Effects of genotype and sex on technological properties and fatty acid composition of duck meat

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ABSTRACT Study was conducted to determine the effects of genotype and sex on the technological properties and fatty acid composition of duck meat. Native (n = 15) and Peking (n = 15) ducks were slaughtered at 10 wk old, and meat samples were taken from *M. pectoralis major* (breast) and *M. peroneus longus* (thigh). The pH_{24}, drip loss, expressed juice, cooking loss, Warner-Bratzler shear force (WBSF), color variables, fatty acid composition, and sensory characteristics were examined. Ultimate pH of breast meat in Peking ducks (6.01) was higher than that of native ducks (5.82). The breast drip loss (3.40%) and cooking loss (31.23%) in native ducks were higher than those in Peking ducks (2.77 and 26.69%, respectively). The expressed juice of thigh meat in native ducks (8.23%) was higher than that of Peking ducks (6.52%). Genotype and sex had no significant influence on WBSF and meat color. Lightness (L*) values of breast and thigh skin were higher in Peking ducks than native ones. In panel evaluation, panelists evaluated the meat of Peking ducks with higher odor and flavor intensity. Breast meat of native ducks had higher Σ-polyunsaturated fatty acid (∑PUFA), ∑*n-6* (omega-6) proportions, nutritive value, the ratio of ΣPUFA to Σ-saturated fatty acid (∑SFA) and lower ∑SFA, atherogenic and thrombogenic indices than Peking ducks. Instrumental and sensory characteristics of duck meat as well as fatty acid composition indicate that duck finishing can be considered as an alternative source of high-quality meat production.

Key words: duck, fatty acids, instrumental meat quality, sensory evaluation

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INTRODUCTION

The importance of the products that will be obtained from poultry is great in the nutrition of humans. There is a need for advanced studies in which the measures are investigated to increase the amount and quality of the meat obtained from ducks. Although duck breeding is performed all over the world, it is especially popular in the Continent of Asia. According to the data of 2018 in Turkey, the number of the ducks was 491,561, and it is possible to see duck breeding everywhere throughout the country. However, duck breeding is performed under conditions that are not modern, usually in small-scale family farming (TSI, 2018). Duck breeding is performed with native and Peking ducks. Families dealing with duck breeding give sherbet and milk to the chicks on the first days when they hatch, and go on with chick feed, wet bread, and fresh green grass on the following days. Chicks are kept at home for nearly 2 to 3 wk, and are taken to meadows if the weather is suitable. Ducks are mostly kept in semi-intensive conditions without pools and raised for their meats, livers, feathers, heads, and feet. After slaughtering, some of them are consumed as fresh meat, and some are salted and dried to be used later. Feathers are used in producing pillows and quilt (Sari et al., 2012).

The slaughtering and carcass characteristics were mostly investigated in studies that were conducted on duck meat production (Isguzar et al., 2002; Lacin and Aras, 2008; Erisir et al., 2009) and in some of them, the chemical composition of muscles (Mazanowski and Ksiazkiewicz, 2004; Adamski, 2005); physical properties of meats (pH, color, water-holding capacity) were investigated (Kisiel and Ksiazkiewicz, 2004; Adamski, 2005). Meat quality characteristics in poultry may be influenced by many factors such as animal species and breeds, environment, feeding, and care conditions. These factors are breed, origin, sex, the weight and age at slaughtering, the exercise status of the animals, feeding method, and the applications before and during the slaughtering and environmental factors (Berri, 2004; McKee, 2007). Determining these factors is important in that organizations and regulations may be made for

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ensuring that quality meat production is made. Although many studies have been conducted to determine the meat quality characteristics in broilers, there are limited number of studies conducted on the meat quality in ducks. Most of the studies conducted in Turkey were designed for Peking ducks, and no studies were found in the literature in which the meat quality of the native ducks was investigated.

This study was conducted to determine the effects of genotype (native and Peking) and sex (male and female) on the technological properties and fatty acid composition of duck meat.

MATERIALS AND METHODS

Bird, Management and Diets

The study was designed in accordance with the guidelines for safety evaluation of feed additives in animals by the European Food Safety Authority and Ministry of Food, Agriculture and Livestock of Turkey. The procedures of the study were reviewed and approved by the Kafkas University Ethic Committee for animal experiments (Approval number: 2011–41). The study was conducted in Kafkas University, Veterinary Faculty, Education, Research and Application Farm.

The eggs of the Peking and native ducks were taken from a private farm. Wing numbers were tagged to the chicks that hatched and they were grouped. Intensive system in deep litter housing was used in this study. About 10 cm-thick sawdust was placed to the base of the deep litter system, and the ducks were placed as 4 ducks in 1 m^2 (EC, 2013). In the first week, continuous lighting was provided, and as of the second week, 16-h light and 8-h darkness cycle was provided for the ducks. The temperature of the poultry house was adjusted as 32 to 34°C in the first weeks, and then was gradually reduced as 3 to 5°C, and in the fourth week, it was decreased to 19 to 20°C.

