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The effect of breeder body mass on laying performance, egg quality, and hatching traits of Japanese quail.

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Abstract

Aim of study: The aim of this research was to determine the effect of breeder body mass on egg laying performance, egg quality, and hatching traits of Japanese quail (*Coturnix japonica*).

Area of study: This study was carried out at the Poultry Unit and Research Centre of Çukurova University in the Republic of Türkiye.

Material and methods: In this study, a sum of 216 quails were used. The quails were divided into three experimental groups during the 5 weeks of age based on their body weight: high body mass (HBM) (>310 g), medium body mass (MBM) (290- 310 g), and low body mass (LBM) (<290 g); and then transferred to egg-laying cages. There were three replicates per group. Internal and external egg quality traits, hatching traits, and egg-laying performance were examined.

Main results: Egg production was statistically highest in the MBM group and the lowest in the HBM group ($p \leq 0.05$). The HBM group had the highest average egg weight and the lowest egg weight was observed in the LBM group ($p \leq 0.05$). The Haugh unit, albumen pH, shell thickness, yolk colour traits, shape index, albumen index, hatchability of fertile eggs, and yolk index were not statistically different among the experimental groups ($p \geq 0.05$). The fertility and hatchability of set eggs were statistically highest in the LBM group and lowest in the in the HBM group ($p \leq 0.05$).

Research highlights: Selection for HBM could improve egg weight however; it may have a negative correlation with egg production and hatching traits.

Keywords: Egg quality traits; breeder body mass; hatching traits; Japanese quail.

Efecto de la masa corporal de los reproductores en el rendimiento de la puesta, la calidad de los huevos y los caracteres de incubación de la codorniz japonesa.

Resumen

Objetivo del estudio: El objetivo de esta investigación fue determinar el efecto de la masa corporal de las reproductores en el rendimiento de la puesta, la calidad de los huevos y los caracteres de incubación de la codorniz japonesa (*Coturnix japonica*).

Área de estudio: Este estudio se llevó a cabo en *Poultry Unit and Research Centre of Çukurova University*, República de Turquía.

Material y métodos: En este estudio se utilizaron un total de 216 codornices, las cuales se dividieron en tres grupos experimentales a las 5 semanas de edad según su peso corporal: alta masa corporal (HBM) (>310 g), masa corporal media (MBM) (290-310 g) y baja masa corporal (LBM) (<290 g). Luego, se trasladaron a jaulas de ponedoras. Cada grupo contó con tres repeticiones. Se examinaron las características internas y externas de calidad de los huevos, los rasgos de incubación y el rendimiento de la puesta.

Resultados principales: La producción de huevos fue estadísticamente más alta en el grupo MBM y más baja en el grupo HBM ($p \leq 0,05$). El grupo HBM tuvo el peso promedio de huevo más alto, mientras que el peso más bajo se observó en el grupo LBM ($p \leq 0,05$). No se encontraron diferencias estadísticamente significativas entre los grupos experimentales en la unidad Haugh, el pH de la albúmina, el grosor de la cáscara, el color de la yema, el índice de forma, el índice de albúmina, la incubabilidad de los huevos fértiles y el índice de yema ($p \geq 0,05$). La fertilidad y la incubabilidad de los huevos colocados fueron estadísticamente más altas en el grupo LBM y más bajas en el grupo HBM ($p \leq 0,05$).

Aspectos destacados de la investigación: La selección para HBM podría mejorar el peso del huevo; sin embargo, podría tener una correlación negativa con la producción de huevos y los caracteres de incubación.

Palabras clave: Caracteres de calidad del huevo; masa corporal de las reproductoras; caracteres de incubación; codorniz japonesa.

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Introduction

The production of poultry eggs, especially chicken eggs, has gained substantial interest due to their nutritional benefits, price, and the lack of any religious or traditional condemnation. Moreover, the recent rise in the global economic crisis, especially in developing and underdeveloped countries, has increased the global demand for chicken eggs as the main source of animal protein (Abdallah et al., 2022). Additionally, the demand for poultry products, especially eggs has increased tremendously due to increasing levels of income and standard of living (Pomaah et al., 2023). This has led to an increased interest in the production of other alternative poultry species such as quails for both eggs and meat. For instance, in India, the Japanese quails (*Coturnix japonica*) have been reported as promising poultry species for rural farmers due to their low cost of production and management (Bagh et al., 2016). Japanese quails are the smallest farmed poultry species in terms of size (Panda & Singh, 1990), and are becoming highly significant for their eggs and meat (Dahouda et al., 2013; Mahrose et al., 2021).

