Effects of cottonseed meal on slaughter performance, meat quality, and meat chemical composition in Jiangnan White goslings

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ABSTRACT Cottonseed meal (**CSM**), which is an unconventional protein material with abundant sources, high protein content, and a relatively cheap price, can be used in poultry diets. The aim of this study was to investigate the effects of CSM on slaughter performance, meat quality and meat chemical composition in Jiangnan White goslings. A total of 300 healthy 28-day-old male goslings were randomly divided into 5 treatments, with 6 pens containing 10 geese each. Five isonitrogenous and isocaloric experimental diets were formulated such that 0% (a corn-soybean meal basal diet, control), 25% (CSM_{25}), 50% (CSM_{50}), 75% (CSM_{75}), and 100% (CSM_{100}) protein from soybean meal was replaced with CSM (corresponding to 0, 6.73, 13.46, 20.18, and 26.91% CSM in the feed, respectively). On day 70, 1 goose from each pen (6 geese per treatment) was randomly selected and killed to measure the slaughter performance, meat quality, and the meat amino acid (**AA**) and fatty acid (**FA**) compositions. The results showed that dietary CSM did not affect the slaughter performance or meat quality of geese ($P > 0.05$). The fat content of breast muscle in the CSM_{100} group was higher than that in the control group ($P < 0.05$). A concentration of 13.46% or more dietary CSM increased the threonine content but decreased the cysteine content, and 20.18% dietary CSM also decreased the valine content ($P < 0.05$). Dietary CSM concentration had no effect on the content of total saturated FAs (SFAs, $P > 0.05$), but 20.18 and 26.91% dietary CSM increased the content of total monounsaturated FAs and decreased the content of total polyunsaturated FAs (PUFAs) and PUFA/SFA in the breast muscle of geese ($P < 0.05$). In conclusion, dietary CSM did not affect the slaughter performance or meat quality of geese, but the replacement of soybean meal with CSM in whole or high proportion altered the composition of AAs and FAs in breast muscle.

Key words: cottonseed meal, goose, slaughter performance, meat quality, meat chemical composition

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INTRODUCTION

With the research and development of intensive goose farming technology in China, goose production has become increasingly specialized and widespread (Lu et al., 2011a). The use of full-price compound feed shortens the marketing period of geese, but it also increases the cost of feeding. Considering the strong tolerance and adaptability to roughage of geese, less expensive crop byproducts such as rice husk, corn starch residue, full-fat rice bran and cottonseed meal (**CSM**) are used in goose feed by animal nutritionists (Lu et al., 2011b; Wang et al., 2014; Ding et al., 2016; Sun et al., 2016; Yu et al., 2019).

Cottonseed meal, an oil industry byproduct, is used as a cheaper alternative to soybean meal (**SBM**) in poultry diets (Swiatkiewicz et al., 2016). With the improvement of the cottonseed oil extraction process, the free gossypol content of the CSM decreased (Henry et al., 2001), which greatly improved the availability of CSM as a protein feed material. Swiatkiewicz et al. (2016) reviewed the literature in recent years and showed that diets containing 10 to 15% CSM can be safely used for poultry. Likewise, we previously reported that low-gossypol CSM can completely replace SBM in diet and has no adverse effect on the growth performance of geese (Yu et al., 2019). Previous studies have focused on the effects of CSM on poultry performance but have been limited with respect to livestock product quality.

Goose meat, one of the most commonly consumed animal protein sources, has low fat, high protein, and high unsaturated fatty acid (FA) levels (Liu et al., 2011). The meat of goose is very popular in China, especially in the southern region (Sun et al., 2016). According to statistics, 2.4 million tons of goose meat was produced in China in 2016, which accounted for 94.9% of global goose production (FAO-STAT, 2016). However, it is unclear whether goose meat quality and chemical

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Table 1. Analyzed nutrient content of soybean meal (SBM) and cottonseed meal (CSM) in this study (%).