Ingredient and chemical composition of the feed given to the ducks is given in Table 1. All the ducks were fed ad libitum with 22% crude protein and 12.62 metabolizable energy per 1 kg of feed in the first 5 wk, and with 18% crude protein and 13.05 metabolizable energy per 1 kg of feed ad libitum between the 5-wk age and 10-wk age (NRC, 1994).

Table 1. Ingredient and chemical analysis of the concentrate fed during the starter and grower period.

Items		
Ingredients	Starter contents (%)	Grower contents (%)
Corn	54.00	65.00
Soybean	40.15	29.15
Vegetable oil	3.00	3.00
Lime stone	1.00	1.00
Dicalcium phosphate	1.00	1.00
Dl-Methionine	0.10	0.10
Salt	0.25	0.25
Vit.-Min. Premix[1]	0.50	0.50
Total	100.00	100.00
Chemical analysis		
Dry matter	92.50	93.10
Crude protein (%)	22.00	18.00
Metabolizable energy[2] (MJ/kg)	12.62	13.05
Ether extract (in DM)	3.75	3.35
Crude fiber (in DM)	3.70	4.40
Ash (in DM)	7.70	6.10

[1]Premix provided the following per kilogram of diet: vitamin A, 21,000 IU; vitamin D3, 4,200 IU; vitamin E, 57.7 IU; vitamin K3, 4.38 mg; vitamin B1, 5.25 mg; vitamin B2, 12.25 mg; vitamin B6, 7 mg; vitamin B12, 0.03 mg; folic acid, 1.75 mg; D-Biotin 0.08 mg; vitamin C, 87.5 mg; niacin,70 mg; Cal-D-Pantothenat, 14 mg; choline chloride 218.75 mg; Fe, 140 mg; Zn, 105 mg; Cu, 14 mg; Co, 0.35 mg; 1,1.75 mg; Se, 0.26 mg; Mn, 140 mg.
[2]Provided by calculation (NRC, 1994).

pH Measurement

The ducks were slaughtered in the 10th week. The feathers of the ducks were removed after keeping in hot water at 65°C for a few minutes. After the slaughtering, the *M. pectoralis major* (breast) and *M. peroneus longus* (thigh) from each carcass were removed to investigate the meat quality characteristics of ducks. In the context of the study, the pH_{24}, expressed juice, drip loss, cooking loss, Warner-Bratzler shear force (**WBSF**), fatty acid composition of meat, and the meat and skin color parameters were determined, and sensory evaluations were made.

Ultimate meat pH was measured by directly on *pectoralis major* and *peroneus longus* muscles at 24 h post slaughter using a digital pH meter (model Testo, 205; Testo Inc., Sparta, NJ) equipped with a penetrating probe and thermometer.

Drip Loss and Cooking Loss

Drip loss was measured in *pectoralis major* and *peroneus longus* muscles at 48 h post mortem using the method described by Honikel (1998).

Cooking loss was measured at 48 h post mortem in *pectoralis major muscle* samples, and meat samples were first weighed, and then cooked in a water bath at 80°C for 45 min as described by Honikel (1998).

Warner-Bratzler Shear Force and Expressed Juice

Cooked breast meat samples that were used for cooking loss measurements were then used to investigate WBSF value. At least 4 subsamples were removed from each cooked sample. WBSF values of subsamples were determined using an Instron Universal Testing Machine (Model 3343, Instron Corp., Norwood, MA) equipped with a WBSF apparatus. An average of subsamples was accepted to be WBSF value of that sample. Expressed juice (%) was measured in *pectoralis major* and *peroneus longus* muscles at 96 h post mortem by the modified Grau and Hamm method described by Beriain et al. (2000) using 5 g meat samples from breast and thigh muscles. Expressed juice was calculated as percentage of weight loss of 5 g meat samples, immediately

after being kept under a pressure of 2,250 g weight for 5 min.

Instrumental Colour Evaluation

Color variables of breast and thigh from skin and meat were evaluated using color space specified by the International Commission on Illumination the (**CIELAB** or **CIE L*a*b***). L*, redness (**a***), and yellowness (**b***) values were obtained using Minolta chromameter (model CR-400, Minolta Camera Co., Osaka, Japan) with illuminate D65 as the light source, aperture size of 8 mm, and observation angle of 2°. Areas were chosen that were free of any obvious blood-related defects such as bruises, haemorrhages, or full blood vessels. Nine color measurements were performed from each sample, and color coordinate value was determined by calculating average of these 9 measurements. Skin color measurements were applied at 24 h post mortem, whilst meat color was measured at 48 h post mortem. The bone side of the meat is used for the meat color determination to avoid discolorations of breast and thigh surface.

