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Research Article

Effects of Probiotics and Organic Acids and Their Mixture on Nutrient Digestibility, Growth Performance and Fecal Gas Emission in Grower-Finisher Pigs

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Abstract | This study was carried out to evaluate the effects of dietary supplementation of probiotics (PROB), organic acids (ORAC), and their mix (PROR) on growth performance, nutrient digestibility, and fecal noxious gas concentration in grower-finisher pigs. Twenty-four barrows [(Pietrain × Duroc) × (Landrace × Yorkshire)], with an average initial body weight of 26 ± 0.77 kg (around 75 days old), were equally divided into four dietary groups, 6 replicates each group. The animals were housed individually in metabolism cages. The four experimental diets consisted of a basal diet (CONT), PROB diet (CONT + 0.2% PROB), ORAC diet (CONT + 0.2% ORAC), and PROR diet (CONT + 0.2% PROB + 0.2% ORAC) for 60 days including 2 periods (25-45 kg and 45-65 kg). In comparison to the CONT group, dietary supplementation of PROB or ORAC or PROR increased ADG and decreased FCR ($P < 0.0001$), with the higher ADG and lower FCR for PROR group during the entire experimental period. Pigs fed PROB or ORAC or PROR diets led to higher ($P < 0.05$) apparent total tract digestibility of protein, organic matter, neutral detergent fiber, and phosphorus than those fed CONT diet. A significant decrease in ammonia (NH_3) and hydrogen sulfide (H_2S) concentrations were observed in diets with PROB or ORAC or PROR, with lower values for PROR diet. In conclusion, in grower-finisher pigs, dietary supplementation of either PROB or ORAC as a single product or their combination had improvements in performance parameters, nutrient digestibility, and fecal NH_3 and H_2S emissions compared with CONT diet. There were no differences in performance parameters between the use of the single product and the combination. In general, a diet containing a combination of PROB and ORAC had larger effects on parameters observed than a diet containing either PROB or ORAC.

Keywords | Fecal noxious gas emission, Growth performance, Nutrient digestibility, Organic acid, Pig, Probiotics

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INTRODUCTION

In Vietnam, livestock production is faced with numerous challenges, including the increasing environmental pollution and food safety concerns about animal products. Current economic and farming conditions have led to an increasingly apparent issue of safety in livestock production. The residue of antibiotics, toxic chemicals (melamine, sudan, etc.), and growth promoters (clenbuterol, salbutamol, etc.) in meat, eggs, and milk is a matter of concern not only to farmers but to all consumers. Due to this concern, the Vietnamese government has recently restricted the sub-therapeutic use of some antibiotics in 2014 and banned all antibiotic growth promoters in 2018 (National Assembly, 2018). Therefore, finding alternatives to antibiotics in livestock production are urgently necessary.

In most countries, pig production is usually raised in concentrated areas. This offers some economic benefits, but it also causes environmental pollution due to the emissions of greenhouse gases, ammonia (NH_3), and hydrogen sulfide (H_2S). The target of reducing environmental contamination simply by reducing the number of pigs is unlikely to the economic goal. Therefore, other ways of decreasing harmful gas emissions will have to be considered. Several feeding strategies that could potentially reduce the harmful gas emissions have been studied, such as probiotics (Wutzke et al., 2010), enzymes or amino acids (Vhile et al., 2012), prebiotics (Xu et al., 2002), and phytogenics (Sampath et al., 2020). The dietary probiotics containing *Bacillus subtilis* and *Lactobacillus acidophilus* reduced the emission of NH_3 by altering the gut microbiota (Jeong et al., 2015). It has been proven that decreasing L-tryptophan and increasing fructans in the pig fecal fermentation broth reduced the production of skatole and H_2S by promoting lactic acid bacteria (Sheng et al., 2015). Dietary low and ultra-low crude protein levels with amino acid balance by supplementing crystalline amino acids were shown to reduce ammonia production in pig manure (Powers et al., 2007). Eubiotics are referred as a healthy balance of microflora in the gastrointestinal tract (Nowak et al., 2017). Several types of eubiotics, such as organic acids, essential oil compounds, and probiotics, have been shown to have a positive effect on gut health and overall animal performance (Agboola et al., 2015; Zhang et al., 2016; Lei et al., 2018). However, the extent of the positive effects is variable depending on the products used. A recent approach that is attracting investigations in improving nutrient digestibility, growth performance, and reducing fecal noxious gas emission in pig production is the use of a combination of probiotics and organic acids in the diet. We hypothesized that dietary supplementation with a blend of commercial probiotics and organic acids in pig diet has beneficial effects on growth parameters, digestibility, and fecal noxious gas concentrations by improving nutrient utilization. Therefore, this study evaluated the effects of dietary supplementation with probiotics, organic acids, and their mix on growth performance, nutrient digestibility, fecal noxious gas emissions in grower-finisher pigs.

