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Effects of Different Oils on Production Performance, Serum Indices, and Liver Fatty Acid Composition of Landes Geese During the Force-Feeding Period (Postprint)

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Abstract

This experiment was conducted to investigate the effects of dietary supplementation with different oils on liver production performance, fat deposition, slaughter performance, serum indices, and liver fatty acid composition in Landes geese during the force-feeding period. Eighty 70-day-old female Landes geese with a body weight of (3.0±0.1) kg were randomly divided into 4 groups, with 4 replicates per group and 5 geese per replicate. The goose fat group served as the control group, with 2% goose fat added to the diet; the beef tallow, fish oil, and rapeseed oil groups were experimental groups, with 2% beef tallow, fish oil, and rapeseed oil added to the diet, respectively. The preliminary feeding period lasted 7 days, and the force-feeding period lasted 20 days. The results showed: 1) Liver weight in both the rapeseed oil and beef tallow groups was significantly higher than that in the fish oil group ($P<0.05$), and the liver-to-body ratio in the beef tallow group was significantly higher than that in the goose fat group ($P<0.05$). Live weight and eviscerated carcass weight in the rapeseed oil and goose fat groups were significantly higher than those in the beef tallow and fish oil groups ($P<0.05$). 2) Serum triglyceride (TG), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL) contents in the fish oil group were significantly lower than those in the goose fat group ($P<0.05$); serum LDL content in the rapeseed oil group was significantly lower than that in the goose fat group ($P<0.05$), and its serum total cholesterol (TC) content was significantly lower than that in the beef tallow group ($P<0.05$); serum high-density lipoprotein (HDL) content in the beef tallow group was significantly higher than that in the goose fat group ($P<0.05$); serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities in the beef tallow, fish oil, and rapeseed oil groups were reduced to varying degrees compared with the goose fat group, but the differences were not significant (P>0.05). 3) Compared with goose fat supplementation, fish oil supplementation significantly reduced total saturated fatty acid (SFA) content in the liver (P<0.05), and significantly increased unsaturated fatty acid (UFA) C16:1, C17:1, C18:1n-9, C18:2n-6, C18:3n-3, C20:1n-9, C20:4n-6, C20:5n-3, C22:1n-9, C22:5n-3, C22:6n-3, C24:1n-9, and total UFA contents in the liver (P<0.05); rapeseed oil supplementation significantly reduced total SFA content in the liver (P<0.05), and significantly increased UFA C16:1, C18:1n-9, C18:2n-6, C20:2, C22:1n-9, and total UFA contents in the liver (P<0.05); beef tallow supplementation significantly increased C18:3n-3, C20:5n-3, C22:5n-3, C22:6n-3, and total polyunsaturated fatty acid (PUFA) contents (P<0.05). It was concluded that compared with goose fat supplementation, dietary supplementation with rapeseed oil or beef tallow resulted in better liver production performance in force-fed Landes geese; fish oil and rapeseed oil supplementation increased PUFA content and reduced serum lipid content in the liver of force-fed Landes geese.

Full Text

Effects of Different Oils on Performance, Serum Parameters, and Liver Fatty Acid Composition of Landes Geese During the Overfeeding Period

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Abstract

This experiment was conducted to investigate the effects of dietary supplementation with different oils on liver performance, fat deposition, slaughter performance, serum parameters, and liver fatty acid composition of Landes geese during the overfeeding period. Eighty 70-day-old healthy female Landes geese with body weight of (3.0±0.1) kg were randomly allocated into four groups, each consisting of four replicates with five geese per replicate. The goose fat group served as the control, receiving a diet supplemented with 2% goose fat, while the beef tallow, fish oil, and rapeseed oil groups were experimental groups receiving diets supplemented with 2% beef tallow, fish oil, and rapeseed oil, respectively. The experiment included a 7-day pre-trial period followed by a 20-day overfeeding period. The results showed: (1) Both the rapeseed oil and beef tallow groups exhibited significantly higher liver weight compared to the fish oil group ($P<0.05$), while the beef tallow group showed significantly higher liver weight to body weight ratio than the goose fat group ($P<0.05$). The live weight and eviscerated weight of the rapeseed oil and goose fat groups were significantly higher than those of the beef tallow and fish oil groups ($P<0.05$). (2) The fish oil group demonstrated significantly lower serum triglyceride (TG), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL) contents compared to the goose fat group ($P<0.05$). The rapeseed oil group showed significantly lower serum LDL content than the goose fat group ($P<0.05$) and significantly lower serum total cholesterol (TC) content than the beef tallow group ($P<0.05$). The beef tallow group exhibited significantly higher serum high-density lipoprotein (HDL) content than the goose fat group ($P<0.05$). Serum alanine transaminase (ALT) and aspartate aminotransferase (AST) activities in the beef tallow, fish oil, and rapeseed oil groups were numerically lower than those in the goose fat group, though the differences were not significant ($P>0.05$). (3) Compared with goose fat supplementation, fish oil supplementation significantly reduced total saturated fatty acids (SFA) content in the liver ($P<0.05$) and significantly increased contents of unsaturated fatty acids (UFA) including C16:1, C17:1, C18:1n-9, C18:2n-6, C18:3n-3, C20:1n-9, C20:4n-6, C20:5n-3, C22:1n-9, C22:5n-3, C22:6n-3, C24:1n-9, and total UFA ($P<0.05$). Rapeseed oil supplementation significantly reduced total SFA content in the liver ($P<0.05$) and significantly increased contents of UFA C16:1, C18:1n-9, C18:2n-6, C20:2, C22:1n-9, and total UFA ($P<0.05$). Beef tallow supplementation significantly increased contents of C18:3n-3, C20:5n-3, C22:5n-3, C22:6n-3, and total polyunsaturated fatty acids (PUFA) ($P<0.05$). It is concluded that compared with goose fat, dietary supplementation with rapeseed oil or beef tallow resulted in better liver performance in overfed Landes geese, while supplementation with fish oil and rapeseed oil increased liver PUFA content and reduced serum lipid levels.

