Research Note

Effects of low-protein diets on growth performance and carcass yield of growing White Pekin ducks


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ABSTRACT A dose-response experiment with 6 analyzed dietary crude protein (CP) levels (13.54, 14.37, 14.71, 16.04, 16.61, and 17.22%) was conducted to investigate the effects of low-protein diets on growth performance and carcass yield of growing White Pekin ducks from 14 to 35 d of age. All diets were formulated to contain a similar dietary energy level and the standardized ileal digestible amino acid profile including lysine, methionine, threonine, tryptophan, arginine, isoleucine, valine, and glycine. A total of 288 14-day-old male White Pekin ducks were divided into 6 experimental treatments and each treatment contained 8 replicate pens of 6 birds. Ducks were raised in wire-floor pens from 14 to 35 d of age. At 35 d of age, the weight gain, feed intake, feed/gain, and the yield of carcass, breast meat, leg meat, and abdominal fat of ducks from each pen were measured. As dietary CP decreased from 17.22 to 13.54%, weight gain and feed intake were not affected (P > 0.05) but feed/gain increased when dietary CP decreased to 13.54% (P < 0.05). On the other hand, the yield of carcass, leg meat, and breast meat was not influenced by reducing dietary CP (P > 0.05) but the abdominal fat increased when dietary CP was 13.54% (P < 0.05). Based on broken-line regression, the 14.81 and 14.94% were the minimum dietary CP to keep the feed/gain and abdominal fat similar to the ducks fed with 17.22% CP diets, respectively. In summary, with crystalline amino acid supplementation based on a similar standardized ileal digestible amino acid profile, it was possible to formulate the low-protein diets containing about 15% CP for Pekin ducks without adverse effects on their growth performance and carcass yield.

Key words: ducks, protein, growth performance, carcass yield

INTRODUCTION

Ammonia emission and nitrogen excretion from poultry litter or waste are major environmental pollutants from the poultry industry, and dietary protein level is an important determinant for reducing these pollutants. At present, with use of crystalline amino acids in diet formulation, low-protein diets have become a valid nutritional strategy to reduce nitrogen excretion and ammonia emission. In broilers, with supplementation of crystalline amino acids, a marginal reduction in dietary protein had no negative effect on growth performance and carcass traits, and it resulted in substantial reduction in nitrogen excretion and ammonia emission into the environment (Kerr and Kidd, 1999; Namroud et al., 2008; Attia, 2012a, b; Ospina-Rojas et al., 2014). In growing muscovy ducks from 8 to 12 wk of age, no significant modifications in growth performance or carcass quality were observed when dietary crude protein (CP) was reduced from 16 or 15 to 12% based on similar digestible amino acid profiles including lysine (Lys), methionine (Met), threonine (Thr), and tryptophan (Trp) (Baeza and Leclercq, 1998). Recently, in growing Pekin ducks from 15 to 35 d of age, the effects of different dietary CP levels (19, 17, and 15%) on growth performance and carcass traits of these birds were examined by Zeng et al. (2015a). The amino acids in low-protein diets used by these authors may be not balanced very well because only crystalline lysine, threonine, and methionine hydroxy analog were supplemented to the diets. In addition, the same ratio of Lys, Met, Thr, Trp, and Arginine (Arg) to dietary CP in all diets would lead to less amino acid density in low-CP diets compared with high-CP diets. As dietary CP decreased, the more essential amino acids would become growth-limiting but there is no information on which amino acids are limiting besides Met, Lys, and Thr in duck diets. In broilers, the Met, Thr, Lys, valine (Val), Arg, and Trp were the critical limiting amino acids in a low-protein corn-soybean meal diets (Edmonds et al., 1985; Holsheimer and Janssen, 1991; Attia, 2012a, b). Recently, Ospina-Rojas et al. (2014) successfully...
developed low-protein diets for starter and growing broilers with supplementation of crystalline Val, isoleucine (Ileu), Arg, and glycine (Gly) in diets. Furthermore, the interactive effects of glycine and serine with threonine, methionine, and cystine on growth performance also were observed in broilers (Siegent et al., 2015a,b). Therefore, the Met, Lys, Arg, Trp, Thr, Ileu, Val, and Gly were all considered for the amino acid profile in our study, and dietary levels of these amino acids were all formulated to support duck growth.

