

Effects of Dietary Iodine Supplementation Levels on Growth Performance, Slaughter Performance, Meat Quality and Pelt Quality of Growing Rex Rabbits (Postprint)

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Abstract

This experiment aimed to study the effects of dietary iodine supplementation levels on growth performance, slaughter performance, meat quality, and pelt quality of growing Rex rabbits aged 3-5 months. Two hundred healthy 3-month-old Rex rabbits with similar body weight were randomly divided into 5 groups, with 40 replicates per group and 1 rabbit per replicate. Each group was fed experimental diets supplemented with 0, 0.2, 0.4, 0.8, and 1.6 mg/kg iodine (in the form of potassium iodide) to the basal diet, respectively. The pre-trial period was 7 d, and the formal trial period was 53 d. The results showed that: 1) Under the premise of no significant difference in initial body weight (IBW) ($P>0.05$), dietary iodine supplementation level had a significant effect on final body weight (FBW) of Rex rabbits ($P<0.05$), an extremely significant effect on average daily feed intake (ADFI) ($P<0.01$), but had no significant effects on average daily gain (ADG) and feed to gain ratio (F/G) ($P>0.05$); the ADG and ADFI were highest and F/G was lowest in the 0.8 mg/kg group. 2) Dietary iodine supplementation level had significant effects on hind leg muscle percentage and redness value of Rex rabbits ($P<0.05$), an extremely significant effect on foreleg muscle percentage ($P<0.01$), but had no significant effects on eviscerated yield percentage, loin muscle percentage, and meat quality indicators [pH, drip loss percentage, and meat color (lightness and yellowness values)] ($P>0.05$). 3) Dietary iodine supplementation level had extremely significant effects on pelt area, fur whiteness, and tear strength of Rex rabbits ($P<0.01$), with maximum values observed in the 0.8, 0.4, and 0.4 mg/kg groups, respectively. Dietary iodine supplementation level had significant effects on pelt weight and leather thickness ($P<0.05$), but had no significant effects on hair follicle density, fur glossiness, fur length, tear breakpoint thickness, tensile strength, and specified

load elongation rate ($P > 0.05$). Based on the measured indices in this experiment, the appropriate dietary iodine supplementation level for 3- to 5-month-old growing Rex rabbits is 0.8 mg/kg (the measured iodine value in the diet was 0.92 mg/kg).

Full Text

Effects of Dietary Iodine Supplemental Level on Growth Performance, Slaughter Performance, Meat Quality and Fur Quality of Growing Rex Rabbits

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Abstract

This experiment was conducted to investigate the effects of dietary iodine supplemental level on growth performance, slaughter performance, meat quality, and fur quality of 3- to 5-month-old growing Rex rabbits. Two hundred healthy 3-month-old Rex rabbits with similar body weight were randomly allocated into 5 groups with 40 replicates per group and 1 rabbit per replicate. Each group was fed a basal diet supplemented with 0, 0.2, 0.4, 0.8, or 1.6 mg/kg iodine (as potassium iodide). The adaptation period lasted 7 days and the formal experimental period lasted 53 days. The results showed: 1) Under the premise of no significant difference in initial body weight (IBW) ($P > 0.05$), dietary iodine supplemental level had a significant effect on final body weight (FBW) ($P < 0.05$), an extremely significant effect on average daily feed intake (ADFI) ($P < 0.01$), but no significant effects on average daily gain (ADG) or feed-to-gain ratio (F/G) ($P > 0.05$). The 0.8 mg/kg group exhibited the highest ADG and ADFI and the lowest F/G. 2) Dietary iodine supplemental level had significant effects on hind leg muscle ratio and redness value ($P < 0.05$), an extremely significant effect on fore leg muscle ratio ($P < 0.01$), but no significant effects on eviscerated carcass ratio, lumbar muscle ratio, or meat quality indices including pH, water loss ratio, and meat color (lightness and yellowness values) ($P > 0.05$). 3) Dietary iodine supplemental level had extremely significant effects on fur area, fur whiteness, and tear strength ($P < 0.01$), with maximum values observed at 0.8, 0.4, and 0.4 mg/kg, respectively. Dietary iodine supplemental level had significant effects on fur weight and fur thickness ($P < 0.05$), but no significant effects on hair follicle density, fur glossiness, fur length, tearing break point thickness, tensile strength, or specified load elongation ratio ($P > 0.05$). Based on comprehensive evaluation of all measured indices, the appropriate di-

