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The Effects of Rearing Systems on Incubation, Egg Production and Quality Traits in Pharaoh Quails

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A B S T R A C T

This study was conducted to determine the effect of rearing quails in different rearing systems on egg production, egg quality characteristics, and incubation results. The 360 quails were distributed equally to 3 different rearing groups (cage, enriched cage, and floor) in a male:female mixed at the age of 3 weeks. The eggs were individually weighed and recorded one by one daily (5487 eggs) for 3 months. To determine egg quality and incubation characteristics, 750 eggs were broken, and 3284 eggs were incubated, respectively. The results showed that female quail in the floor group have lower body weight at 6 weeks old (177.19 g), and they reached sexual maturity (age of first egg laying) later (65.36 day, P<0.01), The lowest egg production (61.14%) occurred in the floor group during the 3-month egg production period (P<0.05). The lowest average egg weight (9.07 g) was determined in the floor group (P<0.05). It was determined that the eggs of quails raised in the enriched group had a rounder shape index because they have larger widths (P<0.01). While the highest average yolk height (11.24 mm) was determined in the enriched cage group (P<0.01), the highest averages of albumen length (72.41 mm) and lowest averages of yolk index (48.43%) were determined in the cage group (P<0.01). The lowest average values (113.17) in Haugh unit were detected in the floor group (P<0.05). The highest fertility rate (98.44%) was in Floor♂:Cage♀, the highest hatchability of fertile egg rate (94.67%) was obtained from Enriched♂:Cage♀, and the highest hatchability (89.10%) was obtained from Floor♂:Cage♀ pairing (P<0.05). The lowest fertility rate (88.00%) was obtained from the Enriched♂:Floor♀, the lowest hatchability of fertile egg rate (86.01%) was obtained from the Enriched♂:Enriched♀, and the lowest hatchability (75.62%) was obtained from the Enriched♂: Enriched♀ groups. As a result, it has been revealed that the effect of various rearing systems is different on egg production, egg quality traits, and hatching results in quails. Thus, it has been shown that different programs at the rearing period to be applied to the male and female quails can achieve better incubation results and reproductive success.

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Introduction

Quail, whose intensive production started in Japan, is an important poultry species that is widely bred all over the world, especially in the Asian continent. Although its meat production efficiency is low relatively to chicken, it is considered an alternative protein source thanks to its game bird taste and rapid development. While meat yield-oriented genotypes have not been effective enough due to low feed utilization rates and consumer perception, they are mainly grown for egg production, thanks to their ability to reach sexual maturity in a short period of 6-7 weeks and an annual egg yield of nearly 300 eggs (Minvielle, 1998; Uçar et al., 2020).

The basis of successful quail farming is based on appropriate rearing systems. Badawi (2017) examined the effect of quails reared in cage and floor systems on egg-laying and egg quality characteristics. And reported no difference in body weight averages between groups at the end of the first 6-week growth period. Additionally, no differences were found between the groups in terms of egg production, egg weight, albumen index, yolk index, shell thickness and shape index. But, he reported that the floor group had a higher average in terms of total egg mass. Hossain et al. (2024) compared quails reared in floor and cage systems. They reported that those reared in cages reached the sexual maturity age and 50% egg production level earlier. In addition, they reported that those raised in cages had higher egg production in all weeks, heavier eggs, but thinner shell thickness. While the cage group had higher values in terms of yolk height, yolk diameter, yolk index and albumen height, no difference was found between the groups in terms of Haugh unit.

Kundu et al. (2003), reported that birds reared in cages laid eggs earlier, reached 50% egg production age earlier, had higher egg production and higher hatchability compared to those reared in the floor system. Razee et al. (2016), reported that quails reared in cages heavier compared than quails reared in floor system. Roshdy et al. (2010) stated that quails reared in the floor system achieved higher egg yield, hatchability, yolk index, egg weight and egg mass values compared to those reared in cages. The same researchers determined that there was no difference in the average body weight at 6 weeks of age and egg shell thickness between the rearing systems. However, they determined that those reared in cages between the ages of 8-18 weeks were heavier body weight. They also emphasized that embryo mortality rates were higher in cage system. Elsayed & Gharib (2017), reported that there was no difference in the average egg weights, egg width and albumen width of quails reared in deep litter with coarse sawdust, deep litter with fine sawdust and cage systems. On the other hand, they reported that the cage system had the highest egg length and yolk height ratio, coarse sawdust group had the highest shell thickness, and coarse sawdust group had the thinnest shell thickness. Gözet et al. (2019), obtained the heaviest body weight average from the cage system at 6 weeks of age in quails reared in cage, cage+floor and floor systems.

