Age and sex-related differences in performance, carcass traits, hemato–biochemical parameters, and meat quality in Japanese quails

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ABSTRACT The effect of sex and age of Japanese quails (*Coturnix japonica*) on their performance, blood biochemical parameters, carcass traits, and meat quality was evaluated in this experiment. A total of 450, 3-wk-old Japanese quails (225 males and 225 females) were equally divided into six groups (75 birds each) in a 2 × 3 factorial design, including two sex (male and female) and three slaughter ages (5, 6, and 7 wk of age). Each group was subdivided into five replicates each of 15 birds. The body weight (BW) and feed intake (FI) values were significantly higher in female quails than in males, and these values showed an increasing trend with age. Female quails recorded the higher percentages of liver and giblets, and lower heart percentage than males. Sex × age interaction had a significant impact on carcass parameters except for breast and thigh yield. No significant sex-based differences were detected for quail meat chemical composition except for meat fat content. Moisture and ash content of meat were gradually deceased with age. Meat from female showed higher values for tenderness, intramuscular fat percentage (IMF), and meat lightness, but showed lower values of water holding capacity (WHC) and meat redness. Meat juiciness and tenderness decreased, while WHC, IMF, and meat redness increased with age. Mean values of red blood cells (RBC), packed cell volume (PCV), hemoglobin (Hb), and white blood cells (WBC) were higher ($P < 0.05$) in male quails than female ones. Plasma total protein, cholesterol, triglycerides, calcium, phosphorus, and uric acid were decreased in males comparable to females. The progress in quail age (5 to 7 wk) leads to significant increase in values of RBC, PCV, and Hb. Plasma cholesterol, total protein, triglycerides, and hemoglobin were linearly deceased with age. It could be concluded that Japanese quails (both males and females) should be slaughtered at 5 or 6 wk of age to obtain higher carcass yields and the best meat quality and composition. Furthermore, male quails recorded the highest values of meat quality and composition when compared to females.

Key words: quail, age, sex, carcass traits, hemato–biochemical parameters, meat quality

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INTRODUCTION

Japanese quail (*Coturnix coturnix japonica*) is the smallest poultry species farmed for egg and meat production, and it has also assumed as a worldwide importance as a laboratory animal (Minvielle, 1998; Alagawany et al., 2014). Quail meat has been known for centuries despite of the biblical quotations of their use as a meat source (Alagawany et al., 2014). Quail meat is recommended for the low-fat diet because it contains low amount of fat and cholesterol, especially thanks to its thin skin and low fat accumulation between its tissues. Quail meat has gained much popularity among consumers (Ikhlas et al., 2010). It is an ideal food for all ages due to its high meat yield, less shrinkage during cooking, being more effortless to cook, and being easier to serve (Mountney, 1981). Similar to white meat, quail meat has some advantages compared to red meat in terms of including low fat content and low cholesterol (Jaturasitha et al., 2004). Quail is one of the leanest types of poultry (Bont et al., 2010), and all the types of quails are good sources of some vitamins, such as niacin, thiamin, vitamin B6, riboflavin, and pantothenic acid (Hamm and Ang, 1982). The benefits of quail meat are known as high protein, essential fatty acids, and minerals such as sodium, potassium, and iron. Owing to high metabolic activity in this bird, the amount of glycogen stored in muscles increases and results in high-quality meat (Aminzade et al., 2012).

Performance, carcass composition, meat quality, and blood biochemical parameters are normally modified by sex, age, diet manipulation, and handling. There are several anatomical differences between females and males (Yannakopoulos and Tserveni-Gousi, 1986). Numerous sex-related differences may be demonstrated

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by the physiological alterations in the metabolism process in female birds because of egg laying (Walzem et al., 1999). Quail sex had marked effect on body weight (**BW**; Boni et al., 2010), carcass traits (Kumar et al., 2011; Sartowska et al., 2014), meat quality (Genchev et al., 2008; Choi et al., 2012), and blood parameters (Scholtz et al., 2009). In practice, meat existing on the market is obtained from young quails or from spent quails after egg-laying phase (Shanaway, 1994). The research on different species has reported that the advancement in age is accompanied by changes in carcass traits (Wilkkanowska and Kokoszynski, 2011), meat quality (Lawrie, 1991; Mohammad, 2016), and blood parameters (Hassan, 2010; Ayub et al., 2012). The available information and literatures on the topic of quail age- and sex-related differences in meat composition and meat quality in view of hemato–biochemical changes are scarce. Therefore, in the present work, the aims were to study the effect of sex and slaughter age on BW, feed intake (**FI**), carcass traits, meat quality, and composition, and some blood biochemical parameters of growing Japanese quail.

Table 1. Composition and chemical analysis of experimental basal diet.

Basal diet	(%)
Ingredients	
Yellow corn	52.50
Soybean meal 44% CP	38.20
Corn–gluten 60% CP	4.30
Cotton seed oil	1.60
Di-calcium phosphate	1.60
Limestone	0.90
NaCl	0.30
Premix[1]	0.30
L-lysine	0.03
D-L methionine	0.07
Sand	0.20
Calculated analysis (%)	
CP	24.15
ME kcal/kg	2904
Ca	0.80
Available P	0.46
Lysine	1.31
Methionine	0.50
Met + Cys	0.82

[1]Premix containing per 2.5 kg: Vit A, 12,000,000 IU; Vit D_3, 2,000,000 IU; Vit E, 10 g; Vit k_3, 2 g; Vit B_1, 1,000 mg; Vit B_2, 49 g; Vit B_6, 105 g; Vit B_{12}, 10 mg; pantothenic acid, 10 g; niacin, 20 g; folic acid, 1,000 mg; biotin, 50 g; choline chloride, 500 mg; Fe, 30 g; Mn, 40 g; Cu, 3 g; Co, 200 mg; Si, 100 mg; and Zn, 45 g.

