Effects of Macleaya cordata alkaloids and tea seed polysaccharides on growth performance, serum biochemical indices and lipid peroxidation in yellow-feathered broilers (Postprint)

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Abstract

This experiment aimed to investigate the effects of Macleaya cordata alkaloids and tea seed polysaccharides on growth performance, serum biochemical indices, and lipid peroxidation in yellow-feathered broilers. A total of 750 one-day-old healthy yellow-feathered broilers were randomly divided into 5 groups with 6 replicates per group and 25 birds per replicate. The control group was fed a basal diet, while the experimental groups were fed the basal diet supplemented with antibiotics (10 mg/kg colistin sulfate at days 1-28 and 5 mg/kg flavomycin at days 29-56; antibiotic group), tea seed polysaccharides (0.04%; polysaccharide group), Macleaya cordata alkaloids (10 mg/kg at days 1-28 and 20 mg/kg at days 29-56; Macleaya cordata group), and tea seed polysaccharides (0.04%) + Macleaya cordata alkaloids (10 mg/kg at days 1-28 and 20 mg/kg at days 29-56; polysaccharide + Macleaya cordata group). The experiment lasted for 56 days and was conducted in two phases: days 1-28 and days 29-56. The results showed: 1) During days 1-28, there were no significant differences in average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) among all groups (P>0.05). During days 29-56 and the overall period (days 1-56), the ADFI of the Macleaya cordata group was significantly higher than that of the other groups (P<0.05); there were no significant differences in ADG and F/G among all groups (P>0.05). 2) At day 28, compared with the control group, the serum alanine aminotransferase (ALT), lactate dehydrogenase (LDH) activities, and blood urea nitrogen (BUN) content were significantly decreased (P<0.05), and serum alkaline phosphatase (ALP) activity was significantly decreased (P<0.01) in the other groups; the serum ALP activity of the polysaccharide, Macleaya cordata, and polysaccharide + Macleaya cordata groups was significantly lower than that of the antibiotic group (P<0.01). At day 56, compared with the control group, the serum ALP activity was significantly decreased ($P<0.01$) and serum LDH activity was significantly decreased ($P<0.05$) in the other groups. 3) Compared with the control group, the breast muscle percentage and leg muscle percentage of the Macleaya cordata group and the leg muscle percentage of the polysaccharide and polysaccharide + Macleaya cordata groups were significantly increased ($P<0.05$); compared with the antibiotic group, the breast muscle percentage and leg muscle percentage of the Macleaya cordata and polysaccharide + Macleaya cordata groups and the leg muscle percentage of the polysaccharide group were significantly increased ($P<0.05$); the breast muscle percentage of the Macleaya cordata group was significantly higher than that of the polysaccharide group ($P<0.05$). After muscle storage at 4 °C for 2, 4, and 6 days, compared with the control group, the muscle malondialdehyde (MDA) content was significantly decreased ($P<0.01$) in the other groups; compared with the antibiotic group, the muscle MDA content of the polysaccharide, Macleaya cordata, and polysaccharide + Macleaya cordata groups was significantly decreased ($P<0.01$) after storage at 4 °C for 2 days and significantly decreased ($P<0.05$) after storage at 4 °C for 6 days. In conclusion, dietary supplementation with Macleaya cordata alkaloids and tea seed polysaccharides improved the growth performance and serum biochemical indices of yellow-feathered broilers, with Macleaya cordata alkaloids showing superior effects to tea seed polysaccharides, and both could extend the storage time of chicken meat at 4 °C; this indicates that both Macleaya cordata alkaloids and tea seed polysaccharides can replace antibiotic use in broilers, and combined use is comparable in effect to individual supplementation.

Full Text

Effects of Macleaya cordata Alkaloids and Tea Seed Polysaccharide on Growth Performance, Serum Biochemical Indexes and Lipid Peroxidation of Yellow-Feathered Broilers