etary iodine supplemental level for 3- to 5-month-old growing Rex rabbits is 0.8 mg/kg (with a measured dietary iodine value of 0.92 mg/kg).

Keywords: iodine; growing Rex rabbits; growth performance; meat quality; fur quality

Introduction

Iodine is an indispensable trace element in humans and animals, participating in the metabolism of almost all nutrients and thereby affecting animal growth, development, reproduction, and health. In animals, iodine is primarily used for synthesizing thyroid hormones, which are the main biologically active iodine compounds in the body. Therefore, the physiological role of iodine is mainly realized by influencing thyroid hormone synthesis. As a trace element, iodine is one of the most important micronutrients in animal nutrition, essential for nutritional metabolism, growth, development, and reproduction [1]. Sun [2] reported that iodine deficiency affects normal fur growth, leading to dry and dirty hair coat, slow growth, hair loss or even complete alopecia, thickened skin, and loss of luster in hair and feathers, with generalized fibrosis of the hair coat. Zhu et al. [3] noted that iodine deficiency in sows causes delayed parturition, and the piglets are born hairless or with sparse hair, extremely weak, dying within 1-3 days postpartum, accompanied by systemic skin edema. Xi et al. [4] demonstrated that adding 0.15 mg/kg iodine to the diet can prevent iodine deficiency symptoms in sows. In recent years, numerous studies have investigated iodine requirements in pigs, chickens, cattle, and other livestock and ruminants, as well as the pathogenesis of goiter induced by iodine deficiency and excess using rats. However, research on iodine requirements in rabbits remains scarce. Existing rabbit feeding standards containing iodine recommendations show substantial variation. The NRC (1994) and French INRA (1984) recommend a rabbit iodine requirement of 0.2 mg/kg. The recommended iodine supply for various rabbit types developed by Nanjing Agricultural University and the former Jiangsu Agricultural College also suggests 0.2 mg/kg. In contrast, the French AEC (1993) recommends 1.0 mg/kg. Therefore, this experiment investigated the effects of dietary iodine supplemental level on growth performance, slaughter performance, meat quality, and fur quality of 3- to 5-month-old growing Rex rabbits to determine the appropriate dietary iodine supplemental level and provide a reasonable basis for establishing feeding standards for Rex rabbits in China.

Materials and Methods

1.1 Experimental Diet

The basal diet was formulated according to the NRC (1977) [5] and De Blas et al. [6] standards for growing rabbits. The composition and nutrient levels of the basal diet are presented in Table 1. Experimental diets were prepared

by supplementing the basal diet with iodine in the form of potassium iodide at levels of 0, 0.2, 0.4, 0.8, and 1.6 mg/kg, resulting in five experimental diets with measured iodine values of 0.13, 0.32, 0.51, 0.92, and 1.70 mg/kg, respectively. The diets were pelleted using a pellet mill to produce granular feed with a diameter of 4–6 mm and stored in a ventilated, dry, and dark place.

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

Ingredients	Content (%)	Nutrient levels ²⁾	Content
Corn		DE (MJ/kg)	
Soybean meal		CP (%)	
Wheat bran		CF (%)	
Barley grain (husk)		Ash (%)	
Alfalfa		EE (%)	
Corn germ meal		Lys (%)	
Rice husk powder		Met (%)	
Soybean oil			
Premix ¹⁾			
Total			

¹⁾ Premix provided the following per kg of the diet: VA 8,000 IU, VD 900 IU, VE 50 mg, VK 2 mg, VB 5 mg, VB 10 mg, VB 50 mg, VB 20 mg, I 0.6 mg, VB 2 mg, VB 0.01 mg, Fe 50 mg, Zn (as zinc sulfate) 40 mg, Cu 30 mg, Mn 4 mg, Se 0.4 mg, Co 0.1 mg, CaHPO₄ 15,000 mg, NaCl 5,000 mg, Lys 1,400 mg, Met 1,400 mg, choline chloride 500 mg, bacitracin zinc 300 mg, with the remainder as miscellaneous meal carrier.

