Evaluation of various sulphur amino acid to lysine ratio for growing-finishing pigs fed antibiotic-free diets

Wen-Chao Liu and In-Ho Kim
Department of Animal Resource & Science, Dankook University, Cheonan, Chungnam, South Korea

ABSTRACT
This 10 wk feeding trial was conducted to determine the effect of increasing the standardised ileal digestible (SID) sulphur amino acid to lysine ratio (SAA:Lys) on performance and intestinal health parameters in growing-finishing (50–100kg) pigs fed antibiotic-free diets. A total of 96 pigs [(Landrace × Yorkshire) × Duroc] with an average initial body weight (BW) of 52.2 ± 2.32 kg were randomly assigned to 4 dietary treatments each with 6 replicates (4 pigs per pen, 2 females and 2 males). The dietary treatments were 4 graded levels of SID SAA to Lys ratios (0.57, 0.67, 0.70 and 0.73). During the phase 1 (50–75kg), pigs fed diets with increasing dietary SID SAA:Lys tended to improve the ADG (linear, p = .07) and G:F (linear, p = .06). During the phase 2 (75–100kg), increasing SID SAA:Lys ratio had a tendency (linear, p = .08) to improve the ADG and G:F. Furthermore, the villus-to-crypt ratio of duodenum were linearly increased (p < .05) by increasing SID SAA:Lys at the end of the experiment. Moreover, increasing SID SAA:Lys ratio linearly improved (p < .05) the ratio of faecal Lactobacillus:Escherichia coli in both phase 1 and phase 2. There was a linear decrease (p < .05) in ammonia when pigs were fed diets with increased SID ratio of SAA:Lys in both phase 1 and phase 2. In conclusion, increasing the dietary SID SAA:Lys provided beneficial effect on gut health of growing-finishing pigs fed antibiotic-free diets and showed partial positive effect in growth performance.

Introduction
Although the optimum proportion of sulphur amino acid (SAA, Met and Cys) to lysine for growing-finishing pigs has been widely investigated in recent years (Hahn & Baker 1995; Knowles et al. 1998; Loughmiller et al. 1998; Zhang et al. 2015), the SAA requirement varies depending on response criteria and health status of pigs. According to NRC (2012), the proposed ratio of standardised ileal digestible (SID) SAA to lysine for 50–100 kg pigs ranges from 0.56 to 0.60. However, the ideal AA pattern presented in NRC (2012) are made for health pigs and does not consider any other factors such as changes in feeding regimen (Kahindi 2014). Among these factors, the ban in the use of antibiotic growth promoters in pigs diets should be noted. In addition, as the genetic improvements in pigs breeding, the higher growth rate may result in a greater AA requirements.

The SAA are not only important for protein accretion, but also production of cytokines, mucin, acute phase proteins and glutathione, the mucin is served as a protective barrier to modulate the intestinal function and health (Grimble 2006). It is suggested that about 30% of the dietary SAA is utilised by the gut for epithelial cell differential and mucosal growth (Bauchart-Thevet et al. 2009). Furthermore, available literature indicated that SAA could stimulate humoral and cell-mediated immune responses and the metabolites from Met possess pro- and anti-inflammatory properties (Hunter & Grimble 1994; Brosnan & Brosnan 2006). The feeding programmes without in-feed antibiotic may alter the SAA requirement for optimal performance. More recently, Kahindi (2014) suggested that the SID SAA:Lys ratio recommended by NRC (2012) would be insufficient and should be raised to 0.60 in weaning pigs fed an antibiotic-free diet. We hypothesised that increase in dietary SAA is beneficial for gut health and growth performance of growing-finishing pigs under antibiotics-free feeding regime. Therefore, the present experiment was conducted to determine the effect of...
increasing the SID ratio of SAA:Lys on growth performance and functional digestive parameters of growing-finishing pigs fed an antibiotic-free diet.

Materials and methods

The Dankook University Animal Care and Use Committee (Cheonan, South Korea) reviewed and approved all animal protocols used in the present research.

