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Evaluation of Phenotypic and Genetic Parameters Affecting Reproductive and Productive Traits in Two Quail Strains

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ABSTRACT

The study investigated the influence of genetic strain, generation, and their interaction on reproductive and productive traits in Ukrainian and Jumbo quail breeds. Ukrainian quails showed significantly ($P \leq 0.05$) superior reproductive performance, with higher fertility (90.06 vs. 84.43%) hatchability of set eggs (86.59 vs. 81.22%) and hatching weight (9.45 vs. 8.53g) compared to Jumbo quails, while hatchability of fertile eggs was similar. The progeny generation (G2) exhibited relatively improved fertility (89.52 vs. 84.98%) and hatchability of set eggs (85.00 vs. 82.81%) compared to the parent generation (G1), although G1 showed higher hatchability of fertile eggs (97.44 vs. 94.97%). Ukrainian quails reached sexual maturity earlier (35.50 vs. 36.00 days) and attained higher body weight at first egg (278.34 vs. 236.99 g) first egg weight (10.41 vs. 9.79 g) and mean egg weight (12.36 vs. 11.40 g). Phenotypic correlations revealed negative associations between age at maturity and body weight ($r = -0.326$) or egg weight ($r = -0.112$), and a positive correlation between body weight and egg weight ($r = 0.492$). Heritability estimates were higher for productive traits ($h^2 = 0.56-0.62$) than for reproductive traits ($h^2 = 0.15-0.22$). Strong genetic correlations ($r = 0.43-0.57$) between body weight and egg weight were observed. These findings provide insights for improving quail productivity through selection.

Introduction

The quail is one of the most efficient poultry species, contributing significantly to the commercial poultry industry due to its exceptional egg and meat production (Mizutani, 2003, Boni *et al.*, 2010). Quail meat is particularly valued for its low fat and cholesterol levels, making it a healthier alternative to other poultry products, while their eggs are highly regarded for their rich protein content and distinct flavor (Minvielle, 2004). These birds offer several breeding advantages, including a short generation interval, minimal space requirements, early sexual maturity, rapid growth, high reproductive efficiency, and strong disease resistance (Baumgartner, 1994, Minvielle, 2004, Alkan *et al.*, 2010). These attributes make Japanese quail an excellent candidate for genetic selection programs focused on improving egg and meat productivity.

Highly adaptable, quails can thrive in diverse environmental conditions, making them well-suited to various geographical regions across the world (Farahat *et al.*, 2018, Mnisi *et al.*, 2021). Their resilience has facilitated their widespread distribution and contributed to the development of specialized lines, breeds, and strains designed for specific production purposes, including laboratory strains for research and commercial strains for egg and meat production. Key reproductive and performance traits, such as egg weight, egg production, age at sexual maturity, body weight, fertility, and hatchability, are essential for breeding programs focused on laying quails (Rozempolska-Rucińska *et al.*, 2011, Venturini *et al.*, 2012, Icken *et al.*, 2013). Research has shown considerable variation in these traits among different quail strains (Aboul-Seoud, 2008), highlighting the significance of genetic and phenotypic analyses in guiding effective selection strategies for enhanced egg production (Rosa1 *et al.*, 2018).

The development of distinct quail breeds has been influenced by the demand for specific traits, such as improved meat yield or higher egg production (Ramadan *et al.*, 2022, Elkhaiaf *et al.*, 2023). Currently, there are approximately 70 domestic quail breeds or strains, each exhibiting unique physical and genetic characteristics. Although all domestic quails originate from wild populations, their precise ancestry and the specific wild strains involved in their domestication remain uncertain (Lukanov and Pavlova, 2020). Studies suggest that multiple wild populations contributed to their domestication, with selective breeding enhancing favorable traits over successive generations (Chang *et al.*, 2005).

