Effects of supplemented mode of emulsifier on growth performance, serum biochemical index, quality of meat and skin fat, and nutrient utilization in Pekin ducks

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ABSTRACT In our previous experiment, we found that fats with pre-emulsification (**PreE**), a new supplemented mode of emulsifier, had an improved bioavailability for Pekin ducks than fats without PreE based on dietary EE utilization. Therefore, this study was conducted to investigate the effects of the supplemented mode of emulsifier (PreE vs. emulsifier direct supplementation) on the growth performance, serum biochemical index, quality of meat and skin fat, and nutrient utilization in Pekin ducks. A total of 640 healthy 10-day-old Pekin male ducks (408.65 ± 12.00 g) were randomly allocated into 4 treatments with 16 replicates of 10 birds each. The 4 dietary treatments were as follows: the positive control group (**PC**; the oil supplemented amount of 6%), the negative control group (**NC**; the oil supplemented amount of 5.4%), the emulsifier group (**E**; NC diet with an emulsifier added directly), and the oil pre-emulsification group (PreE; NC diet with oil PreE). The results showed reducing the amount of fat in the diet (NC vs. PC) significantly decreased growth performance and quality of skin fat, and affected serum lipid metabolism ($P < 0.05$). Interestingly, the body weight (**BW**), body weight gain (**BWG**), and the shear force of skin fat were increased, but the feed to gain ratio (**F/G**) was markedly decreased in the PreE group ($P < 0.05$) compared to those in the NC group, and these levels were similar to those in the PC group ($P > 0.05$). Additionally, the utilization of dietary dry matter (**DM**), ether extract (**EE**), and total phosphorous (**TP**) were increased, but the activity of aspartate aminotransferase (**AST**) in serum was decreased in the PreE group compared to those in the NC group ($P < 0.05$). Furthermore, compared to the E group, the F/G was decreased ($P < 0.05$), and the utilization of dietary EE, the shear force of skin fat and content of collagen in skin fat were markedly increased ($P < 0.05$) in the PreE group. However, no differences were observed ($P > 0.05$) in growth performance between the group administered a direct supplementation of emulsifier and the control groups (PC and NC). These results indicate that the negative effect of reducing the oil supplementation amount (−0.6%) in the diet can be restored by supplementation with emulsifier, especially by oil with PreE.

Key words: duck, pre-emulsification, supplemented mode of emulsifier, growth performance, quality of skin fat

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INTRODUCTION

Pekin ducks have a short production cycle and a high requirement for energy (Adeola, 2006). Lipids (fats and oils) are commonly added to poultry diets as a concentrated energy source for gathering the high energy demands for these fast-growing birds (Baião and Lara, 2005; Haetinger et al., 2021). One of the factors that limit the use of high levels of fat in poultry diets is the indigestion of fat (Zampiga et al., 2016; Saleh et al., 2020). The digestion and absorption of fats is a complex process and involves a sequence of physicochemical events, including the breakdown to fat droplets, emulsification, lipolysis, and mixed micelle formation (Ravindran et al., 2016). Fat digestion in poultry initially occurs in the gizzard, where fats are first broken down into small-sized fat droplets due to the mechanical stresses that the gizzard contraction produces (Ravindran et al., 2016; Mcdonald et al., 2022). Fat droplets are further dispersed into microscopic micelles in the gizzard due to the mechanical stresses they experience, as

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well as due to the presence of bile salts and lysophospholipids from digesta refluxed from the duodenum (Mun et al., 2007; Ravindran et al., 2016). Then, with the help of bile salts, lipid hydrolysates present in the small intestine, such as monoacylglycerols, free fatty acids, cholesterol, form the solubilized form of mixed micelles, which are taken up by intestinal epithelial cells through passive diffusion or transport enzymes (Ravindran et al., 2016; Ye, 2020; Mcdonald et al., 2022). Therefore, endogenous emulsifiers and gizzard mechanical stresses in the digestive tract are critical for the efficient digestion and absorption of fats in poultry.

