Inclusion of dietary multi-species probiotic on growth performance, nutrient digestibility, meat quality traits, faecal microbiota and diarrhoea score in growing–finishing pigs

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ABSTRACT

This study evaluated the effects of multi-species probiotic (MSP) in growing–finishing pigs. One hundred and fifty pigs [(Yorkshire × Landrace) × Duroc] with an average weight of 24.5 ± 0.88 kg were fed in two phases in a 16-week trial. Pigs were allotted to one of three diets with basal diet supplemented with 0, 0.1 or 0.2 g/kg MSP. Dietary inclusion of MSP increased (p < .05) body weight, average daily gain and gain:feed without effects of average daily feed intake at overall experiment and apparent total tract digestibility (ATTD) of dry matter (p = .025) and nitrogen (p = .067) at week 16. Dietary inclusion of MSP increased faecal Lactobacilli and decreased E. coli counts (p < .05) during entire experiment. The diarrhoea score in pigs fed the MSP diet was reduced (p < .05) compared with pigs fed the control diet. Dietary MSP exhibited increased sensory evaluation of colour (p = .003) and back fat thickness (p = .012) at week 16. Furthermore, the tendency to increased firmness and reduction of cooking and drip loss (p < .10) was observed. These results suggest the improving effects of dietary inclusion of MSP on growth performances, ATTD of nutrients, faecal microbiota, diarrhoea score and meat quality in pigs.

Abbreviations: 
MSP: multi-species probiotic; BW: body weight; ADG: average daily gain; ADFI: average daily feed intake; G:F: gain:feed ratio; ATTD: apparent total tract digestibility; DM: dry matter; E: energy; N: Nitrogen; NRC: National Research Council; NPPC: National Pork Procedures Council; LMA: longissimus muscle area; BFT: back fat thickness

Introduction

Over the past 50 years, there has been increase in the use of antibiotics in livestock production as a growth promoter which at sub-therapeutic levels lead to the development of resistance among bacterial strains. These antibiotics leave residues in the dressed carcass which led to the banning of antibiotic growth promoter and the need for development of suitable alternatives. In South Korea, using antibiotics as growth promoters in animal feed has been forbidden since 2011 (Global Agricultural Information Network 2011). Probiotics have received considerable attention as suitable alternatives to antibiotics to promote pig growth (Meng et al. 2010; Lan et al. 2017). When administered in sufficient numbers, they are known to have beneficial effects on the health of host (Reid et al. 2003). Many probiotic products are already used in many commercial applications, and bacteria are one of the most commonly used probiotics and are known to be effective in pigs (Fuller 1992; Sinol et al. 2012).

Previous studies with dietary supplementation of Bacillus sp. have reported favourable results in pigs (Hong et al. 2002; Gracia et al. 2004; Wang et al. 2009). In growing–finishing pigs, dietary probiotics can improve growth performance and meat quality (Alexopoulos et al. 2004; Ceslovas et al. 2005; Shon et al. 2005; Davis et al. 2008). It has been well accepted that dietary probiotics could benefit animal performance by producing antibacterial substances in their intestines by competing with harmful gut flora and stimulating the immune system (Fuller 1992; Hossain et al. 2015; Lan et al. 2017). Multi-species preparations have an advantage on growth performances in livestock animals when compared to mono- and multi-strain probiotics (Timmerman et al. 2004). However, there have been limited attempts to develop...
multi-microbe probiotic products and reports on the effect of multi-species probiotic (MSP) on growing-finishing pigs are limited. Therefore, the objective of the study was to investigate the effect of MSP on the growth performance, apparent total tract digestibility (ATTD) of nutrients, faecal bacterial counts, diarrhoea score and meat quality characteristics in growing-finishing pigs.

Materials and methods

Ethical considerations

The experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Dankook University, Cheonan, South Korea.

Source of multi-species probiotics

In this study, commercially available MSP product (SynerZymeF10®, Syner Big Co., Ltd., Chungju-Si, South Korea) that contained *Bacillus coagulans* (*1 × 10⁸* CFU g⁻¹), *B. licheniformis* (*5 × 10⁸* CFU g⁻¹), *B. subtilis* (*1 × 10⁹* CFU g⁻¹) and *Clostridium butyricum* (*1 × 10⁸* CFU g⁻¹) was used.

