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The effect of plumage colour and sex on growth, carcass, and meat quality traits of Japanese quail

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Abstract

The aim of the study was to determine the effect of plumage colour and sex on growth, slaughter-carcass, and meat quality characteristics of Japanese quails. The effect of plumage colour on live weight values from hatching to sixth week was statistically significant. The highest live weight was obtained in quails with grey plumage colour, with the lowest live weight in brown quails. Plumage colour and sex were important determinants in slaughter and carcass traits, except for head and feet values. The highest slaughter, hot carcass, and cold carcass weights were determined in grey quails and the lowest in brown quails. Meat colour parameters (L*, a*, and b*) were similar. Yellow plumage colour produced the best pH_{24} and male quails were generally preferable in terms of meat characteristics. In terms of water holding capacity, the meat of brown and white quails was drier, whereas the meat of grey and yellow quails was juicier. Grey and yellow quails had a lower cooking loss. Grey, followed by yellow, quails had the best live weight, carcass, and meat quality characteristics. Female quails had higher live weight and carcass traits than male quails, but meat quality characteristics of males and females were similar.

Keywords: carcass quality, live weight, meat quality, quail

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Introduction

Quail breeding has been done in some European and Far Eastern countries, especially in Japan, since ancient times. Quails are commercially used in meat and egg production because they are suitable for cage rearing, more can be raised per unit area, have a high egg production, reach sexual maturity at an early age, grow rapidly, and have a short intergenerational period (Anonymous, 1969; Koçak *et al*., 1991; Karabağ *et al*., 2010; Ekizoğlu *et al*., 2017; Ay *et al*., 2023). Currently, quail production and consumption of their products are increasing (Minvielle, 2009; Alkan *et al*., 2010a; Alkan *et al*., 2010b; Karabağ, 2010; Ülger *et al.,* 2023; Ülger & Mahmood, 2023).

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Growth performance and the number of colour mutations reported in quails is still very limited compared to the number reported in other poultry species. Neither mutation nor performance traits have yet been extensively studied in quails (Robertson *et al.,* 1943; Somes, 1979; Cheng & Kimura, 1990). Most of the plumage colour mutations in Japanese quails have been partially documented and described (Merat *et al.,* 1981; Tsudzuki, 1995; Nakane and Tsudzuki, 1998; Minvielle *et al.,* 1999, Minvielle *et al.,* 2003). The plumage colour mutant in Japanese quail has been reported to be white (Roberts *et al*., 1978), and some researchers (Truax & Johnson, 1979; Cheng & Kimura, 1990; Minvielle *et al.,* 2002) have called it recessive white.

Studies on growth performance and plumage colour mutations in quails are not sufficient to evaluate their use in commercial production. The effects of genetic variants of plumage colour on performance traits in Japanese quails have been studied for only a few mutations. For example, the roux mutation that can be used for automatic sexing at one day of age (Minvielle *et al.,* 1999), the recessive white gene (Petek *et al.,* 2004), the curly mutation associated with increased live weight (Minvielle *et al.,* 2005), the dominant lethal yellow mutation (Minvielle *et al.,* 2007), genetic analysis of brown plumage colour in quails (Yılmaz & Çağlayan, 2008), and genes determining yellow and dotted white feather patterns in Japanese quails (Yıldız & Kesici, 1999) have been reported.

Meat colour in poultry is affected by age, sex, genotype, feed, intramuscular fat distribution, water content of meat, pre-slaughter conditions, and processing techniques (Şengül *et al.,* 2018). The colour of meat depends largely on the concentration of myoglobin and partly on the availability of pigments such as haemoglobin in the environment. When myoglobin combines with oxygen, it transforms into oxymyoglobin and turns grey. The colour change of meat can be related to the amount of these pigments in the meat. The chemical structure of the pigments and the reflection rate of light falling on the meat varies (Northcutt, 2007). The colour of poultry meat can vary from bluish white to yellow depending on breed, exercise, age, and diet. In young poultry, there is less adipose tissue under the skin, causing a bluish appearance (Şengül *et al.,* 2018).

