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Heritability and Genetic Correlations of Carcass and Meat Quality Traits in White and Brown Strains of Japanese Quail

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ABSTRACT

Successful breeding programs for Japanese quails rely on accurately estimating genetic parameters linked to economically important traits such as body weight, carcass characteristics, and meat quality. The objective of the present study was to evaluate body weight (BW) characteristics, carcass attributes, and their genetic correlations with select meat quality traits in two strains of Japanese quail (white and brown). A total of 530 quail chicks, with 265 from each strain, were included in the analysis. At six weeks of age, the quails were slaughtered, and carcass traits as well as amino acid profiles were measured. For BW traits, the heritability (h^2) estimates ranged from 0.27 at d 1 to 0.36 at d 42. The h^2 estimated for carcass traits ranged from 0.19 for liver weight, to 0.42 for carcass yield (CY). The h^2 estimated for drip loss (DL) of meat quality was 0.21, and the h^2 estimate was 0.35 for the meat's ultimate Ph (Phu). White quail quails recorded the heaviest weight of all carcass traits. Also, white quails had the highest water-holding capacity (WHC), yellowness (b*), and lightness (L*) with the lowest level of DL, cooking losses (CL), and redness (a*) in muscles compared with brown quails. A high genetic correlation of 0.32 was noted between CW carcass weight (CW) and b*. For the pHU, a negative correlation of -0.11 was exhibited with BW. In contrast, L* appeared to have a positive but smaller relationship with CW and CY. High negative correlations were noted for b* with CY -0.27. The CW showed a moderate relationship (0.19) with CL. In conclusion, the current study revealed that the white quail strain had high BW, as well as the finest carcass traits and meat quality. Therefore, white plumage Japanese quail might be preferred as a meat-producing strain.

Keywords: Amino acid, Carcass, Genetic correlation, Meat quality, Heritability, Quail

INTRODUCTION

The primary goal for poultry producers is to maximize the genetic improvement of the productive traits of chicks (Saghi et al., 2022). Among poultry species, Japanese quails are recognized for their exceptional productivity, particularly in terms of meat and egg production (Minvielle, 2004; El-Attrouny et al., 2020).

Additionally, Japanese quail can be used as animal models in breeding programmed for some attributes, such as lower feed intake, small body size, early maturation, quick life cycle, elevated reproductive efficiency, strong disease resistance, and low production costs (Minvielle, 2004; Narinc et al., 2009; 2013; Molino et al., 2015; Saghi et al., 2022).

Meat consumers have shown a global interest in Japanese quail meat, an ideal protein source for humans due to the quality and quantity of the essential amino acid contents, which are critical in evaluating meat quality (Sabow, 2020).

Compared with other poultry species, Japanese quail meat has low lipid content with a high proportion of unsaturated fatty acids, with beneficial effects on human health as atherosclerotic preventatives (Nasr et al., 2017) compared with those of white meat including broiler chicken (Ioniță et al., 2011) and red meat (Boni et al., 2010). Genchev et al. (2008) demonstrated that consuming two quails per day can supply around 40% of the daily protein requirements for humans, equating to approximately 11 grams of essential amino acids. This amount is comparable to consuming 125-130 grams of red

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meat. Therefore, Japanese quail meat offers a cost-effective and valuable source of animal protein (Vali, 2008), hence it can be considered as a cheaper alternative for chicken meat, especially in developing countries.

To develop a breeding program aimed at enhancing carcass traits in Japanese quail, it is essential to estimate the genetic parameters of body weight, carcass characteristics, and meat quality traits. This forms the foundation for determining the potential for direct selection of these traits (Lotfi et al., 2011; El-Attrouny et al., 2021). Selection has primarily led to improvements in traits with high heritability such as body weight and carcass traits (Khaldari et al., 2010; Zerehdaran et al., 2012). However, a previous study by Narinc et al. (2013) showed that, despite the successful selection for increased carcass yield, the impact on meat quality remains unclarified.

Selection for growth rate, as an important economic trait, could lead to various changes in the meat quality of broiler chickens (Chomchuen et al., 2022). Meat quality is a crucial factor for the poultry industry, as alterations in meat quality could result in a significant economic loss.

Determining the genetic correlations between meat quality traits and other traits is crucial for identifying the direction and magnitude of changes in meat quality before selecting for growth and carcass traits. However, this approach is not well recognized for Japanese quail, as measuring these traits follows a complex process and involves sacrificing a large number of chicks (Le Bihan-Duval et al., 2003; 2008). Thus, the main objectives of the current study were to estimate the heritability and the genetic correlation coefficients between body weight (BW), carcass traits, and meat quality traits, which can be used as a selection criterion in breeding programs of Japanese quail and explore the differences in growth performance, carcass traits and meat quality of two different strains of Japanese quail.

MATERIALS AND METHODS

Animal welfare and ethical approval

The study was carried out at the Poultry Research Facility of the Faculty of Agriculture, Benha University, Egypt, and received approval from the Scientific Ethics Committee of the Animal Production Department, Faculty of Agriculture, Benha University, Egypt (BUAPD-20212).

Housing

In the current study, data were collected from 530 Japanese quail chicks (*Coturnix coturnix japonica*) of two distinct plumage colors, including 265 white and 265 brown. These chicks were obtained from 140 sires and 280 dams. The experiment began in May 2023 and lasted for two months. Each strain of quail, consisting of 265 quails, was sourced from 140 sires and 280 dams. Breeding pairs were housed in individual breeding cages (25 × 35 × 40 cm^2), with one selected male and two females per cage. The practice of housing one male with two females in a breeding cage was common in poultry breeding, including quail, to ensure efficient reproduction and maximize egg production (Shanaway, 1994). The cages had sloped floors to facilitate the collection of pedigreed eggs. Once the eggs were collected, each egg was labeled with the sire and dam's identification. Dams were distinguished by a specific eggshell color pattern within each cage.

After hatching, the chicks were housed in brooding cages at a density of 10 in 10 cm around 100 cm² per quail, and they were wing-banded after hatching. The temperature in brooding cages was not fixed because chicks require different thermal environments as they grow. Therefore temperature was initially set at 35°C using electric heaters for the first five days to maintain body warmth due to their inability to regulate temperature. Their ability to control body temperature improved as they developed, so the temperature was gradually reduced to 32°C, 29°C, and 26°C during the first, second, and third weeks, respectively, to prevent overheating and encourage proper growth. From the fourth week onward, the temperature was maintained between 20°C and 22°C for the remainder of the experiment as the chicks were capable of thermoregulation.