Experimental design, animals, housing and diets

A total of 150 crossbred [(Landrace × Yorkshire) × Duroc] pigs with the weight of 24.5 ± 0.88 kg were used in a 16-week trial. Pigs were allocated to one of three dietary treatments (basal diet supplemented with 0, 0.1 and 0.2 of MSP g/kg). Each treatment consisted of ten replications with five pigs (3 gilts and 2 barrows) per pen in a randomly complete block design based on gender and body weight. Diets in mash form were formulated to meet or exceed the requirements suggested by the NRC (2012, 2012). Pigs were housed in an environmental controlled, slatted-floor facility and mechanical ventilation system. Each pen was equipped with a self-feeder and a nipple water to allow ad libitum access to feed and water throughout the experimental period.

Growth performance traits and apparent total tract digestibility

Pigs were weighed at the initial (day 0) and 6th, 12th and 16th week of the experimental period. Feed consumption was recorded on a per pen basis to calculate average daily gain (ADG), average daily feed intake (ADFI) and gain:feed (G:F) ratio. Chromium oxide (2g kg⁻¹) was added to the diet as an indigestible marker of the diet for 7 days prior to faecal collection at the 6th and 16th week to calculate dry matter (DM), nitrogen (N) and energy (E) digestibility according to AOAC (2007). Faecal samples were collected randomly from at least two pigs (one barrow and one gilt) from each pen, mixed and pooled, and a representative sample was stored in a freezer at −20°C until analysed. They were dried at 70°C for 72 h, ground and passed through 1-mm screen along with feed samples to pass through a 1-mm screen before being analysed for DM [Method 934.01; Association of Official Analytical Chemists (AOAC 2000)], CP (Method 990.03; AOAC 2000), crude fat (Method 920.39; AOAC 1995), Ca (Method 984.01; AOAC 1995) and P (Method 965.17; AOAC 1995). Chromium was analysed using UV absorption spectrophotometry (Shimadzu UV-1201, Shimadzu, Kyoto, Japan) following published method (Williams et al. 1962). The digestibility was calculated according to the following formula:

\[
\text{ATTD} \% = \left[1 - \frac{(N_f \times C_d) - (N_d \times C_f)}{N_d \times C_f}\right] \times 100
\]

where \(N_f\) was a nutrient concentration in faeces (% DM), \(N_d\) was a nutrient concentration in diets (% DM), \(C_f\) was chromium concentration in faeces (% DM), and \(C_d\) was chromium concentration in diets (% DM).

Table 1. Composition of basal diets, g/kg (as-fed basis).

| Ingredients                        | Grower [0–6 weeks] | Finisher [7–16 weeks] |
|------------------------------------|---------------------|-----------------------|
| Maize                              | 547.5               | 614.6                 |
| Soybean meal, 48% CP               | 342.5               | 293.2                 |
| Rape seed meal                     | 20                  | 20                    |
| Tallow (liquid)                    | 51.6                | 44.2                  |
| Limestone                          | 8.4                 | 7.4                   |
| Di-calcium phosphate               | 15.2                | 11.6                  |
| DL-methionine, 99%                 | 0.4                 | 0.2                   |
| L-lysine-HCL, 78.4%                | 2.0                 | 2.0                   |
| Threonine, 98.5%                   | 0.12                | 0.16                  |
| Vitamin premixa a                   | 2.0                 | 2.0                   |
| Mineral premixa b                   | 1.0                 | 1.0                   |
| Salt                               | 2.0                 | 2.0                   |
| Choline                            | 4.5                 | 4.0                   |

- **Calculated composition**
  - Metabolisable energy, MJ/kg: 13.98, 13.90
- **Analysed composition**
  - Crude protein: 152.0, 148.9
  - Crude fat: 76.0, 72.7
  - Crude fibre: 32.9, 29.6
  - Calcium: 6.2, 5.3
  - Phosphorus: 3.1, 2.6
  - Lysine: 9.1, 6.7
  - Met – Cys: 6.5, 5.7

*Provided per kg diet: 20,000 U of vitamin A; 4000 U of vitamin D₃; 80 U of vitamin E; 16 mg of vitamin K₂; 4 mg of vitamin B₁₂; 20 mg of vitamin B₆; 6 mg of vitamin B₂; 0.08 mg of vitamin B₁₂; 120 mg of vitamin B₁₂; 50 mg of vitamin B₁₂; 2 mg of vitamin B₁₂ and 0.08 mg of vitamin B₁₂.

