190 Effect of phytic acid on apparent ileal digestibility of minerals in piglets. T. A. Woyengo*[1], A. Cowieson[2], O. Adeola[3], and C. M. Nyachoti[1], [1]*University of Manitoba*, *Winnipeg, MB, Canada*, [2]*Danisco (UK) Limited*, *Marlborough, UK*, [3]*Purdue University*, *West Lafayette, IN*.

An experiment was conducted to determine the effects of phytic acid (PA) on apparent ileal digestibility (AID) of minerals in piglets. Seven ileal-cannulated weanling pigs were fed a casein-corn starch-based diet with PA (as sodium salt) at 0.0, 0.5, 1.0, or 2.0% in 4 × 4 Latin square design with 3 added columns to give 7 replicates per treatment. The basal diet was formulated to meet NRC (1998) requirements for energy, AA and minerals for weanling pigs and contained chromic oxide (0.3%) as a digestibility marker. The AID of ash, and of 2 multivalent macro-minerals, that is, Ca and P were both linearly and quadratically reduced ($P < 0.05$) by an increase in the level of PA in diet; whereas that of another multivalent macro-mineral, that is, Mg was only linearly reduced ($P < 0.05$) by the PA. An increase in dietary level of PA also resulted in reduced AID of monovalent macro-minerals, that is, Na and K (linear and quadratic, $P < 0.05$), though the differences between diets without and with PA were only significant when PA was added at 2% (49.2 vs -37.9% for Na and 87.6 vs 81.1% for K). The AID values for ash, P, Na and Mg were negative, that is, -54, -27.7, -37.9 and -3.0%, respectively, when PA was supplemented at 2%. The results suggest that PA can reduce the AID of minerals in piglets. The reduced AID of minerals due to PA is partly attributed to their increased endogenous losses as evidenced by negative AID values of some of the minerals and ash at the highest dose of PA used in the current study. The increase in endogenous flow of Na and K may particularly be important as an increased presence of these minerals in the gut will effectively alter electrolyte balance and hence the capacity of the enterocytes to transport AA, glucose and other nutrients. These data are suggestive of potentially adverse consequences of PA on secretion and absorption balance.

Key Words: Phytic Acid, Mineral Digestibility, Piglets

191 Impact of steeping high-moisture corn with phytase on growth performance and phosphorus utilization in liquid-fed starter pigs. D. Columbus*, S. J. Niven, C. L. Zhu, and C. F. M. deLange, *University of Guelph*, *Guelph, ON, Canada*.

The application of phytase in conventional dry pig diets has been studied extensively and improves digestibility of phosphorus (P). The efficacy of phytase may be improved by steeping feedstuffs with phytase prior to feeding. A performance study was conducted to determine the value of steeping high-moisture corn (HMCorn) with phytase for use in P-limited liquid diets. Five pens of 16 pigs (weaned at 19 to 23 days of age; 6.7 ± 0.24 kg BW) were assigned to each of five 3-phase feeding programs for 7 weeks (total P was 0.69, 0.48, and 0.45 % in phase I, II and III diets, respectively). The HMCorn based diets were formulated to contain graded levels of added phytase (0, 62.5, or 125 FTU/kg DM HMCorn) which was added either to a mix of HMCorn and water and allowed to steep for a minimum of 24-h or to the dry feed supplement and mixed with the HMCorn at the time of feeding. The addition of phytase had no impact on ADG or G:F ($P > 0.10$). The soluble P content in duodenal digesta was increased with the addition of phytase (63.3 vs. 49.6 % of total P; $P < 0.05$). Allowing HMCorn to steep prior to feeding did not increase solubilization of P in digesta (65.6 vs. 61.1%; $P > 0.10$). There was no impact of dietary treatment on total tract digestibility of P ($P > 0.05$). Urinary P excretion was higher in pigs fed diets with added phytase (280 vs. 7.59 ug/mL; $P < 0.05$). Addition of phytase to the diets resulted in greater contents of P in carcass (1.56 vs. 1.32%; $P < 0.001$) and metacarpal bones (5.67 vs. 5. 40 %; $P < 0.05$). Metacarpal breaking strength was higher in pigs fed diets with 125 FTU/kg vs. 62.5 FTU/kg added phytase (33.0 vs. 30.3 kg; $P < 0.05$). Added phytase improved retention of P in starter pigs fed P-limited HMCorn based liquid diets, however, there appears to be no benefit to steeping HMCorn with phytase prior to feeding. Responses to both levels of phytase were similar and indicate greater efficacy of phytase in liquid diets than dry diets.

