**Effects of dietary fermented red ginseng marc and red ginseng extract on growth performance, nutrient digestibility, blood profile, fecal microbial, and noxious gas emission in weanling pigs**

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**ABSTRACT**

This study was conducted to determine the effect of dietary fermented red ginseng marc (FRGM) and red ginseng extract (RGE) on performance in weanling pigs. Dietary treatments included: (1) T1, control diet; (2) T2, control diet + 4 g/kg FRGM; (3) T3, control diet + 4 g/kg RGE; (4) T4, control diet + 4 g/kg FRGM + 4 g/kg RGE. On day 21, pigs fed T2 diet had higher apparent total tract digestibility (ATTD) of dry matter (DM) and lower NH3 emission than pigs fed T1 diet \((P < 0.05)\). Meanwhile, pigs fed T2, T3 and T4 diets had higher ATTD of Nitrogen (N) than pigs fed T1 diet \((P < 0.05)\). Moreover, on day 35, pigs fed T2, T3 and T4 diets had higher ATTD of DM and lower H2S emission than pigs fed T1 diet \((P < 0.05)\). In addition, pigs fed T2, T3 and T4 diets had lower fecal *E. coli* counts than pigs fed T1 diet \((P < 0.05)\). In conclusion, supplementation of FRGM and RGE improved nutrient digestibility, decreased fecal *E. coli* counts and fecal noxious gas emission of weanling pigs. However, no statistically significant differences were observed on growth performance and blood profile.

**Abbreviations:** FRGM, fermented red ginseng marc; RGE, red ginseng extract; ADFI, average daily feed intake; ADG, average daily gain; G/F, gain to feed ratio; ATTD, apparent total tract digestibility; BUN, blood urea nitrogen; BW, body weight; DM, dry matter; N, nitrogen; GE, gross energy.

1. Introduction

Various medicinal herbs are now being widely used in recent decades as an alternative to antibiotics owing to their plant-derived properties and growth-promoting effects (Huang et al. 2012; Zhao et al. 2016). Ginseng (*Panax ginseng* Meyer) is a perennial plant that has been used for centuries in Asian countries as an herbal medicine for the treatment of various diseases, due to its capacity to enhance immunity or inhibit inflammation (Lee et al. 2008). Red ginseng is fresh ginseng that is harvested after six years and then processed by steaming with water at 98–100°C followed by drying (Kim and In 2010). Consequently, red ginseng undergoes certain biochemical changes and has pharmacological properties, including antioxidant, anti-aging and hepatoprotective effects (Bak et al. 2012). The extracts of Korean red ginseng are a complex mixture containing ginsenosides, polysaccharides and several other products (Choi et al. 1998). Moreover, the red ginseng extract (RGE) has been reported to exhibit various pharmacological actions, including anti-oxidant, anti-cancer, anti-stress and anti-diabetes activities (Kim et al. 2002; Helms 2004; Kaneko and Nakanishi 2004; Vuksan et al. 2010). Red ginseng marc is a fibrous and insoluble byproduct obtained after the extraction process of red ginseng. It was believed to be a waste product, but recently, studies showed that red ginseng marc powder or fermented red ginseng marc (FRGM) has pharmacological properties and strong antioxidant effects (Lim et al. 2004; Jung et al. 2010; Kim et al. 2016). These benefits may be linked to the presence of bioactive components such as saponins, polysaccharides and alkaloids, which are retained in red ginseng marc after extraction (Francis et al. 2002; Yildirim et al. 2013).

Besides, it was reported that fermentation, apart from being an easy method to preserve raw materials for a short time prior to further processing, could give several advantages (improved flavour, enrichment with desirable metabolites produced by microorganisms and enhanced safety), as reported for other vegetable products (Buckenhuskes et al. 1990). To boost the bioactive activity of red ginseng, fermentation or formulation techniques of red ginseng have been developed and indeed these methods enhance the pharmacological activity of red ginseng (Lee et al. 2008; Jung et al. 2011, 2012). For example, RGE would most likely lead to increases in biological activities, such as antioxidant and anti-inflammatory activity (Lee et al. 2015). Furthermore, Ao et al. (2011a) reported that supplementation of fermented red ginseng had a minor effect on performance while partially improved meat quality in finishing pigs. Fermentation of medicinal herbs such as red ginsengs by microorganisms improved their pharmacological efficacy and neuroprotective activity by changing the contents of constituents of medicinal herbs (Zhao et al. 2016).
Based on our recent literature survey, there are no researches about FRGM and RGE in pigs. Considering the above benefits, we hypothesize that FRGM and RGE may exert positive effects on pigs. Therefore, the objective of this study was to determine the effect of supplementation of pig diets with FRGM and RGE on growth performance, nutrient digestibility, blood profiles, fecal microflora and noxious gas emission of weanling pigs during a 35-day feeding period.