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Abstract: This experiment was conducted to investigate the effects of Macleaya cordata alkaloids and tea seed polysaccharide on growth performance, serum biochemical indexes and lipid peroxidation of yellow-feathered broilers. A total of 750 1-day-old healthy yellow-feathered broilers were randomly allocated to 5 groups with 6 replicates per group and 25 broilers per replicate. Broilers in the control group were fed a basal diet, while those in the experimental groups were fed the basal diet supplemented with antibiotic (10 mg/kg colistin at 1 to 28 days of age and 5 mg/kg flavomycin at 29 to 56 days of age; antibiotic group), tea seed polysaccharide (0.04%; polysaccharide group), Macleaya cordata alkaloids (10 mg/kg at 1 to 28 days of age and 20 mg/kg at 29 to 56 days of age; Macleaya cordata group), or tea seed polysaccharide (0.04%) + Macleaya cordata alkaloids (10 mg/kg at 1 to 28 days of age and 20 mg/kg at 29 to 56 days of age; polysaccharide+Macleaya cordata group). The experiment lasted for 56 days, consisting of two stages: 1 to 28 days and 29 to 56 days of age. The results showed: 1) At 1 to 28 days of age, there were no significant differences in average daily gain (ADG), average daily feed intake (ADFI), or feed-to-gain ratio (F/G) among all groups ($P>0.05$). At 29 to 56 days and 1 to 56 days of age, ADFI in the Macleaya cordata group was significantly higher than in the other groups ($P<0.05$), while ADG and F/G did not differ significantly among groups ($P>0.05$). 2) At 28 days of age, compared with the control group, the activities of alanine aminotransferase (ALT) and lactate dehydrogenase (LDH) and urea nitrogen (BUN) content in serum were significantly decreased in the other groups ($P<0.05$), and serum alkaline phosphatase (ALP) activity was extremely significantly decreased ($P<0.01$). Serum ALP activity in the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was extremely significantly lower than in the antibiotic group ($P<0.01$). At 56 days of age, compared with the control group, serum ALP activity was extremely significantly decreased ($P<0.01$) and serum LDH activity was significantly decreased ($P<0.05$) in the other groups. 3) Compared with the control group, breast muscle rate and leg muscle rate in the Macleaya cordata group, and leg muscle rate in the polysaccharide and polysaccharide+Macleaya cordata groups, were significantly increased ($P<0.05$). Compared with the antibiotic group, breast muscle rate and leg muscle rate in the Macleaya cordata and polysaccharide+Macleaya cordata groups, and leg muscle rate in the polysaccharide group, were significantly increased ($P<0.05$). Breast muscle rate in the Macleaya cordata group was significantly higher than in the polysaccharide group ($P<0.05$). After muscle preservation at 4 °C for 2, 4, and 6 days, muscle malondialdehyde (MDA) content in the other groups was extremely significantly lower than in the control group ($P<0.01$). Compared with the antibiotic group, muscle MDA content in the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was extremely significantly lower after 2 days ($P<0.01$) and significantly lower after 6 days ($P<0.05$) of preservation at 4 °C. In conclusion, dietary supplementation with Macleaya cordata alkaloids and tea seed polysaccharide improved the growth performance and serum biochemical indexes of yellow-feathered broilers, with Macleaya cordata alkaloids showing better effects than tea seed polysaccharide. Both additives prolonged the storage time of chicken meat at 4 °C. These results indicate that Macleaya cordata alkaloids and tea seed polysaccharide can replace antibiotics in broiler production, and their combined use is equivalent to individual supplementation.

Key words: yellow-feathered broilers; Macleaya cordata alkaloids; tea seed polysaccharide; growth performance; serum biochemical indexes

Introduction

Macleaya cordata, also known as "haotonggan" or "shanhaotong" , belongs to the Papaveraceae family and is a perennial herb. Its fruit is rich in alkaloids, mainly including sanguinarine, protopine, chelerythrine, -allocryptopine, and -allocryptopine [1]. Macleaya cordata alkaloids exhibit broad pharmacological activities, such as antibacterial and anti-inflammatory effects, antitumor properties, liver function improvement, and insecticidal action [2], enabling them to replace antibiotics and function as traditional Chinese medicine.

Plant polysaccharides are widely present in plants and are compounds composed of monosaccharides linked by glycosidic bonds. Common examples include Astragalus polysaccharide, Lycium barbarum polysaccharide, seaweed polysaccharide, and tea seed polysaccharide. Studies have found that plant polysaccharides possess hypoglycemic, antitumor, and immunomodulatory effects [3].