Animals, housing and dietary treatments

A total of 96 crossbred pigs [(Landrace × Yorkshire) × Duroc] with an average initial BW of 52.2±2.32 kg were used in the present 10-wk feeding study. Pigs were allocated to 1 of 4 treatments according to their BW and sex with 6 replicates per treatment and 4 pigs per pen (2 females and 2 males). The diets were maize–soybean meal-based and ingredients formulation as described in Tables 1 and 2. The dietary treatments were 4 graded levels of SID SAA to Lys ratios (0.57, 0.67, 0.70 and 0.73). All other nutrients were provided in quantities meeting or exceeding NRC (2012) recommendations for 50–100 kg pigs. In addition, the diets were fed in mash form and did not contain any antibiotic growth promoters. All pigs were housed in an environmentally controlled room with a slatted plastic floor. Each pen (1.8 m width × 3.0 m length) was equipped with a one-sided self-feeder and a nipple drinker to allow pigs ad libitum access to feed and water, respectively.

Experimental procedures and sampling

Individual pig BW were measured on the initial, at the end of 4 week, and the final day of the experiment, and feed consumption was recorded on a pen basis during the experiment to determine average daily gain (ADG), average daily feed intake (ADFI) and gain:feed (G:F).

After pigs were slaughtered at the end of the trial, the entire intestine of 24 selected male pigs (6 pigs/treatment and 1 pig/pen) was then removed and dissected free of mesenteric attachments and placed on a smooth and cold surface. The duodenum were separated. The isolated intestinal segments were immediately opened lengthwise following the mesentery line and flushed with ice-cold saline. Approximately 2 cm segments of the duodenum at consistent locations were collected immediately, fixed in 10% formalin, then subsequently embedded, sectioned and stained

Table 1. Compositions of basal diets for 50–75 kg pigs (phase 1, as-fed basis).

| Item                  | SAA:Lys = 0.57 | SAA:Lys = 0.67 | SAA:Lys = 0.70 | SAA:Lys = 0.73 |
|-----------------------|---------------|---------------|---------------|---------------|
| Ingredient, %         |               |               |               |               |
| Maize                 | 61.25         | 61.16         | 61.13         | 61.10         |
| Wheat                 | 1.50          | 1.50          | 1.50          | 1.50          |
| Molasses              | 3.10          | 3.10          | 3.10          | 3.10          |
| Soybean meal          | 25.68         | 25.68         | 25.68         | 25.68         |
| Rapeseed meal         | 1.60          | 1.60          | 1.60          | 1.60          |
| L-Lysine-HCl (78%)    | 0.04          | 0.04          | 0.04          | 0.04          |
| DL-Methionine (99%)   | –             | 0.07          | 0.07          | 0.09          |
| L-Cysteine (99%)      | –             | 0.05          | 0.05          | 0.06          |
| Tallow (liquid)       | 4.35          | 4.35          | 4.35          | 4.35          |
| Limestone             | 0.79          | 0.79          | 0.79          | 0.79          |
| Dicalcium phosphate   | 1.18          | 1.18          | 1.18          | 1.18          |
| Salt                  | 0.20          | 0.20          | 0.20          | 0.20          |
| Vitamin premixa       | 0.20          | 0.20          | 0.20          | 0.20          |
| Mineral premixa       | 0.10          | 0.10          | 0.10          | 0.10          |
| Choline               | 0.01          | 0.01          | 0.01          | 0.01          |
| Total                 | 100.0         | 100.0         | 100.0         | 100.0         |

Calculated composition

| Item               | ME, kcal/kg | Calculated composition |
|--------------------|-------------|------------------------|
|                    | 3391        | 3390                   |
| Crude protein, %   | 17.50       | 17.50                  |
| Crude fat, %       | 6.80        | 6.80                   |
| Crude fibre, %     | 3.26        | 3.26                   |
| Crude ash, %       | 4.91        | 4.91                   |
| Calcium, %         | 0.68        | 0.68                   |
| Phosphorus, %      | 0.55        | 0.55                   |
| SID lysine, %      | 0.90        | 0.90                   |
| SID methionine, %  | 0.24        | 0.29                   |
| SID cysteine, %    | 0.27        | 0.31                   |
| SID Met + Cys (SAA), % | 0.51     | 0.60                   |

Table 1 continued

| Item               | ME, kcal/kg | Calculated composition |
|--------------------|-------------|------------------------|
|                    | 3389        | 3390                   |
| Crude protein, %   | 17.50       | 17.50                  |
| Crude fat, %       | 6.80        | 6.80                   |
| Crude fibre, %     | 3.26        | 3.26                   |
| Crude ash, %       | 4.91        | 4.91                   |
| Calcium, %         | 0.68        | 0.68                   |
| Phosphorus, %      | 0.55        | 0.55                   |
| SID lysine, %      | 0.90        | 0.90                   |
| SID methionine, %  | 0.24        | 0.29                   |
| SID cysteine, %    | 0.27        | 0.31                   |
| SID Met + Cys (SAA), % | 0.51     | 0.60                   |

