Short communication

Effects of dietary cysteamine supplementation on growth performance and whole-body protein turnover in finishing pigs

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ABSTRACT

The objective of this study was to investigate the effects of dietary cysteamine (CS) supplementation on growth performance and whole-body protein turnover in finishing pigs. This experiment contained 2 trials with the first trial of effect of dietary cysteamine supplementation on growth performance in finishing pigs for 47 d. A total of 16 PIC pigs (60.02 ± 1.01 kg; eight gilts and eight barrows) were randomly assigned to one of two dietary groups, with four pens per group (per pen: one gilt, one barrow). In the second trial, a total of eight PIC barrows (60.04 ± 1.02 kg) were randomly assigned to one of the two dietary groups, with four pens/group (one pig/pen) for 37 d and then the eight barrows were housed individually in metabolism crates (four barrows in control group and four barrows in CS group) for 10 d. The pigs of the first and second trials were fed a basal diet containing 0 (control) or 70 mg CS/kg diet. A total of eight barrows of the second trial received a 7-d nitrogen balance trial. 15N-Glycine (10 mg/kg BW) was gastrically infused after d 5 of the nitrogen balance trial. Feces and urine were collected daily to determine the N output. Results indicated that CS supplementation increased (P < 0.05) average daily gain (ADG), feed intake (ADFI), nitrogen retention, nitrogen retention efficiency, and efficiency of digestible N utilization. In addition, CS supplementation resulted in a decreased (P < 0.05) protein breakdown rate. Net protein gain in nitrogen was increased (P < 0.05) by 63.5%. However, protein synthesis rate, nitrogen flux, and endogenous urinary nitrogen were not affected (P > 0.05). It is concluded that dietary CS supplementation may improve growth performance in finishing pigs. Protein deposition is increased after dietary CS supplementation. This increase is caused by a decrease in protein breakdown.

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1. Introduction

An improvement in pig growth performance for economic purposes can be achieved by enhancing growth rate. The interactions of animals with their environs, which include food balance and quality, affect their growth rate. The effects of these on growth rate are in turn modulated by the endocrine system. Cysteamine (CS; mercaptoethylamine, HS–CH2–CH2–NH2) is biologically derived from cysteine metabolism. It can be used as a feed additive in animal production to stimulate the endocrine system and improve the growth rate of fish, piglets, and finishing pigs (Tse et al., 2006; Xie, 2004; Yang et al., 2005; Dunshea, 2007). Thus, CS can be a viable alternative in promoting the growth rate of pigs. Previous experiments involving rats, sheep, fishes, and piglets have demonstrated that CS increases growth hormone (GH) secretion (McLeod et al., 1995a,b; Spencer, 1984; Xiao and Lin, 2002, 2003; Xie, 2004). The increase in GH secretion is possibly due to the decreasing levels of somatostatin (SS) in the tissue and hypothalamus in response to the action of CS. It is well known that GH increases muscle growth (Machlin, 1972) and decreases fat deposition in pigs (Pursel et al., 1990; Wieghart et al., 1990), lambs (Nancarrow et al., 1991), and salmonids (McLean et al., 1994). The fat reduction can be attributed to the direct action of GH (Etherton et al., 1987;...
Ebert et al., 1988), which also induces absorbed nutrient repartitioning and shifts in the balance of protein deposition from fat cells to muscle cells. GH fulfills its function of growth promotion by improving the production of insulin-like growth factor-I (IGF-I), primarily in the liver, and also in other target organs. IGF-I can stimulate amino acid uptake and protein synthesis in muscle and can greatly reduce the rate of protein breakdown within muscle fibers (Sachek et al., 2004). CS can improve the lean percentage of finishing pigs (Yang et al., 2005). However, the effects of dietary CS supplementation on finishing pigs’ protein metabolism have not been reported. The determination of the kinetic parameters of protein metabolism (protein synthesis and breakdown) can provide an understanding of the mechanisms of CS supplementation in protein accretion and growth promotion.

Our objectives are mainly to: 1) evaluate the growth promotion effect of dietary CS supplementation in finishing pigs; and 2) measure protein turnover in finishing pigs.

2. Materials and methods

2.1. Experimental animals and diets

The experimental protocols used in this study were approved by the Sichuan Agricultural University Institutional Animal Care and Use Committee. This experiment contained 2 trials with the first trial of effect of dietary cysteamine supplementation on growth performance in finishing pigs for 47 d. A total of 16 crossbred (PIC variety) finishing pigs (average initial body weight was 60.02 ± 1.01 kg; eight gilts and eight barrows) were randomly assigned to one of the two dietary groups, with four pens/group (two pigs/pen; per pen: one gilt and one barrow). Each pen was equipped with a feeder and nipple water to allow the pigs free access to feeds and drinking water. Temperature (22 to 26 °C) and a cycle of 16 h light:8 h dark were maintained in the mechanically ventilated room. At 08:00, 11:30, 14:30, and 17:30, feeds were given to pigs for more than 1 h until they refused intake. Feed intakes per pen were recorded daily throughout the duration of the trial.