²⁾ DE was a calculated value, while the others were measured values.

1.2 Experimental Design and Management

Two hundred 3-month-old growing Rex rabbits with good health status and an average body weight of 1,759.3 g were selected for the experiment, with equal numbers of males and females. They were randomly divided into 5 groups based on sex and body weight, with 40 replicates per group and 1 rabbit per replicate. Each group was fed one of the five diets with different iodine supplemental levels. The experimental rabbits were housed individually in cages and fed twice daily (morning and evening). Before the experiment, the rabbit house was thoroughly cleaned and disinfected. During the experimental period, natural lighting and ventilation were provided, with free access to feed and water. The rabbit house was disinfected with rabbits present once per week. The adaptation period lasted 7 days and the formal experimental period lasted 53 days. Feed consumption and body weight gain were recorded weekly at scheduled times. On the final day of the experiment, 8 rabbits from each group with body weights

close to the group average were selected for slaughter to determine slaughter performance, meat quality, and fur quality indices.

1.3.1 Growth Performance Indicators

Body weight at the beginning and end of the experiment was measured and recorded, and feed consumption during the experimental period was calculated to determine average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G).

1.3.2 Slaughter Performance and Meat Quality Indicators

Rabbits were fasted for 12 hours before slaughter and then weighed to obtain live weight prior to slaughter. The eviscerated carcass weight was recorded after bloodletting, skinning, and removal of the limbs, head, heart, lungs, liver, kidneys, and gastrointestinal tract with contents. The lumbar muscle weight was obtained by stripping the lumbar muscles from both sides of the carcass. The forelegs and hind legs were separated from the carcass, and the boneless muscle weight was recorded as fore leg and hind leg muscle weight, respectively. The ratios of these weights to live weight prior to slaughter were calculated as eviscerated carcass ratio, lumbar muscle ratio, fore leg muscle ratio, and hind leg muscle ratio.

pH: At 45 minutes post-slaughter, the pH of the longissimus dorsi muscle at the 5th rib was immediately measured using a Mettler MP 120 pH meter by inserting the probe 3 mm into the muscle (pH min). The measurement was repeated at the same location after 24 hours (pH h).

Water loss ratio: At 4 hours post-slaughter, the eye muscle was sampled and cut along the muscle fiber direction into strips measuring 3 cm × 1 cm × 1 cm, then weighed and recorded as M_0 . One end of the meat strip was hooked with wire and suspended in a paper cup, which was then sealed with plastic wrap (ensuring the meat sample did not contact the cup wall). The sample was placed in a refrigerator at 4 °C for 24 hours, then removed and weighed again as M_1 . The water loss ratio was calculated using the following formula: Water loss ratio (%) = $(M_0 - M_1) / M_0 \times 100$.

Meat color: At 45 minutes post-slaughter, a Japanese CR-10 colorimeter was used in CIE-Lab output mode to measure three cut surfaces of the longissimus dorsi muscle, recording lightness (L), *redness* (a), and yellowness (b^*) values.

1.3.3 Fur Quality Indicators

After slaughter, the rabbit skin was peeled and weighed to obtain fur weight. The fresh skin was laid flat on a table, and its length and width were measured using a flexible ruler. Length was measured from the neck to the tail base, and width was measured at the narrowest part of the mid-abdomen to calculate fur area. Fur length was measured using a straight ruler at three positions, with

the average value used as the final result. After trimming the fur, fur thickness was measured using an MH-YDI digital leather thickness gauge (Shaanxi University of Science and Technology). Hair follicle density was determined by fixing samples in paraformaldehyde, preparing paraffin sections, staining with hematoxylin-eosin (HE), and counting under a microscope at three positions, with the average value used as the final result.

