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ORIGINAL ARTICLE

Performance, carcass traits, meat quality and amino acid profile of different Japanese quails strains

Mohammed A. F. Nasr[1] · El-Shimaa M. R. Ali[1] · Mohamed A. Hussein[2]

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Abstract Poultry production is considered one of the prospective opportunities to accomplish sustainable and quick production of superior protein to challenge the growing mandate for animal protein. Therefore, this study was aimed to explore the difference on growth performance, carcass traits, meat quality and amino acid profile of different Japanese quails strains. A total of 480 quail chicks of four different plumage colors (120 of each white, golden, gray and brown) were collected after hatching. At 6 week of age, birds were stunned and decapitated to determine the physical meat quality, thiobarbituric acid reactive substances and amino acid profile. White quails had the highest weight of slaughter, carcass, dressing, carcass yield, liver, gizzard, heart and spleen (197.27 g, 169.27 g, 91%, 82%, 6.63 g, 6.53 g, 2.27 g and 0.40 g, respectively). Also, they had the highest Ph_U, lightness, yellowness and water holding capacity with the lowest level of redness, cooking losses and thiobarbituric acid in pectoral (6.28, 46.40, 12,46, 22.17, 9.20, 19.21 and 0.44, respectively) and thigh muscles (6.37, 42.30, 11.51, 26.01, 10.12 and 0.93, respectively). Moreover, they possessed the highest level of all essential (11.68 and 10.16 g/100 g protein in pectoral and thigh muscles, respectively) and non essential amino acids (13.27 and 12.54 g/100 g protein in pectoral and thigh muscles, respectively). Therefore, the current study revealed that white quails had the heaviest body weight with the best carcass traits and meat quality.

Keywords Quails · Growth performance · Carcass traits · Meat quality · Amino acid · Plumage color

Introduction

Recently, quails were considered an important for research purposes owing to their early maturity, quick life cycle, producing large number of eggs, low production cost, small body mass and diseases challenge (Oguz and Minvielle 2001). Regardless of the small body mass of Japanese quail, their meat and eggs are commonly demanded everywhere in the world. They are reared primarily for meat (in Europe) and egg production (in Japan), but other Asian nations deemed them as dual-purpose (Mahmoud et al. 2014; Nasr et al. 2016). Poultry making considers one of the prospective opportunities to accomplish sustainable and quick production of superior protein to challenge the growing mandate for animal protein. It provides human with beneficial substances such as conjugated linoleic acid, vitamins, antioxidants, omega 6 and omega 3 PUFA (Cavani et al. 2009). Comparative investigations on physico-chemical characters of meat obtained from quails, broiler chicken and ducks confirmed that quails' meat possessed the lowest-calorie with the highest protein level (Lonita et al. 2008). Furthermore, quail meat is lean with low cholesterol level and provides a superior economical resource of animal protein (Vali 2008).

The daily intake of 2 quails provide human body with 27–28 g protein, constituting 11 g of essential amino acids that covering 40% of human protein requirement which is equivalent to consumption of 125–130 g of pure meat.

✉ Mohammed A. F. Nasr
Mohammed.Nasr@zu.edu.eg; Nasr.maf@gmail.com

[1] Department of Animal Wealth Development, Faculty of Veterinary Medicine, Zagazig University, El-Zeraa Str. 114, Zagazig 44511, Egypt

[2] Food Control Department, Faculty of Veterinary Medicine, Zagazig University, Zagazig, Egypt

Moreover, they fulfill human daily requirement of lysine, leucine, phenylalanine, tyrosine and valine that are based on age, physiological condition and physical activity (Genchev et al. 2008). Consequently, quails meat might be a beneficial supply of protein especially essential amino acids. Several researchers reported that quails had different plumage color variants. Most of those researches focused mainly in inspecting the inheritance mode of the plumage color variants, but small number of efforts were arranged to investigate the production performance (Minvielle et al. 2007). Kerje (2003) reported that feather pigmentation has a prospective effect on tissue coloration and thus influences quail meat acceptability by consumers. Consequently, the current study was designed to explore the difference on growth performance, carcass traits, meat quality and amino acid profile of variant Japanese quails strains.

