Effects of Diet Formulation and Supplementation of an Algoclay Complex-Based Feed Additive in Grow-Finish Diets on Pig Growth Performance and Carcass Characteristics[1,2]

Leandro Del Tuffo, Jason C. Woodworth, Steve S. Dritz,[3] Mike D. Tokach, Joel M. DeRouchey, and Robert D. Goodband

Summary

The objective of this study was to evaluate the effect of feeding an algoclay complex-based feed additive (ACC, Olmix Group, Brehan, France) on growth performance and carcass characteristics of finishing pigs fed two different diet formulation regimens. A total of 1,188 pigs (PIC; 337 × 1050; initially 111.6 lb) were used in a 90-d study. Pens were blocked by initial weight and randomly assigned to diets with 11 pens per treatment and 27 pigs per pen. Dietary treatments were arranged in a 2 × 2 factorial with main effects of ACC addition (none or 0.1% until 220 lb and 0.05% thereafter) and diet formulation regimen (High vs. Low). The High diets were formulated to maximize growth performance and contained 3% added fat with no dried distillers grains with solubles (DDGS). The second feeding regimen (Low) included diets formulated with 70 kcal per lb less net energy, contained 30% DDGS, no added fat, and were formulated 0.10% below the standardized ileal digestible lysine requirement based on the same SID Lys:NE ratio used in the High diets.

For overall performance, there were no interactions observed between diet formulation and added ACC for growth performance criteria, carcass data, or economics. From d 56 to 90, pigs fed the ACC diets had increased ($P < 0.001$) average daily gain (ADG) and improved ($P = 0.016$) feed efficiency (F/G) compared with the control fed pigs. Overall, ADG was greater ($P = 0.027$) for pigs fed ACC diets compared with those fed diets without ACC. Overall, pigs fed High diets had improved growth performance and heavier weights than pigs fed Low diets. For carcass characteristics, pigs fed High diets tended to have greater ($P = 0.062$) loin depth and greater ($P < 0.001$) carcass weight than pigs fed Low diets. No evidence for differences was observed for carcass

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[3] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

characteristics between the control and the ACC fed pigs. For economic analysis, pigs fed High diets had increased feed cost and feed cost per lb gain, but also had greater revenue and income over feed cost (IOFC). No evidence for differences ($P > 0.05$) were observed for feed cost, feed cost per lb of gain, revenue, or IOFC between pigs fed diets with or without ACC. In conclusion, the addition of ACC to finishing diets showed an improvement in growth performance but no differences were observed in the economic analysis. Feeding the High dietary regimen increased feed costs per pig, but the improvements in growth performance offset the added cost and improved IOFC compared with those pigs fed the Low diets.

Introduction

With a constant interest on improving income over feed costs, research has evaluated different enzyme additives—such as proteases, amylases, and phytases—to improve growth performance and increase profitability. An important factor to consider on nutrient digestibility is the enzyme activity within the gastrointestinal tract, and whether it can be modulated with the addition of specific feed additives. In the last decade, several studies have shown the ability of clay-derived compounds to improve digestive enzymes activity through the formation of stable clay-enzyme complexes, therefore, improving nutrient digestibility.[4,5] The ACC used in this trial contains diverse metallic ions that are required cofactors for enzymatic activity. A previous study from France showed that the ACC could increase ileal digestibility of energy and essential amino acids; however, it has never been tested under commercial conditions to determine its influence on growth performance. Therefore, the objective of this study was to determine the effects of adding ACC in diets formulated to maximize growth performance or at a lower nutrient fortification on growth performance and carcass characteristics of grow-finish pigs housed in a commercial research facility.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research-finishing site in southwest Minnesota. The barn was naturally ventilated and double-curtain-sided. Each pen was equipped with a 5-hole stainless steel feeder and bowl waterer for *ad libitum* access to feed and water. Feed additions to each individual pen were made and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN).