As global poultry demand continues to rise, quails are expected to play an increasingly important role, particularly in regions with harsh climates or limited resources (Arunrao *et al.*, 2023). Genetic selection has been widely employed in animal breeding programs, focusing on traits such as increased body weight, and has proven to be an effective approach in improving quail productivity (Hassan *et al.*, 2011, Hassan and Fadhil, 2019). This study aims to evaluate the phenotypic and genetic parameters associated with reproductive and performance traits in two quail strains.

2. Material and Methods

2.1 Location of the experiment

The experiment was carried out at Grdarasha Station and Molecular Laboratory in Dept. of Animal Resources, College of Agriculture Engineering Science, Salahaddin University-Erbil during the period from 1/10/2024 to 16/3/2025, this period included field experimental and laboratory work.

2.2 Experimental design and housing

The experiment was conducted across two generations using Ukrainian Quail (UQ) and Jumbo Quail (JQ). For the first generation, 524 eggs were incubated, resulting in 434 day-old chicks (224 UQ and 210 JQ). In the second generation, 100 fertile eggs from each strain were separately incubated, yielding 89 Ukrainian Quail and 82 Jumbo Quail chicks. In both generations, the birds were divided into seven

family groups per strain and reared until 63 days of age under controlled conditions. A mating system was implemented by housing one male with three females in individual cages, and during the first three weeks, chicks were housed in battery brooders before being transferred to grower cages.

Throughout the breeding phase, the birds received a diet containing 24.37% crude protein and 2,976 kcal of metabolizable energy (ME) per kg, while during the laying period, they were provided a commercial feed with 20% crude protein and 2,850 kcal ME/kg. Feed and water were available ad libitum. Lighting conditions were carefully managed, starting with continuous illumination during the first week and then gradually reduced by 2 hours per week until the birds reached 35 days of age; thereafter, they received 16 hours of light and 8 hours of darkness daily (Soares et al., 2003). Environmental conditions were consistently maintained across both generations, with the house temperature set at 36°C during the first week and lowered by 2°C each week until 8 weeks of age, after which it stabilized between 22°C and 24°C an optimal range for adult quails.

2.3 Incubation and hatchability assessment

The total incubation period was 17 days. Eggs were incubated for 14 days in an incubator set at 37.5°C and 55-60% relative humidity and the eggs were turned 12 times at 45° per day until 14 days of incubation then transferred to a hatching machine set at 36.5°C and 70% relative humidity. After the 17-day incubation period, all hatched chicks were removed from each hatcher basket and all unhatched eggs were opened to establish the infertile eggs and stage of embryonic mortality (Aygün et al., 2012). Fertility was calculated as the percentage of set eggs. The hatchability was calculated as both set eggs and the fertile eggs.

2.4 Productive performance traits

Throughout the investigation, performance traits were evaluated by measuring body weights at first egg (BWFE) in g; age at first egg (AFE) in days; mean weight of eggs (MEW) in g, weights

at first egg (WFE) in g and egg number per bird (ENPH).

2.5 Estimation of genetic parameters

2.5.1 Heritability

Heritability was estimated from sib-analysis using variance components derived from ANOVA tables based on sire and dam effects, following the methodology outlined by (Falconer and Mackay, 1996). The narrow-sense heritability (h^2) was calculated using the following formula:

$$h^2 = \frac{2(\sigma_S^2 + \sigma_D^2)}{\sigma_P^2}$$

Where: σ_{Sire}^2 and σ_{Dam}^2 represent the variance components due to sire and dam (nested within sire), respectively, and $\sigma_{Phenotypic}^2$ is the total phenotypic variance, comprising sire, dam, and residual error components.

2.5.2 Genetic correlation (rG)

Genetic correlations between some reproductive and production traits were estimated from the variance between two traits according to the equation of geometric method (Becker, 1975).

$$r_g = \frac{\sqrt{(Cov_{Z_2X_1} * Cov_{Z_1X_2})}}{\sqrt{(Cov_{Z_1X_1} * Cov_{Z_2X_2})}}$$

Where: 1 is first character and 2 is second character.

