster 100	-	-	1.14	1.14	1.14	1.14
Biochlor	5.56	5.56	-	-	-	-
Alimet	0.07	0.07	0.06	0.06	0.06	0.06
Salt	0.33	0.33	0.57	0.57	0.57	0.57
Sodium bicarbonate	-	-	0.38	0.38	0.38	0.38
Limestone	2.46	1.49	1.35	1.38	1.08	0.47
Ca sulfate	-	-	0.25	0.25	0.25	0.25
Mg oxide	0.41	0.09	0.13	0.38	0.05	0.08
MIN-AD	-	1.78	-	-	0.52	1.66
Mineral oil	0.02	0.02	0.02	0.02	0.02	0.02
Rumensin	0.04	0.04	0.06	0.06	0.06	0.06
Trace minerals & vitamin mix	0.21	0.21	0.04	0.04	0.04	0.04

Table 2. Analyzed nutrient composition (mean) and partitioning of mineral intake by sources

	Prepartum Diet		Postpartum Diet			
	CS	MA	CS-LM	CS-HM	MA-LM	MA-HM
Nutrient, mean						
DM, %	43.0	43.8	43.0	43.2	42.8	43.1

CP, % of DM	14.3	14.1	14.9	15.0	15.2	15.4
ADF, % of DM	28.1	29.5	20.9	21.5	21.2	21.1
NDF, % of DM	43.4	45.4	32.5	32.9	33.2	33.4
Lignin, % of DM	3.9	4.1	2.1	3.3	3.2	3.1
Starch, % of DM	15.8	14.5	25.5	25.3	24.6	25.2
NFC, % of DM	33.0	31.2	45.2	43.7	43.5	43.6
Fat, % of DM	2.17	2.22	3.25	3.10	3.04	2.87
Ca, % of DM	1.44	1.40	1.21	1.13	1.17	1.24
P, % of DM	0.35	0.34	0.36	0.34	0.37	0.36
Mg, % of DM	0.49	0.52	0.35	0.40	0.35	0.48
K, % of DM	1.08	1.08	1.00	0.98	1.02	1.01
S, % of DM	0.45	0.44	0.32	0.33	0.33	0.33
Na, % of DM	0.26	0.25	0.42	0.42	0.43	0.43
Cl, % of DM	0.79	0.80	0.53	0.53	0.54	0.53
DCAD, mEq/100 g DM	-11.2	-11.1	8.7	7.7	8.9	9.2
$NE_{L,}$ Mcal/kg	1.46	1.42	1.69	1.61	1.61	1.60
MP, g/kg DM	90.5	90.2	113.0	113.0	112.7	112.5
MP Intake, g/d	1439	1515	2158	2237	2141	2284
Mineral Intake Sources						
Mg from MIN-AD, % of Mg	-	39.3	-	-	17.1	39.8
Mg from MgO, % of Mg	45.4	9.2	20.6	51.9	7.1	9.3
Mg from Other, % of Mg	54.7	51.5	79.4	48.1	75.8	51.0
Ca from MIN-AD, % of Ca	-	27.3	-	-	9.6	28.8
Ca from Limestone, % of Ca	65.0	40.4	42.4	46.6	35.1	14.5
Ca from Other, % of Ca	35.0	32.4	57.6	53.4	55.4	56.7

After calving, all cows were milked 3X daily. Milk weights and yield were recorded on a daily basis through 42 d postpartum. Milk samples were collected at 3 consecutive milkings each week for analysis of milk fat, protein, lactose, total solids, MUN, and SCC. Milk yield at the corresponding milking was used to weight milk composition and calculate yield of fat, protein, lactose and total solids. Weekly average yield of 3.5% FCM and ECM were calculated. Milk production efficiency was calculated using weekly average DMI and ECM values (efficiency = kg of ECM/ kg of DMI).

Blood samples were collected 2X weekly from -28 d to parturition, within 2 h of parturition, daily 1-7 d postpartum, and 3X weekly 8-21 d postpartum. A subset of samples was analyzed for β-Hydroxybutyrate (BHBA) and nonesterified fatty acids (NEFA). Weekly calculations of pre- and postpartum energy balance (EBAL) were determined according to NRC (2001) equations for energy intake.

Results

Effects of Source on Prepartum Outcomes

As shown in Table 3, prepartum DMI and DMI as a percentage of BW were higher in cows fed MA. Supplemental mineral source also affected calculated EBAL, as cows fed MA had greater values and tended to have higher BCS.

Table 3. Least squares means and standard errors for prepartum DMI, DMI as a % of BW, energy balance (EBAL), BW, BW change, and BCS.

