Research Report

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Effects of including two sources of copper hydroxychloride in diets for growing-finishing pigs

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INTRODUCTION

Recent research at the University of Illinois has demonstrated positive effects of copper hydroxychloride on intestinal health and growth performance of weanling pigs (Espinosa et al., 2017; 2019). It is, however, not known if this effect can also be obtained in growing-finishing pigs. It is also not known if the positive effects of copper hydroxychloride is obtained regardless of the origin of the mineral or if it is specific to the product produced by a specific supplier. It was the objective of this research to test the hypothesis that growth performance of growing-finishing pigs is improved by including copper hydroxychloride in the diets and that the origin of the copper hydroxychloride is not important for the outcome.

MATERIALS AND METHODS

Ninety-six pigs (initial BW: 27.7 ± 3.9 kg) were allotted to 3 treatments. There were 4 pigs per pen and 8 replicate pens per treatment for a total of 24 pens. Pigs were housed in an environmentally controlled barn. Water and feed were available to the pigs on an *ad libitum* basis. Pigs were fed grower diets for 35 d, early finisher diets for 28 d, and late finisher diets for 23 d. In each phase, a basal diet primarily based on corn and soybean meal was formulated (Table 1). This diet was formulated to meet requirement estimates for all nutrients (NRC, 2012). Two additional diets were formulated by adding 150 mg per kg of copper hydroxychloride from two different origins to the basal diet. One source of copper hydroxychloride was produced by Chemlock Nutrition (Cincinnati, OH), whereas the other source of copper hydroxychloride was produced by Micronutrients (Indianapolis, IN). All diets were provided in mash form.

Individual pig weights were recorded at the start of the experiment and at the end of each of the 3 phases. Daily feed allotments were recorded and feed left in the feeders at the end of each phase was recorded as well. If a pig was removed from a pen during the experiment, individual pig weights and the weight of the feed in the feeder at the time of removal were recorded, and feed intake and G:F were adjusted according to the procedure described by Lindemann and Kim (2007).

Diets were analyzed for DM by oven drying at 135 °C for 2 h (method 930.15; AOAC Int., 2007), as well as for dry ash (method 942.05; AOAC Int., 2007). Grower diet samples were analyzed for minerals prior to the start of the experiment to confirm inclusion of copper hydroxychloride (Table 2). Calcium, P, Cu, K, Mg, Mn, and Zn concentrations were determined in diet samples by inductively coupled plasma - optical emission spectroscopy (method 985.01 A, B, and C; AOAC Int., 2007) after wet ash sample preparation (method 975.03 B(b); AOAC Int., 2007). Concentrations of Fe and Se were also determined using inductively coupled plasma-optical emission spectroscopy (method 990.08; AOAC Int., 2007). The concentration of S was determined by gravimetric analysis (method 956.01; AOAC Int., 2007). The GE in the diets were measured using an isoperibol bomb calorimeter (Model 6400, Parr Instruments, Moline, IL). The CP was determined by measuring N (method 990.03; AOAC Int., 2007) using a Leco Nitrogen Determinator (model FP628, Leco Corp., St. Joseph, MI). Insoluble dietary fiber and soluble dietary fiber were analyzed according to method 991.43 (AOAC Int., 2007) using an Ankom TDF Fiber Analyzer (Ankom Technology, Macedon, NY). Total dietary fiber was calculated as the sum of soluble dietary fiber and insoluble dietary fiber. Total acid-hydrolyzed ether extract was analyzed by acid hydrolysis using 3*N* HCl (Ankom$_{\text{HCl}}$, Ankom Technology, Macedon, NY) followed by crude fat extraction using petroleum ether (Ankom$_{\text{XT15}}$, Ankom Technology, Macedon, NY).

