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Evaluation of dietary effects of lactic acid supplementation on growth performance, and nutrient digestibility in weanling pigs

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Abstract

A total of 96 weanling pigs with an initial body weight of 5.96 ± 0.08 kg were randomly allocated to two dietary treatments and fed experimental weaning diets for 36 days in three phases; phase 1: day 1 to 7; phase 2: day 8 to 21, and phase 3: day 22 to 36. Treatments consisted of a basal diet (CON) containing 334.0 g/kg dried whey versus a lactic acid (LA) supplemented diet containing 313.6 g/kg dried whey with 10 g/kg LA during phase 1; a CON diet containing 200.0 g/kg dried whey versus an LA diet containing 186.0 g/kg dried whey with 7 g/kg LA during phase 2. During phase 3, both CON and LA groups were fed a diet without dried whey and LA. Pigs fed the LA diet had a higher average daily feed intake ADFI ($p = 0.014$) and reduced ($p = 0.035$) gain-feed ratio compared to pigs fed CON diet in phase 2. In phase 3, the average daily gain and feed intake were both increased ($p = 0.026$ and; $p = 0.010$, respectively) in the pigs previously fed the LA diet than those fed the CON diet. The apparent total tract digestibility of dry matter and, nitrogen, and the digestible energy were decreased ($p < 0.05$) in the LA diet group on day 7; however, increased ($p < 0.05$) digestibility of dry matter and nitrogen and digestible energy was observed at the end of phase 2 and 3. In conclusion, the inclusion of LA was inferred to have improved the average daily gain, feed intake, and nutrient digestibility during the late weanling period of pigs.

Keywords: growth performance, lactic acid, nutrient digestibility, weaning pigs

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Introduction

Feeding and nutritional strategies are generally considered as paramount tool to ensure the success of weaning age and weight. This holistic approach was adopted in response to legislative changes in many countries which increased restrictions and break the routine on the way farmer were permitted to use antibiotics. Previously, it was a common practice to use in-feed antibiotics, various levels of zinc (Zn) products and/or high levels of copper (Cu) in piglet diets intending to cope up with gut infections and associated post weaning diarrhea (Farmer, 2020; Huting et al., 2021; Sureshkumar and

Kim, 2022). On the other hand, it is well known that weaning procedures create stress to piglet due to direct switch to solid feed and change in mixing them with other litters in new housing yet their immunity is not fully developed, this makes them prone to develop gastro-intestinal infections (Campbell et al., 2013). Therefore, it became imperative to improvise and find long-term innovative solution centered on animal welfare, as well as health of both animals and humans.

Lactic acid (LA) [$CH_3CH(OH)CO_2H$ H^+ + $CH_3CH(OH)CO_2$ - Ka = 1.38 × 10 - 4] is a weak organic acid, and does not have complete dissociation ability in water, but plays a role in several biochemical processes (Avérous, 2008). The presence of undissociated acid (H^+) of lactic acid define its ability to selectively hinders the multiplication of Gram-negative bacterial population such as (*Escherichia, Salmonella*) but does not have any effect on low pH tolerant Gram-positive bacteria such as (*Lactobacilli and Bifidobacterium*) as reported by Alakomi et al. (2000). Willamil et al. (2011) reported that it stimulates digestive enzymes secretion in pigs. Furthermore, Tsiloyiannis et al. (2001) endorsed the ability of LA to resist post-weaning diarrhea. Moreover, literature indicated many positive effects of LA when added in swine diet such as enhancing LA concentrations, provoking the release of pancreatic enzymes in weaning piglets, enhancement of apparent ileal digestibility (AID) of N and amino acid (AA) in finishing period (Ferronato and Prandini, 2020). In chicken, evidence shows that the acidic environment inhibits the growth of pathogenic bacteria, whereas beneficial effect of lactic acid bacteria and digestive enzymes remain active, also showed that lactic acid contributes greatly to the absorption of vitamins D and K, and helps in the formation of soluble salts of calcium (Ca) and iron (Fe).

