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Effect of Supplementing Dietary Magnesium on the Performance and Behavior of Group-Housed Late Gestation Sows

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Summary

A total of 952 mixed-parity sows and gilts (1050, PIC) were used to evaluate the effects of supplementing 0.03% magnesium (Mg) through the inclusion of magnesium oxide (MgO) in the diet fed the last two weeks of gestation on sow performance and behavior. Sows were housed in 18 pens containing 49 to 56 sows per pen. Each pen was equipped with three computerized gestation feeders. Pens of sows were blocked in groups to account for date of pen loading and then allotted to one of two treatments with nine replications per treatment. Treatments consisted of: 1) control diet (corn-DDGS-based) fed at 5.0 lb/sow/day and 2) control diet supplemented with 0.03% Mg through the inclusion of 0.06% MgO. Pens contained sows with different breed dates and treatments started when the first sows reached d 104 of gestation (average day of gestation for the pens: 102.9 ± 1.27). Sows were weighed the day before the start of treatment administration and again upon entry into the farrowing house. Sow body lesions and vulva lesions were recorded the day before exposure to treatment and then again on d 3 and 5 after exposure and finally upon entry to the farrowing house to measure the frequencies of scores. Four sows per pen were selected and had tear stain scores recorded the day before exposure to treatment and upon entry to farrowing to measure the frequencies of scores. Sows were video recorded continuously, and video was analyzed on d 3 and 5 in six 2-h timeframes (0100 to 0300, 0500 to 0700, 0900 to 1100, 1300 to 1500, 1700 to 1900, and 2100 to 2300). Aggressive bouts were defined as: 1) sows knocking or pushing pen mates with their head; 2) sows mounting pen mates; or 3) sows forcefully biting ear, face, body, or vulva of pen mates. The location of aggressive bouts was recorded and categorized as either occurring at the feeder (feeder bout) or elsewhere in the pen (non-feeder bout). One sow per pen was selected based on average body condition and parity of the pen for determination of salivary cortisol levels on d 3 and 5. Those sows were followed through farrowing with one male

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and one female piglet of the average litter BW analyzed for plasma and hair cortisol concentrations. Piglets were restrained on their backs for 3 min before blood collection to induce a stress response, and immediately after, hair samples were taken from the rump and dorsal area. Sows fed increased Mg tended to have greater ADG and ADFI ($P \leq 0.076$) compared with sows fed the control diet. There were no differences in piglet total born, born alive, or number of stillborn; however, there was a tendency ($P = 0.063$) for sows fed increased Mg to have a greater number of pigs weaned. Sow fallout due to mortality or removal in late gestation and through farrowing was decreased ($P = 0.046$) with added Mg. Regardless of treatment, vulva lesion scores numerically became more prevalent at the end of the gestation as sows entered farrowing. The total aggressive bouts decreased ($P = 0.001$) as time of day progressed. Sows fed added Mg had more aggressive bouts at the feeder compared with those fed the control diet ($P = 0.001$). There were no differences in sow salivary, piglet plasma, or hair cortisol levels. In conclusion, supplementing Mg at 0.03% from MgO tended to increase sow ADG and ADFI while decreasing late gestation and farrowing sow fallout. Increased feed intake and reduced fallout from sows fed added Mg may have potentially increased sow activity around feeding stations, contributing to more aggressive bouts at the feeder. Regardless of treatment, sow aggression reduced as the time of day progressed. Despite the effects on sow performance, increasing Mg by 0.03% displayed limited results as a mediator to sow behavior in a group-housed environment.

Introduction

Implementation of gestation group housing has been on the rise in the swine industry with efforts to increase the behavioral freedom of sows. Although sows are less restricted, this strategy led to an increased prevalence of aggressive behaviors, adding a new challenge for production systems. Research has been conducted surrounding gestation aggression[4],[5],[6]; however, most efforts have focused on strategies aimed to reduce aggression immediately after mixing when sows are still developing their social hierarchies[5].

