Effects of Vitamin K3 on Growth Performance, Slaughter Performance, and Apparent Nutrient Utilization Rate in Wulong Geese: Postprint

Authors: Lü Mei, Wang Baowei, Yin Taiyue, Ge Wenhua, Zhang Mingai, Li Wenli

Date: 2017-10-11T00:00:00+00:00

Abstract

This study aimed to investigate the effects of dietary vitamin K3 supplementation levels on growth performance, slaughter performance, and nutrient apparent utilization in Wulong geese. The experiment was divided into two phases. In the 1-4 week phase, 360 one-day-old Wulong geese were randomly allocated into 6 groups with 6 replicates per group and 10 geese per replicate. Group I served as the control group fed a basal diet (vitamin K3 content 1.23 mg/kg), while Groups II-VI were supplemented with 1, 2, 4, 8, and 16 mg/kg vitamin K3 to the basal diet, respectively. In the 5-16 week phase, 324 twenty-eight-day-old Wulong geese were randomly allocated into 6 groups with 6 replicates per group and 9 geese per replicate. Group A served as the control group fed a basal diet (vitamin K3 content 1.18 mg/kg), while Groups B-F were supplemented with 2, 4, 8, 16, and 32 mg/kg vitamin K3 to the basal diet, respectively. The experimental period lasted 16 weeks. The results showed that: 1) Regression analysis revealed that dietary supplementation with 4.81 mg/kg vitamin K3 yielded the maximum average daily gain in the 1-4 week phase, while 11.59 mg/kg vitamin K3 produced the maximum average daily gain in the 5-16 week phase. 2) Compared with the control group, dietary supplementation with 4 mg/kg vitamin K3 in the 1-4 week phase significantly or extremely significantly increased the eviscerated yield and abdominal fat rate ($P<0.05$ or $P<0.01$); in the 5-16 week phase, dietary supplementation with 8 mg/kg vitamin K3 significantly or extremely significantly increased the dressing percentage, semi-eviscerated yield, eviscerated yield, and leg muscle rate ($P<0.05$ or $P<0.01$). 3) Compared with the control group, dietary supplementation with 8 mg/kg vitamin K3 in the 5-16 week phase extremely significantly increased the apparent utilization rate of calcium ($P<0.01$) and significantly increased the apparent utilization rates of dry matter, crude protein, crude fat, neutral detergent fiber, acid detergent fiber,

and phosphorus (P<0.05). In conclusion, under the conditions of this experiment, the appropriate dietary vitamin K3 supplementation levels for Wulong geese aged 1-4 weeks and 5-16 weeks were 4.81 and 11.59 mg/kg, respectively.

Full Text

Effects of Vitamin K3 on Growth Performance, Slaughter Performance and Nutrient Apparent Utilization of Wulong Geese

LV Mei[1], WANG Baowei[2], YIN Taiyue[1], GE Wenhua[2], ZHANG Mingai[2], LI Wenli[1]*

[1]College of Animal Science and Technology, Qingdao Agricultural University, Qingdao 266109, China
[2]Institute of High Quality Waterfowl, Qingdao Agricultural University, Qingdao 266109, China

