

Nonruminant Nutrition: Trace Minerals

107 Oxygen consumption and respiratory control ratio (RCR) of broilers with and without growth enhancing levels of mineral supplementation challenged with *Eimeria maxima*. G. Acetoze*¹, R. Kurzbard¹, J. J. Ramsey², K. C. Klasing¹, and H. A. Rossow³, ¹Department of Animal Science, University of California, Davis, ²School of Veterinary Medicine, University of California, Davis, ³School of Veterinary Medicine, University of California, Tulare.

Respiratory control ratio (RCR, State3/State4) provides an indication of mitochondrial coupling and efficiency of oxidative phosphorylation. However, the effect of dietary minerals fed at growth enhancing levels on mitochondrial function represented by RCR is unknown. Sixteen 7-d-old broilers were randomly assigned to 4 treatments: an infected control diet (Cu 15 ppm and Zn 60 ppm) + *Eimeria maxima* (Ei), 245 ppm Cu from tribasic copper chloride (TBCC) + Ei, negative control (Cu 15 ppm and Zn 60 ppm) - Ei and 2000 ppm Zn from ZnO + Ei. The diet was composed of 49% corn, 40% soybean meal, 6.2% vegetable oil (DM = 90.62%, CP = 21.37%, Fat = 7.7%, ME = 2.89Mcal/day) and were fed for 14 d. Mitochondria O₂ consumption was performed on isolated liver mitochondria (1g liver tissue) according to Ramsey et al. (2004). Statistical analysis was performed in R (version 2.15.1) using ANOVA. There was a trend of State 4 (leak-dependent O₂ consumption) being higher for infected birds fed 2000 ppm ZnO and infected birds fed Zn and Cu at the requirement levels ($P = 0.08$). However, State 3 (maximum ATP stimulated respiration) did not differ between treatments ($P = 0.51$). RCR values were 4.27, 2.40, 2.54 and 2.65 for the negative control group, the positive control group, 245ppm of Cu from TBCC group and 2000 ppm ZnO group, respectively and were different ($P = 0.02$). With the exception of birds not infected with Ei and not treated with high levels of minerals, birds that were fed levels of Cu from TBCC and Zn from ZnO above the requirement had higher RCR's compared with infected birds not treated with high minerals (2.54 and 2.65 versus 2.40, respectively). Levels of minerals (245ppm Cu as TBCC and 2000ppm Zn as ZnO) could possibly be decreasing the activity of Ei by acting as anticoccidials, protecting the cells from inflammation and therefore mitochondria uncoupling, loss of integrity and membrane disruption. Damage to the mitochondria membrane would interfere with proton leak kinetics which is highly related to H⁺ gradient build up during electron transport chain and affects efficiency of H⁺ use for ATP production.

Key Words: broilers, mitochondria, RCR

108 Retention and digestibility of Zn, Cu, Mn, and Fe in pigs fed diets containing inorganic or organic minerals. Y. Liu*¹, Y. L. Ma², J. M. Zhao², M. Vazquez-Añón², and H. H. Stein¹, ¹University of Illinois, Urbana, ²Novus International Inc., St. Charles, MO.

The objective of this experiment was to measure the apparent total tract digestibility (ATTD) and retention rate of Zn, Cu, Mn, and Fe in pigs fed either inorganic micro minerals (IMM) or organic micro minerals (OMM). Thirty 2 barrows (BW: 38.4 ± 10.17 kg) were housed in metabolism cages and assigned to 4 treatments with a 2 × 2 factorial arrangement and 8 replicates per treatment. Semi-synthetic (SS) or corn-soybean meal (CS) diets were formulated with the inclusion of IMM (ZnSO₄·7H₂O, CuSO₄·5H₂O, MnSO₄·H₂O and FeSO₄·H₂O), or OMM [Zn(HMTBa)₂, Cu(HMTBa)₂, Mn(HMTBa)₂ and FeGly] premix. The Zn, Cu, or Mn(HMTBa)₂ (MINTREX®, Novus International Inc., St. Charles, MO) is a chelate of 1 mineral

