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JUMBO BROWN AND GOLDEN ITALIAN JAPANESE QUAIL: A COMPARATIVE EXAMINATION OF EGG QUALITY, EGG YOLK LIPID PEROXIDATION AND FATTY ACID PROFILES

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Abstract: This study was conducted to compare two different Japanese quail (*Coturnix coturnix japonica*) breed lines in terms of egg quality, egg yolk lipid peroxidation, and fatty acid profiles. The research was carried out with Jumbo Brown (Jumbo Brown *Coturnix japonica*) and Golden Italian (Golden Italian *Coturnix japonica*) Japanese quail breed lines with dark brown and golden yellow plumage colors at an average body weight of 200±10 g and 10 weeks of age. The experimental groups consisted of Jumbo Brown Japanese quail breed and Golden Italian Japanese quail breed, each containing 80 Japanese quails fed a standard quail diet. Each group was divided into 20 subgroups, with 4 quails housed in each subgroup. The study lasted for 10 weeks (11–20 weeks) according to the randomized plot experimental design. The egg quality data were recorded over an overall period, divided into two periods of 5 weeks each: period 1 (11 to 15 weeks) and period 2 (16 to 20 weeks). Egg and eggshell weights of the Golden Italian breeds were higher in the overall period ($P<0.05$). The eggshell proportion increased only in the 2nd period in the Golden Italian breed ($P<0.05$). No significant differences were observed between the breed lines in terms of egg-specific gravity, egg shape index, eggshell thickness, albumen index, yolk index, Haugh unit, and egg yolk color (L, a, b) values ($P>0.05$). However, the egg yolk of the Jumbo Brown breed had a higher crude protein content ($P<0.05$). No difference was observed in yolk malondialdehyde values between breeds in fresh and stored eggs ($P>0.05$). Moreover, the egg yolk ΣPUFA/ΣSFA ratio, ΣPUFA, and Σn-6 values were higher in the Jumbo Brown breed than in the Golden Italian breed ($P<0.05$). In conclusion, Jumbo Brown breed eggs may be an alternative to traditionally consumed chicken eggs because of their high yolk crude protein content and favorable fatty acid profile.

Keywords: Japanese quails, Breed, Egg quality, Oxidative stability, Fatty acid profiles, Alternative food

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1. Introduction

Japanese quails (*Coturnix coturnix japonica*) are the smallest birds among poultry species commonly raised for meat and eggs worldwide (Mizutani, 2003; Chang et al., 2005). The breeding and production systems of Japanese quails are similar to those observed in laying hens, and the rearing phase can occur in floor systems or battery cages. Japanese quails can start laying at 42 days of age, and usually continue laying for up to 60 weeks. Egg production peaks at over 95% and maintains high egg production levels (more than 90%) for longer than hens (Bertechini and Oviedo-Rondon, 2023). Therefore, quail farming has become increasingly popular in the poultry industry. However, non-chicken egg production remained at a certain level. It has been reported that 87 million tons of eggs are produced from laying hens worldwide, while only 6.3 million tons of eggs are produced from quails, accounting for 10% of all table eggs (TRIDGE, 2020; FAO, 2021). This can be attributed to the fact that chicken egg production and consumption is a widespread and large-scale industry worldwide, with consumer habits in general. However, the interest of today's consumers in healthy nutrition, food safety, and quality has forced market boundaries to change, and quail farming for egg production has gained momentum, especially in Asian countries such as China, Brazil, and Russia (TRIDGE, 2020). Although quail eggs are smaller and lighter than chicken eggs, they are richer in certain vitamins (B12 sources) and minerals (Fe, P, Se, and Zn) (Tunsaringkarn et al., 2013; Shoemaker, 2020). Therefore, it is important to determine egg quality characteristics and the factors affecting these characteristics to increase the acceptability of quail eggs as an alternative to chicken eggs in human diets.