MATERIALS AND METHODS

Birds, Experimental Design and Husbandry

A factorial experiment (2 × 3) was performed, including two sex (males and females) and three slaughter ages (5, 6, and 7 wk, respectively) to study the effect of sex, slaughter age, and their interaction on the BW, carcass traits, blood parameters, meat quality, and composition of growing Japanese quails. A total of 450 Japanese quail chicks (225 males and 225 females), at 3 wk of age, were randomly divided into six groups of 75 birds (five replicates/group and 15 birds/replicate). Quail chicks prior and during the experimental period were fed ad libitum on the same diet, which formulated to cover the nutrient requirements of growing Japanese quail as recommended by NRC (1994), as shown in Table 1. Birds throughout the whole growing period were reared under the same hygienic, managerial, and suitable environmental conditions, and exposed to 24 h of light per day (continuous light).

Data Collection

BW and FI Birds were individually weighed at 5, 6, and 7 wk of age to calculate the mean value of BW (g) for each experimental group. FI (g/bird per week) was estimated by subtracting the weekly remaining feed from the presented feed.

Carcass Traits At 5th, 6th, and 7th wk of age, five birds from each group were selected, having average BW around the quail group mean, fasted overnight, weighed, and slaughtered. The abdominal cavity was opened, and the edible organs (gizzard, liver, and heart) were removed and weighed, in gram to the nearest three decimal points, and proportionated to the live BW. Whole eviscerated carcasses were individually weighed, and the dressing percentage or carcass yield was recorded.

Meat Quality and Chemical Analysis After dressing, the carcasses were chilled at 1°C for 12 h, and then they were separated into different parts including breast and thigh. These parts were kept and frozen at −20°C till analysis. The meat of frozen parts was separated from bones, homogenized, and analyzed for crude fat, CP, carbohydrate, moisture, and ash (AOAC, 2005). The studied physical meat qualities included juiciness, tenderness, water holding capacity (**WHC**), intramuscular fat percentage (**IMF**), and meat color. Tenderness and juiciness of each breast meat sample were evaluated individually with five trained panelists, on a 1 to 5 scale. The WHC of breast meat was determined according to the method of Whiting and Jenkins (1981). Meat color was examined using a Minolta Chromameter CR-310 (Minolta Corporation, Ramsey, NJ, USA), calibrated with a white calibration plateas described by Roberts et al. (2007). The chromameter measures Hunter L^* (lightness), a^* (redness), and b^* (yellowness) values.

Blood Sampling and Laboratory Analyses At 5, 6, and 7 wk of age, blood samples were collected on random basis from five quails/group into heparinized tubes. Hemoglobin values (Hb; g/dL) were measured in whole blood by using Sahli's acid haematin method. Packed cell volume (**PCV**; %) was measured as described by Schalm (1961). Red blood cells (**RBC**; $106/mm^3$) and white blood cells (WBC; $103/mm^3$) were manually counted using a hemocytometer (Campbell, 1995). Samples were centrifuged at 4000 rpm for 10 min, and sera were kept in Eppendorf tubes at −20°C until analysis. Total protein, glucose, triglycerides (mg/dl), total cholesterol (mg/dl), calcium (mg/dl), phosphorus (mg/dl), and uric acid (mg/dl) were measured by commercial kits (Akiba et al., 1982).

Statistical Analyses

Data were statistically analyzed on a 2 × 3 factorial design basis according to Snedecor and Cochran (1982) using the general linear model function of the SPSS 11.5 for Windows (SPSS, 1998). Differences among means within the same factor were tested using the post-hoc Newman–Keuls test.

RESULTS AND DISCUSSION

BW and FI

Table 2 reports the effects of sex and slaughter age of Japanese quail on BW and FI. These parameters were significantly higher in female quails than in males, and these values showed an increasing trend with the advancement of age. These results are supported by Baumgartner (1994), Boni et al. (2010), and Ojedapo and Amao (2014), who reported that BW and FI were higher in female quails than the males. Furthermore, at d 35 and 42, the male birds had lower ($P < 0.010$) BW, which is to be expected where male quails are normally lighter than females (Yannakopoulos and Tserveni-Gousi, 1986). The difference in BW between females and males, phenomena called sexual dimorphisms, is particularly marked in poultry species (Mignon-Grasteau, 1999). Regardless the sex effect, BW and FI were linearly increased with advancement in age from 5 to 7 wk of age. On the same context, final BW was increased with age from 5 to 11 wk of age (Walita et al., 2017), where quails achieved the best value of BW at slaughter (169 g) at 11 wk of age in comparison with 5 or 8 wk of age. In the present study, BW was affected ($P = 0.001$) by the interaction between sex and age, where the highest BW was recorded in females at 7 wk of age, while the lowest value was recorded in males at 5 wk of age (Table 2).

Carcass Traits

The results of carcass traits are given in Table 2. Due to the sex effect, there were significant changes in liver, heart, and giblets percentages ($P < 0.05$), whereas the females recorded higher percentages of liver and giblets and lower heart percentage than males. These results agree with those reported by Kumar et al. (2011). The heart, liver, and giblets percentage of females improved significantly ($P < 0.05$) than in males (Bonos et al., 2010). In a study, Vali et al. (2005) reported that carcass, breast weight, and thigh yield were influenced by quail sex. Kumar et al. (2011) found that the giblet yield of quails belonging to brown (9.66) and white

Table 2. BW (g) and FI (g/bird/week) and carcass traits (%) of growing Japanese quail as affected by age, sex, and their interaction during the experiment.