It has been reported that characters associated with meat colour in quails are generally moderately- to highly-heritable and may be influenced by sex-linked genes. It has been suggested that genetics has a predominant role in the control of meat quality traits, such as colour and pH. As live weight increases, water and protein levels in the carcass decrease and carcass fat, number of muscle fibres, muscle fibre length, and skeletal muscle proliferation rate increase (Şengül *et al.,* 2018).

The aim of the present study was to determine the effect of different plumage colours and sex on growth, carcass, and meat quality characteristics in Japanese quails.

Materials and Methods

Approval was received by the Animal Experiments Local Ethics Committee of Kafkas University (Decision no: KAU-HADYEK/2016-057). The study was conducted in the quail unit of Kafkas University Faculty of Veterinary Medicine, Education, Research and Application Farm between 2018 and 2022. During the study, 15 consecutive breeding groups were used. The breeding quails used in the study were housed in apartment-shaped cages with dimensions of 110 × 45 × 100 cm (height × depth × width), five floors, and 20 × 45 × 100 cm on each floor, with five separate compartments and one male and three females in each compartment. The broods from which the eggs were obtained were given 20% crude protein and 2900 kcal ME/kg feed *ad libitum*. The quail chicks used in the study were raised in 110 × 45 × 100 cm cages with five floors and 20 × 45 × 100 cm partitions on each floor. The temperature of the environment in which the chicks were housed was kept at 35–37 °C in the first week, then gradually decreased by 3–4 °C per week and gradually decreased to 20–21 °C in the fourth week. Hatched chicks were given feed containing 22% CP and 2900 kcal ME/kg *ad libitum* for 6 w.

In the study, a total of 1171 quails (349 grey, 231 yellow, 304 white, and 287 brown quails) were used to determine growth characteristics. The hatching weight of the chicks was taken with a 0.01 g precision scale and recorded. Thus, each animal was weighed every week until the sixth week and their live weights were recorded.

In order to determine slaughtering and carcass characteristics, a total of 789 quails (201 grey, 190 yellow, 199 white, and 199 brown) were used in the study. At the end of the sixth week, the quails were slaughtered by exsanguination after taking their slaughter weights. Feeding was terminated 10–

12 h before slaughter. After slaughter, the animals were soaked for 2–3 min at 65 ºC in a soaking tank and then plucked. The plucking process was carried out with a semi-automatic plucking machine. Head, leg, and internal organ weights of the plucked quails were taken and hot carcass weights were obtained. The carcasses were kept at +4 °C for 24 h and after the cold carcass weights were taken, they were cut into pieces and thigh, breast, wing, and component weights were taken.

In order to determine meat quality, a total of 214 quails (54 grey, 52 yellow, 54 white, and 54 brown) were used. Samples were taken from the breast area of the carcass and analysed. The samples to be analysed later were frozen at -18 °C until the analysis was done. The pH was measured from the *M. pectoralis* major muscle by using an electrode pH meter twice, within the first 30 min and at 24 h after slaughter. A Minolta colour device was used for colour analysis. Measurements were made from the chest area in three replicates and averaged. Measurements were performed by determining L*, a*, b* values according to CIE colour system.

In order to determine the water holding capacity of the meat, skinless samples of breast meat weighing 2–2.5 g were minced from three different body locations. Five grams of minced meat was taken and placed between two filter paper sheets. A weight of 2250 g was applied to the filter paper between two glass sheets for 5 min, following which, the meat pieces were weighed again through the filter paper. The water holding capacity (%) was determined as the proportion of the difference between the initial and final weights to the initial weight (Barton-Garde *et al.,* 1993).

The cooking loss of the meat was determined by taking approximately 10 g skinless samples from the breast meat and placing them in vacuum bags, which were cooked in a hot water bath at 80 °C for 60 min. The samples were then kept under tap water for ~30 min until they dropped to room temperature (25 °C). The samples were removed from the bags and dried with blotting paper without pressing. Cooking loss (%) was calculated as a ratio of the initial weight to the final weight (Honikel, 1998).

