Effect of antibiotics and synbiotic on growth performance, nutrient digestibility, and faecal microbial shedding in growing-finishing pigs

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**ABSTRACT**

This study evaluated the efficacy of antibiotics and a synbiotic in growing-finishing pigs. One hundred twenty-eight pigs (25.29 ± 1.33 kg) were randomly assigned to 4 dietary treatments: (1) control, basal diet throughout the experiment (CON); (2) basal diet during days 0–42 and basal diet supplemented with synbiotic (1 g/kg probiotics and 1 g/kg prebiotic) during days 42–119 (CS); (3) basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet during days 42–119 (AC); (4) basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet supplemented with synbiotic during days 42–119 (AS). During days 0–42, pigs fed the AC and AS diets had higher average daily gain and gain to feed ratio compared with pigs offered CON and CS diets ($P < 0.05$). Pigs offered the AC and AS diets had greater ($P < 0.05$) apparent total tract digestibility of dry matter and gross energy than pigs fed the CON and CS diets ($P < 0.05$). Pigs offered the AC and AS diets had lower ($P < 0.05$) counts of lactic acid bacteria (day 42) compared with those fed the CON and CS diets. In conclusion, these results demonstrate that supplementation with synbiotic in pigs had no effects on growth performance, nutrient digestibility, and faecal microbial shedding after supplementation with or without antibiotics in growing phase.

1. Introduction

In the past decades, as growth promoters, antibiotics have been widely used in swine production to enhance the growth performance and maintain the health condition of pigs (Casewell et al. 2003; Aarestrup 2012; Barton 2014; Cheng et al. 2014; Unno et al. 2015). However, due to increasing concerns about the emergence of antibiotic resistance and antibiotic residues in animal products, the use of antibiotic growth promoters in feed has been fully or partially banned in several countries (Maron et al. 2013; Diana et al. 2017; Yu et al. 2017). Consequently, there is a great need to explore alternatives to antibiotics in order to maintain animal growth and health.

Probiotics are live microorganisms which confer benefits on the host when administered in adequate amounts (FAO/WHO 2002). Positive responses to the inclusion of probiotics in the diets fed to pigs have been reported in previous studies (Davis et al. 2008; Meng et al. 2010; Zhao and Kim 2015). Meng et al. (2010) reported that supplementation with the combination of *Bacillus subtillus* endospores and *Clostridium butyricum* endospores improved growth performance and nutrient digestibility in growing-finishing pigs. Yoo et al. (2008) noted that multistrain probiotics (*Rhodopseudomonas capsulata*, *Rhizopus oligosporus*, and *Aspergillus oryzae*) improved growth performance in growing pigs. Prebiotics are defined as substrates that are selectively utilized by host microorganisms conferring a health benefit (Gibson et al. 2017). Fructooligosaccharide, an indigestible oligosaccharide, was used as a prebiotic in diets to improve pig performance and intestinal health (Xu et al. 2002; Lei et al. 2017). The term synbiotic describes a combination of probiotic and prebiotic approaches, which may give the synergistic effects of both prebiotics and probiotics on the growth of pigs (Shim et al. 2005; Lee et al. 2009). In current practice, however, many producers still include antibiotics in the feed especially in the early growth phase, but not in the finishing phase. However, limited studies have been conducted to evaluate the efficacy of synbiotics in this production system. Thus, the objective of this study was to evaluate the effect of a synbiotic on growth performance, nutrient digestibility, and faecal shedding of lactic acid bacteria in growing-finishing pigs.

2. Materials and methods

The protocol for this experiment was reviewed and approved by the Animal Care and Use Committee of Dankook University.

2.1. Source of probiotic and prebiotics

The probiotics (ALPHAGRO) used in this study were provided by a commercial company (INSTECH Co., Ltd., Seoul, South Korea) and contained $10^9$ cfu/kg *Clostridium butyricum* endospores, $10^{10}$ cfu/kg *Bacillus subtillus* endospores, and $10^9$ cfu/kg *Rhodopseudomonas capsulata*. The fructooligosaccharide (FOS-MAX®) used in this experiment was obtained from Dreamfeed Inc., Seoul, Republic of Korea.

