Summary

Most of duck production was concentrated in China. Although the data in duck nutrition were very limited in English journals, many duck experiments were conducted in China and many results were published in Chinese journals. In China, studies on the nutrient requirements and feed evaluation for ducks were all conducted extensively. This review summarized some study results on the amino acid, vitamin, and mineral requirements for modern strain Peking ducks and discussed the method of energy evaluation for duck feedstuffs.

Keywords: duck, nutrition

Introduction

China had long history of feeding ducks. The duck moulds found in 1979 were made of jade in B.C. 1200 and duck production were recorded B.C. 500. Nowadays, roasting duck, dried salted duck, braised duck with soy sauce and cold spiced duck were important food in China. Beijing roasting duck and Nanjing salted duck were the most famous food all over China, in 2011, about 3940 million ducks were slaughtered to produce meat in our country and it accounts for about 80% of the total world duck meat production. According to the quantity of Chinese duck production collected from 24 provinces of China by a research group supported by Chinese government, the 90% of duck production came from Peking ducks and the others came from mule duck, laying duck and other local ducks. Almost 90% of the ducks were mainly fed in 16 provinces including Hebei, Beijing, InnerMongolia, Shandong, Jiangsu, Anhui, Zhejiang, Fujian, Hunan, Hubei, Jiangxi, Henan, Guangxi, Guangdong, Sichuan, and Chongqing.

In China, about 23.6 million ton feed for meat duck and 10 million ton feed for laying duck were produced in 2011. All together, about 33.6 million tons feed for duck production were consumed by ducks in last year. At present, like broilers, duck meat was consumed as low-fat meat in China and the production of duck meat increased by the rate of 5% per year. However, although the data in nutrient requirements and feed utilization for ducks were very limited in English journal, many duck experiments were conducted in China and many results were published in Chinese journals. Now, a part of the studies on nutrient requirement (such as amino acid, vitamin, and mineral) and feed evaluation conducted by Professor Hou and his group in China were summarized here as follow:

Amino acid requirement

Lysine

A 2 × 5 factorial experiment containing two ME and CP levels (2900 kcal/kg and 20% and 2610 kcal/kg and 18%) and five lysine levels (0.65%, 0.80%, 0.95%, 1.10%, 1.25%) was conducted to evaluate the effects of dietary energy and protein on lysine requirement of Peking ducklings during starter period. Five hundred and sixty 7-day-old male White Peking ducklings were divided to 10 treatments, each containing 8 replicate pens with 7 birds per pen. These ducklings were raised with feed and water provided ad libitum from 7 to 21 days of age. At 21 days of age, weight gain, feed intake and feed/gain were measured. Compared with ducklings fed 2610 kcal ME/kg and 18% CP diets, feed intake of birds fed 2900 kcal ME/kg and 20% CP diets was reduced significantly, but dietary energy and protein had no significant effects on ME and CP intake of birds. The lysine requirements for weight gain and feed/gain at high and low dietary ME and CP levels were estimated by broken-line regression analysis and lysine requirements at these two conditions were compared by t-test. At 2900 kcal ME/kg and 20% CP level, the lysine requirement for optimal weight gain and feed/gain were 0.84 and 0.90%, respectively. At 2610 kcal ME/kg and 18% CP
level, the lysine requirement was 0.80% for optimal feed/gain. However, when lysine requirement was expressed as a percentage of dietary CP, the lysine requirements for optimal feed/gain at high and low dietary ME and CP levels were 4.45 and 4.44%, respectively, and this difference between them was not significant by t-test. It was concluded that lysine requirement should be expressed as a percentage of dietary CP when dietary energy and protein are changed.