Samples weighing 5 g taken from the breast meat were placed in vacuum bags and sealed. The vacuumed samples were stored at +4 °C. After 72 h and 168 h, the samples were removed from the vacuum bags, dried with a paper towel without pressing, and scanned. The water holding capacity (%) of the meat after 72 and 168 h was determined as the proportion of the difference between the initial weight and final weight of the samples to the initial weight (Bond and Warner, 2007).

A 5-g piece of meat from the pectoral muscle was weighed and kept in an oven at 110 °C for 12 h. The remaining product was weighed and proportioned to the initial weight and the dry matter content was determined as a %. Moisture content was determined by using the formula of 100%-dry matter (Anonymous, 2005).

A 5-g piece of meat from the pectoral muscle was weighed and burned in a muffle furnace at 550 °C for 6 h. At the end of the incineration process, the remaining product was weighed and proportioned to the initial weight and ash content was determined as a % (AOAC, 1990).

The least squares method was applied in SPSS 21.0 software to determine the effects of plumage colour and sex on live weight, carcass, and meat quality characteristics. The significance of the inter-group differences was determined using one-way analysis of variance and Duncan's test.

Results and Discussion

Table 1 shows the effects of plumage colour and sex on weekly live weight values. The effect of plumage colour on weekly live weight values was statistically significant (P <0.001). The grey quails were higher in live weight than the yellow, white, and brown quails in all weeks. Females were heavier than males in all weeks (P <0.01).

Table 2 shows the effects of plumage colour and sex on slaughter and carcass characteristics. Slaughter weight values were determined as 185.74 g, 163.09 g, 161.35 g, and 158.05 g in quails of grey, yellow, white and brown plumage, respectively, and the difference between them was statistically significant (P <0.001). The highest slaughter weight was determined in the grey quails and the lowest slaughter weight was determined in brown quails. The yellow and white quails were similar in terms of slaughter weight. Slaughter weight in females was higher (P <0.01).

Plumage colour influenced hot carcass weight (P <0.001). The highest hot carcass weight was determined in grey quails (139.89 g), whereas the lowest hot carcass weight was determined in the brown quails (119.11 g). In terms of cold carcass weight, the grey quails (136.86 g) were higher than the yellow, white, and black quails (124.44, 117.18, and 116.03 g, respectively) (P <0.001).

Highest weight averages of the carcass parts were obtained in grey quails and the lowest were obtained in brown quails. In the present study, the average breast weights of the grey, yellow, white, and brown quails were 52.88 g, 49.82 g, 47.11 g, and 47.21 g, respectively. The average thigh weight values were 32.01 g, 28.85 g, 26.47 g, and 26.10 g in grey, yellow, white, and brown quails, respectively (P <0.001). The effect of plumage colour and sex on wing weight was statistically significant (P <0.001), and the wing weights were 11.35 g, 10.57 g, 10.37 g, and 9.65 g in grey, yellow, white, and brown quails, respectively. The highest back + neck weight values were determined in the grey quails and the lowest values were obtained in brown quails (P <0.001). Back + neck weights were 40.61 g, 34.13 g, 33.27 g, and 32.38 g in grey, yellow, white, and brown quails, respectively.

The effect of plumage colour on head and feet weights was statistically significant (P <0.001), while head and feet weights of sexes were similar (P >0.05). The effects of plumage colour and sex on heart, liver, gizzard, and intestine weights were statistically significant (P <0.01). Liver weights of grey, yellow, white, and brown quails were 4,17 g, 3,80 g, 3,92 g, and 3,81 g, respectively; gizzard weights were 4.52 g, 4.17 g, 4.34 g, and 4.81 g, respectively, and intestinal weights were 12.40 g, 10.51 g, 9.79 g, and 10.93 g, respectively.