MATERIALS AND METHODS

Experiment location and time

The experiment was done from August to October, 2020 at an opened housing condition of High-Quality Animal Breeding Center, Vietnam National University of Agriculture, Hanoi, Vietnam. The protocol to use animals for the experimental purpose was approved by the Animal Science Committees of the National Institute of Animal Science, Vietnam (NIAS-2019/05).

Source of probiotics and organic acids

In this study, the probiotics (PROB) used was produced by a commercial company (BiOWiSH™ Multibio 3P, BiOWiSH Technologies, Inc., USA). This product is a mixture of *Pediococcus acidilactici* ≥ *1,0* × *10*^{8} *CFU/g; Pediococcus pentosaceus* ≥ *1,0* × *10*^{8} *CFU/g; Lactobacillus plantarum* ≥ *1,0* × *10*^{8} *CFU/g; Bacillus subtilis* ≥ *1,0* × *10*^{7} *CFU/g.*

The organic acids (ORAC) used in our study was produced by a commercial company (Selacid GG, Trouw Nutrition, Netherlands). This product consisted of short chain fatty acids, buffered organic acid and a combination of medium-chain fatty acids (Ngoc et al., 2020).

Experimental design, animal and diet

A total of 24 healthy castrated male pigs [(Pietrain x Duroc) x (Landrace x Yorkshire)] were used in this experiment. The initial weight of experimental pigs was 26 ± 0.77 kg (around 75 days old). Animals were divided into four dietary groups according to equal initial body weight. Each dietary group consisted of 6 replicate pens with one pig per pen (metabolism cage). The animals were kept individually in metabolism cages (1.2 x 0.8m) equipped with a feeder, an automatic pig water nipple drinker, a fecal tray, and a urine bucket. The experimental duration was 60 days and was split into two feeding phases, 25-45 kg (75-105 days old, grower) and 45-65kg (105-135 days old, finisher).

The experimental pigs were fed one of four dietary groups including a basal diet (CONT), PROB diet (basal diet + 0.2% PROB), ORAC diet (basal diet + 0.2% ORAC), and PROR diet (basal diet + 0.2% PROB + 0.2% ORAC). The basal diet was formulated to meet nutrient requirement recommendations by NRC (2012). The main raw ingredients of the basal diet included maize, soybean meal, fish meal, defatted rice bran, and soybean oil, and other additives (Table 1). Raw ingredients were bought once at the beginning experiment and stored in plastic bags placed on a wooden shelf. The mixed diets were prepared every 7 days and kept in plastic containers to ensure the feed quality and prevent mold. Pigs were fed diet in mash form.

The experimental pigs were fed daily at 08h 30 and 16h 30 during the whole experimental duration. The daily amount of feed allowance was adjusted according to feed offered and refused on the previous day. Feed intake was recorded every day. The daily collected refusals were recorded in each metabolism cage before each feeding.

