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Effects of Varying Lipid Sources as Alternatives to Zinc Oxide or Carbadox on Nursery Pig Growth Performance and Fecal Consistency

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Abstract

A total of 360 weaned pigs (DNA; 241 × 600; initially 11.9 ± 0.02 lb) were used in a 35-d study evaluating the ability of varying lipid sources to replace ZnO or carbadox in early nursery pig diets. Pigs were weaned at approximately 21 days of age and allotted to pens based on initial weight in a completely randomized design to one of six dietary treatments: 1) Negative control (no added ZnO or carbadox); 2) Control + 3,000 ppm Zn from ZnO in phase 1 and 2,000 ppm Zn in phase 2; 3) Control + 50 g/ton carbadox; 4) Control + 1% C6:C8:C10 medium chain fatty acid (MCFA) blend; 5) Control + 1% Proprietary Oil Blend (Feed Energy Corp., Des Moines, IA); and 6) Control + 1% monolaurate blend (FORMI GML from ADDCON, Bitterfeld- Wolfen, Germany). There were 6 pigs assigned to each of the 10 replicate pens per treatment. All experimental diets were isocaloric, with choice white grease used to balance the energy level. From d 0 to 19, pigs fed the ZnO or carbadox diets had greater ($P < 0.05$) average daily gain (ADG) than pigs fed the control or Feed Energy oil blend, with pigs fed the MCFA blend or FORMI GML intermediate. These effects were mostly driven by feed intake, which was greater ($P < 0.05$) in pigs fed diets containing ZnO or carbadox than by pigs fed diets containing the 1% MCFA or Feed Energy oil blends. Dietary treatment had a marginally significant effect ($P > 0.078$) on feed efficiency (F/G), with the best feed efficiency for pigs fed carbadox and the poorest feed efficiency in pigs fed the control diet. Both ZnO and carbadox improved ($P < 0.05$) fecal consistency during the treatment period. In summary, ZnO and carbadox continue to be valuable additives to maximize growth in early nursery pig diets. Some lipid products, such as the monolaurate-containing FORMI GML, show greater promise to replace these antimicrobials than others. These findings suggest that additional research is warranted to identify optimal lipid blends that can replace feed-based antimicrobials in early nursery pig diets without negatively impacting fecal consistency or feed intake.

Keywords

lipid sources, nursery pig, antibiotic alternatives, carbadox

Cover Page Footnote

Appreciation is expressed to ADDCON (Bitterfeld-Wolfen, Germany) for partial financial support of this research.

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Effects of Varying Lipid Sources as Alternatives to Zinc Oxide or Carbadox on Nursery Pig Growth Performance and Fecal Consistency[1]

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Summary

A total of 360 weaned pigs (DNA; 241 × 600; initially 11.9 ± 0.02 lb) were used in a 35-d study evaluating the ability of varying lipid sources to replace ZnO or carbadox in early nursery pig diets. Pigs were weaned at approximately 21 days of age and allotted to pens based on initial weight in a completely randomized design to one of six dietary treatments: 1) Negative control (no added ZnO or carbadox); 2) Control + 3,000 ppm Zn from ZnO in phase 1 and 2,000 ppm Zn in phase 2; 3) Control + 50 g/ton carbadox; 4) Control + 1% C6:C8:C10 medium chain fatty acid (MCFA) blend; 5) Control + 1% Proprietary Oil Blend (Feed Energy Corp., Des Moines, IA); and 6) Control + 1% monolaurate blend (FORMI GML from ADDCON, Bitterfeld-Wolfen, Germany). There were 6 pigs assigned to each of the 10 replicate pens per treatment. All experimental diets were isocaloric, with choice white grease used to balance the energy level. From d 0 to 19, pigs fed the ZnO or carbadox diets had greater ($P < 0.05$) average daily gain (ADG) than pigs fed the control or Feed Energy oil blend, with pigs fed the MCFA blend or FORMI GML intermediate. These effects were mostly driven by feed intake, which was greater ($P < 0.05$) in pigs fed diets containing ZnO or carbadox than by pigs fed diets containing the 1% MCFA or Feed Energy oil blends. Dietary treatment had a marginally significant effect ($P > 0.078$) on feed efficiency (F/G), with the best feed efficiency for pigs fed carbadox and the poorest feed efficiency in pigs fed the control diet. Both ZnO and carbadox improved ($P < 0.05$) fecal consistency during the treatment period. In summary, ZnO and carbadox continue to be valuable additives to maximize growth in early nursery pig diets. Some lipid products, such as the monolaurate-containing FORMI GML, show greater promise to replace these antimicrobials than others. These findings suggest that additional research is warranted to identify optimal lipid blends that can replace feed-based antimicrobials in early nursery pig diets without negatively impacting fecal consistency or feed intake.