Z: observations of parents.

X: observations of progeny.

Cov xy: covariance between z & x.

2.5.3 Phenotypic correlation (rP)

The Pearson correlation coefficient based on phenotypic data calculated according to the following formula

$$r_p = \frac{\sum(x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \times \sum(y_i - \bar{y})^2}}$$

X_i, Y_i = observed values for traits X and Y

\bar{x}, \bar{y} = mean values of X and Y

2.6 Statistical analysis

Data were analyzed using the general linear model (GLM) procedure of the statistical analysis system (SAS, 2004) using the following modal: $Y_{ijk} = \mu + S_i + G_j + (SG)_{ij} + e_{ijk}$ Where: Y_{ijk} Observed value of the trait, μ = overall mean, S_i = effect of the i^{th} Strain, G_j = effect of the j^{th} generation ($j=1,2$), $(SG)_{ij}$ = interaction effect between strain and generation, e_{ijk} = residual error assumed to be normally and independently

distributed. Significant differences among means were ranked by using Duncan's multiple range Test (Duncan, 1955).

3. Results and Discussion

The Table (1) summarizes the effects of strains, generation, and their interaction on reproductive traits in two quail strains. Ukrainian quails demonstrated higher reproductive performance compared to Jumbo quails, with significantly greater fertility ($90.06 \pm 0.85\%$ vs. $84.43 \pm 0.51\%$), hatchability of set eggs ($86.59 \pm 0.59\%$ vs. $81.22 \pm 0.45\%$), and hatching weight (9.45 ± 0.20 g vs. 8.53 ± 0.14 g), while hatchability of fertile eggs was similar between the two strains. These findings are consistent with those reported by Ahmed and Al-Barzinji, (2020), who studied three Kurdish quail varieties (desert, brown, and white) and found a significant effect of varieties on average fertility, with the brown quail exhibiting the highest fertility percentage compared to the other varieties. Similarly, Rehman *et al.*, (2022) evaluated three selected quail lines the meat line (WBS), egg line (EBS),

and Random-Bred Control (RBC) and reported significant differences in average fertility among them. Additionally, Nwachukwu *et al.*, (2015) also confirmed that fertility and hatchability can be significantly ($P \leq 0.05$) influenced by the genetic differences among quail genotypes. For generation effects, the progeny generation (G2) had significantly higher fertility ($89.52 \pm 0.98\%$) and hatchability of set eggs ($85.00 \pm 0.83\%$) than the parent generation (G1), which showed $84.98 \pm 0.57\%$ and $82.81 \pm 0.69\%$, respectively. However, hatchability of fertile eggs was significantly higher in G1 ($97.44 \pm 0.35\%$) than in G2 ($94.97 \pm 0.31\%$), while hatching weight did not differ significantly between generations. Similarly, Ibrahim *et al.*, (2022) reported a significant improvement ($P \leq 0.05$) in both fertility and hatchability percentages across generations, from the 1st to the 4th. Fertility increased from 80.34% in the 1st generation to 94.60%, 93.21%, and 94.35% in the 2nd, 3rd, and 4th generations, respectively

Table1: Effects of strains, generation, and their interaction on reproductive traits in two quail strains (Mean \pm SE).