with 2 2-hydroxy-4-methylthio butanoic acid and FeGly (MAAC®) is a chelate of 1 mineral with 1 glycine. Pigs were fed the SS diet without added micro mineral for 2 wk and then randomly assigned to 1 of 4 treatment diets. Fecal and urine samples were collected for 5 d following a 5-d adaptation period. The inclusion of OMM increased ($P < 0.05$) the ATTD and retention rate of Zn, Cu, Mn, and Fe in pigs. No difference was observed between SS and CS diets, except pigs fed CS diets had greater ($P < 0.05$) ATTD of Zn than pigs fed SS diets. Compared with IMM, adding OMM increased ($P < 0.05$) the ATTD and retention of Cu, Mn, and Fe to a lesser extent in SS diets than in CS diets (interaction, $P < 0.05$). This may be due to the greater concentration of phytate in CS diets than in SS diets. Results indicate that organic forms of micro minerals have better digestibility and retention rates compared with inorganic forms.

Table 1. Apparent total-tract digestibility (ATTD) of Zn, Cu, Mn, and Fe in pigs fed diets containing inorganic (IMM) or organic micro minerals (OMM)

	Semi-synthetic		Corn-soybean meal		SEM
	IMM	OMM	IMM	OMM	
Zn					
ATTD, %	49.11	57.63	44.04	53.60	1.75
Retention, %	40.65	48.44	38.61	49.55	1.37
Cu					
ATTD, %	42.93	44.61	35.64	50.46	2.37
Retention, %	39.58	40.83	33.14	47.88	2.31
Mn					
ATTD, %	37.90	40.79	29.50	44.31	2.60
Retention, %	34.12	36.55	27.22	41.67	2.23
Fe					
ATTD, %	38.57	42.03	30.16	47.37	1.88
Retention, %	36.48	40.41	28.00	45.48	1.94

Key Words: apparent total-tract digestibility, micro mineral, pig

109 Microencapsulated zinc oxide on piglets growth performance and intestinal architecture. E. Grilli*¹, B. Tugnoli¹, F. Vitari², A. Piva¹, and A. Prandini³, ¹DIMEVET, University of Bologna, Ozzano Emilia, Italy, ²Department of Health, Animal Science and Food Safety, University of Milan, Milan, Italy, ³ISAN, Università Cattolica Sacro Cuore, Piacenza, Italy.

The aim was to compare low doses of microencapsulated zinc oxide (ZnO; Zincoret) in the diet of piglets with pharmacological level of ZnO on growth and ileal architecture. 144 weaned piglets, divided in 36 pens (n = 9), received a basal diet (NC; Zn at 45 mg/kg) or the basal diet with ZnO at 2850 mg/kg (PC), or with lipid microencapsulated ZnO at 187 or 437 mg/kg (Zn200 and Zn400). After 15 and 49 d, 6 pigs/group/time were euthanized to collect ileal mucosa for immunohistochemistry, histomorphology, and Na-dependent glucose transporter (SGLT-1) gene expression. Pigs BW and feed intake were recorded at 0, 14 and 42 d and ADG and FCR were calculated. Data were analyzed with 1 way ANOVA. At 14d the PC group had a 32% and 7% higher ADG and BW and a lower FCR compared with NC ($P < 0.05$), whereas Zn200 and Zn400 had intermediate values. At 42d both groups receiving microencapsulated ZnO had higher BW than NC and did not differ from PC ($P = 0.01$). ADG was on average 20% higher for PC and Zn400 than the NC ($P = 0.01$) and FCR was lower

in all treated groups compared with NC (-22%; $P < 0.01$). At 14 d, villi length in Zn400 pigs was 9% and 6% higher than in NC and PC, respectively ($P < 0.01$) and the villi: crypts ratio (V:C), as well as % of mitotic cells, were higher in all treated groups compared with NC ($P < 0.01$). SGLT-1 gene expression was the lowest in Zn400 pigs. At 49d villi length and V:C ratio were the highest for PC compared with all of the other groups (+10% than NC; $P = 0.01$). Mitotic cells were the highest in Zn400 group compared with other groups (+3% compared with NC and PC; $P < 0.01$), whereas SGLT-1 expression tended to be lower in Zn200 and Zn400 groups compared with NC and PC ($P = 0.06$). Pigs receiving low doses of microencapsulated ZnO had performance comparable to those receiving pharmacological level of ZnO overall the post-weaning phase. Moreover, in the first 2 weeks, microencapsulated ZnO improved the ileal architecture as reflected by the increased V:C ratio and the % of mitotic cells. The reduced SGLT-1 m-RNA abundance might suggest a reduced availability of glucose in the lumen of ileum, therefore suggesting a lower amount of undigested nutrients.