Usually, the formulation of low-protein diets is based on the similar total or digestible amino acid profiles and they have been developed successfully in broilers (Kerr and Kidd, 1999; Namroud et al., 2008; Award et al., 2014; Ospina-Rojas et al., 2014). Fortunately, the standardized ileal digestibilities (SID) of amino acids in corn and soybean meal for Pekin ducks were determined successfully and the additivity of SID amino acids in the mixed diets including these 2 feedstuffs was confirmed in these ducks (Kong and Adeola, 2013). This makes it possible to continue duck research on the formulation of low-protein diets based on the similar digestible amino acid profiles.

On the other hand, the information on the optimal protein level for growing ducks is still limited. Undoubtedly, the protein recommendation (16%) of NRC (1994) for 2 to 7 wk growing Pekin duck is not enough for modern Pekin ducks. At present, although 19% CP could be used to get the best growth performance and carcass traits of Pekin ducks from 15 to 35 d of age, the 17% may be enough to support duck growth according to the main effects of dietary CP on 35 d body weight gain, eviscerated carcass, and breast yield (Zeng et al., 2015a). Recently, 18% CP had also been used in trial diets to estimate amino acid requirements of modern growing Pekin ducks (Zhang et al., 2014; Zeng et al., 2015b) and thus this value was supposed to be the optimal CP level of standard diets for growing ducks in our study.

Furthermore, in Pekin ducks grown to market age (35 or 49 d of age), most of the feed cost comes from the grower or finisher period and thus the ducks during this period produce more nitrogen excretion and ammonia emission than those produced during the starter period. Therefore, the objective of our study was to examine the effects of low-protein diets with similar SID amino acid profiles including Lys, Met, Thr, Trp, Arg, Ile, Val, and Gly on growth performance and carcass yield of growing Pekin ducks from 14 to 35 d of age and determine the magnitude of reducing dietary protein for these birds.

**MATERIALS AND METHODS**

All procedures of our experiments were approved by the animal care and use committee of the Institute of Animal Sciences of the Chinese Academy of Agricultural Sciences.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Starter diet</th>
<th>Dilution diet</th>
<th>Summit diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>62.04</td>
<td>81.96</td>
<td>65.01</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>34.00</td>
<td>12.22</td>
<td>26.92</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>1.50</td>
<td>1.63</td>
<td>1.58</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.00</td>
<td>1.10</td>
<td>1.00</td>
</tr>
<tr>
<td>Soybean oil</td>
<td></td>
<td>-</td>
<td>2.30</td>
</tr>
<tr>
<td>Vitamin and mineral premix&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>DL-methionine</td>
<td>0.16</td>
<td>0.20</td>
<td>0.15</td>
</tr>
<tr>
<td>L-lysine-HCl</td>
<td>-</td>
<td>0.48</td>
<td>0.13</td>
</tr>
<tr>
<td>L-Tryptophan</td>
<td>-</td>
<td>0.07</td>
<td>-</td>
</tr>
<tr>
<td>L-Arginine</td>
<td>-</td>
<td>0.37</td>
<td>-</td>
</tr>
<tr>
<td>L-Isoleucine</td>
<td>-</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td>L-Threonine</td>
<td>-</td>
<td>0.20</td>
<td>-</td>
</tr>
<tr>
<td>L-Valine</td>
<td>-</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td>Glycine</td>
<td>-</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td>Corn starch</td>
<td>-</td>
<td>0.00</td>
<td>1.61</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Calculated composition</td>
<td>2,809</td>
<td>2,940</td>
<td>2,932</td>
</tr>
<tr>
<td>Metabolizable energy&lt;sup&gt;b&lt;/sup&gt;, kcal/kg</td>
<td>2,809</td>
<td>2,940</td>
<td>2,932</td>
</tr>
<tr>
<td>Calculated composition</td>
<td>2,809</td>
<td>2,940</td>
<td>2,932</td>
</tr>
<tr>
<td>Crude protein</td>
<td>20.35</td>
<td>13.54</td>
<td>17.22</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.49</td>
<td>0.41 (0.40)</td>
<td>0.43 (0.40)</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.35</td>
<td>0.28 (0.25)</td>
<td>0.34 (0.31)</td>
</tr>
<tr>
<td>Lysine</td>
<td>1.10</td>
<td>0.88 (0.85)</td>
<td>0.94 (0.85)</td>
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<tr>
<td>Tryptophan</td>
<td>0.24</td>
<td>0.20 (0.19)</td>
<td>0.22 (0.19)</td>
</tr>
<tr>
<td>Arginine</td>
<td>1.28</td>
<td>1.07 (1.06)</td>
<td>1.13 (1.06)</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.81</td>
<td>0.63 (0.59)</td>
<td>0.72 (0.59)</td>
</tr>
<tr>
<td>Valine</td>
<td>0.93</td>
<td>0.74 (0.72)</td>
<td>0.78 (0.72)</td>
</tr>
<tr>
<td>Glycine</td>
<td>0.84</td>
<td>0.66 (0.63)</td>
<td>0.70 (0.63)</td>
</tr>
<tr>
<td>Serine</td>
<td>1.02</td>
<td>0.62 (0.59)</td>
<td>0.86 (0.83)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Supplied per kilogram of diet: Cu (CuSO<sub>4</sub>·5H<sub>2</sub>O), 10 mg; Fe (FeSO<sub>4</sub>·7H<sub>2</sub>O), 60 mg; Zn (ZnO), 60 mg; Mn (MnSO<sub>4</sub>·H<sub>2</sub>O), 80 mg; Se (Na<sub>2</sub>SeO<sub>3</sub>), 0.3 mg; I (KI), 0.2 mg; choline chloride, 1,000 mg; vitamin A (retinyl acetate), 10,000 IU; vitamin D<sub>3</sub> (Cholecalciferol), 3,000 IU; vitamin E (DL-α-tocopheryl acetate), 20 IU; vitamin K<sub>3</sub> (menadione sodium bisulfate), 2 mg; thiamin (thiamin mononitrate), 2 mg; riboflavin, 8 mg; pyridoxine hydrochloride, 4 mg; cobalamin, 0.02 mg; calcium-D-pantothenate, 20 mg; nicotinic acid, 50 mg; folic acid, 1 mg; biotin, 0.2 mg.