2.2. Experimental design, animals, housing and diets

A total of 128 healthy crossbred [(Yorkshire × Landrace) × Duroc] growing pigs (average body weight: 25.29 ± 1.33 kg) were randomly assigned to 4 dietary treatments: (1) control, basal diet throughout the experiment (CON); (2) basal diet during days 0–42 and basal diet supplemented with synbiotic (1 g/kg probiotics and 1 g/kg prebiotic) during days 42–119 (CS); (3) basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet during days 42–119 (AC); (4) basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet supplemented with synbiotic during days 42–119 (AS). During days 0–42, pigs fed the AC and AS diets had greater ($P < 0.05$) apparent total tract digestibility of dry matter and gross energy than pigs fed the CON and CS diets ($P < 0.05$). Pigs offered the AC and AS diets had lower ($P < 0.05$) counts of lactic acid bacteria (day 42) compared with those fed the CON and CS diets. In conclusion, these results demonstrate that supplementation with synbiotic in pigs had no effects on growth performance, nutrient digestibility, and faecal microbial shedding after supplementation with or without antibiotics in growing phase.
were randomly allotted into 1 of 4 dietary treatment groups according to initial body weight and sex (8 replicate pens per treatment with 2 gilts and 2 barrows per pen) for a 119 days experiment. The dietary treatments were: (1) control, basal diet throughout the experiment (CON); (2) basal diet during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119 (CS); (3) basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet during days 42–119 (AC); (4) basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119 (AS). The antibiotics used in this study contained 100 g/kg chlortetracycline, 100 g/kg sulfathiazole, and 50 g/kg penicillin. The experimental diets were provided in meal form. The doses of probiotics were determined based on the previous study (Meng et al. 2010) and the recommendation of INSTECH Co., Ltd. (Seoul, South Korea). The dose of fructooligosaccharide used in the present experiment was determined based on the study of Lei et al. (2017). The basal diet (Table 1) was formulated to meet or exceed the nutrient requirements of swine according to the NRC recommendations (NRC 2012). The antibiotics, probiotics and prebiotic were supplemented in the diet at the expense of corn. The antibiotics, probiotics and prebiotic were pre-mixed with a small amount (5 kg) of corn and then mixed to the NRC recommendations (NRC2012). The antibiotics, probiotics and prebiotic were supplemented in the diet at the expense of corn. All pigs were housed in an environmentally controlled room with a slatted plastic floor. The room temperature and humidity were 25°C and 60%, respectively. Each pen was equipped with a separate self-feeder and a nipple drinker to ensure ad libitum feeding and access to fresh water throughout the experimental period.

The health condition of the pigs was monitored throughout the experiment. Pigs were weighed individually on day 0, 42 and 119 of the experiment. Feed disappearance was measured on a pen basis on each weighing day, and the amount of wasted feed was recorded daily. The data were used to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G:F).

To estimate the apparent total tract digestibility (ATTD) of dry matter (DM), nitrogen (N), and gross energy (GE), pigs were fed diets supplemented with chromic oxide (2 g/kg) as an indigestible marker before from days 36–42 and 113–119. During days 40–42 and 117–119, fresh faecal samples were collected by rectal palpation from 2 pigs (1 barrow and 1 gilt) per pen. The same 2 pigs were sampled at each time point. The samples were pooled by pen and immediately frozen at −20°C until analysis. Each collection of faeces for 3 days was pooled by pen and dried at 60°C over 72 h. All diets and faecal samples were ground to pass through a 1-mm sieve, after which they were analyzed for DM, N, and GE. DM was determined according to the method (930.15) of AOAC (2007). N was analyzed by an N analyser (Kjøtect 2300 N Analyzer; Foss Tecator AB, Hoganas, Sweden). GE was analyzed by measuring the heat of combustion in the samples, using a bomb calorimeter (Parr 6100; Parr instrument Co., Moline, IL, USA). Chromium was analyzed via UV absorption spectrophotometry (Shimadzu UV-1201; Shimadzu, Kyoto, Japan) according to the method of Williams et al. (1962). The ATTD was then calculated using the following formula: Digestibility (%) = [1−{(Nf × Cd)/(Nd × Cf)}] × 100, where Nf = nutrient concentration in faeces (% DM), Nd = nutrient concentration in diet (% DM), Cd = chromium concentration in diet (% DM), and Cf = chromium concentration in faeces (% DM).