Key Words: microencapsulation, piglet, zinc oxide

110 Effect of dietary zinc and copper sources on wean-to-finish pig performance. J. Morales¹, C. Rapp*², and T. L. Ward³, ¹*Pig Champ Pro Europa, Segovia, Spain*, ²*Zinpro Animal Nutrition Inc., Boxmeer, the Netherlands*, ³*Zinpro Corporation, Eden Prairie, MN*.

A total of 288 weanling pigs (7.5 kg BW; 28 d of age) were used to determine the effect of dietary Zn and Cu source on wean-to-finish growth performance by employing a 2 X 2 factorial arrangement of treatments and randomized complete block design. At weaning (d 1), pigs were blocked by BW and randomly assigned to 1 of 2 treatments for 35 d: (1) 2360 ppm Zn as ZnO + 150 ppm Cu as CuSO₄ [HZCS] or (2) 50 ppm Zn as zinc amino acid complex + 60 ppm Zn as ZnO + 150 ppm Cu as copper amino acid complex [COZC]. At the end of the nursery phase (d 35), one-half of the pigs from each treatment were assigned to 1 of 2 fattening treatments on which they were maintained until the end of the study (d 151): 1) 100 ppm Zn as ZnO [IZ] or 2) 50 ppm Zn as zinc amino acid complex + 50 ppm Zn as ZnO [CZ]. In the nursery, each treatment was replicated 24 times and in fattening, 9 times, with equal numbers of female and male pigs in each pen. Pigs were fed a phase 1 (d 1 to 14), phase 2 (d 15 to 35) and fattener diet (d 36 to 151). In phase 1, ADG and ADFI were increased (157, 130, 233, 202 g/d; $P < 0.05$) and proportion of pigs that needed therapeutic antibiotic treatment decreased (23, 48%; $P < 0.05$) in pigs fed HZCS compared with pigs fed COZC. In phase 2 and in the overall nursery period, ADFI and FCR were lower (646, 703, 467, 519 g/d; 1.47, 1.63, 1.49, 1.60; $P < 0.05$) in pigs fed COZC than pigs fed HZCS. Data were analyzed using the GLM procedure of SAS. No significant ($P > 0.13$) interactions between treatment in nursery and fattening period were observed. From d 131 to 151, ADG was increased (896, 829 g/d; $P < 0.05$) and FCR decreased (2.46, 2.70; $P < 0.05$) in animals consuming CZ compared with IZ. In the fattening period (d 36 to 151), FCR was lower (2.33, 2.41; $P < 0.06$) in pigs fed COZC than in pigs fed HZCS. Overall (d 1 to 151), FCR was decreased (2.22, 2.32; $P < 0.05$) in pigs fed COZC compared with HZCS. High levels of ZnO and CuSO₄ were more effective in mitigating negative effects of weaning immediately post-weaning than complexed Zn and Cu. However, supplementing complexed Zn and Cu in nursery improved feed conversion ratio over the entire nursery and fattening period.

Key Words: swine, growth, trace mineral

111 Effects of selenium-enriched exopolysaccharides produced by *Enterobacter cloacae* Z0206 on growth performance, antioxidant status, and immune functions in weaning piglets. Z. Q. Lu*, G. X. Wu, M. Huang, F. Q. Wang, and Y. Z. Wang, *Institute of Feed Science, Zhejiang University, Hangzhou, Zhejiang, China*.