Materials and methods

Birds and management

The current investigation was accomplished depended on Ethics and Animal welfare committee guidelines (ICLAS) at Poultry Farm, Faculty of Veterinary Medicine, Zagazig University, Egypt (ANWD-206). A total of 480 quail chicks of four different plumage colors, 120 of each white, golden, gray and brown were collected on two batches (each 240 birds) after hatching. Quails used in the present study were originated from *Coturnix coturnix japonica*. Chicks of each color were divided into three replicates (each 20 birds) after identified with wing bands and reared in brooder house which provided with deep litter system. On arrival, the temperature was 38 °C using electric heaters. The temperature was gradually decreased to 34, 28 and 22 °C at the first, second and third week of age, respectively, and then maintained at 18–20 °C during the whole experimental period. Quails were fed ad libitum basic commercial quail's starter mash during the rearing period (24% crude protein and 12.45 MJ/kg metabolisable energy) (NRC 1994) (Table 1). The ration was analyzed on a dry matter basis. The percentages of mortality were comparable for all groups which were 9.16, 10, 10.83 and 11.66% for white, brown, black and yellow quails, respectively.

Table 1 Diet composition in the rearing period (0–6 weeks age)

	Rearing diet
Ingredients	
Yellow corn	51.84
Soybean meal (44%)	26.63
Concentrate (52%)	16.00
Vegetable fat	1.27
Di-calcium phosphate	1.50
Limestone	1.03
DL-methionine	0.09
Lysine	0.08
Vitamin and trace mineral	0.30
Premix	1.06
Coccidostate	0.10
Antioxidant	0.10
Calculated analysis	
ME (MJ/kg)	12.45
Crude protein (cp %)	24.00
Calcium (%)	0.80
Available phosphorus (%)	0.72
Lysine (%)	1.30
Methionine (%)	0.50

Growth performance, carcass traits and meat quality

Chicks were weighed individually on arrival (480 birds) and then biweekly till the end of experiment using digital balance (Sartorius 1202 MP balance, GmbH, Gottingen, Germany). At the 6 week of age (based on Inci et al. 2015), birds were stunned and decapitated after 12 fasting hours and then weighing the bird after bleeding (slaughter weight), carcass (empty carcass) and its organs (heart, liver, spleen and empty gizzard). Two *Longissimus thoracis et lumborum* (*LTL*) muscles were cut from the chilled carcass and the loose connective tissue was gently removed to determine the physical meat quality (pHu, color, cooking loss and water holding capacity), thiobarbituric acid reactive substances (TBARS) and amino acid profile. Ultimate pH (pHu) was recorded 24 h post chilling in a mixture of homogenized 1 g of each thigh muscle (TM) and pectoral muscle (PM) with 10 ml of 5 M iodoacetate for 30 s by a knick digital pH meter (Broadly Corp. Santa Ana, CA, USA) (Korkeala et al. 1986). The color was evaluated on the surface of TM and PM with a MINISCAN XE plus, which presented the average of lightness (L^*), redness (a^*) and yellowness (b^*) coordinates. Cooking loss was estimated by putting approximately 20 g of the muscles in aluminum pans and cooked using an electric oven (preheated to 200 °C) to an internal temperature of 80 °C for 15 min (Cyril et al. 1996). Subsequently, the samples were left for 30 min to cool (15 °C). Cooking loss was demonstrated as a percent through taking away the cooked from the initial samples weight.

Water holding capacity (WHC) was determined by putting 1 g of each TM and PM on tissue paper in a tube

and subsequently centrifuged for 4 min at 1500 r.p.m. The centrifuged residual water was estimated through drying the samples overnight at 70 °C. WHC was estimated using the formula (weight after centrifugation − weight after drying)/initial weight × 100 (Nakamura and Katoh 1985). The thiobarbituric acid was measured to estimate the lipid oxidation through thiobarbituric acid reactive substances (TBARS) (Salih et al. 1987). One g of meat was combined to 40 mM thiobarbituric acid solution in water and afterward heated at 93 °C. A spectrophotometer (Hitachi U-2000, Theodor-Heuss-Anlage 12, Mannheim, F. R. Germany) was used to measure the Malondialdehyde (MDA) content at a wavelength of 532 nm. A solution of tetraethoxypropane was used to measure TBARS through comparing the absorbance with the calibration curve that was expressed as mg of MDA per kg of muscle. Chilled TM and PM without fat were used to estimate the amino acid profile after acid hydrolysis under vacuum in 6 M HCl at 110 °C for 24 h. The hydrolysates were concentrated to dryness under a vacuum and dissolved in 100 µl of 0.2 M citrate buffer (pH 2.2), then the amino acids were determined with a SYKAM Co, S433 (Germany) amino acid analyzer.

