Evaluation of microencapsulated organic acids and botanicals on growth performance of nursery and growing-finishing pigs

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ABSTRACT: A total of 1,215 pigs (L337 × 1050, PIC, Hendersonville, TN) were used to determine the effect of microencapsulated organic acids and botanicals (MOB; AviPlus; Vetagro, Inc. Chicago, IL), on growth performance from weaning to market. Pigs were weaned at approximately 21 d of age and placed in pens based on initial body weight (BW) with 27 pigs per pen in a randomized complete block design. During the 42-d nursery period, pigs were allotted to one of two treatments in an unbalanced treatment structure with 15 pens (replications) fed the control diet and 30 pens (replications) fed diets containing 0.30% MOB from days 0 to 21 and 0.10% from days 21 to 42. On day 42, pigs were transported as intact pens from the nursery to the finishing facility. During the finishing period, three treatments were applied which included: 1) pigs on the control diet in nursery remained on control diets; 2) 50% of pigs provided MOB in nursery were then fed 0.05% MOB throughout finishing, and 3) 50% of pigs provided MOB in nursery were then fed the control diet throughout finishing. All pens of pigs on treatments 2 and 3 were allotted based on ending nursery BW to the finishing treatment. There were 15 replications per treatment in the finishing period. From days 0 to 21, pigs fed diets with MOB had a tendency for increased ($P < 0.058$) gain:feed (G:F) when compared to pigs fed the control diet; however, there was no evidence of difference ($P > 0.05$) for average daily gain (ADG), average daily feed intake (ADFI), or day 21 BW. From days 21 to 42, there was no evidence of difference ($P > 0.05$) for ADG, ADFI, or G:F. For the overall nursery period (days 0 to 42), pigs fed diets with MOB had increased ($P < 0.05$) G:F (660 vs. 670 g/kg) when compared with pigs fed the control diet, but there was no evidence of difference ($P > 0.05$) for day 42 BW, ADG, or ADFI between treatments. From d 42 to 106, there was no evidence of difference ($P > 0.05$) for ADG, ADFI, and G:F. For the overall finishing period (days 42 to 156) and overall experimental period (days 0 to 156), there was no evidence of difference ($P > 0.05$) for BW, ADG, ADFI, or G:F. For mortality and removals, there was no evidence of difference ($P > 0.05$) observed during the nursery, finishing, or overall. In summary, providing MOB during the nursery phase increased G:F in the early and overall nursery phase, but there was no effect on overall wean-to-finish performance.

Key words: acidifier, botanicals, finishing pigs, growth, microencapsulation, nursery pigs

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INTRODUCTION

Organic acids have gained interest in the swine industry as options to improve pig growth performance via multiple mechanisms of actions including acidification of stomach pH, improved nutrient digestion, and control of intestinal pathogens overgrowth (Kil et al., 2011; Suiryanrayna and Ramana, 2015; Tugnoli et al., 2020). In particular, the antimicrobial mode of action of organic acids with a relatively high pKa is connected to their capacity to diffuse through the bacterial cell and then, once inside, dissociate into their anion and release H^+ ions which cause a decrease of the inner pH of the bacterial cell, depletion of ATP, and finally death.

Similar to organic acids, essential oils and botanical compounds (EO) have gained interest due to their broad spectrum of antimicrobial activity as well as anti-inflammatory and anti-oxidant properties (Falcone et al., 2005; Rossi et al., 2020). A combination product of microencapsulated sorbic and citric acids and synthetic thymol and vanillin botanicals (AviPlus; Vetagro, Inc. Chicago, IL) is commercially available to swine producers. Because both organic acids and botanical compounds can rapidly disappear in the upper intestinal tract due to their rapid metabolism, they are able to reach the lower gut, where most of the microbial fermentation and immune system stimulation occur. The combination of these molecules into a matrix of hydrogenated lipids to slow down their release along the gastrointestinal tract may offer synergistic effects on improving swine growth and feed efficiency (Canibe et al., 2005; Grilli et al., 2010; Cho et al., 2014). Therefore, the objective of our current study was to evaluate a microencapsulated blend of organic acids and botanicals (MOB) during the wean-to-finish period on pig growth performance.