Fur glossiness was measured using an HP-386 multi-angle glossiness meter (Shanghai Puxi Optoelectronics Technology Co., Ltd.): the fur was laid flat, three positions on the Rex rabbit fur were selected for measurement, and data at 20° were recorded, with the average of the three positions used as the final result.

Fur whiteness was measured using an SBDY-1 digital whiteness meter following these steps: 1) Turn on the color difference analyzer and preheat for 30 minutes; 2) Open the standard guide, calibrate the instrument using standard white and black plates, use the standard white plate as the sample standard, smooth the fur coat, place it on the instrument to measure whiteness, and record a, b, and L values. System parameters were set as: 10° visual field, D65 light source, and 3 color measurements. The whiteness calculation formula was: L-100.

Tensile strength, tear strength, and specified load elongation ratio of the fur plate were measured on an AI-7000S electronic universal testing machine (Gao Tie Technology Co., Ltd.) according to the QB/T 1269-2012 method.

1.4 Data Processing

Data were analyzed using the GLM procedure in SAS 9.1.3 statistical software for analysis of variance, and Duncan's multiple range test was used for multiple comparisons.

Results

2.1 Effects of Dietary Iodine Supplemental Level on Growth Performance of Growing Rex Rabbits

As shown in Table 2, with no significant difference in initial body weight (IBW) ($P > 0.05$), dietary iodine supplemental level had no significant effects on ADG or F/G of Rex rabbits ($P > 0.05$). As dietary iodine supplemental level increased, ADG showed a trend of first increasing then decreasing, reaching its maximum value in the 0.8 mg/kg group; F/G showed a trend of first decreasing then increasing, reaching its minimum value in the 0.8 mg/kg group. The FBW of rabbits in the 0.8 mg/kg group was significantly higher than the other four groups ($P < 0.05$). Dietary iodine supplemental level had an extremely significant effect on ADFI ($P = 0.0001$), which also reached its maximum value in the 0.8 mg/kg group.

Table 2 Effects of dietary iodine supplemental level on growth performance of growing Rex rabbits (n=40)

Items	Dietary iodine supplemental level (mg/kg)	R-MSE	P-value
	0	0.2	0.4
IBW (g)			
FBW (g)	2,885.17	2,896.61	2,921.14
ADG (g/d)			
ADFI (g/d)	172.93	179.93	181.17
F/G			

In the same row, values with different lowercase letter superscripts indicate significant difference ($P < 0.05$), different uppercase letter superscripts indicate extremely significant difference ($P < 0.01$), and same or no letter superscripts indicate no significant difference ($P > 0.05$). The same applies to the following tables.

2.2 Effects of Dietary Iodine Supplemental Level on Slaughter Performance and Meat Quality of Growing Rex Rabbits

As shown in Table 3, dietary iodine supplemental level had an extremely significant effect on fore leg muscle ratio ($P = 0.0045$), with the 0.8 mg/kg group being extremely significantly higher than the other four groups ($P < 0.01$). Dietary iodine supplemental level had a significant effect on hind leg muscle ratio ($P = 0.0336$), which also reached its maximum value in the 0.8 mg/kg group. Dietary iodine supplemental level had a significant effect on meat color redness value ($P = 0.0498$) but no significant effects on lightness or yellowness values ($P > 0.05$). Dietary iodine supplemental level had no significant effects on eviscerated carcass ratio, lumbar muscle ratio, pH_{min}, pH_h, or muscle water loss ratio ($P > 0.05$).