Egg external and internal quality characteristics can be associated with genetics, feeding, management, storage conditions, stocking density, egg processing, and stage of the production cycle (Douglas, 2013). Punya Kumari et al. (2008) determined that the quality characteristics of Japanese quail eggs have high heritability. In contrast, several studies have reported that plumage color or genetic diversity can play a significant role in quail egg

quality (Hrnčár et al., 2014; İnci et al., 2015; Hassan et al., 2017). Moreover, Cahyadi et al. (2019) found that the eggs of the brown plumage quail line possessed superior external and internal characteristics compared to the eggs of the black plumage line. Petek et al. (2022), however, found that eggs from the cross-line black coloured quail line are heavier and possess higher breaking strength compared to the eggs of the wild-type and recessive white quail lines. They also determined that eggs from the white line of quails had a shorter egg length and the highest shape index values, along with a lighter egg yolk color. However, quail eggs have a low saturated fat ratio and contain high unsaturated fatty acids, thus having an appropriate PUFA/SFA and n-6/n-3 ratio (Cufadar et al., 2021; Göçmen et al., 2021). Previous studies have found that quail eggs have a fatty acid profile above the 0.45 PUFA/SFA ratio and 4:1 n-6/n-3 ratio recommended by the HMSO (1994) for a healthy human diet (Özbilgin et al., 2021). Moreover, quail eggs contain twice as much docosahexaenoic acid (DHA) as chicken eggs do (Kazmierka et al., 2005). Indeed, a healthy fatty acid composition not only serves as a significant energy source in the human body but also plays other biological roles, such as regulating membrane structure and function, modulating intracellular signal pathways, transcription factor activity, gene expression, and production of bioactive lipid mediators (Calder, 2015). Therefore, quail eggs can be promoted in the human diet as an alternative to healthy and balanced diets because of their rich nutrient contents. However, consumers generally have a limited understanding of yolk fat content and composition in eggs, and are unaware of the potential nutritional and health benefits of including quail eggs in human diets. However, the lack of studies on yolk oxidative stability in quail eggs indicates that research in this area is largely limited to chicken eggs. Therefore, further research is needed to characterize the specific nutrient profiles of quail eggs. In this context, this study aimed to comparatively investigate the external and internal egg quality, yolk oxidative stability, and fatty acid profiles of the Jumbo Brown and Golden Italian quail breeds.

2. Materials and Methods

2.1. Bird, Diets, Housing and Management

This research was carried out at Dicle University, Faculty of Agriculture, Department of Animal Science, Poultry Research and Application Facilities. Jumbo brown (Jumbo Brown Coturnix japonica) and golden Italian (Golden Italian Coturnix japonica) Japanese quail (Coturnix coturnix japonica) breed lines with dark brown and golden yellow plumage colors with an average body weight of 200±10 g and 10 weeks of age were used as animal materials. The experiment consisted of groups of Jumbo Brown Japanese quail fed standard quail egg feed and Golden Italian Japanese quail fed standard quail egg feed, each containing 80 laying quails. Each group was divided into 20 subgroups, and four quails were housed in each subgroup. At the beginning of the experiment, the body weights and egg production levels of the quails were determined, and the quails were randomly distributed to the battery cage system according to their similar body weights and egg production levels. Quails were housed in a battery cage system made of galvanized material with a nipple drinker and four compartments (1 m x 0.4 = 0.4 m2) on each floor. The study was conducted for 10 weeks (11 to 20 weeks) according to the randomized plot experimental design, and feed and water were provided ad libitum during the experiment. During the experiment, 16 h of light and 8 h of dark were applied. Lighting was performed using light bulbs at night. The temperature inside the poultry house was maintained at 22-24 °C and the relative humidity was 55-60%. Temperature and humidity were monitored daily during the experiment using a digital temperature and humidity meter (VZN, Türkiye).

The quails were fed laying quail diet throughout the experiment. The diets of the experimental groups were prepared in mash form at the feed production facility of Dicle University, Faculty of Agriculture, Department of Animal Science, in accordance with the nutrient requirements of laying quail, as reported by NRC (1994). To prepare the diets, the nutrient composition of the major ingredients was determined prior to the experiment. The composition (g/kg), nutrient content (%), and Metabolizable Energy (kcal ME/kg) levels of the diets used in this study are presented in Table 1. In addition, the nutrient content of the diets was determined using the Weende analysis method (AOAC 2000). Crude protein (CP) determination in the diet was performed using an automatic nitrogen/protein analyzer (Leco FP-528, USA). Ether extract (EE) analysis was performed using an automatic fat determination (Soxhlet) device (Velp Scientifica, Italy), and crude fiber (CF) content was determined according to the Lepper method (Bulgurlu and Ergül, 1978). Starch determination was carried out in two stages according to the TS ISO 6493 standard (TSE, 2004), and the Luff-Schoorl method reported in the TS 12232 standard was used to determine the sugar content (TSE, 1997). In addition, the following regression equations reported by Carpenter and Clegg (1956) and TSE (1991) (TSE No: 9610) were used to calculate the ME content of the laying quail diet (Equation 1).