Keywords: oil; Landes goose; overfeeding; fat deposition; serum parameters; fatty acid composition

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Introduction

Lipids play a crucial role in dietary formulations by providing high levels of energy and essential fatty acids [1]. The health benefits of polyunsaturated fatty acids (PUFA) have garnered increasing attention. Previous studies have demonstrated that the fatty acid composition of meat and eggs largely reflects dietary lipid sources [2-3], and that PUFA can reduce serum lipid levels and modify fatty acid composition in animal tissues [4-5]. Research has shown that dietary supplementation with vegetable oils and fish oil can effectively increase n-3 PUFA content in pork [6], chicken [7-8], and eggs [9-10]. Zhang et al. [11] reported that different oils added to overfeeding diets significantly altered liver composition in Landes geese. Modifying fatty acid composition to favor higher n-3 PUFA over n-6 PUFA and/or saturated fatty acids (SFA) offers desirable health benefits.

Goose fatty liver (foie gras) possesses exceptional nutritional value and unique health-promoting properties, making it highly favored by consumers. During foie gras production, appropriate dietary oil supplementation serves dual purposes: it acts as a lubricant to prevent esophageal injury while simultaneously elevating energy levels to improve utilization efficiency of dietary energy and nutrients [12], thereby accelerating fatty liver formation. Traditional foie gras production typically employs animal-derived fats, with goose fat being rich in SFA, raising health concerns. Fish oil is an important source of unsaturated fatty acids (UFA), rich in n-3 PUFA such as C18:3n-3 [-linolenic acid (ALA)], C20:5n-3 [eicosapentaenoic acid (EPA)], and C22:6n-3 [docosahexaenoic acid (DHA)] [13], while rapeseed oil contains substantial C18:1n-6 [oleic acid (OA)] [14]. Studies have found that dietary fish oil and rapeseed oil not only enhance animal performance but also enrich PUFA content in livestock and poultry products [14-15]. However, the efficacy of PUFA in goose fatty liver remains inadequately investigated, and reports on how different oils affect liver performance are inconsistent, possibly due to variations in fatty acid composition and ratios among added oils. Therefore, this experiment was designed to compare the effects of goose fat, beef tallow, fish oil, and rapeseed oil on production performance, serum parameters, and liver fatty acid composition in Landes geese under isoenergetic overfeeding conditions, providing a theoretical basis for optimizing dietary formulation techniques for liver-producing geese to improve their physiological status, modify liver fatty acid distribution, and produce nutritionally desirable foie gras.

Materials and Methods

1.1 Experimental Animals

Experimental Landes geese were provided by Changxing Rongyao Goose Industry Co., Ltd. in Huzhou City, Zhejiang Province. The geese were raised under natural lighting conditions with free access to feed and water until 70 days of age.

1.2 Experimental Design

Eighty healthy female Landes geese with similar body weight [(3.0±0.1) kg] were randomly divided into four groups, each comprising four replicates with five geese per replicate. The goose fat group served as the control, receiving a basal diet supplemented with 2% goose fat. The beef tallow, fish oil, and rapeseed oil groups were experimental groups receiving basal diets supplemented with 2% beef tallow, fish oil, and rapeseed oil, respectively.

1.3 Feeding Management

Geese were housed in net-floor pens for overfeeding in small groups. Prior to the pre-feeding period, deworming of experimental geese and disinfection of pens and feeding equipment were completed. Clean drinking water was provided ad libitum, and manure was removed promptly to maintain pen hygiene. During the overfeeding period, the health status of geese was monitored closely.

Corn served as the primary feed ingredient. Screened corn kernels were soaked in water for over 3 hours, boiled for approximately 20 minutes, drained, and then mixed while hot with 2.0% oil, 0.5% salt, and vitamin-mineral premix powder. The mixture was cooled before use. All experimental diets were identical except for the oil source; diet composition is presented in Table 1 . The feeding regimen began with a 7-day pre-trial period followed by a 20-day overfeeding period, with gradually increasing feeding frequency and amounts. During days 1-2, geese were fed 2-3 times daily at 100-150 g per feeding; days 3-7, 3-4 times daily at 250 g per feeding; and days 8-27, 5-6 times daily at 300 g per feeding.

Table 1 Diet composition (as-fed basis) %

Items	Corn	Oil	NaCl	Vitamins
Goose fat group	97.0	2.0	0.5	0.5
Beef tallow group	97.0	2.0	0.5	0.5
Fish oil group	97.0	2.0	0.5	0.5
Rapeseed oil group	97.0	2.0	0.5	0.5

Vitamins provided the following per kg of diet: VA 4,000 IU, VD 600 IU, VK 0.1 mg, VB 0.06 mg, VB 0.6 mg, VB 0.06 mg, VC 2.6 mg, nicotinamide 0.6 mg, D-calcium pantothenate 0.4 mg, folic acid 0.04 mg.

