

Nonruminant Nutrition: Enzymes and minerals

M178 Porcine in vitro degradation and fermentation characteristics of regular and low-fat corn distillers dried grains with soluble without or with carbohydrase. Tofuko A. Woyengo^{*1,2}, Natasha Miceli¹, and Ruurd T. Zijlstra¹, ¹University of Alberta, Edmonton, AB, Canada, ²South Dakota State University, Brookings, SD.

Low-fat corn DDGS (L-DDGS) is available for pig feeding. However, information is lacking on fermentation characteristics of L-DDGS in the pig intestine and on the effect of fiber-grading enzymes (carbohydrases) on fermentation characteristics of L-DDGS. Thus, we determined porcine in vitro digestion and fermentation characteristics of regular (R-DDGS) and L-DDGS without or with a carbohydrase that supplied 4,880 units of xylanase and 608 units of β -glucanase per treated feedstuff in a completely randomized design. Samples were hydrolyzed in 2 steps using pepsin and pancreatin. Subsequently, residues were incubated in a buffer solution with minerals and fresh pig feces as inoculum. Gas production was measured for 72 h, and modeled to estimate kinetics of gas production. Concentration of VFA per unit weight of residue incubated or feedstuff was measured in fermented solutions. Carbohydrase did not affect in vitro digestibility of DM (IVDDM) and total gas production. However, IVDDM for L-DDGS (61.1%) was greater ($P < 0.05$) than that for R-DDGS (54.7%). Also, total gas production for L-DDGS (129.9 mL/g DM) was greater ($P < 0.05$) than that for R-DDGS (119.0 mL/g DM). Total VFA production per unit weight of residue incubated for L-DDGS (2.66 mmol/g DM) was lower ($P < 0.05$) than for R-DDGS (2.93 mmol/g DM). Also, total VFA production per unit weight of feedstuff for L-DDGS (1.19 mmol/g DM) was lower ($P < 0.05$) than for R-DDGS (1.51 mmol/g DM). Carbohydrase and feedstuff interacted ($P < 0.05$) on total VFA production per unit weight of feedstuff such that the carbohydrase tended to increase ($P = 0.09$) total VFA production per unit weight of feedstuff for R-DDGS, but did not affect total VFA production per unit weight of feedstuff for R-DDGS. In conclusion, L-DDGS may be more digestible in the small intestine of pigs than the R-DDGS, whereas R-DDGS may be more fermentable in hindgut of pigs than the L-DDGS. The carbohydrase used in the present study may have limited effect on porcine small intestine digestibility and hindgut fermentation of R-DDGS and L-DDGS.

Key Words: corn DDGS, in vitro fermentation, pig

M179 Nutrient digestibility of sorghum, with or without exogenous enzymes, for young broiler chickens. C. Gallardo, J. C. Dadalt*, J. C. C. Balieiro, and M. A. Trindade Neto, University of São Paulo, Pirassungua, SP, Brazil.

A total of 245 male Cobb broilers (10 to 18 d old) were used to determine the total-tract nutrient digestibility (TTND) of dry matter (DM), mineral matter (MM), metabolizable energy (ME), nitrogen retention (NR), calcium (Ca), phosphorus (P) and neutral detergent fiber (NDF) of sorghum, with or without multi-carbohydrase (Carb) and phytase (Phy) enzyme supplementation. The birds were allotted in a completely randomized design with 5 treatments and 7 replications (7 birds per replication). The experimental period was 8 d, 5 d of adaptation and 3 d of total feces collection. The treatments were: Control diet (CD); CD + 30% sorghum (Sorghum); CD + 30% of sorghum + 200 mg/kg of Carb (Sorghum + Carb); CD + 30% of sorghum + 50 mg/kg of Phy (Sorghum + Phy); CD + 30% of sorghum + Phy + Carb (Sorghum + Phy + Carb). The diets were formulated to meet or exceed the nutrient requirements

(Rostagno et al., 2011) for broiler chickens. The TTND coefficients of sorghum nutrients are presented in the table below. The Carb and Phy, isolated or in combination, improved ($P < 0.05$) the TTND of sorghum. Positive effects of Carb and Phy supplementation in sorghum-based diets for broiler chicks are associated with reduction in the antinutritional factors from ingredient. In general, the enzymes improved the TTND of sorghum for young broiler chickens, however, when isolated, Carb and Phy were effective to improve only NR and ME.

Table 1 (Abstr. M179). Apparent digestibility coefficients and metabolizable energy of sorghum for broiler chickens

Item	DM (%)	NR (%)	ME (kcal·kg ⁻¹)	MM (%)	Ca (%)	P (%)	NDF (%)
Diet							
Sorghum	84.16	63.28	3,887	38.85	56.29	55.12	54.19
Sorghum + Carb	89.49	65.80	3,913	43.46	60.95	57.01	55.28
Sorghum + Phy	90.65	73.50	4,117	42.65	60.52	57.10	56.17
Sorghum + Carb + Phy	90.33	72.54	3,995	38.67	64.63	59.69	57.57
SD by Diet	1.55	2.55	60.99	2.92	3.45	2.66	4.19
P-values for contrasts ¹							
C1	<0.001	<0.001	<0.001	0.044	0.001	0.024	0.252
C2	0.729	0.023	0.476	0.004	0.023	0.044	0.352
C3	0.178	<0.001	<0.001	0.613	0.819	0.949	0.696

¹C1 = Sorghum vs. Sorghum + Carb; Sorghum + Phy; Sorghum + Carb + Phy; C2 = Sorghum + Carb; Sorghum + Phy vs. Sorghum + Carb + Phy; C3 = Sorghum + Carb vs. Sorghum + Phy.

Key Words: antinutritional factor, carbohydrase, phytase

M180 Performance of commercial market hogs supplemented with a new generation *Buttiauxella* phytase. Janet C. Remus^{*1}, Yueming Dersjant-Li², Peter Plumstead³, and Ajay Awati², ¹Danisco Animal Nutrition/DuPont Industrial Bioscience, St. Louis, MO, ²Danisco Animal Nutrition/DuPont Industrial Bioscience, Marlborough, Wiltshire, UK, ³University of Pretoria, Pretoria, South Africa.