Following the brooding period, the quails were transferred to grower cages, with a density of 150 cm² per quail (Shanaway, 1994). Throughout the experiment, the quail had unlimited access to feed and water, and the lighting remained on for 24 hours a day. All quails were fed the same basal diet following recommendations from the Nutrient Requirements of Poultry by the National Research Council (NRC, 1994; as outlined in Table 1).

Table 1. Ingredient, composition, and calculated chemical analysis of the basal diets for growing quails

Ingredients	g/kg DM of Feed
Yellow corn	556.0
Soybean meal (44%CP)	288.0
Corn gluten meal (60% CP)	105.0
Vita. and Min. mix.[†]	3.0
DL-Methionine	1.0
L-lysine	4.0
Wheat bran	20.0
Limestone	19.0
Salt (NaCl)	4.0
Calculated chemical composition (%)	
ME (kcal/kg)	2902.4
CF	3.87
CP	24.01
Na	0.17
Ca	0.82
Available phosphorus	0.41
Methionine	0.56
Lysine	1.39

† Vitamin and trace mineral mixture: Composition per 3 kg. Vit. A 12.000.000 I.U.; Vit. D3 2.000.000 I.U.; Vit. E 10.000 mg; Vit. K3 1000 mg; Vit. B1 1000 mg; Vit. B2 5000 mg; Vit. B6 1500 mg; Vit. B12 10 mg; Niacin 30,000 mg; Biotin 50 mg;

Folic acid 1000 mg; Pantothenic acid 10.000 mg; Choline chloride 500.000 mg; Zinc 50,000 mg; Manganese 60,000 mg; Iron 30,000 mg; Copper 10,000 mg; Iodine 1000 mg; Selenium 100 mg; Cobalt 100 mg; Calcium carbonate to 3 kg.

Body weight, carcass traits, and meat quality

Body weight (BW) was recorded individually at hatch, 3, and 6 weeks of age, namely BW0, BW3, and BW6. Also, BW gain (BWG) was calculated during the period from 3 to 6 weeks of age (WG 3-6). At 6 weeks of age, the feed was withdrawn for 7 h, quails (n = 120) were slaughtered and then weighed after bleeding (slaughter weight (SLW), empty carcass (including the skeletal structure and muscle tissue). The heart, liver, and gizzard were carefully removed, cleaned of any excess fat and moisture, and weighed individually using a digital scale with a precision of ± 0.01 g, then according to Inci et al. (2015), the carcass was kept at 2-4 ^{o}C for 24 h for further analyses. Carcass yield (CY) was determined as a correlation between carcass weight and live body weight.

The pectoral and thigh muscles were extracted from the chilled carcass to assess the physical meat quality, which included ultimate pH (pHu), redness (a*), yellowness (b*), lightness (L*), drip loss (DL), water holding capacity (WHC), and cooking loss (CL) as per Nasr et al. (2017). The ultimate pH (pHu) was measured following the method described by Korkeala et al. (1986). In brief, 24 hours after chilling, 1 gram of both breast muscle (PM) and thigh muscle (TM) was homogenized with 10 ml of 5 mM iodoacetate for 30 seconds using a Knick digital pH meter (Broadly Corp., Santa Ana, CA, USA). Muscle color was evaluated using a colorimeter (Lovibond CAM-system 500) with the CIE a* b* L* system, where a* denotes redness, b* indicates yellowness, and L* represents lightness. Cooking loss was measured by placing 25 g of muscle in aluminum pans and cooking them in a preheated electric oven at 200°C for 15 minutes until an internal temperature of 70°C was reached, as described by Cyril et al. (1996).

Water-holding capacity was assessed following the method outlined by Bouton et al. (1971). A muscle sample weighing 3-4 grams was centrifuged at 10,000 g for 30 minutes in a stainless-steel tube. The released juice was quickly decanted to prevent reabsorption by the meat. The muscle sample was then removed, blotted dry with tissue paper, and reweighed to calculate the amount of liquid loss. To measure thawing and cooking losses, the breast muscle was thawed overnight at 4°C, cooked in a water bath at 85°C for 15 minutes until the internal temperature reached 70°C, and then cooled in crushed ice for 20 minutes. Thawing and cooking loss was calculated as a percentage of the initial fresh muscle weight

Chilled pectoral muscle PM without fat was used to estimate the amino acid profile after acid hydrolysis under vacuum in 6 molars HCl at 110 ^{o}C for 24 h. Chemical analysis of muscle amino acid profiles was assessed using High-performance liquid chromatography (HPLC; Agilent HP 1200 series; USA). The utilized analytical column was Supelcosil C18 (5 µm particle and 80 Ao pore size). Samples and amino acid standards (Purchased from Thermo Fisher Scientific) were injected into the Supelcosil C18 column with 5 µm particle size and 80 Å pore size for separation by HPLC. Amino acid contents in the breast muscle were determined as described by Salah et al. (2019).

Statistical analysis

Descriptive statistics of the productive traits (growth traits, carcass characteristics, meat quality, and amino acid profile) were calculated using the univariate procedure of the SAS software (version 9.4, 2004, SAS Institute). Differences were considered significant at $P \leq 0.05$ and significant differences between means were tested by Duncan's multiple range test (Duncan, 1955). The following model was used:

$Y_{ij} = \mu + P_i + e_{ij}$

Where Y_{ij} = is the observation of the jth trait on the ith quail strain, µ = is the overall mean, P = is the fixed effect of the ith quail strain (with different plumage color, 1 and 2) and e_{ij} = is the residual random effect.

Data on growth traits, carcass characteristics, and meat quality were analyzed using the following multi-trait animal model:

$y = Xb + Z_a u_a + e$

where, y= the vector of observing all traits, b = the vector of fixed effects of strain (two levels), Ua = a vector of random additive genetic effects for each bird in the pedigree, X and Z_a are incidence matrices corresponding to fixed and additive random effects of the chicks, respectively, e is a vector of random residual effects. The VCE6 software was used to estimate the variance components of random effects, heritabilities, and genetic correlations among all combinations of traits (Groeneveld, 2010).

