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Original Research Article

Effects of pantothenic acid on growth performance, slaughter performance, lipid metabolism, and antioxidant function of Wulong geese aged one to four weeks

Baowei Wang*, Xiao Zhang, Bin Yue, Wenhua Ge, Mingai Zhang, Chuanxing Ma, Min Kong

Institute of High Quality Waterfowl, Qingdao Agricultural University, Nutrition and Feed Laboratory of China Agriculture Research System, Qingdao 266109, China

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ABSTRACT

This experiment was conducted to study the effects of pantothenic acid on the growth performance, slaughter performance, lipid metabolism, and antioxidant function of one-to four-week-old Wulong geese and determine the appropriate supplemental level of pantothenic acid. A total of 360 one-day-old Wulong geese were randomly divided into 6 groups with 6 replicates per group and 10 geese (5 males and 5 females) per replicate. The geese in group I (control group) were fed a basal diet, and the geese in groups II to VI (experimental groups) were given the basal diet supplemented with 8, 15, 30, 60, and 120 mg/kg pantothenic acid, respectively. The experiment lasted for 4 weeks. Based on the results of unrelated comparative analysis, the body weight was the highest when the dietary pantothenic acid level was 27.57 mg/kg. When the dietary pantothenic acid level was 26.17 mg/kg, the average daily gain peaked. When the dietary pantothenic acid level was 15.50 mg/kg, the feed:gain ratio was the lowest. The percentage of abdominal fat in groups III and IV was significantly lower than that in group I ($P < 0.05$). The content of total cholesterol in serum in groups III to V was significantly lower than that in group I ($P < 0.05$). The triglyceride content in groups III and IV was significantly lower than that in group I ($P < 0.01$). The high-density lipoprotein–cholesterol content in group IV was significantly higher than that in group I ($P < 0.05$). The total antioxidant capacity of serum and liver in group IV was significantly higher than that in group I ($P < 0.05$). The malondialdehyde content in the liver in groups III and IV was significantly lower than that in group I ($P < 0.05$). Glutathione peroxidase activity in the serum in group IV was significantly higher than that in group I ($P < 0.05$). Glutathione peroxidase activity in the liver in groups IV and V was significantly higher than that in group I ($P < 0.01$). The addition of pantothenic acid in the diet of one-to four-week-old Wulong geese significantly affected the growth performance, slaughter performance, lipid metabolism, and antioxidant function of the geese. In terms of economic benefits, the optimal supplemental level of pantothenic acid in one-to four-week-old geese was 15.50 mg/kg.

1. Introduction

Pantothenic acid is a type of vitamin B that is the prosthetic group of coenzyme A and a part of acyl carrier proteins (ACPs) (Lanska Douglas, 2012). Pantothenic acid is involved in the metabolism of carbohydrates, fats, and proteins in the body, particularly in fat synthesis and metabolism. Coenzyme A transfers acyl during metabolism (Zhang, 1994). Supplementing pantothenic acid in poultry diet can improve the health and performance of chickens. When chickens lack pantothenic acid, growth is affected and feather growth is poor. The chickens develop dermatitis, granular

* Corresponding author.
E-mail address: wangbw@qau.edu.cn (B. Wang).