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

Provided per kg of complete diet: 8 mg of Mn (as MnO2); 60 mg of Zn (as ZnSO4); 5 mg of Cu (as CuSO4·5H2O); 40 mg of Fe (as FeSO4·7H2O); 0.3 mg of Co (as CoSO4·5H2O); 1.5 mg of I (as KI); and 0.15 mg of Se (as Na2SeO3·5H2O).
with haematoxylin and eosin by routine methods. Villus height, crypt depth, and villus height to crypt depth ratio (VH:CD) of the small intestine were measured in approximately 10 microscopic fields using an image analysis system by a blinded investigator.

Fecal microbiota were determined by serial dilution ($10^{-1}$ to $10^{-7}$) in anaerobic diluent before inoculation onto petridishes of sterile agar as described by Bryant and Burkey (1953). Lactobacilli and Escherichia coli present in the fresh faecal samples were enumerated. The medium for Lactobacilli was Rogosa SL agar (Rogosa; Difco Laboratories, Detroit, MI) and for E. coli was MacConkey agar. All the dishes were inverted and incubated anaerobically at 37°C for 48 h after inoculation. The colony counts were then enumerated and results were presented as log10-transformed data.

Fresh faecal samples were collected from at least two pigs in each pen at the end of phase 1 and phase 2 to determine the faecal gas concentration. The NH₃ concentration was calculated using the method of Chaney and Marbach (1962). And 300 g of fresh faecal samples was transferred to a sealed box and fermented for 30 h in an incubator (35°C). The fermented samples using a gas search probe (Gastec Corp., Kanagawa, Japan). Gastec detector tube No.4LK for H₂S, and No.70 for total mercaptans.

**Statistical analysis**

All data were analysed by using mixed procedures of SAS (SAS Inst. Inc., Cary, NC). The model used was $Y_{ijk} = \mu + t_i + r_k + e_{ijk}$, where $Y_{ijk}$ was an observation on the dependent variable $ij$; $\mu$ was the overall population mean; $t_i$ was the fixed effect of SAA:Lys ratio treatments, $r_k$ was the pen as a random effect (growth performance, faecal microflora and faecal gas content) and the individual pig as a random effect (intestinal morphology), and $e_{ijk}$ was the random error associated with the observation $ijk$. Orthogonal comparisons were conducted, using polynomial regression, to measure the linear and quadratic effects of increasing dietary concentrations of supplemental SAA. Differences among treatment means were determined using Duncan’s multiple range test. Statements of statistical significance were based on $p < .05$, and $p < .10$ was considered a trend.

**Results**

As shown in Table 3, during the phase 1, pigs fed diets with increasing dietary SID SAA:Lys tended to improve the ADG (linear, $p = .07$) and G:F (linear, $p = .06$), whereas showed no effect ($p > .10$) on the ADFI. During the phase 2, increasing SID SAA:Lys ratio...

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**Table 2. Compositions of basal diets for 75–100 kg pigs (phase 2, as-fed basis).**