Variable	Treatments		SEM	*P*-values[1]	
	CS	MA		S	S×W
DMI, kg/d	15.9	16.8	0.3	0.03	0.52
DMI, % of BW	2.00	2.10	0.03	0.02	0.88
EBAL, Mcal/d	7.3	8.6	0.4	0.03	0.56
BW, kg	800	801	3	0.70	0.19
BW change, kg[2]	20	22	3	0.58	-
BCS	3.42	3.47	0.02	0.13	0.56

[1]S = source; W = week
[2]Difference between BW measurement at week -3 and week -1

Prepartum plasma NEFA concentrations were lower in cows fed MA, while there were no effects of treatment on plasma BHBA concentrations (Table 4). As shown in Table 5, there were no effects of supplemental mineral source on prepartum plasma concentrations of Ca or Mg, although cows fed MA showed higher concentrations of plasma P.

Table 4. Least squares means and standard errors, or geometric means and back transformed 95% confidence limits, for prepartum and postpartum non-esterified fatty acids (NEFA) and β–hydroxybutyrate (BHBA).

Variable	Treatments				*P*-values[1]			
	CS-LM	CS-HM	MA-LM	MA-HM	S	L	S×L	S×L×D
Prepartum								
NEFA, μEq/L		142 (130-155)		117 (107-129)	0.005	-	-	-
BHBA, mg/dL		5.0 ± 0.2		5.0 ± 0.2	0.86	-	-	-
Postpartum								
NEFA, μEq/L	616 (511-743)	591 (491-713)	519 (427-631)	505 (411-620)	0.09	0.72	0.95	0.39
BHBA, mg/dL	7.9 (6.7-9.2)	6.9 (5.9-8.1)	6.3 (5.3-7.3)	7.3 (6.2-8.6)	0.27	0.84	0.09	0.51

[1]S = source; L = level; D = day

Table 5. Least squares means and standard errors for prepartum and postpartum plasma mineral concentrations.

Variable	Treatments				SEM	*P*-values[1]			
	CS-LM	CS-HM	MA-LM	MA-HM		S	L	S×L	S×L×D
Prepartum									
Ca, mmol/L		2.44		2.44	0.02	0.85	-	-	-

Mg, mmol/L	0.96		0.96		0.01	0.59	-	-	-
P, mmol/L	1.69		1.79		0.03	0.02	-	-	-
Postpartum (d 1-7)									
Ca, mmol/L	2.35	2.37	2.41	2.38	0.04	0.38	0.85	0.54	1.00
Mg, mmol/L	0.84	0.87	0.81	0.84	0.02	0.10	0.11	0.92	0.78
P, mmol/L	1.43	1.38	1.47	1.55	0.07	0.09	0.86	0.32	0.49
Postpartum (d 9-21)									
Ca, mmol/L	2.56	2.63	2.56	2.58	0.03	0.44	0.17	0.40	0.82
Mg, mmol/L	0.91	0.94	0.87	0.92	0.02	0.14	0.07	0.64	0.18
P, mmol/L	1.67	1.70	1.63	1.79	0.06	0.68	0.13	0.30	0.69

[1]S = source; L = level; D = day

Effects of Source and Level on Postpartum Outcomes

Postpartum DMI, EBAL, BW, BW change and BCS are presented in Table 6. Mineral source tended to effect BW change as cows fed MA lost less BW between wk 1 and wk 6 postpartum (CS = -61 vs. MA = -43 kg, P = 0.11). Body condition scores also tended to be higher for cows fed MA; differences were small but consistent with BW change and plasma NEFA concentrations. There were no effects on calculated EBAL or average BW postpartum.

Results for milk yield, composition and production efficiency are presented in Table 7. Milk production efficiency and SCC were not affected by treatment. There were no effects of source or level on milk yield or concentration, true protein, lactose or total solids. A source by week effect was found for fat content and yield, 3.5% fat-corrected yield, total solids yield, and energy corrected yield. These effects were driven primarily by higher fat content and yield in wk 1 for cows fed MA. A level by week effect on milk fat content was observed as cows fed LM had lower milk fat content in wk 5. A level by week effect was also found for MUN concentrations in wk 1, as cows fed LM had higher MUN.

Results for postpartum plasma NEFA and BHBA are presented in Table 4. Cows fed MA tended to have lower plasma NEFA postpartum. A source and level trend was observed for postpartum BHBA; concentrations were numerically lowest in cows fed MA-LM.

Plasma P from d 1-7 postpartum tended to be higher in cows fed MA (Table 5). While no effect of source was found on plasma P from d 9-21, cows fed LM tended to have lower P values during that period. Plasma Mg tended to be lower in cows fed MA and those fed LM postpartum, indicating a source and level trend.

Table 6. Least squares means and standard errors for postpartum DMI, DMI as a % of BW, energy balance (EBAL), BW, BW change, and BCS.

