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Research Article

Effects of Cannabis (*Cannabis sativa* L.) Leaf Supplementation in Broiler Diets on Growth Performance, Carcass Characteristics, and Meat Quality

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ABSTRACT

This study investigated the effects of supplementing broiler diets with *Cannabis sativa L*. leaves on growth performance, carcass characteristics, and meat quality. A total of 150 unsexed broiler chicks (aged 7 days) were randomly assigned to five dietary treatments with three replicates per treatment and 10 birds per replicate. The treatments included a control group fed a basal diet and four experimental groups receiving the basal diet supplemented with 0.5%, 1%, 1.5%, and 2% cannabis leaf powder, respectively. The birds were raised in an open-house system with ad libitum access to feed and water throughout the trial. The results showed that cannabis leaf supplementation had no significant effect on feed intake and feed conversion ratio (FCR) ($P > 0.05$). However, supplementation at 0.5% significantly increased final body weight and average daily gain (ADG) ($P < 0.01$), while the 2% supplementation level resulted in a significant reduction in these parameters ($P < 0.01$). Regarding carcass characteristics, the 0.5% supplementation level increased the percentage of breast and tenderloin yields ($P < 0.01$), whereas the 2% level reduced neck yield ($P < 0.05$). Meat quality parameters, including pH, water-holding capacity, and sensory attributes, were unaffected by dietary cannabis supplementation ($P > 0.05$). However, the 1% supplementation level resulted in a significantly higher b* value in drumstick meat ($P < 0.05$). In conclusion, supplementing broiler diets with 0.5% cannabis leaf powder may enhance growth performance and improve carcass characteristics without negatively affecting meat quality. Further studies are recommended to determine the optimal inclusion level for practical applications in poultry nutrition.

1. Introduction

The broiler industry has undergone rapid advancements in multiple aspects, including genetic improvements, high-quality feed development, and modernized farm management systems. Selective breeding has enabled faster growth rates, while advancements in nutrition and farm management efficiency have further enhanced production potential. As a result, the industry has been able to adequately meet consumer demand and improve overall productivity. Despite these advancements, chemical feed additives (FAs) continue to be widely used in poultry production. Among them, antibiotic growth promoters (AGPs) are commonly added to broiler diets to reduce mortality rates and enhance growth performance. However, the prolonged use of AGPs raises concerns about antimicrobial residues in poultry products, food safety risks, and potential trade restrictions on chicken exports.

To address these concerns, animal nutritionists have turned their attention to natural alternatives, particularly the incorporation of local medicinal herbs in animal feed, such as basil, garlic, and ginger (Khajaren, 2013). These natural additives reduce chemical residues in poultry products while enhancing food safety. Among these, Cannabis sativa has gained interest due to its long history of use in both human and animal nutrition, traditional medicine, textiles, and other applications. Cannabis

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contains over 750 bioactive compounds, with cannabinoids such as Tetrahydrocannabinol (THC) and Cannabidiol (CBD) being the most prominent. These compounds exhibit medicinal properties and have been extensively studied for their potential in treating multiple sclerosis, epilepsy, and cancer. Additionally, cannabis is used as an appetite stimulant, an antiemetic (anti-vomiting agent), and a pain reliever (Hazekamp *et al*., 2007; Bernstein *et al*., 2019).

While research on cannabis supplementation in animal feed remains limited, previous studies suggest potential benefits in broiler production. Cannabis supplementation has been found to reduce disease incidence by lowering serum aspartate aminotransferase (AST) levels, an enzyme associated with liver toxicity (Vispute *et al*., 2019); improve product quality by enhancing chemical composition and meat color attributes (Goldberg *et al*., 2012); and enhance production efficiency, leading to increased body weight and improved feed conversion (Khan *et al*., 2010). However, these findings are not yet conclusive, and further research is needed to determine the optimal supplementation levels and long-term effects of cannabis in broiler diets. Therefore, this study aims to evaluate the effects of cannabis leaf supplementation on growth performance, carcass characteristics, and meat quality in broilers. The findings from this research could provide guidelines for the efficient utilization of local cannabis leaves in poultry nutrition. If proven effective, cannabis leaf supplementation could enhance broiler production performance, generate additional income for farmers, and promote sustainability within the poultry industry.