RESULTS AND DISCUSSION

The descriptive statistics, including the mean, standard deviation, and coefficient of variation, along with the minimum and maximum values for the analyzed traits, were summarized in Table 2. All traits were normally distributed. The average of BW was 7.38 g, 108.6 g, and

207.3 g at 0, 3, and 6 weeks of age, respectively. The average BWG in Japanese quail was 98.3 g during the intervals from 3 to 6 weeks of age (Table 2). The values of BW and BWG were similar to those of Zerehdaran et al. (2012), and Nasr et al. (2017), and higher than those of Oguz et al. (2004). Minvielle (2004) reported that BW for Japanese quail may differ among flocks.

The carcass yield, which was an important economic trait, was determined to be 81.4% of BW (Table 2). The average values for carcass traits (Table 2) were consistent with those reported in the literature, with slaughter weight (SLW) ranging from 163 to 195 g, carcass weight (CW) from 140 to 170 g, and carcass yield from 69 to 81% (Kaye, 2014; Nasr et al., 2017). In contrast, the current results were higher than those of Caron et al. (1990) and Zerehdaran et al. (2012), who revealed that the carcass yield CY was 60-70% of BW. The liver (5.62g) and gizzard (5.29g) weights of quail chicks in the present study were within the range reported in the literature of liver (2.19-5.95 g) and gizzard (2.2-4.7 g; Kaye 2014; Shafik et al., 2022). Kaye (2014) found that the weight of a quail's heart ranged from 1.1 to 4.3 grams, which was consistent with the findings of this study. In this study, the average ultimate pHU of breast meat was 6.14, which was comparable to the values reported by Karakaya et al. (2005) and Genchev et al. (2008), who found pHU levels of 6.17 and 6.38, respectively.). However, Remignon et al., (1998) and Gevrekci et al. (2009) reported lower values of pH_U in quail meat 5.59 and 5.94, respectively, than those reported in the present study. Generally, for broiler chicken meats, the normal pH_U that does not exhibit any quality problems ranges between 5.7 and 6.1 (Barbut, 1997; Zhang and Barbut, 2005).

The current study reported an average value of 47.53, 7.49, and 9.25 for L*, a*, and b*, respectively, for Japanese quail meat are presented in Table 2. Oguz et al. (2004) showed that the means of L*, a*, and b* were 54.92, 9.70, and 5.59, respectively. Similarly, Gevrekci et al. (2009) revealed that the average L*, a*, and b* values of breast meat were 54.87, 9.68, and 3.23, respectively. In a study on Japanese quail by Narinc et al. (2013), the authors determined the breast meat parameters of L*, a*, and b* to be 43.09, 19.24, and 7.74, respectively. Zerehdaran et al. (2012) presented values of 53.88 (L*), 5.52 (a*), and -1.69 (b*) for Japanese quail's breast meat at 42 d of age. Based on the literature review for the meat quality of broiler chicken, the optimum L* ranges between 46 and 53 (Zhang and Barbut, 2005). Meats with an L* value below 46 tend to have a darker color, are firmer, and drier, exhibit high water-holding capacity (WHC), and have a shorter shelf life. The a* and b* values for broiler chicken breast meat typically range from -0.96 to 4.50 for a* and from 6.7 to 13.5 for b*, according to studies by Fletcher et al. (2000), and Le Bihan-Duval et al. (2001; 2008). Higher a* values, ranging between 7.5 and 11, were observed in the breast meat of native chicken breeds (Yue et al., 2010; Jiang et al., 2011).

Table 2. Descriptive statistics and heritability estimate for body weight, carcass traits, and meat quality of two quail strains

Trait	Mean	SD	CV%	Minimum	Maximum	$h^2 \pm SE$
Body weight and gain						
BW at hatch	7.38	1.11	15.04	5.14	11.21	0.23 ± 0.03
BW at 3 weeks	108.6	8.65	7.96	51	132	0.27 ± 0.04
BW at 6 weeks	207.3	35.8	17.26	143	254	0.36 ± 0 .04
Weight gain from 3 to 6 weeks	98.3	6.2	6.30	64	145	0.31 ± 0.05
Carcass traits						
Slaughter weight (g)	198.5	22.3	11.23	170.2	250.6	0.34 ± 0.06
Carcass weight (g)	167.6	16.4	9.78	134.2	1985.1	0.38 ± 0.06
Carcass yield (%)	81.4	7.3	8.96	72.4	86.5	0.42 ± 0.05
Liver weight (g)	5.62	0.52	9.25	4.6	6.8	0.19 ± 0.02
Gizzard weight (g)	5.29	0.25	4.72	4.11	7.3	0.27 ± 0.03
Heart weight (g)	1.97	0.15	7.61	0.98	2.25	0.24 ± 0.03
Meat quality						
Ultimate Ph (Phu)	6.14	0.92	14.8	5.01	7.12	0.35 ± 0.04
Water Holding Capacity (%)	25.55	3.21	12.56	25.3	48.7	0.29 ± 0.04
Cooking loss%	24.20	2.44	10.08	14.3	35.4	0.27 ± 0.03
Drip loss (%)	3.21	0.34	10.59	1.74	5.11	0.21 ± 0.02
Lightness (L*)	47.53	3.51	7.38	34.4	56.6	0.32 ± 0.04
Redness (a*)	7.49	0.52	6.94	4.21	15.6	0.28 ± 0.05

Yellowness (b*)	9.25	0.86	9.29	8.60	12.5	0.33 ± 0.04

SD: Standard deviation; CV: Coefficient of variation

Genetic parameters

Heritability (h^2) estimates for all studied traits are presented in Table 2. The h^2 estimates for BW ranged from 0.23 to 0.36 at BW0 and BW6, respectively, while for meat quality traits h^2 estimates were 0.21 for DL and 0.35 for Phu.

The current h^2 estimates for body weight (BW) align with findings from previous studies on Japanese quail (Saatci et al., 2006; Khaldari et al., 2010; Narinc et al., 2010). Additionally, several researchers have reported high h^2 estimates for BW in Japanese quail (Oguz et al., 2004; Narinc et al., 2010; 2013). The h^2 estimates of carcass traits reported in Table 2 were moderate to high ranging from 0.19 (LW) to 0.42 (CY). A high h^2 estimated of 0.38, and 0.42 for CW and CY, respectively was reported in the current study. However, many researchers reported low heritability estimates ranging from 0.12 to 0.19 for CY in quail (Vali et al., 2005; Narinc et al. 2010; Lotfi et al. 2011). The current results agreed with those reported by Daikwo et al. (2013) who revealed that the heritability of CW was 0.42. Estimated h^2 for liver, gizzard, and heart weight were presented in Table 2. The h^2 estimates for liver, gizzard, and heart weight were 0.19, 0.27, and 0.24, respectively, which were similar to those (0.11 and 0.27) reported by Daikwo et al. (2013), but diverged from those found by de Gaya et al. (2006).