For faecal lactic acid bacteria and coliform bacteria counts, fresh faeces were taken via rectal palpation from 2 pigs (1 gilt and 1 barrow) per pen on days 0, 42 and 119 of the experiment. The same 2 pigs were sampled at each time point. Samples were pooled on a pen basis and placed on ice and immediately transported to the laboratory for microbial analysis. Faeces (1 g) from each pen were diluted with 9 mL of 10 g/kg peptone broth (Becton, Dickinson and Co., Franklin Lakes, NJ, USA) and homogenized. Then, 10-fold dilutions of faecal samples were performed (ranging from $10^{-3}$ to $10^{-6}$) and then cultivated onto MacConkey agar plates (Difco Laboratories, Detroit, MI) for the enumeration of coliform bacteria and lactobacilli medium III agar plates (Medium 638; DSMZ, Braunschweig, Germany) for the enumeration of lactic acid bacteria. The lactobacilli medium III agar plates were then incubated for 48 h at 39°C under anaerobic conditions, while the MacConkey agar plates were incubated for 24 h at 37°C. The coliform bacteria and lactic acid bacteria colonies were counted immediately after removal from the incubator. Values were reported as log$_{10}$ colony-forming units per gram.

### 2.3. Statistical analysis

All experimental data were analyzed as a completely randomized block design using the general linear model procedure of SAS (1996, SAS Inst. Inc., Cary, NC, USA). The pen was

### Table 1. Ingredient composition and chemical analysis of basal diet (as-fed basis).

| Item                              | Days 0–42 | Days 42–119 |
|-----------------------------------|-----------|-------------|
| Ingredients, g/kg                 |           |             |
| Corn                              | 493.7     | 521.8       |
| Wheat                             | 150.0     | 150.0       |
| Soybean meal                      | 224.6     | 156.1       |
| DDGS (corn)                       | 15.0      | 50.0        |
| Palm kernel meal                  | 20.0      | 30.0        |
| Yellow grease                     | 39.0      | 35.0        |
| Molasses                          | 30.0      | 30.0        |
| Limestone                         | 12.7      | 10.6        |
| Mono-dicalcium phosphate          | 5.0       | 4.7         |
| Salt                              | 3.0       | 3.0         |
| DL-methionine                     | 0.3       | –           |
| L-lysine H$_2$SO$_4$               | 2.8       | 2.9         |
| L-threonine                       | –         | 0.2         |
| L-tryptophan                      | –         | 0.1         |
| Phytase                           | 0.5       | 0.5         |
| Vitamin-mineral premix$^a$         | 3.4       | 5.1         |

#### Analyzed composition, g/kg

| Item                              | Days 0–42 | Days 42–119 |
|-----------------------------------|-----------|-------------|
| Moisture                          | 120.6     | 121.0       |
| Crude protein                     | 167.0     | 148.8       |
| Ether extract                     | 64.3      | 63.2        |
| Crude fibre                       | 28.2      | 29.9        |
| Crude ash                         | 51.4      | 47.4        |
| Calcium                           | 7.1       | 6.1         |
| Phosphorus                        | 4.2       | 4.1         |
| Lysine                            | 9.6       | 8.0         |