One of the most important sources of nutrients is eggs and some authors have reported that the eggs of Japanese quails are rich in minerals, vitamins, and antioxidants with 3-4 times superior nutritional value compared to chicken eggs (Lalwani, 2011; Tunsaringkarn et al., 2013; Cadillo et al., 2023). An average quail egg weighs around 11g (Tolik et al., 2014). A higher albumen protein content **(**Genchev, 2012**)** and lower yolk fat content (Sınanoglou et al., 2011) in quail eggs have been reported. Female Japanese quails have a high egg production rate and can lay around 300 eggs per year with their egg production cycle starting around 6 weeks of age (Kaur et al., 2008; Dzuriatmono et al., 2019). Other authors also reported that sexual maturity in Japanese quails may vary between 35 and 45 days (Thomas & Ahujam, 1988; Mınvıelle et al., 2000; Camci et al., 2002; Reddish et al., 2003; Sezer et al., 2006; Alkan et al., 2009; Karabağ et al., 2010**)**. Additionally, a peak production ratio of 88-98% with the peak egg production cycle around 3 months of age has been identified in quails (Nestor & Bacon, 1994; Mınvıelle et al., 2000; Matos et al., 2023).

The internal and external quality of hatching and table eggs are very important for the egg industry (Kocevski, et al., 2011; Hatab et al., 2024). For instance, Khurshid et al. (2003) elaborated that traits such as yolk and albumen weight, shell thickness, shell and egg weight influence hatching performance if other management conditions and fertility are not the limiting factors. Additionally, the breeder's body weight is also an important factor that influences egg-laying performance, hatching and egg quality traits. Martin et al. (1998) reported that female Japanese quails deposit 8% of their body weight in their eggs as compared to only 3% in the case of laying hens. Although, an increase in egg weight has been achieved through selection for higher live weight, this could have negative implications on egg production. To ensure maximum egg production with better egg quality and hatching traits, the selection of breeder parents with the appropriate body weight is very important. Breeder parents with higher body weight are more likely to have higher abdominal fat content, which has an inverse association with hormones related to reproduction. On the other hand, the selection of breeder parents with lower or medium body could have detrimental limitation on the amount of body weight deposited in the egg, resulting in a negative effect on egg quality, hatching traits and egg production. This could also compromise the welfare of the breeder parents.

Therefore, this study investigated the effect of breeder body mass on laying performance, quality, and hatching traits of Japanese quail eggs.

Material and Methods

Housing facility and experimental animals

This study was carried out at the Research and Experimental Unit of Çukurova University in the Republic of Türkiye with a total of 216 quails. Chick and grower conventional cages were used for rearing of the quails for the first 2 weeks (wk) of age and from 2-5 wk of age, respectively. The quails were then transferred to egg-laying cages on the 5 wk (age).

Experimental treatments and replicates

During the 5 wk of age, the young breeder pullets and cockerels were weighed individually using a scale (SCALTEC SBA 41, Germany) with a precision of 0.1 g. After determining their body mass, the birds were allocated to one of the experimental body weight groups: high body mass (HBM) (>310 g), medium body mass (MBM) (290-310 g), and low body mass (LBM) (<290 g); with three replicates per group. For each replicate, the ratio of male to female was 6:18. The ratio of male to female used in each experimental group and replicate is shown in Table 1.

Composition of animal feed used during the experimental period

During the rearing or growing period, a diet containing 22% crude protein, 3000 kcal/kg metabolic energy (ME), 1.1% calcium and 0.43% phosphorus was used. A diet containing 17% crude protein, 2750 kcal/kg ME, 3.5% calcium and 0.42% phosphorus was used during the egg production period. Feed and water were provided *ad libitum*.

Photoperiod during rearing and egg-laying cycle

The birds were exposed to a photoperiod (L, light: D, darkness) of 22 hours (h) of L:2h of D from the first 0-3 days (d) of age, and 21h L:3h D from 4-7 d of age. From 2-5 wk of age, a photoperiod of 10h L:14h D was practiced. Thereafter, 16h L:8h D was ensured throughout the entire egg-laying phase.

Evaluation of egg laying performance

Eggs from the various experimental replicates were collected, counted, and weighed individually every day in the morning throughout the egg-laying period. The collected eggs were weighed using a scale (SCALTEC SBA 41, Germany) with a precision of 0.1 g, and the overall egg weight was evaluated at group level. Additionally, the percentage of total egg production was evaluated at group level using the formula below (Baylan et al., 2024).

$$\text{Egg production rate (\%)} = \frac{\text{Total number of eggs produced during the laying period}}{\text{Total number of hens}} \times 100$$

Incubation conditions and evaluation of hatching traits

A total of three trays with 50 eggs per tray were incubated for each experimental group. The collected fertile eggs were incubated at a standard incubation temperature (37.7 ˚C) and humidity (65%) up to day (d) 15 of incubation. At d 15 of incubation, the eggs were transferred to the hatchery machine at a humidity of 75% and a temperature of 37.5 ˚C. The hatchability of set eggs, hatchability of fertile eggs, and fertility for each replicate tray were calculated, and the overall hatchability of set eggs, hatchability of fertile eggs, and fertility were evaluated at the group level. The formula below was used for evaluating the respective parameters (Allanah et al., 2014; Fathi et al., 2022).

$$\text{Hatchability of set eggs (\%)} = \frac{\text{Total number of hatched chicks}}{\text{Total number of eggs set}} \times 100$$

$$\text{Hatchability of fertile eggs (\%)} = \frac{\text{Total number of hatched chicks}}{\text{Total number of fertile set}} \times 100$$

$$\text{Fertility (\%)} = \frac{\text{Total number of fertile eggs}}{\text{Total number of eggs used}} \times 100$$

Table 1. The ratio of male-to-female Japanese quails in each experimental group and replicate.