Abstract: This experiment was conducted to investigate the effects of dietary vitamin K3 supplementation levels on growth performance, slaughter performance, and nutrient apparent utilization in Wulong geese. The trial consisted of two phases. In the 1-4 week phase, 360 one-day-old Wulong goslings were randomly allocated into 6 groups with 6 replicates per group and 10 geese per replicate. Group I served as the control and received a basal diet containing 1.23 mg/kg vitamin K3, while groups II-VI received the basal diet supplemented with 1, 2, 4, 8, and 16 mg/kg vitamin K3, respectively. In the 5-16 week phase, 324 healthy 28-day-old geese were randomly divided into 6 groups with 6 replicates per group and 9 geese per replicate. Group A was the control fed the basal diet (1.18 mg/kg vitamin K3), and groups B-F received the basal diet supplemented with 2, 4, 8, 16, and 32 mg/kg vitamin K3, respectively. The experimental period lasted 16 weeks. The results showed: 1) Regression analysis indicated that dietary supplementation with 4.81 mg/kg vitamin K3 maximized average daily gain in the 1-4 week phase, while 11.59 mg/kg vitamin K3 maximized average daily gain in the 5-16 week phase. 2) Compared with the control group, supplementation with 4 mg/kg vitamin K3 during weeks 1-4 significantly or extremely significantly increased the percentage of eviscerated yield and abdominal fat (P<0.05 or P<0.01). During weeks 5-16, supplementation with 8 mg/kg vitamin K3 significantly or extremely significantly increased dressing percentage, half-eviscerated yield percentage, eviscerated yield percentage, and leg muscle percentage (P<0.05 or P<0.01). 3) During weeks 5-16, dietary supplementation with 8 mg/kg vitamin K3 extremely significantly improved calcium apparent utilization (P<0.01) and significantly enhanced apparent utilization of dry matter, crude protein, ether extract, neutral detergent fiber, acid detergent fiber, and phosphorus (P<0.05). In conclusion, under the conditions of this experiment, the appropriate dietary vitamin K3 supplementation levels for Wulong geese were 4.81 mg/kg for the 1-4 week phase and 11.59 mg/kg for the 5-16 week phase.

Keywords: vitamin K3; geese; growth performance; slaughter performance; nutrient apparent utilization

---

Vitamin K3 is fundamental for the activation of vitamin K-dependent proteins. Supplementing vitamin K3 in corn-soybean meal diets serves hemostatic functions, promotes carbohydrate metabolism, and inhibits atherosclerosis development. It directly exerts nutritional effects on animals and influences their physiological functions. Previous studies have demonstrated that dietary vitamin K3 supplementation can improve growth performance and blood clotting function in broilers. Chen et al. reported that adding vitamin K3 to sow diets significantly increased litter weaning weight, individual weaning weight, and piglet survival rate, while also improving litter size and birth weight. Additionally, vitamin K3 can enhance digestive and absorptive functions and treat digestive system disorders. Yuan showed that vitamin K3 significantly increased the activities of lipase, trypsin, chymotrypsin, and alkaline phosphatase in juvenile Jian carp, thereby improving digestive capacity. Current research on vitamin K3 primarily focuses on aquatic animals and broilers, with limited reports on geese. Notably, no studies have investigated the effects of vitamin K3 on growth performance, slaughter performance, and nutrient apparent utilization in geese. Therefore, this experiment examined the impact of different dietary vitamin K3 levels on Wulong geese from these perspectives to provide a theoretical basis for scientific vitamin K3 supplementation.

1.1 Experimental Materials and Basal Diets

Vitamin K3 was purchased from Qingdao Puxing Feed Company (Batch No.: 20131209) with a purity of 96%. The basal diet formulation was designed according to nutrient levels recommended by NRC (1994). The feeding period consisted of two phases: 1-4 weeks and 5-16 weeks of age. The composition and nutrient levels of the basal diets are presented in Table 1 . The measured vitamin K3 content in the basal diets was 1.23 mg/kg for the 1-4 week phase and 1.18 mg/kg for the 5-16 week phase.

Table 1 Composition and nutrient levels of basal diets (air-dry basis), %

Items	1-4 weeks	5-16 weeks
Ingredients		
Corn		
Soybean meal		
Fish meal		
Middling		
Corn stover		
$CaHPO_4$		
Limestone		
NaCl		

Items	1-4 weeks	5-16 weeks
Trace elements[1])		
Multivitamin[1])		
Total		
Nutrient levels[2])		
ME/(MJ/kg)		
Crude protein (CP)		
Crude fiber (CF)		
Calcium (Ca)		
Available phosphorus (AP)		
Lysine (Lys)		
Methionine (Met)		
Cysteine (Cys)		
Vitamin K3 (mg/kg)		

[1]) Multivitamin and trace elements provided the following per kg of diets: For 1-4 weeks: VA 1,500 IU, VD_3 200 IU, VE 12.5 mg, VB_1 2.2 mg, VB_2 5.0 mg, niacin 65 mg, pantothenate 15 mg, VB_6 2 mg, biotin 0.2 mg, folic acid 0.5 mg, Fe 90 mg, Cu 6 mg, Mn 85 mg, Zn 85 mg, I 0.42 mg, Co 2.5 mg. For 5-16 weeks: VA 1,500 IU, VD_3 200 IU, VE 12.5 mg, VB_1 2.2 mg, VB_2 5.0 mg, niacin 65 mg, pantothenate 15 mg, VB_6 2 mg, biotin 0.2 mg, folic acid 0.5 mg, Fe 85 mg, Cu 5 mg, Mn 80 mg, Zn 80 mg, I 0.42 mg, Co 2.5 mg.