Sensory Evaluation

Samples cutting from *pectoralis major* muscle for sensory analyses were packaged under vacuum at 24 h postmortem, frozen, and stored at 18°C until panel evaluation. One day before the panel evaluation, the meat samples were taken from the deep freezer and thawed in refrigerator at 4°C. The samples were wrapped with aluminium folio, and cooked at an oven with a temperature of 180°C until the meat reached an internal temperature of 80°C. In measuring the internal temperature of the meat, the 4-channel Testo 177-T4 temperature recording device with a screen and the thermocouple connected to it were used. Then, 7 testing samples 1 × 1 cm in size were taken from each muscle sample, and were kept in an oven at 60°C until they were presented to the panelists. The sensory evaluation was made with the 8-point categorical scale method (Sañudo et al., 1998). Seven panelists who were trained for this purpose and who had 2-yr experience were assigned. The panelists were asked to score the tenderness, juiciness, odor, and flavor intensity of the meat. In panel evaluation, 1 point referred to the lack of an odor that was specific to the species, extremely tough meat, extremely dry meat, extremely weak taste intensity, and 8 points referred to the excessively intense duck meat odor, excessively tender meat, excessively juicy meat, and excessively intense duck meat flavor. The panel evaluations were performed in 3 sessions.

Fatty Acid Analyses

For fatty acid analyses, the samples were taken from the *pectoralis major* at post mortem 24th hour and these samples were packaged under vacuum, stored at –18°C. The fat extraction for fatty acid analyses was performed in the light of the method described by Bligh and Dyer (1959). Nearly 50 mg fat was extracted, and was saponified with 2 mL NaOH of 0.5 N at 90°C for 2 min. After this process, 5 mL 35% boron trifluoride, which was prepared in methanol, was added to the samples that were cooled, and was kept at 90°C for 5 min. n-Heptane (2 mL) was added and was kept at the same temperature for 1 min. Following this, 3 mL saturated NaCl solution was added, and was turned upside down, and after the phase separation, the organic phase that was on the top was collected in gas chromatography (**GC**)—mass spectrometry (**MS**) vials. The fatty acid methyl ester in the heptane phase was kept at –20°C until analyses. After the fatty acid methyl esters were intensified under the nitrogen gas, they were analyzed in GC-MS (HP 68905972). In the analysis, Agilent HP 88 (100 m length, 0.25 mm i.d., 0.20 μm film) capillary colon was used. The injector temperature was adjusted to 250°C, and the detector temperature was adjusted to 270°C. Before the injection, the injector was washed with n-Heptane for 3 times. The injection was made automatically at 1 μL volume and with 1:50 split ratio. The initial temperature of the colon was 150°C, the endpoint temperature was 240°C, and the temperature was increased as 3°C per minute. Helium was used as the carrier gas. After MS identification of chromatographic peaks, it was also determined by comparison of the retention times of reference standards (Sigma Chemical Co, Ltd, Poole, UK).

Statistical Analyses

For the purpose of determining the effect of genotype (native and Peking) and sex (male and female) on instrumental meat quality characteristics, general linear model procedure in SPSS 20.0 program was used. In the statistical model, the genotype, sex, and genotype × sex interaction were considered as the main effect. When the genotype × sex interaction was significant, the 1-way ANOVA and the Duncan's multiple range test were used. The mathematical model for sensory characteristics included main effects of genotype, sex, panelist, session, and significant 2-way interactions of these effects (SPSS, 2015).

RESULTS

The effect of genotype on the pH_{24}, drip loss, and cooking loss of the breast meat was statistically significant ($P < 0.05$), and the effect of genotype × sex interaction was found to be statistically significant for cooking loss (Table 2). The pH_{24} of the breast meat was higher in Peking ducks, and the drip loss and cooking loss were higher in native ducks. The effect of genotype on thigh meat expressed juice was significant, and

Table 2. The effect of duck genotype and sex on pH_{24}, drip loss (%), expressed juice (%) of breast and thigh meat and cooking loss (CL, %), shear force (WBSF, kg) sensory characteristics of breast meat.