Based on the findings of the current study, pH_U was considered the highest heritable trait (0.35). Oguz et al. (2004) presented a high h^2 estimate (0.48) for pH_U. Gevrekci et al. (2009) reported a moderate h^2 estimate of 0.24 for pH_U. In broiler chicken, the pH_U was considered highly heritable as the estimates range between 0.34 and 0.49 Le Bihan-Duval et al. (2001; 2008). However, for commercial turkey lines, low heritability estimates for pH_U in the breast muscle ranging from 0.12 to 0.21 were reported by Le Bihan-Duval et al. (2003).

Meat pH plays a key role in determining the color of poultry meat. According to Fletcher (1999), muscle pH was primarily influenced by the biochemical condition of the muscle at the time of slaughter. As a result, pHu and L* values showed stronger direct additive genetic effects compared to other traits studied. This suggests that these traits may respond well to selection, as their expression was largely driven by additive genetic factors.

The h^2 estimated for water-holding capacity (WHC) was 0.29, closely matching the findings of Rance et al. (2002). However, the h^2 estimates for cooking loss, at 0.31 and 0.35, differed from those reported by Zerehdaran et al. (2012) and Le Bihan-Duval et al. (2008). In terms of cooking loss and drip loss, the h^2 estimates of 0.27 and 0.21, respectively, were higher than those observed in broilers for these traits, as noted by de Gaya et al. (2011).

Table 2 showed that the h^2 estimates for breast meat color traits, including L*, a*, and b*, were 0.32, 0.28, and 0.33, respectively. Oguz et al. (2004) and Gevrekci et al. (2009) reported h2 estimates for L*, a*, and b* at 0.23 and 0.24, 0.45 and 0.35, and 0.22 and 0.15, respectively. Additionally, Le Bihan-Duval et al. (2001; 2008) demonstrated that breast meat color traits were notably heritable, with h^2 values ranging from 0.25 to 0.81 in broiler chickens. These estimates indicated that heritability for meat quality traits ranges from moderate to high, emphasizing the significance of genetic selection in improving meat quality traits in Japanese quail, particularly L*, which was the primary determinant of meat color in this species

Least square means

Table 3 shows the BW of the two Japanese quail strains. Noticeable significant variations were noticed ($p < 0.05$) between the means of BW and BWG of the two Japanese quail strains. The white quail had the highest BW (226.7 g) compared to that of the brown quail (195.2 g) at 6 weeks of age.

On the contrary, Inci et al. (2015) reported that the BW did not vary between different quail strains on the first day of post-hatch. White plumage Japanese quail showed the highest BW compared with the brown strain. Ojo et al. (2014) revealed that the BW of white quails was higher than of brown plumage quails at weeks 2 and 4 of age. Islam et al. (2014) also reported that the white plumage strain of quail had a greater body weight (BW) at 5 weeks of age compared to the brown strain. These differences may be attributed to two factors involved firstly, the effect of recessive gene action, which tends to have a depressive impact on BW, particularly in black and brown quails (Minvielle et al., 2007); and secondly, the enhanced feed conversion efficiency and reduced mortality rate observed in the white strain (Islam et al., 2014). However, inconsistent findings have been reported in the literature on the variations of BW among Japanese quails with different plumage colors. Several studies reported significant differences (Genchev et al., 2008), while some studies showed no differences (Mahmoud et al., 2014). The present results were consistent with studies that demonstrated significant differences in the body weight of quails with varying plumage colors, except on the first day of age.

Table 3. The Least squares mean (± Standard error) of body weight, carcass traits, and meat quality in two quail strains

Trait \ Quails with different plumage color	White	Brown	p-value
Body weight (g)			
BW at 0 week	7.40 ± 0.78	7.30 ± 0.78	0.320
BW at 3 weeks	119.4 ± 3.56[a]	101.3 ± 3.21[b]	0.001
BW at 6 weeks	226.7 ± 5.31[a]	195.2 ± 4.62[b]	0.001
Weight gain from 3 to 6 weeks	105.4 ± 3.1[a]	92.6 ± 2.32[b]	0.001
Carcass traits (g)			
Slaughter weight	218 ± 6.52[a]	187 ± 6.52[b]	0.001
Carcass weight	180 ± 4.69[a]	151 ± 4.69[b]	0.001
Liver weight	6.10 ± 0.75[a]	5.62 ± 0.75[b]	0.001
Gizzard weight	5.72 ± 0.64[a]	4.96 ± 0.64[b]	0.001
Heart weight	2.32 ± 0.21[a]	1.86 ± 0.21[b]	0.001
Carcass yield (%)	82.3 ± 3.84[a]	81.4 ± 3.84[b]	0.015
Meat quality			
Ultimate pH	6.22 ± 0.59	6.10 ± 0.59	0.081
WHC (%)	26.21 ± 2.23[a]	25.14 ± 2.23[b]	0.041
Drip loss (%)	2.12 ± 0.21[b]	2.30 ± 0.21[a]	0.031
Cooking loss (%)	23.74 ± 2.59[b]	24.62 ± 2.59[a]	0.013
Lightness (L*)	48.20 ± 5.63[a]	46.61 ± 5.63[b]	0.001
Redness (a*)	7.38 ± 0.63[b]	7.74 ± 0.63[a]	0.001
Yellowness (b*)	9.40 ± 0.91[a]	9.17 ± 0.91[b]	0.021

[a,b] Means in the same row with different superscript letters are significantly different at $p < 0.05$

Table 3 presents the carcass traits of the two different quail strains. High Significant differences ($p < 0.05$) were shown between the means of the two strains of quails for traits of slaughter weight, carcass weight, carcass yield, liver, gizzard, and heart weight. The white plumage quails recorded the highest slaughter and carcass weights, liver, gizzard, heart, and carcass yield, compared with those of the brown plumage quails (Table 3). This variation between the two strains could be related to the variance in BW at slaughter, which was influenced by intrinsic factors such as genotype. Nasr et al. (2017) described that carcass traits varied between Japanese quail strains. Inci et al. (2015) revealed that carcass characteristics were significantly affected by the feather colors of Japanese quails. In the current study, white quail recorded the heaviest slaughter and carcass weights (218 and 180 g, respectively), which was out of the range of those reported by Kaye (2014) and Sabow (2020).