2. Materials and methods

The experimental protocol used in this study was approved by the Animal Care and Use Committee of Dankook University, which is comparable to those laid down by the Canadian Council on Animal Care.

2.1. Preparation of Fermented Red Ginseng Marc (FRGM) and Red Ginseng Extract (RGE)

Red Ginseng that is the roots of 6-yr-old red ginseng plants (P. ginseng Meyer) was prepared by steaming fresh ginseng at 90–100°C for 3 h and then drying at 50–80°C. RGE was extracted at 85–90°C for 8 h by circulating hot water three times. The water content of the pooled extract was 36% of the total weight. RGE was analyzed using high-performance liquid chromatography. RGE contained the major ginsenosides, including Rb1, 7.44 mg/g; Rb2, 2.59 mg/g; Rc, 3.04 mg/g; Rd, 0.91 mg/g; Re, 1.86 mg/g; Rf, 1.24 mg/g; Rg1, 1.79 mg/g; Rg2, 1.42 mg/g; Rg3, 1.39 mg/g; Rh1, 1.01 mg/g and other minor ginsenosides. Freeze-dried red ginseng marc was fermented using two kinds of microorganisms, Bacillus subtilis (B. subtilis) and Bacillus coagulans (B. coagulans). Approximately 300 g of freeze-dried red ginseng marc was homogenized in 1 L of distilled water. Then, the mixture was autoclaved and allowed to cool before adding the B. subtilis and B. coagulans. The mixture was inoculated with 0.1% (w/w) of microorganisms and the sample was fermented at 700 × g and 30°C for 24 h. After fermentation, the sample was freeze-dried and used for experiments.

2.2. Experimental design, animal, and housing

A total of 140 crossbred [(Landrace × Yorkshire) × Duroc] weanling pigs with an average body weight (BW) of 6.62 ± 0.80 kg were used in a 5-week experiment. Pigs were randomly assigned into one of the four experimental diets according to BW and sex. Pigs were housed in groups of five (three barrows and two gilts) per pen with seven replicates per treatment. The following four treatments were used: T1, control diet; T2, control diet + 4 g/kg FRGM; T3, control diet + 4 g/kg RGE; T4, control diet + 4 g/kg FRGM + 4 g/kg RGE. All diets were provided in mash form and formulated to meet or exceed NRC (2012) nutrient requirements (Table 1). Two periods were consisted of days 0–21 and days 22–35 in the current experiment. All pigs were housed in an environmentally controlled room with a slatted plastic floor. Each pen was equipped with a self-feeder and nipple drinker to allow pigs free access to feed and water throughout the experiment. Temperature during the first week was maintained at 32°C and was decreased by 2.5°C each week thereafter and finally maintained at 22°C.

2.3. Sampling and measurements

Pigs were weighed on a pen basis on days 1, 7, 21, 35 and feed consumption was recorded throughout the experiment. Average daily gain (ADG), average daily feed intake (ADFI) and gain to feed ratio (G/F) were then calculated. From days 14–21 and days 28–35, pigs were fed diets mixed with 0.20% chromic oxide as an indigestible marker to determine ATTD of dry matter (DM) and nitrogen (N). Fecal samples were collected from at least 2 pigs in each pen (one gilt and one barrow; 14 pigs per treatment) at day 20, 21, 34 and 35. All fecal samples, as well as feed samples, were stored at −20°C until analysis, fecal samples were thawed at 60°C for 72 h, after which they were ground to pass through a 1-mm screen. All feed and fecal samples were analyzed for DM (method 930.15, AOAC 2005), crude protein (method 990.15, AOAC 2005), calcium (method 984.01, AOAC 2005) and phosphorus (method 965.17, AOAC 2005). N was determined using a Kjeltec 2300 Nitrogen Analyzer (Foss Tecator AB, Hoengeaes, Sweden). GE was analyzed using an oxygen bomb calorimeter (Parr 1600 Instrument Co., Moline, IL, USA). Chromium was analyzed by ultraviolet absorption spectrophotometry (UV-1201; Shimadzu, Tokyo, Japan) according to the methods of Williams et al. (1962). Digestibility was then calculated using the following formula: ATTD = \[1 - (\frac{N_i \times C_d}{N_d \times C_i})\], where \[N_i\] = nutrient concentration in the feces (%DM), \[C_d\] = chromium concentration in the diets (%DM), \[N_d\] = nutrient concentration in the diets (%DM), \[C_i\] = chromium concentration in the diets (%DM), and \[C_d\] = chromium concentration in the diets (%DM), \[C_i\] = chromium concentration in the diets (%DM), and \[C_d\] = chromium concentration in the diets (%DM), and \[C_i\] = chromium concentration in the diets (%DM).

