Effects of Organic Trace Mineral Supplementation on Sows' Reproductive and Neonates' Growth Performance through 2 wk Postweaning**

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ABSTRACT : A feeding trial using sows and their neonates was conducted to determine the effects of source and level of organic trace mineral supplementation on reproductive performance of sows and the subsequent performance of their neonates through 2 wk post weaning. A total of 16 gestating sows (Landrace×Yorkshire) in parities 2 to 4 were randomly assigned to 4 dietary treatments following a 2×2 factorial arrangement in a completely randomized design. One of the two factors evaluated the effect of the source (inorganic vs organic), and the second factor evaluated the effect of the level (low vs high) of trace minerals added to the diet. The trace mineral premixes were formulated to provide a low concentration of trace minerals (50 ppm Fe/87.5 ppm Fe, 17.5 ppm Cu/85 ppm Cu, 45 ppm Zn/60 ppm Zn, and 20 ppm Mn/17.5 ppm Mn), and a high concentration of trace minerals (100 ppm Fe/175 ppm Fe, 35 ppm Cu/170 ppm Cu, 90 ppm Zn/120 ppm Zn, 40 ppm Mn/35 ppm Mn), when included at 0.20% in sows'/weaned pigs' diets, respectively. The total number born, total born alive and weaned, and the average neonate weight at birth were affected neither by the dietary source nor by the level of trace minerals ($p>0.05$), but an interaction effect ($p<0.05$) between the source and level of trace minerals was observed on the average weight at weaning. The neonates from sows fed the low level of organic trace minerals gained weight at an equal rate compared with those farrowed by sows fed the high level of inorganic trace minerals. Sows fed the organic trace minerals nursed their young with milk higher in Fe and Zn ($p<0.05$) compared with those fed diets with inorganic trace minerals. Consequently, the weaned pigs receiving the organic form of trace minerals tended to grow at a faster rate, consumed less feed and tended to utilize their feed more efficiently ($p<0.10$). It was further observed that the organic trace minerals significantly increased ($p<0.05$) Fe contents in the liver and serum, and Zn in the serum and bone. In conclusion, sows and neonates fed the organic minerals at low level showed similar performance compared with those fed the inorganic minerals at high level as specified in this study. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 9 : 1312-1318)***

Key Words : Trace Minerals, Organic Source, Reproductive, Neonates, Performance

INTRODUCTION

Trace minerals are present in most feed ingredients, but the amount greatly varies. Traditionally, these minerals are supplemented in the diet in the form of inorganic salts, but the availability of minerals in these sources may differ considerably (Close, 1999; Underwood and Suttle, 1999).

There are research reports indicating that binding Cu, Zn, Fe and Mn with amino acids and peptides can enhance the bioavailability of these trace minerals, thereby leading to improvements in parameters such as growth, reproduction and general health status when they are not available in sufficient amounts to meet animal needs. Close (1999) reported that addition of organic iron to a normal lactation diet fed some 7 days before farrowing and throughout a 26-day lactation, improved the feed intake of the sow, as well as the weaning weights of the piglets. The piglets had a higher erythrocyte count and hemoglobin level than piglets from sows receiving inorganic iron sources (Egeli et al., 1998).

Some of the previous reports have also shown that addition of Cu from CuLys improved the performance of weaned pigs. Zhou et al. (1994) compared $CuSO_4$ with CuLys when provided in the diet to weanling pigs over a 24 d period. The piglets on the CuLys diet consumed more feed and had significantly higher growth rates than those fed the $CuSO_4$ diets. According to Coffey et al. (1994), the improvements in growth rate and feed intake were greater in weanling pigs fed diets supplemented with CuLys than in those receiving copper sulfate. These reports were confirmed by Apgar and Kornegay (1996), who stated that ADG tended to be higher for pigs fed CuLys than for pigs fed copper sulfate. Lee et al. (2001) also reported that chelated Cu and Zn could be used at considerably lower concentrations than inorganic sources.

However, there were no differences in the growth of pigs when organic minerals were fed instead of inorganic minerals (Wedekind et al., 1994; Apgar et al., 1995), and most research on organic minerals has been carried out with individual elements, and there has been increased speculation that the greatest effect may be achieved when a combination of trace minerals is used in the diet due to their interactions (Underwood and Suttle, 1999). Several of the trace minerals act synergistically, and their combined

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effectiveness may be greater than when applied individually (Close, 1998). Hence, the objectives of this study were to determine the effects of organic trace minerals (Fe, Cu, Mn and Zn) supplementation of sows' diet on reproduction and the consequent performance of neonatal pigs through 2 wk post weaning.