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nodule crust appears, the eyelids of the chicken stick together, a scab-like injury is observed around the mouth, and stubby tibia occurs. Severe deficiency of pantothenic acid can cause death (Zhang, 2000). Bootwalla and Harms (1991) found that adding at least 4.8 mg of pantothenic acid per kilogram to the corn–soybean diet of white carrier chickens aged 1 to 6 weeks can maintain chicken growth. The content of pantothenic acid in diets is positively correlated with the content of pantothenic acid in the eggs and influences the hatching rate of eggs (Robel, 1993). Deyhim et al. (1992) demonstrated that adding pantothenic acid in broiler diet can promote chicken growth. Yi (2003) noted that breeder diets that lack pantothenic acid result in low egg and hatching rates. Zou (1998) added high doses of pantothenic acid (50, 100, and 150 mg/kg) to the diets of breeder hens. Subsequently, the laying rate of layers increased, broken and abnormal egg rates decreased, fertilized hatching eggs rates were significantly enhanced, and egg quality substantially improved. Qi et al. (1998) reported that broiler diets supplemented with certain amounts of pantothenic acid can increase crude protein, fat, and metabolism rates of calcium and phosphorus. Current research on poultry pantothenic acid levels have focused on chicken. Local and international studies that aim to determine the required amount of pantothenic acid for geese are limited. The National Research Council (NRC, 1994) is the authoritative reference standard in geese diets supplemented with pantothenic acid. The NRC (1994) recommends 15 mg/kg pantothenic acid for one-to four-week-old geese. In the United States, an amount of pantothenic acid that is close to the minimum requirement can prevent typical clinical deficiencies. The NRC-recommended vitamin levels cause geese to appear normal, but the performance of geese is not optimized. In commercial production conditions, the amount of pantothenic acid should be higher than the minimum requirement to optimize the growth and performance of geese. One-to four-week-old Wulong geese were employed to study the effects of varying levels of pantothenic acid on the growth performance, lipid metabolism, and antioxidant ability of geese. We aimed to determine the optimal supplemental level of pantothenic acid, provide a reference database for the nutritional standards of geese, and improve practices in goose production.

2. Materials and methods

2.1. Experimental animals and experimental design

A total of 360 one-day-old healthy Wulong geese with similar weights were randomly divided into 6 groups with 6 replicates per group and 10 geese (5 males and 5 females) per replicate. The geese in group I was fed a diet with an optimal supplemental level of pantothenic acid (9.08 mg/kg). Meanwhile, the geese in groups II to VI were fed the diet with 8, 15, 30, 60, and 120 mg/kg pantothenic acid, respectively. The experiment was conducted for 4 weeks. The experimental geese were provided by the Waterfowl Breeding Base Institute of Qingdao Agricultural University. Pantothenic acid used in the experiment was obtained from calcium pantothenate and purchased from Zhejiang Xin Weipu Limited Company (98% effective ingredient).

2.2. Experimental diet

The basic dietary nutritional levels were adopted from the NRC's (1994) poultry nutritional requirement for geese diet formulation. The basic dietary composition and nutritional levels are shown in Table 1. The content of basic dietary pantothenic acid was 9.08 mg/kg based on high-performance liquid chromatography (Yang et al., 2012).

Table 1
Composition and nutrient levels of basal diet (air-dry basis) (%).

Ingredients	Content	Nutrient levels[2]	Content
Corn	60.00	ME, MJ/kg	11.76
Soybean meal	28.40	CP	18.92
Fish meal	2.00	CF	3.27
Wheat middling	5.00	Ca	0.74
Corn straw	2.00	AP	0.33
$CaHPO_4$	0.84	Lys	1.02
Limestone	0.96	Met	0.31
NaCl	0.30	Cys	0.31
Trace elements[1]	0.20	Pantothenic acid, mg/kg	9.08
Multivitamin[1]	0.30		
Total	100.00		

[1] The multivitamin and trace elements (without pantothenic acid) provided the following (per kilogram of the diet): VA, 1,500 mg; VD_3, 200 IU; VE, 12.5 mg; VK_3, 1.5 mg; VB_1, 2.2 mg; VB_2, 5.0 mg; nicotinic acid, 65 mg; VB_6, 2 mg; biotin, 0.2 mg; folic acid, 0.5 mg; choline, 1,000 mg; Fe, 90 mg; Cu, 6 mg; Mn, 85 mg; Zn, 85 mg; I, 0.42 mg; Se, 0.3 mg; and Co, 2.5 mg.

[2] Pantothenic acid was measured, whereas the other nutrient levels were calculated.

2.3. Feeding management

We disinfected the goose houses prior to experimentation and fed the geese in each house during the entire experimental period. We placed a thick padding on the ground and divided the space into many columns. Water was given *ad libitum*, whereas food was given in smaller amounts and in shorter intervals. We observed the growth performance of the geese.