<sup>b</sup>The values are calculated according to the AME of chickens (Ministry of Agriculture of China, 2004).

<sup>c</sup>The values in parentheses are calculated standardized ileal digestible amino acids.

**Birds and Housing**

The dose-response experiment with 6 analyzed dietary CP levels (13.54, 14.37, 14.71, 16.04, 16.61, and 17.22%) was conducted with 14-day-old male White Pekin ducks. Three hundred and fifty one-day-old male White Pekin ducklings from one commercial hatchery were raised with common starter diets (Table 1) until 14 d of age. On d 14, all birds were weighed individually and the birds with lowest or highest body weight were removed, and finally 288 birds were selected from the remaining birds. Afterwards, these ducks were allotted to 48 wire-floor pens of 6 birds each according to similar pen weight. Each dietary treatment consisted of 8 pens with one pen as one replicate. The experimental
The other amino acids, except methionine, cystine, and glycine+serine (Gly+Ser) were oxidized at 0°C according to the method recommended by Standardization Administration of China (2000). Briefly, methionine and cystine were oxidized at 0°C by performic acid (formic acid: hydrogen peroxide = 9: 1) for 16 h and then hydrolyzed at 110°C by 6 M HCL for 24 hours. The other amino acids, except methionine, cystine, and tryptophan, were hydrolyzed at 110°C by 6 M HCL for 24 hours. Afterwards, the pH of these hydrolyzates were adjusted to 2.2 and then were analyzed by using ion-exchange chromatography with an amino acid analyzer (L-800, Hitachi, Tokyo, Japan). Tryptophan was analyzed by reverse-phase high performance liquid chromatography and fluorometric detection (Waters, Inc., Milford, MA) after alkali hydrolysis at 110°C for 20 h with 4 M barium hydroxide. Afterwards, according to the analyzed amino acids of corn and soybean meal and the SID of amino acids in corn and soybean meal for Pekin ducks published recently by Kong and Adeola (2013), the summit and dilution diets were all formulated according to different mixing ratios of these 2 diets (5:0, 4:1, 3:2, 2:3, 1:4, and 0:5). All experimental diets were cold-pelleted at room temperature and the CP and amino acids of these diets also were analyzed according to the aforementioned methods (Table 2). The analyzed dietary CP levels of these 6 experimental diets were 13.54, 14.37, 14.71, 16.04, 16.61, and 17.22%, respectively.