Normality of data was confirmed and outliers were tested using the UNIVARIATE procedure of SAS (SAS Institute Inc., Cary, NC). Outliers were defined as values that deviate from the treatment mean by more than 3 times the interquartile range. Data were analyzed using the MIXED procedure in SAS. The statistical model included the fixed effect of diet and the random effect of pen. The pen was the experimental unit for all data. Least square means were estimated for each independent variable using the PDIFF statement in PROC MIXED. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

RESULTS

The analyzed composition of diets were within expected ranges (Table 2). The pigs in the study had excellent health status though two pigs died during the study – both pigs were fed the diet with hydroxychloride from source 2 (Micronutrients/Intellibond) and the pigs died in the early finishing period. Another pig, also on the diet containing hydroxychloride from source 2, had to be removed from the study in the early finishing period due to a leg problem. All other pigs showed no signs of health challenges and stayed on experimental diets until the end of the study.

No differences were observed for average BW of pigs at any point in the experiment (Table 3). In the grower phase, pigs fed copper hydroxychloride from source 1 (Chemlock Nutrition, Cincinnati, OH) had greater ($P < 0.05$) ADG than pigs fed the diet without copper hydroxychloride. In contrast, there was no significant improvement of ADG during the grower phase for pigs fed the diet containing copper hydroxychloride source 2. There were no differences among treatments in ADG in the finishing phases, nor for the overall experiment duration. There was a tendency ($P < 0.10$) for pigs fed diets containing copper hydroxychloride source 1 to consume more feed than pigs fed the basal diet during the growing phase, but there were no differences in ADFI during the finishing phases. Gain to feed ratio was not affected by dietary treatment.

The overall ADG and G:F of pigs in the study were excellent and this was likely due to the limited number of pigs per pen and the high health status of pigs used in this experiment. Under commercial conditions, pigs often are health challenged, which results in reduced growth performance compared with what was observed in this experiment. If pigs have intestinal diseases it is possible that copper hydrocychloride will have an even greater positive impact on growth performance than what was observed in this experiment.

In conclusion, pigs fed diets containing copper hydroxychloride tended to eat more during the growing phase, and subsequently, pigs fed copper hydroxychloride from source 1 had greater ADG during this phase. There was no effect of copper hydroxychloride on the growth performance of finishing pigs in the present experiment.

LITERATURE CITED

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Table 1. Ingredient composition of experimental basal diets for pigs in grower, early finisher, and late finisher phases[1]

Ingredient, %	Grower	Early Finisher	Late Finisher
Corn	69.20	74.70	79.85
Soybean meal	25.00	20.00	15.00
Choice white grease	3.00	3.00	3.00
Ground limestone	0.84	0.77	0.70
Dicalcium phosphate	1.05	0.80	0.70
L-Lysine HCl, 78%	0.25	0.17	0.18
DL-Methionine, 98%	0.06	0.00	0.00
L-Threonine, 98%	0.05	0.01	0.02
Sodium chloride	0.40	0.40	0.40
Vitamin-mineral premix[2]	0.15	0.15	0.15

[1]Two diets were formulated in addition to the basal diet for each phase, in which 150 mg/kg of copper, sourced from either Chemlock Nutrition (Cincinnati, OH) or Micronutrients (Indianapolis, IN), was added to the diet in a premix form. Each premix contained 25.88% of one source of copper hydroxychloride (58% Cu) and 74.12% corn and was added to the diet at a rate of 0.10% at the expense of corn.

[2]The vitamin-micromineral premix provided the following quantities of vitamins and micro minerals per kg of complete diet: vitamin A as retinyl acetate, 11,150 IU; vitamin D_3 as cholecalciferol, 2,210 IU; vitamin E as selenium yeast, 66 IU; vitamin K as menadione nicotinamide bisulfate, 1.42 mg; thiamin as thiamine mononitrate, 1.10 mg; riboflavin,6.59 mg; pyridoxine as pyridoxine hydrochloride, 1.00 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.6 mg; niacin, 44.1 mg; folic acid, 1.59 mg; biotin, 0.44 mg; Cu, 20

mg as copper chloride; Fe, 125 mg as iron sulfate; I, 1.26mg as ethylenediamine dihydriodide; Mn, 60.2 mg as manganese hydroxychloride; Se, 0.30mg as sodium selenite and selenium yeast; and Zn, 125.1mg as zinc hydroxychloride.