2.4. Determination index and methods

2.4.1. Growth performance

At the end of 4 weeks, the fasted geese were weighed, and the average daily gain (ADG) was calculated from 1 week to 4 weeks. Dietary consumption was counted daily to compute the average daily feed intake (ADFI). The number of deaths and excluded individuals from each group were noted daily to determine the feed:gain (F:G) ratio.

2.4.2. Slaughter performance

At the end of 4 weeks, 2 geese were selected randomly per replicate for fasting. A total of 72 geese were selected from groups II to VI. Wing vein blood was collected, and the geese were slaughtered. Feeding was stopped 12 h before slaughtering. The dressed weight, half-eviscerated yield, eviscerated yield, abdominal fat, breast muscle, and leg muscle were measured according to the poultry production performance noun terms and metric statistics method (NY/T823-2004). The dressed percentage and percentages of half-eviscerated yield, eviscerated yield, abdominal fat, breast muscle, and leg muscle were calculated.

2.4.3. Fat metabolism indicators

At the end of 4 weeks, 10 mL of blood was collected from the wing vein and centrifuged at 2,700 $\times$ g for 10 min at room temperature to produce the serum samples. The triglyceride (TG), total cholesterol (TCH), high-density lipoprotein–cholesterol (HDL-C), and low-density lipoprotein–cholesterol (LDL-C) contents were determined using the kits produced by the Nanjing Institute of Biological Engineering. UV-1100 ultraviolet visible light spectrophotometric determination was carried out.

2.4.4. Antioxidant index

At the end of 4 weeks, 10 mL of blood was collected from the wing vein and centrifuged at 2,700 $\times$ g for 10 min at room temperature to obtain serum samples. After blood was collected and geese were slaughtered, liver portions were removed and the 10% liver tissue homogenate was prepared. The total antioxidant capacity (T-AOC), total superoxide dismutase (T-SOD), malondialdehyde (MDA), and glutathione peroxidase (GSH-Px) contents were determined using the kits produced by the Nanjing Institute of Biological Engineering. UV-1100 ultraviolet visible light spectrophotometric determination was conducted.

2.5. Statistical analysis

All analyses were performed with the LSD method of one-way ANOVA from SPSS 17.0. The values were given as means ± standard deviation. The various index of linear or curve responses on the level of pantothenic acid added in diet were analyzed by Orthogonal and fit curve equations using curve fitting method. The significance level of 0.05 and high significance level of 0.01 were adopted.

3. Results and analysis

3.1. Effects of the supplemental level of dietary pantothenic acid on the growth performance of Wulong geese

Table 2 shows that the weight of one-to four-week-old geese in groups III and IV was significantly higher than those in group I ($P < 0.01$). The ADG in groups III and IV was significantly higher than that in group I ($P < 0.01$). The F:G ratio in groups III and IV was highly significantly lower than that in group I ($P < 0.01$). The body weight (BW), ADG, and F:G ratio between groups III and IV did not have significantly vary ($P > 0.05$).

The BW, ADG, and F:G ratio between groups V and VI did not have significantly vary ($P > 0.05$). The level of pantothenic acid was greater than 30 mg/kg, and the BW, ADG, and F:G ratio did not significantly vary ($P > 0.05$).

The ADFI and mortality rate did not significantly differ among groups ($P > 0.05$). Therefore, conic fitting was conducted using the BW, ADG, and F:G ratio and the levels of dietary pantothenic acid in groups I to IV. The regression equations were as follows:

$$Y(\mathrm{BW}) = 1.047 + 0.018X - 3.265\mathrm{E}^{-4}X^2\left(R^2 = 0.822, P_Q = 0.000\right);$$

$$Y(\mathrm{ADG}) = 34.741 + 0.628X - 0.012X^2\left(R^2 = 0.820, P_Q = 0.000\right);$$

$$Y(\mathrm{F:G\ ratio}) = 0.001X^2 - 0.031X + 2.465\left(R^2 = 0.721, P_Q = 0.003\right).$$

The above mentioned regression equations suggested that BW was the highest when the dietary pantothenic acid level was 27.57 mg/kg. The average daily gain was the highest when the dietary pantothenic acid level was 26.17 mg/kg. The F:G ratio was the lowest when the dietary pantothenic acid level was 15.50 mg/kg. From an economical perspective, the optimal supplemental level of pantothenic acid was 15.50 mg/kg.