		Breast				Thigh			Breast sensory evaluation			
Item	n	pH_{24}	Drip loss	Expressed Juice	CL	WBSF	pH_{24}	Drip loss	Expressed Juice	Odor intensity	Tenderness	Juiciness	Flavor intensity
Genotype													
Native	15	5.82	3.40	9.55	31.23	2.58	6.07	2.16	8.23	4.527	5.702	4.645	4.638
Peking	15	6.01	2.77	8.53	29.69	2.81	6.22	1.98	6.52	5.083	5.581	4.447	5.191
Sex													
Male	12	5.91	2.94	8.73	31.10	2.75	6.06	1.92	7.81	5.045	5.641	4.632	5.220
Female	18	5.92	3.22	9.35	29.82	2.64	6.22	2.22	6.94	4.565	5.641	4.459	4.610
Genotype × sex													
Native—male	7	5.80	3.01	9.36	30.84[a]	2.50	6.08	2.00	8.55	4.630	5.808	4.892	4.944
Native—female	8	5.84	3.78	9.73	31.63[a]	2.66	6.05	2.31	7.91	4.424	5.595	4.397	4.332
Peking—male	5	6.02	2.87	8.10	31.37[a]	3.00	6.04	1.83	7.07	5.460	5.475	4.372	5.495
Peking—female	10	6.00	2.67	8.96	28.01[b]	2.63	6.39	2.13	5.97	4.707	5.687	4.521	4.887
SEM		0.032	0.131	0.376	0.326	0.099	0.092	0.085	0.318	0.102	0.087	0.087	0.099
P-value													
Genotype		**0.006**	**0.024**	0.189	**0.025**	0.257	0.425	0.306	**0.012**	**0.008**	0.494	0.261	**0.004**
Sex		0.916	0.293	0.419	0.059	0.607	0.394	0.086	0.181	**0.022**	0.999	0.328	**0.001**
Genotype × sex		0.620	0.076	0.747	**0.004**	0.192	0.297	0.997	0.716	0.197	0.239	0.075	0.991

[a,b]Means within a column with no common superscripts differ significantly according to 1-way ANOVA statistics for genotype—sex subgroups ($P < 0.05$).

higher expressed juice value was observed for native ducks.

The results of the sensory evaluations of the breast meats of the ducks are given in Table 2. The panelists evaluated the odor and flavor intensity of the breast meats of the Peking ducks with higher scores when compared with the native ducks, and evaluated odor and flavor intensity in the male duck meats with higher scores when compared with the female duck meats. The effect of genotype and sex on the tenderness and juiciness of the meat was not significant.

The effect of genotype and sex on breast skin L^* value (Table 3) was significant ($P < 0.05$). The breast skin L^* value of the Peking ducks was higher than that of the native ducks, and the L^* value of the female ducks was higher than that of the male ducks. The L^* and b^* values of the thigh skin of the Peking ducks were higher than those of the native ducks. Breast and thigh meat color variables were not influenced by the genotype and sex of duck.

The composition of various individual fatty acids and nutritive indices in the breast meats of the ducks are given in Tables 4 and 5. The proportions of the C16:0, C16:1, C20:0, C22:6 *n-3*, ∑SFA, and atherogenic and thrombogenic indexes were higher in Peking ducks than those of the native ducks. On the other hand, meat of native ducks had higher proportions of C20:1, C18:2*n-6,* C18:3*n-3,* ∑PUFA, ∑unsaturated fatty acid (**∑UFA**), desirable fatty acids (**DFA**), ∑*n*-6, and rates of ∑PUFA/∑SFA, ∑UFA/∑SFA, and nutritive value than Peking ducks. The proportions of C18:1, Σ-monounsaturated fatty acid (**∑MUFA**) and ∑*n*-6/∑***n-3*** (Omega-3) were found to be higher in meat of female duck, while proportions C17:0, C18:0, C18:2 *n-6*, C18:3 *n-3*, C20:5 *n-3,* C22:6 *n-3,* ∑PUFA, ∑*n-6*, ∑*n-3*, DFA, and ∑PUFA/∑SFA ratio were higher in males.

The effect of genotype × sex interaction on C14:1, C17:0, C18:1, C18:3 *n-3*, C20:1, C20:5 *n-3*, ∑MUFA, ∑PUFA, ∑*n*-3, ∑*n*-6/∑*n*-3, and nutritive value were significant. Proportions of C17:0, C18:3 *n-3,* C20:5 *n-3,* ∑PUFA, and ∑*n*-3 were higher in native male duck meats than those of the other subgroups. Proportions of C18:1, ∑MUFA, ∑*n*-6/∑*n*-3 ratio, and nutritive value were higher in native female ducks, while C20:1 proportion was lower in male Peking ducks than those of the other subgroups.

DISCUSSION

Most of the meat quality characteristics such as water-holding capacity, meat color, as well as texture might be affected by ultimate pH (Huff-Lonergan, 2010). In the current study, Peking ducks had a higher breast meat pH_{24} than native ducks while there were no significant differences between breeds in thigh meat pH_{24}. Huda et al. (2011) explained the differences in pH values among different duck muscles by the variation amounts of the total glycogen of each muscle.

Table 3. The effect of duck genotype and sex on skin and meat color variables measured from breast and thigh.