	Replicates (No)					
	1		2		3	
	Male	Female	Male	Female	Male	Female
HBM	6	18	6	18	6	18
MBM	6	18	6	18	6	18
LBM	6	18	6	18	6	18
Total	18	54	18	54	18	54

LBM; Low body mass (<290 g). MBM; Medium body mass (290- 310 g). HBM; High body mass (>310 g).

Evaluation of egg quality traits

On the 18 wk of age, the internal and external quality traits of 15 egg samples per experimental group were analysed. Each egg per group was assessed individually for the egg quality trait and the overall average value was evaluated based on group level. The external quality traits included egg weight, shape index, and shell thickness, while the internal quality traits comprised the yolk colour traits (L*; brightness, a*; redness, b*; yellowness), albumen pH, Haugh unit, yolk index and albumen index. The egg weight was measured using a scale with a precision of 0.1 g (SCALTEC SBA 41, Germany) and a digital Vernier calliper with a precision of ± 0.01 mm (INSIZE 1112-150, Brazil) was used in measuring the egg length and width, the albumen height, width, and length as well as the yolk height and width. Shell thickness was measured by taking portions of eggshells from the broad, middle, and narrow parts. The thickness of each part was then measured with a digital shell thickness gauge with a precision of 0.01 mm (ORKA 100823, Russia) and the mean value of the three portions was recorded. The albumen pH was recorded by separating the albumen from the yolk. The albumen was then collected in a disposable transparent cup and a pH meter (Desc ST300-G, China) was inserted in it for 20-30s. The yolk was collected into a petri dish and then placed into a Konica Minolta Colorimeter device (ColorFlex EZ CR-300, USA) to determine the yolk colour values. The formulae below were used in calculating the respective parameters (Abdallah et al., 2024; Kurşun et al., 2024; Tainika et al.,2024).

$$\text{Shape Index (\%)} = \frac{\text{Egg Width}}{\text{Egg Length}} \times 100$$

$$\text{Shell thickness (mm)} = \frac{\text{narrow + middle + broad portions}}{3} \times 100$$

$$\text{Yolk Index (\%)} = \frac{\text{Yolk height}}{\text{Yolk diameter}} \times 100$$

$$\text{Albumen Index (\%)} = \frac{\text{Albumen Height}}{\text{Average of Albumen lenght and width}} \times 100$$

Haugh Unit =100 log (H+7.57-1.7 x $G^{0.37}$)
G: Egg weight.
H: Albumen height.

Statistical analysis

With the software SPSS version 22, the test of normality of the data was conducted using the Shapiro-Wilk test and all the data showed normal distribution. One-way ANOVA analysis, Duncan test was conducted to analyze the significant difference among the experimental groups. The significant level was accepted at $p \leq 0.05$.

Results

The effect of breeder body mass on average egg weight and total egg production is presented in Table 2. A statistical difference among the experimental groups in relation to overall egg production and egg weight was identified ($p \leq 0.05$). The MBM and HBM groups had the highest and lowest rate of egg production, respectively. However, the highest and lowest average egg weight was observed in the HBM and LBM groups, respectively.

The influence of breeder body mass on external and internal egg quality traits is given in Table 3. There was no significant difference in terms of the egg quality traits among the groups (P>0.05) however; shape index, shell thickness, egg weight, yolk and albumen index, and Haugh unit were all numerically higher in the HBM group than the other groups. Furthermore, the egg weight nearly approached a significant level (p=0.080), which was highest in the HBM group and lowest in the LBM group.

The effect of breeder body mass on yolk colour traits is presented in Table 4. The yolk colour traits were not statistically different between the experimental groups (P>0.05). However, eggs from the MBM group had

Table 2. Effect of breeder body mass on average total egg production and egg weight in Japanese quails (Mean ± SEM).

	Overall Egg Production (%)	Overall Egg Weight (g)
HBM	57.21±3.58[a]	13.38±1.2[a]
MBM	73.83±4.09[b]	13.00±0.78[b]
LBM	70.88±4.17[c]	12.58±0.71[c]
SEM	9.48	2.78
	P values	
	0.010	0.037

Levels not connected by the same letters are significantly different. LBM; Low body mass (<290 g). MBM; Medium body mass (290- 310 g). HBM; High body mass (>310 g). SEM: Standard error of mean.

numerically higher yolk colour trait values than those from the other groups. The redness of the yolk colour nearly reached a significant level (p=0.067), which was highest in the MBM group and lowest in the LBM group.

