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JZ Xin, S Liu

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Research article
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Effects of dietary supplementation with radix hedysari on production performance and antioxidant capacity of sheep

J.Z. Xin,[1] S. Liu[2*]

[1]*School of Life Sciences, Yantai University , Yantai 264005 PR China*

[2]*School of Pharmacy, Yantai University , Yantai 264005 PR China*

ABSTRACT: The aim of this study was to investigate the effects of dietary supplementation with Radix hedysari (RH) on the growth performance, slaughter performance, activity of antioxidant enzyme, and lipid metabolite of sheep. Forty 140-day-old Duhan hybrid ewe were selected and randomly allocated into four groups. Four dietary treatments were used: (1) basal diet without supplementation (Control), (2) basal diet supplemented with 1% RH, (3) basal diet supplemented with 3% RH, and (4) basal diet supplemented with 10% RH. The diets were fed for 75 d, consisting of 10 d for adaptation followed by 65 d of experimental observation. Treatment did not significantly influence ADFI, ADG and FCR. Dietary supplementation with higher RH (3%, 10%) significantly ($P < 0.05$) increased the dressing percentage and net meat weight, and significantly ($P < 0.05$) decreased the omental and perirenal adipose tissue percentage. The 10% RH treatment significantly ($P < 0.05$) increased antioxidant enzyme activities in samples and decreased the content of malondialdehyde (MDA) in samples. The addition of higher RH also decreased significantly ($P < 0.05$) the concentration of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and triglyceride (TG) in samples, and increased the content of HDL-C significantly ($P < 0.05$). Sheep fed RH had more C18:1n9, C18:3n3, MUFA, and UFA, and a higher PUFA/SFA ratio in LD and omental adipose tissue (OAT) than animals in CON. Together, these results suggest that RH has a positive effect on the slaughter performance, antioxidation, lipid metabolite of Duhan hybrid sheep, and is also conductive to providing healthy and nutritious high-quality livestock products.

Keyword: radix hedysari, sheep, slaughter performance, antioxidant capacity, lipid metabolite.

Correspondence author:
S. Liu,
School of Pharmacy, Yantai University , Yantai 264005
PR China
E-mail address: liusheng87@126.com

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INTRODUCTION

Mutton is rich in proteins, vitamins, fatty acids and minerals and is considered an important source of dietary meat for human consumption (Cheng,et al., 2025; Deng et al., 2017; Liang et al., 2020). With the development of economy, there's an increasing number market demand for high quality mutton. The traditional feeding methods for sheep such as grazing on grassland have been prohibited in some places for protecting the grassland ecosystem in China, and the feeding systems of sheep have been transformed into indoor fattening style (Su et al., 2022). The condition of house feeding has caused some problems such as excessive increase in adipose deposits (especially visceral fat deposits) caused by high energy diet and the decrement of antioxidant enzymes activity due to the lack of a certain amount of exercise (Rossi et al., 2013; Su et al., 2022). The massive accumulation of fat has been unable to meet efficiency of animal husbandry and current requirements for human health (Wang et al., 2021). The decrease of antioxidant enzymes activity may result in oxidative stress status of livestock, which affects the growth of animal and quality of animal product (Su et al., 2022). Reducing the excess fat in animal body and improving the antioxidant capacity of body are key focus of animal nutrition and food science. Some natural additives with low toxicity, especially from plants, have been used for improving the growth to enhance the quality of animal product (Casamassima et al., 2012; Deng et al., 2017; Qin et al., 2020; Rossi et al., 2013).

Radix Hedysari (RH), referred to as "HongQi" (HQ) in Chinese, is the dried root of Hedysarum polybotrys Hand.-Mazz and an edible and medicinal plant, which belongs to the fabaceae family (Li et al., 2023; Zhang et al., 2023). The producing areas for RH are mainly in west China, including Gansu, Inner Mongolia and Sichuan (Chen et al., 2019). RH is a well-known Chinese herbal medicine for its multiple biological activity, such as anti-oxidant, lipid-lowering, anti-inflamatory, anti-tumor, immunomodulatory, hypoglycemic, and antihypertensive due to the various effective ingredients, including polysaccharide, flavonoids, ginsenoside, trace elements and amino acids (Li et al., 2023; Wei et al., 2015; Xue et al., 2021). To the best of the authors' knowledge, little information about the effects of dietary RH supplementation on carcass traits, tissue antioxidant status, lipid metabolic balance, and meat quality in sheep is available.

Thus, this study was carried out with a hypothesis that RH supplementation can improve the growth performance, tissue antioxidant, and lipid metabolism of Duhan sheep. The objective of this study is to evaluate the effect of RH as feed additives on the carcass traits, tissue antioxidant status, and lipid metabolic balance of Duhan hybrid sheep, reveal its potential nutritional and health effects, and provide theoretical basis and practical reference for widespread application of RH in the sheep industry.

MATERIALS AND METHODS

Ethics statement

All experiments were conducted according to procedures authorized by Committee of Yantai University for the Care and Use of Laboratory Animals (Approval number, YTU20140803) and performed in compliance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals (publication 86-23, revised in1986).

Animals, diets and experimental design

A total of forty Duhan hybrid ewe at 140 ± 3 d of age and 30.00 ± 0.70 kg live weight were selected from Jiyang County Anfang Sheep Breeding Professional Cooperative, Jinan, Shandong Province, China. The sheep were equally distributed into 4 groups in a completely randomized design, and each group was assigned randomly to 0% Radix Hedysari (control group (CON), basal diet), 1% of Radix Hedysari (1RH group), 3% of Radix Hedysari (3RH group) and 10% of Radix Hedysari (10RH group) containing diets. The Radix Hedysari was obtained from yellow river medicinal materials market (Lanzhou, Gansu Province, China). The nutritional composition of the RH is shown in Table 1. The feeds were pelleted, and ingredients and nutrient contents of basal diets are included in Table 2. All animas were fed an adaptation diet for 10 d ad libitum before formal trial, and formal trial lasted for 65 d.

The sheep house was well ventilated and naturally illuminated. Before the experiment, the floor, walls, and fences of the sheep house were thoroughly disinfected. During the prefeeding period, the health of lambs was evaluated, and all lambs were treated for parasites.