The CY of Japanese quail was influenced by several factors such as strain, line, gender, and slaughter age of chicks (Genchev et al., 2008). A higher CY of Japanese quail was indicative of their exceptional efficiency capacity for meat production. Kaye (2014) reported that the percentages of CY ranged between 72-88.1%, which agrees with those reported in the current study for white (82.3%) and brown (81.4%) quails. However, Caron et al. (1990) presented lower values of CY percentage (67–70%) for Japanese quail, compared to those reported in the current study. In general, means of liver, gizzard, and heart weights in white (6.10, 5.72, and 2.32 g) and brown (5.62, 4.96, and 1.86 g) quails were higher than the range of 2.19-6.63, 2.2-5.53 g and 1.1 and 4.3 g, respectively, reported by Kaye (2014) and Nasr et al. (2017). These findings could be related to the variation of BW, which affects the internal organs weight (Kanlisi et al., 2024). The current study revealed a significant difference in all meat quality estimates between Japanese quail with different plumage colors. The white quail strain had the highest Ph_U, WHC, L*, and b* with the lowest level of DL, CL, and a* compared to the brown quail strain (Table 3). The Ph_U of meat for both white and brown quail strains fell within the reported range of 5.30-6.58 for Japanese quail (Genchev et al., 2008; Narinc et al., 2013; Sabow, 2020).

Barbut (1997) noted that a decrease in meat pH levels leads to reduced water-holding capacity (WHC) and tenderness, causing the meat to become pale, soft, and exudative, and it increases the percentage of cooking loss. In the present study, the meat from white plumage quails demonstrated a higher WHC compared to that of brown plumage quails. However, the detected levels of both strains were approximately similar to those levels for breast muscles (21.68-22.39) and thigh muscles (25.08-26.91) reported by Genchev et al. (2008), Ribarski and Genchev (2013) and higher than the levels (17.7-20.3) reported by Kaye (2014). The present study showed that the CL percentage was within the range (19.9-21.5%) reported in the literature (Zerehdaran et al., 2012), with the lowest CL percentage observed for white plumage quail strain. In contrast, other studies reported higher CL percentages ranging from 13.7 to 34.2% (Narinc et al., 2013) and 27.3 to 31.1% (Kaye, 2014) compared to the findings reported in this study. The present study showed Japanese quail strain has a significant influence on drip loss, where the white plumage quail strain recorded the lowest drip loss compared with the brown plumage strain, hence better meat quality for the white quail strain.

Amino acid profile

The content of protein and amino acids profile of breast muscle meat from both Japanese quail strains was illustrated in Table 4.

The total protein content of Japanese quail breast meat revealed highly significant differences ($p < 0.05$) based on the strain. In this study, the total protein content observed was slightly higher than the values reported by Genchev et al. (2008), who found protein levels of 22.23 g in quail breast. Additionally, the amino acid profiles of both Japanese quail strains closely resembled those reported by Genchev et al. (2008), with the white plumage quail displaying the highest amino acid levels. The current study showed that lysine and glutamic acid levels were the highest, while threonine and methionine levels were the lowest. These findings agree with those reported by Nasr et al. (2017) and Sabow (2020). The current study showed that white plumage quail exhibited the heaviest BW and superior carcass traits and meat quality. These findings contrast with the findings of Zerehdaran et al. (2012) who revealed that selecting Japanese quail for heavier BW and better carcass composition could decrease the meat quality.

Table 4. Total protein and amino acid profile of breast and thigh muscle in two quail strains

Trait \ Quails with different plumage color	White	Brown	MSE	p-value
Indispensable amino acids (g/100 g protein)				
Lysine	2.41[a]	2.16[b]	0.18	0.001
Leucine	2.12[a]	2.04[b]	0.19	0.021
Isoleucine	1.77[a]	1.39[b]	0.05	0.011
Valine	1.27[a]	1.18[b]	0.05	0.001
Threonine	1.11[a]	0.93[b]	0.04	0.024
Methionine	0.84[a]	0.63[b]	0.03	0.025
Phenylalanine	1.13[a]	0.88[b]	0.07	0.001
Total	10.65[a]	9.21[b]	1.25	0.012
Dispensable amino acids (g/100 g protein)				
Glycine	1.15[a]	0.95[b]	0.04	0.001
Tyrosine	2.42[a]	2.13[b]	0.08	0.032
Serine	1.32[a]	1.19[b]	0.05	0.001
Aspartic	2.18[a]	1.89[b]	0.07	0.021
Glutamic	3.37[a]	3.04[b]	0.31	0.001
Alanine	1.17	1.08	0.08	0.031
Arginine	1.61[a]	1.47[b]	0.06	0.001
Total	13.22[a]	11.75[b]	2.10	0.021

[a, b] Means in the same row with different superscript letters are significantly different at $p < 0.05$. MSE: Mean standard error.

Genetic correlations

Table 5 displayed the genetic correlation (rg) estimates between body weight (BW) and various carcass traits concerning meat quality traits. Generally, these correlations were low. Specifically, rg estimates between BW and carcass traits with pHu and water-holding capacity (WHC) ranged from -0.05 (for HW) to 0.15 (for

CW), showing both positive and negative correlations. Notably, low genetic correlation was observed between WHC and BW or carcass traits, suggesting that WHC might be lower in quails with higher carcass and breast yields, as noted by Van Laack et al. (2000) and Le Bihan-Duval et al. (2001).

Low positive genetic correlation estimates were discovered between drip loss with BW, CW, and CY (0.04, 0.07 and 0.17). Color parameters exhibited both negative and positive genetic correlations with body weight (BW) and carcass traits, with rg values ranging from -0.02 to 0.32. Berri et al. (2001) reported that selecting broilers for increased breast meat yield was linked to lower ultimate pH and reduced drip loss, The same researchers, along with Zerehdaran et al. (2012), observed that there was generally a low or negative genetic correlation between BW and color parameters, although a strong association was found between BW and the L* value (Le Bihan-Duval et al., 2001; 2003).