Items		BW (g)	Feed intake (g/bird/week)	Carcass (%)	Liver (%)	Gizzard (%)	Heart (%)	Giblets (%)	Dressing (%)	Breast (%)	Thigh (%)
Sex	Male	191.42 ± 2.65	181.51 ± 3.48	75.60 ± 0.84	2.43 ± 0.35	2.21 ± 0.44	0.91 ± 0.03	5.54 ± 0.21	81.15 ± 0.72	23.57 ± 1.10	15.31 ± 0.55
	Female	205.76 ± 3.17	209.30 ± 3.38	74.47 ± 0.77	3.23 ± 0.63	2.47 ± 0.48	0.77 ± 0.03	6.47 ± 0.35	80.94 ± 1.04	22.82 ± 0.96	15.62 ± 0.35
P-value		0.001	0.001	0.071	0.023	0.152	0.001	0.001	0.744	0.372	0.509
Age	5 wk	164.50 ± 3.25^{c}	177.05 ± 4.27^{c}	74.62 ± 1.05	2.84 ± 0.09^{b}	2.76 ± 0.06^{a}	0.79 ± 0.03	6.30 ± 0.15^{a}	81.02 ± 1.17^{b}	19.59 ± 0.75^{b}	14.33 ± 0.37^{b}
	6 wk	197.03 ± 4.13^{b}	188.52 ± 2.80^{b}	76.05 ± 0.57	3.11 ± 0.41^{a}	2.31 ± 0.21^{b}	0.87 ± 0.04	6.39 ± 0.56^{a}	82.35 ± 0.40^{a}	25.10 ± 0.70^{a}	16.33 ± 0.46^{a}
	7 wk	234.23 ± 6.03^{a}	220.62 ± 3.40^{a}	74.42 ± 1.25	2.53 ± 0.15^{c}	1.95 ± 0.11^{c}	0.85 ± 0.07	5.33 ± 0.18^{b}	79.75 ± 1.29^{c}	24.90 ± 0.48^{a}	15.71 ± 0.51^{a}
P-value		0.001	0.001	0.066	0.001	0.001	0.230	0.001	0.044	0.037	0.049
The interaction											
Male	5 wk	159.93 ± 2.86^{e}	176.88 ± 6.03^{c}	72.64 ± 1.95^{b}	2.68 ± 0.18^{c}	2.70 ± 0.12^{a}	0.79 ± 0.02^{b}	6.18 ± 0.30^{c}	78.82 ± 2.10^{c}	19.89 ± 2.85	13.52 ± 0.23
	6 wk	192.08 ± 4.70^{d}	185.90 ± 3.50^{b}	77.08 ± 0.78^{a}	2.24 ± 0.25^{d}	1.87 ± 0.15^{c}	0.94 ± 0.04^{a}	5.05 ± 0.17^{d}	82.13 ± 0.75^{b}	25.69 ± 1.89	16.02 ± 1.12
	7 wk	222.24 ± 6.36^{b}	181.47 ± 6.59^{b,c}	77.08 ± 1.12^{a}	2.36 ± 0.48^{d}	2.05 ± 0.39^{b}	0.99 ± 0.07^{a}	5.40 ± 0.66^{d}	82.49 ± 1.18^{b}	25.13 ± 1.03	16.37 ± 1.49
Female	5 wk	169.08 ± 2.01^{e}	177.24 ± 5.99^{c}	76.61 ± 0.94^{a}	3.01 ± 0.18^{b}	2.81 ± 0.12^{a}	0.79 ± 0.11^{b}	6.61 ± 0.34^{b}	83.22 ± 1.24^{a}	19.29 ± 0.21	15.15 ± 0.22
	6 wk	201.98 ± 3.08^{c}	191.14 ± 6.66^{b}	75.03 ± 1.04^{a}	3.98 ± 0.44^{a}	2.76 ± 0.19^{a}	0.81 ± 0.07^{b}	7.54 ± 0.29^{a}	82.57 ± 1.31^{b}	24.50 ± 1.63	16.65 ± 1.28
	7 wk	246.22 ± 3.26^{a}	259.50 ± 8.54^{a}	71.77 ± 0.95^{b}	2.70 ± 0.19^{c}	1.84 ± 0.07^{c}	0.71 ± 0.08^{c}	5.25 ± 0.17^{d}	77.02 ± 1.08^{d}	24.67 ± 1.49	15.06 ± 0.62
P-value		0.001	0.001	0.001	0.003	0.015	0.002	0.001	0.001	0.926	0.060

Note: means in the same column within each classification bearing different letters are significantly ($P < 0.05$) different.

Table 3. Meat chemical composition of growing Japanese quails as affected by age, sex, and their interaction.

Items		Moisture (%)	Protein (%)	Carbohydrate (%)	Fat (%)	Ash (%)
Sex	Male	73.89 ± 0.17	19.57 ± 0.18	2.04 ± 0.03	3.16 ± 0.03	1.34 ± 0.01
	Female	73.92 ± 0.17	19.32 ± 0.16	2.02 ± 0.03	3.40 ± 0.04	1.33 ± 0.02
P-value		0.542	0.105	0.213	0.010	0.753
Age	5 wk	74.46 ± 0.24[a]	18.91 ± 0.19[b]	2.07 ± 0.22	3.16 ± 0.03[c]	1.38 ± 0.01[a]
	6 wk	73.76 ± 0.20[b]	19.60 ± 0.21[a]	2.03 ± 0.25	3.26 ± 0.04[b]	1.35 ± 0.03[a]
	7 wk	73.48 ± 0.21[b]	19.82 ± 0.22[a]	1.98 ± 0.26	3.42 ± 0.03[a]	1.29 ± 0.02[b]
P-value		0.039	0.043	0.091	0.008	0.005
The interaction						
Male	5 wk	74.37 ± 0.061	19.06 ± 0.65	2.09 ± 0.07	3.09 ± 0.09	1.38 ± 0.04
	6 wk	73.61 ± 0.44	19.86 ± 0.56	2.04 ± 0.03	3.13 ± 0.11	1.35 ± 0.04
	7 wk	73.68 ± 0.43	19.79 ± 0.40	1.99 ± 0.04	3.25 ± 0.07	1.29 ± 0.03
Female	5 wk	74.54 ± 0.70	18.77 ± 0.71	2.06 ± 0.08	3.23 ± 0.07	1.38 ± 0.04
	6 wk	73.92 ± 0.44	19.34 ± 0.35	2.03 ± 0.09	3.38 ± 0.10	1.34 ± 0.03
	7 wk	73.29 ± 0.41	19.85 ± 0.49	1.98 ± 0.06	3.59 ± 0.08	1.29 ± 0.02
P-value		0.073	0.110	0.0914	0.134	0.0672

Note: means in the same column within each classification bearing different letters are significantly ($P < 0.05$) different.