Table 2
Effects of the supplemental level of dietary pantothenic acid on the growth performance of Wulong geese.

Groups	BW, kg	ADG, g	ADFI, g	F:G ratio
I	1.06 ± 0.04[a]	35.29 ± 1.47[a]	85.81 ± 1.31	2.44 ± 0.14[c]
II	1.12 ± 0.03[ab]	37.44 ± 1.09[ab]	87.34 ± 1.69	2.33 ± 0.11[bc]
III	1.28 ± 0.04[d]	42.83 ± 1.27[d]	88.28 ± 1.73	2.06 ± 0.04[a]
IV	1.29 ± 0.04[d]	43.04 ± 1.39[d]	88.51 ± 2.24	2.05 ± 0.10[a]
V	1.20 ± 0.05[c]	39.91 ± 1.67[c]	87.89 ± 1.49	2.22 ± 0.14[ab]
VI	1.16 ± 0.04[bc]	38.63 ± 1.30[bc]	88.27 ± 0.69	2.29 ± 0.09[bc]
P-value	0.000	0.000	0.370	0.005

BW = body weight; ADG = average daily gain; ADFI = average daily feed intake; F:G ratio = the ratio of feed to gain.
[a,b,c,d] In the same column, values with the same small or no superscripts indicate no significant difference ($P > 0.05$), whereas values with adjacent small letter superscripts denote a significant difference ($P < 0.05$). Alternate small letter superscripts indicate a significant difference ($P < 0.01$).

3.2. Effects of the supplemental level of dietary pantothenic acid on the slaughter performance of Wulong geese

Table 3 shows that the dressed percentage, percentages of half-eviscerated yield, percentage of breast muscle, and percentage of leg muscle of one-to four-week-old Wulong geese in the experimental groups were higher than those in the control group; however, the differences were not significant ($P > 0.05$). The addition of pantothenic acid in the diet could decrease the percentage of abdominal fat. The percentage of abdominal fat in groups III and IV was significantly lower than that in group I ($P < 0.05$). The abdominal fat rate in groups III and IV reduced by 7.02% and 7.89%, respectively, compared with that in the control group, but the difference was insignificant ($P > 0.05$).

A dietary pantothenic acid level of 15 mg/kg could significantly decrease the percentage of abdominal fat of one-to four-week-old geese. When the amount of pantothenic acid was higher than 30 mg/kg, the percentage of abdominal fat began to increase.

3.3. Effects of the supplemental level of dietary pantothenic acid on the lipid metabolism of Wulong geese

Table 4 shows that the TCH content in groups III, IV, and V was significantly lower than that in group I from 1 week to 4 weeks ($P < 0.05$), but the TCH content did not significantly vary among groups III, IV, and V ($P > 0.05$). The TG content in groups III and IV was significantly lower than that in group I ($P < 0.01$), but the TG content did not significantly vary between groups III and IV ($P > 0.05$). The HDL-C content in group IV was significantly higher than that in group I ($P < 0.05$), whereas the LDL-C content in group IV was significantly lower than that in group I. The LDL-C and HDL-C contents in group IV showed no significant difference ($P > 0.05$).

The results showed that a dietary pantothenic acid level of 15 mg/kg could significantly decrease the TCH content of one-to four-week-old geese and substantially decrease the TG content. A dietary pantothenic acid level of 30 mg/kg could significantly decrease the HDL-C content.

3.4. Effects of the supplemental level of dietary pantothenic acid on the antioxidant function in the sera of Wulong geese

Table 5 shows that the activities of T-AOC and GSH-Px in the serum in group IV were significantly higher than those in group I from 1 week to 4 weeks ($P < 0.05$). The activity of T-SOD in the experimental groups was higher than that in the control group, but the difference was not statistically significant ($P > 0.05$). The MDA content in the experimental groups was lower than that in the control group, but the difference was not statistically significant ($P > 0.05$).