The effect of breeder body mass on hatching traits is given in Table 5. A significant difference ($p \leq 0.05$) in terms of the hatchability of set eggs and fertility among the groups was identified. The LBM and HBM groups had the highest and lowest fertility and hatchability of set eggs, respectively. Although the hatchability of fertile eggs did not differ significantly among the groups (P>0.05), numerically it was highest in the LBM and lowest in the HBM group.

Discussion

The HBM group in the current study had the lowest overall egg production but the highest overall egg weight.

Table 3. Influence of breeder body mass on egg quality traits in Japanese quails (Mean ± SEM).

	External Egg Quality Traits			Internal Egg Quality Traits			
	Egg Weight (g)	**Shape Index (%)**	**Eggshell Thickness (mm)**	**Yolk Index (%)**	**Albumen Index (%)**	**Albumen pH**	**Haugh Unit**
HBM	13.57±1.31	78.94±2.48	0.23±1.88	44.87±4.13	9.91±3.16	8.69±0.07	86.88±7.61
MBM	13.33±1.12	77.78±2.41	0.27±1.76	44.75±4.99	9.69±3.60	8.73±0.08	86.47±8.17
LBM	12.85±1.28	78.34±3.51	0.22±1.28	44.00±5.22	8.29±2.99	8.72±0.08	83.38±8.55
SEM	2.79	11.01	2.97	6.14	2.70	2.70	12.09
	P values						
	0.080	0.290	0.136	0.751	0.118	0.208	0.196

LBM; Low body mass (<290 g). MBM; Medium body mass (290- 310 g). HBM; High body mass (>310 g). SEM: Standard error of mean.

Table 4. Effect of breeder body mass on yolk colour traits in Japanese quails (Mean ± SEM).

	Yolk Colour Traits		
	L* (Brightness)	**a* (Redness)**	**b* (Yellowness)**
HBM	40.97±14.68	20.93±7.54	42.48±16.11
MBM	45.34±9.19	23.75±5.33	47.29±9.92
LBM	42.09±8.72	20.67±5.11	43.29±10.28
SEM	5.91	3.39	6.13
	P values		
	0.159	0.067	0.162

LBM; Low body mass (<290 g). MBM; Medium body mass (290- 310 g). HBM; High body mass (>310 g). SEM: Standard error of mean.

Table 5. Influence of breeder body mass on hatching traits in Japanese quails (Mean ± SEM).

	Hatching Traits		
	Hatchability of fertile eggs (%)	**Hatchability of set eggs (%)**	**Fertility (%)**
HBM	72.37±16.22	58.59±15.40^{a}	81.00±9.86^{a}
MBM	81.13±8.04	71.62±8.73^{b}	87.61±3.65^{b}
LBM	81.28±9.17	73.95±10.80^{c}	90.67±3.87^{c}
SEM	11.03	9.58	12.24
	P values		
	0.119	0.009	0.003

Levels not connected by the same letters are significantly different. LBM; Low body mass (<290 g). MBM; Medium body mass (290- 310 g). HBM; High body mass (>310 g). SEM: Standard error of mean.

Similar to our observations, other authors also reported lower egg production but a higher egg weight among hens, and Japanese quails with high body mass (Ipek et al., 2004; Alkan et al., 2010; Taskin et al., 2017; Ekinci et al., 2023). Additionally, Jatoi et al. (2013) confirmed that imported and local hens with high body masses laid eggs with heavier weights compared to their counterparts with medium or low body masses. Contrary to the findings of the present study, Ocak et al. (2004) identified higher egg weight and egg production in hens with high body masses compared to those with low, and medium body masses. Akşit et al. (2003) reported higher egg production and egg weight in hens with low and medium body masses compared to those with high body mass. Additionally, Tyasi et al. (2024) identified heavier egg weight in hens with low and medium body masses compared to those with high body mass.