**Methionine**

Two dose-response trials were conducted to estimated methionine requirement of White Peking ducks. In experiment 1, a 4 × 5 factorial experiment containing four cystine levels (0.325%, 0.406%, 0.487%, 0.568%) and five methionine levels (0.285%, 0.385%, 0.485%, 0.585%, 0.685%) was conducted to evaluate the interrelationship between methionine and cystine in corn-peanut meal diet for Peking ducklings from hatch to twenty-one days of age. Eight hundred one-day-old male white Peking ducklings were assigned to twenty experimental treatments. All treatments were replicated four times using ten ducklings per pen. In experiment 2, dose-response experiment with six dietary methionine levels (0.20%, 0.275%, 0.35%, 0.425%, 0.50%, 0.575%) was conducted with white male Peking ducklings to estimate the methionine requirement of growing ducks from 21 to 49 days of age. One-day-old male white Peking ducklings were fed common starter diets from hatching to 21 days of age and then fed the experimental diets from 21 to 49 days of age. Three hundred thirty-six 21-day-old birds were allotted to 24 pens with 14 birds per pen according to similar pen weight. There were six dietary treatments, each containing 4 replicate pens. In both experiments, growth performance of starter and grower ducks and breast meat yield of growing ducks were all improved significantly and quadratic model were used to estimate the methionine requirement of these ducks. According to this regression analysis, the optimal methionine requirement of Peking ducklings from hatch to twenty-one days of age is 0.481% and the requirement of this amino acid of these growing ducks from 21 to 49 days of age for maximum weight gain and breast meat yield were 0.377% and 0.379%, respectively.

**Methionine analogue**

Two dose-response experiments were conducted to assess the bioefficacy and toxicity of DL-methionine hydroxy analogue free acid (MHA-FA) relative to DL-methionine (DLM) in White Peking ducks. In experiment 1, the methionine-deficient basal diets were supplemented with 5 levels of DLM (0.3, 0.6, 1.0, 1.5, and 2.1 g/kg) or 5 equimolar levels of MHA-FA (0.34, 0.68, 1.13, 1.70, and 2.39 g/kg), respectively. In experiment 2, the methionine-adequate control diets were supplemented with 30 g/kg DLM or equimolar 33.9 g/kg MHA-FA, respectively. Supplementation of DLM and MHA-FA to the basal diets could all improved weight gain and feed conversion efficiency of Peking ducks significantly. According to the slope-ratio assay on equimolar basis, the bioavailabilities of MHA-FA relative to DLM for weight gain and feed conversion efficiency were 65 and 43%, respectively. Excess DLM and MHA-FA caused significant decrease in weight gain and feed intake of ducks but MHA-FA was less growth-depressing and lethal than equimolar DLM.

**Vitamin A**

A dose-response experiment with 5 dietary vitamin A (02,5005,00010,000 and 15,000 IU/kg) was conducted to evaluate the effects of vitamin A on growth performances serum vitamin A, and intestine development of Peking ducks from 0 to 3 weeks of age. A total of 360 one-day-old Peking ducklings were randomly allocated to 5 treatment groups with 6 replicate pens of 12 birds. During the period from hatch to 21 days, these birds were raised with 5 experimental diets in which corn-corn starch-soybean meal basal diets were supplemented with 025005 00010000 and 15000 IU/kg vitamin A respectively. In this study, vitamin A deficiency caused significant growth depression and high morbidity relative to deficiency of this vitamin, and the growth performance (weight gain, feed/gain) was improved and no symptom of vitamin A deficiency was observed when supplemental vitamin A level was 2500 IU/kg and above. At the same time, as dietary vitamin A increased, the serum vitamin A increased significantly but no significant difference was observed between the 10000 and 15000 IU/kg vitamin A-supplemented treatment groups. On the other hand, dietary vitamin A could affect the intestine development of ducks. The villus length, crypt depth, and intestinal wall thickness of duodenum decreased significantly in vitamin A-deficient ducks and the supplementation of vitamin A in diets could reduced this negative effects, but further improvement was not observed when supplemental vitamin A was above 2500 IU/kg. According to the growth performance and intestine development, the minimum requirement
of vitamin A of Pekin ducks from hatch to three weeks of age was 2500IU/kg.