Table 6 shows that the T-AOC activity of the liver in group IV was substantially higher than that in group I from 1 week to 4 weeks ($P < 0.05$). The MDA content in the serum in groups IV and V was

Table 3
Effects of the supplemental level of dietary pantothenic acid on the slaughter performance (%) of Wulong geese.

Groups	Dressed percentage	Percentage of half-eviscerated yield	Percentage of eviscerated yield	Percentage of breast muscle	Percentage of leg muscle	Percentage of abdominal fat
I	87.23 ± 0.17[a]	77.21 ± 1.34[a]	64.83 ± 1.63	1.53 ± 0.14	15.58 ± 0.41[a]	1.14 ± 0.05[c]
II	87.46 ± 0.80[a]	77.69 ± 0.55[a]	65.43 ± 0.83	1.68 ± 0.13	16.34 ± 0.89[ab]	1.10 ± 0.03[abc]
III	87.92 ± 0.57[ab]	77.78 ± 0.52[a]	66.48 ± 1.14	1.74 ± 0.13	16.98 ± 0.46[b]	1.06 ± 0.02[a]
IV	88.36 ± 0.40[b]	79.46 ± 0.67[b]	66.93 ± 1.22	1.81 ± 0.14	17.14 ± 0.65[b]	1.05 ± 0.02[a]
V	87.63 ± 0.59[ab]	77.81 ± 0.98[a]	64.92 ± 1.02	1.60 ± 0.18	16.59 ± 0.39[ab]	1.07 ± 0.06[ab]
VI	87.39 ± 0.14[a]	77.66 ± 0.82[a]	65.27 ± 1.26	1.57 ± 0.21	16.33 ± 0.45[ab]	1.13 ± 0.03[bc]
P-value	0.146	0.094	0.254	0.303	0.062	0.045

[a,b,c] In the same column, values with the same small or no superscripts indicate no significant difference ($P > 0.05$), whereas values with adjacent small letter superscripts denote a significant difference ($P < 0.05$). Alternate small letter superscripts indicate a significant difference ($P < 0.01$).

Table 4
Effects of the supplemental level of dietary pantothenic acid on the lipid metabolism (mmol/L) of Wulong geese.

Groups	TCH	TG	HDL-C	LDL-C
I	3.32 ± 0.23[b]	1.17 ± 0.18[c]	1.54 ± 0.06[a]	2.78 ± 0.14[b]
II	2.93 ± 0.43[ab]	0.84 ± 0.17[ab]	1.63 ± 0.10[abc]	2.67 ± 0.06[ab]
III	2.65 ± 0.35[a]	0.65 ± 0.07[a]	1.79 ± 0.12[bc]	2.61 ± 0.18[ab]
IV	2.49 ± 0.21[a]	0.61 ± 0.17[a]	1.82 ± 0.12[c]	2.49 ± 0.26[a]
V	2.73 ± 0.10[a]	0.74 ± 0.23[ab]	1.76 ± 0.08[bc]	2.64 ± 0.03[ab]
VI	2.97 ± 0.20[ab]	1.03 ± 0.15[bc]	1.60 ± 0.16[ab]	2.75 ± 0.18[ab]
P-value	0.038	0.009	0.047	0.332

TCH = total cholesterol; TG = triglycerides; HDL-C = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol.
[a,b,c] In the same column, values with the same small or no superscripts indicate no significant difference ($P > 0.05$), whereas values with adjacent small letter superscripts denote a significant difference ($P < 0.05$). Alternate small letter superscripts indicate a significant difference ($P < 0.01$).

significantly lower than that in group I ($P < 0.05$), and the MDA content did not considerably vary between groups IV and V ($P > 0.05$). The activity of GSH-Px in the liver in group IV and V was significantly higher than that in group I ($P < 0.01$), and GSH-Px activity did not significantly vary between groups IV and V ($P > 0.05$). The activity of T-SOD in the experimental groups was higher than that in the control group, but the difference was not significant ($P > 0.05$). The MDA content in the experimental groups was lower than that in the control group, but the difference was not significant ($P > 0.05$).