Currently, numerous studies have investigated Macleaya cordata alkaloids and tea seed polysaccharide in animal production. Rao et al. [4] showed that Macleaya cordata extract significantly improved the growth performance of weaned piglets. Li et al. [5] reported that dietary supplementation with 5.0 mg/kg Macleaya cordata extract significantly increased the average daily gain (ADG) and average daily feed intake (ADFI) of piglets, decreased the feed-to-gain ratio (F/G), and extremely significantly reduced serum malondialdehyde (MDA) content. Xu [6] found that dietary supplementation with a certain amount of alfalfa polysaccharide and Astragalus polysaccharide improved the antioxidant capacity of broiler chicks, significantly increased serum total antioxidant capacity (T-AOC), and decreased serum MDA content. Chen et al. [7] showed that tea seed polysaccharide could scavenge hydroxyl radicals, nitrogen radicals, and hydrogen peroxide, while also protecting against DNA oxidative damage caused by hydrogen peroxide. However, research on Macleaya cordata alkaloids and tea seed polysaccharide in poultry production remains limited. Therefore, this experiment aimed to investigate the effects of Macleaya cordata alkaloids and tea seed polysaccharide on growth performance, serum biochemical indexes, and lipid peroxidation of yellow-feathered broilers, providing a basis for their development and utilization as feed additives and exploring their potential as novel, efficient, and green feed additives, thereby offering theoretical support for their application in livestock and poultry production.

1.1 Experimental Materials

Macleaya cordata alkaloids: total alkaloid content of 70%, with sanguinarine accounting for 60% and chelerythrine for 20%, provided by the Hunan Traditional Chinese Medicine Extraction Engineering Research Center; tea seed polysaccharide: purity of 43.4%, provided by the Oil and Fat Teaching and Research

Section of the College of Food Science and Technology, Hunan Agricultural University; antibiotics: colistin for the early stage and flavomycin for the later stage.

1.2 Experimental Animals and Design

A total of 750 1-day-old yellow-feathered broilers of the same batch, with identical genetic background and normal development, were randomly allocated to 5 groups with 6 replicates per group and 25 broilers per replicate. The initial body weight of broilers in each group showed no significant difference ($P>0.05$). A single-factor randomized design was employed. The control group was fed a basal diet, while the experimental groups were fed the basal diet supplemented with antibiotic (10 mg/kg colistin at 1 to 28 days of age and 5 mg/kg flavomycin at 29 to 56 days of age; antibiotic group), tea seed polysaccharide (0.04%; polysaccharide group), Macleaya cordata alkaloids (10 mg/kg at 1 to 28 days of age and 20 mg/kg at 29 to 56 days of age; Macleaya cordata group), or tea seed polysaccharide (0.04%) + Macleaya cordata alkaloids (10 mg/kg at 1 to 28 days of age and 20 mg/kg at 29 to 56 days of age; polysaccharide+Macleaya cordata group). Antibiotic supplementation complied with current Chinese laws and regulations. Broilers were fed mash diets. The experiment lasted for 56 days, consisting of two stages: 1 to 28 days and 29 to 56 days of age.

1.3 Experimental Diets

The basal diets were formulated according to the nutrient requirements for broilers in NRC (1994) and the "Feeding Standard of Chickens" (NY/T 33—2004), using corn, soybean meal, and other ingredients. The composition and nutrient levels are shown in Table 1 .

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

Items	1 to 28 days of age	29 to 56 days of age
Ingredients		
Corn		
Soybean meal		
Rapeseed meal		
Cottonseed meal		
Wheat middlings		
Soybean oil		
Rice bran		
Corn protein meal		
Salt		
Premix1)		
Total		
Nutrient levels2)		
Metabolizable energy ME/(MJ/kg)		

Items	1 to 28 days of age	29 to 56 days of age
Crude protein CP		
Available phosphorus AP		
Lysine Lys		
Methionine Met		

[1]) The premix provided the following per kg of diets: Cu 25 mg, Fe 96 mg, Mn 105.4 mg, Zn 98 mg, Na 0.9 mg, I 1.29 mg, Se 0.225 mg, VA 12 000 IU, VD 2 500 IU, VE 20 mg, VK 3.0 mg, VB 3.0 mg, VB 8.0 mg, VB 7.0 mg, VB 0.03 mg, pantothenic acid 20.0 mg, niacin 50.0 mg, biotin 0.1 mg, folic acid 1.5 mg.

[2]) Nutrient levels were calculated values.