Growth performance

All sheep were weighed on an empty stomach before morning feeding on the 1st and 75th day of the trial period, with the body weight on the 1st day as the initial weight and the body weight on the 75th day

Table 1. Nutritional composition of radix hedysari (mg/100 g dry matter).

Chemical composition	Amount
Amino acids	
Argnine	100.8
Aspartic acid	711.1
Glutamic acid	36.1
Glycine	13.2
Histidine	8.6
Isoleucine	37.6
Leucine	14.2
Lysine	2.1
Methionine	8.6
Phenylalanine	8.7
Proline	1512.3
Serine	201.1
Threonine	231.6
Tryptophane	10.6
Tyrosine	6.12
Valine	14.8
Minerals	
Calcium	0.2727
Copper	0.01924
Iron	0.1325
Magnesium	8.873
Potassium	1.732
Zinc	0.3842
Flavonoids	
Calycosin	2.146
Calycosin-7-glucoside	0.6651
Formononetin	15.31
Isoliquiritigenin	1.745
Medicarpin	18.13
Ononin	24.16
Total radix hedysari polysaccharide	43212.50

as the final weight. The average daily feed intake (ADFI), average daily gain (ADG), and feed conversion rate (FCR) were calculated by recording the body weight, feed intake, and leftover feed of sheep.

Slaughter performance

At the end of the experiment, eight lambs from each group were selected randomly for slaughter after fasting for 12 h, then they were weighed and recorded as the live weight before slaughter (LWBS). After obtaining the slaughter live weight, the sheep were slaughtered in Jiyang County Anfang Sheep Breeding Professional Cooperative following the industrial practice. The weight after removing the fur, head, hoofs, and viscera was recorded as carcass weight and calculate the dressing percentage. The vernier caliper was used to measure the GR value of carcass, and the tissue thickness between the 12th and 13th ribs of sheep at the 11 cm of the midline of the dorsal spine was considered as the GR value. Each carcass was measured three times, and the average value was taken as the GR value. The omentum, mesentery and perirenal adipose tissue were separated and weighed, and the proportion of omental and perirenal adipose tissue to carcass was calculated. The calculation formula of omental adipose tissue (OAT) percentage was as follows: OAT percentage (%) = 100 × (omentum weight + mesentery weight) / (carcass weight). The calculation formula of perirenal adipose tissue percentage was similar to the above one.

Sample collection

The blood samples were collected by 10 mL plastic centrifuge tubes from all lambs, then the blood was centrifuged at 3,500×g for 10 min to obtain serum. All serum samples were stored at −80°C for later analysis. Approximately 30 g samples were taken from: the left longissimus dorsi (LD) muscle between the 7th and 9th ribs, OAT, and the left side of the liver. These samples were immediately frozen in liquid nitrogen and stored at −80°C for later analysis.

The activity of antioxidant enzyme and the content of oxidation products in serum, liver, and LD

Serum, liver, and LD glutathione peroxidase activity (GSH-Px) was determined by colorimetric method, superoxide dismutase activity (SOD) by hydroxylamine method, and total antioxidant capacity (T-AOC) by ABTS method, and malondialdehyde (MDA) content by thiobarbituric acid (TBA) method. The full-band enzyme labeling instrument (SynergyH4, BioTek Company, USA) was used to detected above indexes, and the specific operation method was carried out by referring to the manual of the kit (Nanjing Jiancheng Bioengineering Institute, Nanjing, Jiangsu, China).

Lipid metabolite analyses of serum, liver and LD

Serum, liver and LD lipid metabolite concentrations, including total cholesterol (TC), high-density lipo-

Table 2. Composition and nutrient levels of basal diets (air-dry matter basis, %).

Ingredients	%	Nutrient levels	Content
Corn	19.43	DE (MJ/Kg)	18.22
Corn Stover	30.45	DM	93.6
Soybean meal	8.47	Organic matter, % DM	93.1
Flax seed	7.4	Crude protein, % DM	14.36
Sunflower meal expeller	9.2	NDF, % DM	47.83
Wheatbran	3.2	ADF, % DM	25.34
Peanut cake	7.24	CF, % DM	3.42
DDGS	4.5	Ca, % DM	1.23
Fat powder	3.5	P, % DM	0.73
Red dates	1.2		
Limestone	1.3		
Cottonseed meal	1.2		
$CaHPO_4$	0.69		
NaCl	0.72		
premix[a]	1.5		
Total	100		

DDGS= Distillers Dried Grains with Solubles; DM = dry matter; DE = digestible energy; ME = metabolic energy; NDF = neutral detergent fibre; ADF = acid detergent fibre; CF= crude fat.

[a] The premix provided the following per kg of diet: vitamin A, 3000 IU; vitamin D3, 600 IU; vitamin E, 6 mg; Cu, 11 mg; Fe, 40.0 mg: Mn, 50.0 mg; Zn, 50.0 mg; Se, 0.15 mg; Co, 0.5 mg; I, 0.4 mg; N, 0.2 g; lysine, 0.025 g.

protein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglyceride (TG) were measured by colorimetric method using an automatic biochemical analyzer (Hitachi-7020, Hitachi, Japan). These assays were conducted using commercial kits (Nanjing Jiancheng Bioengineering Research Institute, Nanjing, Jiangsu, China) strictly per the manufacturer's protocol.

Fatty acids analysis of OAT and LD

The method previously described by Wang et al. was used to measure the fatty acid content of the OAT and LD samples (Wang et al., 2019). Using O'Fallon et al.'s method, fatty acid methyl esters were generated from samples containing 0.5 g of LD and 0.02 g of OAT(O'Fallon, Busboom, Nelson, & Gaskins, 2007). After precisely weighing the sample, 0.5 mL of methanol and 0.7 mL of 10 N KOH in water were added to a 10 mL screwcap centrifuge tube. For the sample to properly permeate, dissolve, and hydrolyze, the tube was incubated for 90 minutes at 55 °C, with a seven-second hand shake every twenty minutes. After cooling the tube below room temperature with a cold tap water bath, 0.58 mL of 24 N H2SO4 was added. After mixing the tube by inversion, it was once more incubated for 90 minutes at 55 °C with 7 s hand shaking every 20 minutes while precipitated H2SO4 was present. Following the synthesis of fatty acid methyl esters, the tube was submerged in a bath of cold tap water to lower the temperature. After adding hexane, the mixture was vortexed for six minutes. The hexane layer containing the fatty acid methyl esters was transferred into a gas chromatography vial following a 6-minute centrifugation at 1,500 × g. The GC-2014 gas chromatograph (Shimadzu International Trading Co., Ltd) equipped with a flame-ionization detector was used to analyze fatty acid content, an automatic injector AOC-20I (Shimadzu), and a capillary column (SP-2560 for fatty acid methyl esters; 100 m × 0.25 mm i.d., 0.20-μm fflm thickness, Supelco).