Key Words: High-Moisture Corn, Phytase, Starter Pigs

192 The effects of dietary calcium to total phosphorus ratio (Ca:tP) in diets containing 1000 FTU/kg of phytase on performance in 10-25 kg pigs. K. L. Saddoris*, S. B. Williams, D. W. Dean, and D. R. Cook, *Akey*, *Lewisburg, OH*.

Crossbred pigs (n=924) with an average initial weight of 10.8 ± 0.13 kg were used to determine the optimal Ca:tP ratio in 10-25 kg pigs fed diets supplemented with 1000 FTU/kg of phytase (Phyzyme XP ®). The experimental design was a split plot with sex serving as whole plot and diet serving as subplot. Pigs (22 pigs/pen) were randomly allotted to one of six dietary treatments within sex and block and fed ad libitum for 23 d. Dietary treatments consisted of a basal corn-soybean meal diet with 1000 FTU/kg of Phyzyme XP ® and 0.45% tP (0.15% aP) provided by corn, soybean meal, and dicalcium phosphate. Dietary Ca concentration of the basal diet was 0.40% and Ca:tP ratios were altered by addition of calcium carbonate to achieve Ca concentrations of 0.50, 0.60, 0.70, 0.80, or 0.90%. Calculated Ca:tP ratios were 0.88, 1.11, 1.33, 1,55, 1,77, and 2.0 for dietary treatments 1 thru 6, respectively. Increasing dietary Ca concentrations from 0.40 to 0.90 resulted in a linear ($P<0.01$) decrease in ADG (595 to 532 g/d) and G:F (0.666 vs. 0.613). Additionally, ADFI decreased (linear, $P<0.05$) by 3% as dietary Ca concentrations increased from 0.40 to 0.90%. Pigs fed the 0.40% Ca diet were 5% heavier ($P<0.01$) at the end of the trial period compared to pigs fed diets with 0.90% Ca (24.60 vs. 23.36 kg). Overall, increasing the dietary Ca:tP ratio from 0.88 to 2.0 by increasing Ca concentrations resulted in an 11.8, 3.0, and 8.6% reduction in ADG, ADFI, and G:F respectively. These data indicate Ca:tP ratios as low as 1.11:1 negatively impact performance traits, and that dietary Ca may have a negative effect on the efficacy of phytase to release P from phytate. In conclusion, P release values assigned to phytase may be dependent upon dietary Ca concentrations. Further research is necessary to determine the Ca:tP ratio necessary to optimize phytate-P release with usage of 1000 FTU/kg of phytase.

Key Words: Swine, Phytase, Calcium

193 MINTREX®Zn provides similar performance to ZnO in nursery pigs at lower inclusion. R. J. Harrell, B. V. Lawrence*, R. Anderson, F. Navarro, and C. D. Knight, *Novus International Inc.*, *St. Charles, MO*.

