Effects of dietary supplementation of cysteamine on growth performance, carcass quality, serum hormones and gastric ulcer in finishing pigs

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Abstract: A study was conducted to determine the effects of graded levels of dietary inclusion of a cysteamine (Cs) preparation on growth performance, carcass quality, plasma hormone levels, gastric pH and occurrence of gastric ulcer in finishing pigs. A total of 384 Landrace × Large White finishing pigs, (192 gilts and 192 barrows) with an average initial body weight of 66.05 ± 0.623 kg (mean ± SEM) were randomly divided into 24 floor pens, with eight gilts and eight barrows in each pen (9.2 m²) as one experimental unit. The 24 pens of pigs were randomly allocated to one of three diets: (1) a maize/soybean meal basal diet; (2) the basal diet plus 30 mg Cs kg⁻¹ diet; and (3) the basal diet plus 50 mg Cs kg⁻¹ diet. Dietary supplementation of Cs had quadratic effects (P < 0.01) on final body weight and average daily gain, with optimal responses occurring at 30 mg kg⁻¹. Dietary supplementation of Cs quadratically improved (P < 0.01) average daily feed intake and feed/gain ratio, with optimal responses occurring at 30 mg kg⁻¹. Dietary supplementation of Cs had a quadratic effect (P < 0.01) on muscle RNA/DNA ratio. Furthermore, dietary supplementation of Cs reduced (P < 0.05) back-fat thickness. Dietary supplementation of Cs had quadratic effects (P < 0.05) on plasma glucagon and T₃ hormone levels, with optimal responses occurring at 30 mg kg⁻¹, but had no effect (P > 0.05) on plasma growth hormone, insulin and T₄ levels. There were no apparent pathological changes seen in the stomach mucosa of pigs fed at 30 mg Cs kg⁻¹ compared with the control diet. It is concluded that a low dose of dietary inclusion of Cs at 30 mg kg⁻¹ can improve growth performance and carcass quality without adverse effects on the stomach in finishing pigs.

Keywords: cysteamine; growth performance; carcass quality; gastric ulcer; finishing pigs

INTRODUCTION

Growth in swine is regulated in large part by the brain neuroendocrine growth hormone–insulin–insulin–like growth factors (IGFs) axis.1 Neuroendocrine regulation of growth hormone secretion is multifactorial, with a balance of stimulatory and inhibitory neurohormones acting on pituitary somatotrophs. Growth hormone secretion is inhibited by several neuroendocrine factors, including somatostatin, serotonin, norepinephrine and L-glutamate.2 Somatostatin is the major inhibitory control of basal and neuroendocrine factor-stimulated growth hormone secretion in swine.3 The strengthening action of growth hormone release stimulatory factors or the attenuating action of growth hormone release inhibitory factors attains animal

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growth. Growth hormone release stimulatory factors are known to stimulate growth hormone secretion and thus promote growth in swine, but comparatively little information is available concerning the indirect action of enhancing growth by suppressing the action of growth hormone release inhibitory factors to indirectly induce growth hormone release in swine.\(^3\)

The inhibiting action of somatostatin may provide an alternative means of accelerating growth, since the 14 or 28 amino acid residuals of somatostatin containing an \(\text{S}–\text{S}\) bond are potent inhibitors of endogenous growth hormone secretion.\(^1\) One of the more elegant techniques is represented by the active or passive immunisation of animals against the endogenous regulatory peptides, eg somatostatin, to immunoneutralise them.\(^1,3\) Indeed, application of this method in endocrinology has proved to be feasible and provided remarkable success in some studies with rats and sheep.\(^3–5\) In the case of swine, little published information exists with regard to active or passive immunisation against somatostatin. It is hypothesised that decreased availability of somatostatin might increase circulating growth hormone levels, consequently accelerating growth. However, while growth-promoting effects of anti-somatostatin require further studies, results obtained to date provide reasons for optimism with regard to the application of this methodology to examine swine growth physiology.

The sulfhydryl compound cysteamine (Cs), ie mercaptoethylamine, is biologically derived from cysteine metabolism. Previous experiments involving rats and sheep have demonstrated that Cs increases growth hormone secretion.\(^3–5\) The increase in growth hormone secretion is presumably due to decreasing levels of somatostatin in the tissue and hypothalamus in response to the action of Cs. However, Cs is very easily oxidised in the atmosphere or in the presence of alkaline and metal ion conditions. Many factors can affect the potential use of Cs as a novel growth promoter in animals, including species of animal, feeding time, feeding dosage and chemical stability. Little information is reported about the chronic effect of Cs supplementation on growth performance, carcass characteristics, blood hormone levels and occurrence of gastric ulcer in finishing pigs.