*Provided per kg diet: 142 mg of Cu; 178 mg of Zn; 12.5 mg of Mn; 0.5 mg of I; 0.25 mg of Co; and 0.4 mg of Se.
Faecal bacterial counts and faecal score analysis

Fresh faecal samples were directly collected via rectal massage of two pigs in each pen at 6th and 16th week of the experiment to determine the faecal microbiota counts. One gram of composite faecal sample from each pen was diluted with 9 mL of 1% peptone broth (Becton, Dickinson and Co., Franklin Lakes, NJ) and homogenised. Viable counts of bacteria in faecal samples were determined by plating serial 10-fold dilutions (in 1% peptone solution) onto MacConkey agar plates (Difco Laboratories, Detroit, MI) and Lactobacilli medium III agar plates (Medium 638, DSMZ, Braunschweig, Germany) to isolate *Escherichia coli* and *Lactobacillus*, respectively. *Lactobacilli* medium III agar plates were incubated at 39 °C for 48 h under anaerobic conditions. MacConkey agar plates were incubated at 37 °C for 24 h. The numbers of *E. coli* or *Lactobacillus* colonies were counted immediately after plates were removed from the incubator.

The diarrhoeal score of each piglet was recorded on week 6 and 16 of the trial. Diarrhoea was assessed visually on the basis of consistency of the faeces from the scale 1 = well-formed faeces, 2 = sloppy faeces and 3 = diarrhoea. The faecal score was performed in a treatment-blinded manner by two trained individuals. Scores were recorded on a pen basis observation of individual pigs and signs of stool consistency in the pen.

Meat quality traits

At the end of the experiment, all pigs were slaughtered at a local commercial slaughterhouse when they reached an average BW of 105–110 kg. Carcasses were chilled at 2 °C for 24 h. A sample of the right loin was removed between the 10th and 11th ribs. Meat samples were thawed at ambient temperature before evaluation. Sensory evaluation (colour, marbling and firmness scores) was conducted on the 10th-rib chop according to NPPC (1991) standards at ambient temperature (25 °C). Colour, marbling and firmness were scored by a sensory panel using a five-point scale (1 = pale, devoid of marbling, very soft; 2 = dark, moderately abundant marbling or greater, very firm). The sensory panel was comprised of 10 panelists, all of whom were trained to evaluate the sensory attributes of colour, marbling and firmness (NPPC 1991). Immediately after collection of chops, values for L* (lightness = 89.2), a* (redness = 0.921) and b* (yellowness = 0.783) were obtained from three orientations on the 10th-rib chop using Model CR-410 Chromameter (Konica Minolta Sensing Inc., Osaka, Japan) of CIE (Commission Internationale de l’Eclairage) and Hunter. The colour was measured on each loin meat sample in duplicate with one reading in the anterior and one reading in the posterior portion of the meat. All colour readings were taken on the skin side surface in an area free of obvious colour defects (over scald, bruises and blood accumulation). At the same time, duplicate pH values of each sample were directly measured using a pH meter (Istek, Model 77p). Longissimus muscle area (LMA) and back fat thickness (BFT) were measured by tracing the LM surface at the 10th rib using the aforementioned digitising area-line sensor. Drip loss of ~3 g of meat sample was measured using plastic bag method described by Honikel (1998). Cooking loss was determined using published method (Sullivan et al. 2007). The back fat thickness of carcase was adjusted to live weight of 110 kg as described previously (Ha et al. 2010).

Statistical analysis

All data were analysed as a randomised complete block design and the ANOVA was conducted using the GLM procedure of SAS/STAT® 9.2 (SAS Inst. Inc., Cary, NC). For all response criteria, each pen served as the experimental unit. Variability in the data was expressed as the standard errors mean. Differences among treatment means were determined using Tukey’s range test. Differences were deemed significant when \( p \leq .05 \), and trends were noted when \( .05 < p < .10 \).

Results

In the current study, pigs fed supplemented with 0.02% MSP diet had increased \( (p < .05) \) BW compared than other dietary treatments at week 12 and 16 (Table 2). However, there was tendency to increased ADG \( (p = .099 \) and .054) in pigs due to the inclusion of MSP in diets at week 6 and 16, respectively. Overall, MSP supplementation had significantly increased \( (p < .05) \) ADG and G:F ratio without effects \( (p > .05) \) on ADFI during the entire experiment.