**Vitamin D**

A 2 x 6 factorial experiment containing two dietary calcium (Ca) and non-phytate phosphorus (NPP) levels (0.40/0.20 and 0.80/0.40%) and six vitamin D level (0, 250, 500, 1000, 2000, 3000 IU/kg) was conducted to evaluate the effect of dietary vitamin D on growth performance and bone ash of White Pekin ducklings from hatch to 14 days of age at deficient and normal dietary Ca and NPP level. A total of 720 one-day-old male White Peking ducklings were assigned to 12 experimental treatments, each containing 6 replicate pens with 10 birds per pen, and these birds were raised with feed and water provided ad libitum. At 14 days of age, weight gain, feed intake, feed / gain and the ash, Ca, and P in tibia of each treatment were all measured. In our study, deficiency in dietary Ca and NPP caused significant decrease in weight gain, feed intake and tibia ash but these adverse effects could be alleviated by increasing vitamin D level in diets. However, the growth response to increasing dietary vitamin D was different significantly at deficient and normal dietary Ca/NPP. At dietary 0.40 Ca and 0.20 NPP level, the weight gain and feed intake increased significantly as vitamin D increased from 0 to 3000 IU/kg but these increasing growth response to vitamin D did not take place at dietary 0.80% Ca and 0.40% NPP level. According to growth performance and bone mineralization, the 1000IU/kg vitamin D was enough to support duck growth at normal Ca/NPP level but more vitamin was need when ducks were deficient in Ca and NPP.

**Vitamin E**

Two dose-response trials were conducted to study the effects of vitamin E on growth performance, liver and plasma vitamin E, and antioxidant function of early Peking ducklings from hatch to 3 weeks of age by a completely randomized design. Seven dietary vitamin E levels (7, 12, 17, 27, 47, 107, 407 IU/kg) and four dietary vitamin E levels (1, 11, 21, 101 IU/kg) were used in experiment 1 and experiment 2, respectively. In experiment 1, a total of three hundred ninety-two 1-day-old birds were allocated to 7 dietary treatments according to similar weight, each consisting of 8 replicate pens of 7 birds. In experiment 2, one hundred and ninety-two 1-day-old male white Peking ducklings were allotted into four treatments, each included 6 replicate pens of 8 ducks. At the end of both experiments, the weight gain, feed intake, feed/gain, the vitamin A and antioxidant measurement (thiobarbituric acid reactive substances, Superoxide dismutase, Glutathione peroxidase) in plasma and liver of ducks from each treatment group were measured. In our study, the weight gain and feed intake increased as dietary vitamin E increased but no further improvement took place when dietary vitamin E was above 11 or 12 IU/kg. In the meantime, as dietary vitamin E increased, liver -tocopherol increased and liver thiobarbituric acid reactive substances decreased, significantly, that showed negative linear relationship between dietary vitamin E and liver thiobarbituric acid reactive substances. Above all, supplementation of vitamin E in diets could improve growth performance and reduced lipid peroxidation of pekin ducklings and the vitamin E requirement for weight gain was no less than 12 IU/kg during the starter period from hatch to 21 days of age.

**Riboflavin**

A 2 x 8 factorial experiment containing sex (female and male) and dietary riboflavin level (1.2, 3.2, 5.2, 7.2, 9.2, 11.2, 13.2, 15.2mg/kg) was conducted to evaluate the riboflavin requirements of male and female White Peking ducklings from hatch to 21 days of age, respectively. In this study, a total of 640 one-day-old Peking ducklings including 320 male and 320 female birds were randomly distributed into 80 wire-floor pens of 10 birds sexed separately and each treatment group contained 5 replicate pens. These birds were raised from hatch to 21 days of age. At 21 days of age, the weight gain, feed intake, feed conversion rate, and plasma and liver riboflavin of ducklings from each treatment were measured. In our study, the growth depression, high mortality, and low plasma and liver riboflavin were observed in riboflavin-deficient ducklings and these ill effects could be reduced significantly by increasing dietary riboflavin levels. According to broken-line regression, during the starter period from hatch to 21 days of age, the riboflavin requirements of White Pekin ducklings for weight gain, feed conversion rate, plasma and liver riboflavin of ducklings from each treatment were measured. In our study, the growth depression, high mortality, and low plasma and liver riboflavin were observed in riboflavin-deficient ducklings and these ill effects could be reduced significantly by increasing dietary riboflavin levels.

**Biotin**

A dose-response experiment with 9 dietary supplemental biotin levels (0, 0.03, 0.06, 0.09, 0.12, 0.15, 0.18, 0.21, 1.5 mg biotin/kg) was conducted to study the effects of dietary biotin on growth performance and foot pad dermatitis (FPD) of White Peking ducklings from hatch to 21 days of age. Five hundred seventy-six male 1-d-old Pekin
ducklings were randomly divided into 9 dietary treatments, each containing 8 replicate pens with 8 birds per pen. In our study, final weight, feed intake and body weight gain of Peking ducklings increased significantly as dietary biotin levels increased from hatch to 21 days of age. According to the broken-line regression analysis, the requirement of starter ducklings for weight gain was estimated 0.187 mg/kg when the biotin content of basal diet was omitted. At 28 d of age, dehydration, crack, bleeding and scab, and ulceration were observed in biotin-deficient ducks and these birds obtained the higher external score of FPD, but the score decreased from 8.750 to 0.500 when dietary biotin level increased from 0 to 1.5 mg/kg. According to the external scores, the supplemental biotin level should not be less than 0.21 mg/kg to reduce the incidence of FPD to minimum.

