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Evaluation of Medium Chain Fatty Acids as a Dietary Additive in Nursery Pig Diets

Abstract

A total of 360 pigs [DNA (Columbus, NE) 400 × 200; initial BW = 14.8 lb] were used to evaluate the effects of dietary medium chain fatty acid (MCFA) addition on nursery pig performance. Upon arrival to the nursery, pigs were randomized to pens (5 pigs per pen) and allowed a 6-d acclimation period, at which point pens of pigs were blocked by BW and randomized to dietary treatment (9 pens per treatment). Medium chain fatty acids (Sigma Aldrich, St. Louis, MO) included hexanoic (C6), octanoic (C8), and decanoic (C10), and were guaranteed ≥ 98% purity. Treatment diets were formulated and manufactured in two dietary phases (dietary phase 1 = 15 to 25 lb BW; dietary phase 2 = 25 to 50 lb BW) and were formulated to meet or exceed NRC requirements. Treatments (n = 8) were constructed such that a dose response was created including 0, 0.25, 0.5, 1.0, and 1.5% MCFA blend (1:1:1 ratio C6, C8, and C10) as well as treatments with either 0.5% C6, 0.5% C8, or 0.5% C10. During phase 1, pigs fed increasing MCFA blend had increased (linear, $P \leq 0.003$) ADG and ADFI, as well as improved F/G (quadratic, $P = 0.012$). Pigs fed 0.5% C6 and 0.5% C8 had greater ($P \leq 0.018$) ADG than pigs fed the control diet without MCFA. Pigs fed 0.5% C8 had greater ADFI than control fed pigs ($P = 0.023$), and pigs fed 0.5% C6, 0.5% C8, or 0.5% C10 had improved F/G ($P \leq 0.005$) compared to control fed pigs. Pigs fed 0.5% C8 had a marginally significant increase ($P = 0.094$) in ADFI compared to pigs fed 0.5% blended MCFA. Pigs fed 0.5% C10 tended to have poorer ($P = 0.060$) F/G compared to pigs fed the 0.5% MCFA blend diet. During phase 2, ADG increased (linear, $P = 0.007$) and ADFI marginally increased (linear, $P = 0.052$) with increasing MCFA blend. Pigs fed 0.5% C10 had marginal improvement ($P = 0.079$) in F/G compared to control fed pigs. Overall, ADG and ADFI were increased (linear, $P \leq 0.01$) and F/G improved (linear, $P = 0.004$) with increasing MCFA blend. Pigs fed 0.5% C6 or 0.5% C8 had greater ($P \leq 0.027$) ADG compared to pigs fed the control diet, and F/G was improved ($P \leq 0.003$) when pigs were fed 0.5% C6, 0.5% C8, or 0.5% C10 compared to control.

In summary, adding a blend of MCFA in nursery pig diets led to linear improvement in ADG, ADFI, and F/G. Thus, the use of MCFA products in nursery pig diets offers a significant potential to improve growth performance and economic return to swine producers. Additional research is warranted to determine if commercially available products have a favorable MCFA profile, and if such products yield similar advantages in growth performance and economic return.

Keywords

medium chain fatty acid, nursery pigs

Authors

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Evaluation of Medium Chain Fatty Acids as a Dietary Additive in Nursery Pig Diets

J.T. Gebhardt, K.A. Thomson, J.C. Woodworth, M.D. Tokach, J.M. DeRouchey, R.D. Goodband, and S.S. Dritz[1]

