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Inorganic and organic trace mineral supplementation in weanling pig diets

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ABSTRACT

A study was conducted to evaluate the effects of dietary inorganic and organic trace minerals in two levels of supplementation regarding performance, diarrhea occurrence, hematological parameters, fecal mineral excretion and mineral retention in metacarpals and liver of weanling pigs. Seventy piglets weaned at 21 days of age with an average initial body weight of 6.70 ± 0.38 kg were allotted in five treatments: control diet (no added trace mineral premix); 50% ITMP (control diet with inorganic trace mineral premix supplying only 50% of trace mineral requirements); 50% OTMP (control diet with organic trace mineral premix supplying only 50% of trace mineral requirements); 100% ITMP (control diet with inorganic trace mineral premix supplying 100% of trace mineral requirements); and 100% OTMP (control diet with organic trace mineral premix supplying 100% of trace mineral requirements). Feed intake and daily weight gain were not affected by treatments, however, piglets supplemented by trace minerals presented better gain:feed ratio. No differences were observed at calcium, phosphorus, potassium, magnesium, sodium and sulfur excreted in feces per kilogram of feed intake. Treatments did not affect calcium, phosphorus, magnesium, sulfur and iron content in metacarpals. Trace mineral supplementation, regardless of level and source, improved the performance of piglets.

Key words: nursery phase, performance, weaning, piglet.

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INTRODUCTION

In animal nutrition, trace minerals are used in premixes as inorganic oxides, sulphates, and carbonates, and thus act as catalysts in enzymatic and hormonal processes, influencing maintenance, growth, and bone development (Underwood and Suttle 1999). Nevertheless, the deficiency of these minerals is manifested in many metabolic processes, resulting in lower performance and immune response, being primarily evidenced in animals more susceptible to nutritional effects, such as piglets at nursery phase. Mineral imbalance or mineral deficiency may be caused by the amount of trace minerals below the animal requirement or the presence of antagonistic compounds in diet, which directly affects the absorption of several minerals. Thus, trace minerals are often supplemented in livestock diets at concentrations well above those required by the animals, aiming not to limit the productive performance. Consequently, providing minerals in excess, which are not absorbed by the animal, results in higher levels of these in manure, being potential contaminants of soil and water (Case and Carlson 2002).

With regards to the environmental impact caused by pigs manure, alternatives are evaluated aiming to reduce the waste of nutrients, including trace minerals. One of them is using trace minerals in organic form based on the higher bioavailability of them, which would allow the reduction of mineral supplementation in diets (Baker 1991). By definition, organic minerals are those which have complexed to organic molecules comprising amino acids, carbohydrates, and proteins, as well as other possible linkable components (Mellor 1964). The increased bioavailability of organic minerals might be due to the action of some components in absorption process. Another form of organic minerals effect is based on the formation of stable complexes, which decrease the possibility of forming precipitated salts with compounds, such as phytic acid or insoluble fiber. Thereby, organic trace minerals have become more available due to its greater solubility, and absorption is facilitated by the organic binder components (Kirchgessner and Grassmann 1970).

Newly weaned piglets are very susceptible to enteric disorders mostly during the first week after weaning, and thus sources of minerals that have a higher availability are beneficial not only from a nutritional standpoint but also in relation to the immune effect of certain minerals such as zinc and copper. It has been demonstrated that inorganic and organic trace mineral supplementation did not affect growth performance of pigs (Mahan et al. 1999, Revy et al. 2002). In addition, nursery pig diets are often formulated with mineral levels above those that would be required by animals and thus possible effects of organic supplementation may not be evident.

This study was aimed to determine the effects of dietary inorganic and organic trace minerals (Cu, Fe, Mn, Se, and Zn) in different levels of supplementation with regards to performance, diarrhea occurrence, hematological parameters, fecal mineral excretion, and mineral retention in metacarpals and liver of weanling pigs.

MATERIALS AND METHODS

All experimental procedures were conducted in accordance with the protocol approved by the Animal Care and Use Committee of Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista "Júlio de Mesquita Filho".

ANIMAL, HOUSING, AND EXPERIMENTAL DESIGN

A total of 70 commercial strain mixed-sex (35 barrows and 35 females) pigs with an average initial body weight (BW) of 6.70 ± 0.38 kg were obtained after weaning at 21 days of age for use in the current study. The pigs were housed in floor pens (length = 3.0 m; width = 3.0 m) equipped with a nipple drinker, two-space feeder, and concrete flooring. The pigs were weighed and blocked by initial BW and allotted to five experimental diets according to a randomized complete block design. There were seven pen replicates of two pigs (one barrow and one female) per pen for each treatment.