Table 3 shows the effect of plumage colour and sex on meat quality characteristics. The pH_{30} was 6.00, 5.97, 6.04, and 6.04 (P <0.01) and pH_{24} was 5.72, 5.66, 5.76, and 5.70 (P <0.01), respectively in grey, yellow, white, and brown quails. Plumage colour and sex had no effect on the colour parameters of breast meat with and without skin (P >0.05).

In the present study, the effect of plumage colour on water retention capacity was statistically significant (P <0.01) and was determined as 25.69%, 25.48%, 27.63%, and 26.87% in grey, yellow, white, and brown quails, respectively. The effect of plumage colour on cooking loss was statistically significant (P <0.001), whereas there was no effect of sex (P >0.05). In terms of cooking loss, there was a similarity between grey and yellow quails and between white and brown quails. The highest cooking loss was obtained in yellow quails and the lowest cooking loss was determined in white quails.

The effect of different plumage colours on the 72-h and 168-h drip loss of breast meat was statistically significant (P <0.001) but there was no effect of sex (P >0.05). The 72-h drip loss was highest in grey quails and lowest in brown quails; 168-h drip loss was highest in white quails and lowest in brown quails.

The effect of plumage colour on dry matter, moisture, and ash content of breast meat was statistically significant (P <0.05) and there was no effect of sex (P >0.05). The white quails had a higher DM (P <0.05), the yellow quails had a higher moisture content, and grey quails had a higher ash content (P <0.01).

Hatching weights of chicks of different plumage colours were similar to those reported in many studies (İnal *et al.,* 1996; Sehu *et al.,* 1996; Tığlı *et al.,* 1996; Akbaş & Yaylak, 2000; Saatcı *et al.,* 2003; Saatcı *et al.,* 2006). The statistical differences between the live weight averages reported by İnci *et al.* (2015) according to plumage colour and sex were similar to the present study. The hatching weights obtained in the quails of different plumage colours in the present study were higher than the values reported by Nasr *et al.* (2017) in quails of the same colour. Although the second-week live weights of grey quails were higher than the values reported by Nasr *et al.* (2017) in quails of the same line, the second-week live weights of yellow, brown, and white quails were lower than the values reported by the same researcher. In the current study, week-4 live weights for all plumage colours were lower than the same values reported by Nasr *et al.* (2017) in the same lines.

Minvielle *et al.* (1999) reported that the difference in quail plumage colour had a marked effect on live weight and the wild type group had a higher live weight. Similarly, Genchev *et al*. (2008), Oguz & Minvielle (2001), and Marks (1990) reported that differences in quail plumage colour had a marked effect on live weight and the wild type group had higher live weight. In their study conducted to compare live weights of white-coloured and wild type quails, Tarhyel *et al.* (2012) reported that plumage colour

Table 1. Effect of plumage colour and sex on weekly live weight values

Parameters	Plumage colour					Sex			General
	Gray	Yellow	White	Brown	P	Male	Female	P	
	n = 349	n = 231	n = 304	n = 287		n = 569	n = 602		n = 1171
Hatching	8.60 ± 0.03[a]	8.14 ± 0.04[c]	8.47 ± 0.04[b]	8.40 ± 0.04[b]	0.000	8.33 ± 0.03	8.48 ± 0.03	0.000	8.40 ± 0.02
1. week	25.56 ± 0.20[a]	22.33 ± 0.25[b]	21.78 ± 0.22[bc]	21.22 ± 0.22[c]	0.000	22.38 ± 0.16	23.07 ± 0.16	0.002	22.73 ± 0.11
2. week	48.63 ± 0.49[a]	42.26 ± 0.59[b]	41.82 ± 0.25[b]	39.90 ± 0.53[c]	0.000	42.08 ± 0.38	44.22 ± 0.38	0.000	43.15 ± 0.27
3. week	86.02 ± 0.75[a]	77.51 ± 0.92[b]	74.52 ± 0.80[c]	71.89 ± 0.83[d]	0.000	75.30 ± 0.59	79.68 ± 0.58	0.000	77.48 ± 0.41
4. week	123.86 ± 0.84[a]	111.70 ± 1.03[b]	109.39 ± 0.90[bc]	106.84 ± 0.93[c]	0.000	109.63 ± 0.66	116.26 ± 0.58	0.000	112.95 ± 046
5. week	163.60 ± 0.81[a]	144.83 ± 0.98[b]	140.96 ± 0.86[c]	138.72 ± 0.88[c]	0.000	142.42 ± 0.63	151.63 ± 0.62	0.000	147.03 ± 0.44
6. week	197.76 ± 0.84[a]	172.86 ± 1.03[b]	168.80 ± 0.90[c]	167.72 ± 0.92[c]	0.000	168.81 ± 0.66	184.76 ± 0.65	0.000	176.79 ± 0.46