$^a$Provided per kilogram of complete diet: 4800 IU vitamin A; 960 IU vitamin D3; 20 IU vitamin E; 2.4 mg vitamin K3; 4.6 mg riboflavin; 1.2 mg vitamin B$_6$; 13 mg pantothetic acid; 23.5 mg niacin; 0.02 mg biotin; 12.5 mg Mn (as MnO$_2$); 179 mg Zn (as ZnSO$_4$); 5 mg Cu (as CuSO$_4$·5H$_2$O); 0.5 mg I (as KI); and 0.4 mg Se (as Na$_2$SeO$_3$·5H$_2$O); 75 mg Fe (as FeSO$_4$·7H$_2$O).
considered as the experimental unit. Differences among treatments were separated by Tukey’s range test. Variability in the data is expressed as the standard error of the mean. Probability values less than 0.05 were considered significant.

3. Results

3.1. Growth performance

No death or diarrhoea was observed throughout the experiment. The effects of antibiotics and synbiotic on growth performance are presented in Table 2. During days 0–42, pigs fed the AC and AS diets had higher ADG and G:F compared with pigs offered the CON and CS diets (P < 0.05). However, during days 42–119 and 0–119, there were no differences in ADG, ADFI, and G:F among dietary treatments (P > 0.05).

3.2. Apparent total tract digestibility

During days 40–42, pigs offered the AC and AS diets had greater (P < 0.05) ATTD of DM and GE compared with those fed the CON and CS (Table 3). However, during days 117–119, the ATTD of DM, N, and GE were not affected by dietary treatments (P > 0.05).

3.3. Faecal shedding of lactic acid bacteria and coliform bacteria

Initially, no differences were detected in faecal lactic acid bacteria and coliform bacteria between dietary treatments (Table 4; P > 0.05). On day 42, pigs fed the AC and AS diets had fewer (P < 0.05) lactic acid bacteria counts compared with those fed the CON and CS, although coliform bacteria were not affected. On day 119, however, faecal coliform bacteria and lactic acid bacteria counts were not affected by dietary treatments (P > 0.05).

### Table 2. Effect of antibiotics and synbiotic on growth performance in growing-finishing pigs.

| Items       | CON  | CS   | AC   | AS   | SEM  | P-value |
|-------------|------|------|------|------|------|---------|
| Days 0–42   |      |      |      |      |      |         |
| ADG, g      | 619ab| 625a | 663a | 658a | 10.87| 0.007   |
| ADFI, g     | 1562 | 1573 | 1597 | 1579 | 14.48| 0.350   |
| G:F         | 0.396b| 0.397b| 0.415a| 0.417a| 0.005| 0.005   |
| Days 42–119 |      |      |      |      |      |         |
| ADG, g      | 753  | 762  | 789  | 771  | 19.13| 0.595   |
| ADFI, g     | 2248 | 2253 | 2262 | 2253 | 24.30| 0.982   |
| G:F         | 0.335 | 0.338 | 0.349 | 0.342 | 0.006| 0.367   |
| Days 0–119  |      |      |      |      |      |         |
| ADG, g      | 705  | 714  | 744  | 731  | 15.51| 0.116   |
| ADFI, g     | 2006 | 2013 | 2027 | 2015 | 18.51| 0.651   |
| G:F         | 0.352 | 0.355 | 0.367 | 0.363 | 0.005| 0.072   |

Notes: The dietary treatments were: (1) CON, basal diet throughout the experiment; (2) CS, basal diet during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119; (3) AC, basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119; (4) AS, basal diet supplemented with 1 g/kg probiotics during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119. Abbreviation: ADG, average daily gain; ADFI, average daily feed intake; G:F, gain to feed ratio; SEM, standard error of the mean.