Within this context the present study was undertaken to examine potential effects of the somatostatin-inhibitory agent Cs on growth performance, carcass quality and occurrence of gastric ulcer in finishing pigs fed maize/soybean meal-based diets. A related objective was to further study if the potential effects of Cs supplementation were mediated through the actions of anabolic and catabolic hormones, especially growth hormone.

**MATERIALS AND METHODS**

All animals were cared for according to the guidelines set by the Animal Protection Committee of the Ministry for Agriculture and Nature Protection, Schwerin, Germany.

**Experiment diets**

A maize/soybean meal basal diet (Table 1) was formulated to meet or exceed the nutrient requirements of finishing pigs as suggested by the National Research Council (NRC).\(^6\) The accuracy of diet formulation was examined by analysing dietary crude protein content according to the Kjeldahl method.\(^7\) Three diets were tested, including the basal control diet and two treatment diets in which a Cs preparation (15% cysteamine · HCl) was added to the basal diet at either 30 or 50 mg kg\(^{-1}\). The Cs preparation was provided by Guangzhou Tanke Industry Co Ltd (Guangdong Province, China).

**Feeding trial**

A total of 384 Landrace × Large White pigs (192 gilts and 192 barrows) with an average initial body weight of 66.1 ± 0.6 kg (mean ± SEM) were randomly divided into 24 slatted-floor pens, with eight gilts and eight barrows in each pen (9.2 m\(^2\)) as one experimental unit. The three experimental diets were again randomly allocated to the 24 pens; thus the animal trial was conducted according to a completely randomised one-factorial design. The pigs and pens were in an environmentally controlled room. Feed and water were provided to the pigs *ad libitum*.

**Table 1. Composition of experimental basal diet\(^4\) for finishing pigs (60–90 kg)**

<table>
<thead>
<tr>
<th>Ingredients (g kg(^{-1}))</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>585.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>250.0</td>
</tr>
<tr>
<td>Wheat middlings</td>
<td>50.0</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>90.0</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>10.0</td>
</tr>
<tr>
<td>Limestone</td>
<td>10.7</td>
</tr>
<tr>
<td>Salt</td>
<td>3.0</td>
</tr>
<tr>
<td>Lysine-HCl</td>
<td>1.0</td>
</tr>
<tr>
<td>Vitamin premix(^b)</td>
<td>0.05</td>
</tr>
<tr>
<td>Trace mineral premix(^c)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrient contents (as-fed basis)</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestible energy (MJ kg(^{-1}))(^d)</td>
<td>13.0</td>
</tr>
<tr>
<td>Dry matter (g kg(^{-1}))(^d)</td>
<td>886.3</td>
</tr>
<tr>
<td>Crude protein (g kg(^{-1}))(^e)</td>
<td>173.5</td>
</tr>
<tr>
<td>Ether extract (g kg(^{-1}))(^d)</td>
<td>39.7</td>
</tr>
<tr>
<td>Total calcium (g kg(^{-1}))(^d)</td>
<td>6.8</td>
</tr>
<tr>
<td>Total phosphorus (g kg(^{-1}))(^d)</td>
<td>6.0</td>
</tr>
<tr>
<td>Total lysine (g kg(^{-1}))(^d)</td>
<td>10.4</td>
</tr>
<tr>
<td>Total methionine (g kg(^{-1}))(^d)</td>
<td>2.9</td>
</tr>
<tr>
<td>Total cysteine (g kg(^{-1}))(^d)</td>
<td>3.3</td>
</tr>
<tr>
<td>Total threonine (g kg(^{-1}))(^d)</td>
<td>6.73</td>
</tr>
</tbody>
</table>

\(^{a}\) As-fed basis.  
\(^{b}\) The vitamin premix provided the following (kg \(^{-1}\) diet): vitamin A, 3000 IU; vitamin D\(_{3}\), 510 IU; vitamin E, 20 IU; vitamin B\(_{12}\), 5 mg; vitamin B\(_{6}\), 21 mg; \(\alpha\)-biotin, 100 mg; niacin, 15 mg; d-pantothenic acid, 10 mg.  
\(^{c}\) The trace mineral premix provided the following (kg \(^{-1}\) diet): Ca, 9 mg; Cu, 8.75 mg; Fe, 87.5 mg; Zn, 75 mg; Mn, 30 mg; I, 1 mg; Se, 0.1 mg.  
\(^{d}\) Calculated value based on NRC\(^6\) for pigs.  
\(^{e}\) Analysed value.
Individual pig weights and pen feed intakes were measured weekly. If the feed was dry (not contaminated with water), the weight was recorded directly. If contamination had occurred, the feed was dried and weighed for the correction of feed intake. The experimental feeding period lasted 30 days, during which the animals’ body weight increased from 66 to approximately 90 kg.