Differences between values with different letters in the same row for relevant traits (plumage colour and sex) are significant (P <0.05)

Table 2. Effect of plumage colour and sex on slaughter and carcass characteristics

Parameters	Plumage colour					Sex			General
	Gray	Yellow	White	Brown	P	Male	Female	P	
	n = 201	n = 190	n = 199	n = 199		n = 393	n = 396		n = 789
Slaughter weight (g)	185.74 ± 1.13[a]	163.09 ± 1.17[b]	161.35 ± 1.14[b]	158.05 ± 1.14[c]	0.000	158.36 ± 0.81	175.76 ± 0.81	0.000	167.06 ± 0.57
Hot carcass weight (g)	139.89 ± 1.25[a]	129.06 ± 1.29[b]	120.74 ± 1.26[c]	119.11 ± 1.26[c]	0.000	121.18 ± 0.89	133.22 ± 0.89	0.000	127.20 ± 0.63
Cold carcass weight (g)	136.86 ± 1.17[a]	124.44 ± 1.21[b]	117.18 ± 1.18[c]	116.03 ± 1.18[c]	0.000	117.92 ± 0.84	129.46 ± 0.84	0.000	123.63 ± 0.59
Breast weight (g)	52.88 ± 0.57[a]	49.82 ± 0.59[b]	47.11 ± 0.58[c]	47.21 ± 0.58[c]	0.000	46.58 ± 0.41	51.94 ± 0.41	0.000	49.26 ± 0.29
Thigh weight (g)	32.01 ± 10.28[a]	28.85 ± 10.29[b]	26.47 ± 10.28[c]	26.41 ± 10.28[c]	0.000	27.29 ± 0.20	29.58 ± 0.20	0.000	28.43 ± 0.14
Wing weight (g)	11.35 ± 0.11[a]	10.57 ± 0.11[b]	10.37 ± 0.11[b]	9.65 ± 0.11[c]	0.000	10.10 ± 0.08	10.87 ± 0.08	0.000	10.49 ± 0.05
Back + neck weight (g)	40.61 ± 0.39[a]	34.13 ± 0.40[b]	33.27 ± 0.39[bc]	32.38 ± 0.39[c]	0.000	33.45 ± 0.28	36.74 ± 0.28	0.000	35.08 ± 0.20
Head weight (g)	8.05 ± 0.05[a]	7.30 ± 0.05[b]	6.94 ± 0.05[c]	7.19 ± 0.05[b]	0.000	7.37 ± 0.04	7.37 ± 0.04	0.952	7.37 ± 0.03
Feet weight (g)	3.28 ± 0.04[a]	3.19 ± 0.04[a]	3.02 ± 0.04[b]	2.99 ± 0.04[b]	0.000	3.13 ± 0.03	3.12 ± 0.03	0.800	3.12 ± 0.02
Heart weight (g)	1.65 ± 0.02[a]	1.56 ± 0.02[b]	1.49 ± 0.02[c]	1.16 ± 0.02[c]	0.000	1.48 ± 0.01	1.60 ± 0.01	0.000	1.54 ± 0.01
Liver weight (g)	4.17 ± 0.08[a]	3.80 ± 0.02[b]	3.92 ± 0.08[b]	3.81 ± 0.08[b]	0.002	3.51 ± 0.06	4.34 ± 0.06	0.000	3.92 ± 0.04
Gizzard weight (g)	4.52 ± 0.07[bc]	4.71± 0.07[ab]	4.34 ± 0.07[c]	4.81 ± 0.07[a]	0.000	4.40 ± 0.05	4.79 ± 0.05	0.000	4.59 ± 0.04
Intestine weight (g)	12.40 ± 0.26[a]	10.51 ± 0.27[b]	9.79 ±0.06[c]	10.93 ± 0.26[b]	0.000	9.81 ± 0.18	12.00 ± 0.18	0.000	10.91 ± 0.13