Dietary MSP supplementation led to improve the ATTD of DM and N \( (p = .002 \) and .019, respectively) at week 6, observed increased DM \( (p = .025) \) and tendency of increased N \( (p = .067) \) at week 16 without effects on E \( (p > .05) \) at week 16 (Table 3). There was significantly increased faecal *Lactobacillus* \( (p = .008 \) and .012) and reduced *E. coli* counts \( (p = .04 \) and .053) at week 6 and 16, respectively, and its effects increase the MSP level in the diets. Furthermore, diarrhoea score in pigs fed the MSP diet was decreased \( (p < .05) \)
compared with pigs fed the control diet at week 6 and 16 (Table 4). Pigs fed supplemented with MSP had greater sensory evaluation of colour ($p = .003$) and tendency of increased firmness ($p = .079$), reduced cooking loss ($p = .065$), BFT ($p = .012$) and drip loss ($p = .064$ and .094) at day 5 and day 7, respectively (Table 5). Furthermore, the study showed that increased carcass weight in pigs fed the MSP diet, although the differences ($p > .05$) were not statistically significant. However, no significant ($p > .05$) difference was observed in meat colour, marbling, pH and LMA in the current study.

Discussion

In the current study, dietary inclusion of probiotic led to a greater BW, ADG and G:F ratio without affecting ADFI in growing–finishing pigs compared with CON diet throughout the entire experiment, indicating that the probiotic may had some positive effects on the animal, which is in agreement with Meng et al. (2010) who suggested that dietary mixture of *Bacillus subtilis* and *Clostridium butyricum* increased ADG and G:F without ADFI in growing–finishing pigs. Similarly, Chen et al. (2006) have reported an increased ADG in growing pigs fed diets supplemented with complex probiotic (*Lactobacillus acidophilus, Saccharomyces cerevisiae* and *B. subtilis*) at the amount of 0.2%. Shon et al. (2005) and Alexopoulos et al. (2004) have reported that the significant improvement was observed on growth performances when pigs were fed with multi-species probiotic supplement.

### Table 2. Effects of multi-species probiotic (MSP) supplementation on growth performance traits in growing–finishing pigs.

| Traits                  | CON   | T1    | T2    | SEM  | p-Value |
|-------------------------|-------|-------|-------|------|---------|
| Body weight             |       |       |       |      |         |
| Initial (day 0)         | 23.28 | 23.28 | 23.29 | 0.02 | 1.000   |
| Week 6                  | 52.98 | 54.66 | 54.88 | 0.59 | .103    |
| Week 12                 | 84.62 | 87.94 | 88.86 | 0.40 | .0002   |
| Week 16                 | 107.0 | 111.98| 113.16| 0.74 | .0008   |
| ADG, g                  | 707   | 747   | 753   | 14   | .099    |
| ADFI, g                 | 1567  | 1520  | 1536  | 38.41| .691    |
| G:F                     | 0.452 | 0.492 | 0.489 | 0.012| .106    |
| Week 6                  |       |       |       |      |         |
| ADG, g                  | 754   | 792   | 809   | 18.50| .162    |
| ADFI, g                 | 2344  | 2308  | 2291  | 37.56| .609    |
| G:F                     | 0.322 | 0.343 | 0.353 | 0.012| .235    |
| Week 12                 |       |       |       |      |         |
| ADG, g                  | 798   | 860   | 867   | 18.24| .054    |
| ADFI, g                 | 2814  | 2757  | 2792  | 34.03| .525    |
| G:F                     | 0.284 | 0.312 | 0.311 | 0.009| .103    |
| Overall                 |       |       |       |      |         |
| ADG, g                  | 74.3  | 79.2  | 80.4  | 6.53 | .0008   |
| ADFI, g                 | 2170  | 2125  | 2133  | 28.28| .514    |
| G:F                     | 0.344 | 0.373 | 0.376 | 0.006| .111    |

*CON: basal diet; T1: CON +0.1 g/kg MSP; T2: CON +0.2 g/kg MSP; ADG: average daily gain; ADFI: average daily feed intake; G:F: gain:feed; SEM: standard error of mean.

*Means in the same row with different superscripts differ ($p < .05$).