Statistical analysis

Data were collected and analyzed with SAS statistical system Package (SAS 2008). General Linear Model (GLM) was used to test variations among different plumage color groups with the following model:

$$Y_{ijkl} = \mu + P_i + ß_j + (R_k)_j + e_{ijkl}$$

where Y_{ijkl} is the growth, carcass, meat quality and amino acid of quails, µ is the overall mean, P_i is the effect of ith quails with different plumage colour where i = 1, 2, 3, 4, $ß_j$ is the effect of jth batch where j = 1, 2, $(R_k)_j$ is the effect of kth replicates nested within Jth batches, where k = 1, 2, 3 and e_{ijkl} is the random residuals. Turkey's honest significant difference (HSD) was used for evaluating the significant differences among means. Graphical assessment of the residuals (normality plots) and Shapiro–Wilk tests were made to assess the normality assumption of the residuals. All of them showed compatibility with normality assumption with statistically non-significant results of Shapiro–Wilk tests.

Results

There was no significant difference among the quail chicks body weight of different plumages color at 1 day old. While, at the 6th week of age, the white quail had the highest body weight (205.16 g) and the brown quail had the lowest body weight (174.68 g). The white quail had the highest weight of slaughter and carcass, dressing percentage, carcass yield, weight of liver, gizzard, heart and spleen (197.27 g, 169.27 g, 91%, 82%, 6.63 g, 6.53 g, 2.27 g and 0.40 g, respectively) when compared with the other plumage colors (Table 2). There was a significant difference among quails of different plumage color on all meat quality parameters and amino acid profile. The white plumage quail has the highest Ph_U, lightness, yellowness and WHC with the lowest level of redness, cooking losses and thiobarbituric acid in pectoral (6.28, 46.40, 12,46, 22.17, 9.20, 19.21 and 0.44, respectively) and thigh muscles (6.37, 42.30, 11.51, 26.01, 10.12 and 0.93, respectively) (Table 3). Moreover, they possessed the highest level of all essential and non essential amino acids when compared with other plumage colors (Table 4).

Discussion

The key aim of the current research was to explore the difference on growth performance, carcass traits, meat quality and amino acid profile of variant Japanese quails strains. It is complicated to compare the growth, carcass and meat quality results with those stated in other studies, owing to a multiplicity of reasons including: the genetic features, environmental and managemental provisions, genetic selection, statistical analysis, feeding approach and slaughter age (Vali 2008).

There have been incompatible findings on the body weight difference among the quails with different plumage color. Whereas, a number of authors have established no difference (Mahmoud et al. 2014), others have found a significant difference (Genchev et al. 2008; Tarhyel et al. 2012). Our findings were in compliance with the greater part of studies that detected a significant difference on body weight of quails with different plumage color except at zero day. There was no significant difference of body weight at zero day among the quails of four different plumage color that supported the findings of Inci et al. (2015) who detected no significant variation of body weight among white, dark brown, golden and wild-type quails at zero days. The body weight of white quails were the highest when compared with the others which were comparable with Ojo et al. (2014) who found that the body weight of white plumage color quails surpassed the brown quails at 2 and 4 weeks of age. Moreover, Islam et al. (2014) reported that white quail was heavier at 5th week of age than black, brown and golden quails (2.82, 9.98 and 19.90%, respectively). Also, the albino quail (white) was heavier than the normal color (Tarhyel et al. 2012). This difference may be attributed to; (a) the recessive gene action which has a recessive depressive influence on quail

Table 2 The differences in growth performance and carcass traits among quails with different plumage colour