It was reported that birds with high body mass ovulate heavier or larger egg yolks leading to heavier eggs however, their ovaries lose their function causing a reduction in egg production (Lacin et al., 2008; Najib & Yousif, 2014; Muir et al., 2022b**)**. Moreover, it could be possible that the birds with the high body mass had higher abdominal fat content which has been reported to have a negative correlation with egg production performance (Whitehead et al*.,* 1990; Zhang et al., 2018;). Indeed, Ocak et al. (2004) identified a higher significant abdominal fat in laying hens with high body mass compared to those with medium or low body masses. Robinson & Robinson (1991) reported that at 22 and 62 weeks of age, body fat composition was higher in breeders with high body mass compared to those with medium and low body masses. Akşit et al. (2003) also reported higher levels of triglyceride in breeder hens with high body mass than those with medium and low body masses. Moreover, Walzem & Chen (2014**)** identified that the ovarian function of hens was compromised by fattening/obesity due to the fact that it caused a proapoptotic effect on granulosa cells and also altered hormone production. Since granulosa cells play a major role in ovarian functionality (Zhu et al., 2019), the apoptotic death of the granulosa cells negatively affects ovarian functioning and follicular development. This reason might have contributed to the lower egg production observed in the group with high body mass. It could also be possible that high breeder body mass influences the normal functioning of the hypothalamic-adenohypophyseal-gonadal axis which in turn influences egg production rate. Probably, high body mass might have stimulated the mechanism that activates follicular atresia causing a reduction in the rate of follicular maturation with subsequent reduction in egg production.

In the current study, no significant difference was observed in relation to the external and internal egg quality traits among the experimental groups. In agreement with our findings, other authors have reported no significant effect of breeder body mass on yolk height, yolk index, shape index, Haugh unit and shell thickness in both Japanese quails and other poultry species (Altan et al., 1998; Ocak et al., 2004; Lacin et al., 2008; Ojo et al., 2019**)**. Contrary to the results of the current study, Jatoi et al. (2015) reported higher shell thickness and yolk index in eggs from breeder parents with high body mass. Moreover, higher eggshell thickness has been reported in broiler breeders with high body mass (Akşit et al., 2003). Furthermore, Kırıkcı et al. (2007) reported that breeder body mass had no significant effect on shape and yolk index however, albumen index and Haugh unit was significantly higher in eggs from breeders with low and medium body masses compared to eggs from breeders with high body mass. From the same study, shell thickness was highest in eggs from breeders with medium body mass compared to eggs from breeders with low and high body masses. In addition, it was reported that eggs from pheasants with low body mass had significantly highest and lowest shape index and shell thickness respectively, while the yolk index and Haugh unit was significantly highest in eggs from breeders with higher body mass than eggs from breeders with low and medium body masses (Kırıkçı et al., 2004). The differences in the various reports could be attributed to the breed of quail used, the nutritional components of the experimental feed, and the age of the quails. Moreover, the type of housing system used could be an additional factor affecting the utilization of nutrients leading to variation in the results reported by the various authors.

Although the LBM group had the smallest egg weight, the hatchability of set eggs and fertility were significantly higher in the LBM group compared to the other groups. Similarly, Cahaner et al. (1986) observed that at 35 and 48 weeks of age, the fertility, hatchability of set and fertile eggs of hens from low-fat lines was higher than that of hens from high-fat lines. In addition, selection for higher body mass has been reported to decrease hatchability and fertility of Japanese quails (Rehman et al., 2022). Furthermore, Zhang et al. (2018) have reported higher fertility and hatchability in breeder parents from lean genetics lines compared to those from fat genetic lines. It was suggested that in the current study, the LBM group might have been characterised with lower levels of abdominal fat and Zhang et al. (2018) speculated that the high level of hormones related to reproduction (luteinizing hormone, estrogen and follicle stimulating hormone) which in turn influences the growth of the reproductive system of the female and ovulation might have contributed to the higher rate of fertility in parents from lean female lines. This reason might account for the higher fertility observed in the LBM group than the other groups. Additionally, hatchability has been reported to be influenced by incubation conditions and egg quality, which in turns affect the quality of oocyte (Zhang et al*.,* 2018). Walzem & Chen **(**2014) reported that poor-quality oocytes in chickens has been linked to obesity/fattening and hence, it is suggested that the HBM group might have possessed higher abdominal fat content which negatively affected the expression of genes related to maturation and follicular development as well as reproductive hormones, leading to poor-quality oocytes and the subsequent reduction in hatchability.

Selection for high breeder body mass could improve egg weight however, it may have a negative correlation with egg production and hatching traits.

Ethical approval: This study was conducted under the guidelines for animal experiments of the Ministry of Food, Agriculture and Livestock, Türkiye. Approval was granted by the animal experiments local ethics committee of Cukurova University (Approval number: No 5/ 28.03.2024).

Competing interests: The authors have declared that no competing interests exist.

Authors' contributions: Busra Ozkan: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization. **Nasir Abdallah:** Writing – original draft, Writing – review & editing. **Yunus Emre Boga:** Formal analysis. **Kadriye Kursun:** Writing – review & editing. **Mikail Baylan:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization.

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References

Abdallah N, Kursun K, Baylan M, 2024. Egg quality traits of French pekin ducks reared under the indoor housing systems. In 8th Int Student Science Conf, Izmir (Türkiye), May 23-24. pp: 23-24. https://doi.org/10.52460/issc.2024.029

Abdallah N, Boga YE, Kursun K, Baylan M, 2022. Automation in layer hen production. Int Conf on Research of Agricultural and Food Technologies, Adana (Türkiye), Dec 22. pp:9.