[2]) Vitamin K3 was a measured value, while other nutrient levels were calculated values.

1.2 Experimental Animals and Design

The entire trial comprised two feeding phases: 1-4 weeks and 5-16 weeks of age. In the 1-4 week phase, 360 healthy one-day-old Wulong goslings were randomly divided into 6 groups with 6 replicates per group and 10 geese per replicate. Group I was the control fed the basal diet, while groups II, III, IV, V, and VI received the basal diet supplemented with 1, 2, 4, 8, and 16 mg/kg vitamin K3, respectively. In the 5-16 week phase, 324 healthy 28-day-old geese were randomly allocated into 6 groups with 6 replicates per group and 9 geese per replicate. Group A was the control fed the basal diet, while groups B, C, D, E, and F received the basal diet supplemented with 2, 4, 8, 16, and 32 mg/kg vitamin K3, respectively. The experimental period lasted 16 weeks.

1.3 Feeding Management

Geese had free access to water and feed throughout the experiment. Daily feed intake, temperature, mortality, and culling data were recorded, and the health status of the geese was closely monitored.

1.4.1 Growth Performance Measurement

At 08:00 on the last day of each week, geese were weighed after a 6-hour feed deprivation (water was provided). Feed consumption was measured using the "empty trough method"on a per-replicate basis each weekend. Average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) were calculated for weeks 1-4 and 5-16. Mortality and culling rates were recorded daily.

1.4.2 Slaughter Performance Measurement

At the end of weeks 4 and 16, one goose per replicate with body weight close to the group mean was selected from each group (36 geese total), slaughtered by jugular vein bleeding, and processed for slaughter performance evaluation after wet plucking and moisture removal.

Live weight: Geese were fasted for 12 hours (water provided) and weighed at 08:00 the following day.

Carcass weight: Weight after bleeding, feather removal, and removal of foot cuticle, toe shells, and beak shells.

Half-eviscerated weight: Carcass weight after removal of trachea, esophagus, crop, intestines, spleen, pancreas, gallbladder, reproductive organs, and gizzard contents including the cuticle.

Eviscerated weight: Half-eviscerated weight after removal of heart, liver, gizzard, lungs, and abdominal fat.

Breast muscle weight: Skin was incised along the midline of the sternal crest, and breast muscles (including pectoralis major, pectoralis minor, and third pectoral muscle) were separated from the sternum and weighed.

Leg muscle weight: Starting from the last thoracic vertebra on the back, skin was incised posteriorly along the lumbosacral midline to the base of the tail vertebrae, then vertically toward the abdomen (along the anterior edge of leg muscles). The skin between the breast and thigh was incised along the midline to the pubic end. The hip joints were dislocated to extract both legs intact, and the thigh and drumstick muscles were separated and weighed.

Abdominal fat weight: Fat from the abdominal cavity and around the gizzard was dissected and weighed.

Calculation formulas: - Dressing percentage (%) = (carcass weight/pre-slaughter live weight) × 100 - Half-eviscerated yield (%) = (half-eviscerated weight/pre-slaughter live weight) × 100 - Eviscerated yield (%) = (eviscerated weight/pre-slaughter live weight) × 100 - Breast muscle percentage (%) = (both breast muscles weight/eviscerated weight) × 100 - Leg muscle percentage (%) = (both leg muscles weight/eviscerated weight) × 100 - Abdominal fat percentage

(%) = [abdominal fat weight/(eviscerated weight + abdominal fat weight)] × 100

1.4.3 Nutrient Apparent Utilization

On the final day of week 16, one goose per replicate with body weight close to the group mean was selected and housed in metabolic cages. Each goose was fed 120 g of diet daily with free access to water. After a 4-day adaptation period and 1-day feed deprivation, feces and urine were collected continuously for 3 days during the formal collection period. Feathers and other contaminants were removed from the feces, and nitrogen was fixed with 10% hydrochloric acid. Samples were mixed, dried at 65-75°C, equilibrated for 24 hours at room temperature, weighed accurately, and ground using a small universal grinder for subsequent analysis.