Many studies have verified that exogenous emulsifiers, including hydrophilic and hydrophobic groups, which can enhance the digestion and absorption of fats and thus improve growth performance, have currently been widely used in livestock and poultry feeds (Rovers, 2014; Jansen et al., 2015; Kaczmarek et al., 2015). Inconsistently, some trials revealed that direct addition of emulsifiers into poultry diets showed no significant effects on nutrient digestibility (Zampiga et al., 2016; Liu et al., 2020; Shen et al., 2021). Liu et al. (2020) suggested that the ability of exogenous emulsifiers to increase fat digestibility was not robust due to the short digestive tract and unstable digestibility of broilers. To improve the effectiveness of exogenous emulsifiers in the food industry, the emulsifiers in food may be consumed mainly in the form of emulsified fats (McClements, 2004, 2008; Mun et al., 2007). Garaiova et al. (2007) reported that emulsified fish oil could increase the absorption of longer-chain more highly unsaturated fatty acids, suggesting that the pre-emulsification (**PreE**) of oils may be a useful means of increasing the absorption of fatty acids.

The PreE of fats or oils is a new emulsification method. In this method, a mixture of fat or oil, exogenous emulsifier, and water in a certain proportion is rapidly stirred with a homogenizer for conversion into emulsified fat or oil, which is then added to livestock and poultry feed. In our previous study, we found that fats with PreE had an improved bioavailability for Pekin ducks than fats without PreE based on dietary EE utilization (Zeng et al., 2022). However, in the study of Zeng et al. (2022), we did not compare the effect between PreE and the direct supplementation with emulsifier in ducks. Therefore, the objective of the present study was to evaluate the effects of adding an emulsifier to diets (PreE vs. direct supplementation) on the growth performance, serum biochemical index, quality of meat and skin fat, and nutrient utilization in Pekin ducks.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee of Sichuan Agricultural University approved all procedures used in this study.

Birds, Diets, and Management

One-day-old male Pekin ducks received a standard starter diet containing 11.93 MJ/kg ME and 19.50% CP from 1 to 10 d of age. Then, 640 healthy 10-day-old Pekin male ducks (408.65 ± 12.00 g) were allotted randomly to 4 treatments, and each treatment was divided into 16 replicates (10 birds/rep). The following 4 isonitrogenous and isocaloric experimental diets were formulated: the positive control diet (**PC** diet; the diet is supplemented with 6% poultry fat), the negative control diet (**NC** diet; the diet is supplemented with 5.4% poultry fat), the emulsifier diet (**E** diet; NC diet with an emulsifier added directly), and the oil PreE diet (PreE diet; NC diet with oil PreE). The emulsifier supplemental levels were both 2% of the oil supplemental level in the experimental diets. The emulsifier was provided by Si Chuan Action Biotech Co., Ltd., and contained 41% propionic acid, 24% ammonium propionate, and 10% polyethylene glycol glycerine ricinoleate. The pre-emulsified fat was made as follows: poultry fat, emulsifier, and water were added at a ratio of 150:3:25, after which the mixture was stirred with a homogenizer at 3,000 r/min for 20 s. Then, the pre-emulsified fat was mixer added in PreE diet. All diets were presented in pellet form and formulated to meet or exceed the NRC (1994) requirement for meat ducks. The dietary composition and nutrition density are shown in Table 1. The birds of each replicate were placed in a single cage (1.0 × 0.8 × 0.6 m) with a "23 h on to 1 h off" lighting regimen for the first 3 d and then under "16 h on to 8 h off" lighting for the remainder of the feeding period. They were provided with tap-water and pellet feed ad libitum. The temperature of the experimental room was maintained at 32°C to 34°C for the first 3 d and then reduced to 22°C at the rate of 2°C to 3°C per week.

Sample Collection and Determination

Birds in each cage were weighed, and feed consumption was also recorded on a replicate basis on d 34 after 12 h of fasting. These values were used to calculate the body weight gain (**BWG**), feed intake (**FI**), and feed to gain ratio (**F/G**). One duck per replicate ($n = 16$) was randomly chosen for blood sampling via the jugular vein. Serum was obtained by centrifugation at 3,000 rpm and 4°C for 10 min and finally kept at −20°C for further analysis. The serum concentrations of total triglyceride (**TG**), total cholesterol (**TC**), high-density lipoprotein cholesterol (**HDL-C**), low-density lipoprotein cholesterol (**LDL-C**), very low-density lipoprotein cholesterol (**VLDL-C**), and the activities of alanine aminotransferase (**ALT**) and aspartate aminotransferase (**AST**) were analyzed using the method of our previous study (Zeng et al., 2022).

Once blood was collected, the birds were euthanized by cervical dislocation. A trained person removed the skin fat and breast meat. After removing excess moisture, skin fat thickness was measured. The Hunter lightness (L*), yellowness (b*), and redness (a*) values of

Table 1. Composition and nutrient contents of the experimental diets (air dry basis).

