Dietary resveratrol supplement improves carcass traits and meat quality of Pekin ducks

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ABSTRACT With the increase of consumer demand for high-quality animal protein, it becomes imperative to improve meat quality through nutritional strategy. Resveratrol is a plant polyphenol that exists in grapes and grape products, and it has been considered as a potential functional feed additive. Here, we aimed to explore the optimal dose of resveratrol in Pekin ducks' diet and its effect on improving meat quality. A total of 432 male Pekin ducks (1-day-old) were selected and randomly allotted to 4 treatment groups, with each group containing 6 replicates. Four different levels of resveratrol were evaluated (0, 150, 300, and 450 mg/kg) for 42 d. The carcass traits, meat quality, and muscle fiber characteristics of Pekin ducks were investigated. Results showed that a^*_{24h}, b^*_{24h}, intramuscular fat, crude protein, total flavor amino acid content of duck breast muscle, and a^*_{45min} of duck leg muscle were increased ($P < 0.05$) by resveratrol. Resveratrol also reduced abdominal fat deposition, shear force, L^*_{45min} of breast muscle and drip loss, shear force, and L^*_{45min} of leg muscle. In addition, the breast muscle fibers of resveratrol-fed ducks had lower diameter and cross-sectional area and higher density ($P < 0.05$). Overall, we conclude that dietary resveratrol supplement can effectively improve Pekin duck meat quality, the optimal additional range in diet being 300 to 450 mg/kg. Its underlying mechanism might be partly through stimulation of intramuscular fat and flavor amino deposition and alteration of muscle fiber characteristics.

Key words: resveratrol, carcass trait, meat quality, Pekin duck

2021 Poultry Science 100:100802
https://doi.org/10.1016/j.psj.2020.10.056

INTRODUCTION

In the past decades, great progress has been achieved in livestock-breeding practice. The daily gain, feed conversion rate, and disease resistance of livestock and poultry have been greatly improved (Niwayama et al., 2009). However, this gain in growth rate and feed efficiency has brought negative effects such as the decline of meat quality and flavor (Hocking and P, 2014). The corresponding contradiction is that consumers demand for higher quality livestock and poultry meat products with the improving living standards. It is widely known that tenderness and flavor are the most important factors affecting meat quality (Mir et al., 2017). The tenderness of meat depends on the characteristics of muscle fiber (Koohmaraie et al., 2002), while the content of intramuscular fat and amino acids are the key factors that determine the taste and flavor of meat (Cameron et al., 2000; Nelson et al., 2002).

The Pekin duck is a typical breed that has been highly selected. The Pekin ducks production system is characterized as a low-input, high-reward production system (Xu et al., 2011). The ducks have fast growth rate, and the system is suitable for mass production in areas with good water supply. However, the meat of Pekin ducks is not as delicious as that of local duck breeds. In China, the Pekin duck is not popular in the fresh market. Therefore, it is an urgent nutritional challenge to improve the meat quality of Pekin ducks.

Resveratrol is a natural plant polyphenol, being found widely in grapes, peanuts, and other plants. It is a kind of plant antitoxin and has an extensive range of pharmacological functions. Resveratrol has shown antiinflammatory, anticancer, and antioxidant effects in previous studies (Jang, 1997; Elmali et al., 2007; Liu et al., 2014). Moreover, resveratrol was also found to affect lipid metabolism, regulate adipocyte proliferation, differentiation and apoptosis, and improve meat quality (Ahn et al., 2008; Timmers et al., 2011; Zhang et al., 2015a,b). In the past decades, resveratrol attracted great attention at

Received August 24, 2020.
Accepted October 20, 2020.

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home and abroad regarding its potential medicinal use. At present, most of the research on resveratrol is carried out in mammals and rarely in poultry, especially in ducks. Therefore, we hypothesized that resveratrol could improve Pekin duck meat quality by promoting the intramuscular fat and amino acid deposition or changing muscle fiber characteristics. Therefore, the objective of this study was to seek the optimal dose of resveratrol in Pekin ducks' diet and its effect on improving carcass traits and meat quality.