2. Materials and Methods

2.1 Preparing cannabis leaves

The cannabis leaves used in this study were prepared by washing with clean water to remove any contaminants. The fresh leaves were then weighed and dried at 50°C for 48 hours until they were completely dry. The dry weight was recorded, and the leaves were ground into a fine powder using a blender. The powder was then sieved through a 1-millimeter mesh to ensure uniform particle size. Finally, the bioactive compounds in the cannabis leaf powder were analyzed using High-Performance Liquid Chromatography (HPLC), with the results measured using a Diode Array Detector (DAD). The composition of the bioactive compounds is presented in Table 1.

Table 1 Phytochemical content of cannabis leaves

Item	Value (%w/w)
Cannabidiolic Acid (CBDA)	0.5524
Cannabigerol (CBG)	0.0038
Cannabidiol (CBD)	0.0579
Cannabinol (CBN)	-
Delta-9-tetrahydrocannabinol (A9-THC)	0.1557
Delta 9-Tetrahydrocannabinolic Acid (THCA)	0.6320
Total THC	0.7093

2.2 Experimental animals

This experiment was approved for the use of animals in scientific research by the Faculty of Agricultural Technology and Industrial Technology, Phetchabun Rajabhat University, under approval document number (PCRU/2567/101). The study utilized 150 unsexed Arbor Acres broilers, aged 7 days, in a completely randomized design (CRD). The broilers were randomly assigned to five dietary treatments, with three replicates per treatment and 10 broilers per replicate (6 males and 4 females per replicate). The experimental groups were as follows: Group 1 (CON): basal diet (control). Groups 2–5: basal diet supplemented with 0.5%, 1%, 1.5%, and 2% cannabis leaf powder, respectively. The basal diet consisted of commercial feed base on the nutrient requirements of poultry (Aviagen, 2022), divided into two formulations: starter diet (0–21 days), containing at least 21% crude protein; and finisher diet (22–42 days), containing at least 19% crude protein. All broilers had *ad libitum* access to feed and water throughout the experimental period.

2.3 Broiler Management

The experimental broilers were housed in communal pens, each measuring 1 × 1 meter, with a total of 15 pens (10 birds per pen). They were raised under an open-house system at Phetchabun Rajabhat University, where the average temperature ranged from 21 to 34°C, and the relative humidity averaged 83%. The experiment lasted for five weeks.

2.4 Growth Performance and Carcass Characteristics

Data on body weight, daily feed intake, and mortality rate were recorded throughout the experimental period. At the end of the trial (42 days of age), broilers with body weights closest to the average of each replicate were randomly selected (four birds per replicate: two males and two females) for slaughter. Carcass weight (weight after slaughter, including feet and neck but excluding head and internal organs) was measured following the method described by Faria *et al*. (2010).

The following calculations were performed:

$$\text{Average Daily Gain (ADG)} = \frac{\text{Final weight - Initial weight}}{\text{Number of rearing days}}$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Total feed intake}}{\text{Body weight gain}}$$

$$\text{Carcass yield percentage (\%)} = \frac{\text{Carcass weight (excluding internal organs)} \times 100}{\text{Live weight}}$$

$$\text{Cut-up part yield percentage (\%)} = \frac{\text{Part weight} \times 100}{\text{Carcass weight}}$$

2.5 Meat Quality Evaluation

On the final day of the experiment, broilers were slaughtered, defeathered, and eviscerated, and breast and drumstick meat samples were collected. The samples were then stored in a refrigerator at 4°C for 24 hours for further analysis of meat pH, color, drip loss, cooking loss, and sensory attributes. The pH value of the meat was measured using a pH meter (Model G0842, Schott AG, Germany), while color parameters (L*, a*, and b*) were analyzed using a Hunter Lab MiniScan EZ (Virginia, USA). For drip loss measurement (AOAC, 1990), meat samples were trimmed to remove fat tissue, weighed, and sealed in airtight plastic bags to prevent moisture evaporation and oxidation. The samples were then suspended in a refrigerator at 4°C for 24 hours, after which they were weighed again after gently blotting the excess liquid. Cooking loss measurement (Lawrie and Ledward, 2006) was performed by weighing meat samples, sealing them in poly-bag zipper plastic bags, and boiling them in a water bath at 80°C for 10 minutes. After cooling to room temperature, the samples were weighed again, and cooking loss percentage was calculated. Sensory attributes were evaluated using the 9-point hedonic scale (Chompreeda, 1993). A panel of 30 untrained consumers, aged 18–22 years, assessed color, odor, taste, and texture, following the method described by Wiriyacharee (2018).