Items	PC[1]	NC	E	PreE
Ingredients, %				
Corn	25.75	28.20	28.20	28.20
Wheat	24.10	24.10	24.10	24.10
Soybean meal	20.50	20.94	20.94	20.94
Wheat bran	7.38	5.10	5.10	5.10
Rice bran meal	12.00	12.00	12.00	12.00
Poultry fat/poultry fat with PreE	6.00	5.40	5.40	5.50
Bentonite	0.50	0.50	0.40	0.40
Emulsifier	0.00	0.00	0.10	0.00
Dicalcium phosphate	1.47	1.47	1.47	1.47
Calcium carbonate	1.13	1.13	1.13	1.13
L-Lysine. HCl (98.5%)	0.05	0.05	0.05	0.05
DL-Methionine (99%)	0.15	0.14	0.14	0.14
Sodium chloride	0.30	0.30	0.30	0.30
Choline chloride (50%)	0.15	0.15	0.15	0.15
Vitamin premix[2]	0.03	0.03	0.03	0.03
Mineral premix[3]	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Calculated nutrients, %				
ME, MJ/kg	12.14	12.14	12.14	12.14
Crude protein	17.50	17.50	17.50	17.50
Ether extract	8.11	7.53	7.53	7.53
Calcium	0.86	0.86	0.86	0.86
Total phosphorus	0.80	0.80	0.80	0.80
Available phosphorus	0.41	0.41	0.41	0.41
Total lysine	0.86	0.86	0.86	0.86
Total methionine	0.40	0.40	0.40	0.40
Total threonine	0.62	0.62	0.62	0.62
Total tryptophan	0.20	0.20	0.20	0.20
Analyzed nutrient, %				
Crude protein	17.06	17.07	17.12	17.04
Ether extract	7.44	6.83	6.84	6.79
Calcium	0.99	0.93	1.07	0.99
Total phosphorus	0.72	0.72	0.79	0.76

[1]PC: positive control group; NC: negative control group; E: emulsifier group; PreE: pre-emulsification group.

[2]Vitamin premix provides the following per kg of final diet: vitamin A 8,000 IU; vitamin D_3 2,000 IU; vitamin E 5 mg; vitamin K_2 1 mg; vitamin B_1 0.6 mg; vitamin B_2 4.8 mg; vitamin B_6 1.8 mg; vitamin B_{12} 0.009 mg; niacin 10.5 mg; DL-calcium pantothenate 7.5 mg; folic acid 0.15 mg.

[3]Mineral premix provides the following per kg of final diet: Fe ($FeSO_4 \cdot H_2O$) 80 mg; Cu ($CuSO_4 \cdot 5H_2O$) 8 mg; Mn ($MnSO_4 \cdot H_2O$) 70 mg; Zn ($ZnSO_4 \cdot H_2O$) 90 mg; I (KI) 0.4 mg; Se (Na_2SeO_3) 0.3 mg.

breast muscle and skin fat were determined (Konica Minolta Sensing Inc., Osaka, Japan). Drip loss of meat was determined according to the plastic bag method described by Honikel (1998). Cooking loss was also measured using the method of Honikel (1998). Briefly, meat samples were packed in plastic bags and submitted to cooking in a water bath for 30 min until the internal temperature reached 75°C. Cooking loss was expressed as a percentage of the weight before cooking. Then, these meat samples were cut into 1 × 1 × 2 cm pieces and measured in triplicate on a texturometer TATX-2i. The shear force was expressed in newton (**N**). The moisture, protein, and fat contents of the breast meat and skin fat samples were analyzed according to the procedures of AOAC (2005). The amount of hydroxyproline in skin fat was determined after 15 h of hydrolysis of 1.0 g of meat with 15 mL 6 M HCl at 105°C, as reported by Woessner Jr. (1961). The total collagen content was calculated from the hydroxyproline content using the coefficient 8.0 (Woessner Jr., 1961).

Assay of Nutrient Utilization of Diets

On d 35, a total of 128 ducks (2 ducks per cage and 16 cages per treatment) were housed in individual metabolic cages (50 cm × 50 cm) and fed the original diets mixed with 0.5% titanium dioxide (**TiO_2**) for metabolizable tests. After acclimation for 2 d, excreta were collected on a cage basis for 72 h. After removing debris, fresh excreta samples were gathered from each cage during the last 3 d of the experiment and immediately frozen at −20°C. All diets and dried excreta samples were ground to pass through a 0.5 mm screen using a mill grinder, after which they were analyzed for dry matter (**DM**) (method 930.15; AOAC, 2005), nitrogen (method 976.05; AOAC, 2005), ether extract (**EE**) (method 920.37; AOAC, 2005), calcium (**Ca**) (method 984.01; AOAC, 2000), and total phosphorus (**TP**) (method 965.17; AOAC, 2005). TiO_2 was determined according to the method from Short et al. (1996).