Summary

A total of 360 pigs [DNA (Columbus, NE) 400 × 200; initial BW = 14.8 lb] were used to evaluate the effects of dietary medium chain fatty acid (MCFA) addition on nursery pig performance. Upon arrival to the nursery, pigs were randomized to pens (5 pigs per pen) and allowed a 6-d acclimation period, at which point pens of pigs were blocked by BW and randomized to dietary treatment (9 pens per treatment). Medium chain fatty acids (Sigma Aldrich, St. Louis, MO) included hexanoic (C6), octanoic (C8), and decanoic (C10), and were guaranteed ≥ 98% purity. Treatment diets were formulated and manufactured in two dietary phases (dietary phase 1 = 15 to 25 lb BW; dietary phase 2 = 25 to 50 lb BW) and were formulated to meet or exceed NRC[2] requirements. Treatments (n = 8) were constructed such that a dose response was created including 0, 0.25, 0.5, 1.0, and 1.5% MCFA blend (1:1:1 ratio C6, C8, and C10) as well as treatments with either 0.5% C6, 0.5% C8, or 0.5% C10. During phase 1, pigs fed increasing MCFA blend had increased (linear, $P \leq 0.003$) ADG and ADFI, as well as improved F/G (quadratic, $P = 0.012$). Pigs fed 0.5% C6 and 0.5% C8 had greater ($P \leq 0.018$) ADG than pigs fed the control diet without MCFA. Pigs fed 0.5% C8 had greater ADFI than control fed pigs ($P = 0.023$), and pigs fed 0.5% C6, 0.5% C8, or 0.5% C10 had improved F/G ($P \leq 0.005$) compared to control fed pigs. Pigs fed 0.5% C8 had a marginally significant increase ($P = 0.094$) in ADFI compared to pigs fed 0.5% blended MCFA. Pigs fed 0.5% C10 tended to have poorer ($P = 0.060$) F/G compared to pigs fed the 0.5% MCFA blend diet. During phase 2, ADG increased (linear, $P = 0.007$) and ADFI marginally increased (linear, $P = 0.052$) with increasing MCFA blend. Pigs fed 0.5% C10 had marginal improvement ($P = 0.079$) in F/G compared to control fed pigs. Overall, ADG and ADFI were increased (linear, $P \leq 0.01$) and F/G improved (linear, $P = 0.004$) with increasing MCFA blend. Pigs fed 0.5% C6 or 0.5% C8 had greater ($P \leq 0.027$) ADG compared to pigs fed the control diet, and F/G was improved ($P \leq 0.003$) when pigs were fed 0.5% C6, 0.5% C8, or 0.5% C10 compared to control.

In summary, adding a blend of MCFA in nursery pig diets led to linear improvement in ADG, ADFI, and F/G. Thus, the use of MCFA products in nursery pig diets offers a significant potential to improve growth performance and economic return to swine

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[2] NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.

producers. Additional research is warranted to determine if commercially available products have a favorable MCFA profile, and if such products yield similar advantages in growth performance and economic return.

Introduction

Feed additives have a number of potential uses in swine production including growth promotion, modification of digestive function, and fulfillment of nutritional requirements. Currently, there are a number of products in development with the active ingredient, medium chain fatty acids (MCFA). Research evaluating the potential antibacterial properties of MCFA is quite extensive, primarily to control *Salmonella* within poultry. More recently, MCFA have been shown to be potent antiviral compounds,[3,4] reducing the quantity of detectable viral genetic material and reducing infectivity. In addition to antibacterial and antiviral properties, the use of MCFA also have been evaluated as growth promoting feed additives. However, uncertainty still exists regarding growth promotion benefits, largely due to limited evidence demonstrating specifically which MCFA are beneficial, and at what inclusion level. A number of potential mechanisms may be involved, such as reduction of bacterial contamination within feed prior to ingestion, modification of gut bacterial populations, and reduction of environmental bacterial loads leading to increased piglet health. Fatty acids consisting of chains between 6 and 12 carbon atoms long are considered MCFA. With a significant amount of variability in the composition of commercial products that contain MCFA, it is essential to identify if any specific fatty acids are more efficacious such that products can be identified with a favorable fatty acid profile. In addition, it is essential to quantify a dose response to determine what concentrations should be used in future experiments and potential implementation in feeding programs. Therefore, the objective of this experiment is to characterize the growth performance outcomes following inclusion of hexanoic (C6), octanoic (C8), and decanoic (C10) acid in nursery pig diets.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the K-State Segregated Early Weaning Facility in Manhattan, KS. Following arrival at the research facility, pigs were randomized to pens and allowed a 6-d acclimation period and were fed a commercial starter pellet containing no feed grade antimicrobials. Following acclimation, 360 pigs (DNA 400 × 200, initial BW = 15 lb) were blocked by BW and randomized to dietary treatment. Treatment diets were formulated and manufactured in two dietary phases (phase 1 = 15 to 25 lb BW; phase 2 = 25 to 50 lb BW) and were formulated to meet or exceed NRC[2] requirement estimates. Medium chain fatty acids (Sigma Aldrich, St. Louis, MO) included C6, C8, and C10 and were guaranteed ≥ 98% purity. Treatments (n = 8) were constructed such that a dose response was created including