(9.28) was higher than black spotted strain (8.99). Female birds recorded lower giblet percentage (9.11) than male birds (9.51). The percentage of neck yield was 5.78%. The corresponding means were 10.79, 19.52, 25.07, and 38.32 for wing, back, leg yield, and breast, respectively. Thus, breast meat was the heaviest part in the carcass of quails. With regard to age, all carcass traits, except carcass and heart percentages, were significantly ($P < 0.05$) affected by slaughter age. The highest values of liver (3.11%), giblets (6.4%), breast meat (25.1%), and thigh meat (16.3%) were recorded by birds reared up to 6 wk of age compared to 5 or 7 wk of age. Otherwise, the highest percent of gizzard recorded in quail slaughtered at 5 wk of age. These results are in agreement with those obtained by Wilkkanowska et al. (2011), who found that carcass yield traits were affected by age, whereas the BW was improved with age; also, older quails achieved higher carcass weight when compared to young quails. In the same line, BW was linearly increased with age from 3 to 7 wk of age (Walita et al., 2017).

The sex × age interaction had a significant impact on all carcass parameters vs. breast and thigh meat. The highest values of carcass and heart were obtained from male at 6 or 7 wk of age compared to other groups. The highest percentages of gizzard and dressing and liver and giblets were achieved by female groups at 5 and 6 wk of age, respectively, when compared to the other groups. In Japanese quails, lower breast cut in males than in females has been reported (Vali et al., 2005; Kosshak et al., 2014). On the other hand, other reports have shown no significant effects of sex on breast percentage (Aksit et al., 2003; Genchev et al., 2008). The onset of fattening and metabolic differences could explain the differences of sex (Musa et al., 2006).

Meat Chemical Composition

The effect of sex and age on chemical composition of meat is presented in Table 3. Due to the main effect of sex, no differences ($P > 0.05$) were observed among the groups, except for fat percentage. A higher ($P < 0.01$) fat content was observed in female meat in comparison with male meat. Choi et al. (2012) reported that the oestrogen secreted by ovary could increase lipid deposition among myofibres. Similarly, Genchev et al. (2008) observed significantly higher lipid content in quail female carcasses with skin than those of male ones, while meat dry matter, protein, and ash contents were not significantly different between the two genders. Further, Sartowska et al. (2014) reported no differences in breast meat content of protein and ash between male and female quails. In contrast, Magubane et al. (2013) observed similar fat content in the breast meat of male and female quails.

All parameters related to the chemical composition of meat, apart carbohydrate, were significantly affected by slaughter age, whereas moisture ($P < 0.05$) and ash ($P < 0.01$) contents of meat were gradually deceased with age, but protein ($P < 0.05$) and fat ($P < 0.01$) contents were gradually increased with the age. No effect ($P > 0.05$) was observed for the meat chemical composition due to the interaction between age and sex. These results corroborated with Ilavarasan *et al.* (2016), who found that the meat of older quails had significantly lower moisture and higher protein, fat, and total ash content than young. The moisture content of quail meat decreases as age of the bird increase, which is probably associated with an increase in protein and fat content (Lawrie, 1998).

Meat Quality

Results in Table 4 showed that juiciness was not affected significantly by sex, and these result agreed with Karthika et al. (2016), who reported that the sex of Namakkal quails has no significant effect on the meat juiciness. On contrary to this, sex had a significant effect on the juiciness of duck meat, as showed by Omojola (2007). On the other hand, juiciness significantly ($P = 0.002$) decreased with quail age, where the greatest value (3.95) was achieved at 5 wk of age. These results

Table 4. Meat quality traits of growing Japanese quails as affected by age, sex, and their interaction.

						Breast meat color		
Items		Juiciness	Tenderness	WHC	IMF	L*	a*	b*
Sex	Male	3.73 ± 0.06	4.08 ± 0.06	59.33 ± 0.76	6.27 ± 0.06	50.26 ± 1.38	14.19 ± 0.71	9.71 ± 0.24
	Female	3.83 ± 0.04	4.19 ± 0.08	53.33 ± 0.86	6.66 ± 0.14	53.87 ± 1.29	12.35 ± 0.30	9.72 ± 0.29
P-value		0.099	0.049	0.001	0.004	0.001	0.001	0.997
Age	5 wk	3.95 ± 0.05^{a}	4.33 ± 0.06^{a}	54.33 ± 1.50^{b}	6.20 ± 0.09^{c}	56.64 ± 0.67^{a}	11.50 ± 0.37^{b}	10.37 ± 0.24
	6 wk	3.79 ± 0.05^{b}	4.15 ± 0.03^{b}	56.67 ± 1.43^{a}	6.51 ± 0.14^{b}	51.81 ± 1.24^{b}	13.98 ± 0.63^{a}	9.47 ± 0.31
	7 wk	3.60 ± 0.04^{c}	3.92 ± 0.05^{c}	58.00 ± 1.71^{a}	6.68 ± 0.16^{a}	47.74 ± 0.75^{c}	14.34 ± 0.67^{a}	9.32 ± 0.22
P-value		0.002	0.001	0.032	0.012	0.001	0.001	0.050
The interaction								
Male	5 wk	3.90 ± 0.15	4.23 ± 0.10	57.33 ± 1.53	6.18 ± 0.27	55.38 ± 0.75	11.57 ± 0.23^{c}	10.29 ± 0.65
	6 wk	3.72 ± 0.12	4.13 ± 0.07	59.33 ± 1.52	6.28 ± 0.16	49.16 ± 1.32	15.28 ± 0.67^{a}	9.56 ± 0.60
	7 wk	3.56 ± 0.14	3.88 ± 0.13	61.31 ± 2.08	6.34 ± 0.14	46.23 ± 0.69	15.74 ± 0.79^{a}	9.30 ± 0.67
Female	5 wk	4.00 ± 0.12	4.43 ± 0.10	51.33 ± 2.08	6.22 ± 0.24	57.90 ± 1.19	11.44 ± 0.79^{c}	10.45 ± 0.63
	6 wk	3.86 ± 0.11	4.18 ± 0.08	54.00 ± 2.65	6.73 ± 0.35	54.47 ± 0.51	12.67 ± 0.57^{b}	9.37 ± 1.02
	7 wk	3.64 ± 0.10	3.95 ± 0.13	54.67 ± 2.52	7.02 ± 0.12	49.25 ± 1.06	12.95 ± 0.55^{b}	9.34 ± 0.55
P-value		0.936	0.440	0.862	0.092	0.061	0.022	0.908

Note: Means in the same column without common superscripts are different (P< 0.05). WHC: water holding capacity, IMF: intramuscular fat percentage.

agreed with Wilkanowska and Kokoszynski (2011), who found that juiciness of breast muscles obtained from 33 d old of Pharaoh quail was higher than it at 42 d old. On the other hand, Karthika et al. (2016) reported that quail ages of 4 and 6 wk did not affect juiciness of meat.