Statistical Analysis

The data were subjected to one-way analysis of variance using the GLM procedure of SAS Institute (SAS, 2016). Each replicate was considered an experimental unit. Differences between treatments were detected by Duncan's multiple range tests. The probability of $P < 0.05$ was described as significant. The data are expressed as the mean ± SEM.

RESULTS

Growth Performance

The growth performance results are shown in Table 2. Ducks fed the NC diet showed ($P < 0.05$) lower BW and BWG, and higher F/G compared with ducks fed the PC diet. The direct addition of the emulsifier into the diet (E) had no significant impact ($P > 0.05$) on productive indices compared with the control groups (PC and NC). However, the PreE group presented ($P < 0.05$) higher BW and BWG than that in the NC group, and lower F/G than that in the NC and E groups, which were superior ($P > 0.05$) to the growth performance of the PC group.

Table 2. The effects of supplemented mode of emulsifier on growth performance of Pekin ducks from 11 to 34 d of age.

Items[2]	PC[1]	NC	E	PreE	SEM	*P* value
BW[3], g	2233[a]	2181[b]	2215[ab]	2257[a]	17.99	0.032
BWG, g	1825[a]	1771[b]	1807[ab]	1850[a]	18.39	0.031
F/G, g/g	1.99[bc]	2.05[a]	2.02[ab]	1.97[c]	0.02	0.018
FI, g	3660	3599	3611	3644	36.37	0.654

[a,b,c]Different superscript letters in the same row indicate significant difference ($P < 0.05$).

[1]PC: positive control group; NC: negative control group; E: emulsifier group; PreE: pre-emulsification group.

[2]Each value represents the mean value of 16 replicates/treatment ($n = 16$).

[3]BW, body weight; BWG, body weight gain; F/G, feed to gain ratio; FI, feed intake; SEM, pooled standard error of the mean.

Table 3. The effects of supplemented mode of emulsifier on serum biochemical index of Pekin ducks.

Items[2]	PC[1]	NC	E	PreE	SEM	*P* value
ALT[3], U/L	28.29	31.52	30.43	31.23	1.14	0.180
AST, U/L	23.94[a]	24.71[a]	21.07[ab]	19.45[b]	1.41	0.042
TC, mmol/L	4.12	4.48	4.32	4.31	0.12	0.211
TG, mmol/L	0.78	0.94	0.89	0.88	0.06	0.285
HDL-C, mmol/L	2.32	2.39	2.37	2.46	0.08	0.680
LDL-C, mmol/L	1.46	1.48	1.52	1.49	0.09	0.958
VLDL-C, mmol/L	0.35[b]	0.51[a]	0.48[a]	0.41[ab]	0.04	0.013

[a,b]Different superscript letters in the same row indicate significant difference ($P < 0.05$).

[1]PC: positive control group; NC: negative control group, E: emulsifier group; PreE: pre-emulsification group.

[2]Each value represents the mean value of 16 replicates/treatment ($n = 16$).

[3]AST, aspartate aminotransferase; ALT, alanine aminotransferase; HDL-C, high-density lipoprotein; LDL-C, low-density lipoprotein; SEM, pooled standard error of the mean; TBA, total bile acid; TC, total cholesterol; TG, triglyceride; VLDL-C, very low-density lipoprotein.

Serum Biochemical Index

The activity of AST in serum was significantly decreased in the PreE group ($P < 0.05$), but the ALT activity was not significantly different from those in the NC and PC groups ($P > 0.05$, Table 3). The serum VLDL-C concentration of the PC group was significantly lower than that of the NC and E groups ($P < 0.05$), but was similar to that of the PreE group ($P > 0.05$).

Quality of Meat and Skin Fat

No statistically significant differences in any meat quality parameters were observed among the 4 treatments ($P > 0.05$, Table 4). After reducing the amount of fat used in the NC diet, the shear stress of skin fat was significantly lower than that of the PC group ($P < 0.05$, Table 5), but the declined index was enhanced ($P < 0.05$) by oil PreE.