In addition to aggression after mixing, there is a growing need for research on strategies to manage late gestation aggression. Field reports have suggested that there is an increase in late gestation aggression, specifically during the last week of gestation, visible through an increase in vulva and body lesions. Some potential reasons include increasing discomfort as sows approach farrowing and disruption of pen social dynamics when loading into farrowing. This increase in aggression just before farrowing is not only a welfare concern but may also lead to potential difficulties during parturition.

[4] Stevens, B., G. M. Karlen, R. Morrison, H. W. Gonyou, K. L. Butler, K. J. Kerswell, and P. H. Hemsworth. 2015. Effects of stage of gestation at mixing on aggression, injuries and stress in sows. Appl. Anim. Behav. Sci. 165:40–46. doi:10.1016/j.applanim.2015.02.002.

[5] Greenwood, E. C., K. J. Plush, W. H. E. J. van Wettere, and P. E. Hughes. 2016. Group and individual sow behavior is altered in early gestation by space allowance in the days immediately following grouping. J. Anim. Sci. 94(1):385–393. doi:10.2527/jas.2015-9427.

[6] Verdon, M., R. S. Morrison, M. Rice, and P. H. Hemsworth. 2016. Individual variation in sow aggressive behavior and its relationship with sow welfare. J. Anim. Sci. 94(3):1203–1214. doi:10.2527/jas.2015-0006.

Increasing dietary Mg may be a practical strategy to reduce aggression in group-housed sows. Magnesium supplementation is believed to have a calming effect leading to increased lying behavior in times of stress[7]. Previous research has shown that increased dietary Mg supplementation lowered salivary cortisol concentrations in growing pigs[8]. There are also potential reproductive benefits, as supplementing Mg at rates of 0.015 to 0.03% has been shown to increase serum prolactin levels, which can potentially increase milk production during lactation[9].

Therefore, the overall objective of this study was to evaluate the effects of increasing dietary Mg by 0.03% in late gestation on sow performance, pen behavior, and physiological stress indicators of group-housed sows under commercial conditions.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The experiment was conducted at a commercial sow farm in Carthage, IL. Sows were housed in 18 pens, with each pen (36.66 × 27.66 ft) equipped with three computerized gestation feeders (Gestal; Jyga Technologies, St-Lambert-de-Lauzon, QC, Canada) and four cup drinkers to provide ad libitum access to water. Sows were fed to a set feed allocation and the allocation began at 0100 each day in the computerized feed system.

Animals and diets

A total of 952 mixed-parity sows and gilts (1050, PIC) were used. Sows were housed in 18 pens containing 49 to 56 sows/pen. Pens of sows were blocked in groups, based on earliest breed dates of sows within pen to account for date of pen loading and then allotted to one of two treatments with nine replicate pens per treatment. Pens contained sows with different breed dates and treatments started when the first sows reached d 104 of gestation (average day of gestation for the pens: 102.9 ± 1.27). Treatments consisted of: 1) control diet (corn-DDGS-based) fed at 5.0 lb/sow/day and 2) control diet supplemented with 0.03% Mg through the inclusion of 0.06% MgO fed at 5.0 lb/sow/day (Table 1). Magnesium oxide (56% Mg; Phibro Animal Health Corp., Quincy, IL) was added at the expense of corn. Sows were weighed the day before start of treatment and again upon entering the farrowing house. Litter counts were taken upon birth and then again at weaning to determine litter performance data. Total sow fallout was recorded during the study and included abortions, deaths in gestation, and then lactation death or removal in farrowing.

Within each pen, four sows were selected based on average parity of the pen and average body condition to serve as the focal sows of the pen. All four of these sows had tear stains scored when recording initial BW and again when entering farrowing. Tear stains

[7] Peeters, E., A. Neyt, F. Beckers, S. De Smet, A. E. Aubert, and R. Geers. 2005. Influence of supplemental magnesium, tryptophan, vitamin C, and vitamin E on stress responses of pigs to vibration. J. Anim. Sci. 83:1568–1580. doi:10.2527/2005.8371568x.

[8] O'Driscoll, K., D. M. O'Gorman, S. Taylor, and L. A. Boyle. 2013. The influence of a magnesium-rich marine extract on behaviour, salivary cortisol levels and skin lesions in growing pigs. Animal. 7:1017–1027. doi:10.1017/S1751731112002431.