Nowadays, dried whey is commonly used in weaning pig's diet. Whey are originally by-products derived from cheese processing industry, rich in lactose, which are easily fermentable by lactic acid producing bacteria in digestive system of the pigs to produce lactic acid. Having the above-mentioned functions among others, it is clear that incorporating LA in weaning diet would have promising results especially by creating beneficial balance in the animal microbiome and improve overall gut health leading to stronger growth and efficient feed conversion. To the best of our knowledge there are no similar study on the effect of dietary LA supplementation on gut health in weaning pigs have done so far. Therefore, the objective of this work was to figure out the effect of LA supplementation on the growth performance and nutrient digestibility in weanling pigs.

Materials and Methods

Animal ethics

The experimental protocol for the conduction of this trial got the consent from the committee in charge of Animals Care and Use of Dankook University, Cheonan, South Korea.

Study design, animals and diets

The experiment employed 96 heads cross breed ([Landrace × Yorkshire] × Duroc). 21 day (d) old weaning pigs weighing 5.96 ± 0.08 kg as initial body weight (BW) were split in two dietary treatments employing randomized complete block design in accordance with their sex and BW (8 replicate pens with 6 pigs per pen, 3 gilts and 3 barrows). The dietary treatments were allotted as follows:

- Phase 1 (0 - 7 d): CON-334.0 g/kg dried whey; LA-313.6 g/kg dried whey + 10 g/kg LA

• Phase 2 (8 - 21 d): CON-200.0 g/kg dried whey; LA-186.0 g/kg dried whey + 7 g/kg LA
• Phase 3 (22 - 36 d): Both CON and LA groups were fed a diet without dried whey and LA.

The cost of LA acid as feed additives is very expensive and thus, in this study piglets were allowed to consume decreasing levels of LA. The diet formulation was centered on nutrition requirements as recommended by the NRC (2012) (Table 1). Piglets kept indoors and thermal condition were maintained optimal. Every experimental pen used was furnished with unlimited access of feed and water along the trial period (d 0 to 36).

Table 1. Diet composition (g/kg as-fed basis unless stated otherwise)[x].

Ingredients	Phase 1 (d 0 - 7)		Phase 2 (d 8 - 21)		Phase 3
	CON	LA	CON	LA	(d 22 - 36)
Extruded corn	225.7	225.7	358.8	358.8	505.3
Soybean meal (480 g CP/kg)	150.3	150.3	199.0	199.0	258.4
Fish meal (660 g CP/kg)	80.0	80.0	50.0	50.0	30.0
Soybean oil	37.5	46.1	26.4	34.2	20.0
Dried whey	334.0	313.6	200.0	185.7	-
Lactic acid	-	10.0	-	7.0	-
Glucose	150.0	150.0	140.0	140.0	150.0
Limestone	4.0	4.0	6.0	6.0	10.0
Monocalcium phosphate	6.0	8.0	10.0	10.0	16.0
Salt	2.0	2.0	2.0	2.0	2.0
L-lysine-HCL (780 g/kg)	4.1	4.6	2.5	2.4	2.5
DL-methionine (998 g/kg)	1.5	1.5	1.7	1.7	1.8
L-threonine (890 g/kg)	0.8	0.8	-	-	-
Vitamin premix[y]	1.0	1.0	1.0	1.0	1.0
Mineral premix[z]	2.0	2.0	2.0	2.0	2.0
Choline chloride	1.1	0.4	0.6	0.2	1.0
Calculated energy content					
ME (kcal/kg)	3,350	3,350	3,320	3,320	3,320
Analyzed composition					
Crude protein	213.4	212.1	203.4	202.2	189.7
Lysine	16.2	15.7	14.3	14.2	13.1
Methionine + Cysteine	7.1	6.8	6.0	5.9	5.2
Crude fiber	15.3	15.2	22.1	22.4	30.2
Calcium	9.7	9.2	8.5	8.3	7.8
Phosphorus	7.5	7.6	6.8	6.7	6.0
Lactose	250.0	228.5	150.0	135.0	80.0