	Treatments					*P*-values[1]					
Variable	CS -LM	CS -HM	MA -LM	MA -HM	SEM	S	L	S×W	L×W	S×L	S×L×W
DMI, kg/d	20.7	21.3	20.7	21.4	0.7	0.98	0.32	0.57	0.35	0.88	0.03
DMI, % BW	2.97	3.07	2.92	3.03	0.09	0.57	0.21	0.37	0.40	0.95	0.14
EBAL, Mcal/d	-7.4	-8.5	-9.2	-8.0	1.0	0.51	1.00	0.76	0.41	0.22	0.88
BW, kg	699	698	699	713	7	0.25	0.32	0.34	0.93	0.26	0.24
BW change, kg[2]	-59	-63	-42	-42	13	0.11	0.87	-	-	0.87	-

BCS	3.14	3.14	3.20	3.19	0.04	0.14	0.95	0.78	0.17	0.78	0.97

[1]S = source; L = level; W = week
[2]Difference between BW measurement at week 1 and week 6

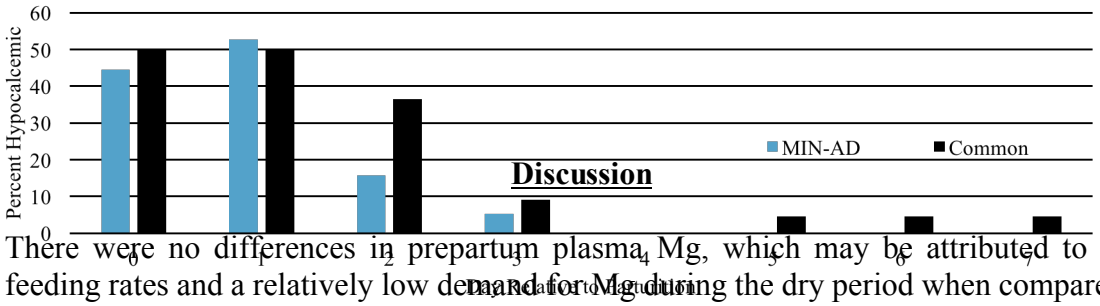
Table 7. Least squares means and standard errors for milk yield, milk composition, and milk production efficiency over the first 6 wk postpartum.

	Treatments					*P*-values[1]					
Variable	CS-LM	CS-HM	MA-LM	MA-HM	SEM	S	L	S×W	L×W	S×L	S×L×W
Milk yield, kg/d	45.0	46.5	45.9	44.0	1.8	0.64	0.89	0.19	0.47	0.30	0.54
Fat, %	3.85	3.72	3.84	3.94	0.11	0.35	0.90	0.07	0.01	0.34	0.84
Fat, kg/d	1.68	1.68	1.75	1.72	0.09	0.51	0.81	0.02	0.44	0.88	0.82
3.5% FCM, kg/d	46.9	47.5	48.4	46.7	2.0	0.85	0.77	0.04	0.27	0.54	0.73
Protein, %	2.86	2.81	2.83	2.87	0.07	0.78	0.90	0.64	0.50	0.49	0.55
Protein, kg/d	1.24	1.24	1.29	1.23	0.05	0.67	0.49	0.18	0.41	0.55	0.24
Lactose, %	4.86	4.84	4.81	4.87	0.05	0.85	0.72	0.29	0.97	0.50	0.97
Lactose, kg/d	2.18	2.23	2.24	2.14	0.10	0.86	0.76	0.26	0.90	0.44	0.66
Total solids, %	12.5	12.3	12.4	12.6	0.2	0.51	0.94	0.38	0.32	0.36	0.77
Total solids, kg/d	5.53	5.56	5.72	5.50	0.25	0.78	0.69	0.05	0.68	0.61	0.51
ECM, kg/d	46.1	46.5	47.6	45.9	1.9	0.80	0.70	0.03	0.50	0.54	0.58
ECM/DMI	2.26	2.22	2.30	2.15	0.07	0.80	0.19	0.27	0.83	0.40	0.46
MUN, mg/dL	6.74	6.58	7.30	6.61	0.35	0.37	0.20	0.74	0.06	0.43	0.47
SCS	1.90	2.09	2.46	1.81	0.47	0.76	0.60	0.83	0.40	0.35	0.57

[1]S = source; L = level; W = week

There were no effects of source or level on plasma Ca concentrations postpartum. As shown in Figure 1, incidence of hypocalcemia was low in this trial. Peak prevalence of hypocalcemia occurred d 1 postpartum, with 51% of cows having concentrations below 2.125 mmol/L and only 23% having plasma Ca below 2.0 mmol/L. By d 3 postpartum, prevalence of plasma Ca below 2.125 mmol/L was 7% and below 2.0 mmol/L was 4%.