Items	SBM	CSM	Item	SBM	CSM
Dry matter	88.50	89.46	Fatty acid (% of total fatty acids)		
CP	42.42	41.34	C14:0	0.17	0.46
Crude fiber	7.54	12.45	C15:0	0.07	0.03
Crude lipid	1.80	1.38	C16:0	14.31	19.54
Ash	6.05	6.45	C18:0	3.48	2.43
Calcium	0.33	0.25	C20:0	0.23	0.36
Total phosphorus	0.62	1.02	C21:0	0.05	0.05
Free gossypol (mg/kg)	0.00	150	Total SFA	18.30	22.87
Amino acid			C16:1	0.19	0.38
Lysine	2.50	1.46	C18:1n-9c	11.27	13.44
Methionine	0.58	0.59	Total MUFA	11.46	13.81
Arginine	3.22	4.48	C18:2n-6c	57.69	61.76
Threonine	1.59	1.23	C18:3n-3	11.11	1.24
Histidine	1.07	1.10	C20:4n-6	0.04	0.00
Isoleucine	1.87	1.12	C20:5n-3	0.49	0.16
Leucine	2.94	1.95	C22:6n-3	0.91	0.15
Phenylalanine	2.04	1.91	Total PUFA	70.24	63.31
Valine	2.05	1.88	PUFA/SFA	3.84	2.77

composition are altered by the use of CSM due to the differences in the chemical composition between CSM and SBM, especially the compositions of amino acids (**AAs**) and FAs. Therefore, the aim of this paper was to investigate the effects of replacing SBM with CSM on slaughter performance, meat quality, and meat chemical composition in Jiangnan White goslings.

MATERIALS AND METHODS

Animal and Housing

All procedures in our experiments were approved by the animal care and use committee of Yangzhou University (Yangzhou, China).

The study was conducted using Jiangnan White geese. The Jiangnan White goose is a 3-line-crossed commercial white goose in China, with the characteristics of intermediate size, rapid early growth, good meat quality, and a strong tolerance and adaptability to coarse feed. A total of 300 healthy male goslings—28 D old with similar body weight (BW), produced by the same flock of geese—were obtained from a commercial hatchery (Changzhou Four Seasons Poultry Industry Co. Ltd., Jintan, China). The birds were randomized to 5 dietary treatments that included 6 replicate pens per treatment and 10 geese per pen. All geese were reared in plastic wire-floor pens (2.28 m × 1.24 m) equipped with a half-open cylindrical water tank and a feed trough. Water and feed were provided ad libitum for 42 D. The room temperature was approximately 20°C, and no heat was provided. The birds were under natural daylight.

Diets

All feed raw materials (i.e., corn, SBM, CSM, rice husks, and wheat bran) were analyzed for crude protein, crude fiber, and calcium. Then, 5 isonitrogenous and isocaloric experimental diets were formulated mainly according to the NRC (1994) recommendations and prior research results (Shi et al., 2007; Wang et al., 2010) for major nutrients of geese. The control group was fed a corn-SBM basal diet, and the 4 experimental diets included 6.73, 13.46, 20.18, or 26.91% CSM (free gossypol: 150 mg/kg), respectively (correspondingly, 25% (CSM_{25}), 50% (CSM_{50}), 75% (CSM_{75}), and 100% (CSM_{100}) dietary protein content provided by SBM in the control diet was replaced with CSM. The chemical compositions of the SBM and CSM are shown in Table 1. The composition and nutrient levels of the experimental diets are listed in Table 2. The FA compositions of these diets are presented in Table 3.