1.4 Measurement Indicators and Methods

At the end of the overfeeding period, all geese were fasted for 8 hours (with free access to water). One to two geese from each replicate (five geese per group) were selected for slaughter and sample collection. Live weight, carcass weight, liver weight, abdominal fat weight, intestinal fat weight, and eviscerated weight were measured. Average feed intake per goose was calculated based on group consumption during the overfeeding period. The following parameters were calculated according to the "Poultry Production Performance Terminology and Measurement Methods" [16] (NY/T 823-2004) for geese:

- Abdominal fat percentage (%) = 100 × abdominal fat weight / (eviscerated weight + abdominal fat weight)

- Intestinal fat percentage (%) = 100 × intestinal fat weight / (eviscerated weight + intestinal fat weight)
- Eviscerated yield (%) = 100 × eviscerated weight / live weight
- Feed-to-liver ratio = average feed intake per goose / liver weight
- Liver-to-body weight ratio (%) = 100 × liver weight / carcass weight

Blood samples were collected into 50 mL tubes without anticoagulant, allowed to stand at room temperature (25°C) for 2 hours, then centrifuged at 4,000×g for 15 minutes at 4°C to separate serum, which was stored at -20°C. Serum triglyceride (TG) and total cholesterol (TC) contents were determined using glycerol-3-phosphate oxidase-p-aminophenol and cholesterol oxidase-p-aminophenol methods, respectively. High-density lipoprotein (HDL), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL) contents were measured by direct assay. Alanine transaminase (ALT) and aspartate aminotransferase (AST) activities were determined by Reitman-Frankel colorimetric methods. All serum parameters were measured using corresponding kits from Nanjing Jiancheng Bioengineering Institute.

Fatty acid composition of different oils and liver samples was determined by gas chromatography. Lipids were extracted from oils and liver tissue using the chloroform/method reported by Folch et al. [17]. Fatty acid methyl esters were prepared using boron trifluoride-methanol according to Morrison et al. [18], then analyzed on an HP-5MS column (30 m × 0.25 mm × 0.2 m) using a gas chromatograph (6890, Agilent Technologies, Santa Clara, CA, USA). The average standard error for all fatty acid measurements was below 5%. Liver crude fat content was determined by Soxhlet extraction according to GB/T 14772-2008 "Determination of crude fat in foods." Liver total cholesterol was measured using an Agilent GC-7960II gas chromatograph: liver tissue was saponified with potassium hydroxide and anhydrous ethanol at 85-95°C for 1 hour, extracted with ether, layered, dried with anhydrous sodium sulfate, evaporated under nitrogen, then mixed with anhydrous ethanol and allowed to stand for 15 minutes before measurement.

1.5 Statistical Analysis

Experimental data were preprocessed using Excel 2010 and expressed as mean ± standard error (mean±SE). One-way ANOVA in SPSS 20.0 statistical software was used for statistical analysis. Differences were considered significant at $P<0.05$, and LSD test was used for multiple comparisons among groups.

Results

2.1 Fatty Acid Composition of Different Oils

As shown in Table 2 , rapeseed oil contained abundant n-6 PUFA (52.38% C18:2n-6), while fish oil contained 28.77% n-3 PUFA (C18:3n-3, C20:5n-3, C22:5n-3, and C22:6n-3), making both oils highly unsaturated. In contrast, beef tallow and goose fat contained higher proportions of SFA compared to fish oil and rapeseed oil. Additionally, goose fat had the highest content of monounsaturated fatty acids (MUFA).

Table 2 Fatty acid composition of different oils (percentage of total fatty acids) %

Fatty acids	Goose fat	Beef tallow	Fish oil	Rapeseed oil
C14:0	0.25	1.16	2.18	0.10
C15:0	0.03	0.14	0.02	0.03
C16:0	24.04	23.48	21.50	4.36
C17:0	0.19	0.21	0.17	0.15
C18:0	21.43	21.63	18.31	1.81
C20:0	0.40	0.49	0.51	0.53
C22:0	0.01	0.02	0.01	0.01
C15:1	0.01	0.01	0.01	0.01
C16:1n-7	2.18	2.01	3.10	1.92
C17:1	0.35	0.42	0.46	0.37
C18:1n-9	49.48	49.06	44.64	47.12
C18:1n-6	1.16	1.12	1.15	1.14
C20:1n-9	1.84	2.87	2.71	2.71
C22:1n-9	0.25	0.30	0.25	0.25
C24:1n-9	0.01	0.01	0.01	0.01
ΣMUFA	49.48	49.06	44.64	47.12
C18:2n-6	1.83	1.95	2.39	52.38
C18:3n-3	0.25	0.14	0.15	6.70
C20:2	0.10	0.03	0.03	0.02
C20:4n-6	0.01	0.01	0.02	0.01
C20:5n-3	0.01	0.01	7.22	0.01
C22:3n-6	0.02	0.02	0.02	0.02
C22:5n-3	0.03	0.04	1.47	0.16
C22:6n-3	0.02	0.03	1.48	0.01
ΣPUFA	1.83	1.95	2.39	52.38

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; UFA: unsaturated fatty acids. The same as below in Table 6 .

2.2 Effects of Different Oils on Liver Performance and Fat Deposition in Overfed Landes Geese

As presented in Table 3 , the fish oil group exhibited the lowest liver weight, which was significantly lower than that of the beef tallow and rapeseed oil groups (P<0.05). The goose fat group ranked second, with liver weights 125 g and 127 g lower than the beef tallow and rapeseed oil groups, respectively, though these differences were not significant (P>0.05). The liver-to-body weight ratios in the beef tallow, fish oil, and rapeseed oil groups were all higher than in the goose fat group, with the beef tallow group being significantly higher (P<0.05). The feed-to-liver ratios in the beef tallow and rapeseed oil groups were lower than in the goose fat and fish oil groups, but no significant differences were observed among groups (P>0.05). The beef tallow group showed lower abdominal fat weight and percentage compared to other groups, while the rapeseed oil group had higher abdominal and intestinal fat weights, though these differences were not significant (P>0.05).