$$\text{ME kcal/kg} = 38*[(CP\times1) + (EE\times2.25) + (\text{Starch}\times1.1) + (\text{Sugar}\times1.05)]+53 \quad (1)$$

2.2. Egg Quality Measurements

In order to determine egg quality in the study, throughout the 10-week experiment, 10 eggs were collected weekly from each group on the same day and hour, and were brought to the Dicle University Faculty of Agriculture Department of Animal Science feed/food analysis laboratory. However, egg quality data were recorded over an overall period of 10 weeks, divided into

two periods of 5 weeks each: period 1 (11–15 weeks) and period 2 (16-20 weeks). In this context, first, the weights (g) of the eggs were determined using a balance with a precision of 0.01 g (Dikomsan FGH series, Türkiye). Subsequently, the width (mm) and length (mm) of the eggs were measured using a digital caliper (Mitutoyo, Japan) and their specific gravity was measured using a RADWAG balance (AS 220.R2, Poland).

Table 1. Ingredients, Composition (%), nutrient content (%), and Metabolizable Energy (kcal/kg) levels of the laying quail diet

Items	%
Corn	52.50
Soybean meal (44% CP)	23.00
Sunflower meal (32% CP)	10.00
Bone meal (27 % Ca, 18 % CP)	2.00
Sunflower oil (8800 Kcal/kg)	3.45
Limestone ($CaCO_3$)	7.20
Dicalciumphosphate	1.10
DL-Methionine	0.10
Vitamin - Mineral Premix[1]	0.25
NaCl	0.40
Analysed chemical composition (%)	
Dry matter	90.5
Crude protein	18.20
Ether extract	5.11
Crude fiber	5.10
Crude ash	13.00
Starch	36.01
Sugar	3.34
Calculated values	
Metabolizable energy (ME poultry), kcal/kg	2819.99
Lysine, %	0.86
Methionine+cystine,	0.70
Ca, %	3.20
Available P,	0.50

[1]Vitamin and mineral premix providing per 2.5 kg of diet: vitamin A, 12000000 IU; Vitamin D3, 2500000 IU; Vitamin E, 30000 mg; Vitamin K3, 4000 mg; Vitamin B1, 3000 mg; Vitamin B2, 7000 mg; Vitamin B6, 5000 mg; Vitamin B12, 15 mg; Ca-D pantothenate, 10000 mg; Biotin, 45 mg; Vitamin C, 50000 mg; Folic acid, 1000 mg; Niacin amide, 30000 mg; Choline chloride, 200000 mg; Mn (II) oxide, 80000 mg; Fe (II) sulphate, 50000 mg; Cu (II) sulphate, 5000 mg; Zn sulphate, 60000 mg; Ca iodide, 1000 mg; Na selenite, 150 mg,; Apo karotenoik ester 10%, 500 mg; and Kantaksantin 10% 2000 mg.

Shell weights (g) were weighed on a balance, and shell proportions (%) were determined by relating shell weights to egg weights. Shell thickness (mm) was measured using an electronic digital micrometer (Mitutoyo, Japan) with a range of 0-25 mm and a precision of 0.001 mm. Egg shape index was calculated according to the equation reported by Anderson et al. (2004) (Equation 2).

$$\text{Egg shape index, \%} = (\text{egg width}/\text{egg length}) \times 100 \quad (2)$$

Egg albumen length (mm) and width (mm) and yolk diameter (mm) were measured with a digital caliper (Mitutoyo, Japan). Egg albumen and yolk heights (mm) were determined using a mechanical pedestal micrometer (Accud, Türkiye). The egg albumen index and egg yolk index were determined using the following equations (Equations 3-4) reported for laying hens by Heiman and Carver (1936) and Funk (1948):

$$\text{Albumen index, \%} = \frac{AH}{\left[\frac{(LDA+SDA)}{2}\right]} 100 \quad (3)$$

here, AH is Albumen height, LDA is long diameter of albumen and SDA is short diameter of albumen.

$$\text{Yolk index, \%} = \frac{Yolk\ height}{Yolk\ diameter} 100 \quad (4)$$

Haugh units were calculated using the following formula based on the values of white height (mm) and egg weight (g) per egg (Haugh, 1937) (Equation 5):

$$\text{Haugh unit} = 100 \times \log(\text{albumen height} + 7.57 - 1.7 \times \text{egg weight}^{0.37}) \quad (5)$$