Sample Collection and Measurements

At 70 D of age, geese were weighed after a 6-h fast and feed intake was recorded by replicate to calculate average daily gain (**ADG**) and average daily feed intake (**ADFI**). The feed/gain ratio (F/G) was calculated as the ratio between ADFI and ADG in each replicate. Then, 1 goose from each pen with BW similar to the mean weight of the pen was selected, weighed individually, and slaughtered by exsanguination. After bleeding and plucking, the weight was recorded. The geese were then eviscerated, and the semieviscerated carcass, eviscerated carcass, breast muscle, thigh muscle, and abdominal fat were weighed. The percentages of carcass, semieviscerated carcass, and eviscerated carcass were calculated relative to the live BW, while the percentages of breast muscle, thigh muscle, and abdominal fat were calculated relative to the eviscerated carcass weight. After weighing, the left side of the breast meat was immediately divided into 2 pieces. One part was used to measure color, pH value, shear force, and water-holding capacity, and the other part was frozen

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

Items	Control	CSM_{25}	CSM_{50}	CSM_{75}	CSM_{100}
Ingredient, %					
Corn	58.40	59.59	60.78	61.96	63.15
Soybean meal	26.90	20.18	13.45	6.73	0.00
Cottonseed meal	0.00	6.73	13.46	20.18	26.91
Rice husk	7.70	6.92	6.15	5.40	4.63
Wheat bran	3.30	2.80	2.29	1.78	1.28
Limestone	1.02	1.07	1.12	1.17	1.22
Calcium hydrogen phosphate	1.26	1.22	1.18	1.14	1.10
DL-methionine	0.12	0.12	0.12	0.12	0.12
L-lysine HCl	0.00	0.07	0.15	0.22	0.29
Salt	0.30	0.30	0.30	0.30	0.30
Premix[1]	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00
Nutrient level[2], %					
ME (MJ/kg)	11.04	11.04	11.04	11.04	11.04
CP	16.95	17.01	16.98	17.10	17.07
Crude lipid	1.90	1.86	1.75	1.83	1.80
Crude fiber	6.58	6.70	6.68	6.72	6.80
Calcium	0.83	0.90	0.85	0.88	0.86
Available phosphorus	0.42	0.42	0.42	0.42	0.42
Lysine	0.85	0.84	0.86	0.84	0.83
Methionine	0.37	0.34	0.36	0.35	0.37
Arginine	1.11	1.20	1.35	1.47	1.63
Threonine	0.65	0.64	0.65	0.66	0.63
Histidine	0.31	0.32	0.33	0.31	0.32
Isoleucine	0.64	0.62	0.59	0.57	0.54
Leucine	1.28	1.25	1.22	1.19	1.17
Phenylalanine	0.78	0.81	0.80	0.79	0.86
Valine	0.72	0.74	0.73	0.75	0.73
Free gossypol (mg/kg)	0	10.10	20.19	30.27	40.37

[1]One kilogram of premix contained 1,200,000 IU retinol, 400,000 IU rachitasterol, 1,800 IU D-a-tocopherol, 150 mg coagulation vitamin, 90 mg thiamine, 800 mg riboflavin, 320 mg pyridoxine, 1 mg cobalamin, 4.5 g nicotinic acid, 1,100 mg pantothenic acid, 65 mg folic acid, 5 mg biotin, 45 mg choline, 6 g Fe (ferrous sulfate), 1 g Cu (copper sulfate), 9.5 g Mn (manganese sulfate), 9 g Zn (zinc sulfate), 50 mg I (potassium iodide), and 30 mg Se (sodium selenite).

[2]Analyzed values except for ME, available phosphorus and free gossypol.

at −20°C until analysis of the contents of moisture, protein, and fat and the composition of AAs and FAs.

Meat Quality

The meat color was measured at 3 randomly selected positions using a chroma meter (Konica Minolta, CR-400, Osaka, Japan), and the results were expressed as CIE (Commission Internationale de l'Eclairage) L*, a*, and b*. The pH value was recorded at 45 min post-mortem using a pH meter (pH-STAR, Matthaus, Berlin, German). According to the method of Tang et al. (2009), the shear force and expressible moisture were measured using a digital tenderness meter (C-LM3B, Tenovo, Beijing, China) and a meat quality pressure meter (Meat-1, Tenovo, Beijing, China), respectively.

Chemical Analysis of Meat

The contents of crude moisture, crude protein, and crude fat in the breast muscle were analyzed according to the procedures set forth by the Association of Official Analytical Chemists (AOAC International, 1995).