**Table 1.** Composition of the experimental diets (as-fed basal).

| Items | Phase 1 (days 0–21) | Phase 2 (days 22–35) |
|-------|---------------------|---------------------|
| Ingredient (g kg⁻¹) | Extruded corn 368.0 | 492.8 |
| | Fermented oat 60.0 | 60.0 |
| | Soybean meal (440 g kg⁻¹ crude protein) 267.2 | 289.2 |
| | Fish meal 50.0 | 20.0 |
| | Soybean oil 50.0 | 38.0 |
| | Lactose 60.0 | – |
| | Whey powder 100.0 | 73.0 |
| | Dicalcium phosphate 12.0 | 15.0 |
| | Sugar 20.0 | – |
| | L-Lys-HCl (780 g kg⁻¹) 2.5 | 1.5 |
| | DL-Met (500 g kg⁻¹) 1.5 | 1.5 |
| | L-Thr (890 g kg⁻¹) 0.8 | – |
| | Vitamin premixa 1.0 | 1.0 |
| | Mineral premixb 2.0 | 2.0 |
| | Limestone 3.0 | 4.0 |
| | Salt 2.0 | 2.0 |

**Calcium composition (g kg⁻¹)**

| Metabolizable energy (kcal kg⁻¹) | 3480 | 3413 |
|---------------------------------|------|------|
| Crude protein                   | 217.8| 215.8|
| Calcium                         | 8.1  | 7.9  |
| Total phosphorus                | 7.1  | 7.0  |
| Available phosphorus            | 4.9  | 4.8  |
| Digestible methionine           | 5.2  | 5.0  |
| Digestible lysine               | 14.8 | 13.2 |
| Digestible threonine            | 6.1  | 6.0  |
| Digestible tryptophan           | 0.6  | 0.5  |

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*Provided per kg of complete diet: 11,025 IU of vitamin A; 1103 IU of vitamin D₃; 44 IU of vitamin E; 4.4 mg of vitamin K; 8.3 mg of riboflavin; 50 mg of niacin; 4 mg of thiamine; 29 mg of d-pantothenic acid; 166 mg of choline and 33 μg of vitamin B₁₂.

*Provided per kg of complete diet: 12 mg of Cu (as CuSO₄·5H₂O); 80 mg of Fe (as FeSO₄·7H₂O); 85 mg of Zn (as ZnSO₄); 8 mg of Mn (as MnO₂); 0.28 mg of I (as KI); and 0.15 mg of Se (as Na₂SeO₃·5H₂O).

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concentration in the diets (%DM) and Ci = chromium concentration in the feces (%DM).

For the blood profile, 2 pigs were randomly selected from each pen. Venous blood samples were taken via anterior vena cava puncture and added to heparinized tubes for blood urea nitrogen (BUN) and transaminases [aspartate transaminase (AST) and alanine aminotransferase (ALT)] analysis, as well as non-heparinized tubes for serum creatinine, triglyceride and total cholesterol analysis. The same pigs were bled on day 21 and 35. After collection, BUN concentration was analyzed using the Abbott Spectrum uria nitrogen test (Series II, Abbot Laboratories, Dallas, TX). Creatinine concentrations were determined using an Astra-8 Analyzer (Beckman Instruments, Inc., Brea, CA 92621). The concentrations of triglyceride and total cholesterol in serum samples were analyzed with an automatic biochemical analyzer (RA-1000, Bayer Corp., Tarrytown, NY) using colorimetric methods. Blood plasma was separated by centrifugation at 2000 g for 30 min at 4°C. The blood AST or ALT in the blood plasma were assessed using an automatic biochemistry analyzer (HITACHI 747, Japan).