Moisture content was determined by GB/T 6435-1986, crude ash by GB/T 6438-1992, crude protein (CP) by Kjeldahl method (GB/T 6432-1994), ether extract (EE) by ether extraction (GB/T 6433-2006), calcium by potassium permanganate titration (GB/T 6436-2002), phosphorus by molybdenum yellow colorimetry (GB/T 6437-2002), neutral detergent fiber (NDF) by filter bag technique, and acid detergent fiber (ADF) by GB/T 6434-2006. Organic matter (OM) content was calculated as: OM = dry matter (DM) - crude ash.

Nutrient apparent utilization (%) = [(nutrient content in diet - nutrient content in feces)/nutrient content in diet] × 100.

1.5 Statistical Analysis

Data were analyzed using one-way ANOVA with LSD multiple comparisons in SPSS 19.0 software. Results are expressed as "mean ± standard deviation." Dose-response relationships were fitted with quadratic curves using Excel 2003, and optimal supplementation levels were calculated from the quadratic equations. $P<0.05$ and $P<0.01$ were considered significant and extremely significant, respectively.

2.1 Effects of Vitamin K3 on Growth Performance of Geese

As shown in Table 2 , during weeks 1-4, ADG in groups III, IV, V, and VI was extremely significantly higher than in group I ($P<0.01$). No significant differences were observed in ADFI among groups ($P>0.05$). The feed-to-gain ratio in groups III, IV, V, and VI was extremely significantly lower than in groups I and II ($P<0.01$), with group IV showing a 5.80% reduction compared to group I. Mortality rate in group II decreased compared to group I, while groups III, IV, and V had zero mortality. Overall, the optimal dietary vitamin K3 level for Wulong geese aged 1-4 weeks was 4 mg/kg based on ADG, ADFI, and F/G.

During weeks 5-16, ADG in group D was significantly higher than in groups A and B ($P<0.05$), with no significant differences among groups C, D, E, and F ($P>0.05$), though groups E and F showed a declining trend compared to group D. Group D achieved the highest ADG. ADFI in groups C, D, E, and F was significantly higher than in group A ($P<0.05$) but not significantly different from group B ($P>0.05$). The feed-to-gain ratio in groups A, B, C, and D decreased with increasing vitamin K3 levels, with group D being significantly lower than groups A and B ($P<0.05$). Group C showed no significant differences with other groups ($P>0.05$), while group F had a significantly higher F/G than group D ($P<0.05$) but was not significantly different from groups A, B, and C ($P>0.05$). Overall, the optimal dietary vitamin K3 level for Wulong geese aged 5-16 weeks was 8 mg/kg.

Quadratic curve fitting and regression analysis revealed significant relationships ($P<0.05$) between vitamin K3 supplementation level (X) and ADG (Y_1) and F/G (Y_2) during weeks 1-4, and ADG (Y_3) and F/G (Y_4) during weeks 5-16. The regression equations were:

Weeks 1-4:
$Y_1 = -0.032X^2 + 0.308X + 38.84$ ($R^2 = 0.839$, $P = 0.027$)
Maximum ADG was achieved at 4.81 mg/kg vitamin K3.

$Y_2 = 0.002X^2 - 0.022X + 2.233$ ($R^2 = 0.793$, $P = 0.031$)
Minimum F/G was achieved at 5.5 mg/kg vitamin K3.

Comprehensive analysis suggests an optimal vitamin K3 level of 4.81-5.50 mg/kg for 1-4 week-old Wulong geese.

Weeks 5-16:
$Y_3 = -0.011X^2 + 0.255X + 33.44$ ($R^2 = 0.709$, $P = 0.034$)
Maximum ADG was achieved at 11.59 mg/kg vitamin K3.

$Y_4 = 0.002X^2 - 0.06X + 5.416$ ($R^2 = 0.690$, $P = 0.046$)
Minimum F/G was achieved at 15.00 mg/kg vitamin K3.