### Diets

Experimental diets with 6 dietary CP levels were prepared by mixing summit and dilution diets according to dilution technology. First, the CP levels of corn and soybean meal were determined by the Kjeldahl procedure according to the method recommended by Standardization Administration of China (1994). The amino acids of these 2 feedstuffs were analyzed according to the method recommended by Standardization Administration of China (2000). Briefly, methionine and cystine were oxidized at 0°C by performic acid (formic acid: hydrogen peroxide = 9: 1) for 16 h and then hydrolyzed at 110°C by 6 M HCL for 24 hours. The other amino acids, except methionine, cystine, and tryptophan, were hydrolyzed at 110°C by 6 M HCL for 24 hours. Afterwards, the pH of these hydrolyzates were adjusted to 2.2 and then were analyzed by using ion-exchange chromatography with an amino acid analyzer (L-800, Hitachi, Tokyo, Japan). Tryptophan was analyzed by reverse-phase high performance liquid chromatography and fluorometric detection (Waters, Inc., Milford, MA) after alkali hydrolysis at 110°C for 20 h with 4 M barium hydroxide. Afterwards, according to the analyzed amino acids of corn and soybean meal and the SID of amino acids in corn and soybean meal for Pekin ducks published recently by Kong and Adeola (2013), the summit and dilution diets were all formulated according to different mixing ratios of these 2 diets (5:0, 4:1, 3:2, 2:3, 1:4, and 0:5). All experimental diets were cold-pelleted at room temperature and the CP and amino acids of these diets also were analyzed according to the aforementioned methods (Table 2). The analyzed dietary CP levels of these 6 experimental diets were 13.54, 14.37, 14.71, 16.04, 16.61, and 17.22%, respectively.

### Statistical Analysis

The one-way ANOVA was performed using SAS software (SAS Institute, 2003), with pen used as the experimental unit for analysis. The variability in the data was expressed as the standard error of the means (SEM) and a probability level of <0.05 was considered to be statistically significant. The broken-line regression analysis (Robbins et al., 2006) was used to estimate the minimum CP requirements for ducks using the NLIN procedure (SAS Institute, 2003). The broken-line model was provided as follows:

\[ y = l + u(r - x) \]

where \( y \) = growth performance or carcass traits, \( x \) = analyzed dietary CP (%), \( r \) = dietary CP requirement (%), \( l \) = the response at \( x = r \), and \( u \) = the slope of the curve. In this model, \( y = l \) when \( x > r \).
Table 3. Effects of low-protein diets on growth performance of White Pekin ducks from 14 to 35 d of age.1

<table>
<thead>
<tr>
<th>Dietary CP (%)</th>
<th>CP intake (g/bird per d)</th>
<th>Feed intake (g/bird per d)</th>
<th>Weight gain (g/bird per d)</th>
<th>Feed/gain (g/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.22</td>
<td>37.9</td>
<td>220.2</td>
<td>112.6</td>
<td>1.96</td>
</tr>
<tr>
<td>16.61</td>
<td>37.3</td>
<td>224.8</td>
<td>113.9</td>
<td>1.97</td>
</tr>
<tr>
<td>16.04</td>
<td>35.4</td>
<td>220.7</td>
<td>112.0</td>
<td>1.97</td>
</tr>
<tr>
<td>14.71</td>
<td>32.2</td>
<td>218.2</td>
<td>110.4</td>
<td>1.98</td>
</tr>
<tr>
<td>14.37</td>
<td>32.1</td>
<td>224.4</td>
<td>113.2</td>
<td>2.04</td>
</tr>
<tr>
<td>13.54</td>
<td>30.4</td>
<td>224.4</td>
<td>110.3</td>
<td>2.04</td>
</tr>
<tr>
<td>SEM</td>
<td>0.46</td>
<td>1.36</td>
<td>0.71</td>
<td>0.007</td>
</tr>
<tr>
<td>Probability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>&lt;0.001</td>
<td>0.64</td>
<td>0.62</td>
<td>0.01</td>
</tr>
<tr>
<td>CP broken-line</td>
<td>0.001</td>
<td>0.63</td>
<td>0.46</td>
<td>0.02</td>
</tr>
</tbody>
</table>

1Results are means with n = 8 per treatment.

RESULTS AND DISCUSSION

In our study, decreasing dietary CP had no significant negative effects on weight gain and feed intake of ducks (P > 0.05) but the feed/gain of growing Pekin ducks increased (P < 0.05) when dietary CP decreased from 17.22 to 13.54% (Table 3). Our results were in agreement with the results observed in finishing muscovy ducks from 8 to 12 wk of age (Baeza and Leclercq, 1998). In their study, with crystalline amino acid supplementation based on the same digestible amino acid profiles including Lys, total sulphur-containing amino acids, Thr, and Trp, reducing dietary CP from 16 or 15 to 12% did not influence the final body weight, weight gain, and feed intake of these birds but feed/gain increased markedly when dietary CP was reduced to 10%. However, our results were partially different from a recent publication on Pekin ducks (Zeng et al., 2015a). In their study, reducing dietary CP from 17 to 15% not only increased feed/gain markedly but also reduced the 35 d body weight and 14 to 35 d weight gain of birds significantly. The reason for these differences between their and our results may be that no other crystalline amino acids except Lys, Thr, and methionine hydroxy analogue were supplemented to their diets compared with our study.