Variables	Quails with different plumage colour				RSD	*P* value
	White	Golden	Gray	Brown		
BW 0 day (g)	7.10	7.00	7.04	7.06	0.521	0.456
BW 2 weeks (g)	48.81^{a}	47.67^{b}	44.70^{c}	43.26^{d}	1.18	<0.001
BW 4 weeks (g)	193.56^{a}	187.79^{a}	179.90^{b}	161.66^{c}	29.05	<0.001
BW 6 weeks (g)	205.16^{a}	194.46^{b}	188.61^{b}	174.68^{c}	30.82	<0.001
Slaughter weight (g)*	197.27^{a}	185.02^{b}	178.93^{c}	164.47^{d}	4.67	<0.001
Carcass weight (g)	169.27^{a}	159.50^{b}	152.10^{c}	141.73^{d}	5.10	<0.001
Carcass yield (%)	82^{a}	82^{a}	81^{b}	81^{b}	7.69×10^{-3}	<0.001
Liver weight (g)	6.63^{a}	6.03^{b}	6.00^{b}	4.13^{c}	0.50	<0.001
Gizzard weight (g)	6.53^{a}	5.90^{b}	5.83^{b}	3.77^{c}	0.29	<0.001
Heart weight (g)	2.27^{a}	1.87^{b}	1.63^{c}	1.30^{d}	0.16	<0.001
Spleen weight (g)	0.40^{a}	0.37^{b}	0.33^{c}	0.10^{d}	0.06	<0.001

Means in the same row with a common superscript letter or without superscript letters did not differ significantly ($P > 0.05$) based on Tukey's honest significant difference (HSD)

RSD residual standard deviation

* Slaughter weight (g): the weight after bleeding

Table 3 The differences in meat quality among quails with different plumage color

Variables	Pectoral muscle				RSD	*P* value	Thigh muscle				RSD	*P* value
	Quails with different plumage colour						Quails with different plumage colour					
	White	Golden	Black	Brown			White	Golden	Black	Brown		
Ultimate Ph (Ph_u)	6.28^{a}	6.25^{b}	6.21^{c}	6.11^{d}	0.05	<0.001	6.37^{a}	6.24^{d}	6.33^{b}	6.31^{c}	0.04	<0.001
Lightness (L*)	46.40^{a}	45.90^{b}	45.20^{b}	44.23^{c}	0.04	<0.001	42.30^{a}	42.10^{b}	41.20^{c}	41.20^{c}	4.75×10^{-3}	<0.001
Redness (a*)	9.20^{c}	9.24^{b}	9.32^{a}	9.31^{a}	4.75×10^{-3}	<0.001	10.12^{d}	10.23^{b}	10.20^{c}	10.61^{a}	4.73×10^{-3}	<0.001
Yellowness (b*)	12.46^{a}	12.31^{c}	12.42^{b}	12.10^{d}	0.04	<0.001	11.51^{a}	11.42^{b}	11.26^{d}	11.29^{c}	0.05	<0.001
Cooking loss (%)	19.21^{d}	19.65^{b}	19.40^{c}	20.6^{a}	0.04	<0.001	24.41^{a}	20.91^{b}	24.20^{a}	19.21^{c}	4.75×10^{-3}	<0.001
WHC (%)	22.17^{a}	22.16^{a}	21.15^{b}	21.17^{b}	0.08	<0.001	26.01^{a}	21.01^{c}	25.04^{b}	20.03^{d}	4.72×10^{-3}	<0.001
TBARS	0.44^{c}	0.64^{b}	0.79^{a}	0.64^{b}	0.04	<0.001	0.93^{c}	0.98^{a}	0.95^{b}	0.92^{c}	0.04	<0.001

Means in the same row with a common superscript letter or without superscript letters did not differ significantly ($P > 0.05$) based on Tukey's honest significant difference (HSD)

RSD residual standard deviation, *WHC* water holding capacity, *TBARS* thiobarbituric acid reactive substances and expressed as mg of MDA per kg of muscle tissue

weight that was more obvious in black, golden and brown quails (Minvielle et al. 2007), (b) better feed conversion with lower mortality (Islam et al. 2014).

The carcass yields of the four different plumage color quails in the current study were within the range of 72–88.1% that reported by Kaye (2014). While, our results were higher than Caron et al. (1990), who reported that the quail carcass yield percentage was 67–70%. The carcass yield of Japanese quail is governed by slaughter age, strain, line and sex of quails (Genchev et al. 2008). The higher carcass yield of Japanese quails is an indicator for their eminent efficiency and their ability for meat production. In spite of the slaughter and carcass weight of white quail was the heaviest in the current study, but they were within the reported range of 163–195 and 140–169 g, respectively (Kaye 2014). The liver and gizzard weight of brown, black and golden quail were comparable to the range of 2.19–5.95 and 2.2–4.7 g, respectively that reported by Kaye (2014). The quail heart weight was ranged between 1.1 and 4.3 g (Kaye 2014) which supported our results. These findings may be attributed to the difference of body weight that affected the internal organs weight (Bacon and Nestor 1983).