A total of 1,188 pigs (PIC; 337 × 1050; initially 111.6 lb) were used in a 90-d study. Pens were blocked by BW and randomly assigned to diets with 11 pens per treatment and 27 pigs per pen. Dietary treatments were arranged in a 2 × 2 factorial with main effects of diet formulation regimen (High or Low) and ACC addition (none or 0.1% until 220 lb of BW and 0.05% thereafter; MFeed+, Olmix Group, Brehan, France).

The diets (Table 1) were corn-soybean-based and provided in three phases from d 0 to 28, 28 to 56, and 56 to 90. Diets fed to maximize growth performance (High) were

[4] Cabezas, M. J., D. Salvador, and J. V. Sinisterra. 1991. Stabilization-activation of pancreatic enzymes adsorbed on to a sepiolite clay. *J. Chem. Tech. Biotechnol. 52:* 265-274.

[5] Parisini, P., G. Marttelli, L. Sardi, and F. Escribano. 1999. Protein and energy retention in pigs fed diets containing sepiolite. Anim. Feed Sci. Technol. 79:155-162.

formulated to contain 3% added fat with no DDGS. The other dietary regimen (Low) was formulated to have 70 kcal per lb less net energy, contained 30% DDGS, no added fat, and was formulated 0.10% below the standardized ileal digestible lysine requirement based on the same SID Lys:NE ratio as used in the High diets.

Pens of pigs were weighed, and feeder measurements were recorded on d 0, 13, 28, 42, 56, 75, and 90 to calculate ADG, average daily feed intake (ADFI), and F/G. On day 75, the 3 heaviest pigs in each pen were weighed and marketed according to the normal farm marketing strategy. On d 90, final pen weights were recorded and pigs were tattooed with a pen identification number and transported to a USDA-inspected packing plant (JBS Swift and Co., Worthington, MN) for processing and carcass data collection. Carcass measurements included hot carcass weight (HCW), backfat, loin depth, and percentage lean. Percentage lean was calculated from a plant proprietary equation. Carcass yield was calculated by dividing the pen average HCW by the pen average final live weight obtained at the farm.

For the economic analysis, feed cost per pig, feed cost per lb of gain, revenue per pig, and income over feed cost (IOFC) were calculated on a pen basis. Corn was valued at $3.25/bu ($116/ton), soybean meal at $290/ton, DDGS at $130/ton, L-lysine at $0.69/lb, DL-methionine at $1.20/lb, L-threonine at $0.89/lb, L-tryptophan at $3.90/lb, and ACC at $1.87/lb. Feed cost per pig was calculated by multiplying the feed cost per lb by ADFI and by the number of days in each phase, then adding up the values of each phase. Feed cost per lb of gain was calculated by dividing the feed cost per pig by the overall weight gain. Revenue was obtained by multiplying carcass gain by an assumed value of $70 per cwt of carcass. The IOFC was calculated by subtracting the feed cost per pig from revenue per pig.

Data were analyzed using the GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) in a randomized complete block design with pen as experimental unit. The treatments were analyzed as a 2 × 2 factorial with main effects of diet regimen (High vs. Low), and ACC inclusion (none or 0.1% until 220 lb of body weight and 0.05% thereafter) and their interactions on growth performance and carcass characteristics. A linear mixed model was used with treatment as fixed effect and block as random effect. Hot carcass weight was used as a covariate for analyses of backfat, loin depth, and lean percentage. Results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P < 0.10$.

Results and Discussion

The analyzed DM, total lysine, Ca, and P content of the experimental diets (Table 2) were consistent with formulated estimates. A mycotoxin analysis was performed on phase 3 diets and results showed values below practical quantification limits for all mycotoxins except for vomitoxin, which ranged from 416 to 747 ppb for treatment diets.

There was a significant diet formulation by ACC treatment interaction ($P = 0.014$) for ADFI from d 0 to 28. Pigs fed High diets without ACC had greater ADFI than pigs fed High diets with ACC (Table 3). However, pigs fed Low diets with ACC had greater ADFI than pigs fed Low diets without ACC. No evidence for interactions ($P > 0.05$)

between formulation method and ACC were observed for the other growth performance criteria, carcass data, or economics.