Results obtained from this study showed a significant ($P = 0.049$) improvement in the tenderness of female meat as compared with males. The same trend was observed for age effect, and it was significantly ($P = 0.001$) improved with early age (5 wk) in comparison with 6 and 7 wk of age, as shown in Table 4. These results agreed with Genchev et al. (2010), who noticed that the tenderness of quail breast meat increased in both sexes by about 11% with advancing slaughter age of birds from 31 to 42 d for males ($P < 0.001$) and females ($P < 0.01$). The tenderness of quail meat is a complex trait depending on several factors, especially the proportion of tissue that builds up the muscle. The higher tenderness of female quail's meat could be attributed to the slightly high percentages of dark muscle fiber, which has smaller diameter than that of the light ones (Riegel et al., 2003). Recently, Reddy et al. (2017) discussed this trait in chicken meat and reported that the decreasing tenderness with increasing of age might be due to increase in the diameter of muscle fiber, connective tissue, and cross linkages between the polypeptide chains with age advancement.

The good WHC of breast meat guarantees excellent technological properties of meat. WHC was significantly ($P = 0.001$) decreased in female groups vs. males (Table 4). The quail male meat recorded higher value of WHC (59.33) than female ones (53.33), and this result was in disagreement with Reddy et al. (2017), who showed that the effect of sex was insignificant on WHC of Rajasri chicken meat. In view of age effect, the present results in Table 4 showed that WHC increased significantly ($P = 0.032$) with the advancement in quail age, and this observation agreed with Wilkanowska and Kokoszynski (2011), who found that the WHC of breast muscles obtained from a 42 d old of Pharaoh quail was higher than it at 33 d old. The IMF was significantly ($P < 0.05$) influenced by sex and age (Table 4). The quail female meat recorded higher IMF value (6.66%) than males (6.27%), and this result was supported by Reddy et al. (2017), who revealed that the effect of sex was significant ($P < 0.05$) on a percent of crude fat of breast meat for Rajasri chicken. While these results are in contrary to the observations of Gecgel et al. (2015), who found that the meat of male Japanese quail had higher fat content than female quail meat. Regarding to age effect, IMF was linearly increased ($P < 0.05$) with the progress of slaughter age. Our results agree with research on animal meat, which has indicated that the increase in age is accompanied by an increase in intramuscular fat (Lawrie, 1991). Also, Boni et al. (2010) noticed that the meat of a young quail has significantly ($P < 0.05$) lower fat content than in meat of a spent quail.

Quail meat color of lightness (L^*) and redness (a^*) was significantly ($P < 0.01$) affected by age (Table 4), whereas the higher values of (L^*) and (a^*) were 56.64 and 14.34 at 5 and 7 wk of age, respectively. Also, yellowness (b^*) was significantly ($P \leq 0.05$) decreased with increasing quail age. These results are in close agreement with findings by Genchev et al. (2010), who tested quail breast meat at four ages of 31, 35, 39, and 42 d old. Also, Ikhlas et al. (2010) reported similar results on young (8 wk old) and spent quail (8 mo old). In relating to sex effect, meat color of (L^*) in females and (a^*) in males recorded the highly significant ($P = 0.001$) values of 53.87 and 14.19, respectively. In contrary, the breast meat color of yellowness (b^*) was insignificantly affected by age. These results are partly agreed with Genchev et al. (2010) with ages of 35 and 42 d.

All physical quality traits (juiciness, tenderness, WHC, IFM, lightness L^*, and yellowness b^*) of quail meat under study were insignificantly affected by the interaction between sex and age except for breast meat color of redness (a*), which significantly ($P < 0.05$) gave the highest value at 7 wk of age in males meat as compared with the lowest value at 5 wk of age in females meat. In conclusion, the sex and age had significant effects on physical qualities of a Japanese quail. According to WHC, it is recommended that the slaughter of Japanese quail at 6 or 7 wk, especially the male sex, can be considered more beneficial as shown in results of the present work.

Hemato-biochemical Parameters

The hematological and biochemical blood parameters established in growing Japanese quail are shown in Table 5. Due to the main effect of sex, mean values of RBC, PCV, Hb, and WBC were higher ($P < 0.05$) in male quails than female ones. The opposite trend was detected for blood biochemical parameters, with the exception of glucose concentration. Plasma total cholesterol, total protein, triglycerides, calcium, phosphorus, and uric acid were significantly ($P < 0.001$) decreased, while plasma glucose was increased ($P < 0.05$) in males when compared to females. The present results for hematological parameters are in agree with Hajkhodadadi et al. (2013) for PCV and WBC. Changes of total protein, total cholesterol, glucose, triglycerides, and uric acid between sexes were similar to those reported by Scholtz et al. (2009). They found that total protein, total cholesterol, triglycerides, and uric acid values were higher ($P < 0.01$) in females, whereas males had higher levels of glucose ($P < 0.05$). Numerous sex-related differences may be demonstrated by the physiological alterations in metabolism process in female birds because of egg laying. Throughout the laying stage, the hepatic biosynthesis of phospholipids, triglycerides, and cholesterol is increased (Walzem et al., 1999).