MATERIALS AND METHODS

Animals, Diets, and Experimental Design

This animal trial procedures were conducted in accordance with the guidelines of the National Institutes of Health Guide for the Care and Use of Laboratory Animals, and the study protocol was approved by the Institutional Animal Care and Use Committee (**IACUC**) of Hunan Agricultural University.

White Pekin ducks were purchased from Hunan Xiangjia Husbandry (Changde, China). A total of 432 male Pekin ducks (1 day old) with similar body weight were selected and randomly allotted to 4 treatment groups; each group contains 6 replicates with 18 birds per group. This experiment trial lasted for 42 d. The 4 experimental treatments were design as follows: 1) basal diet, 2) basal diet + 150 mg/kg resveratrol, 3) basal diet + 300 mg/kg resveratrol, and 4) basal diet + 450 mg/kg resveratrol. The basal diet was formulated to meet or exceed all the nutrient requirements of poultry according to National Research Council (1994) (Nutrition et al., 2000), and the ingredients' composition and nutrient levels of the basal diet are shown in Table 1. Animals were reared in cage with ad libitum feed. Ducks, feedstuff, and drink water facilities were checked every 8 h, and the mortality rate was recorded. Resveratrol was extracted from *Polygonum cuspidatum*, the purity of which is more than 98%, provided by Hunan Engineering and Technology Center for Natural Products. This animal experiment was carried out in the Yuanjiang experimental site of Institute of Bast Fiber Crops, Chinese Academy of Agricultural Sciences.

Slaughter Surveys and Sample Collection

On day 42, ducks were weighed, and the bird with median BW from each pen was selected for sampling. The slaughter performance was measured and calculated according to the poultry production performance noun terms and metric statistics method (NY/T823-2004). Then, breast and drumstick muscle samples from the right side of the carcass were taken out and frozen at −20°C for muscle composition analysis. Another muscle sample was stored in formalin for muscle fiber sectioning and histology.

Meat Quality

Muscle tissues from breast and drumstick were taken to determine index of meat quality. The pH and color were measured at 45 min and 24 h after slaughter with a digital pH-meter (Testo 205; Testo SE & Co, Lenzkirch, Germany) and a chromameter CR-400 (Konica Minolta, Osaka, Japan), respectively. Drip loss was determined by the following method: within 1 h after slaughtering, about 1-cm-thick muscle sample trimmed off fat was weighed (W_1) and then hung in a plastic cup with iron wire; it was put into a fresh-keeping bag and sealed and stored in a refrigerator at −4°C; after 24 h, the surface water was wiped with filter paper and then reweighed (W_2). Drip loss% = $(W_1 - W_2)/W1*100$.

Forty-eight hours after postmortem, those muscle samples were packed in plastic bags and heated in hot water until the meat center temperature reached 70°C. Cooking loss was calculated. Then it was cooled and cut into long strips in the direction parallel to the muscle fibers (about 5 g) for shear force value test, and by using a shear apparatus (C-LM3B; Harbin, China), each sample was cut 3 times to measure and calculate average shear force value (N).

Chemicals

About 50 g of breast or leg muscle samples were freeze-dried for 72 h to calculate the percentage of dry matter. Dried samples were crushed and analyzed for crude protein and fat content according to AOAC (1995) methods. The amino acid content in muscle was analyzed on an L-8800 automatic amino acid analyzer (Hitachi, Japan).

Muscle Fiber Characteristic

The breast and leg muscle samples were made into paraffin sections. After hematoxylin-eosin staining, the optimal sections were observed under a microscope, and histological images were captured for image analysis. The diameter and density of muscle fibers were measured by using the Image-Pro Plus software (Media Cybernetics, Silver Spring), and the cross-sectional area of muscle fibers was calculated.

Statistical Analysis

Results are given as mean values and a pooled SEM. All data were analyzed using the GLM procedure of SAS 9.4 software (SAS Inst. Inc., Cary, NC). Then Duncan's multiple range test and Orthogonal polynomial contrasts were applied. If P value is less than 0.05, significant different is defined.

RESULTS

Carcass Traits

There were no significant differences in dressing percentage, semi-eviscerated rate, eviscerated rate, leg muscle percentage, and breast muscle percentage among the 4 groups ($P > 0.05$) from Table 2. Compared with the basal diet group, the abdominal fat percentage of

Table 1. Ingredient composition and nutrient levels of basal diet (air-dry basis).