Throughout the study, pigs fed High diets were heavier ($P < 0.001$) than pigs fed Low diets (Table 3 and main effects Table 4). Also, for all three phases, pigs fed High diets had greater ($P < 0.001$) ADG and better ($P < 0.001$) F/G than pigs fed Low diets. Moreover, in phase 3 (d 56 to 90) pigs fed High diets had decreased ADFI compared with pigs fed Low diets. Overall, pigs fed High diets had greater ($P < 0.001$) ADG, decreased ($P < 0.047$) ADFI and better ($P <0.001$) F/G than pigs fed Low diets.

In phase 1 and 2 (d 0 to 28 and 28 to 56, respectively), there was no evidence ($P > 0.05$) for an ACC effect on growth performance. From d 56 to 90, pigs fed diets with ACC had increased ($P < 0.001$) ADG and improved ($P = 0.016$) F/G compared with pigs fed diets without ACC. There was a tendency ($P = 0.063$) for heavier weights on d 75 for pigs fed ACC diets. Also, a tendency ($P = 0.070$) for heavier final weight (d 90) was observed for pigs fed ACC diets. Overall, ADG was greater ($P = 0.027$) for pigs fed ACC diets compared with pigs fed diets without ACC.

For carcass characteristics, pigs fed High diets had marginally ($P = 0.062$) greater loin depth and greater ($P < 0.001$) carcass weight than pigs fed Low diets. No evidence for differences ($P > 0.05$) were observed for carcass yield, backfat thickness, loin depth, or percentage lean for pigs fed ACC. Mortality and percentage of pigs removed from the study due to poor growth were not different between treatments.

For economics, pigs fed High diets had greater ($P < 0.001$) feed cost and feed cost per lb of gain, but also greater ($P < 0.001$) revenue and IOFC per pig than pigs fed Low diets. No evidence for differences ($P > 0.05$) was observed for feed cost per lb of gain, revenue, and IOFC between the diets with and without ACC.

In conclusion, feeding diets formulated with higher lysine, added fat, and no DDGS had improved growth performance and IOFC as expected, compared with pigs fed the low-energy-low lysine diets. The addition of ACC resulted in an improvement in growth performance; however, because of numerical reductions in yield, this difference was not reflected in hot carcass weight. Consequently, the economic analysis showed no differences due to ACC addition. Additional research is necessary to confirm the improvement in growth performance with the addition of ACC.

Table 1. Diet composition (as-fed basis)[1]

	Dietary phase					
	1		2		3	
Item	High[2]	Low[3]	High	Low	High	Low
Ingredient, %						
Corn	68.13	59.52	74.91	65.38	77.79	67.55
Soybean meal	26.47	8.01	19.80	2.27	16.99	0.22
DDGS, 8% oil[4]	-	30.00	-	30.00	-	30.00
Beef tallow	3.00	-	3.00	-	3.0	-
Calcium phosphate	0.50	0.09	0.40	-	0.40	-
Limestone	0.97	1.23	0.98	1.23	0.88	1.10
Sodium chloride	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine-HCl	0.28	0.53	0.28	0.50	0.29	0.50
DL-Methionine	0.06	-	0.03	-	0.03	-
L-Threonine	0.09	0.09	0.09	0.07	0.11	0.08
L-Tryptophan	0.001	0.04	0.01	0.04	0.01	0.04
Phytase[5]	0.01	0.01	0.01	0.01	0.01	0.01
Vitamin and mineral premix[6]	0.15	0.15	0.15	0.15	0.15	0.15
ACC[7]	+/-	+/-	+/-	+/-	+/-	+/-
Total	100	100	100	100	100	100

continued

Table 1. Diet composition (as-fed basis)[1]