This experiment was conducted to determine if a new generation phytase from *Buttiauxella* sp. can replace all inorganic phosphate (PO₄) in diets also reduced in Ca and ME and fed to commercial pigs from 12 kg to slaughter while maintaining performance and carcass quality. Four treatments were tested in a randomized block design with 9 replicate pens, each with 31 mixed sex pigs of Newsholm Choice genetics. The corn-soybean meal-wheat middlings-based treatment diets are (1) positive control (PC) that met nutrient requirements; (2) negative control (NC) without inorganic PO₄ and with incremental phase nutrient reductions of 0.131% Ca and 35 kcal ME/kg; (3) NC+500 FTU/kg phytase (NC+500) and (4) NC+1000 FTU/kg phytase (NC+1000). The mash diets were fed ad lib in 5 feed phases. Data were tested using the Fit Model procedure in JMP, mean separation utilized Tukey's test. Significance was $P \leq 0.05$ unless noted. Due to poor growth at the end of Finisher 1, the NC was placed on PC feed in Finisher 2 (F2) to see if they could get to target weight. Performance from Nursery 2 (N2) thru F2 shows the PC and NC+1000 have similar ADG and improved results versus NC. The

NC+500 had better ADG and FCR than the NC and had similar FCR with PC and NC+1000 in N2 thru F2. From N2 to processing, the PC and both phytase treatments were similar on performance (no NC due to insufficient pens at target weight by F2 end). No differences noted for carcass weight, lean carcass or yield. Carcass data for PC, NC+500, and NC+1000 shows that the NC+500 had higher 10th rib fat but had a tendency ($P = 0.07$) toward lower yield while NC+1000 had lower muscle depth. Overall, the data indicate that 500 and 1000 FTU phytase/kg can replace all inorganic PO_4 and maintain performance compared with PC in pigs fed a corn-soybean meal-wheat middlings based diet.

Table 1 (Abstr. M180). Performance and carcass data

Treatment	N2 to F2 (12-120 kg)			Carcass	
	ADG, kg	ADFI, kg	FCRmc	Muscle depth, mm	10th rib backfat, mm
PC	0.78 ^{ab}	2.17 ^a	2.80 ^{ab}	63.78 ^a	18.94 ^b
NC	0.69 ^c	1.98 ^b	2.86 ^a		
NC+500	0.75 ^b	2.09 ^{ab}	2.77 ^b	63.91 ^a	19.72 ^a
NC+1000	0.79 ^a	2.20 ^a	2.79 ^{ab}	62.63 ^b	18.99 ^b
P-value	<0.01	<0.01	0.05	0.02	0.05

Key Words: *Buttiauxella* phytase, pig, performance

M181 Ileal amino acid digestibility in high protein sunflower meal and pea protein isolate fed to growing pigs with or without multi-carbohydase supplementation. J. C. Dadalt^{*1}, D. E. Velayudhan¹, M. A. Trindade Neto², and C. M. Nyachoti¹, ¹University of Manitoba, Winnipeg, MB, Canada, ²University of São Paulo, São Paulo, SP, Brazil.

Eight ileal-cannulated barrows (initial BW = 23.5 ± 0.85 kg) were used to determine the apparent (AID) and standardized (SID) ileal AA digestibilities in high protein sunflower meal (HiPSF) and pea protein isolate (PPI) with or without multi-carbohydase enzyme (MC) supplementation. Pigs were randomly assigned to 1 of 5 treatments in a replicated 4 × 5 incomplete Latin square design to give 8 observations per treatment. The experimental diets consisted of HiPSF or PPI as the sole source of protein with or without MC and a low-protein diet (5% casein) used to quantify endogenous AA losses. All diets contained titanium dioxide (0.3%) as indigestible marker. Pigs were given their daily feed allowance at a rate of 4.5% of BW determined at the beginning of each experimental period. Each experimental period lasted 7 d and the ileal digesta were collected on d 6 and 7. All data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included diet as the fixed variable and animal and period as the random variables. In general, AA digestibilities were higher in PPI than in HiPSF, with the exception of Met and Cys ($P > 0.05$). There was no effect of MC ($P > 0.05$) on AA digestibility. The AID and SID of essential AA in HiPSF and PPI (without MC) were, respectively: Arg, 83.2, 87.8 and 90.0, 94.2; His, 29.6, 40.3 and 50.0, 60.5; Ile, 73.9, 79.8 and 83.1, 88.6; Leu, 72.9, 78.0 and 83.4, 87.7; Lys, 66.1, 72.6 and 88.3, 91.4; Met, 82.1, 86.0 and 80.8, 87.3; Phe, 75.5, 79.0 and 83.0, 86.1; Thr, 62.3, 72.9 and 72.6, 82.6; Val, 70.1, 76.1 and 79.2, 85.0. The MC increased ($P < 0.01$) the AID and SID of Proline (75.37 vs 82.14% and 86.82 vs 93.66%, respectively) in PPI. Compared with HiPSF, PPI had better digestible AA profile for growing pigs. However, no differences were detected for the digestibility of most AA when diets were supplemented with MC.

Key Words: enzyme, high-protein sunflower meal digestibility, pea protein isolate

M182 Ileal amino acid digestibility in rice polished and broken fed to weaned pigs with or without multi-carbohydase and phytase supplementation. J. C. Dadalt^{*1}, G. V. Polycarpo¹, C. Gallardo¹, T. W. Almeida¹, J. C. S. M. Souza¹, F. E. L. Budiño², and M. A. Trindade Neto¹, ¹University of São Paulo, São Paulo, SP, Brazil, ²Institute of Animal Science, Nova Odessa, SP, Brazil.