Table 4 The differences in amino acid profile among quails with different plumage color

Variables	Pectoral muscle				RSD	*P* value	Thigh muscle				RSD	*P* value
	Quails with different plumage colour						Quails with different plumage colour					
	White	Golden	Black	Brown			White	Golden	Black	Brown		
Essential amino acids (g/100 g protein)												
Lysine	2.97^{a}	2.02^{c}	1.99^{c}	2.18^{b}	0.36	<0.001	1.99^{a}	1.95^{b}	1.95^{b}	1.99^{a}	0.08	0.005
Leucine	2.20^{a}	2.17^{a}	2.19^{a}	2.11^{b}	0.08	<0.001	1.96^{a}	1.91^{c}	1.93^{b}	1.93^{b}	5.90×10^{-3}	<0.001
Isoleucine	1.46^{a}	1.33^{b}	1.33^{b}	1.46^{a}	0.05	<0.001	1.38^{a}	1.23^{c}	1.26^{b}	1.25^{b}	0.04	<0.001
Threonine	1.04^{a}	0.91^{d}	1.03^{b}	0.99^{c}	7.15×10^{-3}	<0.001	0.99^{a}	0.97^{ab}	0.96^{c}	0.96^{c}	0.04	0.007
Phenylalanine	0.98^{a}	0.96^{b}	0.98^{a}	0.94^{c}	8.64×10^{-3}	<0.001	0.97^{a}	0.96^{b}	0.88^{d}	0.90^{c}	6.18×10^{-3}	<0.001
Valine	1.40^{a}	1.38^{a}	1.32^{b}	1.31^{b}	0.05	<0.001	1.30^{a}	1.24^{c}	1.29^{ab}	1.26^{bc}	0.08	<0.001
Tyrosine	0.69^{a}	0.63^{bc}	0.64^{b}	0.62^{c}	0.04	<0.001	0.67^{a}	0.61^{b}	0.60^{b}	0.66^{a}	0.06	<0.001
Methionine	0.70^{a}	0.52^{c}	0.52^{c}	0.67^{b}	0.06	<0.001	0.60^{a}	0.54^{b}	0.52^{c}	0.52^{c}	0.04	<0.001
Cystine	0.24^{a}	0.23^{b}	0.20^{d}	0.21^{c}	6.47×10^{-3}	<0.001	0.30^{a}	0.20^{c}	0.20^{c}	0.30^{a}	0.05	<0.001
Total essential amino acids	11.68^{a}	10.15^{c}	10.21^{c}	10.49^{b}	0.61	<0.001	10.16^{a}	9.61^{c}	9.59^{c}	9.77^{b}	0.35	<0.001
Non-essential amino acids (g/100 g protein)												
Serine	0.60^{a}	0.52^{b}	0.59^{a}	0.52^{b}	0.61	<0.001	0.60^{a}	0.52^{c}	0.56^{b}	0.52^{c}	0.06	<0.001
Aspartic acid	2.29^{a}	1.99^{c}	2.16^{b}	2.29^{a}	0.055	<0.001	2.05^{a}	2.01^{b}	2.01^{b}	2.01^{b}	7.90×10^{-3}	<0.001
Glutamine	4.29^{a}	4.28^{a}	4.22^{b}	3.96^{c}	0.06	<0.001	3.99^{a}	3.73^{b}	3.98^{a}	3.97^{a}	0.07	<0.001
Proline	0.98^{a}	0.81^{b}	0.71^{d}	0.76^{c}	0.05	<0.001	0.77^{a}	0.66^{c}	0.74^{b}	0.65^{c}	0.06	<0.001
Alanine	1.30^{a}	1.02^{d}	1.18^{b}	1.14^{c}	0.06	<0.001	1.42^{a}	1.18^{b}	1.18^{b}	0.99^{c}	0.06	<0.001
Arginine	1.49^{a}	1.48^{a}	1.48^{a}	1.34^{b}	0.06	<0.001	1.42^{a}	1.27^{d}	1.39^{b}	1.31^{c}	0.06	<0.001
Histidine	1.005^{a}	0.97^{d}	1.003^{a}	0.99^{c}	0.06	<0.001	0.99^{a}	0.96^{b}	0.98^{ab}	0.98^{ab}	0.08	0.047
Glysein	1.32^{a}	1.29^{b}	1.28^{b}	1.01^{c}	0.08	<0.001	1.30^{a}	1.12^{c}	1.10^{c}	1.20^{b}	0.05	<0.001
Total nonessential amino acids	13.27^{a}	12.37^{c}	12.62^{b}	12.02^{d}	0.33	<0.001	12.54^{a}	11.45^{d}	11.94^{b}	11.63^{c}	0.34	<0.001
Total protein content	24.95^{a}	22.52^{b}	22.82^{b}	22.51^{b}	0.04	<0.001	22.70^{a}	21.06^{c}	21.53^{b}	21.44^{b}	0.67	<0.001