El-Sheikh et al. (2016) found the maturity weight of the reared to be higher in the floor system than in the cage system. There was no difference in egg shape index, shell thickness, yolk index and Haugh unit traits between the systems. They calculated the average fertility rate and, as a result, hatchability to be higher in the floor system. Karousa et al. (2015) found that the cage system was higher in terms of egg production and hatchability of fertile egg, but the floor system was higher in terms of fertility rate. They found no difference in hatchability. Padmakumar et al. (2000) reported that while there was no difference in body weight in the cage and floor systems, quails reared in the cage system reached the first egg laying age and 50% egg production age earlier. Also, the cage group had higher egg production. Galić et al. (2021) did not calculate the difference between yolk index and Haugh unit in quails raised in the cage and aviary system. The albumen index average was found to be higher in the cage group. Fouzder et al. (1999) reared quails in cages, on slatted floor and on littered floor system. The highest body weight average at 6 weeks of age was determined in the cage group.

Although, Aljubory & Tikriti (2023) found that the cage system was higher than the floor system in terms of Haugh unit, they reported that there was no difference between the averages of egg weight, shell thickness, egg shape index, yolk index and albumen index. Ramankevich et al. (2022) when they compared groups enriched with nest, scratcher, tunnel, block, sand and feeder with the control group, they found that the fertility rate was highest in the tunnel enrichment, equal to the control in the feeder group, and lower than the control in the others. Laurence et al. (2015) revealed that the welfare levels of quails reared in an enriched system increased and they were better able to cope with chronic stressors. Narinç & Sabuncuoğlu (2022) determined the highest body weight of quails at 6 weeks of age in the cage system, then in the enriched cage system and the lowest in the floor system. Alindekon et al. (2019) reported that there was no difference between cage and floor systems in terms of body weight. Nordi et al. (2012) reported that quails reared in an enriched system had a better welfare level as a result of having more freedom of movement.

It can be seen that although floor and cage systems are frequently compared in various studies, enriched cage systems in quail rairing are not emphasized enough. There are almost no studies in the literature that examine together egg production, egg quality characteristics and incubation results. In this study was aimed to determine the effects of different rearing systems including cage, floor, and enriched on hatchability, egg production and egg quality traits in quail.

Materials & Methods

All procedures were carried out in accordance with the rules declared by the Ankara University Experimental Animals Ethics Committee (2024-10-79)**.** Quails of the Pharaoh (Wild Type) genotype were used as study material. During the first 3 weeks the birds were reared together in the floor system. At the age of 3 weeks, a total of 360 quails were distributed equally to 3 different rearing systems (cage, enriched cage and floor) in a male:female mixed. The dimensions of the cage were 120×300×30 cm and it was enriched by adding sand, soil, stones, perches and beak stones to another cage of the same dimensions. A sawdust floor system with the same dimensions was also created. Feed in powder form was given to the animals for the first 6 weeks. Feed content given in the first 3 weeks was 20.0% crude protein, 3050 kg/kcal metabolic energy, 2.6% crude fiber, 5.2% crude ash, 5.1% raw oil, 0.7% calcium, 0.6% phosphorus and 0.2% sodium. The feed content given between 4-6 weeks was 18.5% crude protein, 2750 kg/kcal metabolic energy, 5.5% crude fiber, 9.0% crude ash, 4.0% raw oil, 1.5% calcium, 0.6% phosphorus and 0.2% sodium. For the first 6 weeks, the feed was given to the birds in powder form. At the age of 6 weeks, a total of 90 female quails (30 from each system) were selected and individually housed in cages. Following the completion of the 6th week, the animals were subsequently transferred to separate cages. Once again, a sample of 10 males was collected from each system, resulting in a total of 30 males. Then arranged in a manner where each male was allocated to three females, with the pen being changed every two days and one female from each group. Feed content given to birds during the egg production period; 17% crude protein, 2550 kg/kcal metabolic energy, 8.5% crude fiber, 13.0% crude ash, 3.0% raw oil, 3.5% calcium, 0.6% phosphorus and 0.3% sodium. For the egg production period, the feed was given to the birds in crumble form. Feed and water were provided *ad libitum* throughout the entire trial period. The study continued for about 3 months during summer and laid eggs were individually weighed and recorded every day (totally 5487 eggs were obtained). Experiment was carried out under the natural lighting and natural ventilation conditions. The mating scheme according to rearing system groups is shown in Figure 1.