| Item                  | SAA:Lys = 0.57 | SAA:Lys = 0.67 | SAA:Lys = 0.70 | SAA:Lys = 0.73 |
|-----------------------|----------------|----------------|----------------|----------------|
| Ingredient, %         |                |                |                |                |
| Maize                 | 72.74          | 72.66          | 72.64          | 72.62          |
| Wheat                 | 1.50           | 1.50           | 1.50           | 1.50           |
| Molasses              | 3.10           | 3.10           | 3.10           | 3.10           |
| Soybean meal          | 15.58          | 15.58          | 15.58          | 15.58          |
| L-Lysine-HCl (78%)    | 0.25           | 0.25           | 0.25           | 0.25           |
| dl-Methionine (99%)   | 0.04           | 0.04           | 0.05           | 0.06           |
| L-Cysteine (99%)      | 0.04           | 0.04           | 0.05           | 0.06           |
| Tallow (liquid)       | 4.35           | 4.35           | 4.35           | 4.35           |
| Limestone             | 0.79           | 0.79           | 0.79           | 0.79           |
| Dicalcium phosphate   | 1.18           | 1.18           | 1.18           | 1.18           |
| Salt                  | 0.20           | 0.20           | 0.20           | 0.20           |
| Vitamin premix        | 0.20           | 0.20           | 0.20           | 0.20           |
| Mineral premix        | 0.10           | 0.10           | 0.10           | 0.10           |
| Choline               | 0.01           | 0.01           | 0.01           | 0.01           |
| Total                 | 100.0          | 100.0          | 100.0          | 100.0          |
| Calculated composition|                |                |                |                |
| ME, kcal/kg           | 3405           | 3405           | 3404           | 3404           |
| Crude protein, %      | 13.42          | 13.42          | 13.42          | 13.43          |
| Crude fat, %          | 7.04           | 7.04           | 7.04           | 7.04           |
| Crude fibre, %        | 2.73           | 2.73           | 2.73           | 2.73           |
| Crude ash, %          | 4.33           | 4.33           | 4.33           | 4.33           |
| Calcium, %            | 0.64           | 0.64           | 0.65           | 0.65           |
| Phosphorus, %         | 0.50           | 0.50           | 0.50           | 0.50           |
| SID Lysine, %         | 0.80           | 0.80           | 0.80           | 0.80           |
| SID Methionine, %     | 0.20           | 0.24           | 0.25           | 0.26           |
| SID Cysteine, %       | 0.26           | 0.30           | 0.31           | 0.32           |
| SID Met + Cys (SAA), %| 0.46           | 0.54           | 0.56           | 0.58           |

*aProvided per kg of complete diet: 11,025 U vitamin A; 1,103 U vitamin D₃; 44 U vitamin E; 4.4 mg vitamin K; 8.3 mg riboflavin; 50 mg niacin; 4 mg thiamine; 29 mg d-pantothenic; 166 mg choline; 33 µg vitamin B₁₂.

*bProvided per kg of complete diet: 8 mg of Mn (as MnO₂); 60 mg of Zn (as ZnSO₄); 5 mg of Cu (as CuSO₄·5H₂O); 40 mg of Fe (as FeSO₄·7H₂O); 0.3 mg of Co (as CO₃SO₄·5H₂O); 1.5 mg of I (as KI); and 0.15 mg of Se (as Na₂SeO₃·5H₂O).
had a tendency (linear, $p = 0.08$) to improve the ADG and G:F, however, there was no difference ($p > 0.10$) in ADFI among the treatments.

As presented in Table 4, the VH:CD of duodenum were linearly increased ($p < 0.05$) by increasing SID SAA:Lys at the end of the experiment. In addition, increasing SID SAA:Lys ratio had a tendency to improve the villus height of duodenum (linear, $p = 0.07$).

Regarding of the faecal microflora, increasing SID SAA:Lys ratio linearly improved ($p < 0.05$) the Lactobacillus concentrations and the ratio of Lactobacillus:E.coli, while tended to reduce ($p = 0.09$) the E. coli counts during phase 1 (Table 5). Meanwhile, the ratio of Lactobacillus:E. coli was increased ($p < 0.05$) by increasing SID SAA:Lys ratio during phase 2, and a trend towards an increase in Lactobacillus counts ($p = 0.08$) and a decrease ($p = 0.07$) in E. coli concentrations of faeces was observed. In terms of faecal noxious gas content, there was a linear decrease ($p < 0.05$) in ammonia when pigs fed diets with increased SID ratio of SAA:Lys in both phase 1 and phase 2 (Table 6).

### Discussion

The goal of this study was to determine the effect of increasing SID SAA to Lys ratio in growing-finishing pigs fed an antibiotic-free diet. Based on the standardised ileal digestion, the NRC (2012) recommendation of SAA and Lys requirements for 50–75 kg pigs were 10.2 and 17.9 g/d, and for 75–100 kg pigs were 10.5 and 18.3 g/d, respectively. Which indicated that the ratio of SAA:Lys for 50–100 kg health pigs was about 0.57. However, the SAA requirement recommended for growth rate may be not enough under antibiotic-free feeding regimen (Kahindi 2014). In addition, considering the genetic improvements in swine production, we set a high level of SAA:Lys range from 0.67 to 0.73 in our study. In the present study, increasing the SID SAA:Lys showed partial positive effect on growth performance. Similar to our study, Kahindi (2014) reported that increasing the SID SAA:Lys ratios tended to improve the ADG and G:F in weaning pigs. It is known that the SAA plays an important role in the innate immune system and stimulating humoral and cell mediated immune responses, and changes on granulocytes, monocytes and macrophages resulting from different dietary SAA content have been observed (Hunter & Grimble 1994). Therefore, the reason for the enhanced growth performance in this study may be attributed to the beneficial effects of SAA on immune system, thus reducing the subclinical or clinical infections, and subsequently improved the health status and protein deposition of pigs.