Table 5. Estimates of genetic correlations among body weight and carcass traits with meat quality traits in two quail strains

Trait	PHu	WHC	DL	CL	L*	a*	b*
BW6	-0.11(0.02)	-0.24(0.10)	0.04(0.02)	-0.08(0.01)	-0.06(0.02)	-0.04(0.02)	-0.24(0.04)
CW	0.08(0.01)	0.15(0.09)	0.07(0.01)	0.19(0.07)	0.10(0.03)	0.09 (0.02)	0.32(0.09)
CY	0.04(0.03)	0.11(0.06)	0.17(0.06)	-0.17(0.02)	-0.08(0.02)	0.14 (0.06)	-0.27 (0.05)
LW	-0.09(0.03)	-0.15(0.08)	-0.10(0.04)	-0.31(0.11)	0.17(0.06)	-0.02(0.01)	0.06(0.02)
GIZ	-0.05(0.06)	-0.32(0.11)	-0.09(0.03)	-0.20(0.07)	-0.17(0.08)	-0.18(0.03)	-0.12(0.08)
HW	-0.19(0.02)	0.06(0.01)	-0.21(0.02)	-0.19(0.08)	-0.11(0.05)	0.09 (0.03)	-0.30(0.03)

BW6: Body weight at 6 wks, CW: Carcass weight, CY: Carcass yield, LW: Liver weight, GIZ: Gizzard weight, HW: Heart weight, pHu: Ph Ultimate, WHC: Water Holding Capacity (%), DL: Drip loss (%), CL: Cooking loss, L*: Lightness, a*: Redness, b*: Yellowness.

CONCLUSION

White quails exhibited the heaviest body weight and the best carcass traits. Carcass and meat quality traits of Japanese quail were highly heritable, indicating that these traits could have been enhanced through genetic selection. Moreover, selecting for higher body weight and carcass traits in Japanese quail may have negatively impacted meat quality by reducing redness and ultimate pH, while increasing lightness, cooking loss, and yellowness of the meat. Therefore, it was essential to consider meat quality traits alongside performance traits in the selection index to preserve high-quality meat products in Japanese quail.

DECLARATION

Competing interests

The authors declare that they have no conflicts of interest.

Availability of data and materials

The data that support the findings of this study are available from the authors upon reasonable request from the corresponding author.

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Ethical considerations

The authors have avoided plagiarism, misconduct, data fabrication/falsification, and double submission/publication and have given consent to publish this article.

Authors` contributions

Mahmoud. M. El-Attrouny and Mahmoud. M. Iraqi designed the research project. Mahmoud. M. El-Attrouny and Mahmoud. M. Iraqi experimented and collected data. Mahmoud. M. El-Attrouny and Farid. S. Nassar analyzed the data and interpreted the results. Mahmoud. M. El-Attrouny and Farid. S. Nassar wrote the initial manuscript. The authors revised the manuscript together and prepared the last edition for submission and publication.

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REFERENCES

Barbut S (1997). Problem of pale soft exudative meat in broiler chickens. British Poultry Science, 38(4): 355-358. DOI: https://www.doi.org/10.1080/00071669708418002

Berri C, Wacrenier N, Millet N, and Le Bihan-Duval E (2001). Effect of selection for improved body composition on muscle and meat characteristics of broilers from experimental and commercial lines. Poultry Science, 80(7): 833-838. DOI: https://www.doi.org/10.1093/ps/80.7.833

Boni I, Nurul H, and Noryati I (2010). Comparison of meat quality characteristics between young and spent quails. International Food Research Journal, 17: 661-667. Available at: http://www.ifrj.upm.edu.my/17%20%2803%29%202010/IFRJ-2010-661-666%20Nurul%20Malaysia.pdf

Bouton PE, Harris PV, and Shorthose WR (1971) Effect of ultimate pH upon the water-holding capacity and tenderness of mutton. Journal of Food Science, 36: 435-439. DOI: https://www.doi.org/10.1111/j.1365-2621.1971.tb06382.x

Caron N, Minvielle F, Desmarais M, and Poste LM (1990) Mass selection for 45-day body weight in Japanese quail: Selection response, carcass composition, cooking properties, and sensory characteristics. Poultry Science, 69: 1037-1045. DOI: https://www.doi.org/10.3382/ps.0691037

Chomchuen K, Tuntiyasawasdikul V, Chankitisakul V, and Boonkum W (2022). Genetic evaluation of body weights and egg production traits using a multi-trait animal model and selection index in Thai native synthetic chickens (Kaimook e-san2). Animals, 12(3): 335. DOI: https://www.doi.org/10.3390/ani12030335

Cyril HW, Castellini C, and Dal AL BOSCO A (1996). Comparison of three cooking methods of rabbit meat. Italian Journal of Food Science, 4: 337-339. Available at: https://hdl.handle.net/11391/121177

Daikwo SI, Momoh OM, and Dim NI (2013). Heritability estimates of genetic and phenotypic correlations among some selected carcass traits of Japanese quail (*Coturnix coturnix* japonica) raised in a subhumid climate. Journal of Biology, Agriculture and Healthcare, 3(5): 60-65. Available at: http://www.iiste.org/Journals/index.php/JBAH/article/view/5370/5349

de Gaya LG, Ferraz JBS, Rezende FM, Mourão GB, Mattos EC, Eler JP, and Michelan Filho T (2006). Heritability and genetic correlation estimates for performance and carcass and body composition traits in a male broiler line. Poultry Science, 85: 837-843. DOI: https://www.doi.org/10.1093/ps/85.5.837

de Gaya LG, Mourão GB, Ferraz JBS, Mattos EC de, Costa AMMA da, Michelan Filho T, Rosa AF, Felício AM, and Eler JP (2011). Estimates of heritability and genetic correlations for meat quality traits in broilers. Scientia Agricola, 68: 620-625. DOI: https://www.doi.org/10.1590/S0103-90162011000600002

Duncan DB (1955). Multiple range and multiple F tests. Biometrics, 11: 1-42. DOI: https://www.doi.org/10.2307/3001478

El-Attrouny MM, Iraqi MM, and Mohamed SAH (2021). The estimation of genetic parameters for body weight, body dimension, and carcass traits in four Egyptian chickens strains. Journal of World's Poultry Research, 11: 230-240. DOI: https://www.doi.org/10.36380/jwpr.2021.28