Comprehensive analysis suggests an optimal vitamin K3 level of 11.59-15.00 mg/kg for 5-16 week-old Wulong geese.

Table 2 Effects of vitamin K3 on growth performance of geese

<table>
<tr><th>Groups</th><th>ADG (g)</th><th>ADFI (g)</th><th>Mortality rate (%)</th></tr>
<tr><td>Weeks 1-4</td><td></td><td></td><td></td></tr>
<tr><td>I</td><td>36.39$±0.80^{Aa}|81.38±1.53|2.24±0.03^{Aa}||II|37.11±0.73^{ABa}|82.92±0.53|2.23±0.03^{Aa}||III|38.33±
value||||| *
*Weeks5 −
16 *
*||||A|30.50±0.81^a|172.17±1.47^a|5.65±0.10^a||B|31.65±0.90^a|175.37±2.14^{ab}|5.54±0.09^a||C|34.0</td><td></td><td></td></tr>
<tr><td>P-value</td><td></td><td></td><td></td></tr>
</table>

In the same column, values with different small letter superscripts indicate significant difference (P<0.05), different capital letter superscripts indicate extremely significant difference (P<0.01), and same or no letters indicate no significant difference (P>0.05). The same applies below.

2.2 Effects of Vitamin K3 on Slaughter Performance of Geese

As shown in Table 3 , at 4 weeks of age, no significant differences were observed in dressing percentage, half-eviscerated yield percentage, breast muscle percentage, or leg muscle percentage among groups (P>0.05). Group II showed a 10.38% increase in abdominal fat percentage compared to group I (P<0.05). Group V exhibited a 4.52% increase in eviscerated yield percentage (P<0.05) and a 20.75% increase in abdominal fat percentage (P<0.01) compared to group I. Group VI showed a 2.95% increase in eviscerated yield percentage (P<0.05) and a 17.92% increase in abdominal fat percentage (P<0.01) compared to group I. Overall, the appropriate dietary vitamin K3 level for 1-4 week-old Wulong geese was 4-8 mg/kg based on slaughter performance.

At 16 weeks of age, group D achieved the highest values for dressing percentage, half-eviscerated yield percentage, eviscerated yield percentage, abdominal fat percentage, breast muscle percentage, and leg muscle percentage, showing increases of 6.68% (P<0.01), 5.04% (P<0.01), 5.36% (P<0.01), 14.20% (P>0.05), 12.44% (P>0.05), and 15.07% (P<0.05) compared to group A, respectively. Group B showed higher slaughter performance indices than group A, though not significantly (P>0.05). Group C exhibited a 3.79% increase in eviscerated yield percentage compared to group A (P<0.05), with other indices not significantly different from groups A and B (P>0.05). Groups E and F showed declining trends compared to group D. Overall, the appropriate dietary vitamin K3 level for 5-16 week-old Wulong geese was 8-16 mg/kg.

Table 3 Effects of vitamin K3 on slaughter performance of geese, %

<table>
<tr><th>Weeks of age</th><th>Groups</th><th>Dressing percentage</th><th>Half-eviscerated yield percentage</th><th>Eviscerated yield percentage</th><th>Abdominal fat percentage</th><th>Breast muscle percentage</th><th>Leg muscle percentage</th></tr>
<tr><td>4 weeks</td><td>I</td><td colspan="6">87.25$±2.48|76.82±1.29|65.45±0.38^a|1.06±0.08^{Aa}|1.73±0.05|15.91±0.77|||II|87.49±1.63|77.72±1
∗16$weeks$∗
∗|A|82.41±2.66^{Aa}|73.42±1.26^{Aa}|67.01±2.86^{Aa}|1.69±0.17|10.93±0.45|11.61±0.84^a|||B|83.87±1.06</td></tr>
<tr><td></td><td>P-value</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