Table 3 Effects of different oils on fatty liver performance and fat deposition of Landes geese in overfeeding phase (n=5)

Items	Goose fat group	Beef tallow group	Fish oil group	Rapeseed oil group
Liver weight/g	807.26±71.95ab	932.68±38.81a	773.04±92.46b	934.62±61.37a
Liver weight to body weight ratio/%	11.91±1.12b	15.54±0.78a	13.33±1.28ab	13.89±1.04ab
Feed intake/liver weight	27.44±1.98	24.19±1.05	28.67±3.84	23.38±1.51
Abdominal fat weight/g	422.16±29.77	375.16±10.64	388.00±8.45	434.40±29.37
Percentage of abdominal fat/%	8.56±0.51	8.54±0.19	8.98±0.37	8.59±0.41
Intestinal fat weight/g	287.04±23.93	284.64±7.49	263.36±15.96	293.00±22.75
Percentage of intestinal fat/%	5.97±0.42	6.63±0.23	6.26±0.35	5.99±0.45

In the same row, values with no letter or the same letter superscripts indicate no significant difference (P>0.05), while different lowercase letters indicate significant difference (P<0.05). The same as below.

2.3 Effects of Different Oils on Slaughter Performance of Overfed Landes Geese

Table 4 shows that the rapeseed oil and goose fat groups had significantly higher live weight and eviscerated weight compared to the beef tallow and fish oil groups (P<0.05). The goose fat group achieved the highest eviscerated yield, though no significant differences were observed among groups (P>0.05).

Table 4 Effects of different oils on slaughter performance of Landes geese in overfeeding phase (n=5)

Items	Goose fat group	Beef tallow group	Fish oil group	Rapeseed oil group
Live weight/kg	6.77±0.07a	6.35±0.08b	6.06±0.17b	7.09±0.14a
Eviscerated weight/kg	4.50±0.06a	4.02±0.11b	3.95±0.12b	4.61±0.16a
Percentage of eviscerated yield/%	66.45±1.04	63.73±1.72	65.20±1.25	64.90±1.42

2.4 Effects of Different Oils on Serum Parameters of Overfed Landes Geese

As shown in Table 5 , the goose fat group exhibited relatively high serum TG, TC, LDL, and VLDL contents along with low serum HDL content. Compared to the goose fat group, the fish oil group showed significantly reduced serum TG, LDL, and VLDL contents (P<0.05), while the rapeseed oil group demonstrated significantly lower serum LDL content (P<0.05). The goose fat group had lower serum HDL content than other groups, with the beef tallow group showing a significant difference (P<0.05). Serum ALT and AST activities in the beef tallow, fish oil, and rapeseed oil groups were numerically lower than in the goose fat group, but the differences were not significant (P>0.05). Additionally, the rapeseed oil group exhibited significantly lower serum TC content than the beef tallow group (P<0.05).

Table 5 Effects of different oils on serum parameters of Landes geese in overfeeding phase (n=5)

Items	Goose fat group	Beef tallow group	Fish oil group	Rapeseed oil group
TG/(mmol/L)	4.85±0.64a	4.43±0.50a	2.70±0.19b	3.62±0.38ab
TC/(mmol/L)	12.19±0.85ab	13.73±1.03a	11.26±0.99ab	10.29±1.34b
HDL/(mmol/L)	5.95±1.32b	9.29±0.77a	7.96±0.55ab	6.70±0.92ab
LDL/(mmol/L)	2.54±0.14a	2.87±0.20a	1.81±0.19b	1.81±0.14b
VLDL/(mmol/mL)	322.64±25.92a	286.97±26.31ab	261.81±10.49b	299.05±29.60ab
ALT/(U/L)	30.89±5.68	20.87±3.95	21.82±3.04	25.05±3.07
AST/(U/L)	23.68±5.45	20.94±4.47	19.13±2.25	19.56±3.00

2.5 Effects of Different Oils on Liver Fatty Acid Composition of Overfed Landes Geese

Table 6 reveals that the goose fat group had relatively high C14:0 and C16:0 contents in the liver, while the beef tallow group showed higher C18:0, C18:3n-3, C20:1n-9, and C22:5n-6 contents. Compared with goose fat supplementation, fish oil supplementation significantly reduced hepatic SFA contents including C14:0, C16:0, C18:0, and total SFA ($P<0.05$), while significantly increasing hepatic UFA contents including C16:1, C17:1, C18:1n-9, C18:2n-6, C18:3n-3, C20:1n-9, C20:4n-6, C20:5n-3, C22:1n-9, C22:5n-3, C22:6n-3, C24:1n-9, and total UFA ($P<0.05$). Rapeseed oil supplementation significantly reduced hepatic SFA contents including C14:0, C15:0, C16:0, C18:0, and total SFA ($P<0.05$), while significantly increasing hepatic UFA contents including C16:1, C18:1n-9, C18:2n-6, C20:2, C22:1n-9, and total UFA ($P<0.05$). Compared with the goose fat group, the beef tallow group showed no significant differences in total SFA and total UFA contents ($P>0.05$), but significantly increased contents of C18:3n-3, C20:5n-3, C22:5n-3, C22:6n-3, and total PUFA ($P<0.05$).

Table 6 Effects of different oils on fatty acid composition in liver of Landes geese in overfeeding phase (percentage of total fatty acids, n=5) %

Fatty acids	Goose fat group	Beef tallow group	Fish oil group	Rapeseed oil group
C14:0	1.24±0.03a	1.23±0.01a	1.05±0.02b	1.08±0.02b
C15:0	0.19±0.01ab	0.21±0.01a	0.17±0.01b	0.19±0.01ab
C16:0	24.04±0.04a	23.48±0.15b	21.50±0.04c	23.45±0.05b
C17:0	0.40±0.01b	0.49±0.02a	0.51±0.01a	0.53±0.01a
C18:0	21.43±0.14a	21.63±0.15a	18.31±0.19c	19.94±0.11b
C20:0	0.01±0.00b	0.02±0.00a	0.01±0.00b	0.01±0.00b
C15:1	0.01±0.00b	0.01±0.00b	0.02±0.00a	0.01±0.00b
C16:1	2.18±0.02b	2.01±0.02c	3.10±0.03a	1.92±0.02d
C17:1	0.35±0.01c	0.42±0.02b	0.46±0.01a	0.37±0.01c
C18:1n-9	49.48±0.16a	49.06±0.18a	44.64±0.21c	47.12±0.12b
C20:1n-9	1.84±0.04c	2.87±0.05b	2.71±0.04b	2.71±0.04b