Means in the same row with a common superscript letter or without superscript letters did not differ significantly ($P > 0.05$) based on Tukey's honest significant difference (HSD)

RSD residual standard deviation

Meat pH is considered the most important parameter that affects the poultry meat quality including tenderness, color, and storage life (Kaye 2014). The white quail has the highest Ph_U of meat when compared with the other genotypes, but all of them were within the reported range of 5.30–6.58 in quail (Genchev et al. 2008; Zerehdaran et al. 2012; Narinc et al. 2013). The meat of Japanese quail possessed the highest pH levels before and after rigor mortis (6.58 and 6.38, respectively) when compared with chickens, partridges and turkeys (Karakaya et al. 2005). The discrepancies in pH might be due to the difference in feeding pattern, muscle glycogen level (Tarasewicz et al. 2007), the level of post mortem anaerobic glycolysis (Ribarski and Genchev 2013) ante mortem stress, breed and the genetic dissimilarity within breeds (Terlouw 2005). Normally, the pHu of broiler chicken meat are 5.7–6.1 that do not show any quality hazards (Barbut 1997). While, pHu of quails meat are higher due to the muscle morphology. Actually, the chicken and turkey breast muscles are completely constructed of glycolytic fibers (white) (Bakalivanova 2007) that described by excessive glycogen and minimal creatine phosphate content. This deduces a further rapid depletion of muscle glycogen stores without opportunity for ATP resynthesis. While, in Japanese quails, the muscles are constructed of oxidative fibers (red) that have an immense store of creatine phosphate which provides the energy for re-production of ATP with the higher mitochondria level supplies oxygen for the aerobic glycolysis deceleration. Therefore, this type of muscles is

described with a slower progress of rigor mortis and consequently higher pH levels (Walasik et al. 2006).

Water holding capacity is noticeable to the customer when exploring packaging meat in the retail supplies. Customers distinguish fresh meat with free fluid or exudates around the products (poor WHC) (Karakaya et al. 2005). A growing number of studies have provided that the low meat pH levels reduce the WHC, tenderness quality (pale, soft and exudative) of meat and augment the cooking loss percentage (Barbut 1997). The water holding capacity of white quail meat was the highest when compared with the other plumage colors. But, the detected levels of the four different plumage colors are approximately similar to the results of Genchev et al. (2008) and Ribarski and Genchev (2013) (21.68–22.39 and 25.08–26.91 for breast and thigh muscle, respectively) and higher than that reported by Kaye (2014) (17.7–20.3). The cooking loss percentage in the current study is comparable with the reported range of 19.9–21.5% (Zerehdaran et al. 2012) and the lowest percentage was detected on white quail. While, others reported higher cooking losses percentages (13.74–34.23%, Narinc et al. 2013 and 27.3–31.1, Kaye 2014) than that reported in our study. Meat lipid oxidation is measured by the levels of fats and meats rancidity that are based mainly on the amount of poly unsaturated fatty acids (Gray et al. 1996). The oxidation is coupled with the development of rancid flavor, drip loss and a dietetic meat quality (Buckley et al. 1995). TBARS in the current study was lower in the white quails when compared with the other plumage colors, which reflected the better meat quality of white quails.

Meat color is an organoleptic parameter that may be directly assessed and signified the topographic region, species, freshness and tenderness of meat. It is the instant perceived by consumers when procuring meat (Fanatico et al. 2007). It depends on the heme pigments quantity (myoglobin), post mortem modifications, intramuscular fat quantity, color and dissemination. Meat color may be influenced by several factors; for instance breed, sex, age, feeding strategy, pre-slaughter condition, stunning, slaughter, temperature of scalding and cold storage technique (Fletcher 2002). The higher level of meat lightness (L*) denotes paleness with poor quality (Wattanachant et al. 2004), while the redness levels based mainly on myoglobin that present in muscle fibers.

