



EFFECTS OF MAGNETIZED WATER AND TIME-RESTRICTED FEEDING ON SELECTED REPRODUCTIVE AND HORMONAL PARAMETERS IN JAPANESE QUAIL (*coturnix japonica*)

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ABSTRACT

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This study aimed to investigate the effects of magnetized water and time-restricted feeding on selected reproductive and hormonal parameters in Japanese quail (*Coturnix japonica*). A total of 312 day-old unsexed chicks were utilized in the experiment. The birds were randomly distributed to four treatments (78 chicks each): T1 (unmagnetized water with *ad libitum* feeding), T2 (unmagnetized water with 5-hour daily feed restriction), T3 (magnetized water with *ad libitum* feeding), and T4 (magnetized water with 5-hour daily feed restriction). Each treatment consisted of three replicates (26 chicks per replicate), with housing, management, and feeding conditions standardized across all groups; the results showed a significant increase ($P \leq 0.05$) in testicular weight and testosterone concentration in males receiving magnetized water compared with those receiving unmagnetized water. Females that consumed magnetized water also exhibited a significant increase ($P \leq 0.05$) in ovarian weight and serum FSH and LH concentrations. Time-restricted feeding had no significant effect on testicular weight or testosterone concentration in males, whereas *ad libitum*-fed females showed significantly higher ($P \leq 0.05$) ovarian weight and FSH and LH concentrations compared with feed-restricted females. The interaction effect revealed significantly higher ($P \leq 0.05$) testicular weight and testosterone levels in males of T3 and T4 compared with T1 and T2. Females in T3 and T4 showed significantly higher ovarian weight and FSH levels compared with T1 and T2, while T3 recorded the highest LH concentration. The findings revealed that magnetized water, alone or in combination with time-restricted feeding, may improve certain reproductive and hormonal parameters in Japanese quail.

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INTRODUCTION

Water is essential for life and all vital processes (Chaplin, 2006), and it is critical in poultry production because birds consume about twice as much water as feed (Amaral, 2004). Water facilitates digestion, nutrient absorption, thermoregulation, immune function, and waste removal (Ebrahimi *et al.*, 2024; Bruno *et al.*, 2011). Magnetic fields can modify water's physical and chemical properties due to its molecular nature (Ovchinnikova & Pollack, 2009). A water molecule consists of one oxygen atom covalently bonded to two hydrogen atoms in an isosceles triangular configuration, with a bond angle of approximately 105° (Boufa, 2021). Due to the electronegativity of oxygen, the molecule possesses partial negative and positive charges; consequently, water molecules interact via electrostatic attraction,

forming hydrogen bonds that facilitate the aggregation of molecules into larger molecular clusters; consequently, water molecules interact via electrostatic attraction, forming hydrogen bonds that facilitate the aggregation of molecules into larger molecular clusters. This occurs due to the breaking of hydrogen bonds, resulting in a bond angle of 103 degrees instead of 105 degrees in ordinary water. Consequently, this leads to the formation of smaller water clusters consisting of 6–7 molecules rather than larger molecular aggregates (Boufa, 2021). This results in increased permeability of magnetized water molecules through cell membranes, thereby enhancing nutrient absorption and digestion across the digestive tract, which improves the utilization of nutrients and minerals in the body (Verma, 2011; Varkey *et al.*, 2017; Wang *et al.*, 2018; Hassan *et al.*, 2018). Magnetized water also has reduced viscosity, by up to 4%, and lower surface tension, making it a more effective solvent and improving nutrient and water transport throughout the body (Khudiar & Ali, 2012; Al-Hilali, 2018; Karkush *et al.*, 2019; Mustafa, 2019).

Time-restricted feeding is an important management strategy for improving poultry production efficiency and reducing problems associated with rapid growth. It regulates energy intake, lowers carcass fat deposition, and reduces mortality from ascites and death syndrome (SDS), especially under heat stress (Tolkamp *et al.*, 2005; Zhan *et al.*, 2007; David & Subalini, 2015). Short-term early feed restriction can induce compensatory growth, allowing birds to reach market weight with improved feed conversion efficiency without compromising welfare (Zhan *et al.*, 2007; Dawkins & Layton, 2012). Time-restricted feeding also reduces metabolic heat production and alleviates heat stress (Medugu *et al.*, 2010; De Silva & Kalubowila, 2012). Reproductive efficiency is regulated by the hypothalamic–pituitary–gonadal axis through FSH and LH in females and testosterone in males. Therefore, this study evaluated the effects of magnetized water and time-restricted feeding on testicular and ovarian weights, FSH and LH concentrations in females, testosterone concentration in males, and their interaction in Japanese quail.