Measurements and data collection

Animal performance

The weight of experimental pigs was individually measured at the beginning, the middle, and the end of the experiment before the morning feeding. Average daily feed intake (ADFI), average daily gain (ADG), and feed conversion ratio (FCR) were measured for each pen, diet group, and each experimental period.

Table 1: Ingredients and nutrient values of the experimental diets.

Item	Grower phase	Finisher phase
Ingredient (% as-fed basic)		
Corn	60.0	60.0
Soybean meal	19.5	18.8
Fish meal	2.00	-
Defatted rice bran	15.0	17.1
Soybean oil	2.00	2.65
Dicalcium phosphate	0.65	0.60
Limestone	0.10	0.10
Vitamin and mineral premixes[1]	0.25	0.25
NaCl	0.50	0.50
Total (%)	100	100
Chemical composition (% DM) and energy value (kcal/kg DM)		
Dry matter (%)	90.0	90.1
Crude protein (%)	17.5	16.5
Crude fiber (%)	5.46	5.67
Neutral detergent fiber (%)	18.8	19.6
Calcium (%)	0.59	0.51
Total phosphorus (%)	0.50	0.45
Total Lysine (%)	0.94	0.77
Total Methionine + Cysteine (%)	0.56	0.53
Total Threonine (%)	0.68	0.64
Total Tryptophan (%)	0.23	0.22
ME[2] (Kcal/kg)	3101.5	3105.6

Grower phase, 25-45 kg (75-105 days old); finisher phase, 45-65 kg (105-135 days old). [1]Premix in 1 kg: Vitamin A - 1,600,000 IU; Vitamin D3 - 32,000,000 IU; Vitamin E - 2400; Vitamin K3 - 400 IU; Vitamin B1 - 160 IU; Vitamin B2 - 480 IU; Vitamin B6 - 240 IU; D-calcium pantothenate - 2120 mg; Biotin - 12.8 mg; Manganese - 5.6 g; Zinc - 16g; Iron - 12,8 g; Copper - 19,2 g; Iodine - 0,2 g; Cobalt - 0.112 g; Selenium - 0.016 g. [2]ME values of the diets was calculated based on ME values of ingredients referenced from NRC (2012).

Digestibility

In this experiment, 5 days before the end of each experimental period, total feces from individual pigs were collected twice a day (8.00 AM and 5.00 PM) according to the method as described previously by Oanh et al. (2019). The individual collected feces were stored at - 20°C until analysis. At the end of each collection period, the total fecal samples were thawed, pooled, mixed by an individual. Fecal samples (10%) were then taken and analyzed for the determination of chemical compositions.

Apparent total tract digestibility (ATTD) of nutrient components (protein, neutral detergent fiber (NDF), organic matter, and phosphorus) were calculated for individual animals using the method as described previously (Kong and Adeola, 2014):

$$ATTD = (N_d - N_f)/N_d*100$$

Where;
Nd is the amount of nutrient intake (g); Nf is the amount of fecal nutrient (g).

Noxious gas emission

Fresh fecal samples were collected individually from 4 dietary groups (6 pigs per treatment) at day 30 of each experimental phase. Approximately 300 g of fresh fecal samples were collected and transferred to a sealed box and fermented for 12h in a temperature room (28°C). The fermented samples were then put into a container (40 x 40 x 60 cm) with a small hole connecting a transparent plastic tube into the Kimoto HS7 sampler (made in Japan) to collect air samples for the determination of NH_3 and H_2S concentrations. The NH_3 is absorbed into dilute H_2SO_4 solution to form ammonium sulfate. Determination of NH_3 concentration is measured by the indolphenol blue absorbance spectrophotometry at 625 nm, which is formed by the reaction of ammonia, hypochlorite and phenol, with the participation of the reaction stabilizer, sodium nitroprusside (JIS K 0099, 2020). The H_2S is absorbed into cadmium sulfate ($CdSO_4$) solution, reacting with the p-amino dimethyl aniline solution in the presence of ferric chloride ($FeCl_3$) in the acidic environment to form a methylene blue complex. The concentration of H_2S was determined by the colorimetric method (JIS K 0099, 2020).