[1] Appreciation is expressed to ADDCON (Bitterfeld-Wolfen, Germany) for partial financial support of this research.

Introduction

Antimicrobial agents, such as ZnO and carbadox have been utilized for decades to improve nursery pig health and growth performance, with one of the possible mechanisms being that they may prevent and control disease. Despite the benefits of these products, there is consumer and regulatory pressure to reduce the use of heavy metals and feed-based antibiotics. Carbadox is disallowed in most European pork production, and regulations are pending to prevent the use of high levels of ZnO due to environmental or health concerns. Within the United States, both feed additives are allowed and strictly regulated by the U.S. Food and Drug Administration to avoid the risk of potential residues and to maintain environmental and consumer health. However, as consumer pressure mounts to remove both from modern pork production, the swine industry is searching for antimicrobial replacements that can yield the same positive effects, while avoiding any negative consequences. Controlled research has reported increased growth performance when various lipid-based additives, such as MCFA, are fed in mid-to-late-nursery diets, even in the absence of health challenges.[2,3,4] However, field research has shown mixed results, especially when supplementation begins in early nursery. Therefore, the objective of this study was to evaluate the effectiveness of three different lipid-based additives as replacements for ZnO and carbadox on growth performance and fecal consistency in early nursery swine diets.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol for this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS.

A total of 360 weaned pigs (DNA; 241 × 600; initially 11.9 ± 0.02 lb) were used in a 35-d experiment with 6 pigs per pen and 10 replicate pens per treatment. Each pen provided *ab libitum* access to feed and water. Upon weaning at approximately 21 d of age, pigs were individually weighed and allotted to pens based on weight in a completely randomized design to 1 of 6 dietary treatments: 1) Control (no added ZnO or carbadox); 2) Control + 3,000 ppm Zn from ZnO in phase 1 and 2,000 ppm Zn in phase 2; 3) Control + 50 g/ton carbadox; 4) Control + 1% blend of C6:0, C8:0, and C10:0 in a 1:1:1 blend (MCFA); 5) Control + 1% Proprietary vegetable oil blend (Feed Energy Corp., Des Moines, IA); and 6) Control + 1% FORMI GML (ADDCON, Bitterfeld-Wolfen, Germany). Diets were fed in 3 phases: phase 1 from d 0 to 7, phase 2 from d 7 to 19, and phase 3 from d 19 to 42. Phase 3 was a common diet fed to all pigs. Diets were made at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS, and fed in pelleted form in phase 1 and meal form in phases 2

[2] Cochrane, R. A., S. S. Dritz, J. C. Woodworth, A. R. Huss, C. R. Stark, M. Saensukjaroenphon, J. M. DeRouchey, M. D. Tokach, R. D. Goodband, J. F. Bai, Q. Chen, J. Zhang, P. C. Gauger, R. J. Derscheid, R. G. Main, and C. K. Jones. 2017. Assessing the effects of medium chain fatty acids and fat sources on PEDV RNA stability and infectivity. J. Anim. Sci. 95(2):94.

[3] Thomson, K. A., J. T. Gebhardt, A. B. Lerner, J. C. Woodworth, M.D. Tokach, J. M. DeRouchey, B. D. Goodband, and S.S. Dritz. 2018. Evaluation of medium chain fatty acids as a dietary additive in nursery pig diets. J. Anim. Sci. 96(2): 252-253.