Twenty-five barrows (initial BW = 8.81 kg ± 1.52 kg) were used to determine the apparent (AID) and standardized (SID) ileal AA digestibilities in rice polished and broken (RB) with or without multi-carbohydase (Carb) and phytase (Phy) enzyme supplementation. Pigs were allotted in a completely randomized design to 5 treatments with 5 replicates. The experimental diets consisted of RB as the sole source of protein without enzymes, with Carb, Phy or Carb+Phy and a low-protein diet (5% casein) used to quantify endogenous AA losses. All diets contained chromic oxide (0.3%) as indigestible marker. Pigs were given their daily feed allowance at a rate of 4.5% of BW determined at the beginning of each experimental period. Animals were slaughtered at d 43 and ileal contents collected. The data were analyzed using the GLM (SAS Inst. Inc., Cary, NC), and means were compared by Tukey's test. The phytase, singly or in combination with multi-carbohydase, improved AID and SID ($P < 0.05$) of histidine, leucine and lysine of polished and broken rice, while singly carbohydase improved only AID and SID ($P < 0.05$) of histidine. Coefficients of AID and SID of AA in RB (without enzymes) were, respectively: Arg, 0.662 and 0.841; His, 0.626 and 0.769; Ile, 0.596 and 0.792; Leu, 0.700 and 0.790; Lys, 0.663 and 0.775; Met, 0.710 and 0.808; Phe, 0.721 and 0.843; Thr, 0.492 and 0.650; Val, 0.630 and 0.811; Ala, 0.509 and 0.613; Asp, 0.618 and 0.735; Glu, 0.667 and 0.778; Pro, 0.623 and 0.853; Ser, 0.404 and 0.716; Tyr, 0.744 and 0.865. In general, these results were lower than those in NRC (2012). Underestimated digestibility coefficients may be related to animal ages in the present study, since most of the studies in literature were obtained from pigs with higher weights. The phytase, singly or combined with carbohydase, improves the digestibility of His, Leu and Lys in rice polished and broken.

Key Words: alternative ingredient, enzyme, piglet

M183 Ileal amino acid digestibility in micronized full fat soybean fed to weaned pigs with or without multi-carbohydase and phytase supplementation. J. C. Dadalt^{*1}, C. Gallardo¹, T. W. Almeida¹, P. A. P. Ribeiro¹, G. V. Polycarpo¹, G. Galvão¹, B. A. Malheiros¹, F. E. L. Budiño², and M. A. Trindade Neto¹, ¹University of São Paulo, São Paulo, SP, Brazil, ²Institute of Animal Science, Nova Odessa, SP, Brazil.

Twenty-five barrows (initial BW = 8.53 kg ± 1.48 kg) were used to determine the apparent (AID) and standardized (SID) ileal AA digestibilities in micronized full fat soybean (MFFS) with or without multi-carbohydase (Carb) and phytase (Phy) enzyme supplementation. Pigs were allotted in a completely randomized design under 5 treatments and 5 replicates. The experimental diets consisted of MFFS as the sole source of protein without enzymes, with Carb, Phy or Carb+Phy. A low-protein diet (5% casein) was used only to calculate the digestibility of the MFFS. All diets contained Chromium (0.3%) as indigestible marker. Pigs were given their daily feed allowance at a rate of 4.5% of BW determined at the beginning of each experimental period. Animals were slaughtered at d 43 and ileal contents collected. The data were analyzed using the GLM (SAS Inst. Inc., Cary, NC), and means were compared by Tukey's test. The AID and SID of AA in MFFS (without enzymes) were lower (average 16.9 and 14.7%, respectively) compared with NRC (2012). Underestimated digestibility coefficients may be related with animal ages in the present study, since most of the studies

related in literature were obtained from pigs with higher weights. There was no effect of Carb, Phy or Carb+Phy ($P > 0.05$) on AA digestibility. According with literature, sometimes the use of exogenous enzymes to degrade indigestible dietary components has inconsistent results mainly because of the presence of complex substrates in feedstuffs and the use of enzyme activities often not suitable for effective hydrolysis of such components. The AID and SID of AA in MFFS (without enzymes) were, respectively: Arg, 71.6 and 76.5; His, 69.8 and 77.0; Ile, 59.9 and 66.0; Leu, 68.1 and 74.2; Lys, 75.8 and 79.6; Met, 72.3 and 81.1; Phe, 68.8 and 74.2; Thr, 61.4 and 74.6; Val, 65.2 and 72.1; Ala, 66.7 and 78.0; Asp, 66.9 and 69.8; Glu, 71.1 and 75.0; Pro, 70.1 and 80.7; Ser, 70.0 and 81.5; Tyr, 68.9 and 74.0. Carbohydrase and phytase, alone or in combination, don't affect AA digestibilities of MFFS for weaned pigs.

Key Words: antinutritional factor, enzyme, piglet

M184 Nutrient digestibility of rice bran, with or without exogenous enzymes, for young broiler chickens. C. Gallardo, J. C. Dadalt*, J. C. C. Balieiro, and M. A. Trindade Neto, *University of São Paulo, Pirassununga, SP, Brazil.*

A total of 245 male Cobb broilers (10 to 18 d old) were used to determine the total-tract nutrient digestibility (TTND) of dry matter (DM), mineral matter (MM), metabolizable energy (ME), nitrogen retention (NR), calcium (Ca), phosphorus (P) and neutral detergent fiber (NDF) of rice bran (RB), with or without multi-carbohydrase (Carb) and phytase (Phy) enzyme supplementation. The birds were allotted in a completely randomized design with 5 treatments and 7 replications (7 birds per replication). The experimental period was 8 d, 5 d of adaptation and 3 d of total feces collection. The treatments were: Control diet (CD); CD + 30% of RB; CD + 30% of RB + 200 mg/kg of Carb (RB+Carb); CD + 30% of RB + 50 mg/kg of Phy (RB+Phy); CD + 30% of RB + Carb + Phy (RB+Carb+Phy). CD was used only to calculate the digestibility of the RB. The diets were formulated to meet or exceed the nutrient requirements (Rostagno et al., 2011) for broiler chickens. The TTND coefficients of RB are presented in Table 1. Alone or combined, Carb and Phy improved ($P < 0.05$) the TTND of RB. These results are associated with enzymatic activity to enhance nutrient digestibility, focusing primarily on removing the antinutritive effects of nonstarch polysaccharides (NSP), such as arabinoxylans and β -glucans from broiler diets based on viscous grains. In general, enzymes improved the TTND of RB for young broiler chickens.