1.4 Management

The experiment was conducted in an open chicken house with high-low bed floor rearing. The lighting schedule was 14 h light:10 h dark (14 L:10 D). Temperature was maintained at 30-33 °C for days 1-7, 27-29 °C for days 8-14, 24-26 °C for days 15-21, 22-23 °C for days 22-28, and 20-21 °C for days 29-56. Normal temperature was maintained using boiler heating, with natural ventilation. Chicken house hygiene was cleaned regularly, relative humidity was maintained at 55%-65%, and broilers had free access to water and feed. Routine immunization procedures were followed.

1.5.1 Growth Performance

During the experiment, growth and health status of broilers were observed, and feed consumption was recorded by replicate. Body weight was measured on days 28 and 56 in the morning (after 8 h fasting), and ADFI, ADG, and F/G were calculated for each group.

1.5.2 Serum Biochemical Indexes

On days 28 and 56 in the morning (after 8 h fasting), one broiler with body weight close to the group average was selected from each replicate, and 10 mL of blood was collected from the wing vein. After clotting, serum was collected by centrifugation at 3,000 r/min for 10 min, aliquoted, and stored at -20 °C for determination of serum biochemical indexes. Serum alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), lactate dehydrogenase (LDH) activities, and urea nitrogen (UN) content were measured using a Mindray BS-200 automatic biochemical analyzer. Reagent kits were purchased from Shenzhen Mindray Bio-Medical Electronics Co., Ltd., and all indexes were strictly measured according to the relevant kit instructions.

1.5.3 Carcass Traits and Muscle MDA Content

On day 56, one broiler with body weight close to the group average was selected from each replicate, weighed, slaughtered by neck bleeding, and breast muscle rate and leg muscle rate were calculated according to the "Terminology and Measurement Methods for Poultry Production Performance" (NY/T 823—2004). The formulas were as follows:

Breast muscle rate (%) = 100 × breast muscle weight / eviscerated weight;
Leg muscle rate (%) = 100 × leg muscle weight / eviscerated weight.

Approximately 50 g of breast muscle from the same location was preserved at 4 °C for determination of MDA content. The measurement method was as follows: after preserving the muscle at 4 °C for 2, 4, and 6 days, MDA content was strictly measured according to the kit instructions from Nanjing Jiancheng Bioengineering Institute.

1.6 Data Processing and Analysis

Experimental data were analyzed using the one-way ANOVA procedure of SPSS 16.0 software. Duncan's multiple comparison was used for significant differences among groups. $P<0.05$ was considered statistically significant. Results are expressed as "mean ± standard deviation".

2.1 Growth Performance

As shown in Table 2 , at 1 to 28 days of age, there were no significant differences in ADG, ADFI, or F/G among all groups of yellow-feathered broilers ($P>0.05$). At 29 to 56 days and 1 to 56 days of age, ADFI in the Macleaya cordata group was significantly higher than in the other groups ($P<0.05$), while ADFI in the control, antibiotic, polysaccharide, and polysaccharide+Macleaya cordata groups showed no significant differences ($P>0.05$). ADG and F/G did not differ significantly among groups ($P>0.05$).

Table 2 Effects of Macleaya cordata alkaloids and tea seed polysaccharide on growth performance of yellow-feathered broilers

Items	Control group	Antibiotic group	Polysaccharide group	Macleaya cordata group	Polysaccharide+Macleaya cordata group	P-value
1 to 28 days of age						
FBW/g	495.13±9.37	516.30±6.65	512.78±7.07	498.18±12.06	508.01±5.35	

Items	Control group	Antibiotic group	Polysaccharide group	Macleaya cordata group	Polysaccharide+Macleaya cordata group	P-value
ADG/(g/d)	21.58±0.42	21.72±0.57	22.59±0.31	22.42±0.34	22.19±0.25	
ADFI/(g/d)	37.78±0.63	38.20±0.72	38.72±0.70	39.14±0.67	38.46±0.55	
F/G	1.75±0.01	1.76±0.02	1.72±0.01	1.74±0.04	1.73±0.03	
29 to 56 days of age						
FBW/g	1 290.07±13.21	1 291.61±13.98	1 302.07±13.76	1 331.83±13.69	1 297.44±13.53	
ADG/(g/d)	36.13±0.73	38.07±0.77	37.37±0.76	38.45±0.76	37.20±0.75	
ADFI/(g/d)	99.66±1.79	100.76±1.78	100.74±1.76	105.02±1.75	102.02±1.73	<0.05
F/G	2.76±0.06	2.65±0.05	2.70±0.06	2.73±0.06	2.74±0.05	
1 to 56 days of age						
ADG/(g/d)	29.42±0.72	29.56±0.24	29.61±0.74	30.54±0.27	29.73±0.18	
ADFI/(g/d)	69.30±1.06	69.93±0.55	69.47±1.07	72.73±1.35	70.29±0.77	<0.05
F/G	2.36±0.03	2.37±0.04	2.35±0.03	2.38±0.04	2.36±0.03	