Fatty acids	Goose fat group	Beef tallow group	Fish oil group	Rapeseed oil group
C22:1n-9	0.25±0.01c	0.30±0.01b	0.25±0.01c	0.25±0.01c
C24:1n-9	0.01±0.00b	0.01±0.00b	0.02±0.00a	0.01±0.00b
C18:2n-6	1.83±0.03d	1.95±0.03c	2.39±0.03a	2.10±0.04b
C18:3n-3	0.25±0.01c	0.14±0.01b	0.15±0.01b	0.21±0.01a
C20:2	0.10±0.00b	0.03±0.00	0.03±0.00	0.02±0.00
C20:3	0.05±0.02	0.03±0.00	0.03±0.00	0.15±0.01b
C20:4n-6	0.16±0.01b	0.17±0.01b	0.28±0.01a	0.17±0.01b
C20:5n-3	0.02±0.00c	0.03±0.00b	0.07±0.00a	0.02±0.00c
C22:3n-6	0.03±0.00	0.02±0.00	0.02±0.00	0.01±0.00c
C22:5n-3	0.02±0.00b	0.04±0.00a	0.04±0.00a	0.02±0.00b
C22:6n-3	0.02±0.00c	0.03±0.00b	0.06±0.00a	0.02±0.00c
ΣMUFA	48.69±0.15c	48.99±0.17c	52.96±0.22a	50.77±0.08b
ΣPUFA	1.83±0.03d	1.95±0.03c	2.39±0.03a	2.10±0.04b
ΣUFA	50.52±0.17c	50.94±0.18c	55.35±0.22a	52.87±0.12b

2.6 Effects of Different Oils on Liver TC and Crude Fat Content in Overfed Landes Geese

Table 7 indicates that the fish oil group had significantly lower liver TC content than the beef tallow group ($P<0.05$), while no significant differences in crude fat content were observed among groups ($P>0.05$). Total liver fat content did not differ significantly among groups ($P>0.05$).

Table 7 Effects of different oils on liver TC and crude fat contents of Landes geese in overfeeding phase (n=5)

Items	Goose fat group	Beef tallow group	Fish oil group	Rapeseed oil group
Total cholesterol TC	4.36±0.06ab	4.50±0.06a	4.29±0.08b	4.37±0.02ab
Crude fat CF	7.90±0.09	7.90±0.16	7.94±0.12	7.96±0.11

Discussion

3.1 Effects of Different Oils on Liver Performance and Fat Deposition

Oils provide essential nutritional functions for poultry beyond their thermogenic effects, supplying essential fatty acids—particularly linoleic acid (C18:2n-6) and linolenic acid (C18:3n-3) that cannot be synthesized in animal tissues [19]. Research indicates that poultry utilize unsaturated fatty acids (UFA) more efficiently than saturated fatty acids (SFA), with the metabolizable energy value of oils increasing with higher contents of unsaturated long-chain fatty acids and free fatty acids, while decreasing with higher saturated long-chain fatty acid contents [20]. Among vegetable oils, rapeseed oil is particularly rich in UFA [21]. To improve dietary energy and oil utilization efficiency, this experiment supplemented different oils in the diet. The results demonstrated that the rapeseed oil and beef tallow groups achieved superior liver performance, while the goose fat and fish oil groups showed inferior performance. Bao et al. [22] reported that in foie gras production, dietary vegetable oil (rapeseed oil) yielded slightly greater average liver weight than animal fat (lard), though the difference was not significant. Xu [23] found that feeding vegetable oils rich in MUFA increased liver weight in Cherry Valley ducks, consistent with our results. These findings suggest that geese utilize different oils differently, likely due to their distinct fatty acid compositions. Rapeseed oil’ s high UFA content and beef tallow’ s high SFA content both promoted substantial fat deposition in the liver, whereas fish oil’ s distinctive fishy odor and susceptibility of its PUFA to -oxidation may have impaired digestion and absorption. Therefore, Landes geese demonstrated higher utilization efficiency for rapeseed oil and beef tallow, thereby enhancing dietary energy utilization and overfeeding efficacy.

In this experiment, abdominal fat percentage was minimally affected by oil type, with no significant differences among treatments—consistent with previous findings that abdominal fat deposition is not influenced by fat type [24-26]. Edwards et al. [27] reported that chickens fed high-fat diets had slightly higher carcass fat content than controls, though differences were not significant, possibly because increased net energy in high-fat diets expanded the energy-to-protein ratio. Thus, when dietary fat and energy increase, dietary PUFA does not further promote abdominal fat deposition.