Table 3 Effects of dietary iodine supplemental level on slaughter performance and meat quality of growing Rex rabbits (n=8)

Items	Dietary iodine supplemental level (mg/kg)	R-MSE	P-value
	0	0.2	0.4
Eviscerated ratio (%)			
Lumbar muscle ratio (g/kg)			
Fore leg muscle ratio (g/kg)	8.84	9.20	10.02
Hind leg muscle ratio (g/kg)	11.65	12.95	14.48
pH _{min}			
pH _h			
Water loss ratio (%)			
Lightness			

Items	Dietary iodine supplemental level (mg/kg)	R-MSE	P-value
Redness	42.14	42.93	44.48
Yellowness			

2.3 Effects of Dietary Iodine Supplemental Level on Fur Quality of Growing Rex Rabbits

As shown in Table 4, dietary iodine supplemental level had extremely significant effects on fur area ($P = 0.0011$) and fur whiteness ($P = 0.0079$) ($P < 0.01$). As dietary iodine supplemental level increased, fur area first increased then decreased, reaching its maximum value in the 0.8 mg/kg group. Dietary iodine supplemental level had an extremely significant effect on tear strength of Rex rabbit fur ($P = 0.0093$), reaching its maximum value in the 0.4 mg/kg group. Dietary iodine supplemental level had a significant effect on fur thickness ($P = 0.0360$), which showed a trend of first increasing then decreasing as dietary iodine supplemental level increased, reaching its maximum value in the 0.8 mg/kg group. Dietary iodine supplemental level had a significant effect on fur weight ($P = 0.0143$), reaching its maximum value in the 0.8 mg/kg group. Dietary iodine supplemental level had no significant effects on hair follicle density, fur glossiness, fur length, tearing break point thickness, tensile strength, or specified load elongation ratio ($P > 0.05$).

Table 4 Effects of dietary iodine supplemental level on fur quality of growing Rex rabbits (n=8)

Items	Dietary iodine supplemental level (mg/kg)	R-MSE	P-value
	0	0.2	0.4
Fur area (cm ²)	1,431.25	1,678.50	545.25
Fur weight (g)	405.63	437.50	452.50
Fur thickness (mm)	1.81	2.11	2.11
Hair follicle density (mm ²)			
Fur glossiness (20°)			
Fur whiteness (10°)	86.58	85.24	89.01
Wool length (cm)			
Tear strength (N/mm)	12.14	14.52	14.54
Tearing break point thickness (mm)			
Tensile strength (N/mm ²)			
Stretched ratio (N/mm ²)			

Discussion

3.1 Effects of Dietary Iodine Supplemental Level on Growth Performance of Growing Rex Rabbits

As a trace element, iodine is essential not only for humans but also for animal growth, development, and production. The primary role of iodine is to participate in the synthesis of thyroid hormones, promote biological oxidation, regulate protein synthesis and decomposition, facilitate carbohydrate and lipid metabolism, regulate water-salt metabolism, promote vitamin absorption and utilization, enhance enzyme activity, and stimulate growth and development, thereby indirectly affecting physiological functions of the animal body [7]. Xi et al. [4] reported that dietary supplementation with 0.50-1.50 mg/kg iodine could increase litter size and average birth weight of piglets. Xu et al. [8] used potassium iodate as an additive and found that adding 0.41 mg/kg iodine to dairy cow diets could meet iodine requirements and improve pregnancy rate, average conception rate per estrus cycle, and first-service conception rate, as well as increase daily milk yield, thereby enhancing reproductive and productive performance. Bedi et al. [9] found that goats supplemented with 0.08 mg iodine daily achieved better growth rates. Li et al. [10] fed experimental diets supplemented with 0.2, 0.4, 0.8, 1.6, and 3.2 mg/kg iodine and reported that for 1- to 4-week-old Wulong geese, ADG and ADFI were highest at a dietary iodine level of 0.4 mg/kg, which significantly increased ADG and ADFI and significantly reduced F/G compared with the control group. Liu et al. [11] found that dietary iodine supplementation significantly increased ADG in meat rabbits from weaning to 2 months of age. The present experimental results showed that with no significant difference in IBW, dietary iodine supplemental level had a significant effect on FBW and an extremely significant effect on ADFI in growing Rex rabbits. As dietary iodine supplemental level increased, both parameters first increased then decreased, reaching maximum values at a dietary iodine supplemental level of 0.8 mg/kg. This indicates that adding an appropriate level of iodine to the diet helps improve growth performance of growing Rex rabbits, which is consistent with previous research findings.