Egg yolk color was determined by measuring brightness (L*), redness (a*), and yellowness (b*) using a colorimeter (3nh, China). The L* values ranged from 0 (completely black) to 100 (completely white). A lower L value indicates a darker color, whereas a higher L value indicates a lighter color. The a* value indicates where the color lies in the spectrum, from green (negative values) to red (positive values). This value ranges from -50 to +50, with -50 being exactly green and +50 being exactly red. b* indicates where the color lies in the spectrum from blue (negative values) to yellow (positive values). This value ranges from -50 to +50, with -50 being exactly blue and +50 being exactly yellow. Three readings were taken for each sample, and the instrument was calibrated with white and black tiles before each measurement.

2.3. Determination of Egg Nutrient Composition

Dry matter (DM), crude ash (CA), crude protein (CP), and ether extract (EE) analyses of egg albumens, yolks, and edible parts were performed according to the AOAC (2000). The DM values of the egg samples were determined by drying a certain amount of samples at 105 °C overnight, and the CA values were determined by incineration at 550 °C overnight. CP values were measured using an automatic nitrogen/protein analyzer (Leco FP-528, USA). EE was determined by extracting the samples with hexane (Tekkim, Türkiye) for a certain period in an automatic oil determination (Soxhlet) device

(Velp Scientifica, Italy). The determined values were obtained on a dry-matter basis.

2.4. Analysis of Egg Yolk Lipid Peroxidation

The amount of malondialdehyde (MDA), a secondary decomposition product of lipid peroxidation, in yolk samples from eggs stored at room temperature (22±2°C) on different days (0, 14, and 28) was determined using the TBARS (thiobarbituric acid-reactive substance) method developed by Witte et al. (1970). The absorbance of the pink complex formed as a result of the reaction between MDA and thiobarbituric acid (TBA; Merck, Darmstadt, Germany) was measured spectrophotometrically (UV-1201, Shimadzu, Kyoto, Japan) at 532 nm. A solution of trichloroacetic acid (TCA; Merck, Darmstadt, Germany) (20% weight/volume) was used for extraction. The MDA standard graph was drawn by preparing dilutions of 1.1.3.3 tetraethoxypropane (Merck, Darmstadt, Germany) at 0.5, 1, 2, 4, 5, 10, and 20 µmol/L. TBARS values were expressed in mg MDA/kg of egg yolk.

2.5. Determination of Egg Yolk Fatty Acid Profile

For the fatty acid profile of egg yolk, fats were extracted from 20 egg yolks, 10 from each group, using the solvent method with a 2:1 ratio of chloroform/methanol (Anonymous, 1987). Fatty acid methyl esters of egg yolks were determined according to the Turkish Food Codex, European Communities Commission Regulation (Announcement No.2014/53) using a gas chromatography device (Agilent 7890 GC/FID, USA) equipped with a flame ionization detector and a silica capillary column (Anonymous, 2014). Nitrogen was used as the carrier gas and the flow rate was set to 35 mL/min. The hydrogen and air pressures were set at 0.5 kg/cm. The oven temperature was initially maintained at 165 °C for 15 min and then raised to 200 °C at a rate of 5 °C/min, and the injector and detector temperatures were held constant at 250 °C. The injection volume was 1µl. The fatty acid composition of egg yolk was expressed as a % of the total fatty acids.

2.6. Statistical Analysis

Statistical analyses of the data from the experimental groups were performed using SPSS (version 22.0; SPSS, 2013). The normality was checked using the Shapiro-Wilk test, and Levene's test was for homogeneity of variances. Statistical calculations of the groups were evaluated using an independent sample t-test. ANOVA was used to determine the differences in MDA data according to the storage periods. Values with a significance level of $P<0.05$ were considered statistically significant, and $0.05<P<0.10$ were considered as trends.

3. Results

3.1. External and Internal Egg Quality

The weekly egg external quality values of the two quail breeds are summarized in Table 2. Eggs of Golden Italian quail breeds in the same age group were heavier than Jumbo Brown quail eggs in the 1st period (11–15 weeks) and overall period (11–20 weeks) ($P<0.05$).