This study was conducted to investigate the effects of Se-enriched exopolysaccharides (Se-Exo, 536 mg/kg Se) on growth performance, antioxidant status and immune functions in weaning piglets. A total of 150 piglets [(Landrace × Yorkshire) × Duroc] weaned at 28 d of age with an initial BW of 8.11 ± 0.12 kg were randomly allocated into 5 groups of 3 replicates each. The 5 treatments were: basal control diet (CON), Na₂SeO₃ diet (CON + 0.30 mg/kg Na₂SeO₃), Na₂SeO₃+ astragalus polysaccharide (APS) diet (CON + 0.30 mg/kg Na₂SeO₃ + 560 mg/kg APS), Na₂SeO₃+ EPS diet (CON + 0.30 mg/kg Na₂SeO₃ + 560 mg/kg EPS) and Se-Exo diet (CON + 560 mg/kg Se-Exo). On d 58, samples were taken for analysis: blood for total antioxidant content (T-AOC), glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), tumor necrosis factor- α (TNF- α), interleukin-6 (IL-6), immunoglobulin G and M (IgG, IgM); liver, jejunum and ileum for gene expression of proline-arginine rich 39-amino acid peptide (PR-39), Hepcidin and porcine β -defensin-2 (pBD-2). Compared with CON group, ADG was enhanced in the Na₂SeO₃+APS, Na₂SeO₃+EPS and Se-Exo groups (+8.9%, +9.9% and +12.3%, resp., $P < 0.05$) and F:G was decreased (-10.2%, -8.4 and -10.2%, resp., $P < 0.01$). There were no differences in ADG between pigs fed the Na₂SeO₃+APS, Na₂SeO₃+EPS and Se-Exo diets. The Se-Exo group had higher serum T-AOC (+29.6%), GSH-Px (+25.6%) and SOD (+18.6%) activities than the CON group ($P < 0.05$), and the T-AOC activity in Se-Exo group was higher than the Na₂SeO₃ group ($P = 0.035$). Increases ($P < 0.05$) in serum IgG (+54.0%), IgM (+56.1%), TNF- α (+61.6%) and IL-6 (+47.5%) were observed in the Se-Exo group compared with the CON. Pigs fed Se-Exo diet had higher PR-39 and Hepcidin gene expression levels in liver ($P < 0.001$) and pBD-2 gene expression levels in jejunum and ileum ($P < 0.05$) compared with the CON group. These results implicated that the combined effects of Se and exopolysaccharide are responsible for the bioactivity of Se-Exo which would be expected to be a new immunopotentiator in weaning piglets.

Key Words: exopolysaccharide, immunity, weaning piglet

112 Effects of chromium-loaded chitosan nanoparticles on growth, carcass characteristics, pork quality, and lipid metabolism in finishing pigs. M. Q. Wang*, Y. D. He, C. Wang, H. Li, S. Y. Chen, W. J. Tao, and S. S. Ye, *Animal Science College of Zhejiang University, Hangzhou, Zhejiang, China*.

Numbers of researches have been conducted to study the effects of Cr from different chemical forms. The study was conducted to evaluate the effects of chromium-loaded chitosan nanoparticles (Cr-CNP) on growth, carcass characteristics, pork quality and lipid metabolism in finishing pigs. A total of 160 barrows (66.1 ± 1.01 kg BW) were randomly divided into 4 groups, each group with 4 pens, 10 pigs per pen. Pigs were fed same basal diet (CP 17.98%, DE 13.2MJ/kg, Lys 1.05%, Met 0.45%) supplemented with 0, 100, 200, or 400 μ g/kg Cr from Cr-CNP, respectively. All pigs were given free access to feed and water for 40 d. Average daily gain, feed intake and feed gain ratio were collected. Eight pigs from each treatment were slaughtered to measure carcass lean ratio, longissimus muscle area (LMA), backfat thickness, 45 min pH, Hunter L, a, b value, 24-h drip loss, and some serum parameters and enzymatic activities. The results showed that feed gain ratio of pigs fed supplemental Cr-CNP was decreased ($P < 0.05$). Dietary Cr-CNP increased the carcass lean ratio ($P < 0.01$) and LMA ($P < 0.01$), decreased carcass fat ratio ($P < 0.001$) and backfat thickness (P

<0.001) with linear and quadratic manner. The 24 h drip loss was linear and quadratic decreased ($P < 0.01$), while 45 min pH value and Hunter L, a, b values in longissimus muscle were unaffected. Supplemental Cr-CNP linearly increased serum free fatty acids ($P < 0.001$), lipase activity ($P < 0.01$) and serum insulin-like growth factor I ($P < 0.01$), while linearly decreased serum insulin ($P < 0.001$). Dietary supplementation of Cr-CNP also linearly decreased activities of fatty acid synthase

($P < 0.01$) and malate dehydrogenase ($P < 0.01$), while increased the activity of hormone-sensitive lipase ($P < 0.05$) in subcutaneous adipose tissue with linear and quadratic manner. The present results suggested that dietary supplementation of Cr as Cr-CNP had beneficial effects on growth, carcass characteristics and pork quality, and positively affected on lipid catabolism in finishing pigs.

Key Words: chromium, carcass characteristics, lipid metabolism