MATERIALS AND METHODS

Experimental procedure, animals and diets

Metal proteinates of Fe, Cu, Zn and Mn and their corresponding inorganic salts were used in the preparation of organic and inorganic trace mineral premixes, respectively. The premix was formulated to provide a low concentration (50 ppm Fe/87.5 ppm Fe, 17.5 ppm Cu/85 ppm Cu, 45 ppm Zn/60 ppm Zn, and 20 ppm Mn/17.5 ppm Mn), and a high concentration (100 ppm Fe/175 ppm Fe, 35 ppm Cu/170 ppm Cu, 90 ppm Zn/120 ppm Zn, and 40 ppm Mn/35 ppm Mn) of trace minerals when included at 0.20% in sows'/weaned pigs' diet, respectively. The high concentration for the Cu and Zn is the maximum level permitted by the Ministry of Agriculture in Korea for sows/weaned pigs (MAF, 1999). The metal proteinates for Fe, Cu, Zn and Mn were manufactured and provided by Tongwoo TMC Co. in Korea. Metal proteinate is defined by the Association of American Feed Control Officials (AAFCO, 1998) as a product resulting from the chelation of a soluble metal salt with amino acids and/or partially hydrolyzed protein.

A total of 16 gestating sows (Landrace×Yorkshire) in parities 2-4 were randomly allocated to 4 dietary treatments and were randomly assigned to the 16 farrowing crates following a 2×2 factorial arrangement in a completely randomized design. One of the two factors evaluated the effect of the source of trace minerals, and the second factor evaluated the level of trace minerals added to the diet. Each treatment was replicated 4 times.

The lactation diet was formulated to meet or exceed the nutrient requirements listed in NRC, 1998. The composition of the basal diet is presented in Table 1. At 7 d prepartum and throughout the lactation period (21 d), the sows were fed their treatment diet. Each sow was fed 3.5-5.0 kg daily according to the sow's appetite. At 7 and 14 d postpartum, approximately 20 to 30 ml of milk was collected from the functional glands of each sow after the injection of oxytocin. The milk samples were placed into plastic vials, stored at -20°C, and later analyzed for Zn and Fe.

Litter size and piglet weights at birth and at weaning were recorded. Pre-weaning livability of piglets was likewise recorded.

The consequent performance of weaned pigs (Landrace ×Yorkshire×Duroc) from sows fed diets supplemented with different sources and levels of trace minerals was evaluated through 2 wk post weaning. Weaned pigs were housed in pens (1.9×2.3 m) with partially slotted floors (55.5%), following the same experimental design and dietary treatments as were used in sows. Each litter or average piglet within the litter served as replicate. The pigs were allowed *ad libitum* access to the experimental diets (Table 1) from self-feeders and to water from nipple waterers. Creep feeds for suckling pigs were available from d 3 to d 21 after birth. Piglets' weights and feed intake were recorded at 21 d and 35 d after birth.

At 28 d, one pig from each replicate of each treatment

Table 1. Feed ingredient and nutrient composition of basal diets

	Lactation	Pre-starter	Starter
Ingredient (%)			
Corn, ground	51.17	-	22.22
Extruded corn	-	47.18	-
Whey powder	-	30.00	25.00
Soybean meal (44%)	30.64	-	19.56
Bakery by-product	-	7.40	10.00
Lactose	-	-	5.00
Blood plasma protein	-	5.00	5.00
Fish meal (68%)	-	4.00	4.00
Sucrose	-	2.00	4.00
Wheat bran	5.00	-	-
Soy oil	-	2.70	2.00
Animal fat	4.73	-	-
Molasses	3.00	-	-
Tricalcium phosphate	2.00	-	-
Mono calcium phosphate	-	0.11	0.95
Rapeseed meal (38%)	2.00	-	-
Salt	0.55	0.10	0.10
Limestone	0.34	-	0.40
Mineral premix [1]	0.20	0.20	0.20
Vitamin premix [2]	0.12	0.25	0.30
Probiotics	0.15	-	-
L-lysine (78%)	0.04	0.06	0.18
DL-methionine (50%)	0.02	0.06	0.30
ZnO	-	0.34	0.34
Acidifier	-	0.15	-
Apramycin (100 g/kg)	-	0.15	0.15
CTC (100 g/kg)	-	0.10	0.10
Mecadox (50 g/kg)	-	0.10	0.10
Choline chloride (25%)	-	0.10	0.10
Total	100.00	100.00	100.00
Calculated nutrient composition			
ME, kcal/kg	3,300	3,400	3,400
Crude protein, %	19.15	24.00	21.69
Calcium, %	0.90	0.80	0.80
Avail. phosphorus, %	0.45	0.50	0.54
Lysine, %	1.10	1.60	1.50
Met+cys, %	0.66	0.84	0.84