EXPERIMENTAL DIETS

A three-phase feeding program was used with corn-soybean meal-based diets: pre-starter I (from 0 to 9 days), pre-starter II (from 10 to 29 days), and starter (from 30 to 42 days). The treatments (as-fed basis) were: control diet (no added trace mineral premix); 50% ITMP (control diet with inorganic trace mineral premix supplying only 50% of the animal requirements); 50% OTMP (control diet with organic trace mineral premix supplying only 50% of trace mineral requirements); 100% ITMP (control diet with inorganic trace mineral premix supplying 100% of trace mineral requirements); and 100% OTMP (control diet with organic trace mineral premix supplying 100% of the animal requirements) (Table I).

All diets were formulated to meet or exceed Rostagno et al. (2005) requirements for all nutrients except Cu, Fe, Mn, Se, and Zn. Metal proteinates

TABLE I
Composition of the experimental diets, as-fed basis (%).

Ingredient	Experimental period (days)		
	0 - 9	10 - 29	30 - 42
Corn	52.76	57.00	67.57
Soybean meal (45%)	31.84	31.70	28.43
Milk product[a]	7.00	4.82	-
Sugar	1.00	0.75	-
Soybean oil	1.42	1.42	0.97
Dicalcium phosphate	2.36	1.79	1.60
Limestone	0.54	0.73	0.63
Salt	0.60	0.49	0.46
L- lysine.HCL	0.76	0.46	0.20
L- threonine	0.28	0.16	0.02
DL-methionine	0.14	0.09	-
L- tryptophan	0.04	0.01	-
Vitamin premix[b], %	0.10	0.10	0.10
Organic/inorganic trace mineral supplementation[c]	-	-	-
Antioxidant (BHT), %	0.02	0.02	0.02
Colistin, %	0.03	0.03	0.03
Inert (kaolin), %	1.19	0.40	0.37
Total	**100.00**	**100.00**	**100.00**
Calculated values			
Crude protein, %	21.00	21.00	18.13
Calcium, %	0.89	0.80	0.72
Available phosphorus, %	0.56	0.45	0.40
Metabolizable energy (kcal/kg)	3,225	3,225	3,230
Digestible lysine (%)	1.52	1.33	0.99
Digestible methionine (%)	0.43	0.37	0.25
Digestible tryptophan (%)	0.26	0.23	0.19
Digestible threonine (%)	0.96	0.84	0.62

[a]Nuklospray 40% of lactose. [b]Provided per kilogram of diet. [c]Supplementation of 0.125 (50% IM or 50% OM) and 0.250 kg (100% IM or 100% OM), depending on treatment.

of Cu, Fe, Mn, Se, and Zn and their corresponding inorganic salts were used in the preparation of organic and inorganic trace mineral premixes, respectively (Table II). Both trace mineral premixes contained I and Co from inorganic source. Crystalline lysine, threonine, methionine and tryptophan were added to obtain equal amounts of digestible amino acids in all experimental diets.

TABLE II
Inorganic and organic trace mineral premixes.

Inorganic trace mineral premix	**Purity (%)**	**Amount (mg/kg of premix)**	**Amount (g/ton of diet)**
Copper sulfate	25.00	12.00	48.00
Iron sulfate	30.00	80.00	266.67
Manganese sulfate	31.00	40.00	129.03
Zinc sulfate	35.00	100.00	285.71
Sodium selenite	45.00	0.36	0.80
Calcium iodate *	62.00	1.00	1.61
Cobalt sulfate *	20.00	0.20	1.00
Subtotal			732.83
Inert **			1767.17
Total			2500.00[1]
Organic trace mineral premix	**Purity (%)**	**Amount (mg/kg of premix)**	**Amount (g/ton of diet)**
Copper proteinate	10.00	12.00	120.00
Iron proteinate	15.00	80.00	533.33
Manganese proteinate	10.00	40.00	40.00
Zinc proteinate	15.00	100.00	666.67
Selenium proteinate	0.10	0.36	360.00
Calcium iodate *	62.00	1.00	1.61
Cobalt sulfate *	20.00	0.20	1.00
Subtotal			2082.61
Inert **			417.39
Total			2500.00[1]

[1] Trace mineral supplementation at 0.25% or 2.5 kg / ton of diet to meet 100% of mineral recommendation;
* In treatments where there were trace mineral supplementation, and iodine and cobalt were added at level of 1.0 and 0.2 mg / kg of diet, respectively, both inorganic source. **qsp – kaolin.