ME, metabolizable energy.
[x] d 0 to 7: CON, control diet containing 334.0 g/kg dried whey; LA, a diet containing 313.6 g/kg dried whey with 10 g/kg lactic acid; d 8 to 21: CON, control diet containing 200.0 g/kg dried whey; LA, a diet containing 186.0 g/kg dried whey with 7 g/kg lactic acid; d 22 to 36: Same diets without lactic acid.
[y] Provided per kg of complete diet: Vitamin A, 11,025 IU; vitamin D3, 1,103 IU; vitamin E, 44 IU; vitamin K, 4.4 mg; riboflavin, 8.3 mg; niacin, 50 mg; thiamine, 4 mg; d-pantothenic, 29 mg; choline, 166 mg; and vitamin B12, 33 µg.
[z] Provided per kg of complete diet: Cu (as $CuSO_4{\cdot}5H_2O$), 12 mg; Zn (as $ZnSO_4$), 85 mg; Mn (as MnO_2), 8 mg; I (as KI), 0.28 mg; and Se (as $Na_2SeO_3{\cdot}5H_2O$), 0.15 mg.

Experimental procedures, sampling and assay

The BW was measured on individual basis at the inception of experiment, d 7, 21, and 36 using GL-6000S machine (G-Tech Inc., LTD., Korea) and the feed consumption was recorded on a pen basis intending to calculate the average daily gain (ADG), average daily feed intake (ADFI), and gain/feed ratio (G/F). 2 g/kg of chromium oxide (Cr_2O_3) was added to the diet as tool (indigestible marker) to calculate the digestibility coefficient at d 0, 15, and 29 of the experiment. At least 2 piglets from each pen, were employed to grab fecal on d 7, d 21, and d 36. Later, feed and fecal samples were taken to the forced-air oven for 72 hours at 70°C to dry and subsequently they were minced and filtered to pass through a 1-mm screen and then stored at -20°C until the time for analysis. The nutrient digestibility of dry matter (DM), nitrogen (N), and gross energy (GE) were analyzed according to the procedures of AOAC (2000) as previously described by Muhizi and Kim (2021). The Chromium levels were detected via UV absorption spectrophotometry (UV-1201, Shimadzu, Japan) and the apparent total tract digestibility (ATTD) of DM, N and gross energy (GE) were calculated using indirect-ratio methods described by Williams et al. (1962) and was calculated follows: ATTD expressed in (%) = 100 - [{(NF/ND) × (CrD/CrF)} × 100], where-by ATTD is an abbreviated form of the apparent total tract digestibility, whereas NF, ND, CrD, and CrF stands for nutrient concentration level in the feces sample, nutrient concentration level in the diet, chromium concentration level in the diet, and chromium concentration level in the feces sample, respectively. The GE was determined by measuring the heat of combustion in the samples using a Parr 6100 oxygen bomb calorimeter (Parr instrument Co., USA). The N concentration was found using formula previously describes by Muhizi and Kim (2021).

Statistical analysis

Data were analyzed by Student t test of SAS software (SAS Inst. Inc., USA), with the pen being defined as the experimental unit. Data are reported as means with standard error and probability values less than 0.05 were considered significant.

Results

Growth performance

The effect of LA on growth performance is presented in Table 2. The body weight did not exhibit any significant difference between treatments along the course of the experiment. In phase 1, ADG and feed efficiency was decreased ($p = 0.001$) by dietary LA addition, whereas the ADFI was not affected between CON and LA. Pigs fed a LA-containing diet had higher ADFI ($p = 0.014$) compared to those in CON treatment in phase 2 but G/F was decreased ($p = 0.035$) significantly. In phase 3, ADG and ADFI were both increased ($p = 0.026$; $p = 0.010$ respectively) in the pigs previously fed the LA diet than those fed the control diets. The overall ADFI was greater ($p = 0.031$) in the LA group receiving lactic acid during phases 1 and 2. than that in the control group, whereas the G/F was similar between treatments.