Zinc is a trace mineral with multifunctional properties including a role in normal growth, immunity, skin integrity, and an essential component in a multitude of enzyme reactions. Organic trace minerals offer the opportunity to feed less total mineral because of improved bioavailability compared to inorganic sources. MINTREX®Zn (ZnMin) contains 2 HMTBa ligands chelated with one Zn molecule. This study examined the effect of Zn source and level on weaned pig performance. Pigs with an average initial weight of 7.06±0.13 kg were blocked by sow parity (1 vs. 2-4 vs. 5+) and randomly assigned to one of five Zn diets: 120:0, 0:0, 60:0, 30:30, and 0:60 ppm Zn as ZnO:ZnMin, respectively. Complex diets were formulated to meet or exceed the requirements of weaned pigs except for Zn. Diets were fed in 3 different phases (0 to 10, 11 to 21, and 21 to 35 days postweaning). No differences in ADG or ADFI were detected from 0 to 10 or 11 to 21 days of study (P > 0.15). Pigs fed the 0:0 (0.933±0.050) zinc diet had 13% lower GF than pigs fed the 120:0 (1.074±0.050) and 30:30 (1.079±0.050) ppm Zn diet (P < 0.05) from 0 to 10 days. No differences in GF were detected between treatments from 11 to 21 days of study (P > 0.15). Pigs fed the 120:0 (563±15 g/d) had 10% greater ADG (P < 0.05) than the 0:0 (507±15 g/d) and 60:0 (520±15 g/d) fed pigs, but similar ADG to pigs fed the 30:30 and 0:60 Zn diets (P > 0.10) from 21 to 35 days. Pigs fed the 120:0 (0.696±0.007), 30:30 (0.692±0.007), and 0:60 (0.683±0.007) had similar GF (P> 0.15), but higher than pigs fed the 0:0 Zn diet (0.663±0.007; P < .05) from 21 to 35 days. Overall, from 0 to 35 days, no differences in final bodyweight, ADG or ADFI were detected between treatments (P >0.10). Pigs fed the 120:0 (0.742±0.005), 30:30 (0.747±0.005), and 0:60 (0.738±0.005) had similar GF (P > 0.20), but were all higher than the 0:0 Zn diets (0.717±0.005; P < 0.05). These results suggest that at least 21 days postweaning are needed to elicit signs of a Zn deficiency and dietary Zn concentrations can be reduced by feeding MINTREX®Zn.

Key Words: Zinc, Source, Swine

194 Combination of organic and inorganic trace minerals for sows and weaned pigs. G. J. M. M. Lima*[1], F. Catunda[2], W. Close[3], L. C. Ajala[1], and F. Rutz[4], [1]*Embrapa – Swine and Poultry Res. Center*, *Brazil*, [2]*Alltech*, *Brazil*, [3]*Close Consulting*, *U.K.*, [4]*UFPel*, *Brazil*.

This study was conducted to determine the effects of combining inorganic and organic sources of trace minerals (TM) on the performance of sows along five consecutive parities and their offspring. In Experiment 1, 80 gilts were randomly divided and given two diets: T1 – TM supplemented with inorganic sources (120 ppm Zn, 40 ppm Mn, 120 ppm Fe, 15 ppm Cu, 0.3 ppm Se); T2 – TM supplemented with a combination of inorganic and organic sources in the following amounts: 80 + 40 ppm Zn, 20 + 20 ppm Mn, 30 + 90 ppm Fe/kg, 5 + 10 ppm Cu, 0 + 0.3 ppm Se, 0 + 200 ppb Cr, respectively. In Experiment 2, 96 weaned piglets from T1 and T2 fifth parity sows were equally allotted to receive diets with either inorganic or inorganic + organic TM, at the same levels described, in a 2 X 2 factorial experiment. In both experiments there was no significant interaction among main factors (P>0.05). Sow reproductive variables as well as piglet weights at birth and at weaning were not affected by treatments (P>0.05). Combination of inorganic and organic TM significantly increased the number of live piglets at birth (10.93 ± 0.17 vs. 11.80 ± 0.17, P=0.0003) and at weaning (10.16 ± 0.16 vs. 10.90 ± 0.15, P=0.0008) and decreased the number of stillbirths (0.48 ± 0.05 vs. 0.30 ± 0.05, P=0.007) and mummies (0.10 ± 0.03 vs. 0.04 ± 0.03, P=0.12). Milk selenium was increased (28.71 ± 1.99 vs. 38.94 ± 2.00 ppb, P=0.0004) with the inclusion of organic TM. In Exp. 2, there was no significant effects of sow or piglet dietary treatments or their interaction (P>0.05) except for feed conversion ratio, which was better for piglets born from sows that were fed T2 diets (1.67 ± 0.02 vs. 1.62 ± 0.02, P=0.06). While the combination of inorganic and organic TM confirms previous positive effects on litter size, this finding has yet to be completely understood. It may be hypothesized that the increase of bioavailability of the organic TM sources is responsible for part of the verified benefits. In addition, it may be that inorganic TM at NRC levels have detrimental effects.