Villus height and crypt depth were indirect indicators of the maturity and functional capacity of enterocytes, and longer villi provided an increased absorptive area in the small intestine (Pluske et al. 1997). Previous studies have demonstrated that SAA

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**Table 3.** Effects of standardised ileal digestible (SID) sulphur amino acid:lysine ratios (SAA:Lys) on growth performance of growing-finishing pigs fed an antibiotic-free diet.

| SID SAA:Lys ratio | p-Value | Linear | Quadratic |
|-------------------|---------|--------|-----------|
| Items             |         |        |           |
| Phase 1 (50–75 kg) |         |        |           |
| ADG, g/d         | 0.57    | 0.67   | 0.70      | 0.73 | 0.01   | .06 | .31 |
| ADFI, g/d        | 1898    | 1976   | 1967      | 1972 | 17     | .07 | .23 |
| G:F               | 0.35    | 0.36   | 0.37      | 0.372| 0.01   | .06 | .31 |
| Phase 2 (75–100 kg) |        |        |           |
| ADG, g/d         | 2772    | 2754   | 2778      | 2767 | 19     | .08 | .32 |
| ADFI, g/d        | 2677    | 2663   | 2628      | 2657 | 28     | .49 | .47 |
| G:F               | 0.27    | 0.28   | 0.296     | 0.289| 0.007  | .08 | .19 |

SEM: Standard error of mean.

**Table 4.** Effects of standardised ileal digestible (SID) sulphur amino acid:lysine ratios (SAA:Lys) on intestinal morphology of growing-finishing pigs fed an antibiotic-free diet.

| SID SAA:Lys ratio | p-Value | Linear | Quadratic |
|-------------------|---------|--------|-----------|
| Items             |         |        |           |
| Duodenum          |         |        |           |
| Villus height, μm  | 424.83  | 430.97 | 442.25    | 437.16| 5.66   | .07 | .34 |
| Crypt depth, μm   | 253.98  | 250.06 | 247.84    | 245.82| 4.02   | .34 | .95 |
| VH:CD             | 1.68    | 1.73    | 1.77     | 1.79  | 0.04   | .03 | .36 |

SEM: Standard error of mean.

a,bMeans in the same row with different superscript differ significantly ($p < 0.05$).
serves to modulate the intestinal function and health through being components of the protective mucin barrier, and about 30% of the dietary SAA is utilised by the gut for epithelial cell differential and mucosal growth (Bauchart-Thevret et al. 2009). Indeed, it has been reported that dietary Met deficiency induced small intestinal villus atrophy (Jahoor et al. 1995). On the other hand, pigs fed diets without antibiotic might cause a thicker intestinal wall and more mucin production in order to prevent pathogenic microbes infections (Dibner & Richards 2005), there would be a great allocation of SAA towards maintenance.

As expected, our study found that the villus-to-crypt ratio of small intestine were linearly improved by increasing dietary SID SAA:Lys. These findings are in agreement with the previous studies (Bauchart-Thevret et al. 2009; Kaewtapee et al. 2010; Kahindi 2014), they suggested that the improvement of small intestinal morphology as a result of increasing SAA or Met content in pigs diets. Therefore, it can be concluded that dietary SAA content promoted intestinal growth and abundant SAA could enhance enterocytes production by the crypt leading to longer villi. Additionally, the beneficial effects on intestinal development and health may also be responsible for the superior growth performance that was observed in this study.

The faecal shedding of *Lactobacillus* and *E. coli* are also routinely regarded as a reliable indicator of gut health, and the ratio of *Lactobacillus: E. coli* with an increase commonly considered beneficial (Pierce et al. 2005). O’Shea et al. (2010) demonstrated that pigs are susceptible to dietary manipulations that alter community dynamics of the resident gastrointestinal microflora. In addition, it is known that the profile of gut microflora can be affected by a variety of factors such as diet composition (Haenen et al. 2013). The present data indicated that increasing dietary SAA level had a positive effect on faecal microflora. There is currently no available information focus on faecal microbial shedding by influencing of feeding diets with increased ratio of SAA:Lys to pigs, thus, no comparisons could be made with other studies. However, according to a previous study conducted by Dahiya et al. (2007), increasing dietary Met content increased the intestinal lactobacillus population while reduced the growth of *Clostridium perfringens* and coliforms in broilers that was inoculated with *Clostridium perfringens*. It has been suggested that some of the SAA is utilised by the gut commensal bacteria (Dahiya et al. 2007), so the SAA may have capacity to promote the beneficial microbial growth, thus competing with the harmful bacteria.