The program temperature was set as follows: 120 °C for 5 min, increased at 3.0 °C/min to 230 °C and held for 3 min, and finally, at 1.5 °C/min to 240 °C and held for 20 min. Nitrogen (1 mL/min flow rate) was used as the carrier gas with a pressure of 233.6 kPa. The split ratio was 1:9. The injector temperature was set at 260 °C and the detector temperature was set at 280 °C. The fatty acid methyl esters peaks were routinely identified by comparing

their retention times with those of known external standard mixes of 37 fatty acid methyl esters (Sigma Aldrich, China).

STATISTICAL ANALYSIS

A one-way analysis of variance (ANOVA) was used to analyze the data with SPSS 26.0 software. The results are presented as the mean values and SEM. Differences among means were considered significant when P values were < 0.05, and P values of >0.05 and ≤ 0.10 were considered to indicate a tendency.

RESULTS

Growth performance

As shown in Table 3, there were no significant differences in ADFI, ADG, and FCR among the treatments during the experiment.

Slaughter performance

As shown in Table 4, compared with the CON group, dietary higher RH (3%, 10%) supplementation significantly increased the dressing percentage and net meat weight of Duhan hybrid sheep ($P < 0.05$), and decreased omental adipose tissue percentage and perirenal adipose tissue percentage significantly ($P < 0.05$), and the live weight and carcass weight of Duhan hybrid sheep tended to increase ($P = 0.083$; $P = 0.061$) in the higher RX group.

Antioxidant enzyme activities and MDA content

The GSH-Px activity in serum, liver and LD was presented in figure 1A. Dietary supplementation with 10% RH significantly (P<0.05) increased the GSH-Px activity of serum and liver compared to the

Table 3. Effect of dietary radix hedysari supplementation on growth performance of Duhan hybrid ewe (n = 8).

Items	CON	1RH	3RH	10RH	SEM	*P*-value
Initial body weight, kg	30.25	31.45	31.32	30.60	1.25	0.805
Final body weight, kg	45.65	44.25	46.45	47.15	1.08	0.32
ADFI, kg						
d 1 to 75	1.71	1.69	1.75	1.73	0.56	0.13
ADG, kg						
d 1 to75	0.21	0.17	0.20	0.22	0.12	0.72
FCR, %						
d 1 to 75	12.2	10.0	11.6	12.7	0.85	0.42

Note: ADFI = average daily feed intake, ADG = average daily gain (ADG), FCR = feed conversion rate, SEM = Standard Error of Mean. Means within a row with different superscript letters are significantly different (P < 0.05).

Table 4. Effect of dietary radix hedysari supplementation on slaughter performance of Duhan hybrid ewe (n =8).

Items	CON	1RH	3RH	10RH	SEM	*P*-value
Live weight before slaughter, kg	44.75	43.85	45.75	46.83	1.25	0.083
Carcass weight, kg	21.84	21.78	22.98	23.42	0.89	0.061
Dressing percentage, %	48.76^{b}	49.65^{b}	50.21^{a}	50.09^{a}	1.65	0.032
Net meat weight, kg	18.35^{b}	18.23^{b}	19.30^{a}	19.68^{a}	0.98	0.023
GR value, mm	14.74	14.12	14.23	14.61	1.23	0.51
Omental adipose tissue percentage, %	2.79^{a}	2.72^{a}	2.31^{b}	1.87^{b}	0.03	0.022
Perirenal adipose tissue percentage, %	2.84^{a}	2.18^{a}	2.09^{b}	1.92^{c}	0.32	0.031

Note: SEM = Standard Error of Mean. Means within a row with different superscript letters are significantly different ($P < 0.05$).

CON, RH1 and RH3 group, yet the GSH-Px activity in serum and liver did not differ among the three groups. There was no significant difference in the activity of GSH-Px in LD of Duhan hybrid sheep between the CON and RH group.

The SOD activity in serum, liver and LD was shown in figure 1B. In comparison to the CON group, the SOD activity of serum in RH10 group increased significantly ($P<0.05$). There was no significant difference in the activity of SOD in liver and LD of Duhan hybrid sheep between the CON and RH group.

The T-AOC activity of serum, liver and LD was presented in figure 1C. Compared with the CON, RH1, and RH3 group, the 10% RH treatment increased the T-AOC activity in serum, liver and LD