[1] Supplied per kg diet: depending on the dietary treatment plus 0.75 mg Co, 0.75 mg I and 0.23 mg Se.
[2] Supplied per kg diet: 12,000 IU vitamin A, 3,000 IU vitamin D_3, 30 IU vitamin E, 3.45 mg Vitamin K_3, 1.8 mg vitamin B_1, 14.4 mg Vitamin B_2, 3 mg vitamin B_6, 0.045mg vitamin B_{12}, 30 mg pantothenic acid, 90 mg niacin, 0.105 mg biotin, 0.75 mg folic acid.

was stunned by electrocution. A blood sample was collected via venipuncture from the anterior vena cava, placed into heparinized vacuum tubes and stored at -20°C. Then pig was immediately incised to obtain liver and bone samples for trace mineral analyses.

Chemical and statistical analyses

Bone samples were cleaned of all soft tissues. Bone with associated cartilages was dry-ashed at 550°C and wet-ashed with 1:1 HCl. Milk and liver samples were ashed and solubilized as indicated above. Digested samples were diluted with deionized distilled water; with 2% HCl for blood serum, as necessary for trace mineral determination. The Fe and Zn concentrations in milk and in blood serum, Cu and Fe in liver, and Mn and Zn in bone were determined by flame atomic absorption spectrophotometry (Model 904AA, GBC, Australia).

Individual sows and neonates/weaned pigs within litters were used as experimental units. Data were analyzed in a 2×2 factorial arrangement using the GLM procedure of SAS (1985). The mean differences between treatments and the main effects of source and level were detected using Duncan’s multiple range tests (Duncan, 1955).

RESULTS

Reproductive performance

The total number born, total born alive and weaned, and the average neonate weight at birth were affected neither by the dietary source nor by the level of trace minerals ($p>0.05$), but an interaction effect ($p<0.05$) between source and level of trace minerals was observed on the average neonate weight at weaning (Table 2). Neonates of sows fed the low level of organic trace minerals and those of sows fed the high level of inorganic trace minerals gained weight at equal rates ($p>0.05$).

Trace mineral concentrations in milk

Milk collected at 14 d postpartum from sows supplemented with the low level of organic trace minerals contained more Fe ($p<0.05$) than those receiving the other treatments (Table 2). Milk Fe and Zn were significantly raised in sows supplemented with organic minerals ($p<0.05$), compared with those supplemented with inorganic minerals, except milk Zn at 7 d postpartum. Milk Fe and Zn at both 7 and 14 d postpartum were not influenced by the dietary level of trace minerals in the sows' diet ($p>0.05$).

Neonates' performance during lactation

Growth rate tended to improve in neonates from sows supplemented with the low level of organic trace minerals ($p<0.10$) (Table 2). The magnitude of the difference in ADG between neonates of sows fed the low and the high level of either source was small. No differences ($p>0.05$) were observed between the two sources, and none of the differences at any week was significant ($p>0.05$).

Weaned pigs' performance

There was an interaction effect ($p<0.05$) between the source and level of trace minerals observed on ADFI (Table 3). The pigs receiving the low level of organic trace minerals and those receiving the high level of inorganic trace minerals similarly consumed less feed ($p<0.01$). Regardless of the level of trace minerals, pigs receiving the organic form tended to grow at a faster rate ($p<0.10$), consumed less feed and tended to utilize their feed more efficiently ($p<0.10$) than those fed the inorganic trace minerals.