Table 1 (Abstr. M184). Apparent digestibility coefficients and metabolizable energy of rice bran for broiler chickens

Item	DM (%)	MM (%)	ME (kcal·kg ⁻¹)	NR (%)	Ca (%)	P (%)	NDF (%)
Diet							
RB	66.42	75.38	3765	62.04	49.31	69.60	68.09
RB + Carb	69.82	80.59	3916	66.42	56.64	74.11	74.80
RB + Phy	70.36	75.85	3999	70.25	58.34	71.11	74.59
RB + Carb + Phy	75.07	78.14	4252	70.07	57.76	74.88	68.61
SD by Diet	1.74	2.25	53.52	2.28	3.94	1.88	2.76
P-values for contrasts ¹							
C1	<0.001	0.009	<0.001	<0.001	<0.001	<0.001	<0.001
C2	<0.001	0.939	<0.001	0.117	0.886	0.016	<0.001
C3	0.582	<0.001	0.007	0.005	0.432	0.007	0.892

¹C1 = RB vs. RB + Carb; RB + Phy; RB + Carb + Phy; C2 = RB + Carb; RB + Phy vs. RB + Carb + Phy; C3 = RB + Carb vs. RB + Phy.

Key Words: antinutritional factor, carbohydrase, phytase

M185 Effects of phosphorus source and content on bone mineralization and performance of broiler chickens. Roseline Kahindi*¹, Phil Thacker², and Martin Nyachoti¹, ¹*University of Manitoba,* ²*University of Saskatchewan.*

Two hundred and ten 1-d-old, (Ross 308 strain) broiler chicks were housed in a temperature controlled room with 5 birds per cage and randomly allocated to 1 of 7 dietary treatments for a 21 d study. The objective of the study was to determine the effect of feeding diets containing low phytate barley and pea vs. the normal phytate cultivars and the effects of inorganic P reduction on performance and bone characteristics of broiler chicks. The main feed ingredients used were: low phytate barley (LPB), low phytate pea (LPP), normal hull barley (NHB), normal phytate pea (NPP), and soybean meal (SBM). The dietary treatments included (1) Control that was SBM-NHB based with 100% inorganic P; (2) control with 50% inorganic P; (3) low phytate cultivars based on SBM-LPB-LPP with 100% inorganic P; (4) treatment 3 with 50% inorganic P; (5) treatment 3 with no addition of inorganic P; (6) normal phytate cultivars based on SBM-NHB-NPP with 100% inorganic P; (7) normal phytate cultivars with 50% inorganic P. Feed and water were offered ad-libitum throughout the study and average daily gain (ADG) and feed intake (ADFI) were determined weekly and used for calculating feed conversion ratio (FCR). On d 21, 2 birds per cage were killed to collect left tibias for bone length and ash determination. Data were subjected to ANOVA as a completely randomized design using Proc Mixed of SAS 9.2. In addition, orthogonal contrasts were used to compare diets 1 and 2 vs. the rest of the diets, to compare 100 vs. 50% inorganic P diets, and to compare diets with low phytate vs. the normal phytate grain cultivars. The reduction in dietary inorganic P content significantly decreased ADG but had no effect on FCR. The ADG was 18 g/chick and lowest ($P < 0.05$) for treatment 7, whereas ADG was similar for treatments 1, 3, and 6 that is, 38, 42, and 41 g/chick, respectively. The overall ADG tended ($P < 0.10$) to be higher for the low phytate compared with normal phytate diets. The tibia ash and length were significantly decreased with inorganic P reduction. The results indicate that feeding low phytate barley and pea based diets can replace 29% of supplemental inorganic P required in normal phytate cultivars.

Key Words: broiler chicken, low phytate cultivar, performance

M186 A comparison of total, apparent total-tract digestible, and standardized total-tract digestible phosphorus on excretion and digestibility of phosphorus in pigs. W. B. Kwon*¹, S. K. Park², and B. G. Kim¹, ¹*Konkuk University, Seoul, Republic of Korea,* ²*Sejong University, Seoul, Republic of Korea.*

An experiment was conducted to test a hypothesis that 3 diet formulation methods of using total, apparent total-tract digestible (ATTD), and standardized total-tract digestible (STTD) phosphorus (P) differ in excretion and digestibility of P in pigs. Twenty-four barrows with an initial BW of 18.1 \pm 0.7 kg were randomly allotted to 3 dietary treatments with 8 replicate pigs per diet in a completely randomized design. Experimental diets were formulated to contain constant amounts of corn, soybean meal, whey powder, and dicalcium phosphate. The 3 diets were formulated based on a total, ATTD, or STTD basis to meet the dietary P requirement by changing the inclusion rate of rice bran at the expense of cornstarch and cellulose. Each experimental period consisted of a 4-d adaptation period and a 5-d fecal collection period. During the collection period, total feed intake did not differ among the treatments. The daily P intake and daily P output of pigs fed the diet based on ATTD P was greater (10.87 vs. 7.65 or 8.96 g/d and 4.27 vs. 2.60 or 3.30 g/d, respectively; $P < 0.05$) compared with the total P- or STTD P-based group. The ATTD of P was not different among the treatment groups.

Taken together, formulating a diet based on total P or STTD P resulted in less P excretion mainly due to the less concentration of dietary P compared with a diet based on ATTD P. Further research is warranted to investigate performance and P retention in pigs fed diets formulated based on total P, ATTD P, and STTD P.

