Effects of dietary supplementation of chitosan on carcass composition and meat quality in growing Huoyan geese

Zhiguo Miao [iD],[*,1,2] Liping Guo,[†,1] Yongliang Liu,[*] Weixin Zhao,[*] and Jingzhou Zhang[*]

College of Animal Science and Veterinary Medicine, Henan institute of Science and Technology, Xinxiang 453003, P. R. China; and †School of Food Science and Technology, Henan institute of Science and Technology, Xinxiang, 453003 P. R. China

ABSTRACT This present study was conducted to investigate the effects of dietary supplementation of chitosan (**CS**) on carcass composition and meat quality in growing Huoyan geese. A total of 320 (28-day-old) growing Huoyan geese (sex balance) with similar body weight were randomly divided into the following 4 main groups: basal diet (control), basal diet + 100 mg/kg CS (CS$_{100}$), basal diet + 200 mg/kg CS (CS$_{200}$), and basal diet + 400 mg/kg CS (CS$_{400}$) groups. Each group includes 4 replicates with 20 geese per replicate, and the feeding trail lasted for 4 wk. The results showed that the geese in CS$_{200}$ group had lower abdominal fat percentage, b* value, shear force, crude fat content, and drip loss of breast and thigh muscle than those in the control group ($P < 0.05$). In addition, the CS$_{200}$ group had higher glutamic acid, glycine, lysine, valine, total nonessential amino acids, total essential amino acids, total amino acids, C22:0, C16:1, C18:1, C20:1, C20:2, C20:5, total monounsaturated fatty acids concentration and polyunsaturated fatty acids (**PUFA**), and saturated fatty acids (**SFA**) ratio and lower total SFA, total PUFA concentration, and total n-6:n-3 ratio in breast muscle than the control group ($P < 0.05$). Taken together, these results indicated that addition of 200 mg/kg CS improved meat quality in growing Huoyan geese through altering slaughter performance, meat traits, amino acids, and fatty acids composition.

Key words: dietary chitosan, growing Huoyan geese, amino acids, fatty acids, meat quality

INTRODUCTION

Growing evidence has shown that chitosan (**CS**) plays an important role in regulating fat metabolism and improving meat quality (Chiu et al., 2017; Liu et al., 2018). Previous findings indicated that dietary CS reduced abdominal fat percentage, saturated fatty acid (**SFA**) concentration, plasma total cholesterol, and high-density lipoprotein cholesterol concentration; increased plasma total monounsaturated fatty acids (**MUFA**); and improved meat quality of broilers (Razdan and Pettersson, 1994; Zhou et al., 2009). Other studies also observed that feeding CS improved whole-body lipid metabolism in piglets (Wang et al., 2003) and decreased serum cholesterol concentrations in prawns and fish (Ørjan et al., 2015; De los Santos Remero et al., 2017). Razdan and Pettersson (1994) found that CS decreased plasma lipid concentration in broiler chickens. Zhao et al. (2017) revealed that 500 mg/kg dietary CS significantly decreased serum triglycerides and total cholesterol levels and improved slaughter performance in Yangzhou geese. Xia and Zhao (2010) observed that supplementation of CS depressed ether extracted carcass fat content and elevated crude protein concentration in goose meat. Chang et al. (2008) reported that dietary supplementation of CS decreased the carcass fat and increased crude protein and tenderness, but no differences were observed in carcass traits. Lokman et al. (2019) also observed that CS improved carcass quality and depressed fat deposition. Numerous studies have also demonstrated that CS can improve the meat quality in pigs, broiler chickens, and fish. However, little is known about the effects of CS on carcass traits and meat quality in growing Huoyan geese. Therefore, the present experiment aimed to investigate the effects of dietary supplementation of CS on carcass traits, compositions of amino acids and fatty acids, and meat quality in growing Huoyan geese. These data would provide a scientific basis for the rational dietary addition of CS in geese.

