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EFFECTS OF DIETARY LEVELS OF MANGANESE AND MAGNESIUM ON PERFORMANCE OF GROWING-FINISHING SWINE RAISED IN CONFINEMENT AND ON PASTURE [1]

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RESEARCH on the optimum dietary levels of manganese and magnesium for growing swine is limited. Johnson (1940) fed pigs diets containing 0.3 to 100 ppm Mn and observed no difference in growth rate. Similarly, Liebholz, Speer and Hays (1962) found that 0.4 ppm Mn in the diet of baby pigs was sufficient to support maximum growth. A level of 4,000 ppm Mn was not toxic but growth rate of the pigs was reduced.

No difference in growth rate and feed efficiency was found in pigs fed semi-purified diets from weaning to market weight when levels of Mn ranged from 0.5 to 40 ppm (Plumlee *et al.*, 1956). Grummer *et al.* (1950) fed pigs a basal diet containing 12 ppm Mn supplemented with 40, 80 and 160 ppm Mn. Pigs consuming diets supplemented with 40 ppm gained significantly faster than those on the basal diet but performance was not improved with higher levels of Mn.

Miller *et al.* (1963, 1965, 1965a,), studying the magnesium requirement of the baby pig, found that 325 ppm was adequate for normal growth; whereas Mayo, Plumlee and Beeson (1959) reported that 400 to 500 ppm Mg was needed in the diet for maximum gains in pigs from weaning (3 or 9 weeks of age) to market weight.

Little research has been reported on possible interrelationships among Mn, Mg and environment in swine. Therefore, the research reported here was conducted to determine the effect of various levels of supplemental Mn and Mg, singly and in combination, on gain, feed conversion and certain bone characteristics of growing swine, raised in confinement and on pasture.

Materials and Methods

One hundred and ninety-eight crossbred pigs averaging 17.3 kg. were allotted at random within weight groups to three replications in a 2 x 2 x 3 factorial arrangement of six dietary treatments on either pasture or confinement to concrete. Barrows and gilts were balanced within treatments with 15 pigs per treatment in confinement on concrete and 18 pigs per treatment on alfalfa-brome pasture. Composition of the experimental diets is shown in table 1.

Manganese and magnesium were supplemented to the diet at 0/0, 50/0, 100/0, 0/100, 50/100 and 100/100 ppm for treatments 1 through 6, respectively. A 14% protein diet was fed throughout the experiment with both calcium and phosphorus maintained at 0.65%. All pigs were provided water from the City of Lincoln water system. The pigs were slaughtered at approximately 98 kg. of body weight.

Just prior to slaughter, blood was drawn from the brachial veins and allowed to coagulate. After centrifugation the serum portion was removed for analysis of Mn and Mg. Mg concentration was determined with a Perkin-Elmer Model 303 atomic absorption spectrophotometer [4] using a 25:1 dilution with distilled water. Manganese levels in the serum were apparently too low for detection with the spectrophotometer. No attempt was made to concentrate the serum.

The hind legs were obtained from the carcasses at the George A. Hormel Packing Plant, Fremont, Nebraska. The fourth metatarsal bone of the right hind leg was excised, identified by number with India ink, and boiled in water for 10 minutes. Following boiling, all fleshy tissue was scraped from the bone and it was allowed to air-dry for 5 days. The metatarsals were then prepared for fat extraction

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[4] Perkin-Elmer Corporation, Norwalk, Connecticut.