[4] Thomas, L. L., H. E. Williams, J. C. Woodworth, M. D. Tokach, R. D. Goodband, S. S. Dritz, J. M. DeRouchey, and D. Mellick. 2019. Evaluation of a medium chain fatty acid-based feed additive for nursery pigs. J. Anim. Sci. 97(2):72-73.

and 3. Diets were blended and analyzed for proximate analysis and fatty acid profile at Midwest Laboratories, Omaha, NE.

Pigs and feeders were weighed on d 0, 7, 19, and 35 to determine ADG, average daily feed intake (ADFI), and F/G. Fecal scoring was conducted by two independent, trained scorers on d 0, 1, 2, 7, 14, 19, 28, and 35 to categorize the consistency of piglet feces per pen. Fecal scoring was categorized as a numerical scale from 1 to 5 as follows: 1, hard pellet-like feces; 2, firm formed stool; 3, soft moist stool that retains shape; 4, soft unformed; and 5, watery liquid stool. Data were analyzed using the GLIMMIX procedure of SAS (v 9.4, SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Results were considered significant if $P \leq 0.05$ and marginally significant if $0.05 > P \leq 0.10$.

Results and Discussion

In the first week post-weaning, pigs fed diets containing carbadox had greater ($P < 0.05$) ADG than those fed the MCFA or Feed Energy vegetable oil blends. Feed intake was greater ($P < 0.05$) when pigs were fed diets supplemented with ZnO compared to those with the MCFA or Feed Energy vegetable oil blend. This led to a marginally significant impact of diet on F/G from d 0 to 7, with the best F/G occurring in pigs fed carbadox or FORMI GML and the poorest F/G in pigs fed the MCFA blend. In phase 2 (d 7 to 19), pigs fed diets containing ZnO had greater ($P < 0.05$) ADG than those fed either the control or diets containing the MCFA or Feed Energy vegetable oil blends. This was due to pigs fed the ZnO diet having greater ($P < 0.05$) ADFI than those fed the MCFA or Feed Energy vegetable oil blends. Feed efficiency was best ($P < 0.05$) for pigs fed the diet with MCFA and poorest for those fed the control diet with others intermediate. During the entire treatment period (d 0 to 19), pigs fed diets containing ZnO or carbadox had greater ($P < 0.05$) ADG than those fed control diets or diets containing the Feed Energy vegetable oil blend. There was a substantial feed intake improvement ($P < 0.05$) in pigs fed diets containing ZnO compared to those fed control diets or the MCFA or Feed Energy vegetable oil blends, but there was no overall difference in feed efficiency during the treatment period.

As expected, there were no discernable differences ($P > 0.10$) between treatments in pigs fed common diets during phase 3 (d 19 to 35). However, there was sufficient difference in early growth performance to cause significant differences in overall ADG and ADFI from d 0 to 35. While all treatments had pigs starting with the same average weight, up to 0.7 lb difference in body weight was observed among treatments just one week post-weaning. By the end of the 35-d experiment, pigs fed diets containing ZnO or carbadox were at least 2.3 or 1.6 lb heavier than those fed control diets or diets containing the MCFA or Feed Energy vegetable oil blends.

Initial fecal scoring on d 0 of the experiment showed similar fecal scores for all pigs at placement. However, on d 1, 2, 7, 14, and 19, pigs fed the ZnO and carbadox treatment had significantly lower ($P < 0.05$) fecal scores when compared to those fed the control diet or diets containing MCFA blend, Feed Energy vegetable oil blend, or FORMI GML. Upon transitioning pigs to the phase 3 common diet on d 21, fecal scores were standardized across treatment.

In conclusion, these results show that ZnO and carbadox are valuable additives to help maximize performance in the early nursery period. Some lipid-containing feed additives, such as FORMI GML, may result in similar performance as these antimicrobials, while others may reduce feed intake and subsequent growth when included in early nursery diets. Thus, additional research is warranted to further study the effectiveness of different types of lipids to replace ZnO or feed-based antibiotics.