Therefore, the present study was designed to: (1) evaluate the effect of magnetized water and time-restricted feeding on testicular and ovarian weights in male and female Japanese quail; (2) determine the effect of magnetized water and time-restricted feeding on FSH and LH concentrations in females and testosterone concentration in males; and (3) investigate the interaction between magnetized water and time-restricted feeding on gonadal weights and reproductive hormone levels in both sexes.

MATERIAL AND METHODS

The experimental protocol was conducted as part of an officially registered postgraduate research project approved by the Faculty of Agriculture and the University Council at Latakia University (Decision No. 5324, Meeting No. 27, dated 27 August 2023). In the absence of a formal institutional animal ethics committee registration number, all experimental procedures involving Japanese quail were carried out strictly in accordance with internationally accepted guidelines for the care and use of laboratory animals, ensuring proper handling, minimal distress, and optimal welfare of the birds throughout the study.

Experimental Location

The experiment was conducted on a private poultry farm in the Ma'arshour

area in Hama, Syria, from April 4 to November 20, 2024.

Methodology

During the initial rearing phase (weeks 1–2), a total of 312 day-old straight-run Japanese quail chicks of homogenous body weight were randomly distributed into two main groups (156 chicks per group): the first group received unmagnetized water, while the second group was supplied with magnetized water. Each group comprised six replicates, with 26 birds per replicate. The magnetized water group received treated water continuously from day one until the end of the experimental period. During this two-week preliminary period, all chicks had free access (*ad libitum*) to a standard starter diet. The distribution of chicks, experimental groups, and the magnetic field intensity applied during the first two weeks of rearing are detailed in Table 1.

Table 1: Experimental groups, chick distribution, and magnetic field intensity during the initial rearing period (weeks 1–2).

Treatments	Type of water	Magnetization intensity (Gauss)	Water circulation time (min)	Total number of chicks	Chicks per replicate
T1	Unmagnetized water	-	-	156	26
T2	Magnetized water	3323	60	156	26

At the beginning of the third week, the chicks were redistributed into four experimental treatments (78 chicks per treatment), with each treatment comprising three replicates of 26 chicks each. Concurrently, the 5-hour daily feed restriction program (removal of feeders from 12:00 PM to 5:00 PM) was implemented in the designated groups until the end of the trial, as detailed in Table 2. The experimental treatments were structured as follows:

- T1: Unmagnetized water with *ad libitum* feeding.
- T2: Unmagnetized water with 5-hour daily time-restricted feeding.
- T3: Magnetized water with *ad libitum* feeding.
- T4: Magnetized water with 5-hour daily time-restricted feeding.

Prior to initiating this phase, the poultry house was partitioned into four separate compartments (corresponding to the treatments) spanning a total area of 25 m². The birds were reared on a deep litter system consisting of wood shavings, and unmagnetized or magnetized water was supplied using plastic drinkers with a capacity of 1.5 liters.

Source of Magnetized Water

The magnetization of water was performed using a water magnetizer with an intensity of 3,323 Gauss, equivalent to 332.3 milliTesla Figure. 1. The magnetic field intensity was measured using a (Sensor Mobile-CASSY 524 009) device from (LD Didactic GmbH, Germany, in the laboratories of the Faculty of Science (Physics Department) at the University of Latakia (Figure 2). A water magnetizer was installed

on the farm's main tank, and the water flow rate through the magnetization device was (0.058 L/S). A plastic tank was used to collect the water after magnetization. The water was continuously recirculated from the tank back through the magnetizer using a water pump for a duration of 60 minutes to ensure the quality of the magnetization process, as shown in Table 2.

Table 2: Experimental design and treatment allocations from week 3 until the end of the experiment.