Differences between values with different letters in the same row for relevant traits (plumage colour and sex) are significant (P <0.05)

Table 3. Effect of plumage colour and sex on meat quality characteristics

Parameters	Plumage colour				P	Sex		P	General
	Gray	Yellow	White	Brown		Male	Female		
	n = 54	n = 52	n = 54	n = 54		n = 108	n = 106		n = 214
pH_{30}	6.00 ± 0.02^{ab}	5.97 ± 0.02^{b}	6.04 ± 0.02^{a}	6.04 ± 0.02^{a}	0.004	6.02 ± 0.01	6.00 ± 0.01	0.305	6.01 ± 0.01
pH_{24}	5.72 ± 0.02^{ab}	5.66 ± 0.02^{c}	5.76 ± 0.02^{a}	5.70 ± 0.02^{bc}	0.001	5.69 ± 0.01	5.73 ± 0.01	0.019	5.71 ± 0.01
Skinned L*	62.78 ± 0.78	62.07 ± 0.79	60.14 ± 0.78	61.12 ± 0.78	0.094	61.30 ± 0.55	61.75 ± 0.56	0.567	61.52 ± 0.39
Skinned a*	9.49 ± 0.38	9.90 ± 0.39	9.12 ± 0.38	9.42 ± 038	0.550	9.50 ± 0.27	9.46 ± 0.27	0.914	9.48 ± 0.19
Skinned b*	9.31 ± 0.41	9.37 ± 0.42	9.50 ± 0.41	8.17 ± 0.41	0.080	9.13 ± 0.29	9.05 ± 0.29	0.839	9.09 ± 0.21
Skinless L*	52.22 ± 0.81	51.73 ± 0.82	51.11 ± 0.81	52.73 ± 0.81	0.531	51.94 ± 0.57	51.95 ± 0.58	0.994	51.95 ± 0.41
Skinless a*	10.95 ± 0.40	11.12 ± 0.41	11.01 ± 0.40	11.12 ± 0.40	0.988	10.89 ± 0.28	11.21 ± 0.58	0.434	11.05 ± 0.20
Skinless b*	7.92 ± 0.41	7.34 ± 0.41	6.69 ± 0.41	6.78 ± 0.41	0.119	7.19 ± 0.29	7.18 ± 0.29	0.971	7.18 ± 0.20
Water holding capacity %	25.69 ± 0.59^{bc}	24.48 ± 0.60^{c}	27.63 ± 0.59^{a}	26.87 ± 0.59^{ab}	0.001	25.75 ± 0.42	26.58 ± 0.42	0.165	26.17 ± 0.30
Cooking loss %	30.75 ± 0.80^{a}	31.63 ± 0.81^{a}	27.38 ± 0.80^{b}	27.60 ± 0.80^{b}	0.000	28.64 ± 0.57	30.03 ± 0.57	0.085	29.34 ± 0.40
72 h Drip loss %	6.03 ± 0.26^{a}	4.86 ± 0.27^{b}	4.70 ± 0.26^{b}	3.58 ± 0.26^{c}	0.000	4.74 ± 0.19	4.85 ± 0.19	0.675	4.79 ± 0.13
168 h Drip loss %	6.40 ± 0.28^{bc}	6.55 ± 0.29^{b}	8.27 ± 0.28^{a}	5.61 ± 0.28^{c}	0.000	6.43 ± 0.20	6.97 ± 0.20	0.052	6.71 ± 0.14
Dry matter %	27.26 ± 0.62^{ab}	28.71 ± 0.63^{a}	26.19 ± 0.62^{c}	27.21 ± 0.62^{ab}	0.045	27.14 ± 0.44	27.54 ± 0.44	0.524	27.34 ± 0.31
Moisture %	72.75 ± 0.41^{a}	71.25 ± 0.42^{b}	73.80 ± 0.41^{a}	73.76 ± 0.41^{a}	0.000	72.86 ± 0.29	72.92 ± 0.29	0.868	72.89 ± 0.21
Ash %	1.23 ± 0.05^{b}	1.52 ± 0.05^{a}	1.52 ± 0.05^{a}	1.44 ± 0.05^{a}	0.000	1.39 ± 0.04	1.48 ± 0.04	0.100	1.43 ± 0.03