The results showed that a dietary pantothenic acid level of 30 mg/kg could significantly increase the activity of T-AOC and GSH-Px in the serum of one-to four-week-old geese.

A dietary pantothenic acid level of 30 mg/kg could significantly increase the activity of T-AOC in the liver, substantially elevate the activity of T-AOC in the liver, and considerably decrease the MDA content in the liver.

4. Discussions

4.1. *Effects of the supplemental level of dietary pantothenic acid on the growth performance of Wulong geese*

Pantothenic acid, which is a type of water-soluble vitamin B, can strengthen digestion and absorption and promote animal growth. An experiment in the United States confirmed that fodder fortified with B vitamins can significantly improve daily gain and feed reward (Sun and Mike Coelho, 2002). Beer et al. (1963) showed that chicken fodder with 6–8 mg/kg pantothenic acid can improve the

Table 5
Effects of the supplemental level of dietary pantothenic acid on the antioxidant function in the serum of Wulong geese.

Groups	T-AOC, U/mL	T-SOD, U/mL	MDA, nmol/mL	GSH-Px, U/mL
I	11.16 ± 1.12[a]	116.49 ± 6.66[a]	6.24 ± 0.40	898.27 ± 67.48[a]
II	12.99 ± 0.69[abc]	122.62 ± 4.27[ab]	5.88 ± 0.62	1013.26 ± 118.29[ab]
III	15.08 ± 1.17[bc]	124.45 ± 3.54[b]	4.72 ± 1.08	1167.49 ± 182.50[bc]
IV	15.50 ± 2.81[c]	124.48 ± 3.65[b]	4.47 ± 0.87	1233.75 ± 128.13[c]
V	14.34 ± 1.36[bc]	125.09 ± 3.99[b]	4.63 ± 1.15	1185.77 ± 112.95[bc]
VI	12.75 ± 0.94[ab]	123.39 ± 2.98[ab]	5.45 ± 0.63	976.21 ± 74.23[ab]
P-value	0.037	0.228	0.108	0.028

T-AOC = total antioxidative capacity; T-SOD = total superoxide dismutase; MDA = methane dicarboxylic aldehyde; GSH-Px = glutathione peroxidase.
[a,b,c] In the same column, values with the same small or no superscripts indicate no significant difference ($P > 0.05$), whereas values with adjacent small letter superscripts denote a significant difference ($P < 0.05$). Alternate small letter superscripts indicate a significant difference ($P < 0.01$).

Table 6
Effects of the supplemental level of dietary pantothenic acid on the antioxidant function in the liver of Wulong geese.

Groups	T-AOC, U/mg prot	T-SOD, U/mg prot	MDA, nmol/mg prot	GSH-Px, U/mg prot
I	1.52 ± 0.38[a]	225.71 ± 20.63	2.62 ± 0.41[c]	102.80 ± 22.71[a]
II	1.71 ± 0.26[ab]	233.67 ± 13.40	2.18 ± 0.36[abc]	117.29 ± 27.40[a]
III	1.96 ± 0.03[bc]	239.45 ± 24.91	2.05 ± 0.12[abc]	171.22 ± 28.25[bc]
IV	2.17 ± 0.10[c]	245.96 ± 10.47	1.74 ± 0.32[a]	197.56 ± 16.40[c]
V	2.07 ± 0.22[bc]	254.36 ± 17.57	1.83 ± 0.31[a]	186.68 ± 25.40[c]
VI	1.68 ± 0.28[ab]	248.33 ± 13.91	2.54 ± 0.49[bc]	135.28 ± 43.99[ab]
P-value	0.044	0.424	0.049	0.007