The following calculations were performed:

$$\text{Drip loss} = \frac{\text{Initial weight - Final weight} \times 100}{\text{Initial weight}}$$

$$\text{Cooking loss} = \frac{\text{Initial weight - Final weight} \times 100}{\text{Initial weight}}$$

2.6 Statistical Analysis

The collected data were analyzed using Analysis of Variance (ANOVA), and mean differences were tested using the Least Significant Difference (LSD) method with SPSS statistical software. The results were presented as mean ± standard error of the mean (Mean ± SEM). Statistical significance was determined at P < 0.05.

3. Results and Discussion

3.1 Bioactive Compound Composition in Broiler Meat

The bioactive compounds detected in broiler meat are presented in Table 2. The study found that cannabis leaf supplementation did not result in detectable residues of tetrahydrocannabinol (THC), a compound that could potentially impact consumers. However, at the 2% supplementation level, a trace amount of cannabidiol (CBD) was detected, measuring 0.0011% of the total meat weight. CBD is a naturally occurring compound in cannabis and is generally recognized as safe. It has no reported adverse effects on physiology, biochemistry, behavior, or addiction in both animals and humans. According to the World Health Organization (WHO, 2018), the amount of CBD required to potentially affect humans must reach 150 mg and be consumed continuously over an extended period. Therefore, the presence of CBD in broiler meat due to cannabis leaf supplementation is unlikely to pose any health risks to consumers.

Table 2 Phytochemical content in broilers meat products supplemented with cannabis leaves

Item (%w/w)	Levels of dietary cannabis leaves (%)				
	CON[1]	0.5	1	1.5	2
Cannabidiol (CBD)	-	-	-	-	0.0011
Delta-9-tetrahydrocannabinol	-	-	-	-	-
Delta-9-tetrahydrocannabinol Acid	-	-	-	-	-

Remark:[1] CON = Control diet.

3.2 Growth Performance

As shown in Table 3, cannabis leaf supplementation did not affect feed intake or feed conversion ratio (FCR; P > 0.05). This finding is consistent with the study by Sopian *et al*. (2024), which investigated the supplementation of cannabis by-products (leaves and stems) in broiler diets at levels of 0%, 0.5%, 1%, and 2%, reporting no significant impact on FCR (P > 0.05). However, their study observed a reduction in feed intake, which differs from the findings of He *et al*. (2024), who supplemented hemp seeds in the diets of 50-day-old Three-Yellow chickens at 0%, 5%, 10%, and 20% levels, resulting in increased feed intake.

Regarding final body weight, weight gain, and average daily gain (ADG), the highest values were observed in broilers supplemented with 0.5% cannabis leaves (1,571.70 g and 54.53 g/bird/day, respectively), whereas the lowest values were recorded in the 2% supplementation group (1,476.34 g and 51.16 g/bird/day, respectively; P < 0.01). The increase in body weight and ADG may be attributed to cannabinoid compounds, particularly Tetrahydrocannabinol (THC), which stimulates appetite by promoting ghrelin (hunger hormone) secretion (Famii and Oluwafeyikemi, 2024).

However, high levels of cannabis leaf supplementation may alter feed palatability, leading to reduced feed intake (Sopian *et al*., 2024). These findings align with the study by Famii and Oluwafeyikemi (2024), which supplemented cannabis leaves in broiler diets at levels of 0%, 0.1%, 0.2%, 0.4%, and 0.8%, reporting that broilers in the 0.8% supplementation group exhibited significantly higher body weight than other groups (P < 0.05), Additionally, Beiń *et al*. (2024) supplemented cannabidiol (CBD) extract in broiler diets under bacterial stress from Clostridium perfringens at 3% of feed, finding that broilers maintained higher body weights despite being under stress (P < 0.05).