Items	Fertility (%)	Hatchability of set egg (%)	Hatchability of Fertile egg (%)	Hatching Weight (g)
Overall mean	87.25 \pm 0.67	83.90 \pm 0.56	96.21 \pm 0.30	8.99 \pm 0.14
Strains (S)				
Ukrainian	90.06 \pm 0.85a	86.59 \pm 0.59a	96.20 \pm 0.46a	9.45 \pm 0.20a
Jumbo	84.43 \pm 0.51b	81.22 \pm 0.45b	96.21 \pm 0.40a	8.53 \pm 0.14b
Generation (G)				
Parents generation(G1)	84.98 \pm 0.57b	82.81 \pm 0.69b	97.44 \pm 0.35a	8.90 \pm 0.19a
Progeny generation(G2)	89.52 \pm 0.98a	85.00 \pm 0.83a	94.97 \pm 0.31b	9.08 \pm 0.21a
Interaction(S*G)				
Ukrainian*G1.	86.72 \pm 0.37b	84.85 \pm 0.69b	97.84 \pm 0.41a	9.30 \pm 0.30a
Jumbo *G1.	83.23 \pm 0.73c	80.77 \pm 0.80c	97.04 \pm 0.55a	8.50 \pm 0.17b
Ukrainian*G2.	93.41 \pm 0.68a	88.32 \pm 0.56a	94.57 \pm 0.38b	9.60 \pm 0.27a
Jumbo *G2.	85.63 \pm 0.50b	81.67 \pm 0.41c	95.37 \pm 0.47b	8.55 \pm 0.24b

^{a-d}Column indicates no significant difference within a parameter for values sharing the same superscripts ($P \leq 0.05$).

Hatchability also improved significantly, rising from 50.84% in the 1st generation to 69.09%, 75.28%, and 77.19% in the subsequent generations, while, Rehman and Qaisrani, (2013) also observed variations in IFE (Infertile Eggs %) among close-bred stocks of Japanese quails. A significant interaction between strain and generation ($S \times G$) was found for all traits. The

Ukrainian G2 generation had the highest fertility ($93.41 \pm 0.68\%$) and hatchability of set eggs ($88.32 \pm 0.56\%$), whereas the Jumbo G1 generation had the lowest values ($83.23 \pm 0.73\%$ and $80.77 \pm 0.80\%$, respectively). The highest hatchability of fertile eggs ($97.84 \pm 0.41\%$) was recorded in the Ukrainian G1 generation, while the Ukrainian G2 generation

showed a reduction in this trait ($94.57 \pm 0.38\%$). Additionally, hatching weight was significantly higher in both Ukrainian generation (9.30 ± 0.30 g and 9.60 ± 0.27 g for G1 and G2, respectively)

compared to their Jumbo counterparts. Ibrahim *et al.*, (2022) reported a significant interaction ($P \leq 0.05$) between genetic lines and generation in quails.

Table2: Effects of strains, generation, and their interaction on productive traits in two quail strains (Mean \pm SE).

Items	Age Maturity (day)	Body weight at first Egg (g)	first Egg weight (g)	Egg Weight (g)
Overall mean	35.63 \pm 0.18	257.67 \pm 3.67	10.10 \pm 0.16	11.88 \pm 0.15
Strains (S)				
Ukrainian	35.50 \pm 0.30a	278.34 \pm 2.57a	10.41 \pm 0.19a	12.36 \pm 0.21a
Jumbo	36.00 \pm 0.22b	236.99 \pm 1.90b	9.79 \pm 0.23b	11.40 \pm 0.16b
Generation (G)				
Parents generation(G1)	35.75 \pm 0.18a	249.32 \pm 4.58a	10.02 \pm 0.21a	11.83 \pm 0.16a
Progeny generation(G2)	35.50 \pm 0.30a	266.01 \pm 5.19b	10.18 \pm 0.24b	11.94 \pm 0.26a
Interaction(S*G)				
Ukrainian*G1.	35.50 \pm 0.18a	268.90 \pm 1.50b	10.33 \pm 0.28a	12.27 \pm 0.21a
Jumbo *G1.	36.00 \pm 0.30a	229.75 \pm 1.09d	9.72 \pm 0.30a	11.39 \pm 0.16b
Ukrainian*G2.	35.00 \pm 0.47a	287.78 \pm 2.40a	10.55 \pm 0.28a	12.48 \pm 0.37a
Jumbo *G2.	36.00 \pm 0.33a	244.23 \pm 1.54c	9.87 \pm 0.37a	11.42 \pm 0.30b

^{a-d}Column indicates no significant difference within a parameter for values sharing the same superscripts ($P \leq 0.05$).