T-AOC = total antioxidative capacity; T-SOD = total superoxide dismutase; MDA = methane dicarboxylic aldehyde; GSH-Px = glutathione peroxidase.
[a,b,c] In the same column, values with the same small or no superscripts indicate no significant difference ($P > 0.05$), whereas values with adjacent small letter superscripts denote a significant difference ($P < 0.05$). Alternate small letter superscripts indicate a significant difference ($P < 0.01$).

growth rate and survival rate of chicken. By contrast, foods with low levels of pantothenic acid can inhibit the growth of chicks. This effect can be counteracted by increasing the amount of pantothenic acid in chick fodder. Qi et al. (1998) noted that 10 mg/kg pantothenic acid in fodder can improve the daily gain of broilers. Zhao et al. (2015) determined that an appropriate amount of pantothenic acid (a minimum level of 40.00 mg/kg) in fodder helps reduce the growth of rabbit–feed conversion ratio. In the present study, adding 27.57 mg/kg pantothenic acid in fodder significantly increased the weight of geese, whereas adding 26.17 mg/kg pantothenic acid significantly increased the ADG of the birds. The results of this study are consistent with the literature. Pantothenic acid did not significantly affect the feed intake of geese, but adding 15.50 mg/kg pantothenic acid in fodder significantly decreased the F:G ratio. This result indicated that the growth-promoting effect of pantothenic acid in geese was not caused by increased intake. However, increased intake improved feed efficiency.

4.2. Effects of the supplemental level of dietary pantothenic acid on the slaughter performance of Wulong geese

Slaughter performance indicators are a set of metrics that reflect the different amounts of nutrients in various tissues and different parts of the same tissue. Many factors influence the deposition rate. Pantothenic acid is a cofactor of coenzyme A. Coenzyme A is crucial in fat metabolism. A previous study found that ACP plays an important role in the carbon chain synthesis of fatty acid synthesis (Ball, 1998). Shibata et al. (2013) found that adding pantothenic acid can reduce body fat deposition. In the present study, adding 15 mg/kg pantothenic acid in diets could significantly reduce the abdominal fat of goose. This result demonstrated the regulatory role of pantothenic acid on the fat metabolism of goose. The slaughter rate and eviscerated rate are the main indexes that depict the performance of broilers (Wei, 2001). The tests showed that the slaughter rate, half net carcass rate, eviscerated rate, rate of breast muscle, and leg muscle rate of pantothenic acid improved in the experimental groups, unlike in the control group. Thus, pantothenic acid affected the slaughter performance of geese. The influence of pantothenic acid on the slaughter performance of geese has not yet been reported, and the effect of pantothenic acid on the slaughter performance mechanism must be studied further.

4.3. Effects of the supplemental level of dietary pantothenic acid on the lipid metabolism of Wulong geese

Pantothenic acid is a part of the coenzyme A, and coenzyme A is an auxiliary factor of 70 kinds of enzymes in organisms (approximately 4% of the total amount of enzymes); coenzyme A is important in carbohydrate, fat, and amino acid metabolism in many reversible acetylation reactions (Shiau and Hau, 1999). Acid reflux also synthesizes fatty acid synthase cofactor (4-phosphopantetheine mercaptoethylamine), and panthenol mercaptoethylamine can reduce the concentrations of cholesterol and TG (Yang and Xiao, 2008). The total cholesterol and TG are two important indicators of the body's lipid levels. The high-density lipoproteincholesterol is a serum protein that is rich in phospholipids; this serum protein can eliminate free cholesterol in liver tissue cells and remove intracellular cholesterol organizations (Wang et al., 2002). The main function of LDL-C is to transport cholesterol to the cells throughout the body and facilitate liver bile acid; thus, LDL-C plays an important role in cholesterol metabolism. Hsu et al. (1988) determined that dietary pan-acyl amine can reduce TG in the liver and serum cholesterol levels of hens. Wittwer et al. (1990) observed that the serum TG and free fatty acid concentrations in rats significantly increased after the rats were administered pantothenic acid-deficient feed. Avogaro et al. (1983) determined that the two-pantothenic acid metabolite of pantothenic acid amine sulfur can reduce diabetes-related lipid metabolism disorders, cholesterol, serum total cholesterol of hyperlipoproteinemia patients, LDL cholesterol, and TG fat content. This metabolite can also improve the HDL-C levels. The tests in the present study showed that dietary pantothenic acid of 15 mg/kg could significantly reduce the TCH and TG contents in geese. Meanwhile, adding 30 mg/kg pantothenic acid could significantly increase the HDL-C content, which agrees with the abovementioned findings. These results indicated that pantothenic acid regulated lipid metabolism in geese.