### Table 3. Effects of multi-species probiotic (MSP) supplementation on apparent total tract digestibility of nutrients in growing–finishing pigs.

| Traits                  | CON   | T1    | T2    | SEM  | p-Value |
|-------------------------|-------|-------|-------|------|---------|
| Week 6                  |       |       |       |      |         |
| Dry matter              | 74.24 | 76.78 | 77.20 | 0.51 | .002    |
| Nitrogen                | 73.81 | 75.95b| 76.12a| 0.71 | .019    |
| Energy                  | 74.18 | 75.35 | 75.58 | 0.93 | .506    |
| Week 16                 |       |       |       |      |         |
| Dry matter              | 70.32 | 72.89a| 73.96a| 0.85 | .026    |
| Nitrogen                | 69.63 | 71.77 | 72.32 | 0.84 | .068    |
| Energy                  | 70.05 | 72.07 | 72.32 | 0.76 | .104    |

*CON: basal diet; T1: CON +0.1 g/kg MSP; T2: CON +0.2 g/kg MSP; SEM: standard error of mean.

*Means in the same row with different superscripts differ ($p < .05$).

### Table 4. Effects of multi-species probiotic (MSP) supplementation on faecal microflora and diarrhoea score in growing–finishing pigs.

| Items                              | CON   | T1    | T2    | SEM  | p-Value |
|------------------------------------|-------|-------|-------|------|---------|
| Faecal microbial counts (log10 CFU g$^{-1}$) |       |       |       |      |         |
| Week 6                             |       |       |       |      |         |
| *Lactobacillus*                     | 7.26b | 7.37a | 7.41a | 0.02 | .009    |
| *E. coli*                           | 6.46a | 6.35ab| 6.30b | 0.03 | .04     |
| Week 16                            |       |       |       |      |         |
| *Lactobacillus*                     | 7.31b | 7.45a | 7.51a | 0.02 | .012    |
| *E. coli*                           | 6.52  | 6.42  | 6.39  | 0.02 | .054    |
| Diarrhoea Score$^c$                 |       |       |       |      |         |
| Week 6                             | 1.78  | 1.70  | 1.64  | 0.04 | .051    |
| Week 16                            | 1.52  | 1.28  | 1.12  | 0.06 | .042    |

*CON: basal diet; T1: CON +0.1 g/kg MSP; T2: CON +0.2 g/kg MSP; SEM: standard error of mean.

$^c$Means in the same row with different superscripts differ ($p < .05$).

### Table 5. Effects of multi-species probiotic (MSP) supplementation on carcass and meat quality characteristics in growing–finishing pigs.

| Traits                  | CON   | T1    | T2    | SEM  | p-Value |
|-------------------------|-------|-------|-------|------|---------|
| Meat Colour             |       |       |       |      |         |
| Lightness (L*)          | 58.34 | 58.42 | 58.79 | 1.42 | .971    |
| Redness (a*)            | 17.08 | 17.47 | 17.65 | 0.44 | .672    |
| Yellowness (b*)         | 6.16  | 6.10  | 6.07  | 0.32 | .980    |
| Sensory evaluation      |       |       |       |      |         |
| Colour                 | 3.37  | 3.65a | 3.78a | 0.04 | .003    |
| Firmness               | 2.88  | 3.19  | 3.28  | 0.12 | .079    |
| Marbling               | 1.90  | 2.06  | 2.16  | 0.19 | .667    |
| Cooking loss, %         | 30.83 | 29.4  | 28.29 | 1.08 | .066    |
| Drip loss, %            | 8.42  | 6.63  | 7.29  | 0.80 | .342    |
| Day 1                   | 13.96 | 12.43 | 12.96 | 0.67 | .330    |
| Day 5                   | 19.10 | 16.91 | 16.86 | 1.13 | .065    |
| Day 7                   | 23.91 | 23.06 | 22.65 | 0.64 | .094    |
| pH                     | 5.37  | 5.41  | 5.30  | 0.07 | .623    |
| Back fat thickness, mm  | 20.12 | 19.68ab| 18.48a| 0.39 | .012    |
| LMA, cm$^2$             | 68.49 | 68.58 | 70.44 | 0.93 | .316    |
| Carcase weight, kg      | 18.77 | 19.00 | 19.16 | 0.73 | .246    |

*CON: basal diet; T1: CON +0.1 g/kg MSP; T2: CON +0.2 g/kg MSP; SEM: standard error of mean.