		Breast skin color			Breast meat color			Thigh skin color			Thigh meat color		
Item	n	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Genotype													
Native	15	64.88	5.23	10.94	32.34	19.91	− 0.63	66.49	4.20	7.66	35.46	16.79	0.40
Peking	15	66.91	6.15	11.19	33.57	20.28	− 0.65	68.81	4.60	9.93	34.48	16.83	0.09
Sex													
Male	12	64.96	5.66	10.88	33.18	20.29	− 0.50	67.71	4.58	8.94	35.27	16.46	0.02
Female	18	66.82	5.72	11.24	32.72	19.90	− 0.79	67.60	4.22	8.65	34.67	17.16	0.46
Genotype × sex													
Native—male	7	63.70	4.95	10.62	32.32	19.74	− 0.70	66.41	4.26	7.93	35.88	16.76	0.38
Native—female	8	66.06	5.51	11.26	32.35	20.08	− 0.56	66.57	4.14	7.39	35.05	16.83	0.41
Peking—male	5	66.23	6.38	11.15	34.04	20.84	− 0.30	69.00	4.91	9.94	34.66	16.16	− 0.34
Peking—female	10	67.59	5.93	11.22	33.09	19.72	− 1.01	68.63	4.30	9.92	34.30	17.50	0.51
SEM		0.415	0.341	0.349	0.360	0.195	0.198	0.497	0.236	0.536	0.469	0.330	0.266
P-value													
Genotype		**0.021**	0.188	0.724	0.100	0.347	0.948	**0.028**	0.401	**0.044**	0.307	0.957	0.565
Sex		**0.034**	0.931	0.612	0.523	0.322	0.467	0.917	0.451	0.795	0.531	0.296	0.418
Genotype × sex		0.552	0.468	0.684	0.501	0.073	0.293	0.795	0.608	0.815	0.804	0.344	0.446

Table 4. The effect of duck genotype and sex on fatty acid composition of breast meat (%).

Item	C14:0	C14:1	C15:0	C16:0	C16:1	C17:0	C18:0	C18:1	C18:2 *n-6*	C18:3 *n-3*	C20:0	C20:1	C20:5 *n-3*	C22:6 *n-3*
Genotype														
Native	0.399	0.051	0.062	19.28	2.585	0.309	5.555	44.59	18.51	1.638	0.887	0.541	3.236	0.872
Peking	0.376	0.054	0.057	20.82	3.132	0.279	5.882	43.60	17.41	1.401	0.992	0.480	2.942	1.097
Sex														
Male	0.405	0.057	0.059	20.00	2.779	0.331	6.017	43.20	18.54	1.610	0.940	0.500	3.433	1.141
Female	0.370	0.049	0.061	20.01	2.937	0.258	5.421	45.00	17.38	1.429	0.939	0.520	2.745	0.828
Genotype × sex														
Native—male	0.433	0.065^{a}	0.064	19.58	2.593	0.406^{a}	5.876	42.36^{b}	19.23	1.805^{a}	0.855	0.571^{a}	4.096^{a}	1.082
Native–female	0.365	0.037^{b}	0.060	18.98	2.577	0.213^{c}	5.235	46.29^{a}	17.78	1.471^{b}	0.919	0.511^{a}	2.376^{c}	0.663
Peking—male	0.377	0.049^{a,b}	0.054	20.43	2.966	0.256^{b,c}	6.158	44.03^{b}	17.85	1.415^{b}	1.026	0.430 ^{b}	2.770^{b,c}	1.200
Peking—female	0.376	0.060^{a}	0.061	21.22	3.297	0.303^{b}	5.606	43.17^{b}	16.97	1.388^{b}	0.958	0.530^{a}	3.114^{b}	0.994
SEM	0.011	0.004	0.003	0.197	0.064	0.014	0.143	0.323	0.184	0.030	0.020	0.011	0.104	0.034
P-value														
Genotype	0.318	0.708	0.359	**<0.001**	**<0.001**	0.307	0.263	0.137	**0.006**	**<0.001**	**0.016**	**0.011**	0.168	**0.002**
Sex	0.130	0.242	0.716	0.812	0.225	**0.018**	**0.047**	**0.010**	**0.004**	**0.006**	0.972	0.384	**0.003**	**<0.001**
Genotype × sex	0.148	**0.011**	0.265	0.091	0.184	**<0.001**	0.879	**<0.001**	0.443	**0.017**	0.118	**0.002**	**<0.001**	0.124

[a-c]Means within a column with no common superscripts differ significantly according to 1-way ANOVA statistics for genotype—sex subgroups ($P < 0.05$).