Ingredient, g/kg	0–21 d	22–42 d
Corn	470	587
Soybean meal	357	210
Wheat bran	85	120
Soybean oil	41.2	38.0
Limestone	14.4	14.0
Dicalcium phosphate	16.1	14.9
Salt	4.0	4.0
DL-Methionine	1.7	1.4
L-Lysine	0.6	0.7
Premix[1]	10.0	10.0
Total	1,000	1,000
Calculated composition		
ME, Kcal/kg	3,087	3,150
CP, g/kg	219.5	161.7
Calcium, g/kg	9.2	8.4
Phosphorus, g/kg	7.2	6.4
Available phosphorus, g/kg	4.9	4.5
Methionine, g/kg	4.7	3.8
Lysine, g/kg	11.2	7.6

[1]Premix provides the following for per kilogram diet: vitamin A 11,000 IU; vitamin D3 3,000 IU; vitamin E 30 IU; vitamin K3 2.5 mg; vitamin B1 2 mg; vitamin B2 8 mg; vitamin B12 0.02 mg; calpanate 20 mg; niacin 50 mg; folic acid 1 mg; biotin 0.1 mg; iron 60 mg; Cu 10 mg; Zinc 50 mg; Mn 90 mg; Selenium 0.2 mg; I 0.3 mg.

Pekin ducks fed with 450 mg/kg resveratrol decreased by 26.27% ($P = 0.04$), and there was a linear relationship between resveratrol and the abdominal fat rate of Pekin ducks ($P = 0.007$).

Meat Quality

Table 3 shows that there was no significant difference in drip loss, cooking loss, pH_{45min}, and pH_{24h} among the 4 groups. Compared with the basal diet group, the shear force of duck breast muscle which was fed with 450 mg/kg resveratrol decreased by 10.27% ($P = 0.026$). There was a linear relationship between resveratrol and breast muscle shear force. Forty-five minutes after slaughter, the breast muscle color L* of 150 mg/kg resveratrol group was significantly lower than that of the basal diet group ($P = 0.047$), but there was no significant difference in breast muscle color a* and b* between each group. Twenty-four hours after slaughter, compared with the basal diet group, adding 150 mg/kg, 300 mg/kg, and 450 mg/kg resveratrol increased breast muscle color a* by 8.56, 7.41, and 9.94%, respectively, with a significant linear relationship ($P = 0.029$). Moreover, the duck breast muscle color b* increased by 5.76, 10.99, and 12.30%, respectively, and showed a linear relationship ($P = 0.014$). There was no significant difference in breast muscle color L* among these groups ($P > 0.05$).

No significant difference was found in cooking loss, pH_{45min}, pH_{24h}, and meat color (24 h after slaughter) among those leg muscle samples of each group. Compared with the basal diet group, the drip loss of leg muscle of 450 mg/kg resveratrol group decreased by 16.32% ($P = 0.012$). The shear force of leg muscle of 300 mg/kg resveratrol group decreased by 13.17% ($P = 0.039$). Forty-five minutes after slaughter, compared with the basal diet group, adding 150 mg/kg, 300 mg/kg, and 450 mg/kg resveratrol decreased ($P = 0.001$) 4.57, 2.61, and 4.71% leg muscle color L*, respectively, with a significant linear relationship ($P = 0.002$); moreover, it linearly increased leg muscle color a* by 5.24, 9.21, and 18.71%, respectively. There was no significant difference in leg muscle color b* among these groups ($P > 0.05$).

Meat Chemical Analysis

As presented in Table 4, there was no significant difference in crude moisture, dry matter, and intramuscular fat among the breast muscle samples in the different groups ($P > 0.05$). Compared with the basal diet group, adding 300 mg/kg resveratrol increased intramuscular fat and crude protein content of breast muscle ($P < 0.05$). No significant difference was found in crude moisture, dry matter, intramuscular fat, and crude protein among the 4 leg muscle samples ($P > 0.05$).