Allanah TO, Okonkwo JC, Omeje SI, 2014. Fertility and hatchability characterization of three strains of egg type chickens. J Biosci: 3(6) 59-68. https://doi.org/10.14196/sjbs.v3i6.1537

Alkan S, Karabag K, Galic A, Balcioğlu MS, 2009. Effects of season and line on sexual maturity and some egg yield traits in selected Japanese quails. J Appl Anim Res: 35(2): 105-108. https://doi.org/10.1080/09712119.2009.9706997

Alkan S, Karabağ K, Galiç A, Karsli T, Balcioğlu MS, 2010. Effects of selection for body weight and egg production on egg quality traits in Japanese quails of different lines and relationships between these traits. Kafkas Univ Vet Fak Derg: 16 (2): 239-244. htpps://doi.org/10.9775/kvfd.2009.633

Akşit M, Yalçın S, Karul AB, 2003. Physiological stress parameters during food withdrawal period in force moulted hens. Arch fur Geflügelkd: 67 (5): 212 – 216.

Altan Ö, Oğuz İ, Akbaş Y, 1998. Effects of selection for high body weight and age of hen on egg characteristics in Japanese Quail. Turk J Vet Anim Sci: 22(6): 467-474.

Bagh J, Panigrahi B, Panda N, Pradhan CR, Mallik BK, Majhi B, Rout SS, 2016. Body weight, egg production, and egg quality traits of gray, brown, and white varieties of Japanese quail in coastal climatic condition of Odisha. Vet World: 9(8): 832. https://doi.org/10.14202/vetworld.2016.832-836

Baylan M, Kursun K, Abdallah N, Celik LB, Yenilmez F, Kutay H, 2024. The effect of housing systems on the growth, egg production, overall egg weight and egg quality traits of a new Turkish laying hen hybrid, Akbay. Rev Bras Cienc Avic:26(3):eRBCA-2024. https://doi.org/10.1590/1806-9061-2024-1924

Cadillo AE, Malaver RH, Herrera FF, Degollar EM, Julca AC, Lara RT, Martineza RP, 2023. Analysis of Quality and Shelf Life of Quail Eggs in Sauce of Beta Vulgaris" Beterraga". Chem Eng Trans: 101:247-52. https://doi.org/10.3303/CET23101042

Cahaner A, Nitsan Z, Nir I, 1986. Reproductive performance of broiler lines divergently selected on abdominal fat. Poult Sci: 65(7):1236-43. https://doi.org/10.3382/ps.0651236

Camci, O, Erensayin C, Aktan S, 2002. Relations between age at sexual maturity and some production characteristics in quails. Arch fur Geflugelkd: 66(6): 280-282.

Dahouda M, Adjolohoun S, Montchowui EH, Senou M, Hounsou NMD, Amoussa S, Vidjannagni DS, Abou M, Toleba SS, 2013. Growth performance of quails (Coturnix coturnix) fed on diets containing either animal or vegetable protein sources. Int J Poult Sci: 12(7): 396-400. https://doi.org/10.3923/ijps.2013.396.400

Dzuriatmono ST, Widyas N, Cahyadi M, Wati AK, Dewanti R, 2019. Egg production of black and brown Japanese quails raised under battery cage system. The 8th Int Sem on Tropical Animal Production, Yogyakarta (Indonesia), Sept 23–25 (Indonesia). pp:012042. https://doi.org/10.1088/1755-1315/387/1/012042

Ekinci O, Esenbuga N, Dagdemir V, 2023. The effects of body weight and age on performance, egg quality, blood parameters, and economic production of laying hens. J Hell Vet Medical Soc: 74(2): 5809-5816. https://doi.org/10.12681/jhvms.30324

Fathi M, Abou-Emera O, Al-Homidan I, Galal A, Rayan G, 2022. Effect of genotype and egg weight on hatchability properties and embryonic mortality pattern of native chicken populations. Poult Sci: 101(11):102129. https://doi.org/10.1016/j.psj.2022.102129

Genchev A, 2012. Quality and composition of Japanese quail eggs (Coturnix Japonica). TJS: 10(2): 91-101.

Hatab MH, Chen W, Abouelezz K, Elaroussi M, Badran A, Zoheir K, El-Komy E, Li S, Elokil A, 2024. Effects of exposing Japanese quail eggs to a low dose of gamma radiation and in ovo feeding by two sources of trace elements on embryonic development activities. Poult Sci:103(3):103364. https://doi.org/10.1016/j.psj.2023.10336

Ipek A, Sahan U, Yilmaz B, 2004. The effect of live weight, male to female ratio and breeder age on reproduction performance in Japanese quails. S Afr J Anim Sci: 34(2): 130-134.