The Pearson correlation analysis revealed notable relationships between reproductive and productive traits in both Jumbo and Ukrainian quail breeds (Table 3). In the Jumbo quail (values above the diagonal), age at maturity (AM) showed significant positive correlations with first egg weight (FEW, $r = 0.471$) and fertility (F, $r = 0.422$), whereas in the Ukrainian quail (values below the diagonal), AM was negatively correlated with body weight at first egg (BWFE, $r = -0.328$) and hatchability of set eggs (HSE, $r = -0.554$). These findings align with Nwachukwu *et al.*, (2015), who reported a strong positive association ($r = 0.810$) between egg weight and normal chick percentage in Panda White quails, although other studies (Khurshid *et al.*, 2004; Daikwo, 2011) documented weaker correlations ($r = 0.18$ and 0.21 , respectively). Body weight at first egg (BWFE) exhibited significant negative correlations with fertility (F) and hatchability of set eggs (HSE) in both breeds, notably in Jumbo quail with $r = -0.555$ and $r = -0.613$, and in Ukrainian quail with $r = -0.588$ and $r = -0.599$. First egg weight (FEW) and egg weight (EW) were positively correlated with fertility and

hatchability traits, with FEW strongly correlating with fertility ($r = 0.831$, Jumbo) and hatchability of set eggs ($r = 0.741$, Jumbo). Fertility (F) and hatchability of set eggs (HSE) were highly positively correlated in both breeds ($r = 0.907$ Jumbo; $r = 0.929$ Ukrainian). Additionally, hatching weight (HW) was positively correlated with first egg weight ($r = 0.579$, Ukrainian), fertility ($r = 0.524$, Jumbo), and hatchability of set eggs ($r = 0.445$, Jumbo), suggesting that heavier hatchlings are linked to improved reproductive outcomes. Notably, Ahmed and Al-Barzinji, (2020) reported an exceptionally high correlation ($r = 0.998$) between fertility and hatchability, reinforcing the critical role of these parameters in reproductive performance.

Table (2) presents the effects of strains, generation, and their interaction on productive traits in two quail strains (Ukrainian and Jumbo). The overall mean values for age at maturity, body weight at first egg, first egg weight, and egg weight were 35.63 ± 0.18 days, 257.67 ± 3.67 g, 10.10 ± 0.16 g, and 11.88 ± 0.15 g, respectively. Significant differences were observed between strains, with the Ukrainian strain showing earlier maturity (35.50 ± 0.30

days), higher body weight at first egg (278.34 ± 2.57 g), first egg weight (10.41 ± 0.19 g), and egg weight (12.36 ± 0.21 g) compared to the Jumbo strain, which had values of 36.00 ± 0.22 days, 236.99 ± 1.90 g, 9.79 ± 0.23 g, and 11.40 ± 0.16 g, respectively. The present findings align with those of Maiorano *et al.*, (2009), Nasr *et al.*, (2017) and Tavaniello *et al.*, (2014), who reported significant differences in body weight among Japanese quail lines selected for either meat (broiler) or egg (layer) production. These differences were attributed to negative genetic correlation between body weight and reproductive traits, age, and management practices, particularly nutrition (Tavaniello, 2014). Moreover, Mirza *et al.*, (2025) reported that the addition of a dietary supplement to both drinking water and feed significantly enhanced final body weight, feed conversion ratio (FCR), and European Production Efficiency Factor (EPEF), further highlighting the influence of nutritional interventions on performance traits. Ibrahim *et al.*, (2021) compared two quail strains Jumbo and Gray and found a significant difference in body weight, with the Jumbo line showing superior growth performance. Likewise, Lan *et al.*, (2021) compared four Japanese quail breeds black, brown, wild, and yellow and observed significant differences in average egg weight among the breeds. In agreement, Islam *et al.*, (2014) found significant variation in the age at first egg production among Japanese, brown, white, and black quail, with Japanese quails beginning egg production earlier than other breeds. Additionally, Ahmed, (2021) reported that three local quail varieties demonstrated high repeatability estimates for