As the females were watched separately, the calculation of egg production per hen per day was performed. Once again, the rate of eggs that were broken or cracked was assessed on an individual basis, and the number of eggs that successfully hatched was determined by subtracting the number of broken or cracked eggs from the total number of eggs. The weights of the eggs were observed on a daily basis and measured using a scale that had a precision of 0.001 g.

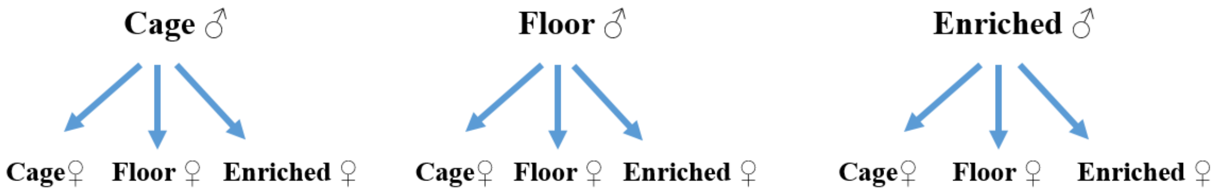

Figure 1. Mating scheme according to rearing systems

The average weights of the first 10 eggs of each female were also determined. In order to assess the characteristics of egg quality, a total of 750 eggs were examined. Specifically, 250 eggs were collected during the 3rd, 8th, and 13th weeks of egg production and subsequently broken for analysis. The eggs were immediately broken on the day of their laying, without any delay. The egg's width and length were measured using a digital calliper with a precision of 0.01 mm. The shape index was then determined by dividing the egg's width by its length and multiplying the result by 100. The shell thickness was measured using a compact digital thickness gauge with a measuring range of 0.00-12.70 mm. Measurements were taken in three regions: the small, middle, and large ends of the shell. The average shell thickness was then determined based on these measurements. The heights of the albumen and yolk were measured using a tripod micrometre with a measuring range of 0.00-20.00 mm. The yolk diameter, albumen width, and albumen length were measured using a digital calliper with a precision of 0.01 mm. The Haugh Unit, Albumen Index and Yolk Index was calculated from formulas below (Sarıca & Erensayın, 2018);

$$\text{Haugh Unit} = 100\log(H + 7.57 - 1.7\, G^{0.37})$$

Where;
H : Albumen height
G : Egg weight

$$AI = \frac{AH}{AL} \times 100$$

Where;
AI : Albumen Index (%)
AH : Albumen Height (mm)
AL : Average Length ∧Width of Albumen (mm)

$$\text{Yolk Index (\%)} = \frac{\text{Yolk Height (mm)}}{\text{Yolk Diameter (mm)}} \times 100$$

Except for the first 2 weeks of egg production and the weeks of egg breaking, the eggs obtained were incubated every 5 days in the other weeks. Each loaded batch was considered as a replicate and 11 replicates were created for the incubation results. A total of 3284 eggs were incubated. Infertile eggs and embryo deaths were identified by macroscopic examination of the opened eggs. The hatching results obtained from these eggs were calculated with the help of the formulas below (Uçar, 2020; Uçar et al., 2020);

$$\text{Fertility Rate (\%)} = \frac{\text{Number of Fertile Egg}}{\text{Number of Incubated Egg}} \times 100$$

$$HFE = \frac{\text{Number of Chick}}{\text{Number of Fertile Egg}} \times 100$$

HFE : Hatchability of Fertile Egg (%)

$$\text{Hatchability (\%)} = \frac{\text{Number of Chick}}{\text{Number of Incubated Egg}} \times 100$$

$$EED = \frac{\text{Number of Embryo Death (1–5 days)}}{\text{Number of Fertile Egg}} \times 100$$

EED : Early Embryo Death (%)

$$MED = \frac{\text{Number of Embryo Death (6–15 days)}}{\text{Number of Fertile Egg}} \times 100$$

MED: Middle Embryo Death (%)

$$LED = \frac{\text{Number of Embryo Death (16–18 days)}}{\text{Number of Fertile Egg}} \times 100$$

LED: Late Embryo Death (%)

SPSS Software was used in the statistical analysis. When the means of the GLM were significantly different, the means were compared using Duncan's test for multiple comparisons.