Table 3 Effects of cannabis leaves supplementation in broilers diets on broilers growth performance

Items[1]	Levels of dietary cannabis leaves (%)					P-value
	CON[2]	0.5	1	1.5	2	
IBW (g/b)	43.80 ± 0.38	44.93 ± 1.56	44.43 ± 0.91	43.98 ± 2.18	44.03 ± 0.27	0.8220
FBW (g/b)	1,554.49 ± 12.19^{ab}	1,571.70 ± 19.96^{a}	1,546.53 ± 46.58^{ab}	1,515.83 ± 14.41^{bc}	1,476.34 ± 19.00^{c}	0.0078
BWC (g/b)	1,510.69 ± 12.49^{ab}	1,526.76 ± 19.22^{a}	1,502.09 ± 46.42^{ab}	1,471.85 ± 13.86^{bc}	1,432.32 ± 19.00^{c}	0.0078
FI (g/b/d)	71.24 ± 2.16	70.80 ± 2.51	70.66 ± 2.19	68.72 ± 2.14	67.50 ± 0.05	0.1895
ADG (g/b/d)	53.96 ± 0.45^{ab}	54.53 ± 0.69^{a}	53.65 ± 1.66^{ab}	52.57 ± 0.49^{bc}	51.16 ± 0.6^{c}	0.0079
FCR	1.32 ± 0.05	1.30 ± 0.06	1.32 ± 0.01	1.31 ± 0.04	1.32 ± 0.02	0.9575

Remark: $^{a-c}$ Mean values in same row with different superscripts differ significantly (P<0.05).

[1] IBW, initial body weight; FBW, final body weight; BWC, Body weight change; FI, feed intake; ADG, average daily gain; FCR, feed conversion ratio.

[2] CON = Control diet.

Table 4 Effects of cannabis leaves supplementation in broilers diets on broilers carcass characteristics

Items	Levels of dietary cannabis leaves (%)					P-value
	CON[1]	0.5	1	1.5	2	
Live weight (g)	1,557.92 ± 7.24^{ab}	1,573.46 ± 2.37^{a}	1,546.43 ± 6.66^{b}	1,520.29 ± 5.25^{c}	1,481.50 ± 20.28^{d}	<.0001
Carcass weight (g)	1,440.75 ± 6.52^{a}	1,458.38 ± 3.48^{a}	1,440.60 ± 4.72^{a}	1,417.63 ± 7.16^{b}	1,384.76 ± 19.67^{c}	<.0001
Carcass yield (%)	80.66 ± 0.40^{c}	80.85 ± 0.15^{c}	81.17 ± 0.38^{bc}	81.49 ± 0.14^{ab}	81.89 ± 0.50^{a}	0.0090
Head	2.89 ± 0.05	2.95 ± 0.09	2.90 ± 0.06	2.85 ± 0.05	2.77 ± 0.10	0.0851
Neck	3.93 ± 0.07^{a}	3.96 ± 0.09^{a}	3.84 ± 0.23^{a}	3.82 ± 0.09^{ab}	3.61 ± 0.02^{b}	0.0394
Leg	3.91 ± 0.02	3.90 ± 0.04	3.86 ± 0.03	3.84 ± 0.09	3.88 ± 0.05	0.1369
Breast	22.81 ± 0.73^{ab}	23.73 ± 1.41^{a}	21.56 ± 0.46^{bc}	20.52 ± 0.72^{c}	18.76 ± 0.18^{d}	0.0002
Thigh	15.43 ± 0.47	16.09 ± 0.85	14.69 ± 0.82	12.36 ± 3.33	13.48 ± 0.33	0.0980
Drumstick	11.53 ± 0.10^{a}	11.60 ± 0.10^{a}	11.01 ± 0.04^{b}	11.15 ± 0.13^{b}	11.03 ± 0.06^{b}	<.0001
Wing	11.23 ± 0.39^{a}	11.17 ± 0.32^{a}	10.02 ± 0.18^{b}	9.06 ± 0.15^{c}	8.72 ± 0.06^{c}	<.0001
Tenderloin	3.79 ± 0.06^{b}	3.81 ± 0.09^{a}	3.69 ± 0.13^{a}	3.53 ± 0.05^{b}	3.29 ± 0.02^{c}	<.0001

Remark: $^{a-d}$ Mean values in same row with different superscripts differ significantly (P<0.05).

[1] CON = Control diet.

