Effects of Different Dietary Oils on Growth Performance, Carcass Characteristics, and Meat Quality of Broiler Chickens: Postprint

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Abstract

This study aimed to investigate the effects of dietary supplementation with different oils on growth performance, slaughter performance, meat quality, and plasma lipid metabolism in broiler chickens. A total of 360 healthy 1-day-old Arbor Acres male broiler chicks were randomly allocated to 4 groups and fed diets containing soybean oil (SO, control), chicken oil (CO), linseed oil (LO), or fish oil (FO). Oil supplementation levels were 3.0% during the starter phase (1-21 days of age) and 3.5% during the grower phase (22–42 days of age). The results showed that: 1) The 42-day body weight (BW), average daily gain (ADG) during the grower phase, and overall ADG of broiler chickens in the FO group were significantly lower than those in the SO and CO groups (P<0.05). 2) Compared with the SO group, breast muscle percentage in the CO group was significantly reduced at 21 days of age (P<0.05), and that in the FO group was significantly reduced at 42 days of age (P<0.05). 3) Compared with the SO group, drip loss in the CO and FO groups was significantly increased (P<0.05); pH at 45 min (pH45 min) and ΔpH of breast muscle in the CO and LO groups were significantly increased (P<0.05); lightness value at 45 min (L*45 min) in the CO group was significantly increased (P<0.05), whereas L*45 min and L*24 h values in the FO group were significantly decreased (P<0.05); redness value at 45 min (a*45 min) in the LO and FO groups was significantly increased (P<0.05), whereas a*24 h value in the CO group was significantly decreased (P<0.05); yellowness value at 45 min (b*45 min) and b*24 h values in the CO and LO groups were significantly increased (P<0.05), and b*24 h value in the FO group was significantly increased (P<0.05). 4) Compared with the CO group, plasma total cholesterol content in the LO group was significantly decreased at both 21 and 42 days of age (P<0.05); compared with the SO group, triglyceride and low-density lipoprotein cholesterol contents in the LO group were significantly decreased at 42 days of age (P<0.05); compared with the SO group, high-density lipoprotein cholesterol content in the CO group was significantly increased at 42 days of age (P<0.05). In conclusion, compared with SO, CO did not affect broiler growth performance but resulted in poorer meat color and increased drip loss; FO reduced broiler growth performance, improved meat color, but increased muscle drip loss; LO did not affect broiler growth performance, regulated plasma lipid metabolism, and improved meat color.

Full Text

Effects of Different Oils on Growth Performance, Carcass Quality and Meat Quality in Broilers

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Abstract: This experiment was conducted to investigate the effects of dietary supplementation with different oils on growth performance, carcass characteristics, meat quality, and plasma lipid metabolism in broiler chickens. A total of 360 healthy 1-day-old male Arbor Acres broilers were randomly divided into 4 groups and fed diets containing soybean oil (SO, control), chicken oil (CO), linseed oil (LO), or fish oil (FO). Oil supplementation levels were 3.0% during the starter phase (1–21 days) and 3.5% during the grower phase (22–42 days). The results showed that: 1) Body weight at 42 days of age, average daily gain (ADG) during the later phase, and ADG during the entire experimental period were significantly lower in the FO group compared with the SO and CO groups (P<0.05). 2) Compared with the SO group, breast muscle percentage was significantly reduced in the CO group at 21 days of age and in the FO group at 42 days of age (P<0.05). 3) Drip loss was significantly higher in the CO and FO groups compared with the SO group (P<0.05). The pH at 45 minutes post-slaughter (pH45 min) and pH decline (ΔpH) were significantly higher in the CO and LO groups (P<0.05). Lightness at 45 minutes (L*45 min) was significantly increased in the CO group but decreased in the FO group (P<0.05), while L*24 h was significantly lower only in the FO group (P<0.05). Redness at 45 minutes (a*45 min) was significantly higher in the LO and FO groups (P<0.05), whereas a*24 h was significantly lower only in the CO group (P<0.05). Yellowness at 45 minutes (b*45 min) and at 24 hours (b*24 h) was significantly higher in the CO and LO groups (P<0.05), and b*24 h was also significantly increased in the FO group (P<0.05). 4) Plasma total cholesterol (TC) content at both 21 and 42 days of age was significantly lower in the LO group compared with the CO group (P<0.05). At 42 days of age, plasma triglyceride (TG) and low-density lipoprotein cholesterol (LDL-C) contents were significantly lower in the LO group compared with the SO group (P<0.05), while high-density lipoprotein cholesterol (HDL-C) content was significantly higher in the CO group (P<0.05).