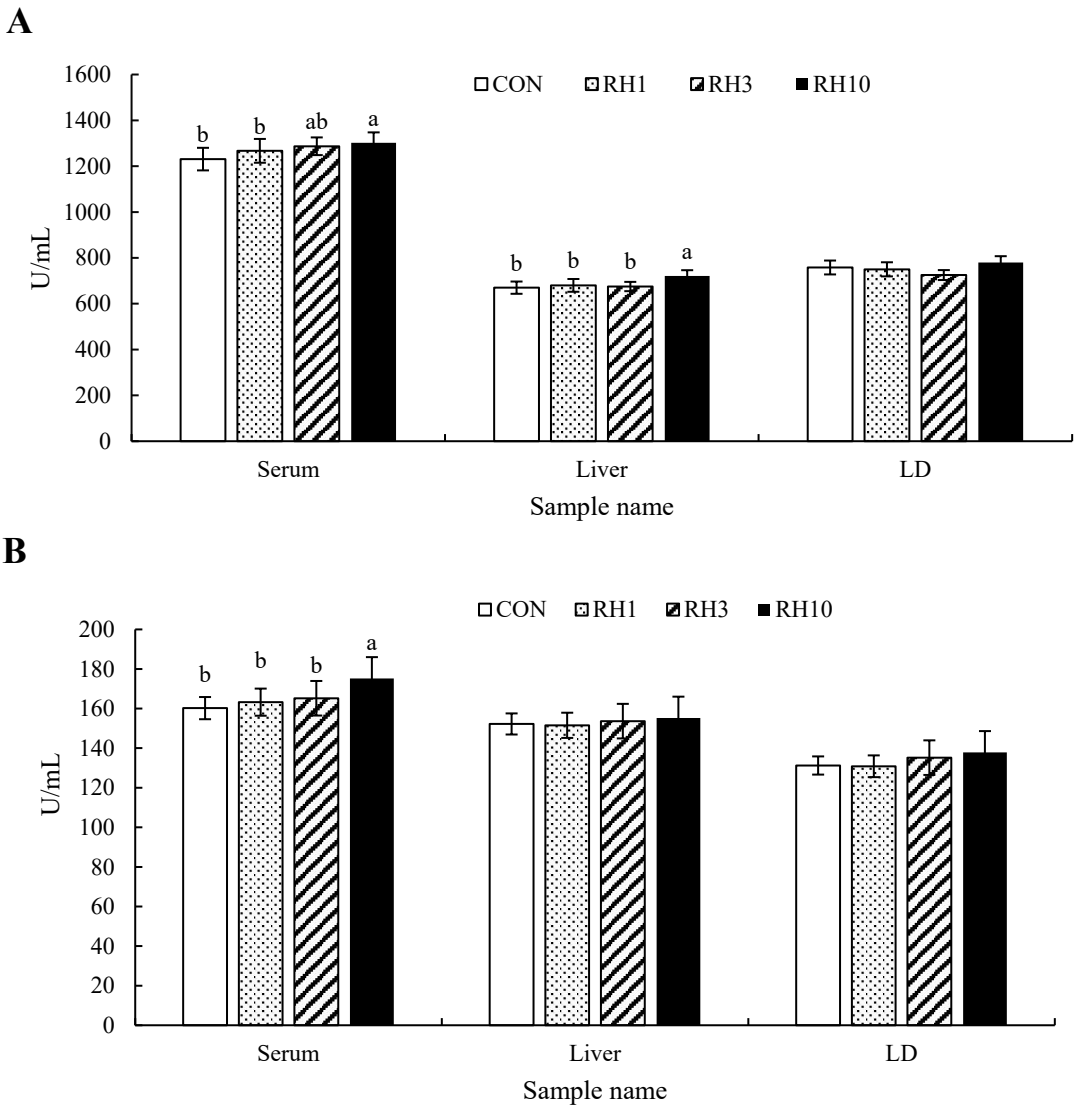

Figure 1. Effect of supplementation of different amounts of radix hedysari on antioxidant enzyme activities and MDA content in serum, liver and LD of Duhan hybrid ewe (n = 8). A-C Effect of supplementation of different amounts of radix hedysari on antioxidant enzyme (GSH-Px, SOD, T-AOC) activities in serum, liver and LD of Duhan hybrid ewe (n = 8). D Effect of supplementation of different amounts of radix hedysari on MDA content in serum, liver and LD of Duhan hybrid ewe (n = 8). Means within the same sample at different groups with different letters (a - c) are different ($P < 0.05$). Error bars represent the standard error of the mean. SOD = superoxide dismutase; GPX = glutathione peroxidase; T-AOC = total antioxidant capacity; MDA = malondialdehyde.