**Sample collection**

At the end of the experiment, 12 pigs (four pigs from each of the three diets) were randomly selected and a blood sample (5 ml) was collected from each via the anterior vena cava. After collection the blood samples were placed on ice for 2 h and then centrifuged at 1500 × g and 4°C for 15 min. Plasma samples were collected and frozen (−20°C) until subsequent analyses for hormones (growth hormone, insulin, glucagon, T3 and T4). The 12 pigs were slaughtered by exsanguination after electrical stunning. Longissimus muscle samples were excised and immediately frozen in liquid nitrogen, then stored at −70°C until extraction of DNA and RNA.

**Measurements of carcass quality**

At the termination of the experiment the carcass quality measurements, including the first-rib back-fat thickness (A), the 10th-rib 3/4 back-fat thickness (B) and the last-rib back-fat thickness (C), were determined by real-time ultrasonic technology (ULTRA-SCAN-50 System, Ultra-Scan Corporation, Amherst, NY, USA) for all live pigs (128 pigs from each of the three diets).8

**Determination of stomach fluid pH and gastric ulcer**

After slaughtering the above 12 pigs, stomach fluid pH was measured at three different areas in the stomach with a microelectrode (PHS-3B, Shanghai Rex Instruments Factory, Shanghai, China). Stomach fluid pH was measured at three different areas in the stomach with a microelectrode (PHS-3B, Shanghai Rex Instruments Factory, Shanghai, China). After the stomach fluid pH was measured at three different areas in the stomach with a microelectrode (PHS-3B, Shanghai Rex Instruments Factory, Shanghai, China), the stomachs were opened along the greater curvature, stomach contents removed and the stomachs inverted. All dissected stomachs were examined for the occurrence of gastric ulcer with the unaided eye within 60 min of exsanguination.

**Plasma hormone assays**

The determinations of plasma growth hormone, glucagon, insulin, T3 and T4 were performed with human growth hormone, glucagon, insulin, T3 and T4 RIA Kits (Shanghai Biology Produce Co Ltd, Shanghai, China) respectively. All samples were analysed in duplicate. These assays showed good cross-reactivity to pigs. All steps of the RIA methods for these plasma hormones were performed according to the manufacturer’s instructions.

**DNA and RNA analyses**

A UNIQ-10 Column Genomic DNA Isolation Kit (SK1223) and UNIQ-10 Column Total RNA Isolation Kit (SK132) (Shanghai Sangao Biological Engineering Technology and Service Co Ltd, Shanghai, China) were employed to isolate total DNA and RNA simultaneously from longissimus muscle samples. The contents of total DNA and RNA were quantified using a Beckman DU 64 spectrophotometer (Beckman Instruments Inc, Upland, CA, USA).2 DNA and RNA purified from salmon (Sigma Chemical Co, St Louis, MO, USA) were used as standards.

**RESULTS**

**Growth performance and carcass quality**

Effects of Cs supplementation on performance and carcass quality of finishing pigs (60–90 kg) are shown in Table 2. Dietary supplementation of Cs had quadratic effects \( (P < 0.01) \) on final body weight and average daily gain, with optimal responses occurring at 30 mg kg\(^{-1}\). Furthermore, dietary supplementation of Cs quadratically improved \( (P < 0.01) \) average daily feed intake and feed/gain ratio, with optimal responses occurring at 30 mg kg\(^{-1}\). Dietary supplementation of Cs generally reduced \( (P < 0.05) \) back-fat thickness, with the optimal response occurring at 30 or 50 mg kg\(^{-1}\).

**Plasma hormone levels and muscle RNA/DNA ratio**

As shown in Table 3, dietary supplementation of Cs had quadratic effects \( (P < 0.05) \) on plasma glucagon and T3 hormone levels, with optimal responses occurring at 30 mg kg\(^{-1}\). However, dietary supplementation of Cs had no effect \( (P < 0.05) \) on plasma growth hormone, insulin and T4 levels.

Dietary supplementation of Cs had a quadratic effect \( (P < 0.01) \) on muscle RNA/DNA ratio (Fig 1). However, there was no significant difference \( (P < 0.05) \) in muscle RNA/DNA ratio between dietary supplementation of Cs at 30 and 50 mg kg\(^{-1}\).