Jatoi AS, Sahota AW, Akram M, Javed K, Jaspal MH, Mehmood S, Hussain J, Ishaq HM, Bughio E, 2015. Egg quality characteristics as influenced by different body sizes in four close-bred flocks of Japanese quails. J Anim Plant Sci: 25(4): 921-926.

Jatoi AS, Sahota AW, Akram M, Javed K, Jaspal MH, Hussain J, Mirani AH, Mehmood S, 2013. Effect of different body weight categories on the productive performance of four close-bred flocks of Japanese quails. J Anim Plant Sci: 23(1): 7-13.

Karabağ K, Alkan S, Balcıoglu MS, 2010. The differences in some production and clutch traits in divergently selected Japanese quails. Kafkas Univ Vet Fak Derg: 16(3):383-387.

Kaur S, Mandal AB, Singh KB, Kadam MM, 2008. The response of Japanese quails (heavy body weight line) to dietary energy levels and graded essential amino acid levels on growth performance and immuno-competence. Livest Sci: 1:117(2-3):255-62. https://doi.org/10.1016/j.livsci.2007.12.019

Khurshid A, Farooq M, Durrani FR, Sarbiland K, Chand N, 2003. Predicting egg weight, shell weight, shell thickness and hatching weight of Japanese quail using various egg traits as regressors, Int J Poult Sci: 2: 164-167. https://doi.org/10.3923/ijps.2003.164.167

Kırıkçı K, Günlü A, Cetin O, Garip M, 2007. Effect of hen weight on egg production and some egg quality characteristics in the partridge (Alectoris graeca). Poult Sci: 86(7):1380-3. https://doi.org/10.1093/ps/86.7.1380

Kırıkçı K, Çetin O, Günlü A, Garip M, 2004. Effect of hen weight on egg production and some egg quality characteristics in pheasants (Phasianus colchicus). Asian-Australas J Anim Sci: 17(5):684-687. https://doi.org/10.5713/ajas.2004.684

Kocevski D, Nikolova N, Kuzelov A, 2011. The influence of strain and age on some egg quality parameters of commercial laying hens. 3rd Int Conf "New Perspectives and Challenges of Sustainable Livestock Production, Belgrade (Republic of Serbia), Oct 5–7. pp: 1649-1655.

Kurşun K, Abdallah N, Baylan M, 2024. Egg quality characteristics of Sussex chickens reared under the housing conditions of Cukurova University farm. Int Conf on Research of Agricultural and Food Technologies, Adana (Türkiye), Oct 4-6. pp: 01047. https://doi.org/10.1051/bioconf/20248501047

Lacin E, Yildiz A, Esenbuga N, Macit M, 2008. Effects of differences in the initial body weight of groups on laying performance and egg quality parameters of Lohmann laying hens. Czech J Anim Sci: 53(11): 466-471.

Lalwani, 2011 cited from Tunsaringkarn T, Tungjaroenchai W, Siriwong W, 2013. Nutrient benefits of quail eggs. IJSRP: 3(5):1-8.

Mahrose KM, Michalak I, Farghly M, Elokil A, Zhang R, Ayaşan T, Mekawy A, Fazlani S, 2021. Role of clay in detoxification of aflatoxin B 1 in growing Japanese quail with reference to gender. Vet Res Commun: 45:363-371. https://doi.org/10.1007/s11259-021-09817-z

Matos Júnior JJ, Furtado DA, Ribeiro NL, Marques JI, Leite PG, Nascimento JW, Rodrigues VP, Lopes Neto JP, Rodrigues LR, Santos SG, Oliveira AG, 2023. Productive performance, egg quality and the morphometry of the organs of Japanese quails (Cotournix cotournix Japônica) kept at different temperatures. Food Sci Technol: 43: e117822. https://doi.org/10.1590/fst.117822

Martin AG, Franklin WM, Maffiol A, 1998. Quail: An egg and meat production system. ECHO, USA: 1-14.

Minvielle F, Monvoisin JL, Costa J, Maeda Y, 2000. Long-term egg production and heterosis in quail lines after within-line or reciprocal recurrent selection for high early egg production. Br Poult Sci: 41(2): 150-157. https://doi.org/10.1080/713654914

Muir WI, Akter Y, Bruerton K, Groves PJ, 2022. The influence of hen size and diet nutrient density in early lay on hen performance, egg quality, and hen health in late lay. Poult Sci: 101(10): 102041. https://doi.org/10.1016/j.psj.2022.102041

Najib H, Al-Yousif Y, 2014. Egg size Saudi local layers as affected by line of the bird (body weight at sexual maturity) and Dietary fat level. Int J Poult Sci: 13(8): 442-448. https://doi.org/10.3923/ijps.2014.442.448

Nestor KE, Bacon WL, 1994. Changes in the frequency and size of smooth muscle tumors in Japanese quail lines differing in body weight. Poult Sci: 73(7):947-952. https://doi.org/10.3382/ps.0730947

Ocak N, Sarica M, Erener G, Garipoglu AV, 2004. The effect of body weight prior to molting in brown laying hens on egg yield and quality during second production cycle. Int J Poult Sci: 3(12): 768-72. https://doi.org/10.3923/ijps.2004.768.772

Ojo V, Ayorinde KL, Fatoki HO, 2019. Relationship between body weight and some egg production trait in the Japanese quail. NISEB: 11(1): 89-94.