Table 2. External egg quality values of two different Japanese quail breeds

Items	Jumbo Brown	Golden Italian	SEM[1]	*P*-value
Egg weight, g				
11 to 15 wk	12.30[b]	12.97[a]	0.162	0.027
16 to 20 wk	11.60	12.32	0.238	0.133
11 to 20 wk	11.95[b]	12.65[a]	0.160	0.024
Egg specific gravity				
11 to 15 wk	1.062	1.063	0.001	0.390
16 to 20 wk	1.053	1.058	0.003	0.355
11 to 20 wk	1.057	1.061	0.002	0.288
Egg shape index, %				
11 to 15 wk	76.57	77.87	0.564	0.287
16 to 20 wk	78.79	78.46	0.617	0.803
11 to 20 wk	77.68	78.16	0.438	0.599
Eggshell weight, g				
11 to 15 wk	1.39	1.44	0.032	0.471
16 to 20 wk	1.18[b]	1.44[a]	0.049	<0.001
11 to 20 wk	1.29[b]	1.44[a]	0.031	0.008
Eggshell proportion, %				
11 to 15 wk	11.30	11.16	0.250	0.800
16 to 20 wk	10.29[b]	11.72[a]	0.292	0.014
11 to 20 wk	10.74	11.44	0.190	0.063
Eggshell thickness, mm				
11 to 15 wk	0.291	0.284	0.005	0.563
16 to 20 wk	0.282	0.302	0.011	0.411
11 to 20 wk	0.286	0.293	0.006	0.603

Differences between mean values with different letters (a-b) in the same row are statistically significant at $P<0.05$ level. [1]SEM, standard error of means.

In addition, eggshell weight in the 2nd period (16 to 20 weeks) and overall period and eggshell proportion in the 2nd period were higher in Golden Italian quail breeds (P<0.05). In contrast, egg specific gravity, egg shape index, and egg shell thickness were not significantly different among the quail breeds (P>0.05). However, the proportion of eggshells tended to increase in the Golden Italian quail breeds for the overall period.

There was no difference in the egg albumen index, egg yolk index, Haugh unit, and yolk L, a, and b values between quail breeds in all periods (P>0.05; Table 3).

3.2. Egg Nutrient Composition

The nutrient compositions of egg yolk, egg albumen, and edible egg parts of the quail breeds are listed in Table 4. Accordingly, only the yolk CP content of the Jumbo Brown quail breed was significantly higher than that of the Golden Italian quail breeds (P<0.05). In contrast, it was found that yolk DM and egg albumen EE of Golden Italian quail breeds showed an increasing trend compared to Jumbo Brown quail breeds.

Table 3. Internal egg quality values of two different Japanese quail breeds

Items		Jumbo Brown	Golden Italian	SEM[1]	*P*-value
Albumen index, %					
11 to 15 wk		9.05	8.39	0.307	0.306
16 to 20 wk		10.08	9.21	0.525	0.438
11 to 20 wk		9.57	8.80	0.315	0.231
Yolk index, %					
11 to 15 wk		42.15	44.00	0.716	0.213
16 to 20 wk		42.03	41.35	0.978	0.750
11 to 20 wk		42.09	42.67	0.611	0.644
Haugh unit					
11 to 15 wk		87.07	84.25	0.960	0.171
16 to 20 wk		86.48	85.37	1.233	0.678
11 to 20 wk		86.45	84.81	0.708	0.257
Egg yolk color					
	L	57.34	58.41	2.665	0.854
11 to 15 wk	a	28.11	27.15	1.980	0.826
	b	32.43	32.98	2.421	0.917
	L	50.32	52.20	3.997	0.828
16 to 20 wk	a	20.25	21.15	1.001	0.681
	b	30.60	30.93	1.848	0.935
	L	53.83	55.31	2.451	0.772
11 to 20 wk	a	24.18	24.15	1.341	0.992
	b	31.51	31.95	1.499	0.888

L*= brightness, a*= redness, b*= yellowness, [1]SEM, standard error of means. P<0.05.