MATERIALS AND METHODS

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This experiment was conducted at New Horizon Farms research nursery and finishing facilities located in Pipestone, Minnesota. In the nursery, each pen (3.65 × 2.44 m) had plastic slatted floors and was equipped with a six-hole stainless steel dry feeder and a pan waterer allowing ad libitum access to feed and water. Phase 1 diets were manufactured at Hubbard Feeds, Mankato MN, and all other diets were manufactured at the New Horizon Farms feed mill in Pipestone, MN. In the grow-finish phase of the study, each pen (5.49 × 2.74 m) was equipped with a 4-hole stainless steel dry self-feeder and a waterer cup for ad libitum access to feed and water. Feed additions for the nursery and finishing phases to each pen were delivered and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN). Pens of pigs were weighed, and feed delivery and disappearance were determined weekly during the nursery phase and approximately every 2 weeks during the finisher phase. Weights and feed measurements were used to determine growth performance (average daily gain [ADG], average daily feed intake [ADFI], and gain:feed [G:F]). Under the circumstance where a pig died or needed to be removed from the study due to disease or injury, the weight of the pig was recorded, and the pig was classified as a mortality or removal.

A total of 1,215 pigs (L337 × 1050, PIC, Hendersonville, TN) were weaned at approximately 21 d of age and placed in pens based on initial body weight (BW). There were approximately 27 pig per pen during the 42-d nursery period. Pens of pigs were allotted to one of two dietary treatments in an unbalanced treatment structure with 15 pens (replications) fed the control diets and 30 pens fed diets containing 0.30% MOB (Aviplus; Vetagro, Inc. Chicago, IL) (Table 1) from days 0 to 21 and 0.10% from days 21 to 42. Nursery diets were fed in three phases, with pharmacological levels of Zn in phase 1 and 2 (3,000 mg/kg added from ZnO in phase 1 and 2,000 mg/kg in phase 2). Diets were formulated to meet or exceed requirement estimates (NRC, 2012). Multiple samples (per phase) of complete diets were collected and pooled into one homogenized sample per dietary treatment. Samples were stored at −20 °C until they were submitted for analysis (Ward Laboratories, Kearney, NE) for dry matter (method 935.29; AOAC International, 2019), CP (method 990.03; AOAC International, 2019), and Ca and P (Method 985.01; AOAC International, 2019).

On d 42, pigs were transported as intact pens from the nursery to a finishing facility. During the finishing period, three treatments were applied which included: 1) pigs fed the control diets in nursery remained on control diets; 2) 50% of pigs in nursery fed MOB were then fed 0.05% MOB throughout finishing; and 3) 50% of pigs in nursery fed MOB were then fed control diets throughout finishing. All pens of pigs on finishing treatments 2 and 3 were allotted based on ending nursery BW to ensure nursery ADG had no influence on the finishing period. There were 15 replications per treatment in the finishing period.

Data were analyzed using R Studio (Version 4.0, R Core Team. Vienna, Austria) with pen serving as the experimental unit. The study was a randomized complete block design with weight block included in the model as a random effect. Preplanned contrast

Table 1. Composition of nursery and grow-finish diets (as-fed basis)