Fecal samples were collected directly by massaging the rectum of 2 pigs in each pen (1 gilt and 1 barrow) on day 21 and 35. Samples from each pen were pooled and placed on ice for transportation to the lab. The obtained fecal sample (1 g) from each pen was diluted with 9 mL of 10 g L⁻¹ peptone broth (Becton, Dickinson and Co., Franklin Lakes, NJ, USA) and homogenized. Viable counts of bacteria in the fecal samples were then conducted by plating serial 10-fold dilutions (in 10 g L⁻¹ peptone solution) onto MacConkey agar plates (Difco Laboratories, Detroit, MI, USA), lactobacilli medium III agar plates (Medium 638; DSMZ, Braunschweig, Germany) and Rapaport Vassiliadis broth plates (Neogen Corporation) to isolate the E. coli, Lactobacillus and Salmonella, respectively. The MacConkey agar plates, lactobacilli medium III agar plates and Rapaport Vassiliadis broth (Neogen Corporation) plates were incubated for 24 h at 37°C, 48 h at 39°C and 48 h at 42°C, respectively. The E. coli, Lactobacillus and Salmonella colonies were counted immediately after removal from the incubator.

For analysis of noxious gas emissions, 300 g of fresh feces were randomly collected from 2 pigs (1 gilt and 1 barrow) in each pen on day 21 and 35 of the experiment. The total sampled feces were then stored in 2.6-L sealed plastic boxes with a small hole in the middle of one side that was sealed with adhesive plaster. These samples were permitted to ferment for 7 days at room temperature (32°C). After the fermentation period, an appropriate instrument (Gas Detector, GV-100S; Gastec Corp., Kanagawa, Japan) was used for gas detection (Gastec Detector Tube No. 3La for NH₃ and No. 4LK for H₂S; Gastec Corp.). Before measurement, the fecal samples were manually shaken for approximately 30 sec to disrupt any crust formation and to homogenize the samples and then 100 mL of the headspace air was sampled from approximately 2.0 cm above the sample.

### 2.4. Statistical analysis

All data were subjected to the GLM procedures of SAS (2001) as a randomized complete block design (SAS Inst. Inc., Cary, NC). The individual pig was used as the experimental unit. Differences among all treatments were separated by Duncan’s multiple range test. A probability level of P < 0.05 was considered to be statistically significant.

### 3. Results and discussion

#### 3.1. Growth performance and ATTD of nutrients in weanling pigs

Throughout the experiment, there were no differences (P > 0.05) in ADG, ADFI and G/F among all the treatments (Table 2). As shown in Table 3, on day 21, the ATTD of DM in T2 treatment was significantly (P < 0.05) higher than that of T1 treatment. Meanwhile, the ATTD of N was significantly (P < 0.05) increased in pigs fed with T2, T3 and T4 diets compared to pigs fed with T1 diet. However, the all the treatments had no significant (P > 0.05) difference in their effect on energy. On day 35, pigs fed with T2, T3 and T4 diets had significant (P < 0.05) higher DM digestibility than pigs fed with T1 diet. However, no significant (P > 0.05) effect on ATTD of energy and N was observed among the treatments.

Several studies have demonstrated that the immunostimulatory functions of ginseng could be due to the effects of its ginseng polysaccharides (Lee et al. 1997). Xi et al. (2017) reported that dietary maternal ginseng polysaccharides supplementation would affect the immune function of sows and

### Table 2. Effect of dietary fermented red ginseng marc and red ginseng extract on growth performance in weanling pigs.