Table 4. Nutrient content of eggs of two different Japanese quail breeds (%, in DM)

Egg nutrient content		Jumbo Brown	Golden Italian	SEM[1]	*P*-value
Egg yolk	DM(Fresh)	50.00	52.74	0.819	0.094
	CP	33.68[a]	30.24[b]	0.896	0.046
	EE	53.71	51.92	1.030	0.417
	CA	3.15	3.49	0.211	0.453
Egg albumen	DM(Fresh)	11.81	12.62	0.595	0.528
	CP	83.99	86.39	1.566	0.476
	EE	1.74	1.78	0.215	0.932
	CA	5.57	7.01	0.424	0.088
Edible part (whole)	DM(Fresh)	25.82	26.79	0.705	0.124
	CP	44.88	43.83	1.212	0.228
	EE	43.52	42.72	0.662	0.118
	CA	4.60	5.41	0.348	0.269

Differences between mean values with different letters (a-b) in the same row are statistically significant at P<0.05 level. DM= dry matter, CP= crude protein, EE= ether extract, CA= crude ash, [1]SEM, standard error of means.

3.3. Egg Yolk Lipid Peroxidation

The effects of genotype, storage time, and genotype*storage time on yolk MDA values in quail breed eggs stored at room temperature on days 0, 14, and 28 were found to be insignificant (P>0.05) (Table 5).

3.4. Egg Yolk Lipid Profile

The fatty acid profiles of quail egg yolks are presented in Table 6. Accordingly, linolelaidic acid was higher in Jumbo Brown quail eggs than in Golden Italian quail eggs (P<0.05). In contrast, gadoleic acid and cis 11,14-eicosadienoic acid values were higher in Golden Italian quail eggs (P<0.05). In addition, when the eggs of quails were evaluated in terms of yolk total fatty acid content, it was observed that ΣPUFA and Σn-6 values and ΣPUFA/ΣSFA ratio were higher in the Jumbo Brown quail breeds (P<0.05).

Table 5. TBARs (mg MDA/kg) values of fresh and stored egg yolks from two different Japanese quail breeds

	*TBARs value	SEM[1]	*P*-value
Genotype			
Jumbo Brown	0.79	0.013	0.991
Golden Italian	0.79		
Storage time			
Day 0	0.78		
Day 14	0.77	0.013	0.639
Day 28	0.81		
Genotype*Storage time			
Jumbo Brown d0	0.78		
Jumbo Brown d14	0.80		
Jumbo Brown d28	0.79	0.037	0.572
Golden Italian d0	0.78		
Golden Italian d14	0.75		
Golden Italian d28	0.83		

TBARs= thiobarbituric acid reactive substances, MDA= malondialdehyde, [1]SEM, standard error of means. P<0.05.

Table 6. Fatty acid composition of egg yolks of two different Japanese quail breeds (g/100 g total fat)

Fatty acids, %	Jumbo Brown	Golden Italian	SEM[1]	*P*-value
Myristic acid (C14:0)	0.48	0.48	0.054	0.968
Methyl myristoleate (C14:1)	0.60	0.85	0.116	0.304
Pentadecanoic acid (C15:0)	0.04	0.04	0.006	0.641
Palmitic acid (C16:0)	22.60	23.06	0.519	0.688
Palmitoleic acid (C16:1)	3.23	3.74	0.217	0.267
Heptadecanoic/Margaric acid (C17:0)	0.15	0.15	0.024	0.932
Heptadecanoic acid (C17:1)	0.08	0.09	0.015	0.922
Stearic acid (C18:0)	6.63	6.74	0.309	0.872
Trans-Octadecanoic acid (C18:1N9T)	46.43	46.72	0.589	0.825
Linolelaidic acid (C18:2N6T)	14.17[a]	11.39[b]	0.622	0.014
Alpha-Linolenic acid (C18:3N6)	0.19	0.16	0.025	0.551
Arachidic acid (C20:0)	0.14	0.21	0.028	0.283
Gadoleic acid (C20:1)	0.09[b]	0.35[a]	0.054	0.016
Cis 11,14-Eicosadienoic acid (C20:2)	0.03[b]	0.31[a]	0.051	0.003
Cis 11,14,17eicosatrienoic acid (C20:3N3)	0.49	0.41	0.063	0.558
Heneicosanoic acid (C21:0)	0.03	0.02	0.005	0.225
ΣSFA	30.07	30.69	0.692	0.683
ΣUFA	65.32	64.02	1.026	0.558
ΣMUFA	50.44	51.75	0.661	0.351
ΣPUFA	14.88[a]	12.28[b]	0.599	0.017
ΣPUFA/ΣSFA	0.50[a]	0.40[b]	0.019	0.003
Σn-9	49.84	50.90	0.675	0.466
Σn-6	14.36[a]	11.55[b]	0.625	0.013
Σn-3	0.49	0.41	0.063	0.558
Σn-6/Σn-3	29.29	28.17	1.038	0.618

Differences between mean values with different letters (a-b) in the same row are statistically significant at P<0.05 level. SFA= saturated fatty acids, UFA= unsaturated fatty acids, MUFA= monounsaturated fatty acids, PUFA= polyunsaturated fatty acids, n-9= omega 9 fatty acids, n-6= omega 6 fatty acids, n-3= omega 3 fatty acids, [1]SEM, standard error of means.