Chemical analysis

The diet and fecal samples were analyzed for dry matter, crude protein, ether extract, total ash according to standard methods (AOAC, 1990). The NDF content was analysed by the method of Van Soest et al. (1991). Organic matter content was measured as the difference between dry matter and total ash contents.

Data analysis

The experimental data were analyzed as a completely randomized design using the GLM procedure of Minitab Software, version 16. The metabolism cage was used as the experimental unit. Treatment means which show significant differences at the probability level of $P<0.05$ were compared using Tukey's pairwise comparison procedure.

RESULTS AND DISCUSSION

Animal performance

In the current study, no pigs were lost during the experiment. Performance indices of experimental diet groups are given in Table 2. The ADFI was similar (P > 0.05) among the dietary groups during the grower, finisher, and whole experimental periods. In addition, there was no significant effect of dietary treatment (P = 0.17) on final BW in the grower period, whereas final BW in the finisher period differed significantly among diets (P = 0.01), with a lower value in the CONT pigs. In the grower period, there was a significant effect of dietary treatment (P < 0.0001) on ADG and FCR, with the CONT pigs having lower ADG and higher FCR than the experimental pigs, while no significant differences in ADG and FCR were observed among diets supplemented with PROB or ORAC alone or in combination (P > 0.05). In the finisher period, pigs fed CONT diet had lower ADG and higher FCR than pigs fed PROR diet (P < 0.05), however ADG and FCR parameters were not significantly different among CONT, PROB, and ORAC diets (P > 0.05). During the whole experimental period, significantly higher ADG (PROR > ORAC > PROB > CONT) and lower FCR (PROR < ORAC < PROB < CONT) were observed (P < 0.0001) among the diets.

Digestibility

In both experimental periods, the ATTD of crude protein, NDF, organic matter, and phosphorus were affected (P < 0.05) by the dietary groups (Table 3). In the grower period, a lower ATTD of crude protein, organic matter, and phosphorus was observed in CONT diet compared with other diets (P < 0.0001). The ATTD of NDF was recorded for the lowest value (P < 0.0001) in the CONT diet (50.94%), followed in increasing order by PROB diet (58.73%), ORAC diet (61.69%), and PROR diet (68.43%). In the finisher period, the ATTD of crude protein was lower (P < 0.01) in CONT diet than those in the experimental diets. The ATTD of NDF was higher in PROR diet than that in CONT diet (P < 0.0001), while PROB and ORAC diets had a similar ATTD of NDF to PROR and CONT diets (P > 0.05). Dietary supplementation of PROB or ORAC or PROR increased significantly the ATTD of organic matter and phosphorus compared to CONT diet (P < 0.05).

Fecal ammonia and hydrogen sulfide emissions

In both grower and finisher periods, the concentration and emission characteristics of NH_3 and H_2S from pig feces were significantly decreased (P < 0.0001) in the dietary treatments supplemented with PROB or ORAC or PROR compared with the CONT treatment (Table 4). Additionally, the concentrations of NH_3 and H_2S were significantly lower (P < 0.0001) in the PROR diet than those in CONT and PROB diets during the finisher period.

Table 2: The effects of probiotics, organic acids and their mix on average daily feed intake, average daily gain and feed conversion ratio (n=6).