Table 3. Fatty acid composition of diet (% of total fatty acids).[1]

Item	Control	CSM_{25}	CSM_{50}	CSM_{75}	CSM_{100}
C14:0	0.10	0.12	0.13	0.14	0.15
C15:0	0.04	0.04	0.03	0.03	0.02
C16:0	13.24	13.51	13.71	13.85	14.10
C18:0	1.89	1.80	1.71	1.61	1.52
C20:0	0.30	0.32	0.33	0.33	0.34
C21:0	0.03	0.01	0.01	0.02	0.03
Total SFA	15.60	15.80	15.92	15.98	16.16
C16:1	0.15	0.16	0.17	0.17	0.18
C18:1n-9c	16.03	16.32	16.57	16.84	17.06
Total MUFA	16.18	16.48	16.74	17.01	17.24
C18:2n-6c	62.57	62.79	63.15	63.56	63.87
C18:3n-3	4.98	4.41	3.77	3.13	2.50
C20:4n-6	0.02	0.02	0.01	0.01	0.00
C20:5n-3	0.30	0.19	0.16	0.13	0.10
C22:6n-3	0.35	0.32	0.25	0.18	0.13
Total PUFA	68.22	67.73	67.34	67.01	66.60
PUFA/SFA	4.37	4.29	4.23	4.19	4.12

[1]Analyzed values. SFA = Saturated fatty acid; MUFA = Monounsaturated fatty acid; PUFA = Polyunsaturated fatty acid.

Crude moisture content was determined by oven drying at 105°C overnight. Crude protein (N × 6.25) was measured by the Kjeldahl method with the Kjeltec System 8400 (FOSS NIRSystems Inc., Hillerød, Denmark). Crude fat was extracted in a Soxhlet apparatus using petroleum ether.

The AA contents of the samples were measured using a Waters ion-exchange high-performance liquid chromatography system (GC-9A, Shimadzu, Japan) coupled to a Venusil column (4.6 mm × 250 mm × 5 μm) at a flow rate of 1 mL/min, an injection volume of 10 μL, and an absorbance wavelength of 254 nm. The temperature was controlled to be 40°C. The analytes were determined based on their retention times.

This study was performed according to the General Administration of Quality Supervision, Inspection, and Quarantine of China (GB/T 5009.168-2016). FAs were analyzed using a gas chromatography system (7890A, Agilent Corp., Santa Clara, US) coupled to a CD-2560 capillary column (100 m × 0.25 mm × 0.20 μm). The injection volume was 1 μL, the injector temperature was 270°C, and the detector temperature was 280°C. The nitrogen constant linear flow rate was set to 0.5 mL/min, and the split ratio was 1:100. The initial column temperature was held at 100°C for 13 min, increased to 180°C at 10°C/min and held for 6 min. Then, the temperature was increased to 200°C at 1°C/min, held for 5 min, and finally increased to 230°C at 5°C/min and maintained for 10.5 min. The analytes were determined based on their retention times, and FA concentrations were calculated based on their peak areas.

Statistical Analysis

All data were analyzed using a one-way ANOVA in SPSS 17.0 (SPSS Inc., Chicago, IL, USA). Each replicate pen served as an experimental unit for all statistical analyses. Significant differences among the

Table 4. Slaughter performance of geese fed increasing dietary levels of cottonseed meal (%).[1]

Item	Control	CSM_{25}	CSM_{50}	CSM_{75}	CSM_{100}	SEM	*P*-value
Dressing percentage	86.64	88.13	86.99	88.43	86.69	0.266	0.079
Half-eviscerated carcass yield	78.42	79.08	78.81	79.62	78.28	0.250	0.472
Eviscerated carcass yield	70.54	71.22	71.00	71.23	70.17	0.284	0.737
Breast yield	10.59	10.24	10.84	10.74	10.67	0.181	0.882
Thigh yield	15.38	15.84	16.02	16.25	15.35	0.183	0.466
Abdominal fat yield	2.70	2.95	2.67	3.19	2.98	0.109	0.574

[a,b]Means with different superscripts within the same row differ significantly ($P < 0.05$).
[1]Each value represents the mean of 6 replicate pens.