*Means in the same row with different superscripts differ ($p < .05$).
According to Meng et al. (2010), MSP could increase the ATTD in the growing phase, but not in the finishing phase of pigs. Moreover, Balasubramanian et al. (2016) reported that Bacillus spp. probiotic in diets significantly increased nutrient digestibility in growing–finishing pigs. Cernauskiene et al. (2011) suggested that probiotics are normal components of the swine intestinal microbiota, which could produce lactic acid to reduce the pH value of the intestinal content and inhibit the development of invasive pathogens. Jin et al. (1997) reported that continuous feeding of direct-fed microbes to livestock could maintain the beneficial intestine microbiota by producing organic acids, hydrogen peroxide, inducing competitive exclusion of pathogenic bacteria and excreting antagonistic activity towards pathogenic bacteria. Previous studies reported that single probiotic did not affect the growth performance and nutrient digestibility in growing–finishing pigs (Kim et al. 1993; Kornegay and Risley 1996). But, in this study, ADG and G:F were increased all over the experiment, which may confirm the idea that diets supplemented with MSP could improve the growth performance and nutrient digestibility of growing–finishing pigs.

The present study revealed that dietary inclusion of MSP in pigs had effects on faecal bacterial counts and diarrhoea score, which are in agreement with Dowarah et al. (2017) who reported that dietary inclusion of MSP had significant effects on faecal bacterial counts and reduced diarrhoea score in pigs. This may be due to the microbiota balance in the gut being optimised, resulting in an improved utilisation of nutrients and reduced diarrhoea score. In this study, modest but statistically significant effects on Lactobacilli and E. coli counts were observed in faecal after pigs were fed with supplemented MSP, which are in agreement with Balasubramanian et al. (2016) and Yan and Kim (2013) who reported that inclusion of dietary probiotic increased the faecal Lactobacillus and decreased E. coli counts in growing–finishing pigs. Thus, it may the reason behind reduced diarrhoea incidence in pigs. Nevertheless, B. subtilis H4 (6 × 10^11 CFU mL^-1) supplementation did not affect faecal counts of Lactobacillus or E. coli in growing and finishing pigs (Giang et al. 2011). Therefore, we suggest that the rationale for the enhanced growth performance and feed efficiency is likely to be the increased apparent nutrient digestibility and the faecal Lactobacillus and decreased E. coli concentration, and diarrhoea score by dietary inclusion of MSP.

Data obtained from this study revealed that meat colour scores and firmness values were increased when pigs were fed with dietary inclusion of MSP than the CON diet, indicating that probiotic reduced lipid peroxidation in the muscles by maintaining the integrity of cell membranes and reduced the rate of water loss, affecting WHC. Our result consistent with Balasubramanian et al. (2016) reported that probiotic supplementation had beneficial effects on the increased sensory evaluations of colour and decreased drip loss in growing–finishing pigs. In our results, dietary inclusion of MSP was a tendency to reduced cooking and drip loss. Drip loss is a common indicator of meat quality, with lower drip loss indicating better meat quality. Similarly, Liu et al. (2013) reported dietary supplementation with probiotic can significantly reduce the drip loss and cooking loss by 24.40% and 11.45%, respectively, compared to the CON group. Generally, meat pH is a direct reflection of muscle acid content and it affects sheer force, drip loss and the colour of the meat (Hossain et al. 2015). In contrast, our experiment showed no significant effect of MSP on some meat quality traits (meat colour, marbling, pH, LMA, carcase weight) was found. Moreover, some authors (Ceslovas et al. 2005; Kim 2005; Ganeshkumar et al. 2009) reported that pigs receiving probiotic supplementation had significantly higher carcase weight, thus affecting the meat quality. However, complex multi-probiotic supplementation in diets to improve meat quality has been questioned, because results in pigs have been inconsistent. These contradictory results may be due to differences in experiment conditions, dosage level, bacteria species used and the pig’s genotype (Rekiel et al. 2005).

Conclusions

In conclusion, these findings suggested that dietary supplementation with the MSP was effective in improving growth performance and demonstrated that MSP may play a role in combating the diarrhoea caused by enterotoxigenic strains of E. coli, which indicates the maintenance of gut environment. There were beneficial effects on sensory evaluation of meat, BFT, cooking and drip loss; however, further studies are needed to determine the effects of MSP as supplementation to analyse the other meat quality traits in growing–finishing pigs.

Disclosure statement

No potential conflict of interest was reported by the authors.

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