Key Words: diet formulation, phosphorus, swine

M187 Standardized total tract digestibility of phosphorus in various inorganic phosphates fed to growing pigs. W. B. Kwon* and B. G. Kim, *Konkuk University, Seoul, Republic of Korea.*

An experiment was conducted to determine the standardized total-tract digestibility (STTD) of phosphorus (P) in 5 sources of inorganic phosphate fed to pigs. The 5 sources of inorganic phosphate were dicalcium phosphate (DCP, 19.3% P), monocalcium phosphate (MCP, 22.7% P), monodicalcium phosphate (MDCP, 22.0% P) which is the mixture of MCP and DCP at a ratio of 3:1, monosodium phosphate (MSP, 24.5% P), and tricalcium phosphate (TCP, 19.4% P). Six barrows with an initial body weight of 42.4 ± 1.1 kg were individually housed in metabolism cages equipped with a feeder. Pigs were randomly allotted to a 6×6 Latin square design with 6 dietary treatments and 6 periods. Each experimental period consisted of a 4-d adaptation and a 5-d collection period. Five experimental diets contained 0.25% P from each inorganic phosphate as a sole source of P, and were formulated to contain calcium in amounts that were 1.3 times greater than the concentration of P except the TCP diet. A P-free diet mainly based on cornstarch, gelatin, and sucrose was also prepared to estimate the basal endogenous loss of P. Feces were collected using the marker-to-marker procedure. Data were analyzed using the MIXED procedure of SAS with a model including dietary treatment as a fixed variable and animal and period as random variables. Values for the apparent total-tract digestibility of P in DCP, MCP, MDCP, and MSP (83.0, 86.5, 81.4, and 88.7% respectively) were greater ($P < 0.05$) than in TCP (67.0%). Values for the STTD of P in DCP, MCP, MDCP, and MSP (89.8, 93.3, 88.2, and 95.5%) were also greater ($P < 0.05$) than in TCP (72.8%). In conclusion, digestibility of P in TCP was less than other inorganic P sources.

Key Words: inorganic phosphate, phosphorus digestibility, swine

M188 Effect of phosphorus and calcium depletion-repletion sequences on femoral mechanical properties in growing pigs.

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Consequences of a P-Ca deficient diet (depletion) or a control diet (repletion) on the mechanical properties of growing pig femurs were studied. Two different groups of pigs were fed with different P-Ca depletion-repletion sequences, that involved a control diet (C) or a deficient diet (L), supplying 100% or 60% of P-Ca requirements, respectively, in an incomplete factorial design. The first group (n = 30; initial BW 24 ± 3.3 kg) received during 2 28-d phases CC, CL or LC dietary treatments. The second group (n = 50; initial BW 24 ± 2.8 kg) received during three 28-d phases CCC, CLC, LCC, LLC or LLL diets. At the end of the 2nd and 3rd phases, respectively, pigs were killed and right femurs collected for computer tomography (CT) scans and mechanical tests. Data were analyzed using Proc Mixed procedures and orthogonal contrasts for treatments interferences. A 28-d repletion period in the 2nd phase (CC, LC) increased (43%, $P = 0.03$) bone-bending moment (BM, kg-mm)

compared with depleted pigs (CL). Repletion P-Ca diets in the 3rd phase (CCC, CLC, LCC and LLC) increased BM ($P < 0.01$) and strain ($P = 0.03$) compared with LLL pigs. Moment of inertia (MI, mm⁴) tended to be lower ($P = 0.08$) in depleted animals (LLL) compared with repleted animals, resulting in a reduced ($P = 0.02$) bone stress (kg/mm²) in LLL pigs. However, neither bone MI nor stress differed among treatments. P-Ca depletion at the end of the 2nd or 3rd phase (CL, LLL) reduced bone mechanical properties. No differences were found between CC and LC treatments regarding mechanical properties, which implies bone recovery from P-Ca deficiencies of the 1st phase. Mechanical properties after three 28-d growing phases (final BW 107 ± 11.3 kg) are shown in the table. Superscripts indicate treatment differences ($P < 0.05$). A 28-d repletion in the 3rd phase (CCC, CLC, LCC or LLC) is sufficient for recovery from previous deficiencies as similar mechanical properties were detected among treatments.

Table 1 (Abstr. M188).

Item	Trait					SEM
	CCC	CLC	LCC	LLC	LLL	
BM (kg·mm)	3049 ^A	2501 ^A	2527 ^A	2354 ^{AB}	1726 ^B	259
Strain	0.026 ^{AB}	0.027 ^{AB}	0.030 ^A	0.025 ^{AB}	0.023 ^B	0.002
Stress (kg/mm ²)	1.346	1.129	1.170	1.105	0.886	0.123

Key Words: phosphorus-calcium, depletion-repletion, mechanical properties

M189 Effects of dietary calcium concentrations on growth performance, litter quality, and tibia characteristics in starter broiler chickens.

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The objective of this experiment was to investigate the effects of dietary calcium (Ca) concentrations on growth performance, litter quality, and tibia characteristics in starter broiler chickens. A total of 2,520 one-day-old broiler chicks were used and housed in floor pens for 3 weeks. Birds were randomly allotted to 1 of 6 dietary treatments with 6 replicates. Each replicate consisted of 70 chicks. Dietary Ca concentrations were set to 1.0, 0.9, 0.8, 0.7, 0.6, and 0.5%. Non-phytate P (NPP) was maintained at 0.35% and 0.02% of a 5,000 FTU/g phytase (Phyzyme XP, Danisco Animal Nutrition, Marlborough, UK) was included in all diets. At the end of experiment, 2 birds from each replicate were euthanized and tibia samples were collected. Litter samples were also collected from each pen floor. Pre-planned orthogonal polynomial contrast test was performed to determine linear and quadratic effects of Ca concentrations. Results indicated that decreasing concentrations of Ca in diets from 1.0 to 0.5% increased (linear, $P < 0.05$) BW, BWG, FI, and feed efficiency. Litter quality including litter pH, litter moisture, and litter nitrogen and tibia characteristics including breaking strength were not affected by dietary Ca concentrations. In conclusion, decreasing concentrations of Ca from 1.0 to 0.5% in diets containing 0.35% NPP and phytase (1,000 FTU/kg) have positive effects on growth performance of starter broiler chickens, but little effects on litter quality and tibia characteristics.

Key Words: starter broiler chicken, dietary calcium, performance

M190 Effects of dietary calcium concentrations on growth performance, litter quality, and tibia characteristics in growing broiler chickens. Jong Hyuk Kim¹, Byung Bo Lee*¹, Moon Chan Kim¹, Jae Sang Um², and Dong Yong Kil¹, ¹*Chung-Ang University, Anseong-si, Gyeonggi-do, Republic of Korea*, ²*Nonghyup Feed, Gangdong-gu, Seoul, Republic of Korea*.