MATERIALS AND METHODS

Experimental Design and Diets

All bird-handing protocols in this study were approved by the Animal Care and Use Committee of Henan Institute Science and Technology (Xinxiang, P.R. China). A total of 320 (28 D of age, sex balance) healthy growing Huoyan geese with similar body weight (1.09 ± 0.02 kg) were randomly divided into 4 groups (control, CS_{100}, CS_{200}, and CS_{400} groups). Each group includes 4 replicates with 20 geese per replicate. Control group was fed a basal diet without CS, and CS_{100}, CS_{200}, and CS_{400} groups were fed the same basal diets containing 100, 200, and 400 mg/kg CS, respectively. The basal diet was formulated to meet or exceed the National Research Council (NRC, 1994) nutrient requirements for growing geese. The feeding trail lasted for 4 wk (from 28–56 D of age), and the composition and nutrient levels of the basal diet are shown in Table 1. Crude protein (CP), calcium (Ca), and phosphorus (P) content of experimental diets was analyzed according to the Association of Official Analytical Chemists (AOAC, 2000) procedures. Metabolic energy was calculated according to NRC (1994). The CS in present study was purchased from Shanghai Lanji technology development Co., Ltd. (Shanghai, P.R. China) with deacetylation degree more than 90.00% and viscosity of 45 cps. All birds were reared in the same condition and had *ad libitum* access to an experimental diet and water via nipple drinkers.

Slaughter and Carcass Measurements

At the 56 D of age, a total of 32 geese (8 geese per group, sex balance) were randomly selected, weighed, and slaughtered (cutting the carotid arteries) after fasting 12 h. The slaughter procedures were conducted according to the methods of Geldenhuys et al. (2013).

Table 1. Ingredients and nutrients of the experimental of diets (air-dry basis).

Ingredients		Nutrition level	
Corn (%)	66.75	ME (MJ/kg)[2]	11.55
wheat bran (%)	15.00	Crude protein (%)	15.00
Soybean (%)	8.99	Calcium (%)	0.80
Fish meal (%)	3.0	Available phosphorus (%)	0.40
Limestone (%)	0.18	Lysine (%)	0.95
$CaHPO_4$ (%)	0.67	Methionine + Cystine (%)	0.67
DL-Methionine (%)	0.08	Threonine (%)	0.16
L-lysine-HCL (%)	0.33		
Premix[1] (%)	5.00		
Total (%)	100		

Abbreviation: ME, metabolic energy.

[1]Premix supplied per kg: 30,000 IU of vitamin A; 5,000 IU of vitamin D_3; 20 IU of vitamin E; 38 mg of vitamin K_3; 5 mg of vitamin B_1; 10 mg of vitamin B_2; 60 mg of nicotinamide; 5 mg of vitamin B_6; 10 mg of D-calcium pantothenate; 3 mg of pyridoxol; 0.1 mg of biotin; 1,000 mg of choline; 1 mg of folic acid; 20 μg of vitamin B_{12}; 5 mg of Cu; 100 mg of Fe; 80 mg of Mn; 100 mg of Zn; 0.1 mg of Se (Na_2SeO_3); 0.15 mg of Co (LCO_4); 0.4 mg of I (KIO_3).

[2]Calculated values.

Briefly, the heads, both of feet, tip of wing, and skin of every experimental goose were removed, and then the geese were eviscerated and weighed to determine dressing percentage. The neck was removed, and the carcass was split longitudinally. Abdominal fat and breast and thigh muscles were removed and weighed to calculate the percentages of breast and thigh muscle, abdominal fat, eviscerated carcass percentage, and half eviscerated carcass percentage. After slaughtering, the meat samples were chilled for 24 h at 4°C, then the breast and thigh muscles from the left side were taken to split into 2 parts. One part was used to measure drip loss, color, and pH value, and the other part was frozen in liquid nitrogen and stored at −70°C until subsequent analyses of chemical composition, shear force, amino acids, and fatty acids composition according to the method of Liu and Zhou (2013).

pH and Color Measurement

The breast and thigh muscles of each experimental goose were used to determine dry matter, CP, and crude fat (CF) content according to the methods of AOAC (2000). After storage for 24 h at 4°C, the meat color (containing L*, a*, and b* value, with L* indicating lightness, a* the redness, b* the yellowness) were determined using a colorimeter (Konica Minolta CR 410; Sensing Inc, Osaka, Japan), and meat pH value was determined using a pH meter (Model PC 510; Cyber scan, Singapore) according to the methods described by previous researchers (Damaziak et al., 2016; Boz et al., 2019).