Results and Discussion

The body weight of the birds according to the groups and gender at 3 weeks of age (beginning of trial), 6 weeks of age (end of growing or beginning of production) and 19 weeks (end of trial) of age are shown in Table 1.

There was no difference between the groups at the beginning of the trial (P>0.05). Since genders were not clearly separated according to breast feather color in this week, general averages are given in Table 1. At 6 weeks of age, quails reared in the floor system reached the lowest body weight (P<0.01). While the difference between the genders was insignificant (P>0.05), when looked at according to the rearing, a numerical difference between the genders was noticeable only in the birds in the floor system. While some researchers (Padmakumar et al., 2000; Roshdy et al., 2010; Badawi, 2017) claim that the rearing system does not make any difference in terms of body weight at 6 weeks of age, others (Fouzder et al., 1999; Razee et al., 2016; Gözet et al., 2019) reported that those reared in cages were heavier, as in our study. However, on the contrary, there were studies reporting that those raised on the floor were heavier than those in cages (El-Sheikh et al., 2016).

Table 1. Body weight averages according to group and gender (g)

Group/Gender		Beginning	Beginning of Egg Production	End
		3 weeks of age	6 weeks of age	19 weeks of age
Cage		48.35	193.90[a]	251.79
Floor		48.41	177.19[b]	254.30
Enriched		49.05	198.53[a]	248.32
SEM		0.922	3.285	4.624
	Female	---	191.51	269.91[a]
	Male	---	188.24	233.03[b]
SEM		---	2.594	3.626
Cage	Female	---	193.85	267.70
	Male	---	193.95	235.89
Floor	Female	---	181.86	272.27
	Male	---	172.51	236.33
Enriched	Female	---	198.82	269.77
	Male	---	198.24	226.88
SEM		---	4.492	6.278
P values				
Group		0.842	0.001	0.663
Gender		---	0.390	0.001
Group x Gender		---	0.524	0.697

SEM: Standard error of mean; [a,b] Means with different superscripts differ significantly (P<0.05).

Table 2. Egg yield traits according to the rearing systems of females

Group	Age of first egg (day)	Body weight at first egg laying (g)	Weight of first egg (g)	First ten egg weight (g)
Cage	52.78[c]	270.13	9.68	10.76
Floor	65.36[a]	273.85	10.55	10.93
Enriched	57.26[b]	276.78	9.75	10.98
SEM	1.447	4.385	0.303	0.160
P values	0.001	0.542	0.085	0.608
Total Egg Yield	Months (%)			Average
	1	2	3	
Cage	63.45[a]	82.14	69.51	71.53[a]
Floor	39.17[b]	73.66	68.70	61.14[b]
Enriched	64.73[a]	75.67	69.29	69.85[a]
SEM	3.216	3.609	3.237	2.763
P values	0.001	0.233	0.983	0.020
Hatching Egg Yield	Months (%)			
Cage	60.79[a]	79.17	67.07	68.95[a]
Floor	37.43[b]	71.09	67.09	59.23[b]
Enriched	62.84[a]	73.55	66.84	67.67[a]
SEM	3.071	3.675	3.214	2.718
P values	0.001	0.293	0.998	0.026
Broken-Cracked Egg Yield	Months (%)			
Cage	2.98	2.98	2.44	2.77
Floor	1.90	2.57	1.61	1.99
Enriched	1.90	2.12	2.45	2.18
SEM	0.757	0.847	0.532	0.428
P values	0.518	0.777	0.439	0.417

SEM: Standard error of mean; [a,b] Means with different superscripts differ significantly (P<0.05).

While there was no difference in 6-week body weight between the cage and enriched system in our study, Narinç & Sabancuoğlu (2022) reported that quails reared in the cage system reached higher body weight than both the enriched cage and floor systems. The difference between the groups at the end of the growing period was not determined at the end of the production period (P>0.05). However, at the end of the experiment, it was determined that females were approximately 37 g heavier than males (P<0.01).