In conclusion, compared with SO, CO did not affect growth performance but resulted in poorer meat color and increased drip loss; FO reduced growth performance and increased muscle drip loss but improved meat color; LO had no adverse effects on growth performance, regulated plasma lipid metabolism, and improved meat color.

Keywords: oil; growth performance; meat quality; broilers

Introduction

Advances in modern breeding have accelerated broiler growth rates, increasing the required nutrient density in diets. Dietary oil supplementation has become an effective means to promote animal growth and improve feed conversion efficiency. Oils are widely used in feed due to their good palatability, provision of essential fatty acids, promotion of nutrient digestion and absorption, and reduction of dust. Feed oils are derived from animal and plant sources. Animal-derived oils contain more saturated fatty acids (SFA), while plant-derived oils contain more unsaturated fatty acids (UFA). Because UFAs are more readily absorbed and have higher metabolic energy values, fat utilization efficiency is greater, making them commonly used for young animals with high economic value. Additionally, relatively low-cost animal fats such as tallow, chicken oil (CO), and lard have become common feed ingredients, though research on CO in broiler production remains limited.

Based on the number of double bonds, UFAs can be classified as monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA). PUFAs include n-6 series (e.g., linoleic acid, arachidonic acid) and n-3 series (e.g., linolenic acid, eicosapentaenoic acid [EPA], and docosahexaenoic acid [DHA]). n-3 PUFAs are essential for the body, cannot be synthesized endogenously, and must be supplied through the diet; they are closely associated with cardiovascular and other diseases. Current research on n-3 PUFA-rich oils in broiler diets has focused primarily on deposition patterns, with fewer studies examining effects on muscle appearance and color. PUFAs can negatively affect meat quality by making fat softer and more susceptible to oxidation, though some studies indicate that diets with different oil saturation levels have no significant effect on muscle toughness, chewiness, or flavor in broilers. Dietary PUFAs can reduce plasma triglyceride (TG) and low-density lipoprotein cholesterol (LDL-C) contents while increasing high-density lipoprotein cholesterol (HDL-C) content, though other research shows that fish oil (FO) and soybean oil (SO) do not affect plasma TG and LDL-C levels in chickens.

SO is rich in linoleic acid (55.55%), linseed oil is rich in linolenic acid (55.84%), FO is rich in EPA and DHA (accounting for over 30% of total lipids), and CO contains high levels of SFA such as palmitic acid. Therefore, this experiment used commonly used SO as the control to investigate the effects of dietary supplementation with CO, linseed oil (LO), and FO on growth performance, carcass characteristics, muscle quality, and plasma lipid metabolism in broilers, aiming to provide support for oil application in broiler production.

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1 Materials and Methods

1.1 Experimental Materials

Chicken oil was purchased from Huadu Broiler Company, while soybean oil, linseed oil, and fish oil were purchased from supermarkets. The physicochemical indices and fatty acid compositions of the oils are shown in Table 1 .

Table 1 Characteristics and fatty acid composition of different oils

1.2 Experimental Design and Diets

A single-factor experimental design was employed. Three hundred sixty 1-day-old male Arbor Acres broilers with an average body weight (BW) of approximately 44.03 g were selected and randomly divided into 4 groups, each fed diets containing SO, CO, LO, or FO. Oil supplementation levels were 3.0% during the starter phase (1–21 days) and 3.5% during the grower phase (22–42 days). Each group had 6 replicates with 15 birds per replicate. A four-tier cage system was used. Experimental diets were formulated according to NRC (1994), the Chinese Feeding Standard of Chickens (NY/T 33-2004), and the AA Broiler Management Guide. Diet composition and nutrient levels are shown in Table 2 .

Table 2 Composition and nutrient levels of experimental diets (air-dry basis)

1.3 Management

During the experiment, birds had free access to feed and water under 24-hour lighting. Room temperature was maintained at 33°C for the first 3 days, then reduced by 2°C weekly until reaching 24°C, which was maintained thereafter. Management followed the AA Broiler Management Guide with routine vaccination and disinfection, and the chicken house was well ventilated. Temperature and humidity were recorded continuously, the house was cleaned daily, and mortality was recorded.