	Nursery diet, phases[1]			Finishing diet, phases[2]			
Item	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 4
Ingredient, %							
Corn	42.20	47.05	48.35	52.70	59.95	66.15	69.50
Soybean meal (46.5% CP)	15.05	24.95	27.30	23.95	16.60	10.50	7.20
Whey permeate	17.50	9.00	–	–	–	–	–
Enzymatically treated soybean meal[3]	6.65	–	–	–	–	–	–
Distillers dried grains with solubles	5.00	10.00	20.00	20.00	20.00	20.00	20.00
Fish meal	5.00	5.00	–	–	–	–	–
Beef tallow	–	1.00	1.00	1.00	1.00	1.00	1.00
Corn oil	3.00	–	–	–	–	–	–
Spray-dried blood plasma	2.50	–	–	–	–	–	–
Limestone	0.73	0.80	1.25	1.20	1.30	1.25	1.25
Monocalcium P, (21% P)	0.45	0.30	0.50	–	–	–	–
Sodium chloride	0.30	0.50	0.55	0.35	0.35	0.35	0.35
L-Lys-HCl	0.40	0.48	0.50	0.45	0.45	0.45	0.40
DL-Met	0.20	0.19	0.10	0.04	0.03	–	–
L-Thr	0.20	0.19	0.13	0.09	0.08	0.08	0.08
L-Trp	0.02	0.03	0.02	0.02	0.03	0.04	0.03
L-Val	0.10	0.10	0.05	–	–	–	–
Zinc oxide	0.42	0.27	–	–	–	–	–
Phytase[4,5]	0.02	0.05	0.05	0.04	0.04	0.04	0.04
Vitamin premix[6]	0.05	–	–	–	–	–	–
Trace mineral premix[7]	0.13	–	–	–	–	–	–
Selenium premix	0.05	–	–	–	–	–	–
Nursery vitamin and trace mineral premix[8]	–	0.15	0.15	–	–	–	–
Grow-finish vitamin and trace mineral premix[9]	–	–	–	0.15	0.15	0.15	0.15
Tri-basic copper chloride	–	–	0.02	–	–	–	–
MOB[10]	(±)	(±)	(±)	(±)	(±)	(±)	(±)
Total	100	100	100	100	100	100	100
Calculated analysis							
Standardized ileal digestible (SID) AA							
Lysine	1.40	1.38	1.30	1.18	1.00	0.85	0.73
Ile:Lys	55	57	61	62	61	60	63
Leu:lysine	115	121	140	148	157	168	185
Met: Lys	37	38	33	30	31	30	33
Met and Cys: Lys	58	58	57	55	57	58	64
Thr: Lys	64	63	62	61	61	62	66
Trp: Lys	18.2	18.3	18.3	18.6	18.9	18.8	18.7
Val: Lys	71	70	72	71	72	73	77
Total Lys, %	1.57	1.56	1.48	1.35	1.15	0.99	0.86
ME, kcal/kg	3,532	3,358	3,287	3,314	3,318	3,327	3,329

Table 1. Continued

	Nursery diet, phases[1]			Finishing diet, phases[2]			
Item	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 4
NE, kcal/kg	2,665	2,500	2,436	2,476	2,516	2,553	2,571
SID Lys:NE, g/Mcal	5.25	5.52	5.34	4.77	3.98	3.33	2.84
STTD P, %[11]	0.56	0.51	0.47	0.36	0.34	0.33	0.32
Na, %	0.42	0.36	0.29	0.21	0.21	0.20	0.20
Cl, %	0.74	0.67	0.50	0.37	0.37	0.37	0.36
Analyzed values, %[12]							
CP	21.7–21.7	21.1–21.1	21.7–22.6	20.1–20.5	17.0–17.7	12.7–11.7	11.8–11.8
Ca	0.81–0.72	0.77–0.83	0.71–0.67	0.74–0.58	0.58–0.60	0.50–0.70	0.57–0.49
P	0.69–0.66	0.57–0.65	0.51–0.58	0.38–0.44	0.39–0.41	0.32–0.31	0.32–0.30

Nursery diets were provided in three phases from days 0 to 42. Finishing diets were provided in four phases from day 42 to the end of the trial.

[1]Phase 1 nursery diets were provided as a 1.81 kg/pig feed budget. Phase 2 nursery diets were provided after phase 1 until day 21. Phase 3 diets were provided from days 21 to 42.

[2]Diets were provided in four phases: Phase 1 diet was fed from 23 to 39 kg, Phase 2 diet was fed from 39 to 64 kg, Phase 3 diet was fed from 64 to 91 kg, and Phase 4 diet was fed from 91 kg to the end of the trial.

[3]HP 300 (Hamlet Protein, Findlay, OH).

[4]Quantum Blue 5G (AB Vista, Plantation, FL) provided 1,959 FTU/kg was used in phase 1 diets.

[5]Optiphos 2000, (Huvepharma Inc., Peachtree City, GA) provided 500 phytase units (FTU)/kg of diet, for an estimated release of 0.14% available P.

[6]Provided per kg of premix: 11,100,196 IU vitamin A; 2,000,360 IU vitamin D; 59,996 IU vitamin E; 6000 mg vitamin K; 50 mg vitamin B12; 8,001 mg riboflavin; 41,000 mg pantothenic acid; 45,002 mg niacin; 1,200 mg folic acid; and 200 mg biotin.

[7]Provided per kg of premix: 160,090 mg Zn from zinc sulfate; 134,000 mg Fe from ferrous sulfate; 40,000 mg Mn from manganese oxide; 13,340 mg Cu from copper sulfate; and 666 mg I from calcium iodate.