The first egg laying ages of females raised in cage, floor and enriched systems were 52.78, 65.36 and 57.26 days, respectively. In terms of age at first egg laying, females reared in the cage system were the earliest, then in the enriched system, and females reared in the floor system were the latest (P<0.01). It has been reported in the literature that quails reared in a traditional cage system, as in our study, reach sexual maturity at the earliest (Padmakumar et al., 2000; Kundu et al., 2003; Hossain et al., 2024). While there was no difference between the groups in body weights at the age of first egg (P>0.05), it can be said that the females in the groups laid their first eggs when they weighed an average of 270 g and above (Table 2). There was no difference between the average weight of the first egg and the weight of the first ten eggs (P>0.05).

While no difference was detected in the broken-cracked egg yield between the groups, a difference was observed only in the first month egg yields in terms of hatching egg rate and total egg rate. First-month total egg yields in cage, floor and enriched systems were determined as 63.45, 39.17 and 64.73%, respectively, and hatching egg yields were determined as 60.79, 37.43 and 62.84%, respectively (P<0.01). There was no difference between the groups in the 2nd and 3rd months of the trial (P>0.05). While the 3-month general total egg yield averages were found to be 71.53, 61.14 and 69.85%, respectively (P<0.05). The hatching egg yields were found to be 68.95, 59.23 and 67.67%, respectively (P<0.05). This difference in general averages is seen as a reflection of the first month egg production averages (especially first 3 weeks of production, in Figure 2), and it is clear that the most important reason for this is that the birds in the floor system start egg production late. While, Badawi (2017) stated that the rearing system does not matter in terms of egg yield, other studies reported that those raised in cages had higher egg yield, similar to the findings of our study (Padmakumar et al., 2000; Kundu et al., 2003; Karousa et al., 2015; Hossain et al., 2024).

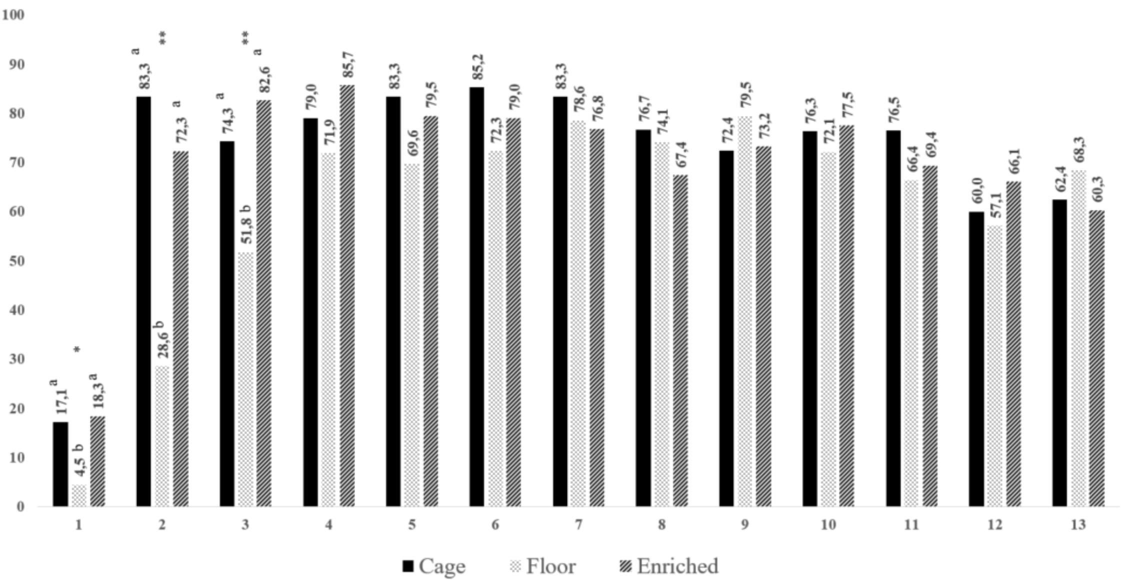

Figure 2. Egg yields (per hen per week) of female groups (*:P<0.05; **:P<0.01 – a,b duncan)