Mineral concentrations in blood, liver and bone

The effect of the source and level as well as the interaction effect were observed in weaned pigs' liver and

Table 2. Effect of source and level of trace minerals on sow and neonatal pigs performance

Parameter	Inorganic source		Organic source		SE	Probability[1]		
	Low	High	Low	High		Source	Level	S×L
Total born	13.67	10.67	10.00	11.67	2.86	NS	NS	NS
Total born alive	11.00	10.00	9.67	11.63	1.85	NS	NS	NS
Total weaned	8.33	7.00	8.00	8.33	2.25	NS	NS	NS
Average piglet weight at birth, kg	1.63	1.57	1.55	1.32	0.19	NS	NS	NS
Average piglet weight at weaning, kg [2]	5.93[bc]	6.05[ab]	6.41[a]	5.64[c]	0.36	NS	0.09	0.03
ADG (0-3 wk) [2]	205[b]	213[ab]	231[a]	206[b]	16.58	NS	NS	0.10
Mineral concentration in milk, ppm[3]								
7 d Fe	1.54	1.59	1.65	1.63	0.07	0.04	NS	NS
Zn	1.59	1.62	1.65	1.63	0.07	NS	NS	NS
14 d Fe[2]	1.76[c]	1.81[b]	1.86[a]	1.83[ab]	0.05	0.01	NS	0.02
Zn	1.77	1.82	1.86	1.83	0.05	0.05	NS	NS

[1] NS=Not significant ($p>0.05$).
[2] Values with different superscripts of the same row significantly differ ($p<0.05$); ($p<0.10$) for ADG.
[3] Fresh basis.

Table 3. The consequent performance of weaned pigs as influenced by source and level of trace minerals

Parameter	Inorganic source		Organic source		SE	Probability[1]		
	Low	High	Low	High		Source	Level	S×L
Body weight, kg								
3 wk[2]	5.93[bc]	6.05[ab]	6.41[a]	5.64[a]	0.36	NS	0.09	0.03
5 wk	10.07	9.18	10.63	9.85	0.78	NS	0.06	NS
ADG, g	296	224	301	301	47.78	0.10	NS	NS
ADFI, g[2]	391[a]	311[b]	296[b]	364[a]	48.54	NS	NS	0.01
F/G	1.37	1.40	0.99	1.22	0.26	0.08	NS	NS

[1] NS=not significant (p>0.05).
[2] Values with different superscripts of the same row significantly differ (p<0.05).

serum Fe content (Table 4). Liver and serum Fe of weaned pigs fed the high level of organic trace minerals was generally higher (p<0.05), compared to those in the other treatments, whereas the liver Cu was influenced only by the level of trace minerals in the diet. The higher the level of trace minerals in the diet, the higher the concentration of Cu in the liver (p<0.05). On the other hand, Zn in bone and in serum was influenced by the source but not by the level of trace minerals. Pigs receiving the organic trace minerals had a higher concentration of Zn in bone (p<0.05) and in serum (p<0.05) than those receiving the inorganic trace minerals. Mn in bone was not affected by the dietary level of trace minerals, but tended to be high in pigs fed the organic trace minerals (p<0.10).

DISCUSSION

Information on the effects of Fe, Cu, Zn and Mn in organic form on the reproductive performance of sows is limited, and their effect on the consequent performance of neonates has not previously been reported. Trace minerals such as Fe, Cu, Zn and Mn play specific roles not only in growth but also in reproduction, and if for any reason there is a deficiency in the diet or in the body, then a high level of performance cannot be achieved (Fehse and Close, 2000). It has been suggested that inclusion of organic trace minerals better meets the needs of the animal (Zhou et al., 1994; Lee et al., 2001). In this study there were no significant differences in total born and total born alive observed among the treatments and this could be attributed to the complexity of the female reproductive process. As mentioned by Vandergrift (1993), one of the benefits that could be achieved by using organic minerals is improved female reproduction via reduced embryonic death loss, improved uterine environment, reduced incidence of cystic ovaries and increased estrus intensity. In such cases a long-term feeding period with dietary variables seems necessary before positive effects on reproduction are demonstrable. Fe in particular improves reproductive performance in sows, probably through the action of the iron-dependent uterine protein, uteroferrin, which is secreted in early pregnancy and therefore enhances embryo survival (Close, 1999). The experiment conducted by Fehse and Close (2000) to establish whether a special supplement of organic minerals provided in addition to the normal inorganic sources of minerals in the diet of the gestating and lactating sow was effective, covered the whole reproductive cycle of sows. They reported improved sow performance in terms of the total number of pigs born, born alive and weaned. In the current study, feeding dietary variables was initiated 7 d prepartum, which was not long enough to influence the reproductive parameters except for average neonate weight at weaning. It was observed that feeding sows with low a level of organic trace minerals weaned heavier neonates (p<0.05), compared to the other treatments. This observation partly supports the reports by Close (1999) that