[9] Zang, J., J. Chen, J. Tian, A. Wang, H. Liu, S. Hu, X. Che, Y. Ma, J. Wang, C. Wang, G. Du, and X. Ma. 2014. Effects of magnesium on the performance of sows and their piglets. J. Anim. Sci. Biotechnol. 5:39. doi:10.1186/2049-1891-5-39.

were recorded on a 0 to 5 scale (Table 2). At initial weight, d 3, and d 5 after exposure to treatment and then upon entry to farrowing, all sows within the pen had body and vulva lesion scores recorded. Sow body lesion scores were recorded on a scale of 0 to 3 with vulva scoring on a scale from 0 to 2.

Video analysis

Using video cameras (PAR-ALLTXIRA28WL: Fixed lens, IP67 Weatherproof, 2 Megapixel Turret, 2.8mm lens with 30fps(60Hz); Innovative Video Technology, Hauppauge, NY) connected to a network video recording system (PN3A-64FNH: NTSC/PAL, 64 Ch TVI NVR, AC110-240V; Innovative Video Technology, Hauppauge, NY), sows were video recorded continuously. Recorded video was analyzed on d 3 and 5 in six 2-h timeframes (0100 to 0300, 0500 to 0700, 0900 to 1100, 1300 to 1500, 1700 to 1900, and 2100 to 2300). Aggressive bouts were defined as: 1) sows knocking or pushing pen mates with their head; 2) sows mounting pen mates; or 3) sows forcefully biting ears, face, body, or vulva of pen mates. Aggressive bouts were defined as either "feeder aggressive bouts" or "non-feeder aggressive bouts". Feeder aggressive bouts were defined as bouts that occurred while at least one sow was standing behind the feed stations with her nose in the station. All other aggressive bouts were labeled "non-feeder" bouts. The combination of both feeder and non-feeder aggressive bouts was labeled as "total" aggressive bouts.

Biological tissue and fluid analyses

Within each pen, one sow was chosen to have salivary cortisol levels analyzed. Saliva was collected between 0700 and 0900 on d 3 and 5 after exposure to treatment. Saliva samples were collected using Oasis Diagnostics Super-SAL Universal Saliva Collection Kit (Oasis Diagnostics, Vancouver, WA). Sows voluntarily chewed on the collection device until fully saturated. Samples were compressed into 2-mL containers and stored at −4°F on farm until samples were moved to the University of Missouri and stored at −112°F until analysis. Samples of focal sows were analyzed using a commercially available ELISA kit for salivary cortisol (IBL Cortisol Free in Saliva ELISA; Minneapolis, MN) following the manufacturer's instructions.

Sows selected for salivary collection were also tracked through farrowing for collection of piglet blood and hair cortisol. The day before weaning, all piglets within the litter were weighed and the male and female closest to the average weight of the litter were selected for blood collection. Piglets were restrained on their back for 3 min to induce a stress response, and then blood samples were collected in tubes containing an anticoagulant (Greiner Bio-One North America Inc., Monroe, NC). Blood samples were spun down within 4 h of sample collection with plasma samples stored at −112°F until further analysis. Cortisol analysis was performed on all plasma samples using an IBL America Cortisol ELISA Kit (IBL ELISA; Minneapolis, MN).

At the same time as blood collection, hair samples were collected for additional cortisol analysis. A hair sample was collected from the rump and dorsal area of the piglets and processed as previously described by Byrd et al.[10]. Dried samples were stored at −112°F until further analyses. For cortisol analyses, 400 μL of phosphate-buffered saline was

[10] Byrd, M. H., L. F. Brito, J. Musa, S. Diggs, L. K. Senn, H. Wen, P. H. F. Freitas, J. L. Byrd, F. Tiezzi, C. Maltecca, Y. Huang, A. P. Schinckel, and J. S. Johnson. 2025. Characterizing the effects of gestational heat stress on reproductive efficiency and thermoregulation in replacement gilts divergently selected for thermotolerance in the F1 generation. J. Anim. Sci. 103:skaf353. doi:10.1093/jas/skaf353.

added to the extracted hair samples and samples were analyzed for cortisol using a commercially available ELISA kit (IBL ELISA; Minneapolis, MN).