Table 5. Meat quality and proximate composition of breast muscle from geese fed increasing dietary levels of cottonseed meal.[1]

Item	Control	CSM_{25}	CSM_{50}	CSM_{75}	CSM_{100}	SEM	*P*-value
L*	35.78	38.06	37.05	36.56	37.22	0.374	0.416
a*	17.40	17.28	16.88	17.61	17.58	0.249	0.907
b*	5.14	5.80	5.22	5.73	6.24	0.151	0.113
pH value	6.18	6.35	6.21	6.14	6.24	0.057	0.856
Expressible moisture, %	11.42	10.08	9.83	10.92	11.83	0.571	0.800
Shear force, N	43.87	41.45	43.57	43.05	48.95	1.052	0.218
Moisture, %	71.87	71.82	70.95	70.97	70.85	0.263	0.584
Protein, %	21.39	21.07	22.26	21.74	21.18	0.176	0.198
Fat, %	4.42[b]	4.53[b]	4.33[b]	4.84[a,b]	5.65[a]	0.150	0.021

[a,b]Means with different superscripts within the same row differ significantly ($P < 0.05$).
[1]Each value represents the mean of 6 replicate pens.

treatment means were determined at $P < 0.05$ by Duncan's multiple range tests.

RESULTS

Growth Performance

Geese in the CSM_{75} and CSM_{100} groups had a higher BW at 70 D and ADFI and ADG from 28 to 70 D than those of the control group ($P < 0.05$). However, increasing dietary CSM did not affect the F/G during the whole experimental period ($P > 0.05$) (Detailed data was shown in Yu et al., 2019).

Slaughter Performance

As shown in Table 4, the dietary CSM had no significant effect on slaughter performance, including slaughter yield, half-eviscerated carcass yield, eviscerated carcass yield, breast yield, thigh yield, and abdominal fat yield ($P > 0.05$).

Meat Quality and Proximate Composition

The meat quality and proximate composition of the breast muscle of the geese are presented in Table 5. The fat content of breast muscle in the CSM_{100} group was higher than that in the control group ($P < 0.05$), whereas the moisture and protein contents of the breast muscle did not differ among the 5 groups ($P > 0.05$). There were no effects on the meat quality of breast muscle, including meat color, pH value, expressible moisture, and shear force ($P > 0.05$).

Table 6. Amino acids composition of breast muscle from geese fed increasing dietary levels of cottonseed meal (g/100 g of protein).[1]

Item	Control	CSM_{25}	CSM_{50}	CSM_{75}	CSM_{100}	SEM	*P*-value
Aspartic acid	6.34	6.34	6.40	5.96	6.30	0.087	0.532
Glutamic acid	11.27	11.23	11.73	10.79	11.56	0.170	0.506
Serine	2.95	2.93	3.27	3.00	3.17	0.048	0.131
Glycine	3.00	2.95	3.02	2.73	2.95	0.046	0.265
Histidine	2.00	2.00	2.17	2.13	2.23	0.040	0.265
Arginine	5.32	5.33	5.67	5.12	5.41	0.081	0.368
Threonine	2.68[b]	2.63[b]	3.70[a]	3.43[a]	3.60[a]	0.097	<0.001
Alanine	4.22	4.21	4.36	3.99	4.28	0.061	0.432
Proline	3.01	2.96	3.02	2.76	2.96	0.044	0.323
Tyrosine	0.69	0.67	0.68	0.63	0.70	0.012	0.449
Valine	4.41[a]	4.38[a]	4.32[a]	3.86[b]	4.02[a,b]	0.073	0.047
Methionine	1.98	1.95	2.01	1.87	1.96	0.028	0.626
Cysteine	1.89[a]	1.93[a]	0.76[b]	0.69[b]	0.71[b]	0.116	<0.001
Isoleucine	3.46	3.43	3.52	3.26	3.43	0.050	0.589
Leucine	5.75	5.70	5.84	5.42	5.72	0.081	0.571
Phenylalanine	3.09	3.06	3.11	2.89	3.06	0.043	0.523
Lysine	5.60	5.54	5.78	5.30	5.60	0.083	0.533
TAA	67.67	67.25	69.39	63.85	67.67	0.963	0.506
EAA	26.96	26.67	28.28	26.03	27.38	0.394	0.515
DFAA	30.14	30.07	31.17	28.58	30.50	0.437	0.473