Table 4. Effect of source and level of trace minerals on liver, bone and serum mineral concentration in weaned pigs

Mineral, ppm[2]	Inorganic source		Organic source		SE	Probability[1]		
	Low	High	Low	High		Source	Level	S×L
Liver								
Cu	19.05	20.34	19.18	21.29	1.16	NS	0.001	NS
Fe[3]	354.85[b]	355.40[b]	357.63[b]	403.33[a]	25.19	0.006	0.01	0.01
Bone								
Zn	68.25	69.43	71.73	72.98	3.30	0.04	NS	NS
Mn	1.15	1.21	1.30	1.29	0.14	0.10	NS	NS
Serum								
Fe[3]	0.96[b]	1.16[a]	1.19[a]	1.20[a]	0.13	0.003	0.01	0.02
Zn	0.79	0.81	0.94	0.90	0.08	0.001	NS	NS

[1] NS= not significant (p>0.05).
[2] Fresh basis.
[3] Values with different superscripts of the same row significantly differ (p<0.05).

addition of organic Fe to a normal lactation diet fed some 7 d before farrowing and throughout a 26 d lactation improved weaning weights of neonates.

No matter how large or small the litter size, the sow is best suited to provide nutrition support to neonates. Milk is known to contain rich varieties of substances that may aid development of pig postnatally, and it is generally thought that the concentration of some of these substances, such as minerals, is influenced more by diet composition and bioavailability as a result of transfer from plasma to the mammary gland. However Pond et al. (1961) conclusively stated that, whether Fe sources are administered to dams orally or via injection, Fe concentration in milk is not increased sufficiently to prevent anemia in the offspring. As cited by Hill et al. (1983) Fe and Cu are resistant to the influence of dietary levels, whereas Zn and Mn can be increased in milk by increasing the dietary levels of the dam. In the present study, the source of trace minerals influenced the Fe and Zn concentration in milk collected at 7 d and 14 d postpartum, except for Zn at 7 d postpartum. This suggests that Fe and Zn in organic forms are efficiently utilized and transferred to the mammary gland regardless of levels. Hill et al. (1983) reported that milk Zn concentration at all stages of lactation was similar for gilts and sows receiving 0 to 500 ppm supplemental dietary Zn, but was raised in those fed 5,000 ppm of supplemental Zn. On the other hand, sows receiving 150 ppm of Fe and 60 ppm of Zn in the diet had 1.50 and 1.34 mg/liter and 4.93 and 4.53 mg/kg on a fresh basis of Fe and Zn, respectively, in milk samples at 1 and 2 wk post-farrowing (Pond et al., 1965). In this study, sows were supplemented with 100 ppm of Fe and 90 ppm of Zn for the high level of either source of trace minerals. The low values obtained for Zn in milk compared to those of Pond et al. (1965) could be due to differing Zn stores of the sow or differing sensitivity of the analytical techniques.

Although there was no significant difference in the growth rate of neonates at any week within the nursing period, the tendency of neonates from sows receiving a low level of organic minerals to grow faster ($p<0.10$) resulted in heavier body weight at weaning ($p<0.05$), compared to the other treatments. These neonates received higher concentrations of Fe and Zn in milk, and therefore gained more weight at weaning ($p<0.05$), compared to those nursed by sows fed inorganic trace minerals. This suggests that providing the low level of organic trace minerals to sows could exert the same growth-promoting effect as receiving the high level of the same trace minerals in inorganic form. The results probably indicate that trace minerals in organic form enhance the bioavailability of the minerals when they are at the low level.