Apart from WBC, the progress in quail age (5 to 7 wk) leads to significant increase in values of RBC ($P = 0.045$), PCV ($P = 0.011$), and Hb ($P = 0.001$). The levels of total cholesterol ($P < 0.05$), total protein ($P < 0.05$), triglycerides ($P < 0.01$), and hemoglobin ($P < 0.01$) were linearly increased with advancement in age, but glucose, calcium, phosphorus, and uric acid were apparently increased ($P > 0.05$). Our data are supported by those obtained by Sujata et al. (2014), who found that the mean values of RBC, PCV, Hb, and WBC were linearly increased ($P < 0.05$) with age in Japanese quail. However, Oluwasanmi and Temitayo (2014) recorded no significant changes with age in RBC, PCV, Hb, and WBC for Japanese quail. Our results for blood biochemical parameters are consistent with Ayub et al. (2012), who found that the serum contents of cholesterol, albumin, total protein, globulin, uric acid, and calcium of Japanese quail were increased with age. The level of serum cholesterol was 91.95 mg/dl at 5th wk of age, and this level increased to 466.11 mg/dl at

Table 5. Hemato–biochemical parameters of growing Japanese quails as affected by age, sex, and their interaction.

Items		RBCs (× 10^6/mm^3)	PCV (%)	Hemoglobin g/ dl	WBCs (× 10^3/mm^3)	Total protein /dl	Glucose mg/dl	Total Cholesterol mg/dl	Triglycerides mg/dl	Uric acid mg/dl	Calcium mEq/L	Phosphorus mEq/L
Sex	Male	2.93 ± 0.08	33.64 ± 1.65	14.37 ± 0.68	26.11 ± 1.13	4.47 ± 0.09	315.56 ± 7.96	156.28 ± 3.69	162.67 ± 5.21	7.11 ± 0.32	5.23 ± 0.11	5.16 ± 0.12
	Female	2.70 ± 0.21	32.02 ± 1.24	12.52 ± 0.25	25.01 ± 0.97	4.85 ± 0.18	297.33 ± 4.79	177.72 ± 3.42	954.67 ± 48.0	9.73 ± 0.99	10.63 ± 0.41	6.28 ± 0.19
P-value		0.004	0.009	0.001	0.035	0.020	0.047	0.001	0.001	0.001	0.001	0.001
Age	5 wk	2.71 ± 0.21^{b}	31.66 ± 0.95^{b}	12.28 ± 0.29^{c}	25.11 ± 1.37	4.32 ± 0.11^{c}	296.83 ± 6.80	160.42 ± 5.43^{b}	488.67 ± 15.36^{c}	8.02 ± 0.56	7.44 ± 1.12	5.36 ± 0.22
	6 wk	2.81 ± 0.20^{a,b}	32.86 ± 1.32^{a,b}	13.25 ± 0.49^{b}	25.29 ± 0.52	4.69 ± 0.13^{b}	307.83 ± 9.96	163.92 ± 6.56^{b}	539.67 ± 16.70^{b}	8.49 ± 0.69	7.75 ± 1.16	5.84 ± 0.33
	7 wk	2.93 ± 0.09^{a}	33.98 ± 1.82^{a}	14.80 ± 0.89^{a}	26.28 ± 1.23	4.97 ± 0.21^{a}	314.67 ± 8.90	176.67 ± 5.29^{a}	647.69 ± 21.36^{a}	8.75 ± 0.69	8.59 ± 1.44	5.97 ± 0.34
P-value		0.045	0.011	0.001	0.122	0.010	0.244	0.017	0.001	0.265	0.066	0.064
The interaction												
Male	5 wk	2.85 ± 0.04	32.00 ± 0.29	12.27 ± 0.35^{d}	25.76 ± 1.51	4.31 ± 0.36	293.67 ± 17.04	151.33 ± 11.24	146.33 ± 6.66^{e}	6.89 ± 0.19	4.98 ± 0.19	4.92 ± 0.31
	6 wk	2.93 ± 0.04	33.54 ± 1.46	14.10 ± 1.15^{b}	25.45 ± 0.30	4.52 ± 0.28	327.33 ± 15.69	150.83 ± 7.01	166.67 ± 15.18^{d}	6.99 ± 0.21	5.24 ± 0.26	5.18 ± 0.34
	7 wk	3.00 ± 0.06	35.38 ± 0.36	16.73 ± 0.45^{a}	27.12 ± 0.56	4.58 ± 0.10	325.67 ± 25.79	166.67 ± 8.62	175.00 ± 7.21^{d}	7.46 ± 0.22	5.46 ± 0.41	5.37 ± 0.37
Female	5 wk	2.56 ± 0.21	31.31 ± 1.36	12.30 ± 1.05^{d}	24.46 ± 1.06	4.33 ± 0.26	300.00 ± 19.31	169.50 ± 8.32	831.00 ± 34.18^{c}	9.16 ± 0.89	9.90 ± 0.75	5.79 ± 0.17
	6 wk	2.69 ± 0.24	32.17 ± 0.91	12.40 ± 0.50^{d}	25.14 ± 0.71	4.86 ± 0.28	288.33 ± 10.01	177.00 ± 9.16	912.67 ± 29.19^{b}	9.99 ± 0.56	10.26 ± 1.17	6.49 ± 0.47
	7 wk	2.85 ± 0.03	32.57 ± 1.50	12.87 ± 0.78^{c}	25.45 ± 1.18	5.36 ± 0.43	303.67 ± 12.66	186.67 ± 6.71	1120.30 ± 39.07^{a}	10.05 ± 1.43	11.72 ± 1.22	6.57 ± 0.68
P-value		0.637	0.272	0.003	0.479	0.135	0.118	0.710	0.003	0.696	0.300	0.662

Note: means in the same column within each classification bearing different letters are significantly ($P < 0.05$) different.

7th wk. Our findings are in agreement with the results of Hassan (2010), who observed a gradual increase in concentration of cholesterol with age, where the lowest value was observed at 8 wk of age, while the highest one was observed at 30 wk of age. Also, an increase was observed in plasma total protein and albumin with progressing age of female Japanese quails (Hassan, 2010). The increase in total protein, albumin, total cholesterol, and triglycerides may be attributed to secretion of estrogen at the onset of egg production that induced hepatic biosynthesis of lipoproteins, phospholipids, triglycerides, and cholesterol; Walzem et al., 1999). However, Bahie El-Deen et al. (2009) stated that total protein levels decreased with age of Japanese quail.