El-Attrouny MM, Manaa EA, and Ramadan SI (2020). Genetic evaluation and selection correlated response of growth traits in Japanese quail. South African Journal of Animal Science, 50: 325-333. DOI: http://www.doi.org/10.4314/sajas.v51i1.15

Fletcher DL (1999). Broiler breast meat color variation, pH, and texture. Poultry Science, 78: 1323-1327. DOI: https://www.doi.org/10.1093/ps/78.9.1323

Fletcher DL, Qiao M, and Smith DP (2000). The relationship of raw broiler breast meat color and pH to cooked meat color and pH. Poultry Science, 79: 784-788.DOI: - https://www.doi.org/10.1093/ps/79.5.784

Genchev A, Mihaylova G, Ribarski S, Pavlov A, and Kabakchiev M (2008). Meat quality and composition in Japanese quails. Trakia Journal of Sciences, 6: 72-82. Available at: http://www.uni-sz.bg/tsj/TJS-Vol.6%20N4%202008/Genchev_kachestvoEn.pdf

Gevrekci Y, Oğuz I, AKŞİT M, Oenenc A, Oezdemir D, and Altan O (2009). Heritability and variance component estimates of meat quality in Japanese quail (*Coturnix coturnix* japonica). Turkish Journal of Veterinary & Animal Sciences, 33: 89-94. DOI: https://www.doi.org/10.3906/vet-0603-30

Groeneveld E (2010). VCE user's guide and reference manual version 6.0. Available at: Ftp://Ftp Tzv Fal de/Pub/Vce6/Doc/Vce6-Manual-31-A4 Pdf

Inci H, Sogut B, Sengul T, Sengul AY, and Taysi MR (2015). Comparison of fattening performance, carcass characteristics, and egg quality characteristics of Japanese quails with different feather colors. Revista Brasileira de Zootecnia, 44: 390-396. DOI: https://www.doi.org/10.1590/S1806-92902015001100003

Ioniță L, Popescu-Micloșanu E, Roibu C, and Custură I (2011). Bibliographical study regarding the quails' meat quality in comparison to the chicken and duck meat. Lucrări Ştiinţifice-Seria Zootehnie, 56: 224-228. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/20113368920

Islam MS, Faruque S, Khatun H, and Islam MN (2014). Comparative production performances of different types of quail (*Coturnix coturnix* japonica). The Agriculturists, 12(2): 151-155. DOI: http://www.doi.org/10.3329/agric.v12i2.21744

Jiang RR, Zhao GP, Chen JL, Zheng MQ, Zhao JP, Li P, Hu J, and Wen J (2011). Effect of dietary supplemental nicotinic acid on growth performance, carcass characteristics and meat quality in three genotypes of chicken. Journal of Animal Physiology and Animal Nutrition, 95: 137-145. DOI: https://www.doi.org/10.1111/j.1439-0396.2010.01031.x

Karakaya M, Saricoban C, and Yilmaz MT (2005). The effect of various types of poultry pre-and post-rigor meats on emulsification capacity, water-holding capacity and cooking loss. European Food Research and Technology, 220: 283-286. DOI: https://www.doi.org/10.1007/s00217-004-1068-1

Kaye J (2014). Genetic parameters of bodyweight and some economic important traits in the Japanese quail. Ph. D. Thesis, Bello University, Zaria, Nigeria. Available at: https://kubanni.abu.edu.ng/items/4f41daf8-6953-4128-befb-43d99e7a13c1

Khaldari M, Pakdel A, Yegane HM, Javaremi AN, and Berg P (2010). Response to selection and genetic parameters of body and carcass weights in Japanese quail selected for 4-week body weight. Poultry Science, 89: 1834-1841. DOI: https://www.doi.org/10.3382/ps.2010-00725

Korkeala H, Mäki-Petäys O, Alanko T, and Sorvettula O (1986). Determination of pH in meat. Meat Science, 18, 121-132. DOI: :https://www.doi.org/10.1016/0309-1740(86)90088-4

Kanlisi RA, Amuzu-Aweh EN, Naazie A, Otsyina HR, Kelly TR, Gallardo RA, Lamont SJ, Zhou H, Dekkers J, and Kayang BB (2024). Genetic architecture of body weight, carcass, and internal organs traits of Ghanaian local chickens. Frontiers in Genetics, 15: 1297034. DOI: https://www.doi.org/10.3389/fgene.2024.1297034

Le Bihan-Duval E, Berri C, Baéza E, Millet N, and Beaumont C (2001). Estimation of the genetic parameters of meat characteristics and of their genetic correlations with growth and body composition in an experimental broiler line. Poultry Science, 80: 839-843. DOI: https://www.doi.org/10.1093/ps/80.7.839

Le Bihan-Duval É, Berri C, Baéza É, Santé V, Astruc T, Rémignon H, Le Pottier G, Bentley J, Beaumont C, and Fernandez X (2003). Genetic parameters of meat technological quality traits in a grand-parental commercial line of turkey. Genetics Selection Evolution, 35: 623-635. DOI: https://www.doi.org/10.1051/gse:2003043

Le Bihan-Duval E, Debut M, Berri CM, Sellier N, Santé-Lhoutellier V, Jégo Y, and Beaumont C (2008). Chicken meat quality: genetic variability and relationship with growth and muscle characteristics. BMC Genetics, 9: 1-6. DOI: https://www.doi.org/10.1186/1471-2156-9-53

Lotfi E, Zerehdaran S, and Azari MA (2011). Genetic evaluation of carcass composition and fat deposition in Japanese quail. Poultry Science, 90: 2202-2208. DOI: https://www.doi.org/10.3382/ps.2011-01570

Mahmoud B, Farahat G, and El-Full E (2014). Genetic and phenotypic correlations of body weight and shank length with some egg production-related traits in two Japanese quail genotypes differing in plumage colour. Egyptian Poultry Science Journal, 34: 133-149. DOI: https://www.doi.org/10.21608/epsj.2014.5309

Minvielle F (2004). The future of Japanese quail for research and production. World's Poultry Science Journal, 60: 500-507. DOI: https://www.doi.org/10.1079/WPS200433

Minvielle F, Gourichon D, Ito S, Inoue-Murayama M, and Rivière S (2007). Effects of the dominant lethal yellow mutation on reproduction, growth, feed consumption, body temperature, and body composition of the Japanese quail. Poultry Science, 86: 1646-1650. DOI: https://www.doi.org/10.1093/ps/86.8.1646