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS [a, b]

Ingredient	%
Ground yellow corn	83.23
Soybean meal (50% protein)	13.02
Ground limestone	0.46
Dicalcium phosphate	1.69
Salt (iodized)	0.50
Trace mineral premix [c, d]	0.10
Vitamin-antibiotic premix [e]	1.00

[a] 14% protein.
[b] Basal diet calculated 8.1 ppm Mn and 1,280 ppm Mg.
[c] Contribution of trace mineral premix to each diet in ppm is copper from CuO, 10; iron from $FeCO_3$, 100; zinc from ZnO, 100; manganese from MnO, 0, 50 or 100; and magnesium from MgO, 0 or 100.
[d] Trace mineral mixes provided by Calcium Carbonate Company, Quincy, Ill.
[e] Composition per kg. of complete diet: Vit. A, 2,640 I.U.; vit. D_2, 396 I.U.; riboflavin, 1.76 mg.; calcium pantothenate, 6.6 mg.; niacin, 17.6 mg.; choline chloride, 110 mg.; vit. B_{12}, 11.0 μg.; ethoxyquin, 3.96 mg.; and chlortetracycline, 22 mg.

by drilling a 0.30 cm. hole in each end at the epyphisial cartilage and placed in methyl alcohol for 48 hours. The metatarsals were air-dried for 48 hr., oven dried at 100° C. for 12 hr. and then extracted with anhydrous ethyl ether in a side chamber apparatus for 12 hr. and allowed to air-dry for 10 days.

The breaking strength (BKS) of the metatarsals was determined by using a Fred S. Carver Laboratory Press.[5] The pressure required to supply the force to break the bones was read directly from a gauge and is the value reported.

[5] Fred S. Carver, Inc., One Chatham Road, Summit, New Jersey.

The broken metatarsals were dried for 24 hr. at 100° C. prior to weighing for ashing. The bones were ashed at 700° C. (Blair, Diack and Macpherson, 1963) in a muffle furnace for 10 hours. The ash was ground and a sample treated with ml. of 4N HCl and heated in a water bath at 60° C. to complete the dissolution of the ash. The samples were analyzed for Mn and Mg by atomic absorption spectrophotometry.

The ash sample was diluted 1,000:1 with 0.10% lanthanum solution for Mn analysis and 5,000:1 with distilled water for Mg determinations.

The data were analyzed statistically by analysis of variance methods (Steel and Torrie, 1960).

Results and Discussion

Treatment means for criteria of response are presented in tables 2 and 3. Gains were depressed when 50 ppm Mn was supplemented, which resulted in a significant quadratic effect (P<.05) of Mn levels on average daily gain. This observation does not agree with Grummer *et al.* (1950) who observed maximum gains when pigs were fed 52 ppm Mn or Plumlee *et*

TABLE 2. EFFECT OF ADDED DIETARY LEVELS OF MN AND MG ON GAIN, FEED INTAKE AND FEED/GAIN OF SWINE [a, b]

Confinement [c]				Pasture [d]			
	Mg, ppm				Mg, ppm		
Mn, ppm	0	100	Av. Mn	Mn, ppm	0	100	Av. Mn
			Av. daily gain, kg. [e, f]				
0	0.83	0.80	0.81	0	0.83	0.81	0.82
50	0.76	0.82	0.79	50	0.85	0.77	0.81
100	0.83	0.84	0.84	100	0.84	0.81	0.83
Av. Mg	0.80	0.82	....	Av. Mg	0.84	0.80	....
			Av. daily feed intake, kg. [g]				
0	2.43	2.40	2.41	0	2.35	2.22	2.29
50	2.24	2.37	2.30	50	2.38	2.18	2.29
100	2.42	2.41	2.41	100	2.39	2.26	2.33
Av. Mg	2.36	2.39	....	Av. Mg	2.37	2.22	....
			Av. feed/gain				
0	2.93	2.96	2.94	0	2.84	2.73	2.78
50	2.91	2.86	2.89	50	2.79	2.82	2.80
100	2.88	2.84	2.86	100	2.83	2.75	2.79
Av. Mg	2.91	2.89	....	Av. Mg	2.82	2.76	....

[a] Basal 14% protein corn-soybean meal diet.
[b] Av. initial wt. 17.4 kg., duration of test, 84 days.
[c] 15 pigs/treatment.
[d] 18 pigs/treatment.
[e] Quadratic effect of Mn levels significant (P<.05).
[f] Location x Mg interaction significant (P<.10).
[g] Location x Mg interaction significant (P<.05).