Meat Amino Acid Content

Seventeen amino acids were analyzed in breast and leg muscles, including 7 essential amino acids and 10 nonessential amino acids. Table 5 shows that the content of Glu in breast muscle was the highest, followed by Lys and Arg. Compared with the basal diet group, adding 450 mg/kg resveratrol significantly increased the content of His, Arg, Cys, Ile, and Phe in breast muscle, but there was no significant difference in total amino acid content and total essential amino acid content among the 4 groups. However, the total contents of nonessential amino acids and flavor a mino acids in 300 mg/kg and 450 mg/kg resveratrol groups were significantly higher ($P = 0.043$) than those in the basal

Table 2. Effect of resveratrol on carcass traits of Pekin ducks.

	Resveratrol (mg/kg)					*P* value		
Items (%)	0	150	300	450	SEM	ANOVA	Linear	Quadratic
Dressing percentage	87.2	86.52	86.56	86.72	0.63	0.863	0.622	0.513
Half-eviscerated yield	81.63	81.15	81.01	80.9	0.62	0.848	0.411	0.701
Eviscerated yield	75.09	74.44	76.11	74.91	0.97	0.667	0.797	0.777
Breast muscle rate	14.81	16.64	14.95	15.2	0.86	0.427	0.893	0.370
Leg muscle rate	10.94	10.4	11.3	10.35	0.63	0.671	0.763	0.751
Abdominal fat rate	1.18[a]	1.01[a,b]	0.99[a,b]	0.87[b]	0.07	0.040	0.007	0.727

[a,b]Within a row, means with different superscript letters are significantly different ($P < 0.05$).

Table 3. Effect of resveratrol on meat quality of Pekin ducks.

Items		Resveratrol (mg/kg)				SEM	*P* value		
		0	150	300	450		ANOVA	Linear	Quadratic
Breast muscle	Drip loss (%)	2.93	2.83	3.14	2.83	0.34	0.907	0.993	0.756
	Cook loss (%)	40.19	37.62	38.97	38.47	1.51	0.684	0.580	0.501
	Shear force(N)	3.70^{a}	3.62^{a}	3.76^{a}	3.32^{b}	0.22	0.026	0.042	0.085
	pH_{45min}	6.8	6.8	6.84	6.75	0.03	0.268	0.360	0.195
	$pH_{24\ h}$	6.41	6.41	6.39	6.49	0.05	0.575	0.375	0.342
	L^{*}_{45min}	41.06^{a}	38.92^{b}	40.45^{a}	39.67^{a,b}	0.52	0.047	0.279	0.202
	a^{*}_{45min}	15.56	16.33	16.28	16.64	0.83	0.823	0.400	0.809
	b^{*}_{45min}	5.24	6.01	5.72	5.75	0.34	0.470	0.431	0.291
	$L^{*}_{24\ h}$	40.64	39.9	40.65	41.12	0.71	0.675	0.490	0.400
	$a^{*}_{24\ h}$	17.41^{b}	18.90^{a}	18.70^{a,b}	19.14^{a}	0.48	0.048	0.029	0.289
	$b^{*}_{24\ h}$	3.82^{b}	4.04^{a,b}	4.24^{a}	4.29^{a}	0.13	0.039	0.014	0.512
Leg muscle	Drip loss (%)	3.86^{a}	3.35^{a,b}	3.69^{a,b}	3.23^{b}	0.189	0.012	0.082	0.891
	Cook loss (%)	26.11	26.53	26.14	24.55	1.42	0.765	0.432	0.485
	Shear force (N)	3.34^{a}	3.33^{a}	2.90^{b}	3.16^{a,b}	0.11	0.039	0.067	0.226
	pH_{45min}	6.86	6.82	6.79	6.8	0.04	0.631	0.261	0.532
	$pH_{24\ h}$	6.42	6.41	6.45	6.44	0.04	0.905	0.635	0.957
	L^{*}_{45min}	42.91^{a}	40.95^{b}	41.79^{b}	40.89^{b}	0.32	0.001	0.002	0.118
	a^{*}_{45min}	14.85^{b}	14.11^{b}	15.41^{a,b}	16.75^{a}	0.56	0.024	0.012	0.081
	b^{*}_{45min}	4.99	4.98	4.61	5.02	0.3	0.730	0.800	0.505
	$L^{*}_{24\ h}$	45.65	45.76	45.45	43.88	0.84	0.373	0.150	0.323
	$a^{*}_{24\ h}$	17.08	16.12	16.36	16.85	1.18	0.934	0.939	0.542
	$b^{*}_{24\ h}$	4.08	4.71	4.56	4.38	0.26	0.374	0.521	0.135