Table 3. Egg quality traits according to the rearing systems of femal%s

Egg Weight & Shape	Egg Weight (g)	Egg Width (mm)	Egg Length (mm)	Egg Shape Index (%)
Cage	9.24^{ab}	23.65^{b}	29.93	79.09^{b}
Floor	9.07^{b}	23.60^{b}	29.94	78.96^{b}
Enriched	9.34^{a}	23.87^{a}	29.83	80.14^{a}
SEM	0.075	0.063	0.104	0.194
P values	0.036	0.004	0.683	0.001
Egg Shell Thickness	Small End (mm)	Middle (mm)	Large End (mm)	Average
Cage	0.221	0.219	0.216	0.218
Floor	0.218	0.217	0.215	0.216
Enriched	0.220	0.217	0.217	0.218
SEM	0.002	0.002	0.002	0.002
P values	0.463	0.832	0.757	0.677
Egg Yolk & Haugh Unit	Yolk Height (mm)	Yolk Diameter (mm)	Yolk Index (%)	Haugh Unit
Cage	11.14^{ab}	23.09^{a}	48.43^{b}	113.88^{a}
Floor	11.01^{b}	22.29^{b}	49.58^{a}	113.17^{b}
Enriched	11.24^{a}	22.93^{a}	49.16^{a}	114.09^{a}
SEM	0.050	0.102	0.259	0.234
P values	0.004	0.001	0.007	0.015
Albumen	Albumen Height (mm)	Albumen Width (mm)	Albumen Length (mm)	Albumen Index (%)
Cage	4.65	50.65	72.41^{a}	7.74^{b}
Floor	4.77	49.63	67.38^{b}	8.38^{a}
Enriched	4.76	50.99	69.21^{b}	8.15^{a}
SEM	0.062	0.507	0.747	0.146
P values	0.315	0.146	0.001	0.008

SEM: Standard error of mean; ^{a,b} Means with different superscripts differ significantly (P≤0.05).

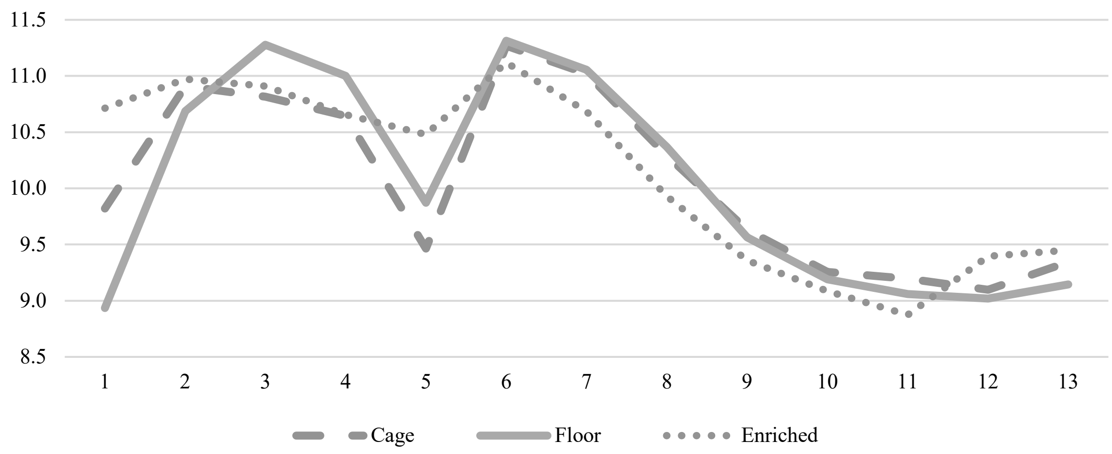

Figure 3. Egg weights of female groups according to weeks

Table 4. Hatching results according to the rearing systems of males&females (%)