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

Item	Phase 1	Phase 2	Phase 3
Ingredient, %			
Corn	44.80	56.70	65.60
Soybean meal, 46.5% CP	18.10	29.10	30.20
Spray dried whey	25.00	10.00	---
Fish meal	4.50	---	---
Fermented soybean meal[2]	3.75	---	---
Monocalcium phosphate, 21% P	0.30	0.90	0.95
Limestone	0.25	0.98	1.00
Sodium chloride	0.30	0.55	0.58
L-Lysine	0.43	0.50	0.55
DL-Methionine	0.23	0.21	0.23
L-Threonine	0.21	0.24	0.25
L-Tryptophan	0.06	0.04	0.07
L-Valine	0.11	0.11	0.14
Trace mineral premix	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25
Phytase[3]	0.08	0.08	0.08
Feed additive[4]	Varied	Varied	---
Total	100.0	100.0	100.0

continued

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

Item	Phase 1	Phase 2	Phase 3
Calculated analysis			
Standardized ileal digestibility (SID) amino acids, %			
Lysine	1.40	1.35	1.24
Isoleucine:lysine	56	55	57
Leucine: lysine	109	112	119
Methionine:lysine	38	36	36
Methionine and cystine:lysine	58	57	58
Threonine:lysine	65	65	65
Tryptophan:lysine	20.3	19.1	18.6
Valine:lysine	68	67	67
Metabolizable energy, Mcal/kg	3.42	3.28	3.42
Crude protein, %	21.0	20.6	20.0
SID lysine:ME, g/Mcal	5.43	5.55	3.72
Total lysine, %	1.54	1.48	1.68
Ca, %	0.65	0.75	0.69
P, %	0.64	0.62	0.68
Available P, %	0.55	0.47	0.38

[1]A total of 360 weanling pigs (DNA 241 × 600) were used in a three-phase nursery trial with 6 pigs per pen and 10 replicates per treatment. Treatment diets were fed from d 0 to 7 (phase 1) and d 7 to 19 (phase 2). A common diet was fed from d 19 to 35 (phase 3).
[2]Hamlet Protein 300 (Hamlet Protein, Inc., Findley, OH).
[3]Ronozyme HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) with an assumed release value of 0.12% available P.
[4]Diets included either 1.5% choice white grease (control); 1.5% choice white grease plus 3,000 ppm Zn from ZnO in phase 1 or 2,000 Zn in phase 2; 1.5% choice white grease plus 50 g/ton carbadox (Phibro Animal Health, Teaneck, NJ); 0.5% choice white grease plus 1.0% C6:0, C8:0, and C10:0 in a 1:1:1 blend; 0.5% choice white grease plus 1% Feed Energy proprietary vegetable oil blend (Feed Energy Corp., Des Moines, IA); or 0.5% choice white grease plus 1% FORMI GML (ADDCON GmbH, Bitterfeld-Wolfen, Germany).

Table 2. Chemical analysis of experimental diets[1]

Item	Control	3,000 ppm P1 2,000 ppm P2 Zn from ZnO	50 g/ton carbadox	C6:C8:C10 blend	Vegetable oil blend[2]	FORMI GML[3]
Phase 1						
Dry matter, %	88.4	88.6	89.1	88.6	89.2	88.6
Crude protein, %	20.8	21.0	21.2	20.8	21.1	20.8
P, %	0.70	0.67	0.71	0.72	0.71	0.70
Ca, %	0.97	0.90	1.17	1.00	0.97	0.96
C6:0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C8:0	<0.01	<0.01	<0.01	0.05	0.05	<0.01
C10:0	<0.01	<0.01	<0.01	0.10	0.10	0.01
C12:0	<0.01	<0.01	<0.01	0.05	0.05	0.10
Phase 2						
Dry matter, %	86.9	87.0	87.3	86.7	87.4	86.8
Crude protein, %	21.3	20.5	21.6	21.1	21.8	22.3
P, %	0.66	0.60	0.65	0.65	0.71	0.67
Ca, %	1.25	1.04	1.54	1.15	1.27	0.99
C6:0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C8:0	<0.01	<0.01	<0.01	0.07	<0.01	0.01
C10:0	<0.01	<0.01	<0.01	0.12	<0.01	0.02
C12:0	<0.01	<0.01	<0.01	<0.01	<0.01	0.09
Phase 3						
Dry matter, %	88.3	---	---	---	---	---
Crude protein, %	21.5	---	---	---	---	---
P, %	0.63	---	---	---	---	---
Ca, %	1.08	---	---	---	---	---
C6:0	<0.01	---	---	---	---	---
C8:0	<0.01	---	---	---	---	---
C10:0	<0.01	---	---	---	---	---
C12:0	<0.01	---	---	---	---	---