### Table 3. Effect of antibiotics and synbiotic on nutrient digestibility in growing-finishing pigs.

| Items, % | CON  | CS   | AC   | AS   | SEM  | P-value |
|----------|------|------|------|------|------|---------|
| Days 40–42|      |      |      |      |      |         |
| DM       | 75.28b| 75.43b| 75.23a| 75.18a| 0.69 | 0.004   |
| N        | 73.54 | 73.98| 75.94 | 75.98 | 0.84 | 0.068   |
| GE       | 74.37b| 74.62b| 76.87a| 76.86a| 0.75 | 0.033   |
| Days 117–119 |      |      |      |      |      |         |
| DM       | 71.35 | 71.76 | 72.13 | 72.01 | 0.88 | 0.926   |
| N        | 69.42 | 69.82 | 70.36 | 70.02 | 1.16 | 0.951   |
| GE       | 70.83 | 71.02 | 71.51 | 71.33 | 0.96 | 0.959   |

Notes: The dietary treatments were: (1) CON, basal diet throughout the experiment; (2) CS, basal diet during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119; (3) AC, basal diet supplemented with 1 g/kg probiotics during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119; (4) AS, basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119. Abbreviation: DM, dry matter; GE, gross energy; N, nitrogen; SEM, standard error of the mean.

*Means in the same row with different superscript differ (P < 0.05).

4. Discussion

In partial agreement with previous experiments (Holt et al. 2011), the results of the present study showed that inclusion of antibiotics in feed improved growth rate and G:F in growing pigs. In the context of the ban of antibiotic growth promoters, increasing efforts have been made to develop alternatives. Beneficial effects of synbiotics on growth performance of pigs have been previously reported. Lee et al. (2009) and Chu et al. (2011) indicated that compared with weaning ([Yorkshire × Landrace] × Duroc; 6.8 kg) or growing ([Yorkshire × Landrace] × Duroc; 11.8 kg) pigs offered diet with antibiotics (oxytetracycline and timanulin), those fed diets supplemented with synbiotics (Aspargillus spp., Saccharomyces spp. or Lactobacillus spp. combined with mannan-oligosaccharide and lactose) obtained comparable growth performance. Although the ADG and ADFI were not affected, Piva et al. (2005) demonstrated that inclusion of a synbiotic (Lactobacillus salivarius 1B 4/11 and lactitol) improved G:F in weaning pigs (Yorkshire × Landrace; 8.6 kg). Additionally, in enterotoxigenic Erichescha coli K88 oral challenge model, Guerra-Ordaz et al. (2014) found that the synbiotic (combination of Lactobacillus plantarum JC1 and lactulose) improved ADG, but ADFI and G:F were not affected in weaning pigs ([Yorkshire × Landrace] × Pietrain; 6.3 kg). However, similar effects of a synbiotic composed of the probiotics (Clostridium butyricum endospores, Bacillus subtilis endospores, and Rhodopseudomonas capsulata) the prebiotic (fructooligosaccharide) could not be observed in the present study when this synbiotic was included in finishing phase after supplementation with or without antibiotics in the growing phase. Similarly, Liong et al. (2007) failed to observe positive effects on growth performance when a synbiotic (containing Lactobacillus acidophilus ATCC 4962, mannitol, fructooligosaccharide, and inulin) was added in a high-fat or low fat diet for pigs (Yorkshire × Landrace) weighing 33 kg. The inconsistent responses to synbiotics on growth performance suggest that the growth-promoting effects of synbiotics are probably dependent on factors such as dietary type, supplemental dose, bacterial species, growth phase of pigs, and hygienic condition of facility.
The improved ATTD of DM and GE in pigs fed diets supplemented with antibiotics may be one reason for the improved growth rate and G:F. However, in accordance with the growth performance, nutrient digestibility was not influenced by supplementation of synbiotics. Consistent with our results, Böhmer et al. (2005) reported that dietary supplementation with the combination of Enterococcus faecium DSM 10663 and inulin did not affect precaecal and faecal nutrient digestibility of DM, GE, and N in growing pigs (German Landrace × Pietrain; 36 kg). Likewise, Weiss et al. (2013) indicated that ileal DM and GE, ATTD of N in growing pigs (German Landrace × Pietrain; 7.5 kg). Moreover, Lee et al. (2009) observed that the ATTD of DM and crude protein was reduced with the addition of synbiotic (containing bacteria, yeast, mould, mannan oligosaccharide, lactose, sodium acetate, and ammonium citrate) in weaning pig (Yorkshire × Landrace) × Duroc; 6.8 kg) diet compared with supplementation of antibiotics (oxytetracycline and trimethoprim).