TABLE 3. EFFECT OF ADDED DIETARY LEVELS OF MN AND MG ON METATARSAL BREAKING STRENGTH, PERCENT BONE ASH, BONE MN AND MG AND BLOOD MG OF SWINE

	Confinement				Pasture		
	Mg, ppm				Mg, ppm		
Mn, ppm	0	100	Av. Mn	Mn, ppm	0	100	Av. Mn
			Metatarsal breaking strength, kg./cm.[2 a, b, c, d]				
0	9.6	7.6	8.6	0	15.2	12.8	14.0
50	6.7	7.2	7.0	50	12.9	13.5	13.2
100	7.6	8.2	7.9	100	17.6	18.7	18.2
Av. Mg	8.0	7.6	...	Av. Mg	15.2	15.0	....
			Bone Ash, % of dry fat-free bone[e, f]				
0	55.3	54.3	54.8	0	56.4	55.1	55.7
50	54.8	53.6	54.2	50	57.0	56.8	56.9
100	54.8	55.4	55.1	100	58.0	56.1	57.1
Av. Mg	55.0	54.4	....	Av. Mg	57.1	56.0	....
			Bone Mn, ppm of bone ash				
0	7.5	7.2	7.3	0	7.0	7.2	7.1
50	7.2	7.6	7.4	50	7.4	7.4	7.4
100	7.7	7.4	7.5	100	7.4	7.2	7.3
Av. Mg	7.4	7.4	...	Av. Mg	7.2	7.3	...
			Bone Mg, % of bone ash[g]				
0	0.89	0.98	0.94	0	1.03	0.93	0.98
50	0.89	0.94	0.92	50	0.94	0.95	0.94
100	0.90	0.98	0.94	100	0.98	0.91	0.94
Av. Mg	0.89	0.97	....	Av. Mg	0.98	0.93	....
			Blood Mg, ppm[h, i, j]				
0	2.6	2.4	2.5	0	3.4	2.8	3.1
50	2.9	2.7	2.8	50	2.6	3.0	2.8
100	2.7	2.5	2.6	100	3.4	3.0	3.2
Av. Mg	2.7	2.5	...	Av. Mg	3.1	2.9	...

[a] Pressure required to supply force to break metatarsal bone.
[b] Location effect significant (P<.005).
[c] Quadratic and linear effect of Mn levels significant (P<.025 and P<.10).
[d] Location x Mn interaction significant (P<.05).
[e] Location effect significant (P<.10).
[f] Level of Mg significant (P<.05).
[g] Location x Mg interaction significant (P<.10).
[h] Location effect significant (P<.01).
[i] Level of Mg significant (P<.10).
[j] Location x Mn interaction significant (P<.025).

al. (1956) who found no difference in gain and feed efficiency of growing pigs fed 0.5 to 40 ppm Mn.

Average daily gain was also reduced (P< .10) in pigs on pasture compared to those in confinement when 100 ppm Mg was added to the diet (0.80 *vs.* 0.84 kg.). A location x Mg interaction effect (P<.10) was also observed for gain. With 100 ppm Mg, gains were increased in confinement but were lower with the higher level of Mg on pasture. This effect may be accounted for by a significant (P<.05) location x Mg interaction upon feed intake. Pigs fed 100 ppm Mg on pasture had a lower daily feed intake (P<.05) than those in confinement (2.22 *vs.* 2.37 kg.). Feed/gain ratio was not significantly affected by any of the treatments.

Percent bone ash was greater (P<.10) for pigs grown on pasture than for those raised in confinement (56.6% *vs.* 54.7%). When averaged across both locations, percent bone ash was significantly lower (P<.05) when 100 ppm Mg was supplemented.