Key Words: Litter Size, Reproductive Performance, Milk Composition

195 Effects of copper sulfate, tri-basic copper chloride, and zinc oxide on weanling pig growth and plasma mineral levels. N. W. Shelton*[1], M. D. Tokach[1], J. L. Nelssen[1], R. D. Goodband[1], S. S. Dritz[1], J. M. DeRouchey[1], and G. M. Hill[2], [1]*Kansas State University*, *Manhattan*, [2]*Michigan State University*, *East Lansing*.

Two four-wk experiments were conducted to determine the effects of increasing dietary Zn and Cu levels on weanling pig performance. In each experiment, 180 21-d old weanling pigs (PIC; 5.65 kg in Exp. 1, and 5.98 kg in Exp. 2) were allotted to six treatments with five and six replications in Exp. 1 and 2, respectively. Control diets contained 165 ppm Zn and 16.5 ppm Cu provided by the trace mineral premix. In Exp. 1, treatments were arranged as a 2 × 3 factorial using two levels of added Cu from tri-basic copper chloride (TBCC; 0 or 150 ppm) and three levels of added Zn from ZnO (0, 1500, or 3000 ppm from d 0 to 14 and 0, 1000, or 2000 ppm from d 14 to 28). From d 0 to 28, TBCC increased (P<0.01) ADG (375 vs 344 g/d) and ADFI (509 vs 469 g/d) over control pigs. Increasing dietary Zn increased (linear, P<0.003) ADG and ADFI from d 0 to 14 (184, 192, and 233 g/d; 226, 238, and 279 g/d) and d 0 to 28 (342, 352, and 385; 463, 479, and 525). Dietary Cu had no (P>0.63) effect on plasma Cu. The only Cu × Zn interaction was for plasma Zn (P<0.03) with plasma Zn increasing to a greater extent when Zn was added to diets without TBCC than when added to diets with TBCC. In Exp. 2, treatments were arranged as a 2 × 3 factorial using two levels of added Zn from ZnO (0 or 3000 from d 0 to 14 and 0 or 2000 from d 14 to 28) and three Cu treatments (control, 125 ppm from TBCC, or 125 ppm from $CuS0_4$). There were no Zn × Cu interactions (P>0.21). From d 0 to 28, adding TBCC and $CuS0_4$ increased (P<0.01) ADG (304, 333, and 359 g/d), ADFI (465, 490, and 506 g/d) and G:F (0.65, 0.68, and 0.71). Adding dietary ZnO also increased (P<0.01) overall ADG (315 vs 349 g/d) and ADFI (466 vs 507 g/d). The greatest response to ZnO was from d 0 to 14 where ADG (175 vs 225 g/d), ADFI (227 vs 255 g/d), and G:F (0.77 vs 0.88) were all increased (P<0.02). Contrary to many earlier trials, the growth responses from Zn and Cu were additive in these experiments.

Key Words: Weanling Pig, Zinc, Copper

196 Effects of various copper sources on copper bioavailability in broiler chickens. B. J. Min*[1], S. J. Park[2], R. A. Samford[3], and S. W. Kim[1], [1]*North Carolina State University*, *Raleigh*, [2]*Texas Tech University*, *Lubbock*, [3]*Albion Advanced Nutrition*, *Clearfield, UT*.

A total of 560, 1 d old, broiler chickens was used to determine bioavailability of copper when various dietary copper sources were used. Twenty