[1]Complete diet samples were obtained from each dietary treatment and the common phase 3 diet during daily feed additions, representing at least 10 different samples per diet. Samples of diets were pooled and analyzed for dry matter, crude protein, P, Ca, and medium chain fatty acids (Midwest Laboratories Inc., Omaha, NE).
[2]Vegetable oil blend by Feed Energy Corp., Des Moines, IA.
[3]FORMI GML by ADDCON, Bitterfeld-Wolfen, Germany.

Table 3. Effects of ZnO, carbadox, or various lipid additives on nursery pig growth performance[1]

Item[2]	Control	3,000 ppm P1 2,000 ppm P2 Zn from ZnO	50 g/ton carbadox	C6:C8:C10 blend	Vegetable oil blend[3]	FORMI GML[4]	SEM	*P* =
d 0 to 7								
ADG, lb	0.19[abc]	0.21[abc]	0.23[a]	0.12[c]	0.13[bc]	0.22[ab]	0.023	0.003
ADFI, lb	0.25[abc]	0.30[a]	0.26[ab]	0.20[bc]	0.19[bc]	0.26[ab]	0.016	< 0.0001
F/G	1.31	1.43	1.18	1.67	1.46	1.18	0.102	0.055
d 7 to 19								
ADG, lb	0.60[c]	0.76[a]	0.72[ab]	0.65[bc]	0.66[bc]	0.66[abc]	0.025	0.0001
ADFI, lb	0.82[ab]	0.94[a]	0.90[ab]	0.80[b]	0.84[b]	0.84[ab]	0.031	0.004
F/G	1.38[b]	1.24[ab]	1.26[ab]	1.23[a]	1.27[ab]	1.27[ab]	0.111	0.043
d 0 to 19								
ADG, lb	0.44[c]	0.56[a]	0.53[ab]	0.46[bc]	0.43[c]	0.50[abc]	0.019	< 0.0001
ADFI, lb	0.61[b]	0.71[a]	0.66[ab]	0.58[b]	0.56[b]	0.63[ab]	0.023	0.0004
F/G	1.39	1.27	1.25	1.26	1.30	1.26	0.109	0.078
d 19 to 35								
ADG, lb	1.14	1.15	1.17	1.17	1.14	1.14	0.028	0.873
ADFI, lb	1.67	1.75	1.72	1.67	1.59	1.64	0.039	0.089
F/G	1.47	1.53	1.47	1.43	1.40	1.44	0.142	0.158
d 0 to 35								
ADG, lb	0.76[ab]	0.83[a]	0.82[ab]	0.78[ab]	0.75[b]	0.79[ab]	0.019	0.012
ADFI, lb	1.08[ab]	1.18[a]	1.14[a]	1.08[ab]	1.02[b]	1.09[ab]	0.025	0.001
F/G	1.43	1.43	1.39	1.38	1.37	1.38	1.29	0.32
BW, lb								
d 0	12.0	12.0	11.9	12.0	11.9	12.0	0.020	0.696
d 7	13.3[ab]	13.5[a]	13.5[a]	12.8[b]	12.8[ab]	13.5[a]	0.016	0.003
d 19	20.6[c]	22.6[a]	22.2[ab]	20.6[bc]	20.5[c]	21.4[abc]	0.375	< 0.0001
d 35	39.3	41.6	40.9	39.3	38.9	39.7	0.697	0.06