Differences between values with different letters in the same row for relevant traits (plumage colour and sex) are significant ($p<0.05$).

had an effect (P <0.05) on live weight, but the white-coloured group had a lower live weight. These reports support the values obtained in the current study in terms of growth characteristics.

Although the week-6 live weight values obtained in the grey quails were higher than the values reported by Nasr *et al.* (2017) in the same line, the week-6 live weight values determined in the yellow, brown, and white quails were lower than the values reported by the same researcher.

The highest slaughter weight was obtained in the grey quails and the lowest slaughter weight was obtained in brown quails. Slaughter weights of yellow and white quails were similar. According to sex, the highest slaughter weight was obtained in female quails. These statistical differences are similar to the results of numerous studies (İnci *et al.,* 2015; Gontijo *et al.,* 2017; Çetinkaya, 2019; Güler *et al.,* 2019; Şengül *et al.,* 2021). The results obtained in terms of cold carcass weight in the present study were similar to those reported by Doğan Daş *et al.* (2020) in Japanese quails. The cold carcass weight determined in the grey quails in the present study was higher than the cold carcass weight reported by İpek *et al.* (2002) as 130.85 g in quails raised in a cage system. The cold carcass weights determined in this study were similar to the values reported by İnci *et al.* (2015) in quails of different plumage colours.

In the current study, the breast weights of the grey, yellow, white, and brown quails were 52.88 g, 49.82 g, 47.11 g, and 47.21 g, respectively. These values were lower than the values reported by Çetinkaya (2019) in the control group of Japanese quails, compatible with the values reported by Tekin (2018) in the control group of Japanese quails, and similar to the values reported by İnci *et al*. (2015) for dark brown and yellow quails; the value reported by the same researchers for white quails was higher than in the present study.

The average thigh weight values in the present study were 32.01 g, 28.85 g, 26.47 g, and 26.10 g for grey, yellow, white, and brown quails, respectively. These values were similar to those obtained by some researchers (İnci *et al.,* 2015; Gontijo *et al.,* 2017; Tufan *et al.,* 2017; Doğan Daş *et al.,* 2020) for Japanese quails; however, they were lower than the values reported by other researchers (Tekin, 2018; Baytur, 2019; Çetinkaya, 2019).

The highest back + neck weight values were determined in the grey quails and the lowest in the brown quails. The back + neck weight values determined in the grey, yellow, white, and brown quails were compatible with the values reported by Söğüt *et al.* (2015), lower than the values reported by Gözet & Baylan (2020), and higher than the values reported by Tekin (2018).

Heart weights were determined as 1.65 g, 1.56 g, 1.45 g, and 1.16 g for grey, yellow, white, and brown quails, respectively. The heart weights of grey quails were similar those reported by Doğan Daş *et al.* (2020), whereas the heart weights of yellow, white, and brown quails were lower. Heart weights of all plumage colours were higher than the values reported by Rahman *et al.* (2016).