Panda B, Singh RP, 1990. Development in Processing Quail. Worlds Poult Sci J: 46: 219-234.

Pomaah AN, Abdallah N, Kurşun K, Baylan M, 2023. Egg production and consumption: a case study in Teshie municipality (Ghana). OKÜ Fen Bil Ens: 12 (6 Ek Sayı):454-66. https://doi.org/10.47495/okufbed.1265446

Reddish JM, Nestor KE, Lilburn MS, 2003. Effect of selection for growth on onset of sexual maturity in random bred and growth-selected lines of Japanese quail. Poult Sci: 82(2):187-191. https://doi.org/10.1093/ps/82.2.187

Rehman A, Hussain J, Mahmud A, Javed K, Ghayas A, Ahmad S, 2022. Productive performance, egg quality, and hatching traits of Japanese quail lines selected for higher body weight and egg number. Turk J Vet Anim Sci: 46(2): 322-335. https://doi.org/10.55730/1300-0128.4180

Robinson FE, Robinson NA, 1991. Reproductive performance, growth rate and body composition of broiler breeder hens differing in body weight at 21 weeks of age. Can J Anim Sci: 71(4):1223-31. https://doi.org/10.4141/cjas91-145

Sezer M, Berberoglu E, Ulutas Z, 2006. Genetic association between sexual maturity and weekly live-weights in laying-type Japanese quail. S Afr J Anim Sci: 36(2): 142-148. https://doi.org/10.4314/sajas.v36i2.3997

Sınanoglou VJ, Strati IF, Miniadis-Meimaroglou S, 2011. Lipid, fatty acid and carotenoid content of edible egg yolks from avian species: A comparative study. Food Chem: 124(3): 971-977. https://doi.org/10.1016/j.foodchem.2010.07.037

Tainika B, Şekeroğlu A, Akyol A, Şentürk YE, Abaci SH, Duman M, 2024. Effects of Age, Housing Environment, and Strain on Physical Egg Quality Parameters of Laying Hens. Rev Bras Cienc Avic: 26(03), eRBCA-2024. https://doi.org/10.1590/1806-9061-2024-1911

Taskin A, Karadavut U, Tunca RI, Genc S, Cayan H, 2017. Effect of selection for body weight in Japanese quails on some production traits. Indian J Anim Res: 51 (2): 358-364. https://dx.doi.org/10.18805/ijar.11466

Thomas PC, Ahuja SD, 1988. Improvement of broiler quails of CARI through selective breeding. Poultry guide: 25(10): 45-47.

Tolik D, Poawska E, Charuta A, Nowaczewski S, Cooper R, 2014. Characteristics of egg parts, chemical composition and nutritive value of Japanese quail eggs–a review. Folia Biol (Kraków): 62(4):287-292. https://doi.org/10.3409/fb62_4.287

Tunsaringkarn T, Tungjaroenchai W, Siriwong W, 2013. Nutrient benefits of quail eggs. IJSRP: 3(5): 1-8.

Tyasi TL, Sathekge LJ, Hlokoe VR, 2024. Association of Different Body Sizes and Egg Quality Characteristics in White Leghorn Chicken Breed of South Africa. Measurements. J World`s Poult Res: 14(2): 154-159. https://dx.doi.org/10.36380/jwpr.2024.16

Walzem RL, Chen SE, 2014. Obesity-induced dysfunctions in female reproduction: lessons from birds and mammals. Adv Nutr: 5: 199–206. https://doi.org/10.3945/an.113.004747

Whitehead CC, Armstrong J, Herron KM, 1990. The growth to maturity of lean and fat lines of broiler chickens given diets of different protein content: body composition, plasma lipoprotein concentration and initial egg production. Anim Prod: 50: 183–190. https://doi.org/10.1017/S000335610000458X

Zhang XY, Wu MQ, Wang SZ, Zhang H, Du ZQ, Li YM, Cao ZP, Luan P, Leng L, Li H., 2018. Genetic selection on abdominal fat content alters the reproductive performance of broilers. Animal: 12(6): 1232-1241. https://doi.org/10.1017/S1751731117002658

Zhu G, Fang C, Li J, Mo C, Wang Y, Li J, 2019. Transcriptomic diversification of granulosa cells during follicular development in chicken. Sci Rep: 9(1): 5462. https://doi.org/10.1038/s41598-019-41132-1