PERFORMANCE AND DIARRHEA OCCURRENCE

Body weight and feed disappearance were recorded on day 9, 29, and 42 to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G:F)

During the first 21 days of the trial period, fecal scores of piglets were evaluated to verify the influence of treatment on diarrhea occurrence, adapted from Vassalo et al. (1997). Macroscopic appearance of feces were observed by visual analysis according to the following scores: 1 - normal feces, 2 - soft feces and 3 - watery feces. Scores 1 and 2 were considered non-diarrheal and score 3 as diarrheal feces.

CHEMICAL ANALYSIS

On day 42, blood samples (5 mL) were collected from all pigs via sinus orbital puncture into sterilized tubes without anticoagulant. Samples were then immediately centrifuged at 3000 rpm x *g* for 20 min at 4 °C to recover serum. Hematological parameters (hemoglobin, hematocrit, leukocytes, eosinophils, rod neutrophil, segmented neutrophils, lymphocytes, and monocytes) were determined using the ACT-CAP coulter kit.

Fecal samples were collected for the last 13 days of the experimental period to evaluate mineral excretion. Samples were dried and grounded at ball mill. Samples were processed by nitric perchloric digestion and content of P, Ca, K, Mg, Na, S, Cu, Fe, Mn, and Zn were determined in an atomic absorption spectrophotometer (Bataglia et al. 1983). Mineral excretion was calculated by relating the amount excreted with the daily intake of each mineral.

At the end of the 42-day study period, one pigs per pen, totaling 35 animals, were stunned electrically and slaughtered to harvest the liver and the third and fourth metacarpals for mineral concentration (Ca, P, Mg, S, Cu, Fe, Mn, and Zn) analysis, using the same methodology as applied to the feces. The liver was analyzed by wet digestion (Delves 1982) and the metacarpals were processed and analyzed according to the method described by Veloso et al. (2000).

STATISTICAL ANALYSIS

Data were subjected to analysis of variance using GLM procedure of Statistical Analysis System software. Significant result for analysis of variance of means (*P*<0.05) was followed by orthogonal contrasts, as C1 - control diet versus other treatments; C2 - 50% of the animal requirements of trace mineral versus 100% of the animal requirements of trace mineral; C3 - 50% ITMP versus 50% OTMP and C4 - 100% ITMP versus 100% OTMP. For hematological parameters of eosinophils, rod neutrophil and monocytes, data were transformed in $(Y+1)^{½}$ for normal distribution. Data not statistically significant were not discussed in the present work.

RESULTS AND DISCUSSION

PERFORMANCE AND DIARRHEA OCCURRENCE

In the first period (from 0 to 9 days), it was observed that the animals that received trace mineral supplementation had a lower ADFI when compared with CN (Table III).

The animals that received the organic form of trace mineral had lower ADFI, compared with those which received inorganic supplementation meeting 50 or 100% of trace mineral requirement. Although no effect of treatments in ADG, G:F was better when trace mineral supplementation met 100% of the required. For the second period (21 to 50 days of age), the piglets fed trace mineral supplementation

TABLE III
Effects of inorganic and organic trace mineral supplementation on body weight (BW), average daily gain (ADG), average daily feed intake (ADFI), and gain: feed ratio (GF) of weanling pigs.

Item	Treatment					SEM	P-value			
	Control	50% ITMP	50% OTMP	100% ITMP	100% OTMP		C1	C2	C3	C4
				0 – 9 days						
ADG, g	122	91	72	99	81	17.52	NS	NS	NS	NS
ADFI, g	239	225	158	204	141	24.25	*	NS	*	*
GF	0.51	0.41	0.45	0.48	0.57	0.07	NS	*	NS	NS
				10 – 29 days						
ADG, g	164	217	254	235	207	13.75	*	NS	NS	NS
ADFI, g	391	429	438	446	364	19.89	NS	NS	NS	NS
GF	0.42	0.50	0.57	0.53	0.58	0.03	*	NS	NS	NS
				30 – 42 days						
ADG, g	220	262	317	317	284	12.45	NS	NS	NS	NS
ADFI, g	494	503	571	564	479	15.78	NS	NS	NS	NS
GF	0.44	0.52	0.55	0.56	0.59	0.03	*	NS	NS	NS