Figure 1. Hypocalemia prevalence by source (plasma total Ca <8.5 mg/dL



Discussion

There were no differences in prepartum plasma Mg, which may be attributed to high feeding rates and a relatively low demand for Mg during the dry period when compared to the onset of lactation.

Postpartum plasma Mg concentrations tended to differ by dietary level of Mg regardless of source. As dietary Mg increased, slight increases were seen in plasma concentrations of Mg, which supports the idea that feeding higher dietary Mg at least partially offsets colostrum and milk synthesis demands for this mineral. There was a slight trend for a difference by source, however, it is difficult to attribute this to availability as MA was a

significant source of Ca and no differences in plasma Ca concentrations by source were observed.

The small differences in plasma Mg did not affect Ca homeostasis, intake or performance. Formulated Mg concentrations of both LM and HM diets were above NRC (2001) requirements. Additionally, the postpartum diets contained low dietary K which would reduce demand for dietary Mg. It is plausible that all four treatment diets allowed for total absorbed Mg above requirement, and that differences in plasma Mg did not inhibit physiological functions requiring Mg.

The trend for slightly lower Mg plasma levels with MA may be due to interactions between ruminal Ca and Mg and subsequent absorption. Though most Ca is absorbed post-ruminally in ruminants, evidence from transition cows and sheep suggests that significant ruminal absorption of Ca can occur in some situations and that this decreases ruminal Mg absorption. The current study fed relatively high concentrations of Ca both pre- and postpartum. If there was a difference in the solubility of supplemental source minerals, higher intakes or higher soluble Ca in the rumen of cows fed MA may have contributed to differences in Mg absorption. This may have impaired Mg absorption resulting in slightly lower postpartum plasma Mg in those cows. Due to the homeostatic regulation of blood Ca concentrations, potential differences in passive absorption or total supply of Ca may have been compensated for by urinary excretion, resulting in no difference in plasma Ca concentration.

Higher plasma P concentrations were observed both prepartum and in wk 1 postpartum for cows fed MA. Blood P increases as dietary P concentrations increase. If the same is true when total intake of P increases, higher prepartum DMI in cows fed MA may have contributed to higher plasma P prepartum. Because intakes were not consistently higher in wk 1 for cows fed MA, the response in plasma P postpartum due to source may have been a carry-over effect from the dry period. Alternatively, an antagonistic effect of Ca or Mg, depending on the amount and solubility of these minerals in different parts of the gastrointestinal tract, may have been responsible for altering P solubility.

Meaningful differences in DMI and plasma energy metabolites were found in cows fed MA as compared to CS. This suggests performance differences were at least partially the result of some mechanism other than differences in transition period mineral status. Differences in buffering capacity between sources could influence rumen health during the transition period. Subacute rumen acidosis is not highly prevalent in prepartum dairy cows due to the high fiber, low starch rations typically fed. Conversely, diets fed immediately after parturition typically contain high concentrations of rapidly fermentable carbohydrates and have been demonstrated to result in subacute ruminal acidosis. Although variation in mineral source buffering capacity and feeding rates may have contributed to the differences observed in postpartum DMI, it is unlikely this accounts for the increase in prepartum DMI.

Differences in solubility of the supplemental mineral sources fed in the current trial may have altered liquid passage rate and impacted ruminal fermentation. In the high fiber prepartum rations fed in the current trial, any differences in rumen fermentation efficiency

may have resulted in increased fiber digestion rates and DMI. It is also possible that the DMI intake with MA was due to improved palatability.

In this experiment, plasma NEFA concentrations were lower in cows fed MA prepartum, which is consistent with higher DMI observed in this group. Postpartum plasma NEFA concentrations tended to remain low through wk 3 for cows fed MA, despite the time and Mg feeding rate dependent effects on intake. Consistent with lower plasma NEFA concentrations, cows fed MA tended to maintain higher BCS and lose less BW postpartum. Higher milk fat percentage and yield in wk 1 was also observed for cows fed MA. Taken together, the data suggest that mobilized adipose tissue was not the source of additional milk fat and further supports altered ruminal fermentation in cows fed MA.

CONCLUSIONS

Feeding MIN-AD resulted in increased DMI prepartum and in portions of the postpartum period, improved energy balance, higher BCS, and decreased plasma NEFA concentrations. This confirms previous transition cow research and suggests MIN-AD positively impacts DMI and metabolic health.

Varying the primary source of supplemental Ca and Mg and the level of dietary Mg postpartum resulted in small differences in plasma Mg and P concentrations. While no significant difference in Ca concentrations was observed, cows fed MIN-AD showed a transient improvement in plasma Ca postpartum and tended to have lower prevalence of hypocalcemia than those fed MgO. This corroborates MIN-AD's earlier work on plasma mineral status.