Treatments	Type of water	Type of feeding	Magnetization intensity (Gauss)	Water Circulation time (min)	Total number of chicks	Chicks per replicate
T1	Unmagnetized water	<i>Ad libitum</i> feeding	-	-	78	26
T2	Unmagnetized water	Time-restricted feeding (5 h/day)	-	-	78	26
T3	Magnetized water	<i>Ad libitum</i> feeding	3323	60	78	26
T4	Magnetized water	Time-restricted feeding (5 h/day)	3323	60	78	26

Water Management

Unmagnetized and magnetized water were continuously provided to the experimental treatments using 1.5-liter drinkers. To prevent the dissipation of the induced magnetic properties over time, the drinkers were completely emptied and replenished every 6 hours. Unmagnetized water was supplied to the control groups (T1 and T2) before magnetic treatment.



Figure (1). The water magnetizer device used in the experiment.



Figure (2). Measuring the intensity of the magnetic field of a magnetization device.

Experimental Nutrition

The birds were provided with three pelleted diet formulations Table. 3 presents the feeding program applied during the rearing period, including the composition of the feed mixtures and their energy and protein contents, formulated according to the nutritional requirements of the birds at different growth stages.

Table 3: Ingredient composition and calculated nutrient analysis of the experimental diets for Japanese quail.

Ingredient %	Starter diet (1–2 weeks)	Grower diet (3 – 5 weeks)	Layer/Production diet (6 weeks until the end of the experiment)
Yellow corn	31.8	48	43
Wheat	25	9	20
Soybean meal	32	34	22
Protein concentrate	9	5	6
Fat	0.7	2	2
Limestone	1.25	1.7	6.75
Salt	0.25	0.3	0.25
The total%	100	100	100
Diet composition during the rearing period			
Crude protein %	24.66	21.7	20.04
Metabolizable energy (kcal/kg)	2999.2	2900	3106.7

All experimental birds were treated under the same management, care and feeding conditions throughout the experiment. All birds in the different treatments were exposed to a continuous lighting regimen (24 h/day). During the first two weeks of age. Thereafter, the number of hours of lighting was reduced to 22 hours during

the third and fourth weeks, to 21 hours during the fifth week, then to 20 hours during the sixth week, and then reduced to 17 hours until the end of the experiment.

Reproductive Organ Weights

The weight of the testes and ovaries was calculated by randomly selecting six birds from each replicate (3 males, 3 females). So that the sample represented the true distribution of bird weights within each treatment at 44 days of age. Feed was removed from the birds for 8 hours before slaughter, and then the samples were slaughtered, the carcass was cut into pieces the testes and ovaries were carefully excised and weighed using a digital sensitive scale.

Collection of blood samples

At 44 days of age, blood samples were collected from a total of 96 birds across all treatments (representing 12 males and 12 females per treatment). From each replicate, blood samples (2 mL) were obtained at slaughter from 3 males and 3 females (yielding 9 males and 9 females per treatment). Additionally, to enhance measurement accuracy, extra blood samples were collected via the wing vein from non-slaughtered birds at a rate of 1 male and 1 female per replicate (3 males and 3 females per treatment). All blood samples were collected in plain tubes without anticoagulants to allow for serum biochemical analysis. The samples were then centrifuged at 3,000 rpm for 15 minutes to separate the serum. The harvested serum was aliquoted and stored in a freezer at -20°C until further biochemical evaluations were performed.

Estimation of Serum Follicle-Stimulating Hormone (FSH) Concentration

Serum FSH concentrations were determined using a commercial Chicken FSH (Follicle-Stimulating Hormone) ELISA Kit manufactured by FineTest®. The assay is based on the Competitive ELISA principle and was performed according to the manufacturer's instructions. (Khafaji *et al.*, 2021; FineTest, 2024a).

Estimation of Serum Luteinizing Hormone (LH) Concentration

Serum LH concentrations were determined using a commercial Chicken LH (Luteinizing Hormone) ELISA Kit manufactured by FineTest®. The assay is based on the Competitive ELISA principle and was performed according to the manufacturer's instructions. (Khafaji *et al.*, 2021; FineTest, 2024b).

Estimation of Serum Testosterone Concentration

The serum concentration of testosterone was quantified using a commercial enzyme-linked immunosorbent assay (ELISA) kit manufactured by BioCheck, Inc. (Foster City, CA, USA). In contrast to peptide hormones, this assay adopted the Competitive ELISA principle, which is specifically designed for small steroid molecules (Gravina *et al.*, 2017).