Statistical analysis

Sow performance was analyzed using the lmer function from the lme4 package in RStudio [Version 4.0.2 (2020-06-22), R Core Team, R Foundation for Statistical Computing, Vienna, Austria] with pen serving as the experimental unit and sow as the observational unit in a randomized complete block design. Pens were grouped into blocks to account for pen loading date. Treatment was used as a fixed effect in the model and pen and block served as random effects. Sow parity and days exposed to treatment were included as covariates in the model. Count data, including subsequent litter characteristics (total born, liveborn, stillborn, mummies, and weaned) were analyzed using a negative binomial distribution using a log link function. Proportion data, including percent sow fallout, were analyzed using a binomial distribution.

Sow aggressive bouts, sow salivary, piglet hair and plasma cortisol levels were summarized using the GLIMMIX procedure of SAS OnDemand for Academics (SAS Institute, Inc., Cary, NC). Aggressive bouts were reported as a count per hour within each score category by treatment. Data were square-root transformed and then back-transformed to give estimated means. The model for aggressive bouts included treatment, day, time, and their interactions as fixed effects with block as a random effect. Sow salivary cortisol levels were log-transformed and then back-transformed to give estimated means. The model included treatment, day, and their interactions as fixed effects with block as a random effect. Piglet plasma cortisol levels were log-transformed, whereas piglet hair cortisol was square-root transformed, with data then back-transformed to give estimated means. The model for piglet plasma and hair cortisol levels included treatment as a fixed effect with block, sow, and liveborn as random effects. All lesion scoring data were presented through descriptive statistics as the frequency within each score category due to models failing to converge. All results were considered significant with $P \leq 0.05$ and marginally significant with $0.05 < P \leq 0.10$.

Results and Discussion

As expected, the addition of MgO to the experimental diet led to increased analyzed dietary Mg (0.18 vs. 0.22%; Table 1).

There were no differences in initial or farrow entry weights between treatments (Table 3). Added Mg tended to increase ADG and ADFI ($P \leq 0.076$) in late gestation, compared with sows fed the control diet. No differences were observed in total born, born alive, mummies, and number of stillborn pigs. Sows fed supplemental Mg in late gestation tended ($P = 0.063$) to have an increased number of piglets weaned compared with those fed the control diet. There was an observed decrease ($P = 0.046$) in sow fallout percentage when sows were fed supplemental Mg compared with those fed the control diet.

There were minimal numerical differences in frequency of vulva, body lesion, and tear stain scores observed between treatments (data not shown). However, regardless of treatment, vulva lesions numerically became more prevalent at entry into farrowing.

For all categories of aggressive bouts, there were no treatment × day × time, or treatment × time interactions (Table 4). Across all categories, there was a reduction ($P < 0.001$) in aggressive bouts as time progressed each day. This is potentially explained by sows reaching their daily feed allocations at earlier timepoints, then reducing activity as they progressed later into the day resulting in reduced aggressive interactions.

For non-feeder aggressive bouts, there was a treatment × day interaction ($P = 0.022$) with sows fed the control diet having decreased bouts from d 3 to d 5, while sows fed added Mg had an inverse response (data not shown). Sows fed added Mg had a greater number ($P = 0.043$) of aggressive bouts compared with control sows between the hours of 1700 and 1900, with no effect of treatment observed at the other timepoints.

For feeder aggressive bouts, there was a treatment effect ($P = 0.001$) with sows supplemented with Mg having a greater prevalence of aggressive bouts compared with sows fed the control diet. This is potentially due to sows fed increased Mg having numerically more bouts from 0100 to 0300, 1700 to 1900, and 2100 to 2300 compared with control-fed sows.

For total aggressive bouts, there was a tendency for a treatment × day interaction ($P = 0.074$), with a similar response as seen in non-feeder bouts. From 1700 to 1900 h, an increase in both feeder and non-feeder aggression led to sows fed added Mg having an increased prevalence of total aggressive bouts compared with control-fed sows. There were no differences observed between the other timepoints; however, sows fed added Mg had numerically greater total aggressive bouts at each timeframe.