Ammerman et al. (1998) have suggested that organic minerals provide the animal with a metabolic benefit that often results in improved performance. In line with this statement several research reports have been documented, indicating the effectiveness of Cu and/or Zn in organic forms, but limited data is available to evaluate the potential interactive or additive effects of Cu, Zn, Fe and Mn on pig performance. In this report, the interaction effect of the source and level of trace minerals on the neonate weight at weaning (3 wk) was not carried through the starter period (5 wk of age). But otherwise, weaned pigs fed the low level of organic trace minerals consumed less feed ($p<0.05$) and were not different from those fed the high level of inorganic trace minerals. Regardless of level, feeding weaned pigs with organic trace minerals tended to improve the ADG ($p<0.10$) and the F/G ratio ($p<0.10$). This was consistent with the previous reports that ADG tended to be higher in weaned pigs fed diets with CuLys (200 ppm Cu) (Apgar and Kornegay, 1996). The percentage improvements from the CuLys additions (200 ppm Cu) were greater for the growth rate and the feed intake (Coffey et al., 1994) than in pigs fed diets with $CuSO_4$. Although the minimum requirement for Cu is only 5-6 ppm (NRC, 1998), higher levels may stimulate growth. In this study, trace minerals designated as high contained 170 ppm Cu, and 85 ppm Cu for the low level. Apgar et al. (1994) reported that, averaged across Cu sources, there were no differences between 100 and 200 ppm of Cu in the magnitude of improvement over controls for the daily gain, daily feed, or the F/G ratio.

On the other hand, Ward et al. (1996) reported that the growth response of weanling pigs was similar between those fed 250 ppm of Zn from zinc-methionine complex or 2,000 ppm Zn from zinc oxide, which suggests an increase in the bioavailability of Zn in zinc-methionine. This positive response was confirmed by the most recent findings of Lee et al. (2001) that the efficacy of chelated Cu and Zn sources at low levels (85 ppm Cu and 60 ppm Zn) is similar, in terms of growth performance to that of high levels (170 ppm Cu and 120 ppm Zn) of inorganic Cu and Zn. Smith et al. (1997) and Hill et al. (2000) also demonstrated that Cu and Zn have no additive effect on the pig performance. In this study, similar levels of Cu and Zn to those used by Lee et al. (2001) were used. However, it is not known whether the slight improvements in ADG and the F/G ratio were due to a single element or combination of organic Cu, Zn, Fe and/or Mn.

The consequent better growth performance exhibited by the weaned pigs from sows supplemented with organic trace minerals can be related to the pig's stores in the liver, blood serum and bone. It appears that organic trace minerals are absorbed more efficiently, and their retention in the body is higher than that of similar minerals in their inorganic form. The Fe in the liver and the serum, and Zn in the bone and the serum, were higher in pigs fed organic trace minerals than in those fed inorganic form of the same minerals.

These differences in the magnitude of responses with the two sources of trace minerals may be related to differences in bioavailability. This is consistent with the previous reports that Cu-amino acid complexes had higher availability than $CuSO_4$ for rats (Kirchgessner and Grassmann, 1970). Apgar et al. (1995) reported increased Cu deposition in the livers of pigs fed 200 mg/kg of Cu from CuLys, as compared with the livers of pigs fed $CuSO_4$, and they suggested that perhaps the organic Cu source is metabolized differently from $CuSO_4$. Also, the Cu utilization from Cu proteinate and CuLys was higher, based on liver Cu content (Du et al., 1996). However other researchers reported otherwise. Coffey et al. (1994) found that the liver Cu concentrations of pigs fed the highest level of CuLys were lower than those of pigs fed the same concentration using $CuSO_4$. CuLys was added as the sole source of Cu and growth promotant for weanling pigs. Cheng et al. (1998) showed that Zn concentrations in serum, liver, kidney and rib were similar between pigs supplemented with $ZnSO_4$ and those fed ZnLys, which suggests that availability of Zn is similar between ZnLys and $ZnSO_4$ (Kornegay and Thomas, 1975; Hill et al., 1986; Wedekind et al., 1994; Swinkels et al., 1996).

The non-significant result for the concentration of Mn in bone could be due to its adequacy in the diet for normal growth and skeletal development; however, organic trace minerals tended to increase Mn deposition in bone ($p<0.10$). The maximum requirement for growing pigs is probably around 4 mg/kg DM on natural diets (NRC, 1998). Henry et al. (1989) reported the availability of Mn in manganese methionine to be 120% relative to manganese sulfate.

IMPLICATIONS

The results of this study indicate that organic trace minerals supplementation improves sows' reproductive performance to some extent and is efficacious in enhancing growth of neonates through 2 wk post weaning. Although it is not known whether the growth- promoting effect is due to one element or combination of elements, the organic form of trace minerals at low level as specified in this study could provide enough minerals to meet young pigs' needs for growth, even in relatively short-term feeding.

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