C1: NC vs other treatments; C2: 50% vs 100%; C3: 50% IM vs 50% OM; C4: 100% IM vs 100% OM. **P*<0.05; NS: nonsignificant.

in diet had higher ADG and higher G:F compared to pigs from control treatment. Assessing the total period (21 to 63 days of age), ADFI and ADG were not affected by treatments (*P*>0.05). Nevertheless for G:F, piglets supplemented with trace minerals showed better values for this variable.

During lactation, the majority of trace minerals ingested by pigs corresponds to the milk, so at first week post-weaning they still have reserves of these elements which become depleted if there is no supply. In this sense, it is observed that the effect of non supplementation becomes more pronounced from the second week post-weaning, worsening the performance of piglets. The absence of trace mineral supplementation for piglets from 53 days old was observed by Mello et al. (2012), suggesting that the body reserves would be insufficient to meet the requirement for trace minerals in piglets from this age.

Although there was no difference in performance of pigs fed diets containing organic and inorganic sources, the results present the possibility of reducing the amount of some trace elements in up to 50% of what is required, obtaining the same performance of piglets, considering the performance of animals from 0 to 42 days of experimental period. Mello et al. (2012), comparing levels of supplementation of trace minerals in organic form, noted that the level of 25% of what is required promoted performance similar to animals fed diet containing the total requirement. Likewise, the possibility of reducing up to 30% of trace minerals requirement in diets for pigs was demonstrated by Burkett et al. (2005), when supplemented in organic form.

It was observed that animals fed diets with 50% of trace mineral supplementation in inorganic form presented higher diarrhea occurrence, followed by those of 50% OM and 100% IM treatments. Lower values for diarrhea occurrence were observed in animals fed NC and 100% OM (Table IV). The lower diarrhea incidence in piglets fed diets without mineral supplement (NC) may be partly accounted for by the lower intestinal osmolarity. It has been well documented that piglet diarrhea may be associated with enteric pathogens proliferation and nutritional imbalance, such as an increase in intestinal osmolarity (Etheridge et al. 1984). The increase in intestinal osmolarity causes gut inflammation by the reduction of the enzymatic secretion and nutrients absorption.

HEMATOLOGICAL PARAMETERS

There were no treatment differences (*P*>0.05) in the concentrations of leukocytes, eosinophils, segmented neutrophils, and lymphocytes. Significant difference was observed (*P*<0.05) for the concentration of red blood cells, with a higher concentration of this blood component in animals of

TABLE IV
Effects of inorganic and organic trace mineral supplementation on diarrhea occurrence of weanling pigs.

Fecal score	Treatment					Total	SEM	%
	Control	50% ITMP	50% OTMP	100% ITMP	100% OTMP			
Score 1	95	72	116	90	117	490	1.28	34.27
Sscore 2	172	148	122	154	133	729	0.88	50.98
Score 3	27	60	51	42	31	211	2.09	14.75
Total	294	280	289	286	281	1430	0.14	100.00
% Escore 3	9.18^a	21.4^c	17.6^b	14.6^b	11.0^a	14.8		--

Means followed by the same letter do not differ by Kruskal Wallys test (*P*>0.05).

100% OM compared to 100% IM (Table V). Pigs fed 50% ITMP had higher hemoglobin and hematocrit levels compared with those fed 50% OTMP. Some trace elements, due to the functions they serve, may result in physiological modulating when the requirement is not met. Accordingly, the organic iron supplementation at full recommendation, results in higher number of red blood cells in comparison with inorganic supplementation of this mineral. However, the opposite effect was observed when it dropped to 50% of the recommended for trace mineral supplementation, with higher values for hemoglobin and hematocrit in animals supplemented with inorganic trace minerals.

The control pigs showed higher values of rod neutrophils ($P<0.05$) than the other treatments. Depending on the cellular phenomena caused by an inflammatory process, it is observed that the greater presence of neutrophils corresponds to acute inflammation (Eckmann et al. 1993). Thus, the absence of supplemental trace minerals for piglets could result in immune response due to an inflammatory process.