Statistical Analysis

The data of this study were analyzed using a Completely Randomized Design (CRD) based on a factorial experiment with two factors: the first being water type (unmagnetized water and magnetized water), and the second being feeding regime (*ad libitum* feeding and 5-hour daily time-restricted feeding), including their interaction effects.

Data analysis was performed using the SPSS software package (version 24.0; IBM Corp., Armonk, NY, USA), and the significance of differences among the studied means was tested using the Least Significant Difference (LSD) test at a 5% level of

significance ($P \leq 0.05$). In addition, the GenStat software was used to determine the LSD values for the interaction effects.

The mathematical model used for data analysis was as follows:

$$Y_{ijk} = \mu + D_i + E_j + (DE)_{ij} + e_{ijk}$$

Where:

Y_{ijk} = the observation value of the k-th replicate under the i-th water type and the j-th feeding regime.

μ = overall mean.

D_i = effect of the water type (i = magnetized or unmagnetized water).

E_j = effect of the feeding regime (j = *ad libitum* or 5-hour daily time-restricted feeding).

$(DE)_{ij}$ = interaction effect between water type and feeding regime.

e_{ijk} = experimental error.

RESULTS

Testicular Weights

Table 4. shows the effect of water quality and time-restricted feeding on right and left testicular weights of Japanese quail males at 44 days of age. The results revealed a significant effect ($P \leq 0.05$) of magnetized water on the average weights of both right and left testes. Males that received magnetized water recorded significantly higher testicular weights compared with those that received regular water. The mean weights of the right and left testes in males treated with magnetized water were 3.51 and 3.58 g, respectively, whereas the corresponding values in males provided with unmagnetized water were 2.70 and 2.76 g.

Regarding the effect of feeding regimen, no significant differences ($P \geq 0.05$) were observed in the average weights of the right and left testes. However, birds under *ad libitum* feeding showed numerically higher testicular weights (3.20 and 3.28 g for the right and left testes, respectively) compared with birds subjected to feeding restriction (3.01 and 3.06 g, respectively).

The application of magnetized water significantly enhanced ($P \leq 0.05$) testicular weights under both feeding systems. Significantly greater weights of both the right and left testes were observed in T3 (3.62 and 3.39 g, respectively) and T4 (3.71 and 3.45 g, respectively), compared with T1 (2.77 and 2.62 g, respectively) and T2 (2.85 and 2.67 g, respectively).

Table 4: Effects of water type, feeding regimen, and their interaction on the testicular weights (g) of Japanese quail at 44 days of age ($\pm$ SE).

Weight of testes (g)			
Weight of the right testicle (g)		Weight of the left testicle (g)	
Effect of water type			
Unmagnetized water		2.70±0.155 ^b	2.76±0. 114 ^b
Magnetized water		3.51±0.176 ^a	3.58± 0.244 ^a
Effect of time-restricted feeding			
<i>Ad libitum</i> feeding		3.20±0.480 ^a	3.28±0.482 ^a
Feed restriction (5 hours)		3.01±0.441 ^a	3.06±0.469 ^a
Effect of interaction			
Unmagnetized water	<i>Ad libitum</i> feeding	2.77±0.184b	2.85±0.079 ^b
	Feed restriction (5 hours)	2.62±0.097b	2.67±0.055 ^b
Magnetized water	<i>Ad libitum</i> feeding	3.62±0.081 ^a	3.71±0.110 ^a
	Feed restriction (5 hours)	3.39±0.181 ^a	3.45±0.294 ^a
L.S.D for interaction		0.2713	0.3100

Different letters beside the means within each column indicate significant differences ($P \leq 0.05$).

Ovarian Weights

Table 5. shows the effect of water treatment and the effect of time-restricted feeding on ovarian weight in 44-day-old Japanese quail females. A significant effect ($P \leq 0.05$) of magnetized water quality on ovarian weight was observed. Females treated with magnetized water achieved a significant increase ($P \leq 0.05$) in ovarian weight (8.92 g) compared to females treated with regular water (7.02 g).