[a,b]Within a row, means with different superscript letters are significantly different ($P < 0.05$).
[1]L*: lightness.
[2]a*: redness.
[3]b*: yellowness.

diet group. Table 6 shows that the content of Glu in the leg muscle was the highest, followed by Lys and Arg. Compared with the basal diet group, the content of Tyr, Cys, and Phe in the other 3 groups adding resveratrol increased significantly ($P < 0.05$). The contents of Gly and Arg in 150 mg/kg and 300 mg/kg resveratrol groups were significantly higher ($P < 0.05$) than those in basal diet group, and the Lys content in 300 mg/kg and 450 mg/kg resveratrol groups was significantly higher ($P = 0.049$) than that in the basal diet group. There was no significant difference in total amino acid content, essential amino acid content, nonessential amino acid content, and flavor amino acid content among the leg muscle samples ($P > 0.05$).

Muscle Fiber Characteristics

The top half of the Table 7 shows breast muscle fiber traits of Pekin ducks with resveratrol supplement. It can be seen from the data that the 300-mg/kg and 450-mg/kg groups reported significantly ($P < 0.05$) lower diameter and cross-sectional area than the basal diet group and a linear relationship ($P < 0.05$), besides, 450-mg/kg resveratrol group presents the greatest density ($P = 0.03$). The bottom half of the Table 7 shows leg muscle fiber trait; however, no significant difference was found ($P > 0.05$).

DISCUSSION

As the quality requirement by consumer is higher and higher day by day, producing a healthy and delicious meat is a pressing duty for producers. It is an important scientific proposition to effectively improve meat quality through nutrition regulation strategy (Issanchou, 1996). Pekin ducks have the advantages of fast growth, high net meat percentage, and high feed conversion rate, but its poor meat quality is always a problem for increasing its acceptance and consumption (Xu et al., 2012). As a comprehensive concept, animal meat quality is usually reflected by some indices, such as pH value, meat color, hydraulic power, tenderness, flavor, and dripping loss

Table 4. Effect of resveratrol on meat nutrient content of Pekin ducks.

Items (%)		Resveratrol (mg/kg)				SEM	*P* value		
		0	150	300	450		ANOVA	Linear	Quadratic
Breast muscle	Gross moisture	74.45	74.06	71.41	73.77	1.03	0.188	0.324	0.198
	Dry matter	25.54	25.94	26.58	26.23	1.03	0.188	0.324	0.198
	Intramuscular fat	2.24^{b}	2.30^{a,b}	2.71^{a}	2.50^{a,b}	0.14	0.495	0.148	0.891
	Crude protein	20.93^{b}	21.89^{a,b}	24.08^{a}	22.28^{a,b}	0.78	0.025	<0.001	0.208
Leg muscle	Gross moisture	71.65	71.87	72.2	72.69	0.81	0.818	0.353	0.873
	Dry matter	28.35	28.12	27.79	27.31	0.81	0.818	0.353	0.873
	Intramuscular fat	2.75	2.71	2.63	2.79	0.12	0.351	0.335	0.179
	Crude protein	23.80	23.55	23.04	23.10	0.71	0.487	0.814	0.228

[a,b]Within a row, means with different superscript letters are significantly different ($P < 0.05$).

Table 5. Effect of resveratrol on amino acids composition and contents in breast muscle of Pekin ducks (dry weight basis).