[a,b]Means with different superscripts within the same row differ significantly ($P < 0.05$).
[1]Each value represents the mean of 6 replicate pens. TAA = Total amino acid; EAA = Essential amino acid; DFAA = Delicate flavor amino acid.

Amino Acid Composition

The AA levels in breast muscle are shown in Table 6. Geese in the CSM_{50}, CSM_{75}, and CSM_{100} groups had

Table 7. Fatty acid composition of breast muscle from geese fed increasing dietary levels of cottonseed meal (% of total fatty acids).[1]

Item	Control	CSM_{25}	CSM_{50}	CSM_{75}	CSM_{100}	SEM	*P*-value
C14:0	0.25[b,c]	0.24[c]	0.41[a]	0.32[a–c]	0.39[a,b]	0.024	0.040
C15:0	0.31[a]	0.44[a]	0.29[a]	0.09[b]	0.07[b]	0.035	<0.001
C16:0	24.02	24.02	25.56	25.43	26.88	0.368	0.060
C18:0	14.44	14.24	12.57	11.82	11.97	0.515	0.329
C20:0	0.42[a]	0.36[a]	0.39[a]	0.08[b]	0.06[b]	0.039	<0.001
C21:0	0.14[a]	0.16[a]	0.14[a]	0.11[a]	0.02[b]	0.014	0.008
Total SFA	39.74	39.56	39.54	37.89	39.30	0.394	0.598
C16:1	1.91	1.73	2.24	2.09	2.42	0.114	0.354
C17:1	0.14[a]	0.15[a]	0.16[a]	0.06[b]	0.02[b]	0.014	<0.001
C18:1 n-9c	35.68[b]	34.21[b]	36.11[b]	44.09[a]	43.37[a]	1.157	0.004
Total MUFA	37.88[b]	36.21[b]	38.68[b]	46.41[a]	45.95[a]	1.198	0.005
C18:2 n-6c	14.43[a]	14.35[a]	14.09[a]	11.38[b]	10.62[b]	0.412	<0.001
C18:3 n-3	1.34	1.03	1.71	1.29	1.79	0.146	0.457
C20:4 n-6	6.14[a,b]	8.37[a]	5.56[a–c]	3.19[b,c]	2.29[c]	0.605	0.004
C20:5 n-3	0.18[a]	0.20[a]	0.18[a]	0[b]	0[b]	0.021	<0.001
C22:6 n-3	0.19[a]	0.21[a]	0.15[a]	0[b]	0[b]	0.020	<0.001
Total PUFA	22.38[a]	24.23[a]	21.78[a]	15.71[b]	14.75[b]	0.968	0.001
PUFA/SFA	0.56[a]	0.61[a]	0.55[a]	0.41[b]	0.38[b]	0.023	<0.001

[a–c]Means with different superscripts within the same row differ significantly ($P < 0.05$).

[1]Each value represents the mean of 6 replicate pens. SFA = Saturated fatty acid; MUFA = Monounsaturated fatty acid; PUFA = Polyunsaturated fatty acid.

a higher threonine level but a lower cysteine level than those in the control group ($P < 0.05$). Valine levels were significantly lower in the CSM_{75} group than in the control group ($P < 0.05$). No effects of dietary CSM were observed on the contents of other AAs, total amino acids (**TAAs**), essential amino acids (**EAAs**), or delicate flavor amino acids (**DFAAs**) ($P > 0.05$).