Gender	Groups	Fertility Rate	Hatchability of Fertile Egg	Hatchability	Early Embryo Death	Middle Embryo Death	Late Embryo Death
	Cage	92.26[a]	90.34	83.23	3.56[b]	2.07	4.04
	Floor	94.50[a]	88.59	83.56	5.71[a]	2.09	3.60
♂	Enriched	89.69[b]	90.84	81.04	3.01[b]	1.92	4.23
	SEM	0.816	0.924	1.071	0.560	0.402	0.551
	P values	0.001	0.187	0.195	0.001	0.949	0.704
	Cage	94.06[a]	92.15[a]	86.71[a]	2.68[b]	1.72[b]	3.45
	Floor	91.26[b]	89.27[b]	81.18[b]	5.55[a]	1.50[b]	3.68
♀	Enriched	91.13[b]	88.36[b]	79.94[b]	4.05[ab]	2.86[a]	4.73
	SEM	0.816	0.924	1.071	0.560	0.402	0.551
	P values	0.017	0.010	0.001	0.001	0.037	0.215
	Cage ♀	91.40[bcd]	91.47[abc]	83.63[abcd]	3.57[cd]	1.99	2.98[b]
Cage ♂	Floor ♀	92.51[bc]	87.36[bcd]	80.74[cde]	5.53[abc]	1.88	5.24[ab]
	Enriched ♀	92.88[bc]	92.19[ab]	85.31[abc]	1.57[d]	2.33	3.91[ab]
	Cage ♀	98.44[a]	90.33[abcd]	89.10[a]	3.43[cd]	1.67	4.58[ab]
Floor ♂	Floor ♀	93.28[b]	88.59[bcd]	82.68[bcd]	7.06[a]	2.04	2.31[b]
	Enriched ♀	91.77[bcd]	86.87[cd]	78.89[de]	6.65[ab]	2.57	3.91[ab]
	Cage ♀	92.33[bcd]	94.67[a]	87.39[ab]	1.03[d]	1.51	2.79[b]
Enriched ♂	Floor ♀	88.00[d]	91.86[abc]	80.12[cde]	4.07[bcd]	0.57	3.50[ab]
	Enriched ♀	88.74[cd]	86.01[d]	75.62[e]	3.92[bcd]	3.69	6.39[a]
SEM		1.413	1.600	1.855	0.970	0.697	0.758
P values		0.043	0.010	0.003	0.049	0.294	0.001

SEM: Standard error of mean; [a,b] Means with different superscripts differ significantly (P≤0.05). ♂: Male, ♀: Female

Fluctuations were observed in egg weights from week to week, and egg weights tended to decrease towards the end of the experiment (Figure 3, Table 3). The possible reason for this is that the experiment was carried out in the summer months under natural ventilation conditions (Alagawany et al., 2017). Egg weight averages were found to be 9.24, 9.07 and 9.34 g in the cage, floor and enriched system groups, respectively (P<0.05). The highest average egg weight was measured in the enriched system, while the lowest average was measured in the floor system. Contrary to our study in terms of egg weight, they reported (Badawi,2017; Elsayed & Gharib, 2017; Aljubory & Tikriti, 2023) no difference or that the floor system was heavier (Roshdy et al., 2010), while Hossain et al., (2024) reported that, similar to our study, those reared in cages laid heavier eggs.

While there was no difference between the groups in terms of egg length (P>0.05), the enriched system had the highest value in terms of egg width (P<0.01) and as a result, the most round-shaped eggs were obtained from this group. Egg shape indexes were calculated as 79.09, 78.96 and 80.14% in cage, floor and enriched groups, respectively (P<0.01). Contrary to our study, Elsayed & Gharib (2017) reported that they obtained the longest eggs from the cage system, although there was no difference in egg width. Again, unlike our study, Badawi (2017) did not detect any difference between the groups in terms of egg shape index.

No difference was detected between the groups in terms of egg shell thickness (P>0.05). Similar to our study, some researchers found no difference in the egg shell thickness (Roshdy et al., 2010; El-Sheikh et al., 2016; Badawi, 2017;

Aljubory & Tikriti, 2023), while some researchers reported that they obtained eggs with thinner shells from the cage system (Elsayed & Gharib, 2017; Hossain et al., 2024). The group with the highest average yolk height was enriched, while the lowest group was floor (P<0.01). While the cage and enriched groups had similar averages in terms of yolk diameter, the lowest average was again detected in the floor group (P<0.01). However, in terms of yolk index, the lowest average was calculated in the cage group (P<0.01).

There was no difference between the groups in the mean albumen height and albumen width (P>0.05). But, the highest averages in terms of albumen length and the lowest averages in terms of albumen index were determined in the cage group (P<0.01). The lowest value in Haugh unit averages was detected in the floor group (P<0.05). Badawi (2017) found no difference between groups in terms of albumen and yolk index. Hossain et al. (2024) reported that the cage system had a higher average in terms of yolk height, yolk diameter, yolk index and albumen height, but the rearing system was not effective in terms of Haugh unit. Roshdy et al. (2010) reported that the yolk index was higher in the floor system. El-Sheikh et al. (2016) found no difference between the groups in terms of yolk index and Haugh unit. Galić et al. (2021) found no difference in terms of rearing system according to yolk index and haugh unit, but reported that the albumen index was the highest in the cage group. Aljubory & Tikriti (2023) reported no difference in terms of yolk and albumen index.

Incubation results of male and female quails according to rearing systems are given in Table 4. The interaction between male and female groups was found to be significant only in the fertility rate (P<0.05). In other features the difference is not significant (P>0.05). Nine groups were analyzed together to understand more clearly the differences between male and female pairings.