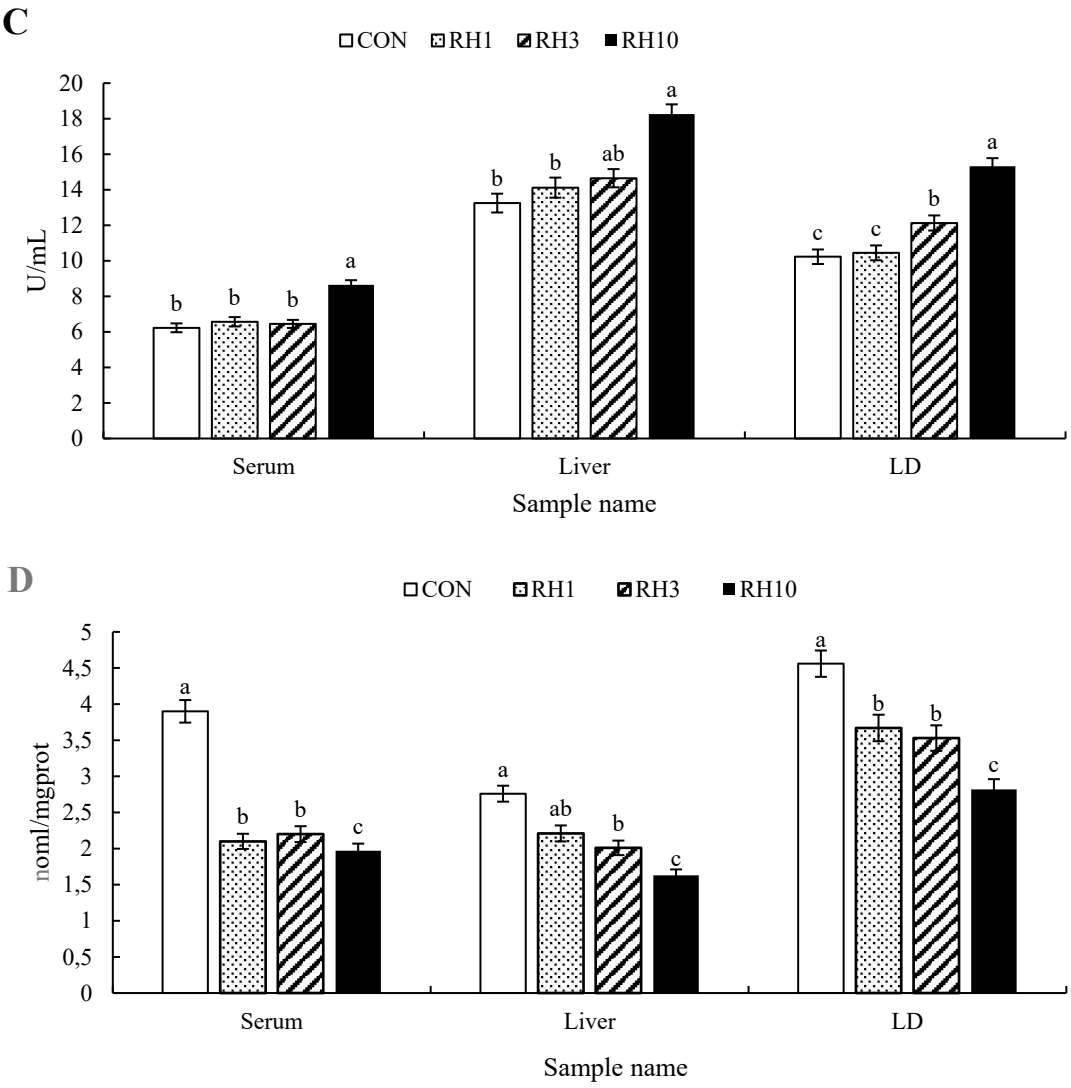

Figure 1.

significantly (P<0.05). The T-AOC activity in serum and liver did not differ among CON, RH1 and RH3 groups. The 3% RH treatment increased the T-AOC activity in LD significantly (P<0.05), compared to CON and RH1, yet there was no significant difference in the activity of T-AOC in LD between the CON and RH1 group.

The content of MDA in samples was reported in figure 1D. Dietary supplementation with RH significantly (P<0.05) decreased the concentration of MDA in serum, liver and LD compared with the CON group. The content of MDA in serum, liver and LD in RH1 group did not differ from RH3 group. The 10% RH treatment decreased the concentration of MDA compared with other treatments significantly (P<0.05).

Lipid metabolite of serum, liver and LD

The content of TC in samples was shown in figure 2A. Dietary supplementation with 3% and 10% RH decreased significantly the concentration of TC in serum compared to CON (P<0.05), while there was no significant difference in the concentration of TC in serum between the RH1 and CON group. After the addition of RH, compared with the CON group, the content of TC in liver in RH3 and RH10 group decreased significantly (P<0.05), yet there was no significant difference in the content of TC in liver between the RH1 and CON group. The concentration of TC in sheep liver did not differ between RH10 and CON group also. After the addition of RH, compared with the CON group, the content of TC in LD in RH10 group decreased significantly (P<0.05), while there was no significant difference

in the concentration of TC in LD among CON, RH1 and RH3 group.

The content of HDL-C in samples was reported in figure 2B.

Dietary supplementation with higher RH (10%) significantly (P<0.05) increased the content of HDL-C in serum compared to the CON. The concentration of HDL-C in serum in lower RH (1%, 3%) groups did not differ from CON. The concentration of HDL-C in serum did not differ among RH groups. There was no significant difference in the concentration of TC in serum among CON, RH1 and RH3 group. The content of HDL-C in liver in RH10 group