In the same row, values with the same or no letter superscripts mean no significant difference (P>0.05), while different small letter superscripts mean significant difference (P<0.05), and different capital letter superscripts mean significant difference (P<0.01). The same as below.

2.2 Serum Biochemical Indexes

As shown in Table 3 , at 28 days of age, compared with the control group, serum ALT and LDH activities and UN content in yellow-feathered broilers were significantly decreased in the other groups (P<0.05), while serum ALP activity was extremely significantly decreased (P<0.01). Serum ALT, LDH activities, and UN content did not differ significantly among the antibiotic, polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups (P>0.05). Compared with the control group, serum ALP activity was extremely significantly decreased in the other groups (P<0.01), and serum ALP activity in the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was extremely significantly lower than in the antibiotic group (P<0.01). Serum ALP activity did not differ significantly among the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups (P>0.05). Serum AST activity did not differ significantly among all groups (P>0.05). At 56 days of age, compared with the control group, serum ALP activity was extremely significantly decreased (P<0.01) and serum LDH activity was significantly decreased (P<0.05) in the other groups. Serum ALP and LDH activities did not differ significantly among the antibiotic, polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups (P>0.05). Serum ALT and AST activities and UN content did not differ significantly among all groups (P>0.05).

Table 3 Effects of Macleaya cordata alkaloids and tea seed polysaccharide on serum biochemical indexes of yellow-feathered broilers

Items	Control group	Antibiotic group	Polysaccharide group	Macleaya cordata group	Polysaccharide+Macleaya cordata group	P-value
28 days of age						
ALT/(U/L)	21.93±3.01	17.38±1.73	17.01±3.70	16.53±2.53	16.56±2.57	<0.001
AST/(U/L)	302.65±22.43	293.68±23.71	287.68±16.42	286.51±20.80	291.51±20.43	
ALP/(U/L)	2 765.87±161.47	2 094.10±143.08	2 072.98±184.24	2 462.12±193.71	2 081.55±121.57	<0.001
LDH/(U/L)	557.27±36.72	575.75±48.48	481.93±31.81	482.01±66.19	486.40±44.47	
UN/(mmol/L)	0.21±0.04	0.15±0.04	0.14±0.03	0.14±0.02	0.15±0.03	
56 days of age						
ALT/(U/L)	13.23±1.82	10.85±3.46	9.47±3.20	8.86±5.35	10.30±2.66	
AST/(U/L)	315.88±27.04	304.98±24.99	298.22±13.62	288.97±13.15	289.00±23.86	
ALP/(U/L)	2 823.10±192.80	2 251.54±166.22	2 289.50±169.13	2 492.66±127.70	2 281.68±187.88	<0.001
LDH/(U/L)	541.47±76.51	453.98±42.34	449.18±47.02	439.78±53.22	427.78±85.87	
UN/(mmol/L)	0.18±0.03	0.21±0.05	0.15±0.07	0.16±0.02	0.17±0.03	

2.3 Carcass Traits and Muscle MDA Content

As shown in Table 4 , compared with the control group, breast muscle rate and leg muscle rate in the Macleaya cordata group, and leg muscle rate in the polysaccharide and polysaccharide+Macleaya cordata groups, were significantly increased (P<0.05). Compared with the antibiotic group, breast muscle rate and leg muscle rate in the Macleaya cordata and polysaccharide+Macleaya cordata groups, and leg muscle rate in the polysaccharide group, were significantly increased (P<0.05). Breast muscle rate in the Macleaya cordata group was significantly higher than in the polysaccharide group (P<0.05), but did not differ significantly from the polysaccharide+Macleaya cordata group (P>0.05). Leg muscle rate did not differ significantly among the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups (P>0.05). After muscle preservation at 4 °C for 2, 4, and 6 days, muscle MDA content in the antibiotic, polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was extremely significantly lower than in the control group (P<0.01), and muscle MDA content did not differ significantly among the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups (P>0.05). At 2 days, muscle MDA content in the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was extremely significantly lower than in the antibiotic group (P<0.01). At 6 days, muscle MDA content in the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was significantly lower than in the antibiotic group (P<0.05).