1.4 Sample Collection and Preparation

1.4.1 Growth Performance and Carcass Characteristics

At 1, 21, and 42 days of age, birds and remaining feed were weighed by replicate to calculate average BW, average daily gain (ADG), average daily feed intake (ADFI), feed-to-gain ratio (F/G), and mortality. At 21 and 42 days of age, one bird per replicate with BW close to the replicate average was selected. Blood (4 mL) was collected from the wing vein into anticoagulant tubes, allowed to clot naturally, and centrifuged at 3,000 r/min for 10 minutes. Plasma was aliquoted into 0.5 mL Eppendorf tubes and stored at -20°C. Birds were then slaughtered to obtain eviscerated carcass, breast muscle, thigh muscle, and abdominal fat, which were weighed to calculate dressing percentage, breast muscle percentage, thigh muscle percentage, and abdominal fat percentage according to the National Poultry Breeding Commission' s calculation methods.

1.4.2 Meat Quality Assessment

At 42 days of age, the right-side breast muscle was completely dissected, weighed, and used to determine muscle pH, color, drip loss, cooking loss, and shear force.

pH Measurement: pH was measured at 45 minutes and 24 hours post-slaughter (stored at 4°C) using a pH meter (CyberScan pH310 waterproof pen-type, EUTECH, Singapore). The probe was inserted approximately 1 cm deep into the breast muscle. Each sample was measured three times and averaged. pH decline (ΔpH) was calculated as the difference between pH45 min and pH24 h.

Color Measurement: Color was measured at 45 minutes and 24 hours post-slaughter (stored at 4°C) using the CIE-Lab system with a WSC-S colorimeter (Shanghai Precision Scientific Instrument Co., Ltd.). Lightness (L*), redness (a*)*, and yellowness (b*) values were recorded, with three measurements per sample averaged.

Drip Loss: Within 45 minutes post-slaughter, approximately 30 g of breast muscle with similar texture and regular shape was weighed (W1), placed in a ziplock bag, inflated with nitrogen to minimize contact with the bag interior, suspended in a 4°C refrigerator, and reweighed after 24 hours (W2) after gently blotting surface moisture with filter paper. Drip loss (%) = [(W1-W2)/W1] × 100.

Cooking Loss: After 24-hour drip loss measurement, the sample was placed in a new ziplock bag and heated in an 80°C water bath until the core temperature reached 75°C. After cooling to room temperature under running water, surface moisture was blotted and the sample was reweighed (W3). Cooking loss (%) = [(W2-W3)/W2] × 100.

Shear Force: After cooking loss measurement, two rectangular samples (2 cm × 2 cm × 1 cm) were cut along the muscle fiber direction. Shear force was measured using a TMS-Pro tenderness analyzer (Food Technology Corporation, Virginia, USA) with the muscle fiber direction perpendicular to the blade. Parameters were set at maximum load 100 N, crosshead speed 150 mm/min, and gap width 6 mm. Each sample was tested three times, and the average of six measurements from two pieces was recorded as the final shear force.

Plasma Lipid Metabolism: Plasma TG, total cholesterol (TC), HDL-C, and LDL-C contents were determined using commercial kits from Shanghai Kehua Bio-Engineering Co., Ltd. on a KHB Excell 310 semi-automatic biochemical analyzer.

1.5 Statistical Analysis

Data are expressed as means ± standard deviation. One-way ANOVA was performed using SPSS 16.0 software, followed by F-test and Duncan' s multiple comparison tests. Differences were considered significant at $P<0.05$.

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2 Results

2.1 Effects of Different Oils on Growth Performance

As shown in Table 3 , there were no significant differences in BW among groups at 21 days of age ($P>0.05$). However, at 42 days of age, BW was significantly lower in the FO group compared with the SO group ($P<0.05$), while CO and LO groups showed no significant differences from the SO group. The FO group also had significantly lower BW than the CO group ($P<0.05$). During days 1–21, ADG did not differ significantly among groups ($P>0.05$). During days 22–42 and 1–42, ADG was significantly lower in the FO group compared with the SO group ($P<0.05$), while CO and LO groups showed no significant differences. The FO group also had significantly lower ADG than the CO group ($P<0.05$).