[8]Each kg of premix contained 66,700 mg Fe from ferrous sulfate, 73,300 mg Zn from zinc oxide, 26,700 mg Mn from manganous oxide, 10,000 mg Cu from copper sulfate, 500 mg I from calcium iodate, 200 mg Se, 5,344,484 IU vitamin A, 100,210 IU vitamin E, 21 mg vitamin B12, 4,007 mg riboflavin, 15,366 mg pantothenic acid, 29,061 mg niacin, 668 mg folic acid, 1,201 mg vitamin B6, 67 mg biotin, 1,336,122 IU vitamin D3, and 1,671 mg vitamin K.

[9]Provided per kg of premix: 3,527,360 IU vitamin A; 881,840 IU vitamin D; 17,637 IU vitamin E; 1,764 mg vitamin K; 15.4 mg vitamin B12; 33,069 mg niacin; 11,023 mg pantothenic acid; 3,307 mg riboflavin; 74 g Zn from zinc sulfate; 74 g Fe from iron sulfate; 22 g Mn from manganese oxide; 11 g Cu from copper sulfate; 0.22 g I from calcium iodate; 0.20 g Se from sodium selenite; and 500,000 FTU phytase from OptiPhos 2000 (Huvepharma Inc., Peachtree City, GA).

[10]A microencapsulated complex of organic acids and botanicals (AviPlus; Vetagro, Inc. Chicago, IL) was provided at 0.30% of the diet from days 0 to 21 and 0.10% of the diet from days 21 to 42, and 0.05% of the diet from day 42 to the end of the experiment.

[11]Standard total tract digestible phosphorous.

[12]The first value represents the nutrient concentration for the control diet, whereas the second value then represents nutrient concentration of the diet with added MOB.

statements were used to evaluate the treatment effects on ADG, ADFI, BW, and G:F. A binomial distribution was used to determine treatment effect on removals and mortality. Nursery data were analyzed as a one-way treatment structure with two treatments. Grow-finish data was also analyzed as a one-way treatment structure with three treatments. Statistical models were fitted using NLME package in R. Results were considered significant at $P < 0.05$ and marginally significant at $0.05 > P < 0.10$.

RESULTS AND DISCUSSION

In the current study, we evaluated the influence of a combination product of micro-encapsulated sorbic and citric acids and synthetic thymol and vanillin botanicals on wean-to-finish growth performance, mortality, and removals. No effects on nutrient digestibility or hindgut fermentation were measured. From days 0 to 21, there was no evidence of difference for ADG, ADFI, or day 21 BW (Table 2). However, a trend for increased ($P < 0.058$) G:F was observed for pigs fed diets with MOB compared with pigs fed the control diets. From days 21 to 42, there was no evidence of difference for ADG, ADFI, G:F, or day 42 BW. For the overall nursery period (d 0 to 42), pigs fed diets with MOB had a 1.5% increase ($P < 0.05$) G:F compared with pigs fed the control diet, but there was no evidence of difference for ADG or ADFI.

For the finishing period, from days 42 to 156, and the overall wean-to-finish period, there was no evidence of difference between treatments for ADG, ADFI, G:F, or final BW. For mortality and removals, there was no evidence of difference observed for nursery mortality, removals, or total

Table 2. Evaluation of a microencapsulated complex of organic acids and botanicals (MOB) on growth performance of nursery and growing-finishing pigs

Item[1]	Nursery performance			SEM	*P*-value
	Control	Added MOB[2]			
d 0 to 42					
ADG, g	383	385		5.37	0.867
ADFI, g	580	573		8.37	0.544
GF, g/kg	660	670		3.00	0.023
	Grow-finish performance				
		Added MOB[2]			
Item[1]	**Control**	**Nursery and finisher[3]**	**Only in nursery[4]**	**SEM**	***P*** **-value**
d 42 to 156					
d 42 BW, kg	23.0	23.0	23.1	0.329	0.958
ADG, g	919	908	922	5.40	0.187
ADFI, g	2,344	2,341	2,353	22.00	0.917
GF, g/kg	392	388	392	17.00	0.463
d 0 to 156					
d 156 BW, kg	127.6	126.3	128.1	0.735	0.236
ADG, g	756	747	757	4.05	0.125
ADFI, g	1,809	1,797	1,807	17.26	0.858
GF, g/kg	418	416	419	2.00	0.593
Mortality, %					
Nursery	0.5	1.0	0.7	0.50	0.710
Finishing	0.7	0.2	0.7	0.40	0.515
Total nursery and finishing	1.1	1.1	1.3	0.60	0.939
Removals, %[5]					
Nursery	10.0	8.6	8.8	1.60	0.739
Finishing	5.4	7.9	6.7	1.30	0.369
Total nursery and finishing	15.6	16.5	15.6	1.80	0.907
Mortality and removals, %					
Nursery	10.6	9.6	9.6	1.30	0.865
Finishing	6.2	8.1	7.4	1.40	0.544
Total nursery and finishing	16.8	17.7	17.0	1.90	0.928