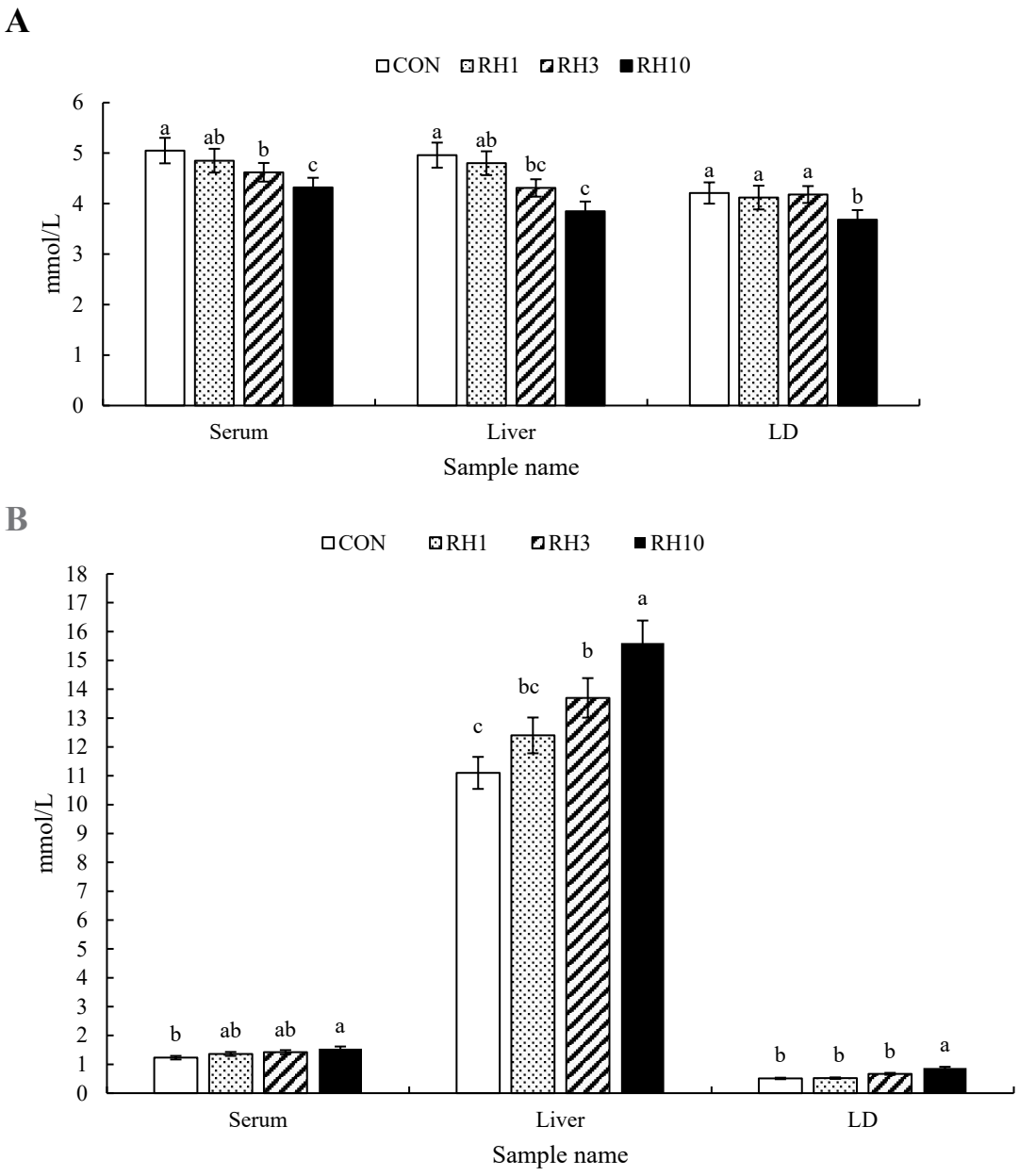

Figure 2. Effect of supplementation of different amounts of radix hedysari on lipid metabolite of serum, liver and LD in Duhan hybrid ewe (n = 8). A-D Effect of supplementation of different amounts of radix hedysari on lipid metabolite (TC, HDL-C, LDL-C, TG) of serum, liver and LD in Duhan hybrid ewe (n = 8). TC = total cholesterol; HDL-C = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol; TG = triglyceride. Error bars represent the standard error of the mean.

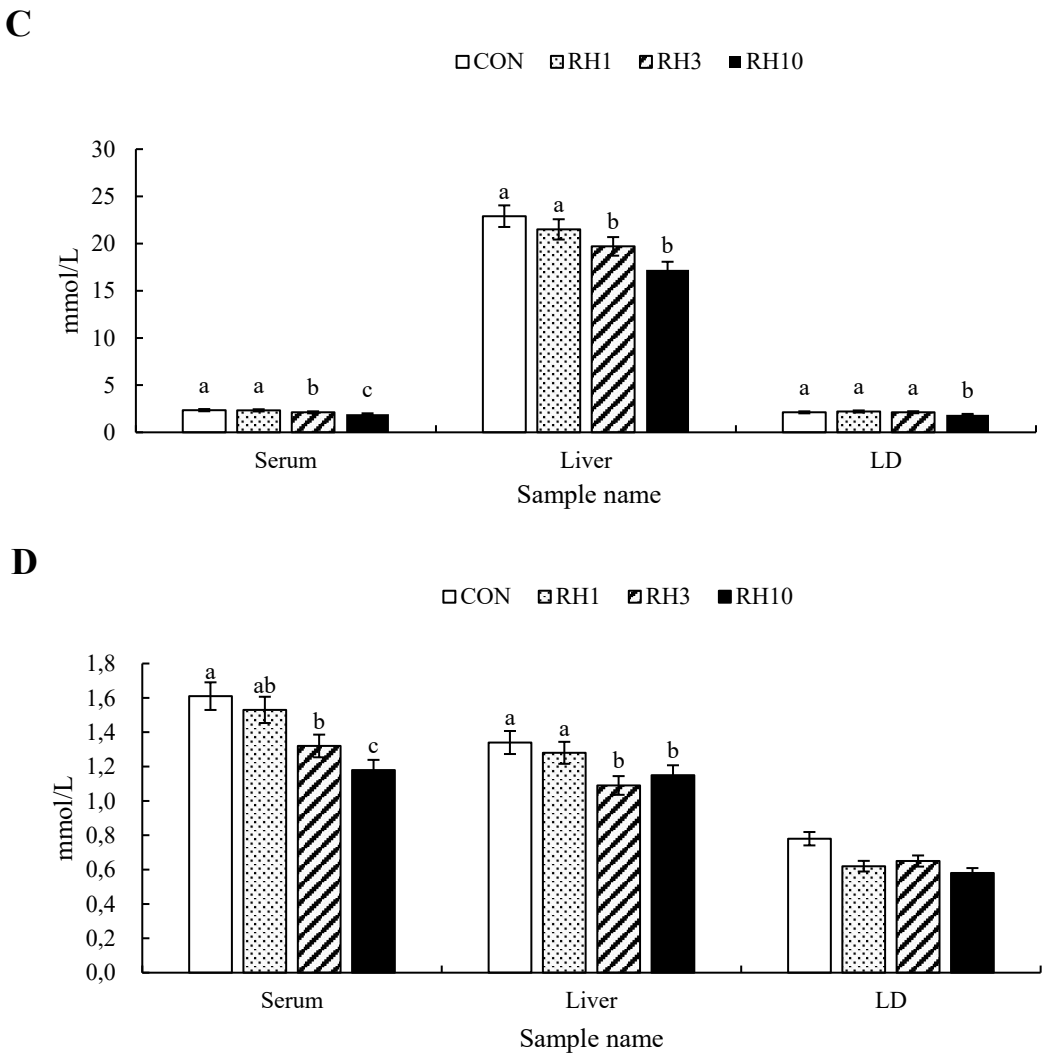

Figure 2.

was significantly higher (P<0.05) than three other groups. The concentration of HDL-C in liver did not differ between RH1 and RH3 group, and there was no significant difference in the concentration of TC in liver between CON and RH1 group. The content of HDL-C in LD in RH10 group was significantly higher (P<0.05) than three other groups, and the samples in the three groups did not differ.

The content of LDL-C in samples was presented in figure 2C. After the addition of higher RH (3%, 10%) decreased the content of LDL-C in serum and liver significantly (P<0.05) compared to the CON and RH1 group, while the concentration of LDL-C in serum and liver in RH1 group did not differ from CON. The content of LDL-C in LD in RH10 group was significantly higher (P<0.05) than RH1, RH3, and CON group, yet the content of LDL-C in LD did not differ among the three groups.

The content of TG in samples was shown in figure 2D. Dietary supplementation with higher RH (3%, 10%) significantly (P<0.05) increased the content of TC in serum and liver compared to the CON. The concentration of TC in serum and liver did not differ between RH1 and CON group. There were no significant differences in the content of TC in LD among the treatments.