4.4. Effects of the supplemental level of dietary pantothenic acid on the antioxidant function in the sera of Wulong geese

Pantothenic acid can protect biofilm systembe by different mechanisms to against lipid peroxidation, which ensures the integrity of the body's cell structure to maintain the normal physiological functions of the body. The total antioxidative capacity is a comprehensive health indicator that measures the body's antioxidative system features. In general, the amount of T-AOC can reflect the condition of the antioxidant defense system in terms of external stimuli compensatory capacity and free radical metabolism in the body (Zheng, 2007). The total superoxide dismutase is an important enzyme in the body that removes free radicals. Thus, T-SOD indirectly indicates the body's ability to eliminate free radicals. The methane dicarboxylic aldehyde is the final product of the lipid peroxidation chain reaction *in vivo*; its content can reflect the extent of lipid and membrane peroxidation in the body (Zhao et al., 2000). The glutathione peroxidase is present in various animals. It can specifically catalyze GSH to reduce an important enzyme. The glutathione peroxidase can eliminate free active oxygen and lipid peroxides induced by OH, thereby reducing free radicals. It can prevent oxidative substances from attacking the cell membrane, protect the integrity of the structure and function of cell membranes, and improve the body's antioxidant capacity. Pantothenic acid can facilitate glutathione biosynthesis, as well as slow down apoptosis and injury. Experimental results showed that pantothenic acid exhibits good protective effects against lipid peroxidation damage in rats (Wittwer et al., 1990). Ding described the two possible mechanisms of pantothenic acid lipid peroxidation protection: 1) pantothenic acid takes the form of CoA-scavenging free radicals and protects the cell membrane from damage; and 2) CoA phospholipids repair cells by promoting synthesis (Wittwer et al., 1990). Zhao et al. (2015) determined that appropriate dietary levels of pantothenic acid can reduce lipid peroxidation and increase growth. In the present study, diets supplemented with 30 mg/kg pantothenic acid could significantly increase T-AOC and GSH-Px activity in serum. Diets supplemented with 30 mg/kg pantothenic acid could significantly increase T-AOC and GSH-Px activity and substantially reduce MDA content in the liver. These findings were similar to the abovementioned studies. Therefore, pantothenic acid was effective against lipid peroxidation. Under a high immune status, the actual pantothenic acid requirement was higher than the maximum recommended requirement to optimize the performance of geese. However, the underlying mechanism has yet to be resolved.

5. Conclusions

1) Pantothenic acid significantly affected the BW, ADG, and F:G ratio of Wulong geese. The BW was the highest when the dietary pantothenic acid level was 27.57 mg/kg. The ADG peaked when the dietary pantothenic acid level was 26.17 mg/kg. The lowest

feed conversion rate was observed when the dietary pantothenic acid level was 15.50 mg/kg.

2) A dietary pantothenic acid level of 15 mg/kg could significantly decrease the abdominal fat of Wulong geese, as well as substantially decrease the TCH and TG contents. A dietary pantothenic acid of 30 mg/kg could significantly increase the HDL-C content.
3) A dietary pantothenic acid level of 30 mg/kg could significantly increase the activity of T-AOC and GSH-Px, as well as considerably decrease the MDA content, in the sera of geese.
4) At a high immune state, pantothenic acid requirement must be increased to optimize the performance of geese. In terms of economic benefits, the optimal supplemental level of pantothenic acid was 15.50 mg/kg in the diets of Wulong geese from 1 to 4 weeks.

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