Table 4. The effects of supplemented mode of emulsifier on quality of breast meat in Pekin ducks.

Items[2]	PC[1]	NC	E	PreE	SEM[3]	*P* value
Drop loss, %	3.33	3.50	3.62	2.86	0.380	0.504
Cooking loss, %	52.91	52.10	51.80	52.15	0.857	0.822
Shear force, N	41.97	45.60	39.00	45.68	2.943	0.304
Breast muscle color (0 h)						
Lightness (L*)	55.46	54.49	53.03	53.74	1.026	0.388
Redness (a*)	14.73	14.10	14.23	14.69	0.406	0.608
Yellowness (b*)	8.32	7.24	7.22	7.31	0.421	0.183
Breast muscle color (24 h)						
Lightness (L*)	48.36	48.92	48.97	49.48	0.802	0.800
Redness (a*)	17.30	18.05	18.05	17.91	0.405	0.506
Yellowness (b*)	8.77	8.47	8.84	9.00	0.287	0.625
Meat chemical composition						
Moisture, %	77.14	77.36	77.12	76.99	0.27	0.815
Fat, %	2.09	1.98	2.17	2.16	0.09	0.405
Protein, %	19.99	19.72	20.13	19.67	0.27	0.581

[1]PC: positive control group; NC: negative control group, E: emulsifier group; PreE: pre-emulsification group.

[2]Each value represents the mean value of 16 replicates/treatment ($n = 16$).

[3]SEM, pooled standard error of the mean.

Table 5. The effects of supplemented mode of emulsifier on quality of skin fat in Pekin ducks.

Items[2]	PC[1]	NC	E	PreE	SEM[3]	*P* value
Skin fat color						
Lightness (L*)	69.53	72.11	71.14	70.84	0.73	0.104
Redness (a*)	11.41	9.28	9.17	9.62	0.68	0.071
Yellowness (b*)	13.31	13.13	13.78	12.82	0.42	0.433
Skin fat chemical composition						
Moisture, %	23.84	22.73	22.28	21.80	0.84	0.372
Collagen, %	0.40[ab]	0.41[a]	0.35[b]	0.42[a]	0.02	0.047
Fat, %	70.64	70.87	72.94	72.58	1.04	0.294
Skin fat thickness, mm	3.50	3.17	3.21	3.49	0.14	0.202
Shear force of skin fat, N	18.00[a]	13.85[b]	12.18[b]	18.36[a]	1.42	0.005

[a,b]Different superscript letters in the same row indicate significant difference ($P < 0.05$).

[1]PC: positive control group; NC: negative control group, E: emulsifier group; PreE: pre-emulsification group.

[2]Each value represents the mean value of 16 replicates/treatment ($n = 16$).

[3]SEM, pooled standard error of the mean.

Nutrient Utilization

As shown in Table 6, after using the emulsifier in the feed (E and PreE), the utilization of TP in the diets was higher ($P < 0.05$) than that in the NC group. Interestingly, DM utilization was higher ($P < 0.05$) in the PreE group compared with those in the NC and PC groups; EE utilization was also improved ($P < 0.05$) in the PreE group compared with that in the E and NC groups. There were no significant differences ($P > 0.05$) in these parameters (energy, crude protein, Ca, and AME) among the 4 groups.

DISCUSSION

In addition to supplying energy, dietary supplementation with fats or oils improves the absorption of fat-soluble vitamins, the palatability of the diets, and the efficiency of utilization of the consumed energy (Baião and Lara, 2005). It has been reported that the addition of fats to poultry diets can improve the performance of poultry and thus improve production efficiency and economic benefits (Peebles et al., 2000; Nayebor et al., 2007; Zampiga et al., 2016). In the present study, we also found that the growth performance of ducks was decreased by the reduction in the dietary fat content (NC vs. PC).

Several studies have reported that dietary supplementation with exogenous emulsifiers contributes to increased growth rates and feed conversion efficiency (Kaczmarek et al., 2015; Zhao and Kim, 2017; Hu et al., 2019; Saleh et al., 2020). However, other reports revealed that the direct addition of lecithin into the diets showed no significant effects on growth performance throughout the whole experimental period (Azman and Ciftci, 2004; Aguilar et al., 2013; Shen et al., 2021). Similarly, we observed that the direct addition of emulsifier (polyethylene glycol glycerine ricinoleate) into the diet showed no significant effects on growth performance (E

Table 6. The effects of supplemented mode of emulsifier on nutrient utilization of Pekin ducks.