Fatty acid composition

The LD fatty acid composition is shown in Table 5. Sheep fed RH had more C18:1n9, C18:3n3, MUFA, and UFA, and a higher PUFA/SFA ratio than animals in CON. The concentration of C18:1n9, C18:3n3, MUFA, PUFA/SFA, and UFA did not differ (P>0.05) among RH groups. There was no significant difference in the concentration of C16:1n7 between the RH1 and CON group. Meanwhile, the concentration

Table 5. Effect of dietary RH supplementation on fatty acid composition of longissimus dorsi muscle of Duhan hybrid ewe (% of total fatty acid) (n = 8)

Items	CON	RH1	RH3	RH10	SEM	*P*-value
C14:0	1.12	1.32	1.22	1.19	0.11	0.25
C16:0	19.23	18.54	18.76	19.01	1.87	0.065
C16:1n7	1.56[b]	2.01[b]	2.56[a]	2.76[a]	0.067	0.035
C18:0	12.32	11.31	12.12	12.54	1.98	0.52
C18:1n9	45.21[b]	52.45[a]	53.36[a]	53.53[a]	3.46	0.023
C18:2n6	8.21	7.89	7.76	8.12	4.23	0.65
C18:3n3	0.51[b]	1.56[a]	1.23[a]	1.35[a]	0.067	0.037
C20:0	0.56	0.76	0.65	0.58	0.056	0.98
C20:1n9	0.54	0.53	0.76	0.85	0.078	0.412
C22:0	1.02	1.12	1.08	1.09	0.089	0.72
C22:6n3	0.45	0.56	0.65	0.75	0.065	0.19
SFA	34.25	33.05	33.83	34.41	4.36	0.59
MUFA	47.31[b]	54.99[a]	56.68[a]	57.14[a]	3.68	<0.01
PUFA	9.17	10.01	9.64	10.22	1.07	0.82
PUFA/SFA	26.78[b]	30.29[a]	28.50[a]	29.70[a]	2.14	0.021
UFA	56.48[b]	65.15[a]	66.32[a]	67.36[a]	5.15	0.013

Note: SFA = saturated fatty acids (sum of C14:0, C16:0, C18:0, C20:0, and C22:0), MUFA = monounsaturated fatty acids (sum of C16:1n9, C18:1n9, and C20:1n9), PUFA = polyunsaturated fatty acids (sum of C18:2n6, C18:3n3, and C22:6n3), UFA = Unsaturated fatty acids (sum of MUFA and PUFA). Means within a row with different superscript letters are significantly different (P < 0.05).

of C16:0 tended (P = 0.065) to be greater in CON samples than in RH group samples.

The OAT fatty acid composition is reported in Table 6. Dietary supplementation with RH increased the concentration of C18:1n9, C18:3n3, SFA, MUFA, and UFA, and ratio of PUFA/SFA compared to CON. The concentration of C18:1n9, C18:3n3, MUFA, PUFA/SFA, and UFA did not differ (P>0.05) among RH groups. There was no significant difference in the concentration of C16:1n7 between the RH10 and CON group. Meanwhile, the concentration of C22:0 and PUFA tended (P=0.058, 0.061) to be lower in CON than in RH group.

DISCUSSION

The AFDI, ADG, and FCR are important indicators which reflect the growth performance of animals. The current study showed that RH supplementation did not affect the growth performance of sheep significantly during the trial. The sheep grew at similar rates and thus had similar carcass weights at the end of the experiment, and this observation could be due to the similar diets with same metabolic energy and crude protein and the same feeding management during the research. In agreement, previous research also reported that dietary plant additives supplementation did not affect the total and forage intake as it was recorded in sheep and in cattle (Beaudet et al., 2020; Deng et al., 2017; Guerrero et al., 2018; Mahouachi et al., 2023). Hence, the RH supply in the current study did not influence significantly the total body weight gain, the animals had the similar AFDI, ADG, and FCR at the end of the study.

Slaughter performance is an important reference indicator as it relates to the evaluation of the nutritional status and feeding management status of mutton sheep. It is also an important indicator of the growth and production performance of animals, which can be measured by carcass weight, dressing percentage, slaughter ratio, net meat weight, ect (Su et al., 2022). The higher net meat weight is conducive to improving the economic benefits of breeding. In the present study, sheep fed higher RH (3%, 10%) possessed dressing percentage and net meat weight compared to the sheep in CON group. Meanwhile, sheep in the two groups also had lower

Table 6. Effect of dietary RH supplementation on fatty acid composition of omental adipose tissue of Duhan hybrid ewe (% of total fatty acid) (n = 8).

Items	CON	RH1	RH3	RH10	SEM	*P*-value
C14:0	3.79	3.56	3.28	3.19	0.46	0.35
C16:0	22.13	21.45	20.15	21.5	1.98	0.57
C16:1n7	1.18[b]	1.67[a]	1.32[a]	1.21[b]	0.15	0.036
C18:0	21.36	28.67	28.65	29.37	2.32	0.76
C18:1n9	32.65[b]	37.23[a]	36.73[a]	39.25[a]	3.78	0.031
C18:2n6	1.76	2.19	2.54	2.01	0.21	0.076
C18:3n3	0.16[b]	1.12[a]	1.32[a]	1.54[a]	0.086	0.045
C20:0	0.54	0.65	0.32	0.42	0.048	0.076
C20:1n9	0.65	0.78	0.93	0.61	0.065	0.21
C22:0	1.01	1.21	1.32	1.28	0.091	0.058
C22:6n3	0.51	0.65	0.58	0.75	0.065	0.51
SFA	48.83[b]	55.54[a]	53.72[a]	55.8[a]	4.89	0.021
MUFA	34.48[b]	39.68[a]	38.98[a]	41.07[a]	3.98	0.018
PUFA	2.43	3.96	4.44	4.3	0.25	0.061
PUFA/SFA	4.98[b]	7.13[a]	8.27[a]	7.71[a]	0.52	0.029
UFA	36.91[b]	43.64[a]	43.42[a]	45.37[a]	3.76	0.013

Note: SFA = saturated fatty acids (sum of C14:0, C16:0, C18:0, C20:0, and C22:0), MUFA = monounsaturated fatty acids (sum of C16:1n9, C18:1n9, and C20:1n9), PUFA = polyunsaturated fatty acids (sum of C18:2n6, C18:3n3, and C22:6n3), UFA = Unsaturated fatty acids (sum of MUFA and PUFA). Means within a row with different superscript letters are significantly different ($P < 0.05$).

omental adipose and perirenal adipose tissue percentage. In previous research, muscle growth has been reported to be accelerated by selection to decrease fat accretion and increase growth rate and (Prache, Schreurs, & Guillier, 2022). Similarly, our results provide evidence that inclusion of higher RH in the diet improves the muscle growth and decrease fat accretion. This may be attributed to the higher RH in the diet, which improves the digestion and absorption of the macronutrients in feed, for RH is a traditional tonic medicine in improving the gastrointestinal tract function (Wei et al., 2015; Zhang et al., 2023).