| Items  | T1   | T2   | T3   | T4   | SE  |
|--------|------|------|------|------|-----|
| Days 0–7 |      |      |      |      |     |
| ADG, g | 219  | 253  | 246  | 243  | 17  |
| ADFI, g | 287  | 325  | 308  | 304  | 14  |
| G/F   | 0.762| 0.802| 0.821| 0.811| 0.073|
| Days 8–21 |      |      |      |      |     |
| ADG, g | 365  | 381  | 383  | 374  | 8   |
| ADFI, g | 476  | 480  | 465  | 468  | 9   |
| G/F   | 0.767| 0.795| 0.833| 0.801| 0.028|
| Days 22–35 |     |      |      |      |     |
| ADG, g | 429  | 438  | 441  | 436  | 20  |
| ADFI, g | 789  | 772  | 769  | 772  | 10  |
| G/F   | 0.543| 0.567| 0.570| 0.562| 0.025|
| Days 0–35 |     |      |      |      |     |
| ADG, g | 362  | 378  | 379  | 372  | 11  |
| ADFI, g | 564  | 566  | 555  | 557  | 9   |
| G/F   | 0.641| 0.669| 0.682| 0.668| 0.022|

Abbreviation: T1, control diet; T2, control diet + 4 g/kg fermented red ginseng marc; T3, control diet + 4 g/kg red ginseng extract; T4, control diet + 4 g/kg fermented red ginseng marc + 4 g/kg red ginseng extract.

Note: SE, Standard error.

### Table 3. Effect of dietary fermented red ginseng marc and red ginseng extract on nutrient digestibility in weanling pigs.

| Items, % | T1    | T2    | T3    | T4    | SE  |
|----------|-------|-------|-------|-------|-----|
| Day 21   |       |       |       |       |     |
| Dry matter | 81.44 | 84.35 | 83.74 | 83.85 | 0.85 |
| Nitrogen  | 79.41 | 82.87 | 82.66 | 82.20 | 0.77 |
| Energy    | 82.28 | 84.72 | 84.38 | 84.19 | 0.97 |
| Day 35   |       |       |       |       |     |
| Dry matter | 80.32 | 82.87 | 82.63 | 82.71 | 0.73 |
| Nitrogen  | 78.06 | 80.60 | 80.30 | 80.63 | 0.98 |
| Energy    | 81.93 | 82.93 | 82.84 | 82.29 | 0.95 |

Abbreviation: T1, control diet; T2, control diet + 4 g/kg fermented red ginseng marc; T3, control diet + 4 g/kg red ginseng extract; T4, control diet + 4 g/kg fermented red ginseng marc + 4 g/kg red ginseng extract.

Note: SE, Standard error.

*Means in the same row with different superscripts differ (P < 0.05).
then improve the immune function and growth of piglets. In addition, Ao et al. (2011a) reported that the inclusion of dietary ginseng (Basal diet + 2 g/kg fermented red ginseng) decreased ADFI in finishing pigs. Besides, the polysaccharides and saponin (bioactive constituent of red ginseng) were found to have a positive effect on the immune function, which has great potential for the use of immune modulators (Isley et al. 2005). It has been suggested that red ginseng may improve physiological function and immunity (Kim 2015). However, no positive influence of FRGM and RGE on growth performance of pigs was observed in this trial. These results are in agreement with those of Ao et al. (2011b) and Bong et al. (2011) who suggested that diet containing fermented red ginseng extract or red ginseng marc as feed additive had no positive effect on the performance in broilers. In addition, Jang et al. (2007b) reported supplementation of fermented wild-ginseng culture by-products had no influence on growth performance of finishing pigs. The different results obtained by various studies have been attributed to sources of ginseng produced by different methods may vary in their structure, chemical composition, or both, which may influence its activity and the amount that should be added to get a growth response (Ao et al. 2011a; Lee et al. 2016).

In the present study, the ATTD of N increased in pigs fed T2, T3 and T4 diets compared to those fed T1 diet on day 21. Moreover, the ATTD of DM increased in pigs fed T2, T3 and T4 diets compared to those fed T1 diet on day 35. These indicates that FRGM and RGE supplementation could improve nutrient digestibility in weanling pigs. Similar results were also reported in previous studies. Jang et al. (2007b) reported that fermented wild-ginseng culture by-product was effective for improving DM in finishing pigs. Moreover, Verse and Marteau (2007) reported that the microflora in the gut plays a crucial role in the anatomical, physiological and immunological organ development of host animals. Therefore, the improved ecosystem might best explain the better nutrient digestibility. In contrast, Ao et al. (2011a) reported no significant difference was observed in all indices (DM, N and energy) after fermented red ginseng supplementation in finishing pigs. The different result may be due to different age of pigs.