Kazimierz et al. (2004) reported significant differences in pH_{24} values between Muscovy ducks and Mullards. Significant breed/genotype effect on pH_{24} values in breast meat was also noticed by various authors (Musa et al., 2006; Qiao et al., 2017). In this study, the effect of sex on the pH_{24} of the breast and thigh meats was not significant. A similar result was also reported for ducks from different genotypes (Kazimierz et al., 2004; Wawro et al., 2004). The pH_{24} values of ducks meat in the present study (between 5.82 and 6.22 depending on genotype and sex) were similar to the reports of 5.90 to 6.37 by Kisiel and Książkiewicz (2004) for Miniduck and Peking ducks. Moreover, Baeza (2006) reported that the average ultimate pH of ducks was 5.8 in breast and 6.2 in thigh muscles. The pH values obtained in the present study (5.82 to 6.20) were not in the intervals which would cause an adverse effect such as PSE (pale, soft, exudative) meat (Huff-Lonergan, 2010).

Water-holding capacity is the ability of meat to hold all or part of its own or added water (Honikel, 2004). If water-holding capacity is low, the more water could be released during raw meat storage, processing and storing after meat processing (Huda et al., 2011) and so results weight losses in final product as well as economic losses. Lower expressed juice in thigh muscle and also lower drip loss and cooking loss values in breast muscle of Peking ducks indicated that these ducks had higher water-holding capacity compared to native ones. Higher water-holding capacity in Peking ducks might be attributed to direct genotype influence as well as higher pH values. Muscle proteins might be denatured in higher pH values and so water-holding capacity decreased (Huda et al., 2011). Witak (2008) also associated the increased water-holding capacity in leg muscle with higher pH values. Moreover, Honikel (2004) noticed that the higher pH value results in the lower cooking loss. It was also found that the effect of sex

Table 5. The effect of duck genotype and sex on ratio and indices based on fatty acid composition for breast meat.

Item	∑SFA %	∑MUFA %	∑PUFA %	∑UFA %	∑PUFA/∑SFA	∑UFA/∑SFA	∑*n-6* %	∑*n-3* %	∑*n-6*/∑*n-3*	Nutritive Value	AI	TI	DFA %
Genotype													
Native	26.49	47.77	24.25	72.02	0.916	2.727	18.51	5.747	3.389	2.615	0.290	0.346	77.58
Peking	28.41	47.27	22.86	70.12	0.806	2.474	17.41	5.441	3.262	2.384	0.319	0.383	76.01
Sex													
Male	27.76	46.53	24.73	71.26	0.894	2.575	18.54	6.185	3.086	2.471	0.304	0.363	77.28
Female	27.15	48.51	22.38	70.89	0.827	2.626	17.38	5.003	3.565	2.528	0.305	0.366	76.31
Genotype × sex													
Native—male	27.21	45.59^{c}	26.22^{a}	71.81	0.965	2.645	19.23	6.984^{a}	2.790^{c}	2.478^{b}	0.297	0.346	77.68
Native—female	25.77	49.95^{a}	22.29^{b}	72.24	0.866	2.810	17.78	4.510^{c}	3.988^{a}	2.753^{a}	0.283	0.346	77.48
Peking—male	28.30	47.48^{b}	23.24^{b}	70.72	0.823	2.506	17.85	5.385^{b}	3.382^{b}	2.465^{b}	0.311	0.379	76.88
Peking—female	28.52	47.06^{b,c}	22.47^{b}	69.53	0.788	2.442	16.97	5.496^{b}	3.142^{b,c}	2.303^{b}	0.327	0.386	75.14
SEM	0.223	0.308	0.207	0.222	0.010	0.030	0.184	0.136	0.090	0.037	0.004	0.004	0.204
P-value													
Genotype	**<0.001**	0.422	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.006**	0.270	0.488	**0.005**	**<0.001**	**<0.001**	**<0.001**
Sex	0.184	**0.004**	**<0.001**	0.403	**0.003**	0.399	**0.004**	**<0.001**	**0.013**	0.456	0.870	0.612	**0.025**
Genotype × sex	0.075	**<0.001**	**<0.001**	0.079	0.133	0.063	0.443	**<0.001**	**<0.001**	**0.007**	0.055	0.649	0.071

[a,b,c]Means within a column with no common superscripts differ significantly according to 1-way ANOVA statistics for genotype—sex subgroups ($P < 0.05$).
Nutritive value = (C18:0 + C18:1)/C16:0.
AI (Atherogenic index) = ((4*C14:0) + C16:0)/ΣUFA.
TI (Thrombogenic index) = (C14:0 + C16:0 + C18:0)/(0.5*C18:1) + (0.5*ΣMUFA) + (0.5*Σn6) + (3*Σn3) + (Σn3/Σn6).
DFA (Desirable fatty acids) = (C18:0 + ΣMUFA + ΣPUFA).

on water-holding capacity of breast and thigh meat was insignificant. Similarly, Baeza et al. (2000) reported that differences between male and female ducks regarding water-holding capacity were not significant. On the other hand, Chartrin et al. (2006) and Larzul et al. (2006) reported significant effect of genotype on cooking loss.