2.3 Effects of Vitamin K3 on Nutrient Apparent Utilization of Geese

As shown in Table 4 , groups B, C, D, E, and F showed higher apparent utilization of DM, OM, EE, Ca, P, NDF, and ADF than group A, with all nutrients showing an initial increase followed by stabilization or slight decline as vitamin K3 supplementation increased. No significant differences were observed in DM apparent utilization among groups C, D, E, and F ($P>0.05$), though group D was significantly higher than group A ($P<0.05$). OM apparent utilization did not differ significantly among groups ($P>0.05$). Groups D and E showed significantly higher CP apparent utilization than group A ($P<0.05$), with no significant differences among groups C, D, E, and F ($P>0.05$). Group D exhibited significantly higher EE apparent utilization than group A ($P<0.05$), with no significant differences among groups C, D, E, and F ($P>0.05$), and no significant differences among groups A, B, C, E, and F ($P>0.05$). No significant differences in NDF apparent utilization were found among groups C, D, E, and F ($P>0.05$), but groups D, E, and F were significantly higher than groups A and B ($P<0.05$). Similarly, no significant differences in ADF apparent utilization occurred among groups C, D, E, and F ($P>0.05$), but groups D, E, and F were significantly higher than groups A and B ($P<0.05$). No significant differences in Ca apparent utilization were observed among groups D, E, and F ($P>0.05$), though group D was extremely significantly higher than groups A and B ($P<0.01$), with no significant differences among groups A, B, and C ($P>0.05$). No significant differences in P apparent utilization were found among groups C, D, E, and F ($P>0.05$), but group D was significantly higher than groups A and B ($P<0.05$), with no significant differences among groups A, B, C, and F ($P>0.05$). Comprehensive analysis indicated that nutrient apparent utilization was highest at a dietary vitamin K3 level of 8 mg/kg for 5-16 week-old Wulong geese.

Table 4 Effects of vitamin K3 on nutrient apparent utilization of geese (DM basis), %

Groups	DM	OM	CP	EE	NDF	ADF	Ca	P
A	$75.08\$\pm1.86^{a}$	78.11 ± 1.35	65.22 ± 1.10^{a}	64.94 ± 0.71^{a}	46.38 ± 0.90^{a}	32.52 ± 3.56^{a}	45.90 ± 0.94^{Aa}	37.87
P-value								

3.1 Effects of Vitamin K3 on Growth Performance of Geese

Appropriate dietary vitamin K3 supplementation can improve animal growth performance, though optimal levels vary by species, growth stage, and production level. Xia et al. reported that high-dose vitamin K3 supplementation in broiler diets showed a growth-promoting trend. Chen et al. demonstrated that vitamin K3 supplementation in sow diets significantly improved piglet weaning performance. Hirayama et al. found that mice fed diets supplemented with 240 mg/kg vitamin K3 exhibited higher body weight and survival rates than controls. The current results showed that 4 mg/kg vitamin K3 supplementation extremely significantly increased ADG and ADFI while reducing F/G and mortality in 1-4 week-old Wulong geese. During weeks 5-16, 8 mg/kg vitamin K3 significantly reduced F/G and increased ADG. Zhang reported that 8 mg/kg vitamin K3 supplementation significantly improved broiler body weight and reduced F/G, consistent with our findings. The observation that 4 mg/kg vitamin K3 extremely significantly improved ADG and reduced F/G in 1-4 week-old geese, while only moderate supplementation improved performance in 5-16 week-old geese, suggests that vitamin K3 may have a greater impact on growing goslings than on finishing geese. According to Ducros et al., vitamin K3 is absorbed in the intestine, transported via the lymphatic system into blood, and bound to β-lipoproteins for distribution to tissues. The more developed intestinal tract of older geese may result in smaller differences in vitamin K3 effects compared to younger birds. The vitamin K3 requirements in this study were higher than NRC (1994) recommendations, possibly due to differences in goose breed, rearing conditions, evaluation criteria, and basal diet composition, warranting further investigation. Additionally, high supplementation levels (groups V and VI) reduced ADG and increased F/G, impairing growth performance, consistent with reports by Li et al. and Liu et al. Based on comprehensive benefit analysis using growth performance as the primary indicator, regression analysis indicated optimal dietary vitamin K3 levels of 4.81 mg/kg for 1-4 week-old geese and 11.59 mg/kg for 5-16 week-old geese.