Table 2. Chemical composition of experimental diets containing no added copper hydroxychloride, a diet containing 150 mg/kg copper hydroxychloride from source 1 (Chemlock Nutrition, Cincinnati, OH), or a diet containing 150 mg/kg copper hydroxychloride from source 2 (Micronutrients, Indianapolis, IN)

	Grower			Early finisher			Late finisher		
Item	Basal	Source 1	Source 2	Basal	Source 1	Source 2	Basal	Source 1	Source 2
DM, %	88.55	89.28	88.85	88.33	88.23	89.15	86.84	86.70	86.74
Ash, %	4.52	4.39	4.65	4.11	3.97	3.87	3.57	3.38	3.16
GE, kcal/kg	4,035	4,045	4,023	4,032	4,029	4,040	3,986	3,982	4,027
CP, %	16.42	15.79	16.27	14.70	14.63	14.57	12.76	12.43	12.19
AEE[1], %	7.00	7.14	6.86	7.02	6.99	7.28	6.19	5.61	5.45
IDF[2], %	12.10	10.80	11.60	11.10	11.40	11.70	11.10	12.10	13.70
SDF[3], %	0.00	1.50	0.30	0.20	0.10	0.70	2.10	0.60	2.50
TDF[4], %	12.10	12.30	11.90	11.30	11.50	12.40	13.20	12.70	16.20
Ca, %	0.66	0.61	0.66	0.61	0.67	0.66	0.55	0.43	0.47
P, %	0.60	0.54	0.58	0.47	0.47	0.50	0.43	0.47	0.46
Mg, %	0.14	0.13	0.13	0.13	0.13	0.13	0.11	0.12	0.13
K, %	0.77	0.76	0.84	0.71	0.70	0.70	0.60	0.62	0.64
Cu, mg/kg	37	237	232	24	227	255	27	134	150
Mn, mg/kg	86	73	76	79	65	80	73	64	57
Fe, mg/kg	271	266	273	215	216	243	273	224	191
Zn, mg/kg	141	142	138	152	127	146	147	139	128
S, %	0.21	0.20	0.20	0.17	0.17	0.17	0.16	0.15	0.15
Se, mg/kg	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20

[1]AEE = Acid hydrolyzed ether extract.

[2]IDF = Insoluble dietary fiber.

[3]SDF = Soluble dietary fiber.

[4]TDF = Total dietary fiber.

Table 3. Growth performance of pigs fed a basal diet containing no added copper hydroxychloride, a diet containing 150 mg/kg copper hydroxychloride from source 1 (Chemlock Nutrition, Cincinnati, OH), or a diet containing 150 mg/kg copper hydroxychloride from source 2 (Micronutrients, Indianapolis, IN)

Item	Basal	Source 1	Source 2	SEM	*P*-value
BW at d 0, kg	27.68	27.63	27.64	1.304	0.999
BW at d 35, kg	60.54	63.99	62.56	1.869	0.439
BW at d 63, kg	91.11	96.19	93.97	2.402	0.344
BW at d 86, kg	118.88	123.76	121.84	2.670	0.443
ADG d 0 – 35, kg	0.939[b]	1.039[a]	0.998[ab]	0.0243	0.029
ADG d 35 – 63, kg	1.092	1.150	1.127	0.0255	0.291
ADG d 63 – 86, kg	1.207	1.198	1.212	0.0305	0.950
ADG, d 0 – 86, kg	1.060	1.118	1.095	0.0215	0.189
ADFI d 0 – 35, kg	1.684	1.862	1.804	0.0498	0.055
ADFI d 35 – 63, kg	2.629	2.844	2.800	0.1009	0.305
ADFI, d 63 – 86, kg	3.383	3.472	3.382	0.0722	0.608
ADFI, d 0 – 86, kg	2.446	2.612	2.549	0.0576	0.147
G:F d 0 – 35, kg	0.559	0.560	0.554	0.0106	0.905
G:F d 35 – 63, kg	0.419	0.405	0.405	0.0092	0.487
G:F, d 63 – 86, kg	0.357	0.345	0.359	0.0066	0.299
G:F, d 0 – 86, kg	0.435	0.428	0.432	0.0050	0.623

[a-b]Means in a row without a common superscript differ ($P < 0.05$).