There have been inconsistent findings on the impact of plumage color on the average meat L*, a* and b*. Some researchers were reported a range of L*48–61.54, a* 13.1–19.20 (Ribarski and Genchev 2013) and b* up to 19.81 (Boni et al. 2010). While, others were reported a lower range of L* 35.89–52.34 (Narinc et al. 2013; Kaye 2014), a* 5.1–14.4 (Kaye 2014) and b* 3.32–13.4 (Narinc et al. 2013; Ribarski and Genchev 2013) of different plumage colors quails. However, our findings are compliant with the studies that detected lower levels of meat color. Regarding the chicken breast meat color, the standard L* would be ranged from 46–53 (Barbut 1997; Zhang and Barbut 2005), consequently meats with L* levels lower than 46 are described to be dark (lower L* values), that means they have a high WHC. A growing number of studies reported that a* value of chicken breast meat ranged from 0.96 to 4.50, and b* levels from 6.7 to 13.5 (Narinc et al. 2013). Therefore, the quail is preferred for producing high meat quality, especially white ones, that supported the findings of Inci et al. (2015) who stated that white-feathered quails wete preferred for producing high quality meat (Inci et al. 2015). The morphological structure of quails meat is formed of a higher percentage of oxidative muscle fibers (red fibers rich in myosin) that affects positively on redness (a*), yellowness (b*) and reduced lightness (Genchev et al. 2010).

Quail meat is considered an outstanding food for human consumption due to its quality and quantity of vitamins, protein and fat contents that gives meat its juiciness and flavor (Gordillo 1998). Meat protein content is a decisive factor for assessing meat quality, particularly its essential amino acids contents. Based on the majority of dieticians, typically live non-trained human organism requires eight EAA (lysine, valine, leucine, isoleucine, threonine, tryptophan, methionine and phenylalanine) (Nedkov 2004). Quail meat is similar to the majority of fowl meat that considered an important resource of protein with great profile of amino acid. It is of high biological significance due to the proportion between nonessential and essential amino acids 1.35:1 (Nedkov 2004). The intake of two quails per day is equivalent to the consumption of 125–130 g pure meat, which affords a total of 27–28 g protein, consisting of 11 g EAA that is equal to 40% of human protein requirements (Nedkov 2004). Our results regarding the EAA percentage in protein of breast and thigh muscle (3.16–3.96, 5.83–6.49, 4.04–4.61, 5.61–6.13, 6.69–7.45, 8.82–9.64% for methionine + cysteine, isoleucine, threonine, valine, phenylalanine + tyrosine and leucine, respectively) are comparable to FAO/WHO consultants in 1973 (Ribarova et al. 1987) who reported that the standard protein should have the following percentages of EAA; 3.5, 4, 4, 5, 5.5, 6 and 7% of methionine + cysteine, isoleucine, threonine, valine, lysine, phenylalanine + tyrosine and leucine, respectively.

Total protein content in the current study were slightly higher than that reported by Genchev et al. (2008), who detected that the protein in quail breast and thigh (5 weeks old) was 22.23–23.38 g and 20.49–20.91 g, respectively. Moreover, the thigh muscles protein content was slightly lower than that the breast muscles which are supported by the finding of others (Caron et al. 1990). But, there was a

slight difference between the amino acid levels of breast and thigh muscles which is in agreement with Khalifa (1995). In spite of the amino acid profiles in quails of four different plumage colors are compatible with the values reported by Genchev et al. (2008), but the white quails had the highest levels. Khalifa (1995) stated that lysine and glutamic acid were the highest levels in EAA and none EAA of quails' meat, respectively while cysteine and methionine were the lowest levels, which is similar to our results. This study revealed that white quails were the heaviest body weight with the best carcass traits and meat quality which is on the contrary with Zerehdaran et al. (2012) who detected that selection for heavier body weight and carcass composition of Japanese quail may reduce the meat quality.

Conclusion

This study concluded that white quails possessed the heaviest body weight with the best carcass traits, meat quality and amino acid contents. Further investigation should be performed to explore the genetic makeup of these different plumage color quails to enable producers to select for the white color and maximize the production with better quality.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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