Drip Loss and Shear Force Measurement

Drip loss of breast and thigh muscles was determined according to the methods described by previous studies (Bianchi et al., 2007; Boz et al., 2016). In addition, the frozen breast and thigh muscle samples were thawed at 4°C, and 3 slices (parallel to the muscle fibers longitudinally) from each meat sample were used to determine the shear force with a Warner-Bratzler shear device (Zwick Roell Group, Ulm, Baden Wuerttemberg, Germany) according to the method described by Liu and Zhou (2013).

Amino Acids Composition Analysis

Amino acids composition of breast muscle samples in each experimental goose was determined using a HITICHI L-8900 automatic amino acid analyzer (Hitachi Ltd., Japan) according to a modification of the methods described by Waheed et al. (2018).

Fatty Acids Composition Analysis

Total fatty acid was extracted from breast muscle sample and methylated and analyzed according to the methods of O'Fallon et al. (2007). The fatty acid methyl ester was separated and quantified according to the

procedure described by previous researcher (Waheed et al., 2018). Results of fatty acids were expressed as the percentage of the total fatty acids identified and grouped as follows: SFA, MUFA, PUFA, n-6, and n-3. In addition, the n-6:n-3 and PUFA:SFA ratio were also calculated.

Statistical Analysis

Statistical ANOVA was performed using the one-way ANOVA procedure of SPSS Statistics 17.0 (IBM, Armonk, NY). Significant differences among all treatment means were measured at $P < 0.05$ by Duncan's multiple range tests. All data were presented as mean $\pm$ SEM (standard error of the means).

RESULTS

Slaughter Performance

The effects of dietary supplementation of CS on slaughter performance in growing Huoyan geese were shown in Table 2. The geese in the CS_{200} group had lower abdominal fat percentage than those in the control group ($P < 0.05$). There was no significant difference among all experimental groups ($P > 0.05$, containing CS_{100}, CS_{200}, and CS_{400}). In addition, dietary CS had no significant effect on the live weight, dressing percentage, eviscerated carcass percentage, halt-eviscerated carcass percentage, breast muscle percentage, and thigh muscle percentage ($P > 0.05$).

Meat Quality

As shown in table 3, the pH, L*, a* value, CP, and DM of breast and thigh muscles in growing Huoyan geese did not differ among all groups ($P > 0.05$, containing the control, CS_{100}, CS_{200}, and CS_{400} groups). Meanwhile, the geese in the CS_{200} group had lower b* value, shear force, CF levels, and drip loss than those in the control group ($P < 0.05$), and no significant differences were observed among all experimental groups ($P > 0.05$).

Amino Acids Composition

The effects of CS on amino acids composition from breast muscle in growing Huoyan geese were shown in Table 4. The geese in the CS_{200} group had higher glutamic acid, glycine, total nonessential amino acids, lysine, valine, and total essential amino acids (**EAA**) concentration than those in the control group ($P < 0.05$), while no significant differences were observed among all experimental groups ($P > 0.05$). In addition, compared with the control group, all experimental groups had higher total amino acids (**AA**) concentration ($P < 0.05$), and no difference was observed among all experimental groups ($P > 0.05$). Meanwhile, other amino acids of breast muscle did not differ among all groups ($P > 0.05$).

Fatty Acids Composition

The effects of CS on fatty acids composition from breast muscle in growing Huoyan geese were shown in Table 5. The geese in the CS_{100}, CS_{200}, and CS_{400} groups had lower total SFA concentrations than those in the control group ($P < 0.05$), and no differences were observed among all experimental groups ($P > 0.05$). The C14:0, C16:0, and C18:0 concentrations of the CS_{200} group were significantly lower than those of the control group ($P < 0.05$). However, compared with the control group, the CS_{200} group had higher C22:0 concentration ($P < 0.05$). There were no significant differences in C14:0, C16:0, C18:0, and C22:0 concentrations among all experimental groups ($P > 0.05$). In addition, the C20:0 of breast muscle did not differ among all groups ($P > 0.05$).