Regarding the effect of feeding pattern, Table. 5 shows a significant effect of time-based feed rationing on ovarian weight. Birds in the free-feeding treatment achieved a significant advantage ($P \leq 0.05$) in ovarian weight (8.35 g) compared to birds in the feed rationing treatment (7.59 g).

Analysis of variance indicates a significant interaction ($P \leq 0.05$) of the effect of water quality and time-based feeding rationing on ovary weight. A significant increase ($P \leq 0.05$) in ovary weight was observed quail females provided with magnetized water. Treatments that were either free-feeding or subjected to feeding rationing, compared to those of Unmagnetized water treatments that were free-feeding and subjected to feeding rationing. The highest ovarian weight was recorded in treatment T3 (9.19 g), followed by T4 (8.65) and T1 (7.51 g), whereas the lowest ovarian weight was observed in the T2 group (6.53 g).

Table 5: Effects of water type, feeding regimen, and their interaction on the ovarian weights (g) of Japanese quail at 44 days of age ($\pm$ SE).

Ovarian weight (g)		
Effect of water type		
Unmagnetized water		7.02 $\pm$ 0.719 ^b
Magnetized water		8.92 $\pm$ 0.574 ^a
Effect of time-restricted feeding		
<i>Ad libitum</i> feeding		8.35 $\pm$ 0.993 ^a
Feed restriction (5 hours)		7.59 $\pm$ 1.296 ^b
Effect of interaction		
Unmagnetized water	<i>Ad libitum</i> feeding	7.51 $\pm$ 0.095 ^b
	Feed restriction (5 hours)	6.53 $\pm$ 0.752 ^b
Magnetized water	<i>Ad libitum</i> feeding	9.19 $\pm$ 0.586 ^a
	Feed restriction (5 hours)	8.65 $\pm$ 0.513 ^a
L.S.D for interaction		1.024

Different letters beside the means within each column indicate significant differences ($P \leq 0.05$).

Serum Testosterone Concentration

Table 6 shows a significant effect ($P \leq 0.05$) of water treatment on serum testosterone concentration. The highest mean testosterone concentration was recorded in birds receiving magnetized water (189.71 ng/dL), compared with those receiving non-magnetized water (167.91 ng/dL).

Regarding time-restricted feeding, no significant difference ($P \geq 0.05$) was observed between the free-feeding and time-restricted feeding treatments.

For the interaction between water treatment and time-restricted feeding, the highest testosterone concentration was recorded in T3 (191.63 ng/dL), followed by T4 (187.80 ng/dL), whereas the lowest concentrations were observed in T1 (169.03 ng/dL) and T2 (166.80 ng/dL).

Table 6: Effects of water type, feeding regimen, and their interaction on the serum testosterone concentrations (ng/dL) of male Japanese quail at 44 days of age ($\pm$ SE).

Testosterone concentration (ng/dL)		
Effect of water type		
Unmagnetized water		167.91 $\pm$ 2.495 ^b
Magnetized water		189.71 $\pm$ 3.420 ^a
Effect of time-restricted feeding		
<i>Ad libitum</i> feeding		180.33 $\pm$ 12.532 ^a
Feed restriction (5 hours)		2177.30 $\pm$ 11.85 ^a
Effect of interaction		
Unmagnetized water	<i>Ad libitum</i> feeding	169.03 $\pm$ 1.715 ^b
	Feed restriction (5 hours)	166.80 $\pm$ 2.981 ^b
Magnetized water	<i>Ad libitum</i> feeding	191.63 $\pm$ 2.577 ^a
	Feed restriction (5 hours)	187.80 $\pm$ 3.404 ^a
L.S.D for interaction		5.162

Different letters beside the means within each column indicate significant differences ($P \leq 0.05$).

Serum FSH and LH Concentrations

Table 7 shows a significant effect ($P \leq 0.05$) of water treatment on serum FSH and LH concentrations in female Japanese quail. The highest concentrations were recorded in females receiving magnetized water (3.78 and 3.28 IU/L for FSH and LH, respectively), compared with those receiving non-magnetized water (3.32 and 2.88 IU/L, respectively).

Time-restricted feeding also significantly affected ($P \leq 0.05$) FSH and LH concentrations, with higher values observed under free feeding (3.63 and 3.18 IU/L, respectively) than under time-restricted feeding (3.46 and 2.98 IU/L, respectively).