It is seen that males growing in the enriched system have the lowest fertility rate. The average fertility rate of male quails according to cage, floor and enriched groups was calculated as 92.26, 94.50 and 89.69%, respectively (P<0.01). On the other hand, in the same groups, the highest early embryo mortality rate was detected in the floor group. Early embryo mortality rates were found to be 3.56, 5.71 and 3.01% in the same order (P<0.01). The effect of the system in which males were reared on hatchability of fertile egg, hatchability, mid-term embryo and late-term embryo mortality rates was not found to be significant (P>0.05). It can be seen that those reared in the cage system have the highest performance in terms of fertility rate, hatchability of fertile egg and hatchability. In terms of fertility rate, the averages of females in cage, floor and enriched systems were found to be 94.06, 91.26 and 91.13%, respectively (p<0.05). The hatchability of fertile egg rates were calculated as 92.15, 89.27 and 88.36%, and the hatchability rates were calculated as 86.71, 81.18 and 79.94%, respectively (P<0.01). In terms of early embryo death, the highest average was determined in the floor group in females, as in the male groups (P<0.01). It was determined that mid-term embryo mortality was higher when females were raised in the enriched system (P<0.05). Kundu et al. (2003) reported higher hatchability in the cage system while Roshdy et al. (2010) reported higher hatchability in the floor system. They also emphasized that embryo mortality rates were higher in the cage system. El-Sheikh et al (2016), calculated the average fertility rate and, as a result, hatchability to be higher in the floor system. Karousa et al. (2015), found that the cage system was higher in terms of hatchability of fertile eggs, but the floor system was higher in terms of fertility rate. Ramankevich et al. (2022) reported that tunnel enrichment achieved the highest fertility rate.

The highest fertility rate (98.44%) was determined in the pairing according to rearing systems in Floor♂: Cage♀ and the lowest fertility rate (88.00%) in Enriched♂: Floor groups (P<0.05). In terms of the hatchability of fertile egg, the highest value (94.67%) was obtained from the Enriched♂: Cage♀ pairing and the lowest average (86.01%) was observed in the Enriched♂: Enriched♀ pairing groups (P≤0.01). The highest average in hatchability (89.10%) was found in the Floor♂: Cage♀ groups (P<0.01). The lowest hatchability average (75.62%) was found in the Enriched♂: Enriched♀ pairing, just like the hatchability of fertile egg rate (P<0.01). The highest rate of early embryo death (7.06%) was found in the Floor♂: Floor♀, while the lowest rate (1.03%) was obtained from Enriched♂: Cage♀ pairing (P<0.05). The highest rate of late embryo death (6.39%) was found in the Enriched♂: Enriched♀ pairing (P<0.01).

Upon analysing the study results, it was discovered that quails raised on the floor until 6 weeks of age will have a lower body weight and hence experience delayed sexual maturation. The study revealed that the consequences of delayed maturity during the raising phase were also evident throughout the egg production phase, with the floor system exhibiting the lowest egg production over the 3-month period. Furthermore, it was noted that the floor group had the lowest average egg weight. Based on the egg shape index, it was found that quails raised in the enriched system produced eggs with a more spherical shape. The enriched group had the highest average yolk height, whereas the cage group had the highest averages for albumen length and the lowest averages for albumen index. The lowest value in Haugh unit averages was detected in the floor group. The highest fertility rate in mating groups of male and female according to rearing systems was Floor♂: Cage♀; the highest hatchability of fertile egg rate was obtained from the Enriched♂: Cage♀ and the highest hatchability rate was found in the Floor♂: Cage♀ pairing group. The lowest fertility rate was determined in the Enriched♂: Floor♀, the lowest hatchability of fertile egg rate was obtained from the Enriched♂: Enriched♀, and the lowest hatchability rate was found in the Enriched♂: Enriched♀ mating groups. In conclusion, it has been discovered that various rearing systems with distinct attributes can provide superior outcomes in terms of egg production, egg quality characteristics, and hatching results. Furthermore, while examining the hatching results, it is possible to assess males and females separately. Thus, it has been shown that different programs at the rearing period to be applied to the male and female quails can achieve better incubation results and reproductive success. It is thought that the findings of this study contribute to the design of new and comprehensive studies on the reflections of some production practices in the rearing period in quails.

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