3.3 Carcass Characteristics

The evaluation of broiler carcass quality, as presented in Table 4, revealed that cannabis leaf supplementation significantly influenced live weight, carcass weight, and carcass yield percentage ($P < 0.01$), as well as the average organ weights ($P < 0.05$). The highest average live weight was recorded in broilers fed 0.5% cannabis leaves (1,573.46 g), while the lowest was found in the 2% supplementation group (1,481.50 g). These results align with feed intake and growth performance data from this study. However, high levels of cannabis leaf supplementation may alter feed palatability, leading to reduced feed intake and consequently affecting broiler body weight (Sopian *et al*., 2024). Previous studies on cannabis supplementation in animals reported similar findings. Abey (2018) found that supplementing 5% and 10% cannabis leaves in rat diets resulted in reduced body weight, whereas Maqbool *et al*. (2023) observed no impact on feed intake or body weight in rats fed cannabis leaves.

Regarding carcass weight, broilers supplemented with 1.5% and 2% cannabis leaves had significantly lower carcass weights than other groups ($P < 0.01$). However, when comparing carcass yield percentage, the 1.5% and 2% supplementation groups exhibited significantly higher carcass yield percentages than other groups ($P < 0.01$). Although these groups showed reduced feed intake, the increased carcass yield percentage could be attributed to improved nutrient digestion and absorption. Cannabinoid compounds are known to play a key role in reducing nutrient malabsorption disorders, regulating gut microbiota balance, reducing intestinal inflammation, and enhancing gut immune function (Karoly *et al*., 2019).

When evaluating individual carcass parts, broilers supplemented with 2% cannabis leaves exhibited a lower neck percentage compared to other groups ($P < 0.05$). Meanwhile, the 0.5% supplementation group showed the highest breast percentage, which decreased as the supplementation level increased ($P < 0.01$). Additionally, thigh and wing percentages were significantly lower in broilers supplemented with 1%, 1.5%, and 2% cannabis leaves compared to the control group ($P < 0.01$). Moreover, the tenderloin percentage was significantly higher in the 0.5% and 1% supplementation groups compared to others, but was lowest in the 2% group ($P < 0.01$). This decrease in tenderloin percentage was consistent with lower feed intake and carcass weight in the 2% cannabis supplementation group. However, these findings contrast with those of Tufarelli *et al*. (2023), who investigated hemp seed meal supplementation in male Hubbard broilers at levels of 0%, 5%, and 10%, reporting no significant effects on carcass quality. Similarly, Sopian *et al*. (2024) found that supplementing cannabis by-products (leaves and stems) at levels of 0%, 0.5%, 1%, and 2% in broiler diets had no significant impact on carcass quality. However, their study observed an increased heart percentage in broilers supplemented with 1% and 2% cannabis by-products, possibly due to the activation of cannabinoid type 1 receptors by Tetrahydrocannabinol (THC), which has been linked to heart enlargement and increased cardiac muscle size (Abey, 2018; Goyal *et al*., 2017).

3.4 Meat Quality

The effects of cannabis leaf supplementation on meat quality, as presented in Table 5, showed that it did not affect the pH values or color parameters (L*, a*, and b*) of breast meat (P > 0.05). This finding is consistent with the study by KaiĆ *et al.* (2024), which investigated cannabis leaf supplementation (*Cannabis sativa*) in Ross 308 broilers at levels of 1%, 2%, and 3%, reporting no impact on meat pH values. Similarly, Beiń *et al*. (2024) supplemented cannabidiol (CBD) extract in broiler diets under bacterial stress from Clostridium perfringens at 3% of feed, and found no significant effects on L*, a*, or b* values. However, in this study, drumstick meat color was affected by cannabis leaf supplementation, with 1% and 1.5% supplementation increasing the b* (yellowness) value (P < 0.01), while 2% supplementation slightly reduced the b* value compared to 1% and 1.5% levels. The increase in b* value may be due to the high carotenoid content in cannabis leaves, particularly β-carotene, which is responsible for color changes from deep green to yellow in plant-based oils (Kopsell *et al*., 2005; Šťastník *et al*., 2019). However, the mechanism by which high cannabis supplementation levels influence meat color remains unclear, although it is suspected that certain bioactive compounds in cannabis may undergo chemical reactions that affect meat color (Kanbur, 2022).