birds were killed at d 0 and ground for carcass sampling. Remaining 540 birds were allotted to 6 dietary treatments: NC (without Cu supplementation); PC (with 25 ppm Cu from Cu-sulfate); CUGLY (with 25 ppm Cu from Cu-glycine chelates); CULYS (with 25 ppm Cu from Cu-lysine chelates); CUAX (with 25 ppm Cu from Cu amino acid complex); and CUAC (with 25 ppm Cu from Cu amino chelates). There were 6 replicates per treatment with initially 15 birds per stainless steel brooder cage with the heater. Birds had feed and water ad libitum during 21 d feeding period. Body weight and feed intake were measured on d 3, 5, 7, 14, and 21. Groups of 3 birds were randomly selected and killed at d 3, 5, 7, 14, and 21, ground together for each day, sampled, and analyzed for Cu. The ADG, ADFI, and gain:feed ratio did not differ among treatment groups. Contents of Cu (mg/bird) in PC (18.08), CUGLY (19.90), CULYS (21.92), CUAX (19.83), and CUAC (19.43) were greater (P<0.05) than NC (6.47) at d 21. Bioavailability of Cu from CUGLY (48.1%), CULYS (52.4%), CUAX (49.5%), and CUAC (47.7%) was greater (P<0.05) than NC (42.0%) during week 1. Bioavailability of Cu from CUAC (50.5%) and CULYS (49.8%) was greater (P<0.05) than NC (44.5%) and CUAX (46.1%) during week 2. Bioavailability of Cu from CULYS (52.4%) was the greatest (P<0.05) and that of CUAC (47.7%), CUGLY (48.9%), and CUAX (49.5%) was greater (P<0.05) than NC (39.0%) and PC (44.1%) during week 3. During the entire period, bioavailability of Cu from CULYS (52.4%) was not different from CUAC (49.0%) but greater (P<0.05) than CUGLY (47.8%), CUAX (47.7%), NC (36.3%) and PC (45.8%). This study indicates that supplement of Cu at 25 ppm from Cu-lysine and Cu amino acids chelates have beneficial effects on Cu bioavailability compared to the use of Cu from Cu sulfate by broiler chickens until d 21 of age.

Key Words: Bioavailability, Broilers, Copper Amino Acid Chelate

197 Supplementing inorganic or organic Se to diets using grains grown in various regions of the United States. D. C. Mahan*[1], J. E. Pettigrew[1], M. D. Lindemann[2], G. L. Cromwell[1], P. S. Miller[1], E. van Heugten[1], S. W. Kim[1], T. D. Crenshaw[1], M. J. Azain[2], and C. R. Dove[2], [1]*NCCC-42 Committee on Swine Nutrition*, [2]*S 1012 Committee on Swine Nutrition*.

Grains grown in various regions of the US vary in their indigenous Se contents that could affect pig tissue Se concentrations and performance responses. A regional study was conducted to evaluate the effects of adding inorganic Se (Na selenite) or organic Se (Se enriched yeast) at 0.15 or 0.30 ppm to grower-finisher pig diets on subsequent tissue Se and performance responses. A basal diet without supplemental Se served as a negative control. The study was a 2 × 2 + 1 factorial conducted in a randomized complete block design in 18 total replicates using a total of 240 pigs. Similar diet formulas were used but incorporated locally grown corn and soybean meal into the diets and were fed from 25 to 115 kg BW. The study was conducted at 9 stations (IL, KY, NE, NC, OH, TX, SD, WI, and GA) with each station completing 2 replicates. Serum Se and glutathione peroxidase (GSH-Px) activity were determined. Samples of liver, loin, and hair were collected at harvest and analyzed for Se. The corn fed and the loin Se at harvest for each station (expressed as mg/kg) were: IL, 0.028, 0.126; KY, 0.017, 0.096; NE, 0.283. 0.345; NC 0.074, 0.082; OH, 0.044, 0.119; TX, 0.132, 0.289; SD, 0.234, 0.527; WI, 0.075, 0.264; and GA, 0.026, 0.130, respectively, and differed (P< 0.01) by station. There were increases (P< 0.01) in loin, liver, and hair Se concentrations as dietary Se increased within each station, but a greater increase occurred when organic Se was fed. This resulted in a Se source x level interaction (P< 0.01). Serum Se and GSH-Px activity increased (P< 0.01) when both Se sources were fed. These results indicate a large difference in grain Se concentrations among the states, that organic Se was incorporated at greater concentrations in the loin, liver, and hair tissues of grower-finisher pigs than inorganic Se, and that this increase occurred in the pigs from each state.

Key Words: Pigs, Selenium

198 Effects of dietary selenium on expression of selenoproteins and activity of antioxidant enzymes in endocrine tissues of growing male pigs. J. C. Zhou[1], J. G. Li[1], K. N. Wang[1], X. Xia[1], Y. J. Zhang[1], Y. Liu[1], Y. Zhao[1], and X. G. Lei*[1,2], [1]*Int. Ctr of Future Agriculture for Human Health, Sichuan Agri. Univ.*, *Ya'an, China*, [2]*Cornell University*, *Ithaca, NY*.