High pH causes faster microbial degradation in poultry meat. The decrease in pH after slaughter causes the meat to become crisp or juicy and has a marked effect on the quality characteristics of the meat. In the present study, the best quails were ranked as yellow, brown, grey, and white in terms of microbial degradation depending on the pH_{24} values of breast meat. The pH_{24} value of grey, yellow, white, and brown quails in the present study was similar to that reported as 5.8 by Genchev *et al.* (2008) in Japanese quails. The pH_{24} values in males and females (5.69 and 5.73) in the current study were higher than those reported by Choi *et al.* (2016) in males and females of the high weight (5.45 and 5.49) and control groups (5.51 and 5.56).

The skinned L* values were 62.78, 62.07, 60.14, and 61.12, and the skinless L* values were 52.22, 51.73, 51.11, and 52.73, respectively, in grey, yellow, white, and brown quails. These values were lower than those reported by Gontijo *et al.* (2017) and Çetinkaya (2019), higher than the values reported by Baytur (2019) and Doğan Daş *et al*. (2020), and similar to the values reported by Aminzade *et al.* (2012) and Choi *et al*. (2016). The b* values determined in the present study were similar to the control quails of Baytur (2019) and Asghar (2021).

In the current study, the water holding capacity values were ranked from high to low as brown, white, grey, and yellow quails. This means that the meat obtained from the brown and white quails was juicier than the meat obtained from the grey and yellow quails. The meat of the brown and white quails was drier, whereas the meat of the grey and yellow quails was juicier. The water holding capacity of the grey, yellow, white, and brown quails was 25.69%, 25.48%, 27.63%, and 26.87%, respectively; these

values were similar those reported by Tekin (2018) and Güler *et al.* (2019), and higher than those reported by Berker (2015) and Çetinkaya (2019).

High cooking loss causes a partial decrease in the nutritional value of meat, a decrease in product quality, and increase in weight (wastage), leading to an increase in economic losses (Karakaya, 1991; Richardson & Mead 1999). In the present study, the cooking loss in the grey and yellow quails was higher than those of the white and brown quails. The cooking loss was higher than the values reported by Choi *et al.* (2016) and similar to the values reported by Çetinkaya (2019) and Doğan Daş *et al.* (2020).

High drip loss, along with weight loss (wastage), has a negative effect on the colour, texture, and crispness of the meat. The 72-h drip loss was highest in the grey quails, 168-h drip loss was highest in the white quails, and drip loss in grey, yellow, and brown quails was similar. In the present study, the 72- and 168-h drip loss was lower than the values reported by Çetinkaya (2019), higher than the values reported by Choi *et al.* (2016) and Sabow (2020), and compatible with the values reported by Samson Kyakma *et al.* (2019).

Meat quality is mostly affected by genetics, environment, feed and slaughter, processing, and storage conditions (Nasir & Grashorn, 2010). Dry matter rates in the current study were lower than the value reported by Baytur (2019) and similar to the value reported by Güler *et al*. (2019). Breast meat ash content in the present study was similar to the values reported by Nasir & Garshorn (2010), Awan *et al.* (2017), and Güler *et al.* (2019), and lower than the values reported by Aşkın (2014) and Çetinkaya (2019). Moisture values were similar to the values reported by Karakaya *et al.* (2005) and Aşkın (2014).

Conclusion

The yellow quails were the best in terms of pH_{24} values and male quails were better than females. There was no effect of plumage colour and sex on meat colour parameters. The meat of the brown and white quails was drier, whereas the meat of the grey and yellow quails was juicier. The cooking loss was less in grey and yellow quails. There was no effect of sex on water holding capacity, cooking loss, and drip loss. The 72-h drip loss was the highest in the grey quails and 168-h drip loss was the highest in the white quail. Grey and yellow quails had the best live weight, carcass, and meat quality characteristics. In terms of live weight and carcass traits, female quails had higher values than male quails. There was no effect of sex on meat quality characteristics.

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Authors' Contributions

KÖ, MS, and MT designed the experiment. KÖ, MS, GG, and ÖK collected the data. KÖ, MS, and MT performed the statistical analysis. KÖ and MS wrote the paper. All authors reviewed and approved the manuscript.

Conflicts of Interest Declaration

The authors declare no conflict of interest.

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