2.2. 15N-Glycine infusion

Protein turnover trial was started at 08:00 on d 5 of the nitrogen balance trial. Eight barrows were gastrically infused with 15N-glycine (99 at %15N, Aldrich Chemical Company, Inc., Delaware, USA) at a dose of 10 mg/kg BW through a fistula. Barrows were maintained in metabolism cages for a 3-d collection of urine under the same conditions as the N balance period. Prior to isotope infusion, a urine sample was also collected from each barrow for 12 h to determine background enrichment of 15N in urinary urea.

2.3. Sample analysis

Feces collected during the N balance period were pooled, freeze-dried and stored at 4 °C for N determination. Urine collected was stored at −20 °C until analysis for N. Samples of diet, urine and feces were analyzed for N content by Kjeldahl method (AOAC, 1998). The N-retention was calculated by minus N excretion (via feces and urine) from N intake. To measure the 15N enrichment of urinary urea, a 10 ml urine sample was converted into (NH4)2SO4 solution by Kjeldahl method (AOAC, 1998). Then (NH4)2SO4 solution was transferred to a titer plate, dried with a food dehydrator, recorded and submitted for analysis of 15N enrichment by automated mass spectrometry (Isotope Mass Spectrometer, Finnigan-MAT 251).

2.4. Calculation of protein turnover

Whole-body protein turnover was calculated according to the method used by Zhang et al. (2008). In brief, the parameters were calculated using Plath’s open three-pool model with total nitrogen in urine as the end-product. In this

### Table 1

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Composition, % (as-fed basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>64.97</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>19.10</td>
</tr>
<tr>
<td>Rapeseed meal</td>
<td>8.00</td>
</tr>
<tr>
<td>Whey power</td>
<td>4.50</td>
</tr>
<tr>
<td>Rapeseed oil</td>
<td>1.34</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>0.84</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>0.22</td>
</tr>
<tr>
<td>L-Lysine · HCl</td>
<td>0.35</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>0.25</td>
</tr>
<tr>
<td>Choline chloride</td>
<td>0.10</td>
</tr>
<tr>
<td>Vitamin premix^a</td>
<td>0.03</td>
</tr>
<tr>
<td>Mineral mix^b</td>
<td>–</td>
</tr>
</tbody>
</table>

^a Premix provided per kilogram diet: retinol acetate, 1926.4 µg; cholecalciferol, 27.5 µg; dl-α-tocopheryl acetate, 30 g; vitamin B12, 30 mg; riboflavine, 15 g; niacin, 15 g; calcium pantothenate, 25 g; folic acid, 20 mg; thiamine, 12 mg; pyridoxine, 6 mg; vitamin K3, 5 mg.
^b Mix provided per kilogram diet: Mn, 6 mg (MnO); Fe, 150 mg (FeSO4·H2O); Cu, 10.5 mg (CuSO4·5H2O); I, 0.42 mg (ethylene diamine dihydroiodide); Se, 0.45 mg (Na2SeO3); Zn, 150 mg (ZnO).
^c In the cysteamine (CS)-supplemented diets, 70 mg/kg CS was added at the expense of corn.

Mineral mixb 0.50
Choline chloride 0.10
Sodium chloride 0.25
Dicalcium phosphate 0.22
Calcium carbonate 0.84
Rapeseed oil 1.14
Whey power 4.50
Rapeseed meal 8.00
Soybean meal 19.10
Corn 64.97

**Calculation composition**

<table>
<thead>
<tr>
<th>DE (MJ/kg)</th>
<th>CP (%)</th>
<th>Calcium (%)</th>
<th>Phosphorus available (%)</th>
<th>Lysine (%)</th>
<th>Methionine (%)</th>
<th>Methionine + cysteine (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.44</td>
<td>17.00</td>
<td>0.50</td>
<td>0.19</td>
<td>0.85</td>
<td>0.22</td>
<td>0.48</td>
</tr>
</tbody>
</table>

**Ingredient composition of the basal diet**
model, dietary nitrogen flows into the non-protein–nitrogen pool. Some of this nutrient nitrogen is used protein synthesis and flows into the protein–nitrogen pool and a small portion is excreted and reaches the urinary whole-nitrogen pool. Non-bound nitrogen in the protein–nitrogen pool resulting from protein breakdown returns to the metabolic pool.