Difference was observed ($P<0.05$) for monocytes value, whereas animals fed diets having 50% of trace mineral recommendation, regardless of the supplementation form, showed higher percentages of this fraction compared to those fed diets with 100% of the recommendations. Accordingly, because the blood sample was performed at 50 days of age, in addition to the acute effect observed in the highest concentration of white cells, it was observed which is considered the early stage of the chronic inflammatory process, denoted by higher concentration of monocytes in animals receiving 50% of the trace mineral recommendation compared to those who received the minerals in its entirety. Excessive levels of trace mineral supplementation, above animal requirements, may promote antimicrobial action, such as zinc and copper, or metabolic action, in the case of selenium (Arthur et al. 2003). Therefore, the reduction of trace mineral supplementation at 50% of what is required resulted in poorer immune response against the challenge faced by the pig at nursery phase.

TABLE V
Effects of inorganic and organic trace mineral supplementation on hematological parameters of weanling pigs.

Item	Treatment					SEM	P-value			
	Control	50% ITMP	50% TMP	100% ITMP	100% OTMP		C1	C2	C3	C4
He, 103 µL	6.10	5.89	5.61	5.57	6.01	0.27	NS	NS	NS	*
Hb, g.dL-1	12.04	12.18	11.12	11.37	11.80	0.26	NS	NS	*	NS
Ht, %	38.00	38.23	36.04	36.09	38.19	0.20	NS	NS	*	NS
Le, µL	10.81	11.79	11.62	10.37	10.91	0.36	NS	NS	NS	NS
Eos, %	1.35	1.43	1.32	1.36	1.28	0.28	NS	NS	NS	NS
Nr, %	1.72	1.50	1.47	1.30	1.36	0.73	*	NS	NS	NS
Ns, %	35.81	44.23	38.00	40.09	37.19	0.56	NS	NS	NS	NS
Linf, %	59.04	51.19	57.85	56.90	60.76	0.43	NS	NS	NS	NS
Mon, %	1.59	1.53	1.54	1.35	1.40	0.46	NS	*	NS	NS

He: erythrocytes, Hb: hemoglobin, Ht: hematocrit, Le: leukocytes; Eos: eosinophils; Nr: rod neutrophil; Ns: segmented neutrophils; Linf: lymphocytes; Mon: monocytes. C1: NC vs other treatments; C2: 50% vs 100%; C3: 50% IM vs 50% OM; C4: 100% IM vs 100% OM. Variables Eos, Nbt and Mon were transformed $(Y + 1)^{1/2}$. *$P<0.05$; NS: nonsignificant.

Fecal Mineral Excretion

No differences were observed ($P<0.05$) for excreted Ca, K, Mg, Na, S, Fe and Zn related to each mineral ingestion (Table VI). It was verified that animals of 50% OM excreted a higher amount of P that those from 50% IM treatment. A lower excretion of Mg for animals supplemented with 50% of what is required by inorganic source in comparison to those from 50% OM treatment was also noted.

When comparing levels (50% *vs* 100%), regardless of source, it was observed that animals fed diets supplemented with 50% of the recommendations had lower amounts of Cu in the feces compared to those fed diets supplemented with 100% of what is required. Animals from 100% OM treatment excreted lower amount of this mineral when compared to those from 100% IM treatment.

In relation to Mn, higher excretion of this mineral was observed from animals of control treatment. Comparing the treatments supplemented with 50% of what is required, it was noted that animals fed diets supplemented with inorganic source excreted less amount of this mineral ($P<0.05$) in comparison to animals fed diets supplemented with OM.

The major benefit of using organic trace minerals is due to the greater availability of these for the animals. As the amount of nutrients excreted is directly proportional to the concentration of these in the diet, with the addition of organic trace minerals in the feeding of pigs, it is possible to reduce the level of inclusion of trace minerals in the diet, achieving the same performance and still reducing the amount of minerals excreted, avoiding excessive supplementation. Therefore, relating the amount excreted with the amount of this mineral intake, it was found that the reduction of 50% of the trace mineral supplementation resulted in no decrease in bioavailability of minerals, except for copper. Creech et al. (2004) reported that trace elements in organic form at reduced levels in piglet diets did not decrease the performance, and there was even lower fecal excretion of Cu, Zn, and Mn.

Mineral Retention in Metacarpals and Liver

There was no effect of treatments in Ca, P, Mg, S, and Fe levels in metacarpals of piglets, whereas the levels of Cu and Mn were lower when animals were fed diets supplemented with trace elements (Table VII).