3.2 Effects of Dietary Iodine Supplemental Level on Slaughter Performance and Meat Quality of Growing Rex Rabbits

Eviscerated carcass ratio is a very important indicator for measuring slaughter performance in livestock and poultry, directly related to dietary nutritional status. The present results showed that dietary iodine supplemental level had no significant effect on eviscerated carcass ratio of Rex rabbits, but exhibited a trend of first increasing then decreasing as iodine supplemental level increased, reaching its maximum value in the 0.8 mg/kg group. Dietary iodine supplemental level had a significant effect on hind leg muscle ratio, which was significantly higher in the 0.8 mg/kg group than in the control group. Dietary iodine supplemental level had an extremely significant effect on fore leg muscle ratio, which was extremely significantly higher in the 0.8 mg/kg group than in other groups.

This indicates that dietary iodine supplementation improved muscle deposition in the fore and hind legs of growing Rex rabbits. Li et al. [10] reported that dietary supplementation with 0.4 mg/kg iodine could extremely significantly increase semi-eviscerated carcass ratio, eviscerated carcass ratio, and breast muscle ratio, and significantly increase dressing percentage and leg muscle ratio in Wulong geese. Meyer et al. [12] found that dietary iodine supplementation had no significant effect on slaughter performance of growing-finishing cattle. The inconsistent results may be due to differences in experimental animal species. Rabbit meat is referred to by experts as ‘beauty meat’ and ‘intelligence meat’ due to its advantages of high protein, high lysine, high digestibility, and low fat content [13]. Zhao [14] noted that meat color, muscle pH, and drip loss are indicators for evaluating meat quality. The present results showed that dietary iodine supplementation had a significant effect on muscle redness, with the lowest redness value in the 0.8 mg/kg group, indicating that appropriate iodine can improve meat quality of growing Rex rabbits.

3.3 Effects of Dietary Iodine Supplemental Level on Fur Quality of Growing Rex Rabbits

Rex rabbit fur is dense, uniform, lustrous, and has good thermal insulation, earning it the reputation as the world’s fourth most important fur raw material. Its quality is influenced by multiple factors, and besides breed and age, dietary nutritional status is an important factor affecting its quality. Zhang [15] reported that appropriate nutritional levels and adequate feed intake can significantly improve fur quality of Rex rabbits. Fur area, hair density, fur weight, and fur thickness are important indicators for evaluating fur quality. In addition to these indices, this experiment also included fur glossiness, tear strength, and tearing break point thickness based on Wu’s [16] proposal that fur quality of Rex rabbits can be evaluated from aspects such as fur color and plate quality. The deformation of Rex rabbit fur under external force and the force it can withstand are important indicators for evaluating its leather mechanical properties and for determining the quality and durability of rabbit fur products. Tensile strength specifically refers to the force per unit cross-sectional area that a sample can withstand when stretched to fracture by axial force, while tear strength assesses the seam strength of rabbit fur [17]. The present results showed that dietary iodine supplemental level had no significant effects on hair follicle density, fur glossiness, tearing break point thickness, tensile strength, or specified load elongation ratio of Rex rabbit fur. Dietary iodine supplemental level had significant effects on fur weight and fur thickness, both reaching maximum values in the 0.8 mg/kg group. Dietary iodine supplemental level had extremely significant effects on fur area, fur whiteness, and tear strength, with fur whiteness and tear strength reaching maximum values in the 0.4 mg/kg group.

Conclusion

Based on comprehensive evaluation of all measured indices in this experiment, the appropriate dietary iodine supplemental level for growing Rex rabbits is 0.8 mg/kg (with a measured dietary iodine value of 0.92 mg/kg).

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