Total MUFA levels of breast muscle in the CS_{200} group were significantly higher than those in the control group ($P < 0.05$), and no differences were determined among all experimental groups ($P > 0.05$). The geese in the CS_{200} group had higher concentrations of C16:1, C18:1, and C20:1 than those in the control group ($P < 0.05$). There were no differences in the concentration of C16:1 and C18:1 among all experimental groups ($P > 0.05$) and the concentration of C20:1 among the control, CS_{100}, and CS_{400} groups ($P > 0.05$). Meanwhile, the C22:1 concentration of breast muscle did not differ among all groups ($P > 0.05$).

Table 2. The effects of chitosan (CS) on slaughter performance in growing Huoyan geese.

Item	Groups				SEM	P value
	Control	CS_{100}	CS_{200}	CS_{400}		
Live weight (kg)	2.915	2.933	2.962	2.941	0.24	0.082
Eviscerated carcass percentage (%)	70.14	71.83	71.61	71.22	1.35	0.112
Half-eviscerated carcass percentage (%)	77.27	78.19	78.64	78.22	1.69	0.214
Dressing percentage (%)	85.66	86.03	86.72	86.31	1.96	0.320
Abdominal fat percentage (%)	3.34[a]	2.76[a,b]	2.64[b]	2.82[a,b]	0.01	0.001
Thigh muscle percentage (%)	14.19	14.28	15.42	14.89	1.22	0.095
Breast muscle percentage (%)	8.86	9.11	9.26	9.04	0.68	0.068

[a,b]In the same column, values with different small letter superscripts mean significant difference ($P < 0.05$).
Control, basal diet. CS_{100}, basal diet + 100 mg/kg CS. CS_{200}, basal diet + 200 mg/kg CS. CS_{400}, basal diet + 400 mg/kg CS. The feeding trail lasted for 4 wk (from 28–56 D of age).

Table 3. Effects of CS on meat quality in growing Huoyan geese.

Item	Control	CS$_{100}$	CS$_{200}$	CS$_{400}$	SEM	P value
Breast muscle						
pH value	6.56	6.50	6.41	6.35	0.28	0.131
CP (%)	23.16	24.82	25.44	24.38	0.65	0.089
CF (%)	4.77[a]	4.22[a,b]	3.31[b]	3.46[a,b]	0.03	0.001
DM (%)	28.11	29.86	32.43	29.09	0.79	0.092
L*	52.36	53.11	53.26	52.47	0.68	0.074
a*	14.52	15.65	16.01	15.28	0.84	0.063
b*	9.88[a]	7.91[a,b]	5.85[b]	6.64[a,b]	0.34	0.001
Shear force (Newton)	44.42[a]	42.18[a,b]	39.12[b]	42.77[a,b]	0.13	0.008
Drip loss (%)	9.74[a]	8.01[a,b]	6.72[b]	7.88[a,b]	0.25	0.004
Thigh muscle						
pH value	6.42	6.38	6.34	6.39	0.19	0.066
CP (%)	19.62	20.88	22.31	21.43	0.71	0.071
CF (%)	4.31[a]	3.89[a,b]	2.94[b]	3.21[a,b]	0.02	0.001
DM (%)	25.42	26.68	27.26	26.41	0.44	0.088
L*	45.94	46.31	46.82	46.26	0.48	0.094
a*	11.56[b]	12.38[a,b]	14.66[a]	12.71[a,b]	0.33	0.002
b*	14.48[a]	12.62[a,b]	11.32[b]	12.54[a,b]	0.15	0.001
Shear force (Newton)	47.12[a]	46.23[a,b]	43.69[b]	45.38[a,b]	0.22	0.002
Drip loss (%)	9.55[a]	8.21[a,b]	7.25[b]	7.61[a,b]	0.13	0.001

[a,b]In the same column, values with different small letter superscripts mean significant difference ($P < 0.05$).

L* = lightness; a* = redness, b* = yellowness.

Control, basal diet. CS$_{100}$, basal diet + 100 mg/kg CS. CS$_{200}$, basal diet + 200 mg/kg CS. CS$_{400}$, basal diet + 400 mg/kg CS. The feeding trail lasted for 4 weeks (from 28–56 D of age).

Abbreviations: CF, crude fat; CP, crude protein; CS, chitosan; DM, dry matter.