Average daily feed intake did not differ significantly among groups during any period ($P>0.05$), though there was a trend toward variation during days 22–42 ($P=0.062$) and 1–42 ($P=0.087$), with the SO group showing the highest ADFI and the FO group the lowest. Feed-to-gain ratio and mortality did not differ significantly among groups during any growth phase ($P>0.05$).

Table 3 Effects of dietary supplementation with different oils on growth performance in broilers

2.2 Effects of Different Oils on Carcass Quality

As shown in Table 4 , the only significant difference among groups was in breast muscle percentage ($P<0.05$), with no significant changes in other carcass characteristics ($P>0.05$). Compared with the SO group, breast muscle percentage was significantly lower in the CO group at 21 days of age and in the FO group at 42 days of age ($P<0.05$).

Table 4 Effects of different oils on carcass quality in broilers

2.3 Effects of Different Oils on Meat Quality

As shown in Table 5 , drip loss was significantly higher in the CO and FO groups compared with the SO group ($P<0.05$). No significant differences were observed in cooking loss or shear force among groups ($P>0.05$). The pH45 min and ΔpH differed significantly among groups ($P<0.05$), with CO and LO groups showing significantly higher values than the SO group ($P<0.05$). Lightness at 45 minutes (L*45 min) was significantly higher in the CO group but significantly lower in the*

*FO group compared with the SO group (P<0.05), while the LO group showed no significant difference. At 24 hours post-slaughter, only the FO group showed significantly lower L*24 h values (P<0.05). Redness at 45 minutes (a*45 min) was significantly higher in the LO and FO groups (P<0.05), while a*24 h was significantly lower only in the CO group (P<0.05). Yellowness at 45 minutes (b*45 min) and at 24 hours (b*24 h) was significantly higher in the CO and LO groups (P<0.05), and b*24 h was also significantly increased in the FO group (P<0.05).

Table 5 Effects of different oils on meat quality of breast muscle in broilers

2.4 Effects of Different Oils on Plasma Lipid Metabolism

As shown in Table 6 , plasma TC content at both 21 and 42 days of age was significantly lower in the LO group compared with the CO group (P<0.05), while no significant differences were observed between the SO and FO groups (P>0.05). At 42 days of age, plasma TG content was significantly lower in the LO group compared with the SO group (P<0.05), with no significant differences in the CO and FO groups (P>0.05). Plasma HDL-C content at 42 days of age was significantly higher in the CO group compared with the SO group (P<0.05), while no significant differences were observed in the LO and FO groups (P>0.05). No significant differences were found in plasma TG or LDL-C contents among groups at 21 days of age (P>0.05).

Table 6 Effects of different oils on plasma lipid metabolism parameters in broilers

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3 Discussion

3.1 Effects of Different Oils on Growth Performance

This study found that FO significantly reduced 42-day BW and ADG during both the later phase and the entire experimental period, resulting in slower growth compared with the SO group, possibly due to reduced feed intake. The FO group showed lower ADFI during days 22–42 and 1–42, likely related to the fishy odor affecting palatability. Additionally, FO has a high degree of unsaturation and is prone to oxidation and rancidity during storage, reducing feed quality and utilization. Studies have shown that FO decreases ADFI, ADG, and BW in broilers and rats, consistent with our findings. Furthermore, dietary FO supplementation at different concentrations (0, 2.5%, 3.0%, 3.5%) affects growth performance differently, with 2.5% FO showing optimal results when considering feed intake and conversion efficiency. Lin et al. reported that 2% FO supplementation significantly reduced ADG and feed conversion efficiency compared with SO, suggesting that FO dosage requires careful consideration. In contrast, the CO group showed better growth performance than the SO group, possibly due to the high palmitic acid content (40.86%) in the CO used in this study. Research has demonstrated that diets supplemented primarily with palm oil significantly increased ADG and feed intake during the starter phase, improved immune function compared with SO and FO, increased the villus height-to-crypt depth ratio in the duodenum, and enhanced nutrient digestibility, thereby promoting broiler growth.

3.2 Effects of Different Oils on Carcass Quality

The lower breast muscle percentage in the CO group at 21 days of age may be attributed to increased body weight with a higher proportion of bone, as early growth primarily involves skeletal development, and CO may promote bone growth, resulting in a relatively lower breast muscle proportion. At 42 days of age, the significantly reduced breast muscle percentage in the FO group may be related to its susceptibility to oxidation and significantly lower growth performance. These findings align with Navidshad' s study, which showed that diets containing 7.0% FO significantly reduced ADG, BW, and breast muscle percentage in broilers, associated with significantly lower plasma TG content, as EPA and DHA can reduce the activity of enzymes involved in TG synthesis and decrease fat deposition.