**Niacin and tryptophan**

A 4 × 5 factorial experiment containing four niacin levels (26, 60, 106, 146 mg/kg) and five tryptophan levels (0.132, 0.167, 0.202, 0.237, 0.272%) was conducted to evaluate the interrelationship between niacin and tryptophan in corn-corn gluten meal-peanut meal diet for Peking ducklings from hatch to twenty-one days of age. Eight hundred and forty one-day-old male white Peking ducklings were assigned to twenty experimental treatments. All treatments were replicated six times using seven ducklings per pen. These birds were raised from hatch to 21 days of age. At 21 days of age, the weight gain, feed intake, and feed conversion rate and plasma 5-hydroxytryptamine and tryptophan of ducklings from each treatment were measured. In our study, the interaction between niacin and tryptophan significantly influenced the weight gain and feed intake and the overall effects of these two nutrients on these parameters were also significant. Niacin deficiency caused growth depression in which weight gain and feed intake were all reduced, but these adverse effects could be alleviated or reversed by increasing dietary tryptophan. Furthermore, according to broken-line regression, the tryptophan requirement for weight gain of starter ducklings at 26, 60, 106, 146 mg/kg niacin were estimated to be 0.242, 0.168, 0.169, 0.170%, respectively, and the tryptophan requirement was significantly higher at 26mg/kg niacin than those at other niacin levels (60, 106, 146 mg/kg) according to t-test analysis, and these results suggested that more tryptophan may be partly converted to niacin in niacin-deficient ducklings. On the other hand, considering unchanged feed conversion rate, the growth depression caused by niacin deficiency may be due to depression of feed intake, and the r of feed intake in this instance may be relative to decreasing of 5-hydroxytryptamine because of the role of this amine in regulation of feed intake. At the same time, the alleviating of growth depression caused by niacin deficiency by increasing tryptophan was not only due to conversion of this amino acid to niacin but also due to the increasing production of 5-hydroxytryptamine converted by tryptophan, which was supported by increasing plasma 5-hydroxytryptamine as dietary tryptophan increased at any niacin level.

**Selenium**

A completely randomized one-factor experiment with seven dietary selenium levels (0.04, 0.24, 0.44, 0.84, 1.64, 3.24, 8.04mg/kg) was conducted to estimate the selenium requirement of male Peking ducks from hatch to 3 weeks of age. Four hundred and twenty 1-day-old Peking ducklings were divided to seven treatment groups with each containing 6 replicate pens of 10 birds and these ducklings were raised until three weeks of age. In our study,
no significant effects of dietary selenium on daily weight gain, daily feed intake were, and feed/gain were observed (P<0.05) and selenium content in blood or liver and glutathione peroxidase increased significantly when dietary selenium was above 0.24 mg/kg. Based on selenium and glutathione peroxidase in tissues, the selenium requirement of Peking ducklings from hatch to 3 weeks of age was 0.24 mg/kg.

**Evaluation of energy in feedstuffs for ducks**

**Energy evaluation by fast force-feeding technique**

**Stress caused by force-feeding and starvation**

Sixty adult Peking drakes were used in this experiment. Before start of the trial, these birds were starved for 12h, but were provided water ad libitum. Before force-fed by 50g feed, ten birds were bleed by web and plasma were collected. Afterwards, the remaining 50 drakes were force-fed 50g feed and then they were fasted for 48 hours but water were provided ad libitum during this period. During this 48-hour period, ten birds were selected randomly and bled by web and plasma were collected at 2, 12, 24, 36, 48 hour after force-fed. the contents of glucose, uric acid, total protein, triglyceride, insulin, triiodothyronine, corticosteroid in plasma were measured.