Meat tenderness is a key factor determining consumer acceptability of cooked meat (Barbut, 1997) and usually associated with amount of intramuscular fat content and structure of muscle fiber. In the present study, the effect of genotype, sex, and genotype × sex interaction on breast meat WBSF value was not significant. Similarly, Chartrin et al. (2006) noticed that the effect of genotype on WBSF values was not significant for Peking, mule, hinny, and Muscovy ducks. In contrast to the current study, Huda et al. (2011) reported that breast meat of Peking ducks was tenderer than Muscovy ducks.

The important traits for eating quality of cooked meat are tenderness followed by flavor and juiciness (Joo et al., 2013). In the present study, neither sex nor genotype affected tenderness as well as juiciness scores. On the other hand, meat from Peking ducks had higher odor and flavor intensity compared to meat from native ones. Moreover, meat from male ducks had higher odor and flavor intensity than females. Meat flavor is affected by several factors such as breed, slaughter age, species, sex, stress level, muscle type, intramuscular lipid content, and diet of animal (Baeza et al., 2010; Joo et al., 2013). Furthermore, the aroma and flavor of duck meats might be influenced by some of the individual fatty acids (Qiao et al., 2017). In the present study, flavor intensity was significantly correlated with the proportions of C18:0 ($r = 0.455$; $P < 0.05$), ∑SFA ($r = 0.460$; $P < 0.05$), and ∑UFA/∑SFA ($r = –0.430$; $P < 0.05$) ratio. Similarly, Qiao et al. (2017) also reported positive correlation of aroma and flavor of duck meats with PUFA and MUFA. In the current study, higher ∑SFA and lower proportion of ∑UFA/∑SFA might be the cause of higher flavor intensity of Peking ducks. Likewise, higher C18:0 of the meat from male ducks might be the cause of its higher flavor intensity.

Color is the most important trait for the meat appearance which strongly influences the consumer's decision to select good quality meat for purchase (Joo et al., 2013). There are important differences between poultry species and even between the muscles of the same animal regarding meat color. While the breast meat and thigh meats of chicken and turkey are clearly light in color, the thigh meat of turkey and the meat of the geese and ducks are generally dark (Kivanc, 2010). Moreover, higher pH value causes darker meat compared to lower pH values (Flecther, 1999). The effects of sex and genotype on meat color in breast as well as thigh were not significant in the current study. Baeza et al. (2000) also noticed that differences between male and female ducks were not significant. In contrast, Huda et al. (2011) reported that Peking duck meat had lower L^* and a^* values than Muscovy ducks in breast and thigh. Chartrin et al. (2006) also reported significant genotype effect on all color parameters in Peking, mule, hinny, and Muscovy ducks.

When the proportions of individual fatty acids in the breast meat of native and Peking ducks were considered, C18:1 (44.59 and 43.60%, respectively) was the most common fatty acid in both breeds. Proportions of C16:0 (19.28 to 20.82%), C18:2 *n-6* (18.51 to 17.41%), and C18:0 (5.56 to 5.88%) followed C18:1. These fatty acids accounted for nearly 88% of total fatty acids in the meat of both breeds. Similar results for predominance order of indicated fatty acids in breast meat of ducks have also been found for Muscovy ducks (Aronal et al., 2012) and A44 strain slaughtered at 7th and 9th week of age (Witak, 2008). Similar with the current results, Wołoszyn et al. (2005) found that intramuscular fatty acids in breast and leg muscles were predominantly unsaturated fatty acids, and C18:1, C16:0, and C18:2 *n-6* were the major fatty acids. However, the proportion of ∑MUFA and especially oleic acid obtained for breast meat in this study seem to be higher than the values reported in the most of previous studies (Wołoszyn et al., 2005; Witak, 2008). This difference might be caused by the factors in the ingredients of feed and duck breeds. Starter and grower diets in the current study contained 54 and 65% corn, while wheat meal was the main component in those studies. Supporting the current results, Chartrin et al. (2006) investigated the influence of overfeeding with corn-based diet on fatty acid composition, and found higher ∑MUFA proportion in breast meat of overfed ducks. The authors noted that overfeeding induces hepatic lipogenesis, and then stimulates an accumulation of triglycerides rich in MUFA in muscles. Similarly, Zanusso et al. (2003) obtained higher oleic acid and ∑MUFA proportions in overfed ducks than control group. Proportions of C18:1 and ∑MUFA reported for overfed ducks by Zanusso et al. (2003) and Chartrin et al. (2006) were also similar with the current results.