The plasma calcium content in the current investigation increased numerically with advancement in age ($P = 0.066$), where the highest value was achieved at 5th wk. In Japanese quails, El-Ghalid (2009) observed an increase in the serum content of calcium with increasing age, which is in agreement with the results by our investigation. Increasing the concentration of calcium with age may be returned to increased steroid hormones secretion. In laying hens, the steroid hormones are involved in the regulation of calcium metabolism via numerous mechanisms of action. Also, the increase in the level of calcium is due to increased blood concentration of protein-bound calcium (Pavlik et al., 2009). In the current study, all blood parameters were not affected by sex × age interaction ($P > 0.05$) apart from triglycerides. The female groups at 7 wk of age achieved the highest (1120.30 mg/dl) value of triglyceride in comparison with the other groups.

From the obtained findings, it could be concluded that Japanese quails (males or females) should be slaughtered at 5 or 6 wk of age to obtain higher carcass yields and to obtain the best meat quality and composition. Furthermore, quail males recorded the highest values of meat quality and composition when compared to females.

REFERENCES

Akiba, Y., L. Jensen, C. Barb, and R. Kraeling. 1982. Plasma estradiol, thyroid hormones, and liver lipid content in laying hens fed different isocaloric diets. J. Nutr. 112:299–308.

Aksit, M., I. Oguz, Y. Akbas, O. Altan, and M. Ozdogan. 2003. Genetic variation of feed traits and relationships to some meat production traits in Japanese quail (*Coturnix coturnix japonica*). Arch. Geflugelkd. 67:76–82.

Alagawany, M., M. E. A. El-Hack, V. Laudadio, and V. Tufarelli. 2014. Effect of low-protein diets with crystalline amino acid supplementation on egg production, blood parameters and nitrogen balance in laying Japanese quails. Avian Biol. 7:235–243.

Alagawany, M., M. E. Abd El-Hack, M. R. Farag, S. S. Elnesr, M. S. El-Kholy, I. M. Saadeldin, and A. A. Swelum. 2018. Dietary supplementation of *Yucca schidigera* extract enhances productive and reproductive performances, blood profile, immune function, and antioxidant status in laying Japanese quails exposed to lead in the diet. Poult. Sci. 97:3126–3137.

Alagawany, M., M. R. Farag, M. E. Abd El-Hack, and A. Patra. 2017. Heat stress: effects on productive and reproductive performance of quail. Worlds Poult. Sci. J. 73:747–756.

Aminzade, B., B., Karami, and E. Loti. 2012. Meat quality characteristics in Japanese quails fed with *Mentha piperita* plant. Anim. Biol. Anim. Husb. 4:20–23.

AOAC. 2005. Official Methods of Analysis, 16th ed. Association of Official Analytical Chemists, Washington, DC.

Ayub, A. M., L. Hmar, L. Inaotombi Devi, M. L. Prava, M. C. Lallianchhunga, and T. C. Tolenkhomba. 2012. Effect of age on the haematological and biochemical profile of Japanese quails (*Coturnix coturnix japonica*). Int. Multidisc. Res. J. 2:32–35.

Bahie El-Deen, M., M. A. Kosba, and A. S. A. Soliman. 2009. Studies of some performance and blood constituents traits in Japanese quail. Egypt. Poult. Sci. 29:1187–1208.

Baumgartner, J. 2009. Japanese quail production, breeding and genetics. J. World Poult. Sci. 50:227–235.

Boni, I., H. Nurul, and I. Noryati. 2010. Comparison of meat quality characteristics between young and spent quails. Int. Food Res. J. 17:661–666.

Bonos, E. M., E. V. Christaki, and P. C. Florou-Paneri. 2010. Performance and carcass characteristics of Japanese quail as affected by sex or mannan oligosaccharides and calcium propionate. South Afr. J. Anim. Sci. 40:173–184.

Campbell, T. W. 1995. Avian Hematology and Cytology. 2nd ed. Iowa State University Press, Ames, Iowa, USA.

Choi, Y. I., H. J. Ahn, B. K. Lee, S. T. Oh, B. K. An, and C. W. Kang. 2012. Nutritional and hormonal induction of fatty liver syndrome and effects of dietary lipotropic factors in egg-type male chicks. Asian Australas. J. Anim. Sci 25:1145–1152.

El-Ghalid, O. A. H. 2009. Exogenous estradiol: blood profile, productive and reproductive performance of female Japanese Quails at different stages of production. Asian J. of Poult. Sci. 3:1–8.

Gecgel, U., I. Yilmaz, E. K. Gurcan, S. Karasu, and G. C. Dulger. 2015. Comparison of fatty acid composition between female and male Japanese quail meats. J. Chem. Article ID 569746, 8, https://doi.org/10.1155/2015/569746.

Genchev, A., G. Mihaylova, S. Ribarski, A. Pavlov, and M. Kabakchiev. 2008. Meat quality and composition in Japanese quails. Trakia J. Sci. 6:72–82.

Genchev, A., S. Ribarski, and G. Zhelyazkov. 2010. Physicochemical and technological properties of Japanese quail meat. Trakia J. Sci. 8:86–94.

Hajkhodadadi, I., M. Kazemi-bonchenari, H. A. Ghasemi, and S. Afshar. 2013. Effect of dietary lysine and sex on performance and immunity parameters of japanese quails. Intl. J. Farm Alli. Sci. 2:1260–1265.

Hamm, D., and C. Y. W. Ang. 1982. Nutrient composition of quail meat from three sources. J. Food Sci. 47:1613–1614.

Hassan, H. A. 2010. Variation in egg performance and plasma constituents at different ages of females Japanese quail. Egypt. Poult. Sci. 30:565–581.

Ikhlas, B., N. Huda, and N. Ismail. 2010. Comparison of meat quality characteristics of young and spent quail. Asian J. Food Agr. Ind. 5:498–504.

Ilavarasan, R., R. J. J. Abraham, and V. Appa Rao. 2016. The relationship between meat quality characteristics and nutritional composition of Nandanam quail-iii slaughtered at different ages. Jour. Anim. Rese. 6:95–100.