Dietary levels of 0, 50 and 100 ppm supplemental Mn resulted in BKS of the fourth metatarsal bones of 11.4, 10.1 and 13.0 kg./cm.^{2}, respectively. The quadratic effect of Mn levels on BKS was significant (P<.025). Also a location x Mn interaction (P<.05) was observed for BKS. When 100 ppm Mn was added to the diet in confinement, BKS decreased. The reverse was true for pigs raised on pasture.

The BKS of metatarsals from pigs raised on pasture was almost twice as great as from pigs raised in confinement, 7.82 *vs.* 15.20 kg./

cm.[2], respectively. The difference was highly significant ($P<.005$). The great difference in BKS of pigs reared in the two environments is unexplained at this time since no measure of forage intake was made for the pigs on pasture.

Bone Mn and Mg levels were not changed by level in the diet. There was a location x Mg interaction ($P<.10$) on bone Mg. Bones from pigs raised in confinement and supplemented with 0 and 100 ppm Mg analyzed 0.89 and 0.97% Mg.; whereas bones from pigs grown on pasture contained 0.98 and 0.92% Mg for the respective dietary levels of Mg. The pigs raised in confinement had bone Mg levels which were positively related to dietary Mg intake. The opposite effect on pasture may reflect the unknown intake of all minerals from the forage and soil.

Blood Mg levels were significantly lower ($P<.025$) in pigs grown in confinement compared to those on pasture. This again may reflect a possible intake of Mg from the forage or soil.

A location x Mn interaction ($P<.025$) on blood Mg level existed between pigs raised in confinement and those on pasture at the three levels of supplemental Mn. Supplementing 50 ppm Mn to diets of pigs in confinement resulted in the highest blood Mg levels but the lowest on pasture.

Dietary Mg tended to have a negative effect ($P<.10$) on blood Mg levels. Pigs in confinement and on pasture had higher serum Mg levels when no Mg was supplemented. The blood Mg levels when 0 and 100 ppm Mg were supplemented were 2.9 and 2.8 ppm, respectively. The effect of supplemental Mg on blood Mg levels was the opposite of that which was expected. However, Tillman (1966) suggested that excess Mg antagonizes calcium and phosphorus, allowing for a lower absorption and greater excretion of both Mg and calcium.

Summary

Manganese and magnesium were supplemented to a corn-soybean meal base diet fed to pigs in confinement and on pasture at the following rates in ppm: 0/0, 50/0, 100/0, 0/100, 50/100 and 100/100.

Average daily gain was significantly reduced when 50 ppm Mn was supplemented to the diet. Supplementing Mg at 100 ppm to pigs on pasture also reduced gains compared to pigs in confinement. A location x Mg interaction for gain and feed intake was observed. Pigs in confinement grew faster and ate more feed when 100 ppm Mg was added to the diet in confinement but both were reduced when this level was fed on pasture. Feed/gain was not significantly affected by any of the treatments.

Percent bone ash was significantly increased when pigs were grown on pasture and when 100 ppm Mg was added to the diet when averaged across both locations.

Breaking strength of the fourth metatarsal bone of pigs grown on pasture was almost twice that of pigs raised in confinement with the difference being highly significant. The quadratic component of the effect of levels of Mn on breaking strength was significant with diets containing 50 ppm producing bones with the lowest strength. The location x Mg interaction was significant. Thus, adding 100 ppm Mn in confinement reduced bone strength but increased it when this level was supplemented on pasture.

Supplementing Mg in confinement increased bone Mg levels, but the reverse occurred for pigs on pasture. Supplementing 100 ppm Mg reduced serum Mg levels in both environments. Pigs raised in confinement also had significantly lower serum Mg levels than pigs reared on pasture. A location x Mn interaction was observed for serum Mg with 50 ppm Mn in confinement producing the highest serum Mg levels and the lowest on pasture.

The pronounced difference in breaking strength of the metatarsals of pigs raised in confinement and on pasture is unexplained at this time.

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