Item	CONT	PROB	ORAC	PROR	SEM	P value
Grower period (25-45kg, 75-105 days old)						
Initial BW (kg/pig)	26.10	26.05	26.07	26.13	0.772	0.99
Final BW (kg/pig)	43.58	45.32	45.75	46.25	0.855	0.17
ADG (g/pig/day)	624.4[b]	688.1[a]	703.0[a]	718.5[a]	11.76	<0.0001
ADFI (kg/pig/day)	1.35	1.34	1.34	1.33	0.017	0.96
FCR (kg feed/kg gain)	2.16[b]	1.94[a]	1.91[a]	1.86[a]	0.038	<0.0001
Finisher period (45-65kg, 105-135 days old)						
Initial BW (kg/pig)	43.58	45.32	45.75	46.25	0.855	0.17
Final BW (kg/pig)	62.93[b]	66.45[ab]	67.20[a]	68.52[a]	1.067	0.01
ADG (g/pig/day)	667.2[b]	728.7[ab]	739.7[ab]	767.8[a]	20.47	0.02
ADFI (kg/pig/day)	1.90	1.90	1.89	1.88	0.017	0.77
FCR (kg feed/kg gain)	2.89[b]	2.61[ab]	2.55[ab]	2.46[a]	0.095	0.02
Overall (25-65kg)						
ADG (g/pig/day)	646.2[b]	708.8[a]	721.6[a]	743.6[a]	10.40	<0.0001
ADFI (kg/pig/day)	1.63	1.62	1.62	1.61	0.015	0.87
FCR (kg feed/kg gain)	2.53[b]	2.29[a]	2.24[a]	2.17[a]	0.040	<0.0001

CONT: basic diet; PROB: CONT + 0.2% commercial probiotics; ORAC: CONT + 0.2% commercial organic acids; PROR: CONT + 0.2% commercial probiotics + 0.2% commercial organic acids. Row means between groups with different superscript letters significantly differ (P < 0.05).

Table 3: The effects of probiotics, organic acids or their mix on the apparent total tract digestibility of nutrient components of the diets (n=6).

Item	CONT	PROB	ORAC	PROR	SEM	P value
Grower period (25-45kg, 75-105 days old)						
Crude protein	81.30[b]	86.01[a]	86.45[a]	87.19[a]	0.84	<0.0001
Neutral detergent fiber	50.94[c]	58.73[b]	61.69[ab]	68.43[a]	1.99	<0.0001
Organic matter	84.01[b]	86.79[a]	87.41[a]	88.84[a]	0.66	<0.0001
Phosphorus	24.79[b]	35.41[a]	37.22[a]	45.41[a]	2.62	<0.0001
Finisher period (45-65kg, 105-135 days old)						
Crude protein	84.51[b]	87.63[a]	88.02[a]	88.55[a]	0.61	0.001
Neutral detergent fiber	60.92[b]	64.42[ab]	65.8[ab]	68.78[a]	1.61	0.020
Organic matter	84.95[c]	86.85[bc]	87.77[ab]	89.30[a]	0.48	<0.0001
Phosphorus	28.11[c]	37.87[b]	38.70[b]	47.87[a]	1.79	0.013

CONT: basic diet; PROB: CONT + 0.2% commercial probiotics; ORAC: CONT + 0.2% commercial organic acids; PROR: CONT + 0.2% commercial probiotics + 0.2% commercial organic acids. Row means between groups with different superscript letters significantly differ (P < 0.05).

Table 4: The effects of probiotics, organic acids or their mix on fecal ammonia (NH_3) and hydrogen sulfide(H_2S) emissions (n=6).