egg number and egg weight. This suggests that as the laying cycle progresses, repeatability improves, leading to better production performance and offering greater potential for genetic improvement in egg-related traits. Regarding generation, the Progeny generation (G2) exhibited a higher body weight at first egg (266.01 ± 5.19 g), first egg weight (10.18 ± 0.24 g), and egg weight (11.94 ± 0.26 g) compared to the Parent generation (G1), which had values of 249.32 ± 4.58 g, 10.02 ± 0.21 g, and 11.83 ± 0.16 g, respectively. However, no significant differences in age at maturity were observed between generations. Significant interactions between strain and generation were found. The Ukrainian G2 generation had the highest body weight at first egg (287.78 ± 2.40 g), first egg weight (10.55 ± 0.28 g), and egg weight (12.48 ± 0.37 g), while the Jumbo G1 generation had the lowest body weight at first egg (229.75 ± 1.09 g) and first egg weight (9.72 ± 0.30 g). Al-Kaisi and Al-Tikriti, (2021) reported that both the generation and the interaction between diallel cross and generation had significant effects ($P \leq 0.05$) on the average body weight at sexual maturity. However, no significant differences were observed between generations or in the interaction between diallel cross and generation for the average age at sexual maturity, the average weight of the first egg, or the average egg weight during the 56-day quail production period. In a related study, Ahmed, (2022) found that the interaction between genetic line and eggshell color had a significant effect ($P \leq 0.05$) on incubation traits, with certain combinations of quail lines and eggshell colors producing superior incubation results.

Table3: Pearson correlation analysis of reproductive and productive traits in both quail strains.

Traits	AM	BWFE	FEW	EW	F	HSE	HFE	H.W
AM		-0.328	0.471*	-0.164	0.422*	0.207	0.278	0.743**
BWFE	0.461*		-0.588*	-0.351	-0.555*	-0.613*	0.210	-0.490*
FEW	0.647**	0.299		-0.019*	0.831**	0.741**	0.311	0.236
EW	0.098	0.442*	-0.113		0.269	0.108	-0.537*	-0.063
F	-0.130	-0.198	-0.207	-0.669**		0.907**	0.353	0.326
HSE	-0.554*	-0.599*	0.398	0.617**	0.929**		-0.036	0.368
HFE	-0.729**	0.322	0.512	0.308	-0.564*	-0.023		-0.262
HW	0.403	-0.253	0.579*	-0.202	0.524*	0.445*	0.183	

The phenotypic correlations among the evaluated reproductive and productive traits are presented in the correlation matrix, where values above the diagonal represent correlation coefficients for the Jumbo quail breed, and those below the

diagonal correspond to the Ukrainian breed. Trait abbreviations are: HW, hatching weight; BWFE, body weight at first egg; AM, age at maturity; FEW, first egg weight; EW, egg weight; F, fertility; HSE, hatchability of set eggs; and HFE, hatchability of fertile eggs. Statistical significance is indicated by * ($P < 0.05$) and ** ($P < 0.01$).