Compared with the control group, the CS$_{200}$ group had lower concentrations of total PUFA ($P < 0.05$). And, the geese in CS$_{200}$ group had higher concentrations of C20:2 and C20:5 than those in the control groups ($P < 0.05$). There were no differences in C18:2 and C20:4 concentrations among all groups ($P > 0.05$). In addition, no difference was observed in C20:5 concentration among all experimental groups and in C20:2 concentration among the control, CS$_{100}$, and CS$_{400}$ groups ($P > 0.05$). In addition, the CS$_{200}$ group had higher total

Table 4. Effects of chitosan (CS) on amino acids composition from breast muscle in growing Huoyan geese.

Item	Control	CS$_{100}$	CS$_{200}$	CS$_{400}$	SEM	P value
Nonessential amino acid (NEAA)						
Arginine (%)	6.40	6.43	6.51	6.46	0.47	0.120
Aspartic acid (%)	7.89	7.82	7.93	7.86	0.82	0.118
Glutamic acid (%)	14.50[b]	15.42[a,b]	15.48[a]	15.38[a,b]	0.05	0.001
Serine (%)	3.86	3.84	3.87	3.82	0.26	0.084
Proline (%)	3.81	3.78	3.86	3.83	0.13	0.069
Glycine (%)	2.74[b]	3.27[a,b]	3.88[a]	3.41[a,b]	0.22	0.002
Alanine (%)	4.23	4.19	4.24	4.20	0.17	0.075
Essential amino acid (EAA)						
Histidine (%)	2.70	2.73	2.81	2.72	0.13	0.081
Isoleucine (%)	3.85	3.88	3.92	3.89	0.14	0.076
Leucine (%)	6.53	6.56	6.62	6.60	0.09	0.054
Lysine (%)	8.29[b]	8.93[a,b]	9.78[a]	8.95[a,b]	0.18	0.047
Threonine (%)	4.94	4.92	4.96	4.93	0.26	0.064
Phenylalanine (%)	3.88	3.89	3.96	3.92	0.05	0.084
Valine (%)	3.83[a]	4.56[a,b]	4.92[a]	4.45[a,b]	0.16	0.002
Methionine (%)	2.44	2.48	2.53	2.45	0.02	0.051
Cysteine (%)	0.73	0.72	0.74	0.71	0.01	0.052
Tyrosine (%)	2.68	2.73	2.80	2.75	0.06	0.063
Total NEAA (%)	43.43[b]	44.75[a,b]	45.77[a]	44.96[a,b]	0.04	0.003
Total EAA (%)	39.87[b]	41.40[a,b]	43.04[a]	41.37[a,b]	0.61	0.002
Total AA (%)	83.30[b]	86.15[a]	88.81[a]	86.33[a]	1.12	0.011

[a,b]In the same column, values with different small letter superscripts mean significant difference ($P < 0.05$).

Control, basal diet. CS$_{100}$, basal diet + 100 mg/kg CS. CS$_{200}$, basal diet + 200 mg/kg CS. CS$_{400}$, basal diet + 400 mg/kg CS. The feeding trail lasted for 4 wk (from 28–56 D of age).

Table 5. Effects of CS on fatty acids composition from breast muscle in growing Huoyan geese.

Item	Groups Control	CS_{100}	CS_{200}	CS_{400}	SEM	P value
SFA						
C14:0 (%)	0.88[a]	0.83[a,b]	0.72[b]	0.79[a,b]	0.02	0.001
C16:0 (%)	16.11[a]	14.42[a,b]	13.81[b]	14.59[a,b]	0.15	0.002
C18:0 (%)	4.08[a]	3.62[a,b]	3.24[b]	3.18[b]	0.09	0.002
C20:0 (%)	1.55	1.48	1.42	1.41	0.18	0.078
C22:0 (%)	1.55[b]	1.61[a,b]	1.84[a]	1.72[a,b]	0.12	0.001
MUFA						
C16:1 n-7 (%)	1.88[b]	2.19[a,b]	2.49[a]	2.12[a,b]	0.08	0.002
C18:1 n-9c (%)	41.63[b]	42.86[a,b]	45.60[a]	44.33[a,b]	0.28	0.014
C20:1 n-9 (%)	1.04[b]	1.13[b]	1.36[a]	1.16[b]	0.03	0.002
C22:1 (%)	0.11	0.13	0.16	0.14	0.08	0.058
PUFA						
C18:2 n-6 (%)	20.31	19.55	19.12	19.64	0.35	0.085
C20:2 n-9 (%)	0.04[b]	0.05[b]	0.12[a]	0.07[b]	0.01	0.001
C20:4 n-6 (%)	0.14	0.11	0.15	0.10	0.02	0.054
C20:5 n-3 (%)	0.59[b]	0.72[a,b]	0.82[a]	0.76[a,b]	0.02	0.001
Total SFA (%)	24.17[a]	21.96[b]	21.03[b]	21.69[b]	0.31	0.002
Total MUFA (%)	44.66[b]	46.31[a,b]	49.61[a]	47.75[a,b]	0.25	0.002
Total PUFA (%)	21.08[a]	20.43[a,b]	20.21[b]	20.57[a,b]	0.22	0.001
Total PUFA:SFA	0.87[b]	0.93[a]	0.96[a]	0.95[a]	0.02	0.001
Total n-6:n-3	34.66[a]	27.31[a,b]	23.50[b]	25.97[b]	0.68	0.033