[1]A total of 360 pigs (DNA 241 × 600) were used in a 3-phase nursery trial with 6 pigs per pen and 10 replications per treatment. Diets included either 1.5% choice white grease (control); 1.5% choice white grease plus 3,000 ppm Zn from ZnO in phase 1 or 2,000 Zn in phase 2; 1.5% choice white grease plus 50 g/ton carbadox (Phibro Animal Health, Teaneck, NJ); 0.5% choice white grease plus 1.0% C6:0, C8:0, and C10:0 in a 1:1:1 blend; 0.5% choice white grease plus 1% Feed Energy proprietary vegetable oil blend (Feed Energy Corp., Des Moines, IA); or 0.5% choice white grease plus 1% FORMI GML (ADDCON GmbH, Bitterfeld-Wolfen, Germany).
[2]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency. BW = body weight.
[3]Vegetable oil blend by Feed Energy Corp., Des Moines, IA.
[4]FORMI GML by ADDCON, Bitterfeld-Wolfen, Germany.
[abc]Means within a row that do not have a common superscript differ $P < 0.05$.

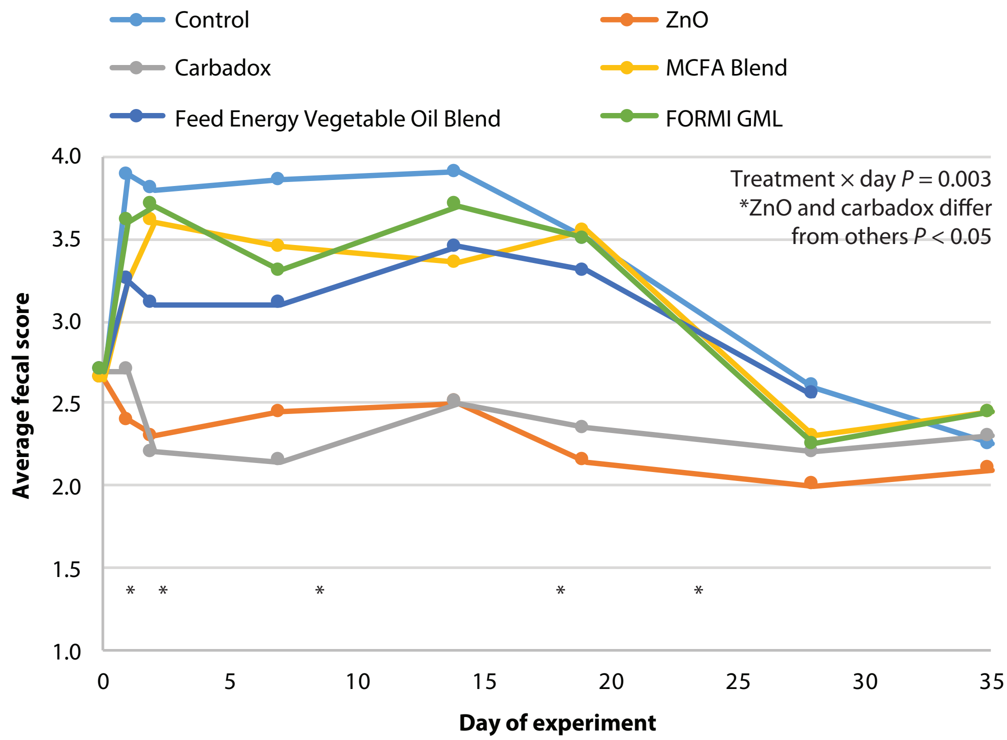

Figure 1. Impact of dietary treatment on fecal score. Fecal scoring was categorized as a numerical scale from 1 to 5 as follows: 1, hard pellet-like feces; 2, firm formed stool; 3, soft moist stool that retains shape; 4, soft unformed; and 5, watery liquid stool.