No difference was observed in egg yolk ΣSFA, ΣUFA, ΣMUFA, Σn-9, Σn-3, and Σn-6/Σn-3 values between the quail breeds (P>0.05).

4. Discussion

The physicochemical properties of eggs are the characteristics that are most valued by consumers. Genchey (2012) reported that egg weight is among the most important parameters, not only for consumers but also for egg producers. In the present study, we found that eggs from Golden Italian quail breeds were heavier than those from Jumbo Brown quail in both the first and overall periods. Previous studies have reported significant differences in egg weights between quail breeds with different plumage colors or genotypes (Hrnčár et al., 2014; Eratalar and Okur, 2020). In another study, eggs from quails with original (wild-type) feather color were reported to be heavier than those from white, dark brown, and golden feathered quail breeds (İnci et al., 2015). Therefore, this difference among breeds may be attributed to genetic structure, age of the animal, laying cycle, diet composition, and environmental temperatures. On the other hand, the eggshell is an important feature in terms of the acceptability of eggs for hatching or table use and for keeping bacteria outside the egg. In the present study, it was found that the average eggshell proportion in weeks 16-20, and eggshell weight in the overall period were higher in Golden Italian quail breeds than in Jumbo Brown quail breeds. Hrnčár et al. (2014) also reported that eggshell weight was higher in meat-type quail breeds than in laying types, but eggshell proportion was not affected by genotype. In another study, İnci et al. (2015) found that eggshell weight was higher in quails with the original (wild type) feather color than in quails with other feather colors. Therefore, an increase in eggshell weight may be associated with an increase in egg weight. In addition, eggshell weight may vary with age, breed, anatomical structure (medullary bone development), dietary composition (presence of P, Zn, Mn, and vitamin D3), and environmental and physiological factors (disease, stress, etc.).

Eggs consist of water, proteins, lipids, minerals, and a small amount of carbohydrates. The chemical composition of eggs is another characteristic, given the importance of producers and consumers. As in chicken eggs, the most nutrient-dense part of quail eggs is yolk. In the present study, the CP content of jumbo brown quail egg yolk was higher than that of golden Italian egg yolk, and the nutrient contents of all other egg parts were similar. These results are consistent with those of previous studies (Zeweil et al., 2006; Dudusola, 2010). Jeke et al. (2018) reported that the CP content in whole eggs is similar in Jumbo Pharaoh and Manchurian golden quail breeds, and higher in A&M giant breeds. The high yolk CP content observed in the present study could potentially be explained by the jumbo brown quail's ability to utilize dietary N more effectively; therefore, the protein may accumulate more in the egg yolk. Consequently, factors such as the protein bioavailability of a specific diet and individual metabolism rate may determine how effectively quails can utilize nitrogen in their diet. Furthermore, genetic factors may also play a role in the ability of jumbo brown quail to produce eggs with a higher CP content.

Lipid oxidation is one of the most important indicators of egg quality. In this study, it was observed that the lipid oxidation marker MDA content of quail eggs stored on different days (0, 14, and 28 days) was not affected by genotype, storage time, and genotype*storage time interactions, and the yolk MDA value ranged between 0.75-0.83 mg/kg yolk. However, in studies conducted on quail eggs, no findings related to the oxidative stability of the egg yolk have been reported. Therefore, these findings were evaluated through similar studies on chicken eggs. Indeed, Goliomytis et al. (2018) reported that the egg yolk MDA value in Lohmann brown-classic laying hens varied between 3.85-5.58 ng/g yolk in eggs stored for different periods. Skřivan et al. (2016) measured the egg yolk MDA value as 0.38 mg/kg yolk on day 0 and 0.82 mg/kg yolk on day 28 in Lohmann brown laying hens. Selim and Hussein (2020) reported an egg yolk MDA value of approximately 45 ng/g yolk after a 7-day storage period in Lohman brown lite-laying hens. High MDA values may indicate the weakness of antioxidant defence mechanisms in cells or their low capacity to cope with oxidative stress. Therefore, the high MDA value in quail eggs suggests that egg yolk is more sensitive in terms of oxidative stability, and that antioxidant defense mechanisms may need to be strengthened. However, these differences between the two breeds may be attributed to diet, age, genetic factors, rearing conditions, environmental stress, temperature, humidity, and hormonal changes during egg formation. The yolk fatty acid profile, egg storage time, and conditions may also affect MDA values. In addition, the fact that the egg yolk MDA values did not change between the two breeds in the current study can be explained by the quails not being subjected to any environmental and physical treatment that would change their oxidative and redox status and being fed with the same conditions and diets. However, it has been reported that the lipid oxidation value for foods suitable for consumption is below 3 mg MDA/kg, and the upper limit is 7-8 mg MDA/kg (Cadun et al., 2005). Therefore, the MDA values obtained were within the appropriate reference range.