Diet	CONT	PROB	ORAC	PROR	SEM	P value
Grower period (25-45kg, 75-105 days old)						
H_2S (mg/kg/m^3)	3.04[a]	1.83[b]	1.99[b]	1.67[b]	0.14	<0.0001
H_2S (mg/pig/m^3)	1.58[a]	0.85[b]	0.95[b]	0.78[b]	0.09	<0.0001
NH_3 (mg/kg/m^3)	8.37[a]	5.29[b]	5.11[b]	4.47[b]	0.22	<0.0001
NH_3 (mg/pig/m^3)	4.36[a]	2.45[b]	2.43[b]	2.12[b]	0.18	<0.0001
Finisher period (45-65kg, 105-135 days old)						
H_2S (mg/kg/m^3)	9.30[a]	5.71[b]	5.10[bc]	4.34[c]	0.33	<0.0001
H_2S (mg/pig/m^3)	7.61[a]	4.01[b]	3.62[bc]	2.72[c]	0.30	<0.0001
NH_3 (mg/kg/m^3)	14.2[a]	8.76[b]	7.72[bc]	6.81[c]	0.36	<0.0001
NH_3 (mg/pig/m^3)	11.6[a]	6.12[b]	5.53[b]	4.27[c]	0.25	<0.0001

CONT: basic diet; PROB: CONT + 0.2% commercial probiotics; ORAC: CONT + 0.2% commercial organic acids; PROR: CONT + 0.2% commercial probiotics + 0.2% commercial organic acids. Row means between groups with different superscript letters significantly differ (P < 0.05).

In the present work, dietary supplementation of probiotics or organic acids or their mixture led to a higher ADG and a lower FCR compared with a control diet over the entire experiment. This indicates that the use of probiotics or organic acids or their mixture in the diet indeed possessed some beneficial effects on the pigs. The reason for positive effects on ADG and FCR could be due to higher ATTD of nutrients in PROB, ORAC, and PROR diets compared to CONT diet in the whole experimental period. In agreement with the results of present work, earlier findings showed that growing pigs fed a diet with added *bacillus*-based probiotics (*Bacillus subtilis*, *Bacillus coagulans*, and *Lactobacillus acidophilus*) or probiotics (*Bacillus licheniformis* and *Bacillus subtilis*) or multi-species probiotics (*Bacillus coagulans*, *Bacillus licheniformis*, *Bacillus subtilis* and *Clostridium butyricum*) increased ADG and feed efficiency (Alexopoulos et al., 2004; Chen et al., 2006; Balasubramanian et al., 2018). A meta-analysis study reported that dietary probiotics supplementation increased ADG and FCR in pig production (Zimmermann et al., 2016). Similarly, dietary supplementation of organic acids (fumaric acid, citric acid, malic acid, and MCFAs) in growing pig diet improved the performance by diminishing gastrointestinal pH leading to alteration of the intestinal microbiota (Upadhaya et al., 2014a). Besides, a previous study by Ngoc et al. (2020) indicated that the Selacid GG (ORAC) supplementation significantly improved the final BW (3.6%), ADG (5.3%), and gain: Feed (8.1%) of pigs in the period 25-100kg. The positive influences of probiotics and organic acids on animal performance could be due to nutrient competition, antimicrobial substances production, intestinal adhesion or competitive inhibition of pathogenic bacteria (Steer et al., 2000; Zimmermann et al., 2016). This reason could be explained for the current study, which indicates that the dietary supplementation with a combination of PROB and ORAC had positive synergism effects on growth performance and FCR than the supplementation with PROB or ORAC alone. These results were confirmed by (Lei et al., 2018).