Jaturasitha, S. P., V. Leangwunta, and M. Kreuzer. 2004. Reducing toughness of beef from *Bos indicus* draught steers by injection of calcium chloride: effect of concentration and time postmortem. Meat Sci. 68:61–69.

Kosshak, A. S., N. I. Dim, O. M. Momoh, and D. Gambo. 2014. Effect of sex on carcass characteristics and correlation of body weight and blood components in Japanese quails. IOSR J. Agr. Vet. Sci. 7:72–76.

Kumar, M. S., R. K. Sudhakar, K. Kondal, and N. Krishnaiah. 2011. Studies on the effect of age and sex on carcass characteristics of various strains of Japanese quail. Ind. J. Poult. Sci. 46:25–30.

Lawrie, R. A. 1991. Meat Science. 5th ed. Pergamon Press, Oxford, UK.

Lawrie, R. A. 1998. Lawrie's Meat Science. 6th ed. Woodhead Publishing Ltd, Cambridge, England.

Magubane, M. M., B. W. Lembede, K. H. Erlwanger, E. Chivandi, and J. Donaldson. 2013. Fat absorption and deposition in Japanese quail (*Coturnix coturnix japonica*) fed a high fat diet. J. South Afr. Vet. Assoc. 84:384.

Mignon-Grasteau, S. 1999. Genetic parameters of growth curve parameters in male and female chickens. Brit. Poult. Sci. 40: 44–51.

Minvielle, F. 1998. Genetic and breeding of Japanese quail for production around the world. In: Proceedings 6th Asian Pacific poultry Congress Nagoya. Japan June 4–7th.

Mohammad, H. K. 2016. Influence of season, sex and age on haematological characteristics, body weight and rectal temperature in black local quail. Bas. J. Vet. Res. 1:340–348.

Mountney, G. J. 1981. Poultry Products Technology. 2nd ed. The AVI Publishing Company, Westport, Conn, USA.

National Research Council, NRC. 1994. Nutrient Requirements of Poultry. 9th ed. National Academy of Science, Washington, DC, USA.

Ojedapo, L. O., and S. R. Amao. 2014. Sexual dimorphism on carcass characteristics of Japanese quail (*Coturnix coturnix japonica*) reared in derived savanna zone of Nigeria. Int. J. Sci. Environ. Technol. 3:250–257.

Oluwasanmi, O. A., and A. Temitayo. 2014. Age-related changes in haematologic parameters of cage-raised Japanese quails (*Cortunix japonica*). J. Vet. Med. Anim. Health 6:104–108.

Omojola, A. M.. 2007. Carcass and organoleptic characteristics of duck meat as influenced by breed and sex. Int. J. Poult. Sci. 6:329–334.

Pavlik, A., M. Lichovnikova, and P. Jelinek. 2009. Blood plasma mineral profile and qualitative indicators of the eggshell in laying hens in different housing systems. Acta Vet. Brno. 78:419–429.

Reddy, N. A., K. K. Reddy, M. S. Kumar, N. Krishnaiah, and V. K. Rao. 2017. Studies on Effect of Sex and Age on Physico-Chemical and Organoleptic Qualities of Rajasri Chicken. Int. J. Curr. Microbiol. App. Sci. 6:406–415.

Riegel, J., F. Rosner, R. Schmidt, L. Schuler, and M. Wicke. 2003. Investigation of meat quality of m. Pectoralis in male and female japanese quails (Coturnix japonica). pp 23–26 in Proceeding of the XVIth European Symposium on the Quality of Poultry Meat. Saint-Brieuc, France.

Roberts, S. A., H. Xin, B. J. kerr, J. R. Russell, and K. Bregendahl. 2007. Effects of dietary fiber and reduced crude protein on ammonia emission from laying-hen manure. Poult. Sci. 86:1625–1632.

Sartowska, K. E., A. Korwin-Kossakowska, E. Polawska, P. Lipinska, and G. Sender. 2014. Sex-related differences in the nutritional value of Japanese quail meat. Int. J. Food Sci. Technol. 49:2635–2642.

Schalm, O. W. 1961. Pages 165–187 in Veterinary Hematology. Lea and Febiger, Philadelphia USA.

Scholtz, N., I. Halle, G. Flachowsky, and H. Sauerwein. 2009. Serum chemistry reference values in adult Japanese quail (*Coturnix coturnix japonica*) including sex-related differences. Poult. Sci. 88:1186–1190.

Shanaway, M. M. 1994. Pages 82–84 in Quail Production Systems – A Review. Food and Agriculture Organization of the United Nations, Rome, Italy.

Snedecor, G. W., and W. G. Cochran. 1982. Statistical Methods. 7th ed. Iowa State University, USA, Ames, Iowa.

SPSS. 1998. SPSS Base 11.5 Application Guide. SPSS Inc., USA.

Sujata, P., P. K. Mohanty, and B. K. Mallik. 2014. Haematological analyses of Japanese quail (*Coturnix Coturnix Japonica*) at different stages of growth. Int. Res. J. Biological Sci. 3:51–53.

Vali, N., M. A. Edriss, and H. R. Rahmani. 2005. Genetic parameters of body and some carcass traits in two quail strains. Int. J. Poult. Sci. 4:296–300.

Walita, K. Z, J. Tanganyika, and S. R. Mussah. 2017. Effect of sex, type of feed and age at slaughter on carcass yield characteristics of Japanese quails (*Cortunix Japonica*) in Malawi. Int. J. Avian Wildlife Biol. 2:50−53.

Walzem, R. L., R. J. Hansen, D. L. Williams, and R. L. Hamilton. 1999. Estrogen induction of VLDLy assembly in egg-laying hens. J. Nutr. 129:467S–472S.

Whiting, R. C., and R. K. Jenkins. 1981. Comparison of rabbit, beef, and chicken meats for functional properties and frankfurter processing. J. Food Sci. 46:1693–1696.

Wilkkanowska, A., and D. Kokoszyński. 2011. Comparison of slaughter value in pharaoh quail of different ages. J. Cent. Eur. Agric. 12:145–154.

Yannakopoulos, A. L., and A. S. Tserveni-Gousi. 1986. Carcase characteristics of Japanese quail at 42 days of age. Br. Poult. Sci. 27:123–127.