A good fatty acid profile is important for egg quality. Indeed, in the present study, it was determined that the fatty acid composition of quail egg yolk is primarily medium-to long-chain, i.e. 14-21 carbon atoms in length. In addition, linolelaidic acid, total PUFA, and total n-6 fatty acids were higher in the jumbo brown breeds, whereas gadoleic acid and cis 11,14-eicosadienoic acid were higher in the golden Italian breeds. Güçlü et al. (2008) found that the total SFA content of egg yolk was higher, but other total MUFA, PUFA, n-3 and n-6 values were similar to the findings of the present study. Cufadar

et al. (2021) found that quail yolk palmitic acid content was similar to the present findings, ΣSFA, ΣPUFA and Σn-3 values were higher, and ΣMUFA values were lower. In a study in which sunflower oil was added to the diets of laying quails as a fat source, it was observed that yolk ΣSFA and ΣPUFA values were higher, ΣMUFA values were lower, and Σn-3 values were similar to the present findings (Göçmen et al., 2021). On the other hand, it is recommended that the human diet as a whole should have a PUFA/SFA ratio above 0.45 and an n-6/n-3 ratio of 4:1 for a healthy life (HMSO, 1994). However, modern Western-type diets usually have a higher n-6/n-3 ratio (10-20:1 or more) (Simopoulos, 1998; 1999). In this context, in the present study, the yolk ΣPUFA/ΣSFA ratio was found to be higher in the Jumbo Brown breeds (0.50) than in the Golden Italian breeds (0.40). Özbilgin et al. (2021) found that the ΣPUFA/ΣSFA ratio of quail egg yolk was 0.58, which is higher than the findings of the present study. Thus, differences were observed between the results of egg yolk fatty acid profile of quail breeds in the present study and those of previous studies. The differences in yolk fatty acid composition may be attributed to the different utilization of dietary nutrients by the quail breeds. Genetic and microbiome factors may also be effective in metabolizing and storing fatty acids. However, the influence of genetics on fatty acid composition is significantly lower than that of diet (Sinclair, 2007). On the other hand, the relatively high levels of trans-octadecanoic acid in the current yolk fatty acid profile have been attributed to the high-concentrate diets fed to quails and the easily fermentable carbohydrate content.

5. Conclusion

Based on these results, the relatively small size of Jumbo Brown quail eggs compared to Golden Italian quail breeds and the low eggshell proportion may be considered disadvantageous for the consumer, table, or hatchery industries. However, the Jumbo Brown quail egg yolk CP, ΣPUFA, total Ω6 fatty acid content, and ΣPUFA/ΣSFA ratio have a more advantageous profile in terms of use in human diets. Moreover, it was observed that even at different storage periods in both quail breeds, yolk lipid oxidation did not exceed the acceptable threshold values. Therefore, quail eggs can be safely added to daily diets in human nutrition without overdoing, considering the amount of trans fatty acids. However, to fully understand the differences in egg quality observed between quail breeds, the diet, genetic profiles, and gut microbiome of quail breeds should be investigated in detail.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	E.Ö.G.	H.H.İ.
C	50	50
D	50	50
S	50	50
DCP	70	30
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	30	70

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

In this study, it was reported by Dicle University Health Sciences Research and Application Center Animal Experiments Local Ethics Committee (DÜHADEK) that local ethical committee approval was not required (protocol code: E- 38588763-041.02-519389 and date: June 22, 2023).

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