	Dietary phase					
	1		2		3	
Item	High[2]	Low[3]	High	Low	High	Low
Calculated analysis						
Standard ileal digestible (SID) amino acids %						
Lysine, %	1.04	0.88	0.88	0.72	0.82	0.67
Isoleucine:lysine	64	60	62	60	61	60
Methionine:lysine	31	31	29	35	29	36
Methionine and cystine:lysine	56	60	56	66	56	69
Threonine:lysine	63	63	64	64	66	66
Tryptophan:lysine	18.5	18.5	18.5	18.5	18.5	18.5
Valine:lysine	70	74	70	78	70	79
Total lysine, %	1.17	1.04	0.99	0.86	0.93	0.81
Net energy, kcal/lb	1,209	1,139	1,219	1,148	1,225	1,152
SID Lysine:NE, g/Mcal	3.01	2.68	2.54	2.19	2.36	2.03
Crude protein, %	17.7	17.0	15.0	14.6	13.9	13.8
Calcium, %	0.53	0.53	0.50	0.50	0.45	0.45
Standard digestible P, %	0.33	0.33	0.30	0.30	0.29	0.29

[1]Phase 1, 2, and 3 were fed in meal form from d 0 to 28, 28 to 56, and 56 to 90, respectively.
[2]Diets formulated to maximize growth performance, with 3% added fat and no dried distillers grains with solubles (DDGS).
[3]Diets formulated with 70 kcal per lb of feed less net energy (NE), no added fat, 30% DDGS and formulated 0.10% below the standardized ileal digestible lysine requirement based on the same SID Lys:NE ratio used in the High diets.
[4]DDGS = dried distillers grains with solubles.
[5]Optiphos 2000 (Huvepharma, Sofia, Bulgaria) provided an estimated release of 0.10% digestible P for phase 1, 2, and 3.
[6]Vitamin and trace mineral premix provided per lb of diet: 111 ppm Zn, 111 ppm Fe, 33 ppm Mn, 17 ppm Cu, 0.33 ppm I, 0.30 ppm Se, 2,400 IU vitamin A, 600 IU vitamin D, 12 IU vitamin E, 1.2 mg vitamin K, 22.5 mg niacin, 7.5 mg pantothenic acid, 2.25 mg riboflavin, and 10.5 μg vitamin B12.
[7]An algoclay complex-based feed additive (ACC; Olmix Group, Brehan, France) was added to the ACC diets at 0.1% in phase 1 and 2, and 0.05% in phase 3.

Table 2. Chemical analysis of experimental diets (as-fed basis), %[1]

	Phase 1				Phase 2				Phase 3			
	High[2]		Low[3]		High		Low		High		Low	
Item[4,5]	No	Yes[4]	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
DM	88.0	88.0	89.1	89.0	88.1	87.9	89.0	89.0	88.0	88.0	88.8	88.8
Total Lys	1.08	1.09	1.04	1.03	1.00	0.94	0.89	0.83	0.92	0.89	0.83	0.84
Ca	0.82	0.75	0.58	0.71	0.56	0.63	0.52	0.47	0.50	0.63	0.44	0.54
P	0.44	0.44	0.46	0.45	0.39	0.37	0.41	0.41	0.37	0.35	0.38	0.40

[1]Diet samples were collected at manufacturing and composite samples were submitted for analysis to Ward Laboratories, Inc. (Kearney, NE).
[2]Diets formulated to maximize growth performance, with 3% added fat and no dried distillers grains with solubles (DDGS).
[3]Diets formulated with 70 kcal per lb of feed less net energy (NE), no added fat, 30% DDGS and formulated 0.10% below the standardized ileal digestible lysine requirement based on the same SID Lys:NE ratio used in the High diets.
[4]An algoclay complex-based feed additive (ACC; Olmix Group, Brehan, France) was added to the ACC diets at 0.1% until 220 lb and 0.05% thereafter.
[5]DM = dry matter. Lys = lysine. Ca = calcium. P = phosphorus.