[a,b]In the same column, values with different small letter superscripts mean significant difference ($P < 0.05$). Control, basal diet. CS100, basal diet + 100 mg/kg CS. CS200, basal diet + 200 mg/kg CS. CS400, basal diet + 400 mg/kg CS. The feeding trail lasted for 4 wk (from 28–56 D of age).

Abbreviations: CS, chitosan; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids.

PUFA:SFA ratio and lower total n-6:n-3 ratio than the control group ($P < 0.05$).

DISCUSSION

Numerous studies demonstrated that dietary supplementation of CS could improve slaughter performance and carcass composition of animals (Zhou et al., 2009; Miao et al., 2018; Lokman et al., 2019). In parallel, this study with supplementation of 200 mg/kg CS significantly decreased abdominal fat percentage of growing Huoyan geese, which suggested that CS has a potent effect in improving fat deposition and meat traits. Previous findings have also reported that dietary supplementation of CS decreased abdominal fat or carcass fat content in chickens, broilers, and geese (Chang et al., 2008; Zhou et al., 2009; Li et al., 2015; Zhao et al., 2017). Kobayashi et al. (2002) reported that dietary supplementation of CS (0.5%) could decrease body fat deposition by reducing lipase activity and fat absorption of the small intestine in broilers. Egan et al. (2015) demonstrated that CS has potent antiobesity or body weight control effects by multiple biological systems in vivo. In addition, no changes in dressing percentage, breast muscle percentage, eviscerated carcass percentage, halt-eviscerated percentage, and thigh muscle percentage were observed in this study. These results are in accordance with those of previous studies on broiler chickens, goose, and Peking duck (Xia and Zhao, 2010; Li et al., 2015; Jiao et al., 2016). However, another study found that addition of 200 mg/kg expanded CS remarkably increased dressing

percentage and carcass lean percentage in growing-finishing pigs (Miao et al., 2018). Inconsistent research results in dressing percentage might be due to species or age differences, as well as duration of feeding CS.

Meat color is usually used for assessing freshness and meat quality (Uhlířová et al., 2018). Previous studies have shown that poultry meat color is influenced by the myoglobin, species, age, sex, diet, and meat processing (Froning, 1995). In this present study, dietary supplementation of CS reduced b* value and CF concentration of breast and thigh muscles in growing geese. The results may be associated with lower CF levels of muscles and abdominal fat percentage (Bihan-Duval et al., 1999). Similar results were reported by Zhou et al. (2009), who observed that the b* value of meat in broilers was reduced as the level of COS in the diet increased. Previous studies showed that higher drip loss of muscles increased liquid outflow and loss of soluble nutrients, which decreases meat quality and flavor of animals (Liu et al., 2011). In this present study, we also observed that drip loss of breast and thigh muscle was decreased by dietary CS. These results suggested that dietary supplementation of CS could improve meat quality and flavor by decreasing drip loss of breast and thigh muscles in growing Huoyan geese. Similar findings were also reported on chickens and geese (Xia and Zhao, 2010; Li et al., 2015). Tenderness (shear force) is one of the most important indicators that reflect meat quality. In the present experiment, the shear force of breast and thigh muscles of growing geese was decreased by addition of dietary CS. This result suggested that dietary CS supplementation

could increase tenderness of breast and thigh muscles and improve meat quality in growing Huoyan geese.