3.2 Effects of Different Oils on Slaughter Performance

Oils exert special energy effects in poultry diets, synergizing with other nutrients to enhance the utilization efficiency of energy from other dietary components, thereby increasing the metabolizable energy value of oils beyond their gross energy content and improving poultry performance [20]. Most studies indicate that poultry absorb vegetable oils more efficiently than animal oils, except for fish oil. An [28] reported that in broilers, feed-to-gain ratio was significantly lower in groups fed palm oil-based or coconut oil-based blended fats compared to lard, with no significant differences from soybean oil. Cai et al. [29] demonstrated that palm oil improved broiler performance; palm oil is rich in palmitic acid (C16:0), which has higher digestibility than stearic acid (C18:0) among SFA. Zhu et al. [30] found that broilers fed soybean oil had significantly higher body weight gain than those fed lard, aligning with our results. In this experiment, the rapeseed oil group achieved higher live weight and eviscerated weight than other groups, with significant differences from the beef tallow and fish oil groups. This indicates that poultry utilize different oils differently, with higher efficiency for UFA than SFA, likely because fats not only provide energy, essential fatty acids, and fat-soluble vitamins for growth and development, improve transport of fat-soluble vitamins, and promote energy utilization, but also constitute body cells, dissolve nutrients, and regulate physiological functions [22]. Most studies have shown that fish oil supplementation yields higher performance [8,26,31]. However, our results did not demonstrate superior performance (e.g., slaughter performance, liver weight, liver-to-body weight ratio) with fish oil supplementation, possibly because oils primarily exert growth-promoting effects during later growth stages, with n-3 fatty acid-rich fish oil having maximal effects in late growth. Our relatively short overfeeding period with adequate energy supply may have precluded significant differences.

3.3 Effects of Different Oils on Serum Parameters

Previous reports indicate that diets rich in UFA can reduce serum TC, TG, and LDL contents while increasing HDL content [3,14]. Our results showed that compared with goose fat, fish oil and rapeseed oil (rich in UFA) reduced serum TG content, while beef tallow (rich in SFA) increased serum TG, TC, HDL, and LDL contents. Elevated serum TG and TC are well-established risk factors for heart disease. VLDL and LDL are major lipoproteins transporting fatty acids and cholesterol through blood circulation. This study demonstrated that compared with goose fat, beef tallow increased serum LDL content, while fish oil and rapeseed oil decreased it. All oil groups showed reduced serum VLDL content compared to the goose fat group. Research suggests that dietary UFA can interfere with VLDL secretion by inhibiting fatty acid synthesis, promoting fatty acid oxidation, increasing lipoprotein lipase activity, and enhancing conversion of fatty acids to phospholipids [32-34]. High-density lipoprotein cholesterol (HDL-C) is known as "good" cholesterol, as HDL removes cholesterol from blood and returns it to the liver for recycling. Studies show that SFA intake impairs HDL antioxidant capacity and increases oxidized lipoprotein content, whereas PUFA intake enhances HDL antioxidant capacity [35]. In our study, serum HDL content was higher in the fish oil, rapeseed oil, and beef tallow groups than in the goose fat group. These results suggest beneficial effects of fish oil and rapeseed oil on cholesterol metabolism, as also described in other studies [24,36-37].

Serum AST and ALT activities are affected by different dietary lipid sources. AST and ALT activities are normally low in blood but increase when liver tissue is damaged, as these enzymes are released from cells into circulation [38]. Although differences in serum AST and ALT activities among groups were not significant in our study, the goose fat group showed numerically higher activities than the beef tallow, fish oil, and rapeseed oil groups. Metwally et al. [39] found that fish oil (5%, 10%) reduced diethylnitrosamine-induced elevation of serum AST and ALT activities in rats. These results suggest that beef tallow, fish oil, and rapeseed oil can protect hepatocytes to some extent and improve liver function in Landes geese.

3.4 Effects of Different Oils on Liver Fatty Acid Composition

High dietary fat intake may promote liver fat accumulation [40], and the fatty acid composition of muscle and liver reflects that of dietary lipids [41]. Studies have shown that diets supplemented with vegetable oils and fish oil effectively enhance n-3 PUFA content in pigs, chickens, and eggs [42]. Research in ducks indicates that under isoenergetic overfeeding conditions, fish oil supplementation improves liver performance and fatty liver quality. Zhou et al. [43] investigated effects of corn oil, soybean oil, and fish oil on Cherry Valley ducks, finding that fish oil and soybean oil groups showed significantly reduced SFA and increased UFA contents in fatty livers. Wan [26] reported that dietary beef tallow, soybean oil, and fish oil increased n-3 PUFA content in liver, subcutaneous fat, and blood of Peking ducks. Our results showed that fish oil supplementation yielded higher hepatic n-3 PUFA content than other groups, primarily due to significantly higher C20:5n-3 and C22:6n-3 contents, while also increasing hepatic n-6 PUFA content. Compared with goose fat, beef tallow supplementation increased hepatic n-3 PUFA content but decreased n-6 PUFA content. Rapeseed oil supplementation did not substantially change hepatic n-3 PUFA content but increased n-6 PUFA content compared with goose fat. Chen et al. [42] studied effects of different oils on fatty acid distribution and n-3 PUFA conversion in duck liver, finding that flaxseed oil and fish oil significantly increased total hepatic n-3 PUFA content, while no significant changes were observed with rapeseed oil or beef tallow—similar to our findings. Du et al. [14] reported that dietary fish oil, flaxseed oil, and rapeseed oil (rich in UFA) increased yolk PUFA content in Shan Partridge ducks. Liver crude fat content did not differ significantly among groups in our study, while fish oil exhibited cholesterol-lowering effects in the liver, consistent with Du et al.' s [14] findings in duck egg yolk.

SFA content positively correlates with liver fat content [44]. López-Ferrer et al. [45] suggested that replacing beef tallow with fish oil reduces dietary SFA content, primarily C16:0 followed by C18:0. Consistent with López-Ferrer et al. [45], our experiment showed that diets supplemented with fish oil and rapeseed oil contained lower SFA than those with beef tallow and goose fat, and hepatic SFA contents including C16:0 and C18:0 were reduced. The health benefits of marine oils like fish oil are attributed to high n-3 long-chain PUFA (n-3 LC-PUFA) content, mainly C20:5n-3, C22:5n-3, and C22:6n-3, which are primarily esterified in TG in fish oil [46]. SFA are more readily deposited in tissues than MUFA and PUFA [41]. The significant reduction in hepatic SFA content after fish oil and rapeseed oil supplementation resulted from corresponding increases in UFA content. This indicates a strong correlation between hepatic SFA content and dietary SFA content in geese. Although SFA sources and transformation are complex due to dual origins (dietary, hepatic, and tissue synthesis) and potential conversion through elongation and desaturation, which may result in low correlation coefficients between tissue and dietary SFA content [26], overfed geese accumulate excessive energy, and hepatic fat may be absorbed directly from the diet when energy expenditure is minimal.