3.2 Effects of Vitamin K3 on Slaughter Performance of Geese

Studies have shown that dietary vitamin K3 supplementation affects bone development and improves slaughter performance in livestock and poultry. Peng et al. reported that 4 mg/kg vitamin K3 in broiler vitamin combinations optimized slaughter performance and carcass quality. Rune et al. demonstrated that high-dose vitamin K3 significantly improved beef cattle slaughter performance and meat quality. Gao showed that 3 mg/kg vitamin K3 supplementation significantly improved duck body weight and slaughter performance. Our results indicated that 4-8 mg/kg vitamin K3 supplementation significantly improved Wulong goose slaughter performance. During weeks 1-4, vitamin K3 supplementation did not significantly affect dressing percentage or breast muscle percentage, possibly related to goose growth characteristics. During weeks 5-16, 8 mg/kg vitamin K3 significantly or extremely significantly increased dressing percentage, eviscerated yield percentage, half-eviscerated yield percentage, and leg muscle percentage. Comparing the two phases revealed different vitamin K3 requirements at different growth stages, necessitating dietary adjustments. Based on comprehensive benefit analysis using slaughter performance as the indicator, optimal dietary vitamin K3 levels were 4-8 mg/kg for 1-4 week-old geese and 8-16 mg/kg for 5-16 week-old geese.

3.3 Effects of Vitamin K3 on Nutrient Apparent Utilization of Geese

Previous studies have shown that vitamin K3 promotes intestinal motility and secretory function, affecting digestive capacity, though most research has focused on aquatic animals with limited reports on geese. Vitamin K3 can significantly increase intestinal cholecystokinin content, and Einarsson et al. found that cholecystokinin stimulates pancreatic secretion of trypsin and chymotrypsin. Our results showed that 8 mg/kg vitamin K3 extremely significantly improved CP apparent utilization, consistent with previous reports. Vitamin K3 significantly increases intestinal alkaline phosphatase (AKP) activity, which participates in nutrient absorption of fats, calcium, and phosphorus. Supplementation above 4 mg/kg significantly or extremely significantly improved EE, Ca, and P apparent utilization. Mathers et al. reported that vitamin K3 affects intestinal microflora and promotes cecal development and digestive capacity. Geese possess well-developed ceca capable of digesting dietary crude fiber, and supplementation with $ $8 mg/kg vitamin K3 significantly improved NDF and ADF apparent utilization compared to the control. Nutrient apparent utilization peaked at 8 mg/kg vitamin K3, with groups E and F showing non-significant declines compared to group D, indicating that exceeding the optimal level does not further improve utilization. Comprehensive analysis suggests that the optimal dietary vitamin K3 level for 5-16 week-old Wulong geese is 8 mg/kg.

1. Regression analysis indicated optimal dietary vitamin K3 levels of 4.81 mg/kg for 1-4 week-old Wulong geese and 11.59 mg/kg for 5-16 week-old Wulong geese.
2. Considering slaughter performance results, optimal dietary vitamin K3 levels were 4-8 mg/kg for 1-4 week-old Wulong geese and 8-16 mg/kg for 5-16 week-old Wulong geese.
3. Dietary vitamin K3 supplementation improved nutrient apparent utilization in 16-week-old Wulong geese, with an optimal level of 8 mg/kg.
4. In conclusion, using growth performance as the primary indicator, the appropriate dietary vitamin K3 supplementation levels are 4.81 mg/kg for the 1-4 week phase and 11.59 mg/kg for the 5-16 week phase.

References

[1] Xu Shixin. Platelet activation and blood coagulation [J]. Foreign Medical Sciences (Section of Clinical Biochemistry and Laboratory Medicine), 2004, 25(5): 480-482.

[2] Si Huazhe, Li Guangyu, Bao Kun, et al. Research progress on effects of vitamins on physiological functions of ruminants [J]. China Feed, 2015(5): 25-28.

[3] Xia Zhaofei, Jin Jiushan. Effects of high-dose vitamin A and K and their interaction on performance and blood clotting function in AA broilers [J]. Chinese Journal of Veterinary Science, 2005, 25(1): 104-107.

[4] Chen Ying, Jin Yayin. Effects of vitamin K supplementation in sow diets on sow and piglet performance [J]. Zhejiang Journal of Animal Science and Veterinary Medicine, 1999(4): 3.