Dietary supplementation of probiotics or organic acids or their mix increased the ATTD of crude protein, organic matter, NDF, and phosphorus compared with control diet (PROR > ORAC > PROB > CONT), which are in line with previous findings (Meng et al., 2010; Upadhaya et al., 2014b; Balasubramanian et al., 2018), demonstrating that dietary supplementation of probiotics and organic acids improved nutrient digestibility. However, some studies showed that single probiotic or organic acids did not influence the nutrient digestibility in grower-finisher pigs (Kim et al., 2005; Upadhaya et al., 2014a; Balasubramanian et al., 2018; Lei et al., 2018). The inconsistencies of reports on the effects of these feed additives on nutrient digestibility may be related to factors such as the nutrition, kind of additive, dosage, environment, management, and animal characteristics (age, breed, period of production). In the present study, the ATTD of crude protein, organic matter, NDF, and phosphorus improved in pigs fed diets supplemented with a combination of PROB and ORAC, compared with those fed CONT diet or diets supplemented with PROB or ORAC alone. In a similar finding by (Lei et al., 2018), the ATTD of dry matter and crude protein increased in finishing pig diet supplemented with the combination of *Enterococcus faecium* and a mixture of organic acids and MCFAs. Devi and Kim (2014) also demonstrated that the ATTD of dry matter and crude protein were higher for diet supplemented with a mixture of MCFAs (caproic acid, caprylic acid, capric acid, and lauric acid) and *E. faecium* DSM 7134 than that of control diet or diets with MCFAs or *E. faecium* DSM 7134 alone. In this study, growth performance and ATTD were improved over the experimental period, which may state that dietary supplementation of probiotics or organic acids, especially their mixture, have positive effects on the growth performance and nutrient digestibility of grower-finisher pigs.

Some of the studies (Han et al., 2001; Ferket et al., 2002; Yan et al., 2010) reported that a reduction of harmful gas emissions from pig manure was related to the improvements in nutrient utilization and intestinal microbial ecosystem. In the present study, pigs fed diets with probiotics or organic acids or their mix had an increase in nutrient digestibility, resulting in a decrease in nutrient excretion (especially crude protein and amino acids); consequently, the fecal NH_3 and H_2S emissions were decreased. These results are in agreement with previous studies (Chen et al., 2006; Yan and Kim, 2013; Lan and Kim, 2019; Nguyen et al., 2019), which showed that dietary probiotics supplementation significantly reduced fecal NH_3 emission in grower-finisher pigs. In a study by (Zhang et al., 2016), the supplementation of benzoic acid combined with probiotics reduced the fecal noxious gas emission (NH_3, total mercaptans, and H_2S), which are the main gas components from pig manure contributed to air pollution. However, Devi and Kim (2014) showed that dietary supplementation of a mixture of MCFAs and probiotics did not decrease in mercaptan, H_2S, and acetic acid emissions but led to a significant reduction in NH_3 emission in weanling piglets. In addition, Lan and Kim (2019) reported that probiotics, such as *Bacillus* sp., are volatile sulfur-degrading bacterium that have been applied to decrease H_2S emission from pig feces. In this study, a significant decrease in fecal H_2S concentration with supplementation by probiotics, or organic acids or their mix, which may also be due to improved utilization of sulfur-containing amino acids. Moreover, the present study indicates a decreased trend of fecal noxious gas emission was found in diet supplemented with a blend of probiotics and organic acids compared with the diet with probiotic or organic acids alone (PROR > ORAC > PROB). This could be due to a synergistic action of the different compositions presented in the probiotics and organic acids.

CONCLUSIONS AND RECOMMENDATIONS

In grower-finisher pigs, supplementation of either PROB or ORAC as a single product or their combination in diets had improvements in performance parameters, nutrient digestibility, and fecal NH_3 and H_2S emissions compared with CONT diet. There were no differences in performance parameters between the use of a single product and the combination. In general, a diet containing a combination of probiotics and organic acids had larger effects on growth performance, nutrient digestibility and fecal NH_3, and H_2S emissions in grower-finisher pigs than a diet containing either probiotic or organic acids.

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NOVELTY STATEMENT

In grower-finisher pigs, a diet containing a combination of PROB and ORAC had more positive impacts on performance parameters, nutrient digestibility, and fecal NH_3 and H_2S emissions than a diet containing either PROB or ORAC.

AUTHOR'S CONTRIBUTION

Conception and design of study: TTBN, PKD.
Acquisition of data: TTBN, NTH, NCO.
Analysis and/or interpretation of data: TTBN, NTH, PKD.
Drafting the manuscript: TTBN, PKD.
Critical review/revision: TTBN, PKD, NCO, NTH.

Conflict of interest

The authors have declared no conflict of interest.

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