The composition of the fatty acids in the diet has great importance regarding human health, especially for prevention of cardiovascular diseases (Anonymous, 1994). Amounts of ∑SFA and ∑PUFA, ratios of *n-6*/*n-3* PUFA and ∑PUFA/∑SFA are commonly used parameters to judge meat nutritional value (Enser et al., 1998). A clear consensus has been reached regarding the adverse effects of the SFAs on plasma low-density lipoprotein levels (Enser et al., 1998). In the current study, meat of native ducks had lower proportions of the C16:0, C20:0, and ∑SFA than their Peking counterparts. On the other hand, increasing the intake of PUFAs, especially *n-3* PUFAs, is recommended in order to reduce the risk of developing cardiovascular disease (Enser et al., 1998). In the current study, breast meat of native ducks had higher proportions of C18:2 *n-6*, C18:3 *n-3*, ∑PUFA, ∑*n-6*, and ∑PUFA/∑SFA ratio compared with meat from Peking ducks. Furthermore, meat of native ducks had higher nutritive value and ∑DFA, lower atherogenic and thrombogenic indexes values than Peking ducks. The differences in the fatty

acid composition of the different duck groups might be due to the source and amount of dietary lipids, as well as breed influence (Aronal et al., 2012). Considering that native and Peking ducks were reared under the same environmental conditions (feeding and housing conditions, slaughter age) in the current study, results for fatty acid composition indicate that meat of native ducks may be more beneficial regarding the nutritional point of view. Significant breed/genotype effect on the concentration of C18:2 *n-6*, ∑SFA, ∑PUFA was observed in the study by Aronal et al. (2012), who found higher C18:2 *n-6* and ∑PUFA and lower ∑SFA concentration in breast meat of Peking ducks than those in Muscovy ducks. Muhlisin et al. (2013) reported higher proportion of C16:0, ∑PUFA, and ∑*n-6* for breast meat of Korean Native Ducks compared with meat of imported commercial ducks. Qiao et al. (2017) also found significant genotype influence on total SFA, MUFA, PUFA, C18:2 *n-6*, ∑PUFA/∑SFA, and *n-6*/*n-3* PUFA for Cherry Valley, Spent Layer, and Crossbred ducks. In terms of human health, the ratio of *n-6*/*n-3* PUFA, which is less than 4.0 (Anonymous, 1994), and the ratio of ∑PUFA/∑SFA, which is higher than 0.45 in the diet, are recommended (Horcada et al., 2012). The ratios of ∑PUFA/∑SFA (0.916 and 0.806 for native and Peking ducks) and *n-6*/*n-3* PUFA (3.39 for native and 3.26 for Peking ducks) determined in this study were found to be in accordance with the recommended values. On the other hand, meat of native ducks has a more favorable $\sum PUFA/\sum SFA$ ratio than that of Peking ducks (0.916 vs. 0.806).

Sex, as a main effect, had significant influence on proportions of C17:0, C18:0, C18:1, C18:2 *n-6*, C18:3 *n-3*, C20:5 *n-3,* C22:6 *n-3,* ∑MUFA, ∑PUFA, ∑*n-6*, ∑*n-3*, DFA and ratios of ∑PUFA/∑SFA and ∑*n*-6/∑*n-3.* The breast meat of the female ducks contained higher proportions of C18:1 and lower proportions of C18:2 *n-6*, C18:3 *n-3*, C20:5 *n-3,* and C22:6 *n-3* than male ducks. These results led to higher total ∑MUFA and ∑*n*-6/∑*n-3,* lower ∑PUFA, ∑*n-6*, ∑*n-3*, DFA and ∑PUFA/∑SFA ratio in female ducks compared with males. On the other hand, significant genotype × sex interaction indicates that higher proportions of C18:1, ∑MUFA in female ducks were only obtained in native ducks, and such a sex effect was not observed in Peking ducks. Furthermore, proportions of C18:3*n-3*, C20:5 *n-3*, ∑PUFA, and ∑*n-3* PUFA were higher in breast meat of male native ducks compared with female native ducks. But, the meat of male and female Peking ducks had similar levels in terms of these fatty acids. In the previous studies, Baeze et al. (2000) and Khalifa and Nassar (2001) found no significant influence of duck sex on the fatty acid composition of breast meat.

CONCLUSIONS

Ultimate pH values obtained both genotypes point favorable meat quality, although Peking ducks had higher pH_{24} values compared to native ducks. Higher water-holding capacity in Peking breast meat might minimize the water release during to storage period, so positively affect meat quality in the final product. Shear force value, color, tenderness, as well as juiciness of duck meat were not affected genotype or sex. On the other hand, panelist gave higher odor and flavor intensity scores to meat from Peking ducks and meat from male ducks. Higher ∑PUFA, ∑*n-6,* ∑DFA proportions, nutritive value, ∑PUFA/∑SFA ratio, and lower ∑SFA, atherogenic and thrombogenic indexes values in breast meat of native ducks indicate more beneficial meat for native ducks regarding human health. However, duck meat from both genotypes had relatively high ∑PUFA/∑SFA ratio, low *n-6*/*n-3* PUFA ratio, and balanced fatty acid composition. Therefore, duck meat might be considered as a better alternative to mammalian and other poultry meats from a human nutrition point of view.

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