This study was conducted to investigate the effects of dietary calcium (Ca) concentrations on growth performance, litter quality, and tibia characteristics in growing broiler chickens. A total of 1,800 21-d-old broiler chickens were used and housed in floor pens for 2 weeks. Birds were randomly allotted to 1 of 6 dietary treatments with 6 replicates. Each replicate consisted of 50 chickens. Dietary Ca concentrations were set to 0.9, 0.8, 0.7, 0.6, 0.5, and 0.4%. Non-phytate P (NPP) was maintained at 0.3% and 0.02% of a 5,000 FTU/g phytase (Phyzyme XP, Danisco Animal Nutrition, Marlborough, UK) in all diets. After 2 weeks, 2 birds from each replicate were euthanized and tibia samples were collected. Litter samples were also collected from each pen floor. Pre-planned orthogonal polynomial contrast test was performed to determine linear and quadratic effects of dietary Ca concentrations. Results indicated that growth performance including BWG, feed intake (FI), and feed efficiency (FE) was not affected by dietary Ca concentrations. Litter quality including litter pH, litter moisture, and litter nitrogen was not influenced by dietary Ca concentrations. However, decreasing concentrations of Ca in diets from 0.9 to 0.4% decreased (linear and quadratic, $P < 0.01$) the concentrations of Ca and P in tibia. In conclusion, decreasing concentrations of Ca from 0.9 to 0.4% in diets containing 0.3% NPP and phytase (1,000 FTU/kg) decrease the concentrations of Ca and P in tibia, but no adverse effects on growth performance and litter quality in growing broiler chickens.

Key Words: growing broiler chicken, dietary calcium, performance

M191 Determination of additivity of apparent and standardized total tract digestibility of phosphorus in mixed diet fed to growing pigs. W. B. Kwon*¹, S. K. Park², and B. G. Kim¹, ¹*Konkuk University, Seoul, Republic of Korea*, ²*Sejong University, Seoul, Republic of Korea*.

This study was conducted to test the hypothesis that the values of standardized total-tract digestibility (STTD) of phosphorus (P) measured in individual feed ingredients are additive when used in diet formulation for swine. Eight crossbred barrows with an initial BW of 30.5 ± 1.5 kg were individually housed in metabolism cages equipped with a feeder. The pigs were randomly allotted to a replicated 4×4 Latin square design with 4 dietary treatments and 4 periods. Three diets were formulated by mixing cornstarch, sucrose, and soybean oil with SBM (50%), wheat (70%), or both (30.6% of SBM and 55.7% of wheat), as the source of P in each diet. A P-free diet was also formulated to estimate the basal endogenous loss of P. All experimental diets were formulated to maintain constant total calcium to total P ratio of 1.2:1 except the P-free diet. Each experimental period consisted of a 4-d adaptation period and a 5-d collection period. Feces were collected using the marker-to-marker procedure. In the mixed diet, a relative contribution of P from SBM and wheat was 51.9 and 48.1%, respectively. The ATTD of P for SBM and wheat was measured to be 40.9 and 41.8%, respectively, and the measured ATTD of P in the mixed diet was greater (45.1 vs. 41.3%; $P < 0.05$) than the predicted ATTD of P. The determined STTD of P for SBM and wheat was 46.4 and 49.3%, respectively, and the measured STTD of P in the mixed diet was not different (49.7 vs. 47.8%; $P = 0.26$) from the predicted STTD of P. In conclusion, the ATTD values

of P are not additive whereas STTD values of P may be additive when formulating swine diets.

Key Words: additivity, phosphorus digestibility, swine

M192 Effect of dietary calcium and phosphorus concentration on apparent ileal and total-tract digestibility of calcium and phosphorus of pigs. Fengrui Zhang*¹, Darryl Ragland², and Layi Adeola¹, ¹*Department of Animal Science, Purdue University, West Lafayette, IN*, ²*Department of Veterinary Clinical Sciences, Purdue University, West Lafayette, IN*.

The objective of this study was to test the hypothesis that the apparent total-tract digestibility (ATTD) of calcium (Ca) is not different from the apparent ileal digestibility (AID) in growing-finishing pigs fed different Ca and Phosphorus (P) concentration diets with a fixed Ca:total P (tP) ratio. Diets with 4 Ca concentrations (0.39%, 0.59%, 0.79% and 0.99%) were formulated by adjusting the dietary level of calcium carbonate. Potassium phosphate was supplemented to adjust the dietary P level and maintain a 1.5:1 Ca:tP ratio. Sixteen pigs (initial BW = 73 ± 4 kg), fitted with a T-cannula at the distal ileum, were sorted by BW and assigned in a randomized complete block design to 4 treatments and 2 experimental periods. Each period consisted of a 3-d acclimation period, a 2-d fecal collection, and a 2-d ileal collection period. Data from the study was analyzed as a split-plot in a randomized complete block design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Diets with different Ca and P levels were the main-plot factor, and digestibility sites (AID and ATTD) were the split-plot factor. Results indicated that the ATTD of Ca or P is not different from AID in all treatments. Furthermore, the results also showed the digestibility of Ca was not affected by the dietary treatments, but the apparent digestibility of Ca had a tendency to increase as the dietary Ca concentration increased (linear, $P = 0.095$). The AID and ATTD of P linearly increased ($P < 0.05$) from 34.45 to 63.07% and 35.96 to 62.35% respectively, as the Ca and P concentration increased. Therefore, current study showed that with the same dietary Ca:tP ratio, there is no difference between the AID and ATTD of Ca and P. Thus, the net absorption of Ca and P in large intestine of growing-finishing pigs is negligible and both AID and ATTD can be used to describe the digestibility of Ca for growing-finishing pigs. It is also concluded that the effects of adding different levels of calcium carbonate and potassium phosphate on digestibility of Ca is not statistically significant, but it increased the apparent ileal and total-tract digestibility of P in the diets based on Corn-SBM.