Conclusion

This experiment demonstrated that compared with dietary goose fat supplementation, rapeseed oil or beef tallow supplementation resulted in superior liver performance in overfed Landes geese. Supplementation with PUFA-rich oils (fish oil and rapeseed oil) improved serum and hepatic lipid parameters without significantly affecting slaughter performance. These oils may be considered as alternatives to goose fat for producing foie gras with high PUFA and low cholesterol content, offering health benefits for human consumption.

References

[1] NRC. Nutrient requirements of fish and shrimp[S]. Washington, D.C.: National Academies Press, 2011: 601-602.

[2] YALCIN H. Chapter 35-Supplemental fish oil and its impact on n-3 fatty acids in eggs[M]//HESTER P. Egg innovations and strategies for improvements. 2nd ed. San Diego: Academic Press, 2017: 373-381.

[3] LIU W M, LAI S J, LU L Z, et al. Effect of dietary fatty acids on serum parameters, fatty acid compositions, and liver histology in Shaoxing laying ducks[J]. Journal of Zhejiang University Science B, 2011, 12(9): 736-743.

[4] KOUBA M, MOUROT J. A review of nutritional effects on fat composition of animal products with special emphasis on polyunsaturated fatty acids[J]. Biochimie, 2011, 93(1): 13-17.

[5] SHEARER G C, SAVINOVA O V, HARRIS W S. Fish oil—How does it reduce plasma triglycerides?[J]. Biochimica et Biophysica Acta: Molecular and Cell Biology of Lipids, 2012, 1821(5): 843-851.

[6] HAAK L, DE SMET S, FREMAUT D, et al. Fatty acid profile and oxidative stability of pork as influenced by duration and time of dietary linseed or fish oil supplementation[J]. Journal of Animal Science, 2008, 86(6): 1418-1425.

[7] HAUG A, NYQUIST N F, THOMASSEN M, et al. n-3 fatty acid intake altered fat content and fatty acid distribution in chicken breast muscle, but did not influence mRNA expression of lipid-related enzymes[J]. Lipids in Health and Disease, 2014, 13(1): 92.

[8] AGHAEI N, SAFAMEHR A, MEHMANNAVAZ Y, et al. Blood and tissue fatty acid compositions, lipoprotein levels, performance and meat flavor of broil-

ers fed fish oil: changes in the pre- and post-withdrawal design[J]. Animal, 2012, 6(12): 2031-2040.

[9] LEMAHIEU C, BRUNEEL C, TERMOTE-VERHALLE R, et al. Impact of supplementation with different omega-3 rich microalgae species on enrichment of eggs of laying hens[J]. Food Chemistry, 2013, 141(4): 4051-4059.

[10] ANTRUEJO A, AZCONA J O, GARCIA P T, et al. Omega-3 enriched egg production: the effect of -linolenic -3 fatty acid sources on laying hen performance and yolk lipid content and fatty acid composition[J]. British Poultry Science, 2011, 52(6): 750-760.

[11] ZHANG C, LIAN C J, YANG Z J, et al. Effects of different fatty source on fatty liver performance and composition of fatty liver in Landes goose[J]. Journal of Animal and Veterinary Advances, 2012, 11(16): 2964-2968.

[12] CHENG L. Special energy effects of oils on poultry[J]. Foreign Animal Science and Technology, 1991, 18(2): 32, 45.

[13] DU X, TIAN Y, LU L Z. Research progress on nutritional regulation of lipid metabolism in poultry and its molecular mechanisms[J]. Journal of Zhejiang Agricultural Sciences, 2016, 57(5): 740-743.

[14] DU X, LIU Y, LU L, et al. Effects of dietary fats on egg quality and lipid parameters in serum and yolks of Shan Partridge Duck[J]. Poultry Science, 2017, 96(5): 1184-1190.

[15] WOODS V B, FEARON A M. Dietary sources of unsaturated fatty acids for animals and their transfer into meat, milk and eggs: a review[J]. Livestock Science, 2009, 126(1/2/3): 1-20.

[16] Ministry of Agriculture of the People' s Republic of China. NY/T 823-2004 Poultry production performance terminology and measurement methods[S]. Beijing: China Agriculture Press, 2004.

[17] FOLCH J, LEES M, SLOANE STANLEY G H. A simple method for the isolation and purification of total lipids from animal tissues[J]. Journal of Biological Chemistry, 1957, 226(1): 497-509.

[18] MORRISON W R, SMITH L M. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol[J]. Journal of Lipid Research, 1964, 5(4): 600-608.

[19] ABEDI E, SAHARI M A. Long-chain polyunsaturated fatty acid sources and evaluation of their nutritional and functional properties[J]. Food Science & Nutrition, 2014, 2(5): 443-463.

[20] LIAN C J, NIU S L, ZHU T, et al. Study on effects of different fat sources on fatty liver and performance of overfed geese[J]. Feed Industry, 2007, 28(19): 30-32.

[21] XIONG Q F, ZHANG X M, WEN J, et al. Comparison of nutritional quality between rapeseed oil and different edible vegetable oils—discussion on genetic improvement of rapeseed quality[J]. Journal of the Chinese Cereals and Oils Association, 2014, 29(6): 122-128.