Nutrient digestibility

The apparent total tract digestibility of DM, N, and DE were decreased ($p < 0.05$) by the LA supplementation to basal diet at the end of phase 1 (Table 3), but increased ($p < 0.05$) the digestibility of DM, N and DE at the end of phase 2 and 3 compared with CON.

Table 2. Effects of lactic acid supplementation on growth performance in weanling pigs.

Item	CON[y]	LA	SE[z]	p-value
BW (kg)	5.88	6.04	0.05	
d 7	6.93	6.86	0.09	0.125
d 21	12.83	12.80	0.28	0.321
d 36	23.02	23.71	0.36	0.251
Phase 1 (d 0 - 7)				
ADG (kg)	0.131a	0.103b	0.01	0.001
ADFI (kg)	0.213	0.210	0.01	0.215
G/F	0.616a	0.488b	0.05	0.021
Phase 2 (d 8 - 21)				
ADG (kg)	0.454	0.457	0.02	0.281
ADFI (kg)	0.673b	0.724a	0.01	0.014
G/F	0.674a	0.631b	0.03	0.035
Phase 3 (d 22 - 36)				
ADG (kg)	0.679b	0.728a	0.02	0.026
ADFI (kg)	1.002b	1.116a	0.03	0.010
G/F	0.678	0.652	0.03	0.318
Overall period (d 0 - 36)				
ADG (kg)	0.476	0.491	0.01	0.168
ADFI (kg)	0.708b	0.773a	0.02	0.031
G/F	0.673	0.635	0.03	0.133

BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; G/F, gain/feed ratio.
[y] Phase 1 (d 0 - 7): CON, control diet containing 334.0 g/kg dried whey; LA, a diet containing 313.6 g/kg dried whey with 10 g/kg lactic acid; Phase 2 (d 8 - 21): CON, control diet containing 200.0 g/kg dried whey; LA, a diet containing 186.0 g/kg dried whey with 7 g/kg lactic acid; Phase 3 (d 22 - 36): Same diets without lactic acid.
[z] Standard error. 8 replicate pens of 6 pigs/pen per treatment.
a, b: Means in the same row with different superscripts differ significantly.

Table 3. Effects of lactic acid supplementation on apparent total tract digestibility of dry matter, nitrogen and energy in weanling pigs.

Item (%)	CON[y]	LA[y]	SE[z]	p-value
D 7				
Dry matter	75.60a	71.66b	1.57	0.011
Nitrogen	74.79a	70.88b	1.80	0.024
Energy	78.34a	75.43b	1.54	0.034
D 21				
Dry matter	77.58b	81.24a	1.26	0.019
Nitrogen	75.48b	79.28a	1.38	0.021
Energy	77.96b	81.35a	1.24	0.023
D 36				
Dry matter	79.21b	82.64a	1.43	0.036
Nitrogen	78.48b	82.15a	1.76	0.028
Energy	80.25b	84.31a	1.28	0.016

[y] D 0 to 7: CON, control diet containing 334.0 g/kg dried whey; LA, a diet containing 313.6 g/kg dried whey with 10 g/kg lactic acid; D 8 to 21: CON, control diet containing 200.0 g/kg dried whey; LA, a diet containing 186.0 g/kg dried whey with 7 g/kg lactic acid; D 22 to 36: Same diets without lactic acid.
[z] Standard error. 8 replicate pens of 2 pigs/pen per treatment.
a, b: Means in the same row with different superscripts differ significantly.

Discussion

The in-feed antibiotics ban as growth promoter has urged the nutritionist to find the best nutritional substitutes that may exert similar antimicrobial functions without causing any harm. In the weaning process, it is obvious that piglets have physiological changes as a result of sudden change of living environment or diet, which may then lead to diarrhea. To cope up with the latter and with the existing ban of in-feed prophylactic use of antibiotics, Organic acids (OAs) has been suggested as candidate substitute for antimicrobial effects among many others.