[3] Cochrane, R. A., S. S. Dritz, J. C. Woodworth, A. R. Huss, C. R. Stark, M. Saensukjaroephon, 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 (Suppl. 2):196 (Abstr.).

[4] Cochrane, R. A., M. Saensukjaroenphon, S. S. Dritz, J. C. Woodworth, A. R. Huss, C. R. Stark, J. M. DeRouchey, M. D. Tokach, R. D. Goodband, J. F. Bai, Q. Chen, J. Zhang, P. C. Gauger, R. Main, and C. K. Jones. 2016. Evaluating the inclusion level of medium chain fatty acids to reduce the risk of PEDV in feed and spray-dried animal plasma. J. Anim. Sci. 94 (Suppl 2):50. doi:10.2527/msasas2016-107.

0, 0.25, 0.5, 1.0, and 1.5% added MCFA blend (1:1:1 ratio C6, C8, and C10) as well as treatments with 0.50% of either C6, C8, or C10. Each pen contained a 4-hole, dry self-feeder and a nipple waterer to provide ad libitum access to feed and water. Pens had tri-bar floors and allowed approximately 2.7 ft^2/pig. Pig weights and feed disappearance were measured on d 0, 7, 14, 21, 28, and 35 to determine ADG, ADFI, and F/G.

Complete diet samples were collected following feed manufacture using a feed probe from every fifth bag, subsampled, and submitted (Ward Laboratories, Inc., Kearney, NE) for analysis of DM, CP, crude fiber, Ca, P, and ether extract. In addition, MCFA concentration was evaluated at the University of Missouri Agricultural Experiment Station Chemical Laboratory (Columbia, MO).

Fecal consistency was evaluated on d 8, 11, 14, 21, 28, and 35 by three independent reviewers per day. Scoring was performed on a 5-point scale with 1 = hard, pellet-like feces; 2 = firm, formed stool; 3 = soft, moist stool that retains shape; 4 = unformed stool; and 5 = watery liquid stool. An average pen score for a given day was calculated based on the three individual scores and included in the statistical model.

Data were analyzed as a randomized complete block design using the GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. For growth performance and fecal consistency data, weight block was included in the model as a random effect. Within these outcomes, linear and quadratic effects of increasing MCFA, as well as preplanned pairwise contrasts comparing individual MCFA supplemented diets to 0.5% 1:1:1 MCFA treatment and control were evaluated. Fecal score data were plotted in histogram format to evaluate the assumption of normal distribution, and resulted in a satisfactory fit. A repeated measure of treatment within block was included in the model for fecal consistency evaluation over time using a first-order ante-dependence covariance structure. An unstructured or first order ante-dependence covariance structure would be appropriate based on the uneven nature of the evaluation days, and first order ante-dependence was selected for use based on an improved Bayesian Information Criterion relative to the unstructured covariance matrix. All results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Analysis of manufactured diets (Table 2) resulted in values consistent with formulation, as expected.