In our study, force-feed could cause stress in drakes but it was not serious, which was supported by increasing plasma T3 after force-fed. Furthermore, after 24 hours post force-fed, the plasma T3 decreased significantly and kept constant which suggested that the stress caused by force-fed could decrease gradually. During this period, the change of glucose and insulin was caused by feed force-fed and the plasma glucose and insulin kept constant after 12 hours post force-fed, which indicate that starvation could not cause serious stress to birds. Therefore, force-fed could cause stress in drake but it could be alleviated in the following fast time.

**Excreta collection time**

Forty-eight adult Peking drakes were used to study optimal starvation time prior to force-fed and excreta collection time according to the time of digesta passing through the intestine when feed residues remained stable in alimentary tract. After starved for 48h, each drake was force-fed by 50g feed. Four drakes were slaughtered and feed residues in alimentary tract were collected at 4, 8, 14, 24, 32, 38, 48, 56h after force-fed, respectively. In our study, the dry matter weight of gross residues in alimentary tract has no significant change after 24 hour post-force-fed. and the gross energy of excreta collected also remained constant after 36 hour post-force-fed. Therefore, the passage time of feed from the alimentary tract of drake is no less than 36h and this time may be used as excreta collection time in fast force-feeding technique.

**Feed intake of force-fed**

Seventy adult Peking drakes were allotted to 7 groups, each group 10 birds. After starved for 36h, drakes of each group were force-fed 0, 30, 50, 70, 90, 110, and 150g feed per bird, respectively, and excreta were collected during the following 36 hours after force-fed. In this study, the apparent metabolizable energy (AME) and true metabolizable energy (TME) increased when the quantity of the force-fed increased from 30 to 70g, and the AME and TME of feeds decreased when quantity of the force-fed exceeded 70g. Moreover, endogenous energy loss of the drake fluctuated slightly when the quantity of the force-fed was less than 90g feed (p>0.05). Therefore, 50-70g is adequate to force-fed draket to evaluate metabolizable energy of feed.

**Metabolizable energy of feedstuffs for duck**

The apparent metabolizable energy of each feedstuffs were determined by fast force-fed technique with 12 adult intact Peking drakes. After deprived of feed for 36 hours, the 12 drakes were tube-fed by 60 g feedstuffs and then all excreta were collected for 36 hours and then they were dried and gross energy of feed and collected excreta were all measured. The endogenous energy losses were estimated by fasting these 12 drake for 36 hours. There existed 14-day interval before determination of metabolizable energy of next feedstuffs. The apparent and true metabolizable energy (AME and TME ) were provided as follow:

**Comparison between duck and chicken in metabolizable energy**

In this study, the apparent metabolizable energy of each feedstuffs were determined by fast force-fed technique with 12 adult intact Peking drakes and 12 adult Hy-Line Brown cockerels, respectively, and there existed 14-day interval before determination.
of metabolizable energy of next feedstuffs. After deprived of feed for 48 hours, the 12 drakes and cockerels were all tube-fed by 50 g feedstuffs and then all excreta were collected for 48 hours and then they were dried and the gross energy of feed and collected excreta were all measured. In this study, there were significant differences in AME of most plant feedstuffs between cockerel and drake. Except cottonseed meal and corn starch, the AME of the feedstuffs for drake were significantly higher than for cockerel.

**Energy evaluation by enzyme digestion**

In this method, the artificial intestinal fluid with the zymography similar to the intestinal fluid of ducks was designed according to the digestive enzymes activities range of intestinal fluid under normal physiological condition. The enzyme digestion method to determine the energy of ducks feedstuffs with pepsin-artifical intestinal fluid was established. It would provide new technique for energy evaluation of feedstuffs. This new technique were established by four trial as follow:

The first trial was conducted to design the “ T ” type cannula to collect enough intestinal fluid continuously without stress. The strcture of this “ T ” type cannula were designed according to the intestinal cannula used in pig, cattle, and sheep. When this new cannula were used to Peking ducks, there were little damage on cannulated intestine and adherence between intestine and abdomen fat
### Difference in AME of feedstuffs between cockerels and drakes MJ/

<table>
<thead>
<tr>
<th>Feedstuffs</th>
<th>Drake</th>
<th>Cockerel</th>
<th>P value</th>
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<tr>
<td>Soybean meal</td>
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* means significant different (p<0.05), the ** means vary significant different (p<0.01)