[22] BAO M D, WANG Y Q, SHI J T, et al. Effects of adding animal and vegetable oils to goose overfeeding diet on fatty liver performance[J]. Livestock and Poultry Industry, 2006(16): 18-19.

[23] XU C L. Study on effects of different vegetable oils on fat metabolism and cholesterol content in fatty liver of Cherry Valley ducks[D]. Master' s thesis. Nanning: Guangxi University, 2007: 25-39.

[24] XIA Z S. Effects of different dietary fats on tissue lipid content and fatty acid composition in growing chickens[J]. Journal of Guangxi Agricultural University, 1998, 17(4): 323-332.

[25] PINCHASOV Y, NIR I. Effect of dietary polyunsaturated fatty acid concentration on performance, fat deposition, and carcass fatty acid composition in broiler chickens[J]. Poultry Science, 1992, 71(9): 1504-1512.

[26] WAN W J. Effects of different oil supplementation on performance, blood lipids and tissue fatty acid composition in Peking ducks[D]. Master' s thesis. Tai' an: Shandong Agricultural University, 2003: 18-39.

[27] EDWARDS H M, Jr, MAY K N. Studies with menhaden oil in practical-type broiler rations[J]. Poultry Science, 1965, 44(3): 685-689.

[28] AN W J. Study on effects of different dietary oil ratios on broiler performance, meat quality and lipid metabolism[D]. Master's thesis. Nanjing: Nanjing Agricultural University, 2010: 38-43.

[29] CAI Z H, GUO J T. Feeding trial of adding palm oil to broiler diets[J]. Fujian Animal Husbandry and Veterinary Medicine, 2000, 22(5): 4-5.

[30] ZHU J P, ZHU J J, WANG X D, et al. Comparative study on application effects of various oils in broiler compound feed[J]. Feed Industry, 1997, 18(4): 5-6.

[31] FENG D Y, ZENG X L, WANG Z, et al. Comparison of application effects of three feed oils in late-stage broiler diets[J]. China Feed, 1997(1): 19-20.

[32] KANG J X, LEAF A. The cardiac antiarrhythmic effects of polyunsaturated fatty acid[J]. Lipids, 1996, 31(Suppl.): S41-S44.

[33] CYBULSKA I. n-3 polyunsaturated fatty acid in cardiovascular disease[J]. Przeglad Lekarski, 2006, 63(8): 685-687.

[34] FERNANDEZ M L, WEST K L. Mechanisms by which dietary fatty acids modulate plasma lipids[J]. The Journal of Nutrition, 2005, 135(9): 2075-2078.

[35] CEDÓ L, METSO J, SANTOS D, et al. Consumption of polyunsaturated fat improves the saturated fatty acid-mediated impairment of HDL antioxidant

potential[J]. Molecular Nutrition & Food Research, 2015, 59(10): 1987-1996.

[36] TRAUTWEIN E A, RIECKHOFF D, KUNATH-RAU A, et al. Replacing saturated fat with PUFA-rich (sunflower oil) or MUFA-rich (rapeseed, olive and high-oleic sunflower oil) fats resulted in comparable hypocholesterolemic effects in cholesterol-fed hamsters[J]. Annals of Nutrition and Metabolism, 1999, 43(3): 159-172.

[37] PHETTEPLACE H W, WATKINS B A. Lipid measurements in chickens fed different combinations of chicken fat and menhaden oil[J]. Journal of Agricultural and Food Chemistry, 1990, 38(9): 1848-1853.

[38] ZHU L H, WU Y J, GUAN J J, et al. Effects of overfeeding on blood parameters, tissue nutrient composition and liver histology in Landes geese[J]. China Poultry, 2010, 32(3): 28-31.

[39] METWALLY N S, KHOLEIF T E, GHANEM K Z, et al. The protective effects of fish oil and artichoke on hepatocellular carcinoma in rats[J]. European Review for Medical and Pharmacological Sciences, 2011, 15(12): 1429-1444.

[40] WESTERBACKA J, LAMMI K, HAKKINEN A M, et al. Dietary fat content modifies liver fat in overweight nondiabetic subjects[J]. The Journal of Clinical Endocrinology & Metabolism, 2005, 90(5): 2804-2809.

[41] QIU H, JIN M, LI Y, et al. Dietary lipid sources influence fatty acid composition in tissue of large yellow croaker (Larmichthys crocea) by regulating triacylglycerol synthesis and catabolism at the transcriptional level[J]. PLoS One, 2017, 12(1): e169985.

[42] CHEN X, DU X, SHEN J L, et al. Original Research: effect of various dietary fats on fatty acid profile in duck liver: efficient conversion of short-chain to long-chain omega-3 fatty acids[J]. Experimental Biology and Medicine, 2017, 242(1): 80-87.

[43] ZHOU L, ZENG Q F, ZHANG K Y, et al. Effects of different oils on fatty liver quality in meat ducks under isoenergetic overfeeding conditions[J]. Chinese Journal of Animal Nutrition, 2010, 22(6): 1558-1565.

[44] TIIKKAINEN M, BERGHOLM R, VEHKAVAARA S, et al. Effects of identical weight loss on body composition and features of insulin resistance in obese women with high and low liver fat content[J]. Diabetes, 2003, 52(3): 701-707.

[45] LÓPEZ-FERRER S, BAUCELLS M D, BARROETA A C, et al. n-3 enrichment of chicken meat. 1. Use of very long-chain fatty acids in chicken diets and their influence on meat quality: fish oil[J]. Poultry Science, 2001, 80(6): 741-752.

[46] GHASEMIFARD S, HERMON K, TURCHINI G M, et al. Metabolic fate (absorption, -oxidation and deposition) of long-chain n-3 fatty acids is affected

by sex and source (krill oil or fish oil) in rat[J]. British Journal of Nutrition, 2015, 114(5): 684-692.

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