**Stomach fluid pH and gastric ulcer**

Effects of dietary supplementation of Cs on stomach fluid pH are shown in Fig 2. Pigs fed the diet with 30 mg Cs kg\(^{-1}\) and the control basal diet had numerically higher pH values than pigs fed the diet with 50 mg Cs kg\(^{-1}\). However, there were no statistical differences \( (P > 0.05) \) in stomach liquid pH among the treatment groups.
Effects of graded levels of dietary supplementation of cysteamine (Cs) on growth performance and carcass quality of finishing pigs (60–90 kg)

Table 2.

<table>
<thead>
<tr>
<th>Item</th>
<th>0 (control)</th>
<th>30</th>
<th>50</th>
<th>SEM(^b)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average initial pen weight (kg per pen)</td>
<td>1055.5</td>
<td>1056.5</td>
<td>1053.9</td>
<td>9.97</td>
<td>0.984</td>
</tr>
<tr>
<td>Average initial pig weight (kg per pig)</td>
<td>65.0</td>
<td>66.0</td>
<td>65.9</td>
<td>0.62</td>
<td>0.984</td>
</tr>
<tr>
<td>Average final pen weight (kg per pen)(^c)</td>
<td>1425.7(^d)</td>
<td>1476.1(^h)</td>
<td>1436.8(^i)</td>
<td>10.2</td>
<td>0.006</td>
</tr>
<tr>
<td>Average final pig weight (kg per pig)(^c)</td>
<td>89.1(^i)</td>
<td>92.3(^h)</td>
<td>89.8(^i)</td>
<td>0.64</td>
<td>0.006</td>
</tr>
<tr>
<td>Average daily gain (g per pig)(^c)</td>
<td>769.0(^c)</td>
<td>875.0(^b)</td>
<td>798.0(^d)</td>
<td>4.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Average daily feed intake (kg per pig)(^c)</td>
<td>3.40(^c)</td>
<td>3.01(^i)</td>
<td>3.11(^i)</td>
<td>0.04</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Feed/gain ratio (kg kg(^{-1}))(^c)</td>
<td>17.2(^h)</td>
<td>12.4(^b)</td>
<td>10.9(^j)</td>
<td>0.39</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Average final pig weight (kg per pig)(^c)</td>
<td>15.7(^i)</td>
<td>12.7(^i)</td>
<td>10.4(^i)</td>
<td>0.42</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

\(^a\) Refer to Table 1 for diet formulation.
\(^b\) Pooled standard error of the means; \(n = 8\).
\(^c\) Quadratic effect \((P < 0.05)\) of Cs supplementation.
\(^d\) Linear effect \((P < 0.05)\) of Cs supplementation.
\(^e\) A-point fat: the first-rib back-fat thickness.
\(^f\) B-point fat: the 10th-rib 3/4 back-fat thickness.
\(^g\) C-point fat: the last-rib back-fat thickness.

There were no apparent pathological changes seen in the stomach mucosa of pigs fed the diet with 30 mg Cs kg\(^{-1}\) and the control diet. However, there was gastric mucosa damage and minor parakeratosis in the stomach of two pigs fed the diet with 50 mg Cs kg\(^{-1}\).

**DISCUSSION**

In the present study, dietary supplementation of Cs at 30 mg kg\(^{-1}\) caused significant increases in the growth rate and feed conversion efficiency of finisher pigs. However, compared with the level of 30 mg kg\(^{-1}\), dietary supplementation of Cs at 50 mg kg\(^{-1}\) significantly decreased average feed intake. Dietary supplementation at both 30 and 50 mg Cs kg\(^{-1}\) significantly improved carcass quality by reducing back-fat thickness. In rats and sheep the effect of Cs supplementation on physiological growth hormone secretion was dose-dependent and reversible.\(^{5,12,13}\) However, significant changes in plasma growth hormone level were not observed in this study. In this study, dietary supplementation of Cs at 30 mg kg\(^{-1}\) significantly reduced the plasma glucagon level but increased the plasma T3 level (Table 3). These results are consistent with the study by Jiang et al.\(^{14}\) who reported that supplementation of Cs at 80 mg kg\(^{-1}\) in diets can significantly increase serum T3 levels in pigs.

Little is known about the mechanisms whereby Cs improves growth and feed conversion and reduces fat deposition in finishing pigs. Apparently, we did not find any evidence to support the hypothesis that Cs supplementation increased serum growth hormone levels in this study.
Dietary supplementation of cysteamine in pigs

A suitable dietary level of Cs supplementation can potentially have the following advantages: (1) no species specificity; (2) a simple chemical compound convenient for administration of as a feed additive in diets for pigs; (3) few food safety concerns; and (4) low cost of its manufacture.

In conclusion, the results of this study suggest that a low dose of dietary supplementation of Cs at 30 mg kg\(^{-1}\) can significantly improve growth performance and carcass quality without adverse effects on the stomach in finishing pigs.

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