During dietary phase 1, pigs fed increasing MCFA blend had increased (Table 3 and 4; linear, $P \leq 0.003$) ADG and ADFI, as well as improved F/G (quadratic, $P = 0.012$). Pigs fed 0.5% C6 or 0.5% C8 had greater ($P \leq 0.018$) ADG than pigs fed the control diet. Pigs fed 0.5% C8 had greater ADFI than control fed pigs ($P = 0.023$), and pigs fed 0.5% C6, 0.5% C8, or 0.5% C10 had improved F/G ($P \leq 0.005$) compared to control fed pigs. Pigs fed 0.5% C8 had a marginally significant increase ($P = 0.094$) in ADFI compared to pigs fed 0.5% blended MCFA. Pigs fed 0.5% C10 had marginally poorer ($P = 0.060$) F/G compared to pigs fed the 0.5% MCFA blend diet. During phase 2, ADG increased (linear, $P = 0.007$) and ADFI marginally increased (linear, $P = 0.052$) with increasing MCFA blend. Pigs fed 0.5% C10 had a marginal improvement ($P = 0.079$) in F/G compared to control fed pigs. Overall, ADG and ADFI were increased ($P \leq 0.010$) and F/G improved ($P = 0.004$) in a linear manner with increasing MCFA blend. Pigs fed 0.5% C6 or 0.5% C8 had greater ($P \leq 0.027$) ADG compared to pigs fed the control diets, and F/G was improved ($P \leq 0.003$) when pigs were fed 0.5% C6, 0.5% C8, or 0.5% C10 compared to control.

No evidence for a dietary treatment × day interaction was observed ($P = 0.110$) for fecal consistency. A significant day effect was observed ($P < 0.001$) but was not our primary interest for interpretation. There was marginally significant evidence that at least one treatment differed from another ($P = 0.068$). With increasing MCFA blend, fecal consistency score was reduced (linear, $P = 0.010$) indicating firmer stool. Pens fed 0.5% C6 or 0.5% C10 had lower ($P \leq 0.045$) fecal consistency scores than pens fed the 0.5% MCFA blend.

In summary, the addition of a MCFA blend in nursery pig diets led to linear improvement in ADG, ADFI, and F/G. Thus, the use of MCFA in nursery diets may be a potential option to improve performance and profitability of swine producers. Additional research is warranted to determine if commercially available products have a favorable MCFA profile, and if such products yield similar advantages in growth performance and economic return.

Table 1. Diet composition (as-fed basis)

Item	Phase 1	Phase 2
Ingredient, %		
Corn	54.92	62.55
Soybean meal, 46.5% CP	26.38	31.60
Whey powder	10.00	---
Soybean oil	1.50	1.50
Calcium carbonate	0.95	1.00
Monocalcium phosphate, 21% P	1.30	1.15
Salt	0.60	0.60
L-Lys HCl	0.50	0.51
DL-Met	0.24	0.23
L-Thr	0.21	0.21
L-Trp	0.05	0.06
L-Val	0.15	0.14
Trace mineral	0.15	0.15
Vitamin premix	0.25	0.25
Phytase[2]	0.07	0.07
Zinc oxide	0.25	---
HP 300[3]	2.50	---
Hexanoic acid[4]	+/-	+/-
Octanoic acid[4]	+/-	+/-
Decanoic acid[4]	+/-	+/-
Total	100	100

continued

Table 1. Diet composition (as-fed basis)

Item	Phase 1	Phase 2
Calculated analysis[5]		
Standardized ileal digestible (SID) amino acids, %		
Lys	1.35	1.35
Ile:Lys	56	55
Leu:Lys	111	113
Met:Lys	37.4	37.3
Met and Cys:Lys	58.2	58.1
Thr:Lys	63.0	62.0
Trp:Lys	20.1	20.3
Val:Lys	70.3	70.1
Total Lys, %	1.48	1.49
ME, kcal/lb	1,519	1,518
NE, kcal/lb	1,135	1,127
SID Lys:ME, g/Mcal	4.03	4.03
SID Lys:NE, g/Mcal	5.40	5.43
CP, %	20.6	21.1
Ca, %	0.75	0.70
P, %	0.68	0.63
Available P, %	0.55	0.46
STTD P, %	0.57	0.50

[1] Phase 1 and 2 diets were fed from approximately 15 to 24 and 24 to 50 lb BW, respectively.
[2] HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.12% STTD P.
[3] HP 300 (Hamlet Protein, Findlay, OH).
[4] Sigma Aldrich (St. Louis, MO), guaranteed ≥ 98% purity added at the expense of soybean oil.
[5] NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.