Key Words: calcium, digestibility, phosphorus

M193 Influence of calcium source and fat level on broiler performance and nutrient utilization. O. El-Husseiny¹ and M. A. Michael*^{1,2}, ¹*Department of Animal Sciences, Cairo University, Egypt*, ²*Affor. and Environment, Ministry of Agriculture, Egypt*.

The objective of this experiment was to evaluate the effect of the dietary inclusion of calcium lactate (CL), calcium bio lactate (CBL) or calcium carbonate (CC) at NRC calcium level, in the presence of 0, 3%, 6% or 9% beef tallow on improving the performance, intestinal digestion and absorption of broiler chicks. Where, CBL derived from reacted between calcium hydroxide and biologically lactic acid secreted from lactic acid bacteria based on probiotic. Three hundred and six 1-d-old Cobb 500 broiler chicks were fed 12 treatments containing 3 calcium sources and 4 fat levels in a 3×4 factorial design with 3 replicates, 10 chicks each. Weight gain (WG), feed intake (FI), feed conversion rate (FCR), blood composition, nutrient digestibility and soap formation

were recorded up to 7 weeks of age. The weight gain of broilers fed diets containing CBL with 6% tallow fortified diet was higher than those fed CL plus 6% tallow. Improvement ($P < 0.05$) in FCR was observed when broilers fed diets contained CL or CBL compared with those fed diets contained CC with different fat levels. Abdominal fat was increased ($P < 0.05$) when broilers fed diets containing CBL with 9% fat than those fed the other calcium sources and fat levels. The digestibilities of all nutrients were higher ($P < 0.05$) with broilers fed diets contained CBL or CL plus 6% tallow than those fed diets contained CC with different fat levels. The highest amount of excreted fat as soap formation were noticed for broilers fed diets contained CC with 9% tallow, while the lowest values observed with those fed diets contained CBL with 6% or 9% tallow. Total blood lipid of broilers fed diets contained CL or CBL with 6 or 9% tallow were greater ($P < 0.05$) compared with those fed the other treatments. Broilers fed diets contained CBL recorded the highest nitrogen and calcium retained compared with those fed diets contained CL or CC. It is concluded that the calcium lactate or calcium bio lactate based on probiotic were effective improving fat absorption and calcium retention with positive effect on broiler performance.

Key Words: calcium bio lactate, beef tallow, soap formation

M194 Dietary nitrogen level affects ileal phosphorus digestion in growing pigs. Pengcheng Xue^{*1}, Darryl Ragland², Kolapo Ajuwon¹, and Olayiwola Adeola¹, ¹Departments of Animal Sciences, Purdue University, West Lafayette, IN, ²Departments of Veterinary Clinical Sciences, West Lafayette, IN.

A study was conducted to investigate the effect of dietary CP levels on ileal phosphorus (P) digestion in growing pigs. A total of 18 ileal-cannulated pigs (initial BW 44.2 ± 3.2 kg) were used in a duplicated 9×3 incomplete Latin Square design, with 9 treatments and 3 7-d experimental periods giving 6 replicates per treatment. The 9 treatments consisted of 1 nitrogen free diet to estimate basal endogenous loss of AA, and 8 corn-soybean meal based diets in a 2×4 factorial arrangement, which included 2 CP levels (6.9 or 13.4%) and 4 apparent total-tract digestible P (ATTDP) levels (0.09, 0.16, 0.24, or 0.32%). Soybean meal and mono-calcium phosphate were used to adjust the CP level and ATTDP level, respectively. Limestone was included in diets to maintain the Ca: ATTDP ratio across treatments. Ileal digesta was collected continuously for 10 h on the last 2 d of each 7-d experimental period. The ileal digesta samples were lyophilized and analyzed to calculate ileal digested N and P. Data were analyzed using PROC MIXED procedure of SAS (9.3) and contrasts were used to test the linear and quadratic effects of increasing levels of P within each CP level. In the model, CP and P levels were considered as fixed effects and block (BW) was the random effect. In the low CP groups (6.9%), the ileal digested P were 0.71, 1.16, 1.64, and 2.03 g/kg of DMI for diets that contained 0.09, 0.16, 0.24, and 0.32% ATTDP, and their counterparts in high CP groups (13.4%) were 0.70, 1.54, 2.03, and 1.99 g/kg of DMI. There was a main effect of CP level ($P < 0.05$) on ileal digested P (g/kg of DMI). The ileal digested P (g/kg of DMI) increased linearly ($P < 0.01$) with increasing ATTDP levels in low CP groups, but the pattern was linear ($P < 0.01$) and quadratic ($P < 0.01$) in high CP groups. In conclusion, this research indicated that the amount of ileal digested P (g/kg of DMI) could be limited by protein deficiency and thus, dietary CP level could affect ileal P digestion.

Key Words: amino acid, ileal digestibility, phosphorus

M195 Could a reduction of crude protein content avoid the use of ZnO and antibiotics in pig diets without affecting their subsequent performance? Sergi López-Vergé, Laia Blavi^{*}, David Solà-Oriol, José Francisco Pérez, and Josep Gasa, *Animal Nutrition and Welfare Service, Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, Bellaterra, Spain.*