[5] Zhang Mingliang, Zhan Lanqi. Analgesic and antiemetic effects of vitamin K3 in treating digestive system diseases [J]. Railway Medicine, 1982, 10(2): 110.

[6] Yuan Jiang. Effects of vitamin K on digestive and absorptive function, immune function and antioxidant status of juvenile Jian carp [D]. Master' s thesis. Ya' an: Sichuan Agricultural University, 2013.

[7] Zhang Hongfu. NRC poultry nutrient requirements (1994 edition) [J]. China Feed, 1995(2): 35-37.

[8] Hirayama K, Uetsuka K, Kuwabara Y, et al. Vitamin K deficiency of germfree mice caused by feeding standard purified diet sterilized by γ-irradiation [J]. Experimental Animals, 2007, 56(4): 273-278.

[9] Zhang CY, Li DF, Wang FL, et al. Effects of dietary vitamin K levels on bone quality in broilers [J]. Archives of Animal Nutrition, 2003, 57(3): 197-206.

[10] Ducros V, Pollicand M, Laporte F, et al. Quantitative determination of plasma vitamin K1 by high-performance liquid chromatography coupled to isotope dilution tandem mass spectrometry [J]. Analytical Biochemistry, 2010, 401(1): 7-14.

[11] Li Youye, Geng Fengqin, Xu Zhanhong. New advances in vitamin K research for poultry nutrition [J]. China Poultry, 1997(11): 40-41.

[12] Liu Chaoming, Wu Caixia, Li Heping. Application of vitamin K in animal husbandry [J]. Farm Science, 2011(7): 40.

[13] Wang Yong, Niu Haihua, Feng Jie, et al. Research progress on effects of vitamin K on animal bone growth and development [J]. Heilongjiang Animal Science and Veterinary Medicine, 2010(13): 35-36.

[14] Zhang Caiyun. Research progress on vitamin K and animal bone development [J]. Chinese Journal of Animal Science (Science and Technology Edition), 2006, 42(9): 60-61.

[15] Hirano J, Ishii Y. Effects of vitamin K2, vitamin D, and calcium on the bone metabolism of rats in the growth phase [J]. Journal of Orthopaedic Science, 2002, 7(3): 364-369.

[16] Peng Huanwei, Ding Xuemei, Bai Shiping, et al. Effects of vitamin combinations in breeder and broiler diets on production performance, antioxidant capacity, and slaughter performance of Qingjia-ma broilers [J]. Feed Industry, 2013, 34(11): 25-32.

[17] Rødbotten R, Gundersen T, Vermeer C, et al. Vitamin K2 in different bovine muscles and breeds [J]. Meat Science, 2014, 97(1): 49-53.

[18] Gao Yan. Vitamin K1 microgranules in meat duck compound feed [J]. Animal Husbandry and Feed Science (Foreign Edition), 1990(6): 27-28.

[19] Dong Biao, Duan Xiujun, Wang Jian, et al. Comparative study on slaughter performance and meat quality of three goose breeds [J]. Jiangsu Agricultural Sciences, 2009(6): 279-281.

[20] Einarsson S, Davies PS, Talbot C. Effect of exogenous cholecystokinin on the discharge of the gallbladder and the secretion of trypsin and chymotrypsin from the pancreas of the Atlantic Salmon, Salmo salar L. [J]. Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology, 1997, 117(1): 63-67.

[21] Sogabe N, Maruyama R, Hosoi T, et al. Enhancement effects of vitamin K1 (phylloquinone) or vitamin K2 (menaquinone-4) on intestinal alkaline phosphatase activity in rats [J]. Journal of Nutritional Science and Vitaminology, 2007, 53(3): 219-224.

[22] Villanueva J, Vanacore R, Goicoechea O, et al. Intestinal alkaline phosphatase of the fish Cyprinus carpio: regional distribution and membrane association [J]. Journal of Experimental Zoology, 1997, 279(4): 347-355.

[23] Mathers JC, Fernandez F, Hill MJ, et al. Dietary modification of potential vitamin K supply enteric bacterial menaquinones in rats [J]. British Journal of Nutrition, 1990, 63(3): 639-652.

Note: Figure translations are in progress. See original paper for figures.