Table 2. Analyzed diet composition (as-fed basis)[1]

	Added MCFA, %[2]							
		C6:C8:C10[3]				C6	C8	C10
Analyzed composition, %[4]	0	0.25	0.5	1.0	1.5	0.5	0.5	0.5
Phase 1								
DM	89.15	89.02	89.02	88.91	88.58	89.66	89.22	89.10
CP	20.90	20.70	21.20	20.90	20.45	20.85	20.50	19.80
ADF	3.90	3.35	3.20	2.45	2.30	4.35	2.80	2.10
Ether extract	4.40	3.95	3.80	2.75	2.15	3.15	2.80	2.90
Ca	0.91	0.91	1.00	0.92	0.95	0.88	0.98	0.93
P	0.76	0.75	0.76	0.67	0.71	0.71	0.72	0.70
Hexanoic acid	0.02	0.10	0.12	0.32	0.47	0.46	0.06	0.03
Octanoic acid	0.01	0.09	0.13	0.33	0.54	0.06	0.44	0.03
Decanoic acid	0.01	0.09	0.15	0.39	0.66	0.03	0.03	0.53
Total MCFA[5]	0.03	0.28	0.40	1.04	1.68	0.54	0.52	0.59
Phase 2								
DM	88.38	88.45	88.19	88.38	87.97	88.67	88.35	88.40
CP	20.90	21.00	21.15	21.10	20.65	20.90	21.50	20.95
ADF	2.80	2.70	2.50	2.35	3.10	3.15	3.05	2.95
Ether extract	3.90	2.90	2.70	2.35	1.90	3.05	3.35	2.90
Ca	0.94	0.87	0.85	0.83	0.84	0.85	0.81	0.85
P	0.69	0.62	0.63	0.65	0.62	0.64	0.64	0.64
Hexanoic acid	0.02	0.07	0.15	0.24	0.50	0.41	0.02	0.01
Octanoic acid	0.01	0.06	0.15	0.29	0.55	0.04	0.37	0.01
Decanoic acid	0.02	0.07	0.18	0.32	0.62	0.02	0.01	0.49
Total MCFA[5]	0.05	0.21	0.48	0.85	1.67	0.47	0.40	0.51

[1] Diets were fed in 2 phases from d 0 to 14 and 14 to 35 for phases 1 and 2, respectively.

[2] Sigma Aldrich (St. Louis, MO). MCFA = medium chain fatty acid.

[3] Consisted of a 1:1:1 blend of C6, C8, and C10.

[4] Complete diet samples were collected following feed manufacture using a feed probe to create a composite sample, subsampled, and submitted to Ward Laboratories, Inc. (Kearney, NE) for proximate and the University of Missouri Agricultural Experiment Station Chemical Laboratory (Columbia, MO) for MCFA analysis performed in duplicate. Reported values are average of duplicate analysis.

[5] Sum of analyzed C6, C8, and C10 medium chain fatty acids.

Table 3. Effect of medium chain fatty acid (MCFA) inclusion on nursery pig growth performance, LS MEANS[1]