| Table 4. Effect of dietary fermented red ginseng marc and red ginseng extract on blood profile in weanling pigs. |
|-----------------|---------|---------|---------|---------|---------|
| BUN, mg/dL      | T1      | T2      | T3      | T4      | SE      |
| Day 21          | 9.86    | 10.38   | 11.46   | 9.90    | 0.92    |
| Creatinine, mg/dL| 0.44    | 0.38    | 0.37    | 0.43    | 0.03    |
| Cholesterol, mg/dL| 73.6    | 74.4    | 74.0    | 64.4    | 3.4     |
| AST, U/L        | 114     | 104     | 118     | 113     | 11      |
| ALT, U/L        | 82      | 90      | 95      | 82      | 10      |
| Triglyceride, mg/dL | 39      | 40      | 42      | 38      | 4       |
| Day 35          | 11.32   | 11.68   | 11.86   | 11.62   | 0.39    |
| Creatinine, mg/dL| 1.05    | 1.07    | 1.07    | 1.11    | 0.02    |
| Cholesterol, mg/dL| 73.6    | 74.4    | 63.0    | 63.4    | 4.6     |
| AST, U/L        | 83      | 86      | 86      | 85      | 5       |
| ALT, U/L        | 64      | 66      | 70      | 68      | 5       |
| Triglyceride, mg/dL | 41      | 43      | 46      | 41      | 5       |

Note: SE, Standard error.

3.2. Blood profile of weanling pigs

The effect of FRGM and RGE on blood profile is summarized in Table 4. No significant (P > 0.05) difference in the influence on BUN, creatinine, cholesterol, AST, ALT and triglyceride was observed on day 21 and 35 of experiment among the all treatments.

Several studies observed that dietary ginseng addition decreased the level of blood lipids (Muwalla and Abuireimeeh 1990; Yokozawa et al. 2004). Kim et al. (2015) reported that the red ginseng marc resulted is advantageous in reducing total cholesterol and triglyceride levels, as well as increasing HDL-C levels (but not LDL-C). It was well documented that the ability of saponins to form insoluble complexes with cholesterol in the digesta, which in turn inhibits intestinal cholesterol absorption and endogenous cholesterol synthesis (Rao and Gurfinkel 2000). Similarly, Jang et al. (2007a) demonstrated that the total cholesterol was decreased by fermented ginseng culture in laying hens. However, no response to FRGM and RGE were observed on blood profile in the present study, which may be attributed to more developed digestive system, improved immunity and increased resistance to intestinal disorders as pigs become older (Nousiainen and Setala 1998). So, the piglets used in this study were young and with immature digestive system. To date, these effects may be caused by the ginseng species, addition level, different sources or process methods (Ao et al. 2011a).

3.3. Fecal microbiota of weanling pigs

The effect of FRGM and RGE on fecal microbiota is summarized in Table 5. On day 21 and 35, pigs fed T2, T3 and T4 diets had decreased (P < 0.05) fecal E. coli counts than pigs fed T1 diet.

A number of pre-clinical studies have reported medicinal benefits of red ginseng including antioxidant, antitumor, antimutagenic (Kubo et al. 1992; Mochizuki et al. 1995; Kim et al. 2002) and a clinical study has reported immunomodulatory actions (Park et al. 2011). Furthermore, red ginseng extract inhibited the breaking of E. coli ColE1 plasmid DNA as well as the nuclear DNA of rat hepatocytes damaged by oxidative stress (Park et al. 2009). In addition, several studies have demonstrated that the immunomodulatory functions of ginseng could be due to the effects of its ginseng polysaccharides (Lee et al. 1997; Xi et al. 2017). Ginseng polysaccharide was the active...
ingredient in FRGM and RGE. Many plants produce a beneficial effect by stimulation of the bacteria selective growth and metabolic activity of caecum and reduce the number of potentially harmful species as *E. coli*. For instance, maternal seaweed-extracted polysaccharide supplementation decreased *E. coli* numbers in the caecum and colon of weaned pigs (Leonard et al. 2011). In the present study, T2, T3 and T4 diets decreased *E. coli* counts on both day 21 and 35. Therefore, we hypothesis that the lower counts of *E. coli* may be a result of the pharmacological actions of ginseng polysaccharides.