Expression and function of selenoproteins in endocrine tissues remain unclear. The present study was conducted to determine responses of mRNA levels of 12 selenoproteins and activities of four antioxidant enzymes in three endocrine organs of pigs to dietary Se deficiency or excess. A total of 30 weanling male pigs (3-wk old) were fed a corn-soybean meal based, Se-deficient (0.02 mg/kg) diet for 4 wk to adjust body Se status and then fed the basal diet supplemented with 0, 0.3 or 3.0 mg Se/kg as Se-enriched yeast (Angel Yeast, Hubei, China). After 8 wk, six pigs from each group were killed to collect plasma, liver, pituitary, thyroid and testis for analysis. Concentrations of Se in the four tissues and plasma increased (P < 0.05) with the increment of dietary Se. While dietary Se supplementation enhanced (P < 0.05) glutathione peroxidase activity in the four tissues, it did not affect activities of glutathione reductase, glutathione S-transferase, or total superoxide dismutase in any tissue. As determined by quantitative real-time RT-PCR, mRNA levels of *GPX1, Txrnd1, SelN* and *SelW* in liver were lower (P < 0.05) in the Se-deficient group than the Se-supplemented groups. However, mRNA levels of *Txrnd1* and *Sep15* in testis were decreased (P < 0.05) by supplementing 3 mg of Se/kg compared with the other two groups. Relatively high expressions of *GPX4, ID3, Sep15, SelK* and *SelN* were detected in pituitary, which was fairly independent of dietary Se concentrations. In conclusion, dietary Se deficiency and excess affected tissue Se concentrations in the three endocrine organs similarly to that in liver, but exerted less impact on the mRNA expression of multiple selenoprotein genes.

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Key Words: Endocrine, mRNA, Selenoprotein

199 Effects of sodium bisulfate on growth performance, slurry characteristics, and nutrient excretion of finishing pigs. J. Jarrett*, S. Carter, J. Bundy, M. Lachmann, and T. Walraven, *Oklahoma State University*, *Stillwater*.

Sodium bisulfate ($NaHSO_4$) is a strong acid that has been used in the poultry industry as a litter additive to reduce pH and ammonia emissions. Little is known about the effects of $NaHSO_4$ in swine slurry when administered as a feed additive. A total of 80 crossbred (D × (L × Y)) pigs were used to determine the effects of $NaHSO_4$ addition to a traditional corn-soybean meal diet on growth performance, slurry

pH and electrical conductivity, and DM, N, and P excretion during a 100-d finishing period. Pigs were blocked by BW, sex, and ancestry and allotted to one of two dietary treatments. The control was a fortified corn-soybean meal diet and the treatment diet consisted of the control diet + 0.30% $NaHSO_4$. Diets were fed in four phases (40 to 62, 62 to 90, 90 to 108, 108 to 128 kg) and formulated on true digestible lysine (0.92, 0.79, 0.65, 0.56%). $NaHSO_4$ was added at the expense of sodium chloride to maintain sodium levels. Pigs were housed in 4 identical, environmentally-controlled rooms equipped with a shallow pit, pull-plug system (20 pigs/room, 2 rooms/trt). Feed intake, pig weight, pit volume, and slurry pH and EC were measured on a weekly basis. Feed and slurry samples were collected weekly and analyzed for DM, N, and P. During the 100-d finishing period, there was no difference ($P > 0.10$) in ADG (0.79 vs. 0.81 kg), ADFI (2.11 vs. 2.19 kg), or G:F (0.37 vs. 0.37). Also, no difference ($P > 0.10$) was observed in pit pH (7.15 vs. 7.20). However, electrical conductivity (8.22 vs. 9.18 mS) of the slurry tended to increase ($P < 0.09$) for pigs fed $NaHSO_4$. There was no difference ($P > 0.10$) in daily DM (230 vs. 237 g), N (33.7 vs. 31.4 g) or P (6.0 vs. 6.2 g) excretion between the 2 diets. $NaHSO_4$ addition did not affect ($P > 0.10$) excretion of sodium or ammonium-N. Sulfur excretion (2.4 vs. 4.0 g) tended to increase ($P < 0.09$) in pigs fed $NaHSO_4$. These results suggest that dietary addition of $NaHSO_4$ does not affect growth performance, pit characteristics, or DM, N or P excretion of finishing pigs.

Key Words: Pigs, Sodium Bisulfate, Nutrient Excretion