TABLE VI
Effects of inorganic and organic trace mineral supplementation on fecal mineral excretion (%).

Item	Treatment					SEM	P-value			
	Control	50% ITMP	50% OTMP	100% ITMP	100% OTMP		C1	C2	C3	C4
Ca, %	19.43	10.71	17.66	17.65	16.03	7.08	NS	NS	NS	NS
P, %	55.48	25.12	51.27	40.91	46.93	17.20	NS	NS	*	NS
K, %	13.42	11.25	12.97	14.45	12.13	5.57	NS	NS	NS	NS
Mg, %	27.55	16.17	28.69	29.45	27.31	12.12	NS	NS	*	NS
Na, %	18.10	11.56	13.74	13.66	14.91	5.98	NS	NS	NS	NS
S, %	12.89	10.16	15.52	17.88	16.39	6.75	NS	NS	NS	NS
Cu, %	34.31	19.29	32.72	52.73	34.76	14.96	NS	*	NS	*
Fe, %	70.72	35.44	56.52	61.75	60.46	24.47	NS	NS	NS	NS
Mn, %	59.56	18.96	45.44	37.78	46.71	19.59	*	NS	*	NS
Zn, %	37.15	22.04	37.46	33.33	34.19	15.31	NS	NS	NS	NS

C1: NC vs other treatments; C2: 50% vs 100%; C3: 50% IM vs 50% OM; C4: 100% IM vs 100% OM. *$P<0.05$; NS: nonsignificant.

With respect to the amounts of supplementation (50% *vs* 100%), it was noted that the deposition of potassium was higher and Cu, Mn, and Zn were lower when 100% of trace mineral recommendation was met. It was further found that the amounts of K, Na, and Mn were higher when animals received treatment 50% OM and the deposition of Mn was lower when the animals received 100% OM. Revy et al. (2002) reported that two sources (organic and inorganic) and two levels of Zn (20 and 30 mg/kg) did not affect the minerals retention in metacarpals. The same was shown by Wedekind et al. (1994) in metacarpals and coccigea vertebrae of pigs that received higher Zn supplementation in diet.

Studies comparing organic and inorganic sources of Cu showed an increased uptake and retention of Cu in pigs fed organic source (Coffey et al. 1994, Veum et al. 2004), which was not observed in the present study for Fe, Cu, and Zn content in bones.

For mineral concentrations in the liver of piglets there were no differences (*P*>0.05) for Ca, K, and Mg (Table VII). For the P content in liver, a difference was observed when comparing sources of minerals using the 100% of trace mineral recommendation and animals fed the inorganic source of trace minerals had higher amount of this mineral compared to those fed the organic source.

TABLE VII
Effects of inorganic and organic trace mineral supplementation on mineral composition (dry matter basis) of metacarpals and liver of weanling pigs.

Item	Treatment					SEM	P-value			
	Control	50% ITMP	50% OTMP	100% ITMP	100% OTMP		C1	C2	C3	C4
Metacarpals										
Ca, mg	228056	226139	215790	229787	221934	0.17	NS	NS	NS	NS
P, mg	99526	96137	96490	97952	95426	0.11	NS	NS	NS	NS
K, mg	1675.0	1789.1	2236.7	2282.7	2147.9	0.91	*	*	*	NS
Mg, mg	3588.0	3500.0	3425.3	3634.4	3578.1	0.16	NS	NS	NS	NS
Na, mg	7756.6	7395.5	7893.4	7856.6	7839.2	0.18	NS	NS	*	NS
S, mg	1073.1	1200.8	1176.6	1061.2	1043.1	0.44	NS	NS	NS	NS
Cu, mg	4180.1	3675.2	3819.3	3362.5	3550.8	0.55	*	*	NS	NS
Fe, mg	60.50	60.44	62.15	63.52	61.68	0.14	NS	NS	NS	NS
Mn, mg	4.74	4.22	4.61	4.19	3.82	0.57	*	*	*	*
Zn, mg	50.14	109.31	104.09	116.86	121.50	1.87	*	*	NS	NS
Liver										
Ca, mg	238.5	246.1	250.4	232.4	261.5	0.31	NS	NS	NS	NS
P, mg	1291.0	1262.5	1278.1	1325.6	1264.1	0.13	NS	NS	NS	*
K, mg	10577.6	10967.4	11218.9	11418.5	11543.9	0.23	NS	NS	NS	NS
Mg, mg	638.3	665.2	630.9	630.9	642.7	0.15	NS	NS	NS	NS
Na, mg	3719.7	3670.5	4268.1	4161.0	4240.7	0.49	NS	NS	*	NS
S, mg	26.9	37.3	33.7	34.3	34.3	0.77	*	NS	NS	NS
Cu, mg	37.6	42.8	39.8	34.0	37.3	0.57	NS	*	NS	NS
Fe, mg	515.0	826.1	837.5	866.7	673.0	1.32	*	NS	NS	*
Mn, mg	17.6	12.9	14.5	15.0	12.9	0.88	*	NS	NS	NS
Zn, mg	87.8	156.1	136.4	134.5	165.0	1.45	*	NS	*	*