### 3.4. Gas emission of weanling pigs

There was a significant decrease (*P < 0.05*) in NH3 and H2S emission associated with the inclusion of FRGM and extract in diets (Table 6). On day 21, pigs fed T2 diet had decreased (*P < 0.05*) NH3 emission than pigs fed T1 diet. Moreover, on day 35, pigs fed T2, T3 and T4 diets had decreased (*P < 0.05*) H2S emission compared to pigs fed T1 diet. However, the absence of effect on acetic acid occurred in both period (day 21 and day 35).

Better nutrient digestibility and improved intestinal microbial balance could lead a decreased fecal noxious gas contents (Ferket et al. 2002; Upadhyaya et al. 2016; Zhang et al. 2016). Yan et al. (2011) also reported that the fecal noxious gas emission is associated with nutrient digestibility because the increased digestibility may result in less substrate available for microbial fermentation in the large intestine, which consequently decreases fecal noxious gas emission. Moreover, a wide number of toxic metabolites as NH4 are generated following microbial fermentation of feed at large intestine. Microflora involved in the formation of various toxic metabolites are *E. coli*, *Clostridium spp.*, etc. In our study, fecal NH3 emission was significantly (*P < 0.05*) decreased in T2 group on d 21. Meanwhile, the ATTD of N was significantly (*P < 0.05*) increased in T2 group compared to T1 group. So, the reduction observed of NH3 could be by the reduction of *E. coli*. On other hand, some studies observed a higher level of total digestive enzyme activity was recorded in shrimp fed *B. subtilis*-supplemented diets (Ziaei-Nejad et al. 2006; Zokaeifar et al. 2012). Chen et al. (2005) reported that supplementation of *bacillus*-based (8. *subtilis*, 1.0 × 107 CFUg−1; *Bacillus coagulans*, 2.0 × 106 CFUg−1 and *Lactobacillus acidophilus*, 5.0 × 106 CFUg−1) probiotics significantly (*P < 0.05*) decreased the fecal NH3-N in finishing pigs. Consequently, the possible mechanism might be feeding of fermented red ginseng marc by *B. subtilis* released digestive enzymes and thus increases nitrogen availability and nutrient digestibility in the intestine, the impact was reflected on the concentration of NH3 in the feces. Interestingly, Choi et al. (2012) discovered that RGE efficiently blocked *H. pylori*-associated H2S generation and these activities may mitigate *H. pylori*-associated inflammation as well as carcinogenesis. Similarly, in present study, we found that both FRGM and extract had significantly (*P < 0.05*) decreased H2S emission on d 35. Because of this study is the first study which investigated FRGM and RGE supplementation in pigs, no more comparisons could be made here and more researches are needed to assess the effects of FRGM and RGE, especially in weanling or growing pigs.

### 4. Conclusion

In conclusion, the results of our study demonstrated that FRGM and RGE had no beneficial effects on performance and blood profile, but improved nutrient digestibility, decreased fecal *E. coli* counts and gas emission in weanling pigs.

### Disclosure statement

No potential conflict of interest was reported by the authors.

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**Table 6.** Effect of dietary fermented red ginseng marc and red ginseng extract on fecal noxious gas emission in weanling pigs.

| Items, ppm | T1 | T2 | T3 | T4 | SE |
|-----------|----|----|----|----|----|
| **Day 21** |    |    |    |    |    |
| NH3       | 15.53ab | 11.78ab | 14.15ab | 14.20ab | 0.89 |
| Acetic acid | 2.40 | 2.25 | 2.23 | 2.23 | 0.08 |
| H2S       | 7.03 | 5.30 | 6.08 | 6.80 | 0.54 |
| **Day 35** |    |    |    |    |    |
| NH3       | 13.48 | 11.58 | 12.00 | 12.25 | 0.58 |
| Acetic acid | 2.13 | 2.03 | 2.03 | 2.00 | 0.11 |
| H2S       | 6.65a | 5.35b | 5.58b | 5.73b | 0.23 |

Abbreviation: T1, control diet; T2, control diet + 4 g/kg fermented red ginseng marc; T3, control diet + 4 g/kg ginseng extract; T4, control diet + 4 g/kg fermented red ginseng marc + 4 g/kg red ginseng extract.

Note: SE, Standard error.

*abMeans in the same row with different superscripts differ (*P < 0.05*).
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