There were no differences in sow salivary, piglet plasma, or piglet hair cortisol levels (Table 5).

In conclusion, added Mg at 0.03% from MgO tended to increase ADG and ADFI before farrowing while decreasing sow fallout in late gestation through the end of lactation. Increased feed intake and reduced fallout from sows fed added Mg may have potentially increased sow activity around feeding stations, contributing to more aggressive bouts at the feeder. Regardless of treatment, sow aggression reduced as the time of day progressed. Despite the effects on sow performance, increasing dietary Mg by 0.03% elicited limited changes in sow behavior in a group-housed environment.

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Table 1. Diet composition (as-fed basis)

Item	Control	Mg
Ingredient, %		
Corn	45.59	45.53
Bakery-soy blend	16.43	16.43
Corn DDGS	35.00	35.00
Limestone	1.61	1.61
Monocalcium phosphate, 21% P	0.46	0.46
Biolys 80, 62.4% Lys	0.42	0.42
L-Thr	0.03	0.03
L-Trp	0.01	0.01
Salt	0.15	0.15
Choline chloride, 60%	0.11	0.11
Vitamin and trace mineral	0.15	0.15
Engage M[1]	0.05	0.05
Magnesium oxide, 56% Mg[2]	---	0.06
Total	100.00	100.00
Calculated analysis		
Standardized ileal digestible amino acids, %		
Lys	60	60
Ile:Lys	75	75
Leu:Lys	239	239
Met & Cys:Lys	78	78
Thr:Lys	75	75
Trp:Lys	19	19
Val:Lys	98	98
Metabolizable energy, kcal/lb	1,422	1,421
CP, %	16.51	16.51
Crude fiber, %	3.72	3.72
NDF, %	14.27	14.27
ADF, %	6.03	6.03
Ca, %	0.81	0.81
STTD P, %	0.36	0.36
Mg, %	0.22	0.25
Chemical analysis[3]		
CP, %	16.34	15.98
Crude fiber, %	3.36	3.46
Crude fat, %	4.92	5.28
Mg, %	0.18	0.22

[1] Calcium aluminosilicate, United Animal Health, Sheridan, IN.

[2] Easy Mix Magnesium Oxide, Phibro Animal Health Corp., Quincy, IL.

[3] Crude protein, crude fiber, and crude fat analysis were run in duplicate by University of Missouri Agricultural Experiment Station Chemical Laboratory. Magnesium analysis was run in duplicate by Kansas State University Soil Testing Laboratory.

Table 2. Scoring scale used to determine body lesions, vulva lesions, and tear staining

Body lesion scoring	
0	No injuries.
1	≤ 4 superficial injuries.
2	5 to 10 superficial injuries and/or less than 2 deep wounds.
3	≥ 11 superficial injuries and/or more than 3 deep wounds.
Vulva scoring	
0	No damage to the vulva.
1	Recent damage, including fresh or scabbed bite wounds but not including old scarring. Vulva lesion > 3 cm length or 1 cm diameter.
2	Deep tissue injury.
Tear stain scoring	
0	No signs of staining.
1	Staining is barely detectable and area stained does not extend below eyelid.
2	Staining is obvious and area stained is approximately < 50% of total eye area.
3	Staining is obvious and area stained is approximately 50 to 100% of total eye area.
4	Staining is severe, area stained is approximately ≥ 100% of total eye area, and area stained does not extend below the mouth line.
5	Staining is severe, area stained is > 100% of total eye area, and area stained extends below the mouth line.