	Resveratrol (mg/kg)					*P* value		
Items	0	150	300	450	SEM	ANOVA	Linear	Quadratic
His	4.23[b]	4.99[a,b]	5.06[a,b]	5.40[a]	0.30	0.0308	0.0144	0.4789
Ser	2.96	3.11	3.09	2.88	0.11	0.4169	0.5994	0.1168
Glu*[1]	8.77	9.96	10.38	9.90	0.45	0.1027	0.0729	0.0772
Asp*	5.25	5.65	5.63	5.05	0.29	0.3958	0.6281	0.1059
Gly*	4.46	4.18	4.63	4.20	0.32	0.7121	0.8229	0.8050
Tyr*	3.16	3.27	3.52	3.38	0.11	0.1291	0.0684	0.2561
Arg	7.93[b]	7.98[b]	7.80[b]	8.96[a]	0.29	0.0358	0.0339	0.0677
Cys	0.77[b]	0.76[b]	0.72[b]	0.93[a]	0.05	0.0426	0.0666	0.0455
Ala*	4.34	4.38	4.87	4.84	0.23	0.2254	0.0637	0.8751
Pro	2.98	2.93	3.15	3.13	0.15	0.6348	0.2982	0.9062
Lys	7.85	8.27	8.88	8.28	0.40	0.3719	0.3071	0.2199
Thr	3.57	3.62	4.10	3.56	0.18	0.1279	0.5600	0.1123
Val	3.85	3.71	4.09	3.83	0.18	0.5169	0.6851	0.7179
Met	1.33	1.36	1.42	1.35	0.05	0.5603	0.6257	0.3076
Ile	3.26[b]	3.27[b]	3.67[a]	3.61[a]	0.13	0.0500	0.0183	0.7759
Leu	5.75	5.64	6.12	6.08	0.25	0.4493	0.1983	0.8898
Phe*	3.56[b]	3.53[b]	3.90[a,b]	4.08[a]	0.15	0.0420	0.0292	0.2946
TAA	74.00	76.60	81.04	79.45	2.20	0.1318	0.0529	0.3465
EAA	29.16	29.40	32.19	30.78	1.00	0.170	0.119	0.457
NEAA	44.84[b]	47.21[a,b]	48.85[a]	48.67[a]	1.32	0.043	0.021	0.408
FAA	26.38[b]	27.70[a,b]	29.40[a]	28.07[a]	0.97	0.049	0.106	0.164

[a,b]Within a row, means with different superscript letters are significantly different ($P < 0.05$).

Abbreviations: EAA, essential amino acid; FAA, flavor amino acid; NEAA, nonessential amino acid; TAA, total amino acid.

[1]Items with * are marked as flavor amino acid.

(Dransfield and Sosnicki, 1999). In recent years, the natural polyphenol resveratrol has attracted wide attention as a potential drug to treat or prevent a variety of diseases (Smoliga et al., 2011). Resveratrol exists in grapes and grape products and has potential properties as an anticancer, antiinflammation, and antioxidative stress molecule. (Borra et al., 2005). Studies have shown that adding resveratrol to animal diet can relieve stress and improve immunity, change the types and characteristics of muscle fiber, improve meat quality, and reduce fat deposition (Liu et al., 2014; Zhang et al., 2017; He et al., 2019). It has been considered as a functional feed additive. However, at present, there are no related published research reports on ducks.

It is reported that resveratrol can effectively regulate lipid and lipoprotein metabolism in rats and alleviate

Table 6. Effect of resveratrol on amino acids composition and contents in leg muscle of Pekin ducks (dry weight basis).

	Resveratrol (mg/kg)					*P* value		
Items %	0	150	300	450	SEM	ANOVA	Linear	Quadratic
His	5.343	5.192	5.236	4.744	0.257	0.331	0.118	0.486
Ser	3.054	3.116	3.097	3.105	0.076	0.930	0.678	0.705
Glu*[1]	10.475	9.989	10.137	9.950	0.340	0.645	0.328	0.643
Asp*	5.205	4.966	4.888	5.264	0.312	0.762	0.940	0.304
Gly*	4.311[b]	5.304[a]	5.365[a]	4.849[a,b]	0.212	0.004	0.073	0.001
Tyr*	3.150[b]	3.761[a]	3.705[a]	3.601[a]	0.111	0.002	0.011	0.003
Arg	8.438[b]	9.570[a]	9.713[a]	9.297[a,b]	0.391	0.049	0.117	0.047
Cys	0.802[b]	0.987[a]	0.960[a]	0.948[a]	0.055	0.012	0.393	0.082
Ala*	4.466	4.535	4.436	4.305	0.180	0.806	0.450	0.558
Pro	2.875	3.047	2.955	2.866	0.091	0.422	0.759	0.141
Lys	8.899[a]	8.499[a,b]	8.043[b]	8.053[b]	0.279	0.049	0.018	0.440
Thr	3.786	3.884	3.803	3.519	0.225	0.642	0.360	0.373
Val	3.817	3.795	3.651	3.572	0.143	0.524	0.156	0.829
Met	1.124	1.060	1.001	1.183	0.132	0.746	0.833	0.328
Ile	3.379	3.475	3.345	3.304	0.102	0.635	0.416	0.486
Leu	5.734	5.723	5.678	5.580	0.145	0.849	0.415	0.752
Phe*	3.546[b]	4.100[a]	3.971[a]	3.896[a]	0.101	0.004	0.042	0.003
TAA	78.402	81.003	79.983	78.036	1.448	0.380	0.707	0.104
EAA	30.284	30.536	29.492	29.107	0.620	0.353	0.116	0.614
NEAA	48.118	50.466	50.491	48.929	0.850	0.154	0.558	0.030
FAA	28.001	28.894	28.796	28.264	0.550	0.227	0.425	0.064