The present study further examined the influence of increasing SID SAA:Lys on aspects of noxious gas emission in pigs. The quantity and composition of resident microbiota and fermentable substrate strongly affect

| Table 5. Effects of standardised ileal digestible (SID) sulphur amino acid:lysine ratios (SAA:Lys) on faecal microflora of growing-finishing pigs fed an antibiotic-free diet. |
|---------------------------------------------------------------|
| **SID SAA:Lys ratio** | 0.57 | 0.67 | 0.70 | 0.73 | SEM | Linear | Quadratic |
| **Phase 1 (50–75 kg)** |                    |        |       |       |     |      |          |
| *Lactobacillus*, log10cfu/g | 6.84 | 6.67 | 7.14 | 7.16 | 0.10 | .02  | .96 |
| *E. coli*, log10cfu/g | 6.87 | 6.60 | 6.51 | 6.43 | 0.17 | .09  | .58 |
| *Lactobacillus:E. coli* | 1.09^b | 1.04^b | 1.10^b | 1.12^a | 0.03 | .02  | .74 |
| **Phase 2 (75–100 kg)** |        |        |       |       |     |      |          |
| *Lactobacillus*, log10cfu/g | 6.70^a,b | 6.67^b | 7.06^a | 6.92^a,b | 0.12 | .08  | .66 |
| *E. coli*, log10cfu/g | 6.53 | 6.36 | 6.08 | 6.10 | 0.17 | .07  | .58 |
| *Lactobacillus:E. coli* | 1.03^b | 1.06^b | 1.17^a | 1.14^a,b | 0.03 | .02  | .47 |

SEM: standard error of mean.
^a,bMeans in the same row with different superscript differ significantly (p < .05).

| Table 6. Effects of standardised ileal digestible (SID) sulphur amino acid:lysine ratios (SAA:Lys) on faecal noxious gas content of growing-finishing pigs fed an antibiotic-free diet. |
|---------------------------------------------------------------|
| **SID SAA:Lys ratio** | 0.57 | 0.67 | 0.70 | 0.73 | SEM | Linear | Quadratic |
| **Phase 1 (50–75 kg)** |                    |        |       |       |     |      |          |
| Ammonia | 9.00^a | 8.81^a,b | 8.70^a,b | 8.52^b | 0.13 | .02  | .95 |
| Hydrogen sulphide | 16.39 | 17.26 | 17.34 | 17.23 | 0.44 | .33  | .16 |
| Total mercaptans | 16.35 | 16.31 | 17.20 | 16.73 | 0.37 | .19  | .67 |
| **Phase 2 (75–100 kg)** |        |        |       |       |     |      |          |
| Ammonia | 11.89^a | 11.37^a,b | 10.64^a,b | 10.02^b | 0.55 | .03  | .93 |
| Hydrogen sulphide | 23.72 | 24.18 | 24.00 | 24.80 | 0.58 | .45  | .59 |
| Total mercaptans | 22.60 | 23.55 | 22.84 | 23.40 | 0.80 | .68  | .60 |

SEM: standard error of mean.
^a,bMeans in the same row with different superscript differ significantly (p < .05).
the noxious gas emitted from animal manure (Ferket et al. 2002). In this study, the changes in intestinal bacterial populations were reflected in noxious gas emission, as a reduction in NH₃ emission was observed when increasing the SID SAA:Lys. This effect could be due to dietary SAA modulated in the intestinal function and health, which in turn enhanced the nitrogen digestibility, the increased digestibility and alteration of the intestinal microflora ecosystem can result in fewer proteolytic substrates for the microbial fermentation in the large intestine (Williams et al. 2001).

Conclusions
In conclusion, the present study demonstrated that in the case of antibiotics-free feeding regime, increasing the dietary SID SAA:Lys had a beneficial effect on intestinal health of growing-finishing pigs and showed partial positive effect on growth performance. However, these effects are still needed to be further investigated in larger populations and different feeding environment.

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Disclosure statement
The authors declare that they have no competing interests.

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