On the other hand, the yield of carcass, leg meat, and breast meat was not influenced by reducing dietary CP from 17.22 to 13.54% (P > 0.05) but the abdominal fat increased (P < 0.05) when dietary CP was 13.54% (Table 4). Similar results were observed in finishing muscovy ducks fed dietary CP from 16 or 15 to 12% at the same digestible amino acid profiles except that abdominal fat was not affected by reducing dietary CP (Baeza and Leclercq, 1998) and lysine levels (Attia, 2003). In 35-day-old Pekin ducks, dietary CP decreased from 19 to 15% led to a decrease in breast meat yield and an increase in breast skin and fat (Zeng et al., 2015a). However, in their study, all diets kept the same ratio of Lys, Met, Thr, Trp, and Arg to dietary CP and this would lead to more reduction of total or digestible amino acids in diets as dietary CP decreased, which may lead to the difference in breast meat yield between their and our results. In addition, due to amino acid imbalance in low-CP diets, there would most likely be increased amino acid catabolism and the carbon skeletons from amino acids would be converted to intermediates for carbohydrate and lipid biosynthesis. This may be the reason for the increase in abdominal fat of ducks fed low-CP diets in the studies of Zeng et al. (2015a) and us.

It was well known that low-protein diets are beneficial to environmental protection, and ammonia emission and nitrogen excretion are reduced markedly when they are applied to the poultry industry, which has been confirmed in broilers (Namroud et al., 2008; Hernández et al., 2012; Attia, 2012a,b; Ospina-Rojas et al., 2014). In our study, the response of CP intake to decreasing dietary CP provided a significant fit to broken-line regression (Figure 1), and this regression showed that the CP intake would decrease linearly when dietary CP was below 17.05%, which may lead to the reduction of ammonia emission and nitrogen excretion as dietary CP decreased. Therefore, it was useful to predict the minimum protein requirement of ducks and the broken-line regression was used to do it. According to this regression, the estimated protein requirements for feed/gain (Figure 2) and abdominal fat (Figure 3) were 14.81 and 14.94%, respectively, and these estimated response values were identical to the observed response data in which the feed/gain and abdominal fat were optimized.

Table 4. Effects of low-protein diets on carcass traits of White Pekin ducks at 35 d of age.1

<table>
<thead>
<tr>
<th>Dietary CP (%)</th>
<th>Carcass (%)</th>
<th>Breast meat (%)</th>
<th>Leg meat (%)</th>
<th>Abdominal fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.22</td>
<td>71.4</td>
<td>10.2</td>
<td>9.7</td>
<td>0.80</td>
</tr>
<tr>
<td>16.61</td>
<td>74.7</td>
<td>10.1</td>
<td>10.0</td>
<td>0.82</td>
</tr>
<tr>
<td>16.04</td>
<td>73.6</td>
<td>10.5</td>
<td>9.9</td>
<td>0.80</td>
</tr>
<tr>
<td>14.71</td>
<td>74.1</td>
<td>9.4</td>
<td>10.0</td>
<td>0.89</td>
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<tr>
<td>14.37</td>
<td>71.7</td>
<td>9.9</td>
<td>9.7</td>
<td>0.86</td>
</tr>
<tr>
<td>13.54</td>
<td>73.7</td>
<td>9.7</td>
<td>9.4</td>
<td>1.09</td>
</tr>
<tr>
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<td>0.58</td>
<td>0.12</td>
<td>0.08</td>
<td>0.022</td>
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<tr>
<td>CP</td>
<td>0.45</td>
<td>0.20</td>
<td>0.17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CP broken-line</td>
<td>0.79</td>
<td>0.14</td>
<td>0.11</td>
<td>0.02</td>
</tr>
</tbody>
</table>

1Results are means with n = 8 per treatment.
when dietary CP was above 14.71% (Tables 3 and 4). These estimated protein requirements were lower than the NRC (1994) recommendation (16%) for Pekin ducks from 2 to 7 wk of age, and these dietary CP levels would be reduced further with the increased age of ducks, as the period of NRC (1994) extended to 49 d of age.

In conclusion, with crystalline amino acid supplementation based on a similar SID amino acid profile, it is possible to formulate the low-protein diets of Pekin ducks without adverse effects on growth performance and carcass yield. According to broken-line regression, the 14.81 and 14.94% were the minimum dietary CP levels of the influence of dietary glycine and serine, with consideration of methionine and cysteine, on growth and feed conversion of broiler chicks from 3 to 7 weeks of age. Br. Poult. Sci. 32:151–158.


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REFERENCES


Accurately extracting the text from the image.