The fat content and fatty acid profile in sheep body are closely associated with meat quality and lipid homeostasis (Prache et al., 2022; Sa et al., 2025). In the present research, including RH in the diet modify fat content and the fatty acid composition in sheep meat and omental adipose tissue. In previous research, RH has been reported to ameliorate lipid metabolism disorders in rat liver via regulating pathways associated with lipid metabolism (Mo, 2022; Sun et al., 2014). In the current study, adding RH in the diet increased the content of unsaturated fatty acids of LD and adipose tissue in sheep. It remains unclear how inclusion of RH in the diet changes the lipid deposition in sheep. Thus, additional research is required to comprehend the exact mechanism of RH in regulating the lipid accretion of sheep.

In many populations, sheep meat is a necessary part of the diet because it offers superior nutrients, such as vitamins, iron, zinc, and other vital micronutrients, as well as carbohydrates, proteins, and fats (Chikwanha et al., 2018). Sheep meat is an excellent source of n-3 polyunsaturated fatty acids (PUFA), branched chain fatty acids, and PUFA biohydrogenation intermediates, particularly conjugated linolenic acid, which may have positive effects on human health (Chikwanha et al., 2018; Prache et al., 2022). The findings from our study revealed that higher RH which have been incorporated into sheep feeds significantly increases the content of C18:3n3 in LD and omental adipose tissue compared to control. However, inclusion of RH in sheep feeds did not change the concentration of C18:2n6 in the two tissues. Contrary to monogastric animals, it is more difficult to manipulate the fatty acid composition of ruminants such as sheep through dietary changes. While the rumen hydrogenates over 90% of the dietary PUFA, some PUFA manage to evade this process. Natural

botanical additives such as flaxseed and algae that are rich in PUFA have been incorporated into sheep and cattle feeds to improve animal performance and muscle n−3 fatty acid content (Ponnampalam et al., 2016). The data from our study suggested that adding RH in sheep feeds enhance the content of C18:3n3 in LD and omental adipose tissue, however, the content of PUFA in RH is less, this may be attributed to the function of RH in regulating intestinal flora homeostasis (Zhang et al., 2023). The exact mechanism remains unclear. Thus, further research is needed about how inclusion of RH in sheep feeds affects the metabolism of fatty acids.

The generation of reactive oxygen species (ROS) such as hydroxyl radicals and hydrogen peroxide induced by oxidative stress which has a profound effect on growth performance and meat quality of animals**.** It is one of useful ways for scholars to improve growth performance and meat quality that relying on nutritional regulation to further the antioxidant capacity of the body (Su et al., 2022). Natural substances, especially from plants, have been actively exploited as potential antioxidants in forage to build up the growth performance of livestock (Luo et al., 2007; Rossi et al., 2013). Previous study shown that RH has been investigated as antioxidant agent due to its antioxidant effect in animal experiments (Liu et al., 2012; Mo, 2022). As observed in our study, adding higher RH increased the activity of GSH-Px, SOD, and T-AOC antioxidant enzyme in serum of sheep and also decreased the MDA levels in tissues of sheep compared to control group. The positive effect of RH on body antioxidant levels may be attributable to the radix hedysari polysaccharide (RHP) content, for it is rich in flavonoid and *radix hedysari* polysaccharide (RHP) (Xue et al., 2021). A large number of studies have shown that RHP can exert antioxidant function by activating antioxidant enzyme activity, scavenging free radicals, reducing MDA content in tissue, preventing DNA damage and lipid peroxidation (F.F. Lei, 2015; Mo, 2022; N. Kou, 2015; X.H. Yang, 2010). In the meantime, prior research has demonstrated that raising the amount of n-3 fatty acids in muscle enhanced antioxidant capacity and decreased lipid oxidation (Ponnampalam et al., 2016). In the present work, the higher RH diet increased the antioxidant capacity of sheep in some tissues, and this is in agreement with previous research.

In contemporary intensive sheep farming, however, producers frequently feed lamb high-energy diets for quick growth in an effort to maximize economic gains. Increased body fat content, nutrient value of meat is affected, and severe lipid metabolic disorder may result from this (Liang et al., 2020). Therefore, exploring the mechanism of manipulating the lipid metabolism via diet in sheep is not only helpful for treating lipid metabolism dysfunction, but also for targetedly enhancing the meat quality. The data from this study suggest that inclusion of higher RH in sheep diet decrease the concentration of TC, LDL-C, and TG, and increase content of HDL-C in serum and liver. Previous research reported that RHP treatment ameliorated lipid metabolism disorders in rat via activating pathways associated with lipid metabolism such as adenosine monophosphate-activated protein kinase pathway by reducing lipogenesis and increasing lipolysis (Sun et al., 2014). Our results corroborate previous findings that RH improve the lipid metabolism via decreasing the level of lipid in tissues.

CONCLUSION

In conclusion, this study showed that dietary RH did not influence growth performance of Duhan hybrid ewe. However, net meat weight and dressing percentage increased with higher levels of RH supplementation. Omental and perirenal adipose tissue percentage decreased with higher levels of RH supplementation, and the fatty acid composition had been changed. In addition, dietary RH increased capacity of the antioxidant enzymes and inhibited MDA formation in tissues. Overall, RH had a positive impact on the diet of Duhan hybrid sheep. By increasing the activity of antioxidant enzymes, this supplement may improve the body's oxidative status and increase net meat weight by reducing the deposition of perirenal and onmental adipose tissue.

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