Table (4) provides heritability estimates for reproductive and productive traits in both Ukrainian and Jumbo quail strains. The results reveal moderate heritability for age at maturity in both strains (0.31 for Ukrainian and 0.39 for Jumbo). Body weight at first egg showed stronger genetic control, with heritability estimates of 0.62 for Ukrainian and 0.56 for Jumbo. First egg weight exhibited moderate heritability in both strains (0.46 for Ukrainian and 0.41 for Jumbo), as did egg weight (0.52 for Ukrainian and 0.44 for Jumbo). These findings align with broader research in poultry genetics, which consistently demonstrates that traits such as live weight have a stronger genetic basis than other production traits. Studies by Daikwo *et al.*, (2013) and Sezer, (2007) reported heritability estimates for live weight ranging from 0.31 to 0.61, reflecting a moderate to high genetic influence. Similarly, Bhowmik and Khan, (2021) observed a heritability of 0.66 for live weight and 0.38 for egg weight, both of which surpassed those of other growth-related traits. In a study by Okuda *et al.*, (2014), which evaluated the heritability of production traits in quails bred over three generations, significant generational variation was observed. For example, the heritability of egg weight declined dramatically from 0.42 ± 1.20 in one generation to 0.05 ± 0.15 in the next. Age at sexual maturity showed a sharp increase from 0.29 ± 0.28 to 0.44 ± 1.63 , while body weight at six weeks decreased from 0.39 ± 0.25 to 0.20 ± 0.20 . These findings underscore the importance of generational changes and selection pressures in

influencing heritability estimates. Additionally, Momoh *et al.*, (2014) estimated the heritability of early reproductive traits, reporting moderate to high values of 0.48 ± 0.17 for age at first egg (AFE), 0.56 ± 0.21 for body weight at first egg (BWFE), and 0.38 ± 0.18 for the weight of the first egg (WFE). These results suggest that early reproductive traits are moderately influenced by genetics, making them responsive to selective breeding. Reproductive traits such as fertility and hatchability, however, showed lower heritability estimates. Fertility percentages had low heritability (0.22 for Ukrainian and 0.15 for Jumbo), suggesting a greater role for environmental factors in their expression. Similarly, hatchability of set eggs exhibited very low heritability (0.12 for Ukrainian and 0.18 for Jumbo), while hatchability of fertile eggs had slightly higher estimates (0.18 for Ukrainian and 0.25 for Jumbo). Hatching weight displayed low to moderate heritability (0.27 for Ukrainian and 0.18 for Jumbo), indicating a weaker genetic influence compared to productive traits such as body weight at first egg and egg weight. In line with these findings, Savegnago *et al.*, (2011) reported that hatchability of total eggs had the highest heritability estimate (0.28 ± 0.04), followed by hatchability of fertile eggs (0.27 ± 0.04) and fertility (0.12 ± 0.04), and Bennewitz *et al.*, (2007) found 0.14 for the same trait. These results highlight that productive traits such as body weight and egg weight are more strongly influenced by genetic factors, while reproductive traits like fertility and hatchability are more susceptible to environmental influences.

Table4: Heritability (h^2) for reproductive and productive traits in two quail strains

	Ukrainian	Jumbo
Age Maturity(day)	0.31	0.39
Body Weight at First Egg(g)	0.62	0.56
First Egg Weight(g)	0.46	0.41
Egg Weight(g)	0.52	0.44
Fertility%	0.22	0.15
Hatchability of Set Eggs%	0.12	0.18
Hatchability of Fertile Eggs%	0.18	0.25
Hatching Weight(g)	0.27	0.18

Table (5) presents the genetic correlations among reproductive and productive traits in two

quail strains, Ukrainian and Jumbo. In both strains, strong positive genetic correlations were observed among body weight at first egg (BWFE), first egg weight (FEW), and overall egg weight (EW). The strongest correlation was recorded between FEW and EW, with values of 0.85 in the Ukrainian strain and 0.76 in the Jumbo strain. Similarly, BWFE was positively correlated with both FEW ($r = 0.57$ in Ukrainian and $r = 0.48$ in Jumbo) and EW ($r = 0.52$ in Ukrainian and $r = 0.43$ in Jumbo), suggesting a close genetic association between early body weight and egg-related traits. According to Hussen *et al.*, (2016), who studied productive traits in Japanese quail at 42 days of age, high genetic correlations were reported between body weight (BW) and both weight gain (WG) and feed intake (FI), with estimates of 0.99 and 0.92, respectively. In contrast, low genetic correlations were found between WG and FI ($r = 0.45$) and between FI and feed conversion ratio