Fatty Acid Composition

As shown in Table 7, the concentrations of FAs in breast muscle changed with the concentrations of FAs in diet. The myristic acid (C14:0) content in the CSM_{50} group was higher than that in the control group ($P < 0.05$). The pentadecanoic acid (C15:0) and arachidic acid (C20:0) contents in the CSM_{75} and CSM_{100} groups and the heneicosanoic acid (C21:0) content in the CSM_{100} group decreased compared with those in the control group ($P < 0.05$). In addition, geese in the CSM_{75} and CSM_{100} groups increased the content of oleic acid (C18:1 n-9c) but decreased the contents of cis-10-heptadecenoic acid (C17:1), linoleic acid (18:2 n-6c), eicosapentaenoic acid (C20:5 n-3), and cis-4,7,10,13,16,19-docosahexenoic acid (C22:6 n-3) in breast muscle compared to those in the control group ($P < 0.05$). The arachidonic acid (C20:4 n-6) content decreased in the breast muscle of the CSM_{100} group compared to that in breast of the control group ($P < 0.05$). Overall, dietary CSM concentration had no effect on the content of total saturated fatty acids (**SFAs**) ($P > 0.05$), but dietary 20.18 and 26.91% CSM increased the content of total monounsaturated fatty acids (**MUFAs**) and decreased the content of total polyunsaturated fatty acids (**PUFAs**) and PUFA/SFA (P/S) in the breast muscle of the geese ($P < 0.05$).

DISCUSSION

Our previous study has shown that low-gossypol CSM can completely replace SBM in diet and has no adverse effect on the growth performance of geese (Yu et al., 2019). Therefore, the current study on this basis was to further evaluate the effect of CSM on slaughter performance, meat quality, and meat chemical composition in Jiangnan White goslings.

Slaughter performance is one of the most important indicators of the economic benefits of breeding and is also a key indicator of the growth performance of meat animals (Li et al., 2017). In the present study, the carcass yield was not affected by the different concentrations of dietary CSM. For other crop byproducts, rice husk, corn starch residue, and full-fat rice bran are also used in geese production. Wang et al. (2014) reported that supplementation of hulled rice or rice husk (17.2% hulled rice and 10.3% rice husk) did not affect the carcass yield of geese at 70 D of age. Ding et al. (2016) also reported that corn starch residue supplementation below 20% did not affect the growth or slaughter performance of geese from 28 to 70 D of age. However, Sun et al. (2016) reported that full-fat rice bran supplementation (6, 12, and 18%) decreased the subcutaneous fat yield and the inclusion of 12 or 18% full-fat rice bran decreased the half-eviscerated carcass yield and eviscerated carcass yield of geese at 70 D of age. The results of the current study suggest that geese that consumed a CSM diet could balance their nutrition intake and achieve optimal performance.

Meat quality is essential in meat consumption. Many factors affect poultry meat quality, such as genetic factors, nutrition, management, biochemical changes, carcass temperature, pre-slaughter factors, primary processing, and further processing (Mir et al., 2017). In the present study, dietary CSM concentrations had no effects on meat quality, including color, pH, expressible moisture, and shear force value. Our results were different from those of Abdallh et al. (2018), who found that in fresh broiler meat (day 1) or during storage (day 1 to day 8), meat color (especially $L^*$and a^*) was increased by CSM inclusion. The reason for the difference between their study and ours may be the difference in the bird breeds. According to NY-T 2793-2015 (Objective methods for evaluating eating quality attributes of meat, Inspection and Quarantine of The People's Republic of China, 2015), the normal values of L^*, a^*, and b^* in fresh chickens are 44 to 53, 2.5 to 6.0 and 7 to 14, respectively. However, the values for goose meat do not fall within these ranges.