A total of 1,215 pigs (initial BW of 5.0 kg) were used in a 156-d growth study with 27 pigs per pen. In the nursery, there were 15 pens (replications) fed the control diet and 30 pens (replications) fed diets containing a microencapsulated complex of organic acids and botanicals (MOB). In the finishing period of the experiment, three treatments were applied which included: 1) pigs on the control diet in nursery remaining on control diets; 2) half of pigs in nursery fed the MOB were fed the MOB throughout finishing; and 3) half of pigs in nursery fed the MOB were then fed the control diets throughout finishing.

[1]BW, body weight; ADG, average daily gain, ADFI, average daily feed intake; GF, feed efficiency.

[2]A combination of micro-encapsulated sorbic and citric acids and synthetic thymol and vanillin botanicals (Vetagro, Inc. Chicago, IL).

[3]The MOB inclusion rate of 0.30% of the diet in phase 1 (1.81 kg/pig feed budget) and phase 2 (ended at d 21) and 0.90 kg/ton 0.10% of the diet from days 21 to 42 of the nursery period. Pigs were then placed on diets that provided 0.05% MOB in the diet of throughout the grow-finish period.

[4]Pigs fed diets with 0.30% MOB in phase 1 (1.81 kg/pig feed budget) and phase 2 (ended at day 21) and 0.10% of the diet from days 21 to 42 during the nursery period and then switched to the control diet from days 42 to 156.

[5]Pigs that have an inability to overcome sickness or injury during the trial were removed and marked as a removal.

nursery mortality and removals. Similarly, in finishing and overall, no evidence of difference was observed for mortality, removals, or total mortality and removals.

Organic acids and EOs can be provided together using microencapsulated technology to allow delayed absorption of the acidifiers and EOs without affecting the bioavailability of the protected compound (Piva et al., 1997; 2007). Grilli et al. (2010) observed that feeding a MOB improved nursery pig (days 0 to 41 after weaning) ADG and ADFI; however, G:F was unaffected. Oh et al. (2018) fed 0.1% or 0.2% MOB to pigs from weaning (6.5 kg) to market (approximately 112 kg). They observed linear increases in ADG and ADFI in the nursery phase and the overall study with increasing 0.2% MOB, but G:F was only improved for the overall study, not in the nursery phase. Cho et al. (2014) observed improved ADG and nutrient digestibility compared to control pigs when diets for finishing pigs were supplemented with the same blend of MOB used in our study. In contrast, we only observed increased G:F initially in the nursery phase, but not for the overall study.

Pure botanicals, which are also commonly referred to as volatile or ethereal oils, acquired from plants have the potential to improve nutrient and energy utilization (Wenk, 2003; Simonson 2004). Commonly, essential oils like thymol and vanillin are used due to their broad spectrum of antimicrobial activity (Falcone et al., 2005; Huang et al., 2010; Gallage et al., 2014). Huang et al. (2010) observed that the inclusion of blended essential oils improved early nursery pig ADG, but the authors observed no other improvements in growth performance. Likewise, in an earlier study from Hong et al. (2004), the authors concluded that plant extracts could be included in the diet of weaned pigs without negatively affecting growth performance. However, in a study from Feldpausch et al. (2018), the authors observed that supplementing an EO failed to affect daily gain, feed intake and resulted in poorer G:F. Gerritsen et al. (2010) observed no growth performance differences from supplementing a blend of organic acids.

In conclusion, the addition of a MOB in our study improved G:F in the nursery period but there was no overall effect on wean-to-finish growth performance or mortality and removals. The evaluation of organic acids and essential oils continues to present challenges to nutritionists as the pig's response to them is variable. However, in light of bans or limitations on the use of feed-grade medications and pharmacological trace minerals, organic acids and EO need to be continually evaluated and screened to determine conditions where they have the greatest responses.

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