Table 3. Effect of added dietary Mg fed to group-housed sows in late gestation on sow and litter performance

	Diet strategy			
Item	Control	0.03% Mg	SEM	*P* =
Sow performance[1,2]				
Parity	3.3	3.3	---	---
Initial BW, lb	578.0	577.5	4.59	0.945
Farrow entry BW, lb	599.0	601.5	4.54	0.697
ADG, lb	2.06	2.34	0.100	0.061
ADFI, lb	4.84	4.96	0.043	0.076
Litter characteristics				
Total born, n	17.5	17.8	0.22	0.372
Born alive, n	15.1	15.4	0.19	0.195
Stillborn, n	1.9	1.7	0.12	0.306
Mummies, n	0.4	0.5	0.04	0.133
Weaned, n	12.1	12.6	0.17	0.063
Sow fallout, %[3]	8.7	5.5	1.69	0.046

[1] A total of 952 mixed-parity sows and gilts (1050, PIC) were used to evaluate the effects of 0.03% added Mg in diets fed the last two weeks of gestation. Sow ADG and ADFI were measured from when the first sows within a pen reached d 104 of gestation, until all sows entered farrowing.

[2] Treatments included: 1) control diet (corn-DDGS-based) fed at 5.0 lb/sow/day and 2) 0.03% Mg through the inclusion of magnesium oxide in the diet fed at 5.0 lb/sow/day.

[3] Sow fallout is defined as sow mortality or removal from the initiation of the trial through the end of subsequent lactation.

Table 4. Effect of added dietary Mg fed to group-housed sows in late gestation on aggressive bouts and their locations

	Diet strategy			
Item	Control	0.03% Mg	SEM	*P* =
Non-feeder bouts[1,2]				
0100 to 0300	13.15	12.20	1.408	0.636
0500 to 0700	17.03	17.66	1.683	0.788
0900 to 1100	13.98	13.57	1.482	0.844
1300 to 1500	7.32	7.64	1.127	0.840
1700 to 1900	4.64	7.52	1.119	0.043
2100 to 2300	4.00	3.13	0.753	0.438
Feeder bouts[1,3]				
0100 to 0300	9.53	14.74	4.300	0.005
0500 to 0700	12.89	14.55	4.273	0.396
0900 to 1100	10.94	12.37	3.951	0.430
1300 to 1500	3.10	4.02	2.343	0.374
1700 to 1900	0.88	2.41	1.878	0.042
2100 to 2300	0.60	1.81	1.674	0.071
Total aggressive bouts[1,4]				
0100 to 0300	23.00	26.86	4.222	0.272
0500 to 0700	30.40	32.18	4.615	0.650
0900 to 1100	25.42	25.55	4.120	0.971
1300 to 1500	10.57	12.23	2.880	0.490
1700 to 1900	5.82	10.41	2.667	0.024
2100 to 2300	4.64	4.99	1.892	0.827

[1] Value represents the number of interactions per hour of video viewed.

[2] Treatment × day × time, P = 0.572; Treatment × time, P = 0.425; Treatment × day, P = 0.022; Day × time, P = 0.946; Treatment, P = 0.664; Time, P < 0.001; Day, P = 0.520.

[3] Treatment × day × time, P = 0.896; Treatment × time, P = 0.584; Treatment × day, P = 0.937; Day × time, P = 0.774; Treatment, P = 0.001; Time, P < 0.001; Day, P = 0.113.

[4] Treatment × day × time, P = 0.818; Treatment × time, P = 0.612; Treatment × day, P = 0.074; Day × time, P = 0.863; Treatment, P = 0.100; Time, P < 0.001; Day, P = 0.236.

Table 5. Effect of added dietary Mg fed to group-housed sows in late gestation on cortisol responses of sow and piglets at weaning[1,2]

	Diet strategy			
Item	Control	0.03% Mg	SEM	*P* =
Cortisol				
Sow salivary, ng/mL[3]	7.38	5.56	1.067	0.156
Piglet plasma, ng/mL[4]	49.92	55.74	6.786	0.556
Piglet hair, pg/mg[5]	7.50	6.54	1.095	0.552

[1] All samples were analyzed for cortisol at the Missouri Stress Physiology Lab by commercially available ELISA kits.

[2] The means reported are the main effect of treatment averaged across sampling day.

[3] Treatment × day, P = 0.877; Day, P = 0.310.

[4] Piglet plasma and hair cortisol were collected from the average-weight male and female in each litter. Piglets were restrained on their backs for 3 min before blood collection to induce a stress response.

[5] Immediately after blood collection, hair samples were collected from the rump and dorsal area of the piglets.