It's well known that ZnO and antibiotics (Ab) are usually included in nursery diets as a therapeutic use to reduce the impact of weaning in young piglets. The objective of this study was to analyze the effect of removing ZnO and Ab associated with CP reduction in piglet's diets in terms of mortality and days required to reach marketing BW (MBW, fixed at 105 kg). A total of 400 crossbreed piglets [Pietrain \times (Landrace \times Large White)] from 40 litters were used. During the nursery period, pigs were reared in 40 pens (10 piglets/pen) and assigned to 2 treatments taking into account the BW at weaning following a RCBD: medicated, M (2,480ppm Zn as ZnO, 120 ppm colistin sulfate, 300 ppm amoxicillin, 11.0 MJ/kg NE, 20.2% CP, 1.37% Lys) and unmedicated, \emptyset (10.6 MJ/kg NE, 16.5% CP, 1.20% Lys) diets until 35 d post-weaning. Thereafter, pigs were moved to a growing-finishing facility (maintaining the same littermates). Pigs were fed ad libitum the same commercial growing and finishing diets (10.0 MJ/kg NE, 16.0% CP, 0.95% Lys). Mortality rate (MR) was monitored from 0 to 14 d post-weaning. All animals were individually weighed at d 2 (CF; cross fostering), d 28 (weaning), d 42 (14 d post-weaning), d 63 (35 d post-weaning) and every 3 weeks until pigs were slaughtered. Data were adjusted using the Gompertz model: $BW = A \times \exp\{-\exp[b - (c \times t)]\}$; the predicted time to reach 7, 10, 20, 40, and 105 kg of BW were statistically analyzed by ANOVA by using the GLM procedure of SAS. No differences in time to reach BW of 7 (M = 34.2 d vs. \emptyset = 35.0 d; $P = 0.22$), 10 (M = 43.5 d vs. \emptyset = 44.3 d; $P = 0.24$), 20 (M = 65.4 d vs. \emptyset = 66.3 d; $P = 0.31$) and 40 kg (M = 95.4 d vs. \emptyset = 96.5 d; $P = 0.28$) were observed. In contrast, time to reach MBW was slightly higher in \emptyset pigs (179.3 d vs. 175.1 d; $P = 0.01$) and also had higher MR than the M (control) diet (11.7% vs. 4.5%; $P = 0.02$) during the 14 d post-weaning. Results suggest that removing ZnO and Ab (also reducing CP and Lys) in early diets, seems not to have a huge impact in the time to reach MBW but causes higher MR in the first 14 d post-weaning.

Key Words: performance, piglet, zinc oxide

M196 Comparing zinc status, growth, and mortality in piglets fed with or without therapeutic doses of Zn oxide. Laia Blavi^{*}, Sergi López-Vergé, David Solà-Oriol, and José Francisco Pérez, *Animal Nutrition and Welfare Service, Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, Bellaterra, Spain.*

Zinc (Zn) is an essential micronutrient required for multiple biological functions and used at therapeutic doses to reduce diarrhea and increase feed intake and performance in piglets. However, high doses of Zn in the diet are associated with heavy metal soil contamination and antimicrobial resistance which it may indicate the need to restrict or modify the therapeutic use of ZnO in piglets. A study was performed to assess how growth, mortality and Zn serum concentration change when Zn therapeutic is removed. A total of 400 weaned piglets [Pietrain \times (Landrace \times Large White)] were assigned to 2 different dietary strategies: Therapeutic (T diet, 122ppm of Zn as nutrient and 2,480ppm Zn as ZnO, 11.0 MJ/kg NE, 20.2% CP, 1.37 Lys) and Nutritional, in which the diet was formulated with a lower CP content, (N diet with 125ppm Zn as nutrient, 10.6 MJ/kg NE, 16.5% CP, 1.20 Lys) during the nursery period

(0 to 35d). On d 35, piglets were moved to the growing barns and fed the same diet (110 ppm Zn, 10.0 MJ/kg NE, 16.0% CP, 0.95 Lys). Piglets were weighted on d 0, 14, 35 and 57 and mortality was registered. Blood samples were obtained from 15 piglets per group to analyze Zn status on d 0, 7, 35 and 49 post-weaning. All studied parameters were analyzed with one-way ANOVA taking into account the experimental treatment as main factor with α level of 0.05. No differences were observed on growth during the whole period, but higher mortality was observed in the N group compared with the T group. A temporary decrease of Zn serum concentration was observed after weaning in pigs fed the N diet (0.95, 0.67 and 1.07 mg/L on d 0, 7 and 35, respectively), whereas T piglets increased Zn concentration (0.95, 1.20, 1.31 mg/L, on d 0, 7 and 35, respectively; $P < 0.001$). When T piglets were moved to the growing barns showed a decrease of Zn concentration (1.05 mg/L on d 49) while the N piglets showed a recuperation of Zn status to physiological levels (1.20 mg/L on d 49). These results might indicate a drop of blood Zn levels and an increase on mortality when therapeutic doses of Zn are removed and low CP diet is used, suggesting the need of using new, more efficient Zn compounds.

Key Words: ZnO, Zn status, piglet

M197 Prediction equation to estimate digestible energy content of crude glycerin for swine based on chemical composition.

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The energy value of crude glycerin (CG) from a palm oil biodiesel facility was determined in growing pigs to estimate its digestible energy

(DE) based on chemical composition. The study was conducted using the mobile nylon bag technique (MNBT). Nylon bags were inserted into the duodenum of 8 barrows (average body weight of 57.7 kg) through simple duodenal T-cannulas. Carboxymethylcellulose was used as a carrier of CG. Treatments consisted of a control (carboximethylcellulose) and 15 mixtures containing 10%, 20% and 30% of CG from 5 different batches of biodiesel production. Each batch showed variation in the content of glycerol and it was analyzed for dry matter (DM), gross energy (GE), ether extract (EE), ash, glycerol (GLY), pH and acid index (AI). Eight bags were administered to each pig daily (2 bags being inserted at 8, 10:30, 13:00 and 15:30 h into each of the 8 barrows). Sixteen nylon bags were prepared for each mixture (one gram per bag) therefore 256 bags were inserted over a 4-d period. The GE of each mixture was determined in a bomb calorimetry. The DE values of each mixture were estimated by difference, where by the DE content of the control was subtracted from each mixture containing CG. A multiple linear regression model was used to determine the value of the DE of CG as the slope relative to the DM of the CG included. The DE values of CG were correlated with its chemical composition and the value ranged from 3264 ± 202 to 3731 ± 202 kcal/kg DM ($P < 0.01$). The prediction model with the lowest AIC (Akaike's information criterion) was selected. DE (kcal/kg as fed) = $[1.29 \times GE$ (kcal/kg as fed)] + $[109.7 \times \text{ash} (\%)] - (19.4 \times GLY)$, (R^2 -adj = 0.999, $P < 0.02$). According to these results, the CG from palm oil biodiesel is a valuable energy source, with DE concentration depending on the concentration of GLY, GE and ash. The DE of crude glycerin was 77.5% of the GE.

Key Words: crude glycerin, digestible energy, prediction