It is suggested that synbiotics may exert the synergistic effects of prebiotics and probiotics, stimulating beneficial bacteria and improving gut health, thereby improving growth and health of pigs (Modesto et al. 2009; Roselli et al. 2017). The combination of Pediococcus acidilactici and oligofructose reduced Enterobacteriaceae numbers and improved Lactobacilli: Enterobacteria ratio, although Lactobacilli counts were not affected in ileal digesta of piglets (German Landrace × Pietrain; 7.5 kg; Weiss et al. 2013). However, in the present study, faecal lactic acid bacteria and coliform bacteria counts did not differ at the end of the study when synbiotic was included in the diet, although lactic acid bacteria were suppressed at the end of growing phase due to the inclusion of antibiotics. In agreement with our results, Böhmer et al. (2005) found that the synbiotic (Enterococcus faecium DSM 10663 and inulin) had no effects on Bifidobacteria, Escherichia, and Lactobacilli counts in faeces of growing pigs (German Landrace × Pietrain; 36 kg). Additionally, Guerra-Ordaz et al. (2013) observed that the combination of lactulose and Lactobacillus plantarum JC1 had no effect on the numbers of faecal coliforms and lactic acid bacteria in weaning pigs (6.4 kg). The reasons for the lack of effect of synbiotic on faecal lactic acid bacteria and coliform bacteria counts in the present study may likely be the dose of synbiotic and the mature digestive and immune system in finishing pigs (Giang et al. 2011; Willamil et al. 2012). Further research is still warranted to assess the effects of different doses of synbiotic in growing-finishing pigs.

In conclusion, the results of this study indicate that supplementation with synbiotic in finishing pigs had no effects on growth performance, nutrient digestibility, and faecal coliforms and lactic acid bacteria after supplementation with or without of antibiotics in the growing phase.

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**Disclosure statement**

No potential conflict of interest was reported by the authors.

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**Table 4. Effect of dietary antibiotics and synbiotic on faecal microbial in growing-finishing pigs.**

| Items, log_{10} cfu/g | CON | CS | AC | AS | SEM | P-value |
|-----------------------|-----|----|----|----|-----|---------|
| **Day 1**              |     |    |    |    |     |         |
| Lactic acid bacteria   | 7.00| 7.04| 7.03| 7.05| 0.10 | 0.987   |
| coliform bacteria      | 5.77| 5.79| 5.71| 5.68| 0.07 | 0.708   |
| **Day 42**             |     |    |    |    |     |         |
| Lactic acid bacteria   | 7.16^a| 7.17^a| 6.79^b| 6.82^b| 0.08 | 0.036 |
| coliform bacteria      | 5.77| 5.75| 5.66| 5.69| 0.09 | 0.801 |
| **Day 119**            |     |    |    |    |     |         |
| Lactic acid bacteria   | 7.28| 7.31| 7.11| 7.20| 0.06 | 0.083 |
| coliform bacteria      | 5.86| 5.83| 5.85| 5.82| 0.07 | 0.974 |

Notes: The dietary treatments were: (1) CON, basal diet throughout the experiment; (2) CS, basal diet during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119; (3) AC, basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet during days 42–119; (4) AS, basal diet supplemented with 1 g/kg antibiotics during days 0–42 and basal diet supplemented with 1 g/kg probiotics and 1 g/kg prebiotic during days 42–119. Abbreviation: SEM, standard error of the mean.

^a,bMeans in the same row with different superscript differ (P < 0.05).
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