Regarding water-holding capacity, cannabis leaf supplementation did not affect cooking loss or drip loss, which aligns with the findings of KaiĆ *et al*. (2024), who supplemented cannabis leaves at 2% and 3% in Ross 308 broiler diets, impacting on meat water-holding capacity.

Table 5 Effects of cannabis leaves supplementation in broilers diets on meat quality in broilers

Item	Levels of dietary cannabis leaves (%)					P-value
	CON[2]	0.5	1	1.5	2	
pH	6.87±0.06	6.56±0.06	6.40±0.20	6.45±0.20	6.53±0.29	0.0753
Breast color[1]						
L*	47.43±5.80	48.33±5.35	48.99±4.88	49.56±5.01	51.87±2.43	0.5235
a*	-0.63±0.88	0.47±0.78	0.57±1.60	0.59±1.56	0.65±1.06	0.4092
b*	11.05±0.84	12.41±0.83	13.86±2.08	14.25±2.12	15.16±2.09	0.0711
Drumstick color[1]						
L*	59.77±6.62	59.53±5.35	59.24±3.30	58.12±4.85	56.58±9.02	0.8287
a*	-3.35±2.15	-3.48±2.23	0.14±0.80	0.22±0.78	-0.36±2.34	0.1257
b*	11.77±2.47^{b}	12.37±1.98^{b}	17.62±1.74^{a}	17.43±1.56^{a}	15.57±1.76^{ab}	0.0438
Water holding capacity (%)						
Cooking loss	0.09±0.00	0.08±0.10	0.10±0.12	0.12±0.00	0.10±0.01	0.5510
Drip loss	0.14±0.01	0.15±0.02	0.78±0.62	0.85±0.64	0.99±0.74	0.2267

Remark:$^{a-b}$ Mean values in same row with different superscripts differ significantly (P<0.05).

[1] L* represents lightness (0 = black, 100 = white); a* represents the redness (-a = green, +a = red); b* represents the yellowness (-b = blue, +b = yellow).

[2] CON = Control diet.

Table 6 Effects of cannabis leaves supplementation in broilers diets on meat sensory evaluation in broilers

Item	Levels of dietary cannabis leaves (%)					P-value
	CON[1]	0.5	1	1.5	2	
Color	3.87±0.97	3.86±0.97	3.77±0.82	3.75±0.78	3.70±0.88	0.7985
Odor	3.47±1.11	3.63±1.00	3.53±0.97	3.58±0.98	3.60±1.10	0.7855
Taste	4.10±0.76	3.90±0.78	3.93±0.74	3.87±0.81	3.67±0.80	0.0945
Texture	3.83±0.91	3.35±0.95	3.33±0.84	3.35±0.885	3.37±0.93	0.0630
Overall	4.10+0.88	4.00±0.80	3.83±0.75	3.98±0.73	3.73±0.64	0.1785

Remark: [1] CON = Control diet.

3.5 Sensory Evaluation of Meat

As shown in Table 6, cannabis leaf supplementation in broiler diets did not affect the sensory attributes of meat, including color, odor, taste, and texture ($P > 0.05$).

This result differs from the findings of Tathong *et al*. (2024), who studied cannabidiol (CBD) supplementation in Boer crossbred goats at levels of 0.1, 0.2, and 0.3 ml per 30 kg of body weight (0.0003%, 0.0007 and 0.001% of body weight) and found that the odor of meat from the supplemented groups was rated higher than that of the control group. This change in odor may be attributed to the presence of phenolic compounds, which exhibit antioxidant properties and inhibit lipid oxidation (Chen *et al*., 2012). As a result, phenolic compounds may contribute to the breakdown of fatty acids and the suppression of volatile organic compounds (VOCs), which are key factors in meat spoilage (Konieczka *et al*., 2022).

4. Conclusion

The supplementation of cannabis leaves in broiler diets did not affect feed intake, feed conversion ratio (FCR), meat pH, water- holding capacity, or sensory evaluation. However, supplementation at 0.5% was found to tend to enhance growth performance by increasing final body weight and average daily gain (ADG), as well as improving breast and tenderloin yield percentages, whereas supplementation at 1% and 1.5% improved the yellowness of meat.

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