	Added MCFA, %[2]								
		C6:C8:C10[3]				C6	C8	C10	
	0	0.25	0.5	1.0	1.5	0.5	0.5	0.5	SEM
BW, lb									
d 0	14.8	14.8	14.9	14.8	14.8	14.8	14.9	14.8	0.17
d 14	22.7	23.3	23.9	24.2	24.7	23.9	24.5	23.2	0.47
d 35	47.5	48.5	50.1	50.4	51.2	49.5	50.2	48.9	0.76
d 0 to 14									
ADG, lb	0.56	0.61	0.65	0.67	0.71	0.65	0.69	0.59	0.028
ADFI, lb	0.73	0.73	0.76	0.81	0.83	0.78	0.82	0.72	0.031
F/G	1.30	1.21	1.17	1.20	1.17	1.19	1.19	1.22	0.020
d 14 to 35									
ADG, lb	1.18	1.20	1.25	1.25	1.26	1.22	1.22	1.22	0.022
ADFI, lb	1.83	1.79	1.86	1.91	1.89	1.85	1.84	1.84	0.037
F/G	1.55	1.50	1.49	1.54	1.50	1.51	1.51	1.50	0.018
d 0 to 35									
ADG, lb	0.93	0.96	1.01	1.02	1.04	0.99	1.01	0.97	0.020
ADFI, lb	1.39	1.37	1.42	1.47	1.46	1.42	1.43	1.39	0.031
F/G	1.49	1.42	1.41	1.45	1.41	1.43	1.42	1.43	0.013
Fecal score[4]	2.9	2.9	2.8	2.9	2.7	2.8	2.9	2.8	0.05

[1] A total of 360 pigs (DNA 400 × 200; initial BW = 14.8 lb) were used in a 35-d experiment with 5 pigs per pen and 9 pens per treatment.

[2] Sigma Aldrich (St. Louis, MO).

[3] Consisted of a 1:1:1 blend of C6, C8, and C10.

[4] Score assigned based on scale ranging from 1 to 5 with 1 = hard, pellet-like feces; 2 = firm, moist stool; 3 = soft, moist stool that retains shape; 4 = unformed stool; and 5 = watery liquid stool. Stool evaluation was performed on d 8, 11, 14, 21, 28, and 35 by three independent reviewers. The average score for each pen on a given day was included in the statistical analysis.

Table 4. Effect of medium chain fatty acid (MCFA) inclusion on nursery pig growth performance, *P*-values[1]

	P <							
	Linear[2]	Quadratic[2]	C6 vs. control	C8 vs. control	C10 vs. control	C6 vs. 0.5% 1:1:1	C8 vs.. 0.5% 1:1:1	C10 vs.. 0.5% 1:1:1
BW, lb								
d 0	0.605	0.641	0.545	0.611	0.809	0.267	1.000	0.790
d 14	< 0.001	0.359	0.030	0.002	0.355	0.991	0.274	0.196
d 35	< 0.001	0.177	0.032	0.005	0.133	0.506	0.978	0.185
d 0 to 14								
ADG, lb	< 0.001	0.376	0.018	0.001	0.395	0.858	0.250	0.164
ADFI, lb	0.003	0.994	0.224	0.023	0.718	0.553	0.094	0.324
F/G	< 0.001	0.012	< 0.001	< 0.001	0.005	0.355	0.398	0.060
d 14 to 35								
ADG, lb	0.007	0.245	0.222	0.211	0.168	0.341	0.357	0.427
ADFI, lb	0.052	0.513	0.722	0.829	0.825	0.839	0.732	0.736
F/G	0.384	0.469	0.190	0.121	0.079	0.300	0.429	0.561
d 0 to 35								
ADG, lb	< 0.001	0.187	0.027	0.006	0.154	0.574	0.996	0.167
ADFI, lb	0.010	0.625	0.467	0.319	0.997	0.942	0.731	0.515
F/G	0.004	0.075	0.002	0.001	0.003	0.197	0.416	0.168
Fecal Score[3]	0.010	0.640	0.037	0.496	0.045	0.610	0.351	0.670

[1] A total of 360 pigs (DNA 400 × 200; initial BW = 14.8 lb) were used in a 35-d experiment with 5 pigs per pen and 9 pens per treatment.

[2] Linear and quadratic contrast statements include treatments fed 1:1:1 blend of MCFA.

[3] Day, $P < 0.001$, Treatment × Day, $P = 0.110$, Treatment, $P = 0.068$.