3.3 Effects of Different Oils on Meat Quality

Drip loss is a quantitative indicator of water-holding capacity. Muscle pH is related to glycogen content and degradation rate and is a primary factor affecting water-holding capacity. Post-slaughter, muscle metabolism shifts from aerobic to anaerobic glycolysis, producing and accumulating lactic acid that causes rapid pH decline, leading to protein denaturation and affecting meat quality. Meat quality is also related to its oxidative status, with the balance between oxidation and antioxidant capacity determining the stability of lipids and proteins. Protein oxidation and denaturation can reduce fatty acid digestibility and affect meat quality. In this study, the significantly higher pH45 min in the LO group indicated better initial meat quality. However, the LO group also showed significantly increased ΔpH and slightly higher drip loss, possibly due to both the higher initial pH and increased PUFA deposition in muscle, making it more susceptible to oxidation. After 24 hours, increased anaerobic glycolysis and lactic acid production led to greater pH decline, reducing water-holding capacity. Both LO and FO improved meat color, increasing a* values and decreasing L* values, possibly due to interactions between PUFAs and myoglobin oxidation resistance. Fresh meat color is related to the type, quantity, and chemical properties of myoglobin, though peroxides and hydroxyl radicals in the body can oxidize ferrous ($Fe2+$) myoglobin to ferric ($Fe3+$) myoglobin, reducing color stability. CO increased drip loss and ΔpH, deteriorating meat color (higher L* and b* values, lower a* value) and quality, possibly related to the effects of SFA on muscle fiber type and energy metabolism. Muscle fiber type and composition determine energy metabolism patterns, with higher proportions of oxidative fibers and lower proportions of glycolytic fibers associated with better meat quality. Studies have shown that compared with UFA (primarily linoleic acid), SFA (primarily palmitic acid) significantly reduced the proportion of oxidative muscle fibers, decreasing meat quality. Additionally, diets supplemented primarily with palm oil significantly increased drip loss at 24 and 48 hours post-slaughter compared with SO, consistent with our findings. Thus, dietary CO supplementation resulted in poorer meat quality in broilers.

3.4 Effects of Different Oils on Plasma Lipid Metabolism

In this study, LO reduced plasma TG, TC, and LDL-C contents, consistent with Li' s findings. Research indicates that α-linolenic acid can reduce TG, TC, and LDL-C contents in serum and liver of laying hens, primarily by altering apolipoprotein (apo-B) content and reducing the activities of acetyl-CoA carboxylase (ACC) and HMG-CoA reductase (HMGR), thereby limiting cholesterol and TG synthesis. FO had no significant effect on plasma TG, TC, or LDL-C contents, similar to Royan' s findings, though other studies have shown that 7.0% FO supplementation reduced plasma TC content in broilers, and increasing FO levels (0–2%) significantly decreased serum TC and LDL-C while increasing HDL-C. These discrepancies may be due to differences in dosage and FO quality. Safamehr et al. reported that increasing FO supplementation (0–4%) significantly reduced TC content after 7 days of feeding, but had no significant effect on TC, TG, or LDL-C after 42 days, suggesting that FO effects on lipid metabolism are more pronounced during early growth. In this study, the CO group showed significantly increased plasma HDL-C content, possibly due to increased TC content and correspondingly increased LDL-C content. CO has high SFA content, and dietary SFA supplementation significantly increased serum TC and LDL-C contents in rats, possibly by downregulating cholesterol 7α-hydroxylase (CYP7A1) expression and inhibiting cholesterol metabolism. Studies have also shown that plasma TC content in broilers is inversely proportional to dietary PUFA content and directly proportional to SFA content.

Compared with SO, CO did not affect broiler growth performance but resulted in poorer meat color and reduced water-holding capacity; FO reduced growth performance and muscle water-holding capacity but improved meat color; LO had no adverse effects on growth performance, regulated plasma lipid metabolism, and improved meat color. Therefore, LO can be widely applied in broiler production, whereas FO and CO should be used with attention to dosage or in combination with other oils to avoid negative effects on growth performance or meat quality.

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