Table 3. Effects of diet formulation and addition of ACC on growth and carcass characteristics of finishing pigs[1]

	High[2]		Low[3]			Probability, P<		
Item	No[4]	Yes[5]	No	Yes	SEM	ACC × Regimen	Regimen	ACC
Weight, lb								
d 0	108.8	108.7	109.3	109.4	1.94	0.815	0.093	0.938
d 28	168.6	168.2	163.6	164.9	2.26	0.234	<0.001	0.548
d 56	226.8	227.9	216.1	216.9	2.46	0.924	<0.001	0.481
d 90	296.4	299.6	279.6	282.4	2.62	0.907	<0.001	0.070
d 0 to 28								
ADG, lb	2.14	2.12	1.94	1.98	0.025	0.167	<0.001	0.565
ADFI, lb	4.66	4.58	4.55	4.68	0.060	0.014	0.848	0.486
F/G	2.18	2.16	2.34	2.36	0.022	0.227	<0.001	0.985
d 28 to 56								
ADG, lb	2.07	2.12	1.85	1.85	0.036	0.456	<0.001	0.598
ADFI, lb	5.46	5.52	5.52	5.59	0.064	0.923	0.317	0.305
F/G	2.64	2.61	2.99	3.03	0.040	0.382	<0.001	0.806
d 56 to 90								
ADG, lb	2.10	2.17	1.96	2.04	0.024	0.895	<0.001	0.001
ADFI, lb	6.58	6.69	6.84	6.87	0.064	0.555	0.001	0.246
F/G	3.14	3.08	3.50	3.38	0.044	0.398	<0.001	0.016
d 0 to 90								
ADG, lb	2.10	2.14	1.92	1.96	0.017	0.911	<0.001	0.027
ADFI, lb	5.61	5.64	5.68	5.76	0.047	0.559	0.047	0.228
F/G	2.67	2.64	2.96	2.94	0.025	0.779	<0.001	0.191

continued

Table 3. Effects of diet formulation and addition of ACC on growth and carcass characteristics of finishing pigs[1]

	High[2]		Low[3]			Probability, P<		
Item	No[4]	Yes[5]	No	Yes	SEM	ACC × Regimen	Regimen	ACC
Carcass data								
HCW, lb	216.6	217.4	204.8	204.6	2.03	0.755	<0.001	0.838
Yield, %	73.1	72.6	73.3	72.5	0.41	0.715	0.908	0.146
Backfat, in[6]	0.68	0.66	0.67	0.69	0.013	0.344	0.204	0.984
Loin depth, in[6]	2.84	2.83	2.80	2.78	0.021	0.639	0.062	0.623
Lean, %[6]	57.1	57.3	57.0	56.7	0.23	0.353	0.116	0.908
Economics, $ per pig[7]								
Feed cost	45.14	46.12	37.33	38.59	0.348	0.668	<0.001	0.261
Feed cost per lb gain[8]	0.24	0.24	0.22	0.22	0.002	0.625	<0.001	0.261
Revenue[9]	94.5	95.1	86.0	85.9	1.04	0.713	<0.001	0.841
IOFC[10]	49.4	49.0	48.6	47.2	0.95	0.570	<0.001	0.838

[1]A total of 1,188 pigs (initial weight = 111.6 lb) were used in a 90-d study with 27 pigs per pen and 11 replicates per treatment.
[2]Diets formulated to maximize growth performance, with 3% added fat and no dried distillers grains with solubles (DDGS).
[3]Diets formulated 70 kcal per pound of feed below the requirement estimates for net energy with no added fat, 30% DDGS and were formulated 0.10% below the standardized ileal digestible lysine requirement based on the SID Lys:NE ratio as estimated in the High diets.
[4]Diets with no addition of an algoclay complex-based feed additive (ACC).
[5]ACC (Olmix Group, Brehan, France) was added to the ACC diets at 0.1% until 220 lb and 0.05% thereafter.
[6]Adjusted for hot carcass weight (HCW).
[7]Corn was valued at $3.25/bu ($116/ton), soybean meal at $290/ton, DDGS at $130/ton, and L-lysine at $0.69/lb.
[8]Feed cost per lb gain = feed cost per pig ÷ overall gain per pig.
[9]Revenue = (HCW × $0.70) – (d 0 BW × 0.75 × $0.70).
[10]Income over feed cost = revenue – feed cost.