Molino AB, Garcia EA, Santos GC, Vieira Filho JA, Baldo GA, and Paz IA (2015). Photostimulation of Japanese quail. Poultry Science, 94(2): 156-161.DOI: http://www.doi.org/10.3382/ps/peu039

Narinc D, Aksoy T, Karaman E, Aygun A, Firat MZ, and Uslu MK (2013). Japanese quail meat quality: Characteristics, heritabilities, and genetic correlations with some slaughter traits. Poultry Science, 92: 1735-1744. DOI: https://www.doi.org/10.3382/ps.2013-03075

Narinc D, Aksoy T, Karaman E, and Karabağ K (2009). Effect of selection applied in the direction of high live weight on growth parameters in Japanese quails. Ziraat Fakültesi Dergisi, Akdeniz Üniversitesi, 22(2): 149-156. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/20103183502

Narinc D, Karaman E, and Aksoy T (2010). Estimation of genetic parameters for carcass traits in Japanese quail using Bayesian methods. South African Journal of Animal Science, 40: 342-347. DOI: http://www.doi.org/10.4314/sajas.v40i4.65253

Nasr MAF, Ali E-SMR, and Hussein MA (2017). Performance, carcass traits, meat quality and amino acid profile of different Japanese quails strains. Journal of Food Science and Technology, 54: 4189-4196. DOI: http://www.doi.org/10.1007/s13197-017-2881-4

National research council (NRC) (1994). Nutrient requirements of poultry, 9th revised Edition. National Academy Press., Washington, D.C. Available at: https://www.nationalacademies.org/our-work/nutrient-requirements-of-poultry-10th-revised-edition.

Oguz I, Aksit M, Onenc A, Gevrekci Y, Ozdemir D, and Altan O (2004). Genetic variability of meat quality characteristics in Japanese quail (*Coturnix coturnix* japonica). Archiv Fur Geflugelkunde, 68: 176-180. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/20043149455

Victoria, O, Fayeye TR, Ayorinde KL, and Olojede H (2014). Relationship between body weight and linear body measurements in Japanese quail (*Coturnix coturnix* japonica). Journal of Scientific Research, 6(1): 175-183. DOI: http://www.doi.org/10.3329/jsr.v6i1.16368

Rance KA, McEntee GM, and McDevitt RM (2002). Genetic and phenotypic relationships between and within support and demand tissues in a single line of broiler chicken. British Poultry Science, 43: 518-527. DOI: https://www.doi.org/10.1080/0007166022000004426

Remignon H, Mills AD, Guemene D, Desrosiers V, Garreau-Mills M, Marche M, and Marche G (1998). Meat quality traits and muscle characteristicsin high or low fear lines of Japanese quails (Coturnix japonica) subjected to acute stress. British Poultry Science, 39: 372-378. DOI: https://www.doi.org/10.1080/00071669888926

Ribarski S and Genchev A (2013). Effect of breed on meat quality in Japanese quails (*Coturnix coturnix* japonica). Trakia Journal of Sciences, 11: 181-188. Available at: http://tru.uni-sz.bg/tsj/N2,%20Vol.11,%202013/A.Gen4ev.pdf

Saatci M, Omed H, and Ap Dewi I (2006). Genetic parameters from univariate and bivariate analyses of egg and weight traits in Japanese quail. Poultry Science, 85: 185-190. DOI: https://www.doi.org/10.1093/ps/85.2.185

Sabow AB (2020). Carcass characteristics, physicochemical attributes, and fatty acid and amino acid compositions of meat obtained from different Japanese quail strains. Tropical Animal Health and Production, 52: 131-140. DOI: and https://www.doi.org/10.1007/s11250-019-01991-2

Saghi R, Rokouei M, Dashab GR, Saghi DA, and Faraji-Arough H (2022). Using a linear-threshold model to investigate the genetic relationship between survival and productive traits in Japanese quail. Italian Journal of Animal Science, 21: 605-611. DOI: https://www.doi.org/10.1080/1828051X.2021.2023332

Salah AS, Ahmed-Farid OA, and El-Tarabany MS (2019). Carcass yields, muscle amino acid and fatty acid profiles, and antioxidant indices of broilers supplemented with 306ymbiotic and/or organic acids. Journal of Animal Physiology and Animal Nutrition, 103: 41-52. DOI: https://www.doi.org/10.1111/jpn.12994

Shafik BM, Kamel ER, Mamdouh M, Elrafaay S, Nassan MA, El-Bahy SM, El-Tarabany MS, and Manaa EA (2022). Performance, blood lipid profile, and the expression of growth hormone receptor (GHR) and insulin-like growth factor-1 (IGF-1) genes in purebred and crossbred quail lines. Animals, 12: 1245. DOI: https://www.doi.org/10.3390/ani12101245

Shanaway MM (1994). Quail production systems: A review. Food and Agriculture Organization of the United Nations, Rome, pp. 135-145. Available at: https://archive.org/details/quailproductions0000shan

Vali N (2008). The Japanese quail: A review. International Journal of Poultry Science, 7: 925-931. Available at: http://www.pjbs.org/ijps/fin1218.pdf

Vali N, Edriss MA, and Rahmani HR (2005). Genetic parameters of body and some carcass traits in two quail strains. International Journal of Poultry Science, 4: 296-300. DOI: http://www.doi.org/10.3923/ijps.2005.296.300

Van Laack R, Liu C-H, Smith MO, and Loveday HD (2000). Characteristics of pale, soft, exudative broiler breast meat. Poultry Science, 79: 1057-1061. DOI: https://www.doi.org/10.1093/ps/79.7.1057

Yue HY, Zhang L, Wu SG, Xu L, Zhang HJ, and Qi GH (2010). Effects of transport stress on blood metabolism, glycolytic potential, and meat quality in meat-type yellow-feathered chickens. Poultry Science, 89: 413-419. DOI: https://www.doi.org/10.3382/ps.2009-00550

Zerehdaran S, Lotfi E, and Rasouli Z (2012). Genetic evaluation of meat quality traits and their correlation with growth and carcase composition in Japanese quail. British Poultry Science, 53: 756-762. DOI: https://www.doi.org/10.1080/00071668.2012.746445

Zhang L and Barbut S (2005). Rheological characteristics of fresh and frozen PSE, normal and DFD chicken breast meat. British Poultry Science, 46: 687-693. DOI: https://www.doi.org/10.1080/00071660500391516