Previous results demonstrated that meat quality, taste, and flavor were influenced by its nutritional composition, which includes amino acids, fatty acids concentration, intramuscular fat levels, and so on (Miao et al., 2018). It is well known that flavor amino acids (glutamic acid, glycine, lysine, valine, and so on) are useful for inducing flavors in food (Ardo, 2006). The present study showed that addition of dietary CS enhanced total nonessential amino acids, total EAA (especially lysine and valine), and total AA concentrations (especially glutamic acid and glycine) in breast muscle of growing Huoyan geese. The results indicated that dietary CS could improve meat quality in breast muscle of growing Huoyan geese through increasing flavor amino acids' concentration. Similar results were reported by Miao et al. (2018), who observed that 200 mg/kg dietary expanded CS increased valine, glycine, glutamic acid, alanine, lysine, and proline concentrations in *longissimus* dorsal muscle of growing-finishing pigs, which suggested that porcine carcass composition and meat quality were affected by dietary expanded CS. However, another study reported that dietary supplementation of CS did not affect total amino acids concentration in breast muscle of princess chickens (Du et al., 2009). Chang et al. (2008) also observed that total AA and EAA in breast muscle of goose were not influenced by dietary CS supplementation. Inconsistent research results in amino acids concentration also might be due to differential species, ages, dosage, and duration of feeding CS.

Goose is characterized by fresh meat quality and good resistance with crude feed (Miao et al., 2019). In China, goose meat accounted for 94.1% of the global goose production. In addition, goose meat is relatively safe for consumers, which contains high protein, low fat, and high unsaturated fatty acid meat content (Boz et al., 2019), and the ratio of n-3:n-6 PUFA is associated with the pathogenesis of many diseases (Simopoulos, 2004). Growing evidence have shown that excessive intake of SFA and cholesterol could result in diabetes, cancer, coronary heart disease, and cardiovascular and cerebrovascular diseases in humans (Katan, 2000). The meat quality in animals is closely associated with its fat content and fatty acids composition (Fisher et al., 2000). Higher n-3 fatty acids and lower SFAs concentrations would improve meat quality and nutritional value, which decreases the risk of cardiovascular diseases (Hu et al., 2001). Liu and Zhou (2013) also reported a lower n-6:n-3 ratio in breast muscle of geese, which is favorable regarding current human dietary guidelines, while higher n-6:n-3 ratio promoted the cardiovascular disease. The present study showed that the total SFA and total n-6:n-3 ratio in breast muscle of growing geese were reduced by addition of dietary CS. These results indicated that dietary CS could improve meat quality and nutritional value through altering composition of fatty acids (especially decreasing C14:0, C16:0, and C18:0, increasing C20:5 concentration) of breast muscle

in growing Huoyan geese. Similar results were observed by Zhou et al. (2009), who reported that dietary supplementation of COS improved meat quality through decreasing total SFA concentration in breast meat of broiler chickens which indicated that consumption of these meat could reduce risk of cardiovascular disease and improve human health. Miao et al. (2018) reported that 200 mg/kg dietary expanded CS decreased C18:0 concentration in *longissimus* dorsal muscle of growing-finishing pigs and improved pork quality. In addition, in this study, we also observed that the total MUFA (C16:1, C18:1, and C20:1), total PUFA (C20:2 and C20:5) concentrations, and total PUFA:SFA ratio were enhanced by dietary supplementation of CS. A similar result was reported by Zhou et al. (2009), who found that COS increased C18:1, C20:1, C20:2, and C20:5 concentrations and total PUFA:SFA ratio of breast muscle in broiler chickens. These results demonstrated that dietary supplementation of CS could improve meat quality through altering fatty acids composition in breast muscle of growing Huoyan geese.

CONCLUSION

The dietary supplementation of CS had a positive effect on slaughter performance, carcass composition, and meat quality in growing Huoyan geese. A diet containing 200 mg/kg CS significantly improved meat quality in growing Huoyan geese through altering slaughter performance, meat traits, amino acids, and fatty acids composition.

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