(FCR, $r = 0.08$). A negative genetic correlation between WG and FCR ($r = -0.41$) indicated that increased weight gain may be associated with improved feed efficiency. Supporting these findings, Salehinasab *et al.*, (2014) reported that egg weight showed positive genetic correlations with several important growth and reproductive traits, including body weight at hatch, body weight at 8 and 12 weeks of age, weight at sexual maturity, and age at sexual maturity. However, they also observed that egg number exhibited a moderate to high negative genetic correlation with egg weight, indicating a trade-off between egg size and quantity. Likewise, Okuda *et al.*, (2014) found a negative correlation between egg number (EGN) and age at sexual maturity (ASM) (-1.21), suggesting that earlier-maturing birds tend to lay more eggs, alongside a weak positive correlation (0.14) between egg number and body weight (BWT).

Table5: Genetic correlation for reproductive and productive traits in two quail strains

Traits	AM	BWFE	FEW	EW	F	HSE	HFE	HW
AM	-	-0.35	-0.17	-0.14	0.09	-0.12	-0.06	0.04
BWFE	-0.28	-	0.57*	0.52*	-0.22	0.33	0.39	0.27
FEW	-0.12	0.48*	-	0.85**	-0.10	0.21	0.30	0.22
EW	-0.09	0.43*	0.76**	-	-0.07	0.18	0.25	0.19
F	0.05	-0.17	-0.05	-0.03	-	0.51	0.43*	-0.14
HSE	-0.07	0.26	0.14	0.11	0.43*	-	0.75	0.36
HFE	-0.03	0.32	0.22	0.18	0.35	0.64**	-	0.28
HW	0.01	0.21	0.16	0.13	-0.09	0.27	0.21	-

The genetic correlations among the evaluated traits are summarized in the correlation matrix, where values above the diagonal represent estimates for the Ukrainian quail breed, and those below the diagonal correspond to the Jumbo breed. HW= hatching weight, BWFE= Body Weight at First Egg, AM= Age Maturity, FEW= First Egg Weight, EW= Egg Weight, F=Fertility, HSE= Hatchability of Set Eggs, HFE= Hatchability of Fertile Eggs. *=significant at ($P < 0.05$). **=significant at ($P < 0.01$).

In terms of reproductive efficiency, fertility (F) demonstrated moderate positive genetic correlations with both hatchability of set eggs (HSE) and hatchability of fertile eggs (HFE) in both strains, with higher values observed in Jumbo quails (0.51 for F–HSE and 0.43 for F–HFE). A strong positive association was also noted between HSE and HFE, reaching 0.75 in Jumbo and 0.64 in Ukrainian quails. In contrast, most other correlations were weak or negative, particularly those involving age at maturity (AM), which generally displayed low or unfavorable relationships with other reproductive and

productive traits. Consistent with these patterns, Savegnago *et al.*, (2011) reported positive and favorable genetic correlations among fertility (FERT), hatchability of fertile eggs (HFE), and total hatchability (HTE), with the strongest association observed between HFE and HTE (0.98). More recently, Esfeden *et al.*, (2024) confirmed these relationships, noting a modest positive genetic correlation (0.32) between fertility and hatchability of fertile eggs, and a high correlation (0.79) between hatchability of fertile eggs and total hatchability.

Conclusions

The results of this study confirm the superior reproductive and productive performance of the Ukrainian quail strain compared to the Jumbo quail, with consistent improvements observed across successive generations. The moderate heritability estimates for productive traits indicate a substantial genetic contribution, while the relatively lower heritability of reproductive traits suggests a greater influence of environmental factors. Moreover, the phenotypic and genetic correlations identified between body weight and egg production traits provide valuable insights for selection strategies. These findings establish the Ukrainian quail as a genetically superior breeding stock and offer essential genetic parameters for optimizing selection programs aimed at enhancing quail productivity.

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Conflict of interest

The authors declare that there are no conflicts of interest associated with this work.

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