[a,b]Within a row, means with different superscript letters are significantly different ($P < 0.05$).

Abbreviations: EAA, essential amino acid; FAA, flavor amino acid; NEAA, nonessential amino acid; TAA, total amino acid.

[1]Items with * are marked as flavor amino acid.

Table 7. Effect of resveratrol on muscle fiber trait of Pekin Duck.

Items		Resveratrol (mg/kg)				SEM	*P* value		
		0	150	300	450		ANOVA	Linear	Quadratic
Breast muscle fiber	Diameter (μm)	29.5[a]	27.89[a,b]	26.68[b]	26.16[b]	0.87	0.050	0.009	0.539
	CSA (μm^2)	690.69[a]	613.76[a,b]	560.21[b]	538.76[b]	37.80	0.045	0.007	0.472
	Density ($/mm^2$)	971.66[b]	968.66[b]	1,053.83[a,b]	1,117.16[a]	27.60	0.003	<0.001	0.244
Leg muscle fiber	Diameter (μm)	63.06	58.82	55.00	57.64	2.37	0.146	0.073	0.162
	CSA (μm^2)	3,157.38	2,722.05	2,409.25	2,625.34	220.17	0.141	0.067	0.155
	Density ($/mm^2$)	167.83	184.33	191.33	223.64	17.11	0.175	0.036	0.662

[a,b]Within a row, means with different superscript letters are significantly different ($P < 0.05$).
Abbreviation: CSA, cross-sectional area.

the side effects of high-fat diet. (Arichi et al., 1982). A series of study have indicated that resveratrol is a potential drug to prevent obesity, and energy metabolism may be limited by it, resulting in lower body fat deposition (Zhang et al., 2015a,b). Resveratrol also showed a similar lipid-lowering effect in fatting pigs (Zhang et al., 2015a,b). Consistent with those literature, this research found that adding resveratrol in diet can reduce the abdominal fat deposition in duck. A possible explanation for this might be that fatty acid uptake from circulating triacylglycerols is restricted. Fat mobilization and fatty acid oxidation are promoted by resveratrol. Resveratrol may also reduce body fat by increasing thermogenesis (Alberdi et al., 2013).

Meat quality is determined with a comprehensive index. The most intuitive standard of meat quality is usually expressed by lightness (L*), redness (a*), and yellowness (b*), which is related to the content of myoglobin, hemoglobin, and cytochrome-c. Drip loss and shear force are closely related to taste, and it is important for holding more water after slaughter to keep meat juicy, which means low percentage of drip loss. The lower the shear force, the better the tender taste. The major findings from this study are that feeding with resveratrol improved a^*_{24h} and b^*_{24h} of duck breast muscle and a^*_{45min} of duck leg muscle, while reducing shear force, L^*_{45min} of breast and drip loss, shear force, and L^*_{45min} of leg muscle. These results agree with findings from other studies where resveratrol has been shown to improve pork and chicken meat quality (Zhang et al., 2015a,b, 2018). Therefore, resveratrol could be considered as functional feed additive for improving duck meat quality. A vitro studies has shown that resveratrol can improve mitochondrial function and increase mitochondrial energy consumption (Price et al., 2012). In short, the substrates of energy metabolism in the muscle will change by resveratrol. Further study should be carried out to make correlation analysis on meat quality and energy metabolism.