Table 4 Effects of Macleaya cordata alkaloids and tea seed polysaccharide on carcass traits and muscle MDA content of yellow-feathered broilers

Items	Control group	Antibiotic group	Polysaccharide group	Macleaya cordata group	Polysaccharide+Macleaya cordata group	P value
Breast muscle rate/%	15.85±0.14	13.30±0.16	13.01±0.17	13.06±0.18	13.07±0.15	<0.001
Leg muscle rate/%	11.23±0.13	9.88±0.29	9.52±0.23	9.50±0.23	9.51±0.23	<0.001
MDA content/(nmoL/mg prot)						
2 days	13.26±0.16	11.48±0.12	11.46±0.23	11.47±0.33	11.47±0.20	<0.001
4 days	6.85±0.32	6.64±0.41	7.23±0.47	7.61±0.84	7.11±0.35	<0.001
6 days	5.14±0.52	5.00±0.55	5.36±0.56	5.90±0.49	5.77±0.70	<0.001

3.1 Effects of Macleaya cordata Alkaloids and Tea Seed Polysaccharide on Growth Performance of Yellow-Feathered Broilers

The results of this experiment showed that dietary supplementation with Macleaya cordata alkaloids increased ADG to some extent and significantly increased ADFI of yellow-feathered broilers, while F/G did not differ significantly from the control and antibiotic groups. The growth performance of broilers in the Macleaya cordata group did not differ significantly from the antibiotic group. These results are consistent with Vieira et al. [8], who showed that dietary supplementation with 37.5 mg/kg Macleaya cordata extract increased ADG of 21-day-old turkeys. Yun [9] reported that dietary supplementation with sanguinarine extract from Macleaya cordata significantly improved ADG and ADFI of yellow-feathered broilers during the late growth stage. Kantas et al. [10] and Cai et al. [11] demonstrated in piglets that dietary supplementation with Macleaya cordata alkaloids improved growth performance of weaned piglets. The improvement in ADG, ADFI, and feed utilization efficiency by dietary Macleaya cordata alkaloids may be attributed to two aspects. First, sanguinarine, an important component of Macleaya cordata alkaloids, can inhibit cholinesterase activity, stimulate saliva secretion, and exert diuretic and peripheral anti-adrenergic sympatholytic effects [12]. It also regulates the tryptophan-5-hydroxytryptamine metabolic pathway by inhibiting aromatic amino acid decarboxylase, thereby increasing feed intake [13]. Second, Macleaya cordata alkaloids can maintain intestinal health, promote intestinal cell proliferation, differentiation, and renewal, and enhance small intestinal digestion and absorption of nutrients, thereby increasing body weight gain [14].

Currently, various isolated plant polysaccharides have demonstrated growth-promoting effects. The results of this experiment also showed that dietary supplementation with tea seed polysaccharide improved growth performance of yellow-feathered broilers, with effects comparable to antibiotics. This is similar to the findings of Yuan et al. [15], who reported that dietary supplementation with 300 mg/kg tea seed polysaccharide had similar effects on broiler growth performance as 5 mg/kg enramycin. Li et al. [16] showed that dietary supplementation with tea seed polysaccharide improved growth performance of piglets. The improvement in broiler growth performance by tea seed polysaccharide may be related to its ability to promote intestinal microflora balance, improve animal health, and thereby enhance nutrient absorption and protein synthesis.