A previous study showed that different protein sources have varying abilities to be synthesized into protein due to differences in the ability to supply AAs (Jørgensen et al., 1984). However, our present results show that the protein content of breast muscle was not affected by increasing dietary CSM concentrations. Similar results were reported for ostriches by Dalle-Zotte et al. (2013), who indicated that a diet containing

3 to 12% CSM had no effects on the protein content of fan fillet ostrich meat. Intriguingly, geese in the CSM_{100} group showed a higher breast muscle fat content compared with that in the control group, which may increase the flavor of goose meat. A high intramuscular fat content is associated with meat flavor and tenderness.

The composition and content of AAs in animal proteins are important indicators for evaluating nutritional value. Meat provides all of the AAs essential for human nutrition (Pereira and Vicente, 2013). In addition, DFAAs, such as glutamic acid, aspartic acid, arginine, alanine, and glycine, are important precursors of volatile flavor compounds in meat (Lee et al., 2011). In the present study, the contents of TAAs, EAAs, and DFAAs in breast muscle did not change, but the contents of threonine, cysteine, and valine in breast muscle changed with the AA level caused by supplementation of dietary CSM. These results are similar to those of Qin et al. (2015), who reported that the concentrations TAAs did not change but that the concentrations of phenylalanine, tryptophan, cysteine, and tyrosine of the *longissimus* muscle decreased when gilts were offered CSM diets. Geldenhuys et al. (2015) also produced similar results, in which the AA composition of Egyptian goose meat varied due to the different diets adopted between summer (grain-based) and winter (forage-based) in South Africa.

The FA composition of poultry meat can be altered easily by diet, especially with respect to the contents of linoleic acid (C18:2 n-6c), α-linolenic acid (C18:3 n-3), and long-chain PUFAs, because the dietary constituents are incorporated into tissue lipids in a more direct manner (Wood and Enser, 1997; MacRae et al., 2005). Geldenhuys et al. (2015) also reported that the contents of oleic acid (C18:1 n-9c), linoleic acid (C18:2 n-6c), and α-linolenic acid (C18:3 n-3) of geese meat showed the greatest variation in terms of diet differences. In this study, the contents of pentadecanoic acid (C15:0), oleic acid (C18:1 n-9c), and long-chain PUFAs such as arachidonic acid (C20:4 n-6), eicosapentaenoic acid (C20:5 n-3), and cis-4,7,10,13,16,19-docosahexenoic acid (C22:6 n-3) varied with the content of FAs in the diet. However, the contents of linoleic acid (C18:2 n-6c) and arachidic acid (C20:0) in meat decreased as the dietary level of these 2 FAs increased. These results indicate that the composition of these FAs in goose meat might hardly be affected by their concentration in the diet. A similar result was also reported by Sun et al. (2016). Taken together, 20.18 and 26.91% dietary CSM increased the content of total MUFAs as the dietary level of MUFAs increased but decreased the contents of total PUFAs as the dietary level of PUFAs decreased. Dietary 20.18 and 26.91% CSM also decreased P/S in the breast muscle of geese. P/S is considered to be important in terms of human health. It is believed that a reduction in the intake of SFAs together with an increase in P/S may decrease the occurrence of cardiovascular disease in humans (Gidding et al., 2006). According to Wood et al. (2008), the recommended dietary intake of P/S must be over 0.4. Our results indicate that 26.91% dietary CSM may be potentially harmful to human health by decreasing P/S (0.38 in breast muscle).

In addition, the variation in the content of key FAs not only leads to changes in nutritional composition but may also have a substantial effect on the flavor profile and ultimate uniformity of meat (Geldenhuys et al., 2015). According to Cameron and Enser (1991), SFAs and MUFAs were positively associated with eating quality traits, while PUFAs were negatively correlated with eating quality. Our results indicate that the eating quality traits of goose meat may be improved by increasing the content of dietary CSM because of the increased MUFA content and decreased PUFA content in meat.

In conclusion, the slaughter performance and meat quality of geese were not affected by dietary CSM. However, the replacement of SBM with CSM in whole or high proportion increased the content of fat in breast muscle and altered the compositions of AAs and FAs in breast muscle.

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