Species and age differences play an important role in duck meat quality (Wang et al., 2017). Even though genetic improvement work is ongoing, nutritional regulation is obviously time sensitive for market. Amino acids and fat content are 2 important factors that affect meat quality (Wood et al., 2008). The type and content of amino acids in muscle determine the nutritional value and taste of animal meat, which is the main index to evaluate meat quality (Wu, 2009). It is generally believed the content of flavor amino acids is a key flavor substance that is related to the taste of meat (Jiang et al., 2016; Wang et al., 2017). In a general sense, glutamate, aspartate, phenylalanine, alanine, glycine, and tyrosine are called flavor amino acids. Glutamate is the main flavor amino acid, and its content will directly affect the favor of meat (Watanabe et al., 2015). Anserine, aspartate, and carnosine were the most relevant metabolites of duck breast meat quality, and nicotinamide in duck breast meat was negatively correlated with cooking loss (Wang et al., 2020). The results showed that resveratrol addition at 300 to 450 m/kg could increase the content of flavor amino acids and nonessential amino acids in Pekin ducks leg muscle, indicating that resveratrol could improve the taste duck meat. Intramuscular fat refers to the fat deposited between muscle fibers and muscle bundles in the muscle. It is composed of fat in intramuscular adipose tissue and muscle fibers. It not only affects the tenderness of meat but also the flavor and content of protein in meat (Chartrin et al., 2006). A momentous finding from this experiment is that dietary resveratrol supplement increased intramuscular fat, crude protein, total amino acid, and flavor amino acid content of duck breast muscle. This is consistent with other research studies which found crude protein content was increased by resveratrol on finishing pigs (Zhang et al., 2017).

This study confirms that resveratrol can improve duck meat flavor by promoting the deposition of intramuscular fat and flavor amino acids. Because resveratrol is proved to be an activator of protein deacetylase SIRT1(-Sirtuin1) (Price et al., 2012), genes that induce oxidative phosphorylation and mitochondrial biogenesis are related to it, and to a large extent, observed effects could be due to the decrease of PGC-1α acetylation and the increase of PGC-1α activity mediated by resveratrol (Lagouge et al., 2006). In this study, intramuscular fat in breast muscle is obviously increased by adding resveratrol. These might be because SIRT1 is activated by resveratrol, and it has an important effect on lipid metabolism. The result shows that the addition of resveratrol significantly increased the histidine content in the chest muscle and the glycine content in the leg muscle of duck. Glycine can synthesize glutathione, and histidine is the precursor of carnosine synthesis, both of which play an important role as an antioxidant. It is reported that

SIRT1 reduces the ability of the forkhead box O to induce apoptosis and improves the antioxidant stress tolerance of cells (de Oliveira et al., 2019).

Muscle is formed by countless muscle fibers. The type and composition of muscle fiber are closely related to the meat quality of animals. It is proved that resveratrol can induce the conversion of glycolysis muscle fibers to oxidized muscle fibers (Zhang et al., 2015b), which means that meat quality changes by resveratrol may depend on the changes in muscle fiber characteristics. In the present study, lower breast muscle diameter and cross-sectional area and higher density were observed with resveratrol supplementation. This finding might also explain the shear force drop with resveratrol supplementation. It is possible that regulation of the SIRT1/AMPK/PGC-1α pathway and the fork head box O by resveratrol plays a very important role in this process (Price et al., 2012). Future experiments will be necessary to confirm these possibilities.

CONCLUSION

This research aimed to explore the effect of dietary resveratrol supplementation on carcass traits and meat quality of Pekin ducks. A significant finding to emerge from this study was that adding 300 to 450 mg/kg resveratrol could improve duck meat quality. This is the useful evidence that resveratrol can promote Pekin duck's intramuscular fat and flavor amino acid deposition and also change the characteristics of muscle fiber. These findings contribute in several ways to our understanding of resveratrol. Moreover, it provides important clues to explore the potential effect mechanisms of resveratrol. Further studies are required to uncover the precise mechanism of these effects.

ACKNOWLEDGMENTS

This research was supported by the National Natural Science Foundation of China (Grant number 31972600).

DISCLOSURES

All authors confirm that no conflict of interest exists regarding this article.

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