3.2 Effects of Macleaya cordata Alkaloids and Tea Seed Polysaccharide on Serum Biochemical Indexes of Yellow-Feathered Broilers

Serum AST and ALT activities are biochemical indicators for assessing normal liver function. When liver function is impaired, serum AST and ALT activities increase [17]. In this experiment, serum ALT and AST activities in the polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups were lower than in the control group, with serum ALT activity at 28 days of age showing a significant difference compared with the control group, while other differences were not significant. This indicates that tea seed polysaccharide and Macleaya cordata alkaloids do not adversely affect metabolism or damage liver cells. Under normal conditions, serum ALP and LDH activities are low. When cells are damaged by various factors (such as stress), cell membrane permeability increases, ALP is released into the blood at an accelerated rate, and serum ALP activity increases significantly [18]. When body tissues and cells are extensively damaged, LDH activity increases significantly. The results of this experiment showed that compared with the control group, tea seed polysaccharide, Macleaya cordata alkaloids, and their combination all extremely significantly decreased serum ALP activity and significantly decreased serum LDH activity in yellow-feathered broilers. Compared with the antibiotic group, tea seed polysaccharide, Macleaya cordata alkaloids, and their combination all extremely significantly decreased serum ALP activity at 28 days of age. This suggests that tea seed polysaccharide and Macleaya cordata alkaloids may protect the intestinal mucosa and reduce the degree of damage. Serum UN content is related to protein metabolism and dietary amino acid balance in animals. When protein metabolism is abnormal, serum UN content increases; when protein metabolism is good, serum UN content decreases [19]. The results of this experiment showed that compared with the control group, tea seed polysaccharide, Macleaya cordata alkaloids, and their combination all significantly decreased serum UN content in 28-day-old yellow-feathered broilers. This indicates that tea seed polysaccharide and Macleaya cordata alkaloids did not affect normal liver and kidney function and improved protein utilization efficiency. The decrease in serum UN content indicates normal excretion of protein metabolism end products and no accumulation of toxic substances in the body. Feeding tea seed polysaccharide and Macleaya cordata alkaloids to yellow-feathered broilers not only does not damage the kidneys but also protects the kidneys and enhances renal excretory function. Additionally, the decrease in serum UN content indicates reduced protein catabolism and increased protein deposition in the body.

3.3 Effects of Macleaya cordata Alkaloids and Tea Seed Polysaccharide on Carcass Traits and Lipid Peroxidation of Yellow-Feathered Broilers

The results of this experiment showed that dietary supplementation with Macleaya cordata alkaloids significantly increased breast muscle rate and leg muscle rate of yellow-feathered broilers. Breast muscle rate and leg muscle rate in the polysaccharide group were higher than in the control group, with breast muscle rate being significantly higher than in the antibiotic group. MDA is a relatively stable lipid peroxide produced when free radicals attack polyunsaturated fatty acids on biological membranes, initiating lipid peroxidation. Tissue MDA content is an important indicator reflecting the degree of lipid peroxidation and is the final product of lipid reactions in the body. MDA content in meat directly reflects the degree of lipid peroxidation in meat [20] and is directly related to meat shelf life. The results of this experiment showed that after muscle preservation at 4 °C for 2, 4, and 6 days, muscle MDA content in the antibiotic, polysaccharide, Macleaya cordata, and polysaccharide+Macleaya cordata groups was extremely significantly lower than in the control group. This is consistent with the findings of Lee et al. [21], who showed that dietary supplementation with 20 and 50 mg/kg sanguinarine significantly decreased leg muscle MDA content in broilers. Yun [9] also demonstrated that dietary supplementation with sanguinarine decreased serum MDA content in 28-day-old yellow-feathered broilers. When sanguinarine supplementation was less than 150 mg/kg, serum MDA content in 56-day-old broilers was significantly lower than in the control and antibiotic groups. Polysaccharides have free radical scavenging and immune function enhancing effects. Xue et al. [22] added 150–450 mg/kg lentinan to diets and found that it significantly increased plasma superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) activities and decreased plasma MDA content in piglets. Li et al. [16] found that dietary supplementation with 600 mg/kg tea seed polysaccharide increased serum SOD activity and decreased serum MDA content in growing pigs. This indicates that supplementation with tea seed polysaccharide and Macleaya cordata alkaloids can extend the shelf storage time of chicken meat, with effects similar to antibiotics.

4 Conclusion

In conclusion, dietary supplementation with Macleaya cordata alkaloids and tea seed polysaccharide improved the growth performance and serum biochemical indexes of yellow-feathered broilers, with Macleaya cordata alkaloids showing better effects than tea seed polysaccharide. Both additives prolonged the storage time of chicken meat at 4 °C. These results indicate that Macleaya cordata alkaloids and tea seed polysaccharide can replace antibiotics in broiler production, and their combined use is equivalent to individual supplementation.

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