2.5. Statistical analysis

Data are expressed as means ± SEM. The data for all parameters determined were analyzed statistically by one-way ANOVA of SPSS 11.0 software (SPSS Inc., Chicago, IL, USA). Individual pigs were used as the experimental unit for all data except that pen was used as the unit for body weight, average daily gain, feed intake, and feed efficiency, but the results are expressed per pig. Results were considered significant at P < 0.05.

3. Results

3.1. Growth performance

The average daily gain and feed intake by CS supplementation were increased (P < 0.05) by 19.5% and 15.4%, respectively. However, body weight and feed efficiency were not affected (P > 0.05) (Table 2).

3.2. Protein utilization and turnover

The nitrogen balance trial indicated that nitrogen retention, nitrogen retention efficiency, and efficiency of digestible N utilization were increased (P < 0.05) to 62.8%, 54.6%, and 50.6% in CS supplementation group. Nitrogen intake, nitrogen in feces and urine, and apparent nitrogen digestibility were not affected (P > 0.05) (Table 3). CS supplementation affected the whole-body protein turnover (Table 4) and resulted in a decreased (P < 0.05) protein breakdown rate (1.61 vs. 1.18 g N/kg W0.75/d). Net protein gain in nitrogen was increased (P < 0.05) by 63.5%, however, protein synthesis rate, nitrogen flux, and endogenous urinary nitrogen were not affected (P > 0.05) (Table 4).

4. Discussion

In this study, dietary CS supplementation caused a significant increase in the growth rate and feed intake of finishing pigs. The growth rate improvement may result from both feed intake and CS themselves. Yang et al. (2005) and Dunshea (2007) report that CS improves the growth rate but not the feed intake, and the result suggests that CS itself contributes to the growth rate. Although final body weight was not significant, it was increased by 6% in dietary CS supplementation, which was some significance in improving economic returns. Average daily gain (increased significantly) and final body weight (were not affected) was inconsistent, the possible explanation was the different calculation method (average daily gain = (final body weight - initial body weight)/feeding time). Here, there were no apparent pathological changes seen in the gastrointestinal tract of pigs given a diet with 70 mg/kg CS. Previous experiments demonstrate higher doses of CS can cause ulcers in the gastrointestinal tract of rats (300 or 400 mg/kg CS) (Fukuhara et al., 2005; Asad et al., 2001; Kapuscinski et al., 1991). CS supplementation (70 mg/kg) enhances antioxidation capacity (data not shown). Thus, it may improve the health of pigs. Growth in pigs is regulated largely by the growth hormone (GH)-insulin-like growth factors (IGFs) axis (Hall et al., 1986; Mak et al., 2008). CS supplementation increased GH and IGF-1 secretion (data not shown), which can change protein metabolism pattern. However, little information is known about the effect of dietary CS supplementation on finishing pigs’ protein metabolism.

The nitrogen balance trial showed that CS supplementation changed nitrogen retention efficiency, efficiency of digestible N utilization, and nitrogen retention, but did not affect nitrogen digestibility. These results indicate that CS supplementation may increase protein gain through modifying protein metabolism but not protein digestion within pigs.
Protein deposition and loss are the results of the small difference between protein synthesis and protein degradation (Simón, 1989). An increase in protein deposition may be achieved either by increasing the rate of protein synthesis or by decreasing the rate of protein breakdown. In addition, if both rates increase, protein deposition may be enhanced if synthesis increases more than the breakdown. Similarly, even if both rates decrease, protein deposition may be increased if the synthesis rate decreases less than the breakdown rate (Krawietzki et al., 1996). CS supplementation did not change the rate of protein synthesis, however, it decreased protein breakdown rate, thus leading to an increase of 0.54 g N/kg W0.75 in protein per day. The results suggest that dietary CS supplementation increases protein retention by decreasing the rate of protein breakdown. According to the body weight and average daily gain in the nitrogen balance trial, the average daily net protein gain for 0, and 70 mg/kg CS supplementation were 16.44 and 26.28 g N, respectively. They were quite close to the results from the nitrogen balance trial, which were 16.23 and 26.42, respectively.

Determining the protein turnover in finishing pigs would be useful in defining the effects of metabolic modifiers on protein accretion and refining amino acid requirements. This should allow better formulation of nutritional support for growth. In this study, dietary CS supplementation was studied specially through ad libitum intake. As for the effect of CS itself on growth performance and protein metabolism, pair-feeding will be considered in the future.

5. Conclusions

Dietary CS supplementation may improve growth performance in finishing pigs. Protein deposition is increased after dietary CS supplementation. This increase is caused by a decrease in protein breakdown.

References