Items[2]	PC[1]	NC	E	PreE	SEM	*P* value
DM[3], %	70.33[b]	69.53[b]	70.87[ab]	71.82[a]	0.61	0.021
EE, %	86.74[ab]	84.71[b]	85.13[b]	89.12[a]	0.91	0.004
Energy, %	74.46	73.99	75.00	75.49	0.46	0.121
AME, kcal/kg	2946	2896	2936	2954	18.05	0.134
Crude protein, %	64.60	62.46	63.44	64.93	1.83	0.773
TP, %	36.71[bc]	31.79[c]	45.07[a]	41.07[ab]	1.77	0.000
Ca, %	37.74	40.84	44.91	41.90	2.74	0.345

[a,b,c]Different superscript letters in the same row indicate significant difference ($P < 0.05$).
[1]PC: positive control group; NC: negative control group, E: emulsifier group; PreE: pre-emulsification group.
[2]Each value represents the mean value of 16 replicates/treatment ($n = 16$).
[3]AME, apparent metabolizable energy; Ca, calcium; DM, dry matter; EE, ether extract; SEM, pooled standard error of the mean; TP, total phosphorus.

vs. NC). Interestingly, compared to the NC group, the PreE group demonstrated a significant improvement in the growth performance of ducks. In fact, the growth performance levels of the PreE group were similar to those in the PC group in the current study. These findings suggest that the addition mode of the emulsifier can present a different effect on the growth performance of ducks.

Papadopoulos et al. (2018) pointed out that the growth performance improvements of birds are associated with improved nutrient utilization. We also found that the utilization of DM, EE, and TP in the diet was improved in the PreE group compared with that in the NC group. In addition, oil PreE further improved EE utilization compared to the direct supplementation of emulsifier (E). These results further indicate that oil PreE can improve growth performance by increasing the availability of dietary nutrients, for example, DM, EE, and TP. Moreover, in the current experiment, the serum VLDL concentration of the PC group was significantly lower than those of the NC and E groups but was similar to that of the PreE group. The free fatty acids for body fat deposition are mainly derived from the degradation of 2 sources of lipoproteins in the blood: chylomicrons transporting dietary lipids taken up by the small intestine and VLDL transporting endogenous lipids synthesized by hepatic cells (Lu, 2015). The results suggested that increasing the fat content in the diet or improving dietary fat utilization may decrease the synthesis of endogenous lipids in the liver and increase the direct transfer of dietary fat to peripheral adipose tissue, especially to subcutaneous adipose tissue in ducks. Consistently, Leveille et al. (1975) showed that a high-fat diet reduces the de novo lipogenesis capacity of poultry livers.

Moreover, the activity of ALT and AST in serum, which mainly spread in plasma of hepatic cell and are released into the blood when the hepatocytes are damaged, is important markers of liver health (Lu, 2015). Interestingly, there were no significant difference in serum ALT and AST activity between the direct supplementation of emulsifier (E) and the control groups (PC and NC), while the activity of AST was decreased in the PreE group compared with those in the NC and PC groups, indicating that the supplemented mode of emulsifier in the diet showed different effects on liver health of meat ducks.

In addition, we found that the shear force and content of collagen in the skin fat of ducks were increased in the PreE group compared with those in the E group. Granot et al. (1991a) reported that skin shear force is highly correlated with skin strength and that skin strength is markedly correlated with collagen content. Additionally, the collagen content of male skin is higher than that of female skin, resulting in an increase in skin tension (Granot et al., 1991b). Smith Jr. et al. (1977) pointed out that higher levels of skin fat, accompanied by a reduction in total collagen concentration, made the skin of females more susceptible to tearing and observed a greater incidence of torn skin in females than in males. However, in our study, we did not observe differences in the content of fat in skin fat and the skin fat thickness of ducks between the PreE group and the E group. With the development of highly automated cage-rearing systems in duck production, the incidence of skin tears, scratches, or skin injuries by pecking has become increasingly serious, resulting in huge economic losses (Xu et al., 2020). Therefore, further studies should be concerned with the effect and mechanism of PreE on quality of skin fat.

CONCLUSIONS

In conclusion, PreE could improve the growth performance, shear force of skin fat, and dietary nutrient utilization and promote the transfer of serum lipids from diets to peripheral adipose tissues. PreE could save 0.6% poultry fat addition, and is a better way to add emulsifiers in the diet than the direct addition of emulsifiers.

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DISCLOSURES

None of the authors have any conflicts of interest to declare.

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