Table 4. Main effects of diet formulation and addition of ACC on growth and carcass characteristics of finishing pigs[1]

	Regimen				ACC[4]			
Item	High[2]	Low[3]	SEM	*P*-value	No	Yes	SEM	*P*-value
Weight, lb								
d 0	108.8	109.4	1.929	0.093	109.0	109.1	1.929	0.938
d 28	168.4	164.3	2.205	<0.001	166.1	166.6	2.205	0.548
d 56	227.4	216.5	2.278	<0.001	221.5	222.4	2.278	0.481
d 90	298.0	281.0	2.375	<0.001	288.0	291.0	2.375	0.070
d 0 to 28								
ADG, lb	2.13	1.96	0.020	<0.001	2.04	2.05	0.020	0.565
ADFI, lb	4.62	4.62	0.053	0.848	4.60	4.63	0.053	0.486
F/G	2.17	2.35	0.019	<0.001	2.26	2.26	0.019	0.985
d 28 to 56								
ADG, lb	2.09	1.85	0.025	<0.001	1.96	1.98	0.025	0.598
ADFI, lb	5.49	5.55	0.045	0.317	5.49	5.56	0.045	0.305
F/G	2.63	3.01	0.030	<0.001	2.81	2.82	0.030	0.806
d 56 to 90								
ADG, lb	2.14	2.00	0.019	<0.001	2.03	2.11	0.019	<0.001
ADFI, lb	6.64	6.86	0.048	0.001	6.71	6.78	0.048	0.246
F/G	3.11	3.44	0.036	<0.001	3.32	3.23	0.036	0.016
d 0 to 90								
ADG, lb	2.12	1.94	0.012	<0.001	2.01	2.05	0.012	0.027
ADFI, lb	5.62	5.72	0.035	0.047	5.64	5.70	0.035	0.228
F/G	2.65	2.95	0.021	<0.001	2.82	2.79	0.021	0.191

continued

Table 4. Main effects of diet formulation and addition of ACC on growth and carcass characteristics of finishing pigs[1]

	Regimen				ACC[4]			
Item	High[2]	Low[3]	SEM	*P*-value	No	Yes	SEM	*P*-value
Carcass data								
HCW, lb	217.0	204.7	1.722	<0.001	210.7	211.0	1.722	0.838
Yield, %	72.8	72.9	0.292	0.908	73.2	72.5	0.350	0.146
Backfat, in[5]	0.66	0.68	0.009	0.204	0.67	0.67	0.009	0.984
Loin depth, in[5]	2.84	2.79	0.015	0.062	2.82	2.81	0.015	0.623
Lean, %[5]	57.2	56.8	0.177	0.116	57.1	57.0	0.173	0.908
Economics, $ per pig[5]								
Feed cost[6]	45.6	38.0	0.262	<0.001	41.2	42.4	0.262	0.002
Feed cost per lb gain[7]	0.24	0.22	0.001	<0.001	0.23	0.23	0.001	0.261
Revenue[8]	94.8	85.9	0.762	<0.001	90.3	90.5	0.762	0.841
IOFC[9]	49.2	48.0	0.705	0.174	49.0	48.1	0.705	0.321

[1]A total of 1,188 pigs (initial weight = 111.6 lb) were used in a 90-d study with 27 pigs per pen and 11 replicates per treatment.
[2]Diets formulated to maximize growth performance, with 3% added fat and no dried distillers grains with solubles (DDGS).
[3]Diets formulated 70 kcal per pound of feed below the requirement estimates for net energy with no added fat, 30% DDGS and were formulated 0.10% below the standardized ileal digestible lysine requirement based on the SID Lys:NE ratio as estimated in the High diets.
[4]An algoclay complex-based feed additive (ACC; Olmix Group, Brehan, France) was added to the ACC diets at 0.1% until 220 lb and 0.05% thereafter.
[5]Adjusted for hot carcass weight (HCW).
[6]Corn was valued at $3.25/bu ($116/ton), soybean meal at $290/ton, DDGS at $130/ton, and L-lysine at $0.69/lb.
[7]Feed cost per lb gain = feed cost per pig ÷ overall gain per pig.
[8]Revenue = (HCW × $0.70) – (d 0 BW × 0.75 × $0.70).
[9]Income over feed cost = revenue – feed cost.