C1: NC vs other treatments; C2: 50% vs 100%; C3: 50% IM vs 50% OM; C4: 100% IM vs 100% OM. *$P<0.05$; NS: nonsignificant.

For Na, there was a significant difference when comparing the two sources at 50% inclusion, with animals fed trace minerals in organic form having higher concentration of Na in liver. For S and Mn, animals of NC showed lower concentrations of these minerals in the liver compared to the other treatments, which may be accounted for by the non-inclusion of trace mineral in the diet.

A difference was observed in Cu content in liver only when comparing levels of trace mineral in diets. Animals fed diets containing 50% of the recommendations had higher concentrations of Cu compared to those fed diets containing 100%. With respect to Fe, when comparing the NC to other treatments, the animals fed the diet without trace mineral supplementation had lower concentrations of this mineral in the liver. However, comparing the two sources of the supplementation under the level of 100%, there was a greater retention of Fe in the liver of animals fed inorganic source.

Animals of NC treatment presented lower concentration of Zn in the liver. Comparing the sources of the trace mineral supplementation in 50% of what is required, animals fed the inorganic source showed higher levels of this mineral in the liver compared to those fed the organic source. Furthermore, when compared animals that received total supplementation of trace minerals in diet, those fed the organic source showed higher Zn concentration in the liver compared to those fed the inorganic source.

Evaluating sources of organic and inorganic trace mineral supplementation, Muniz et al. (2010) observed no change in the levels of Fe, Mn, Zn, and Cu in the liver of weaned piglets. Regarding the levels of supplementation, the results obtained on this study corroborate those found by Martin et al. (2011) who also observed that the concentration of trace elements in the liver increased with increasing levels of supplementation, indicating that among the organs of the digestive system, this would be primarily a storage organ for some minerals.

CONCLUSION

Trace mineral supplementation, regardless of source and level, improved growth performance of weanling pigs. The reduction at 50% of what is required for trace mineral reduces the excretion of some trace elements, and modulates some blood parameters, reflecting in changes of piglet immunological status.

RESUMO

Um estudo foi conduzido para avaliar os efeitos de microminerais inorgânicos e orgânicos na dieta em dois níveis de suplementação, sobre desempenho, ocorrência de diarreia, parâmetros hematológicos, excreção dos minerais nas fezes e retenção dos minerais nos metacarpos e fígado de leitões desmamados. Setenta leitões desmamados aos 21 dias de idade com peso médio inicial de 6,70 ± 0,38 kg foram distribuídos em cinco tratamentos: dieta controle (sem adição de premix micromineral); 50% ITMP (dieta controle contendo premix micromineral inorgânico atendendo a somente 50% da exigência em microminerais); 50% OTMP (dieta controle contendo premix micromineral orgânico atendendo a somente 50% da exigência em microminerais); 100% ITMP (dieta controle contendo premix micromineral inorgânico atendendo a 100% da exigência em microminerais); e 100% OTMP (dieta controle contendo premix micromineral orgânico atendendo a 100% da exigência em microminerais). Consumo de ração e o ganho diário de peso não foram afetados pelos tratamentos, entretanto, os leitões suplementados com microminerais apresentaram melhor eficiência alimentar. Não foram observadas diferenças para as quantidades de cálcio, fósforo, potássio, magnésio, sódio e enxofre excretados nas fezes por quilograma de alimento consumido. Os tratamentos não afetaram os teores de cálcio, fósforo, magnésio, enxofre e ferro nos metacarpos. A suplementação com microminerais, independente dos níveis e da fonte, melhorou o desempenho dos leitões.

Palavras-chave: fase de creche, desempenho, desmame, leitão.

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