As demonstrated earlier, OAs lowers down the pH value of digesta and whole stomach environment, modulate microbial diversity and improve nutrient utilization although the mechanism of action is still speculative. Li et al. (2018) reported that OAs exert positive effect on incidence of diarrhea and gut morphology in weaning fed less digestible diet. In facts, scientific reports appear to be an open discussion about which single acids are effective as acidifier than others in swine diet. Our results of current study showed that dietary LA supplementation did not affect the body weight gain throughout the experiment. Instead, the inclusion of LA decreased the ADG during d 1 to 7, but increased the ADG during last phase when dried whey and LA were not included in the diets. The reason for this decrease In BW may be due to poor digestibility of energy during the first phase of experiment. Also, the replacement of dried whey by LA may lower carbohydrate availability resulting on poor weight gain. Similarly, Cave (1984) observed a reduced feed intake and growth performance in chicks fed higher level of LA. It is also worth to note that high lactose fermentation plus the LA supplementation may interfere growth. However, the current study intends to find a clear reason of these findings. Tugnoli et al. (2020) indicated that the gastric pH is subjected to fluctuations over time after feeding, which perhaps explain the variation of ADG in this study. The decrease in ADG in the first phase may be linked to the fact that weaning was still under stress due to weaning procedure, they were not familiar to solid feed, perhaps late adaptation to new environment when mixed with other litters and possibly more feed wasted at the beginning of the study. While discussing these facts, a question arises whether LA may have influence on palatability but we got answer in a publication by Rudbäck (2013) who proved that pigs accept inclusion levels of lactic acid up to 200 mmol/kg. The increase of feed intake and daily gain in the last two phases may be correlated to the greater digestibility observed in the current study. In agreement with Kiarie et al. (2018) who reported that inclusion benzoic acid potential boosted growth performance and nutrient digestibility in nursery pigs. In line with our findings, reports also observed a decrease in feed intake in weaning piglet fed on 0.4% of 0.2% LA while the same study observed positive influence on growth performance (Walsh et al., 2007; Joo et al., 2009). Kim et al. (2005) earlier found that growth response and feed efficiency in weaning pigs were significantly improved by the addition of 0.8% LA to the drinking water. It is also said that the low pH in the gut environment delays the gastric emptying stimuli which give enough time for digestion and subsequently absorption become greater (Rudbäck, 2013) but rather the higher inclusions rate of acids in pig diet results in less feed consumption (Joo et al., 2009). Nguyen et al. (2020) recommended that the use of mixture of OAs may exhibit synergic effects than single acid supplement. The author also reported that OAs in practice does not have consistent effects due to the wide variety of available OAs products and the various recommended effective dosages with the different combination.

Our results showed that there was significant reduction in DM, N and energy digestibility measured at day 7 of the experiment. However, at days 21 and 36, the digestibility of DM, N and energy was significantly improved in pigs receiving LA supplemented diet. Possible explanations for the decrease in the digestibility during the first phase may be linked not only to the psychological stress that come during weaning procedure but also it is worth noting that the gut of piglet at weaning are still naïve to the solid feeds and thus it may take time for the gut to adapt new feed and get ready to digest solid feeds. Similar results were reported by Joo et al. (2009) that organic acids boosted protein and energy digestibility by lowering down microbial competition with the host animal. The author also mentioned that OAs exert most beneficial effects after 2 weeks of post-weanling. Li et al. (2019) stated that the variation of carbohydrate composition in the diet may have potential influence microbial fermentation and nutrient availability. According to Lee et al. (2021) age of animal may affect the efficiency of OAs on the nutrient's digestibility proven that the supplementation of OAs have improved the nutrient digestibility in growing pigs but in weaning pigs.

Conclusion

In conclusion, it could be inferred that the inclusion of LA had positive effect on the ADG and feed intake and nutrient digestibility during the late period of weanling. Our research team has planned to conduct further studies to elucidate the optimal supplementation levels that may induce better response.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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