Regarding the interaction, the highest FSH concentration was recorded in T3 (3.84 IU/L), followed by T4 (3.71 IU/L), whereas lower values were observed in T1 (3.43 IU/L) and T2 (3.21 IU/L). For LH, T3 recorded the highest concentration (3.36 IU/L), significantly exceeding T1 (2.99 IU/L) and T2 (2.77 IU/L), while no significant ($P \geq 0.05$) difference was observed between T4 and T1.

Table 7: Effects of water type, feeding regimen, and their interaction on serum FSH and LH concentrations (U/L) of Japanese quail at 44 days of age ($\pm$ SE).

FSH and LH hormone concentration (IU /L)			
		FSH	LH
Effect of water type			
Unmagnetized water		3.32 $\pm$ 0.142 ^b	2.88 $\pm$ 0.172 ^b
Magnetized water		3.78 $\pm$ 0.146 ^a	3.28 $\pm$ 0.153 ^a
Effect of time-restricted feeding			
<i>Ad libitum</i> feeding		3.63 $\pm$ 0.260 ^a	3.18 $\pm$ 0.230 ^a
Feed restriction (5 hours)		3.46 $\pm$ 0.287 ^b	2.98 $\pm$ 0.265 ^b
Effect of interaction			
Unmagnetized water	<i>Ad libitum</i> feeding	3.43 $\pm$ 0.09 ^b	2.99 $\pm$ 0.100 ^{bc}
	Feed restriction (5 hours)	3.21 $\pm$ 0.081 ^b	2.77 $\pm$ 0.165 ^c
Magnetized water	<i>Ad libitum</i> feeding	3.84 $\pm$ 0.175 ^a	3.36 $\pm$ 0.140 ^a
	Feed restriction (5 hours)	3.71 $\pm$ 0.100 ^a	3.19 $\pm$ 0.128 ^{ab}
L.S.D for interaction		0.2238	0.2553

Different letters beside the means within each column indicate significant differences ($P \leq 0.05$).

DISCUSSION

The present study demonstrated that both magnetic water treatment and feeding regimen play important roles in regulating reproductive development and endocrine activity in Japanese quail. The findings clearly indicate that the use of magnetized water significantly enhanced gonadal growth and reproductive hormone secretion in both sexes, while the 5-hour daily time-restricted feeding regimen exerted comparatively moderate physiological effects, which were largely associated with changes in body weight and nutrient availability without inducing severe nutritional stress.

In male quail, the significant increase in testicular weight observed in birds provided with magnetized water was accompanied by elevated serum testosterone concentrations, indicating enhanced steroidogenic activity and reproductive maturation. This response may be associated with enhanced testicular development and steroidogenic activity. Furthermore, the positive relationship between testicular size and testosterone production has been widely reported, reflecting the greater capacity of enlarged testes (specifically through increased Leydig cell populations within the interstitial tissue) to synthesize and secrete androgens (Garamszegi, 2005; Skrobanek *et al.*, 2009). Consequently, the improved nutrient utilization, enhanced blood microcirculation, and cellular metabolic efficiency associated with magnetic water treatment appear to act synergistically to promote both somatic development and neuroendocrine-driven reproductive activity.

Conversely, time-restricted feeding did not significantly influence testicular weight or testosterone concentration, suggesting that the applied feeding regimen had no significant effect on these reproductive parameters. These findings are consistent with previous reports indicating that short-term feed restriction during early growth stages does not markedly impair male gonadal development in Japanese quail (Lamošová *et al.*, 2004). However, the significant interaction between water type and feeding regimen implies that magnetic water treatment may act as a physiological buffer to mitigate the mild environmental stress associated with temporary dietary restriction. Reduced corticosterone secretion (the primary avian stress hormone) under lower stress conditions may enhance hypothalamic secretion of gonadotropin-releasing hormone (GnRH), thereby stimulating pituitary release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which are essential for testicular growth and steroidogenesis (Saraswati *et al.*, 2013).

A similar pattern was observed in female quail, where magnetized water significantly increased ovarian weight, indicating enhanced reproductive organ development and functional maturation. This improvement may be mediated by elevated gonadotropin concentrations, as FSH and LH play central roles in follicular recruitment, ovarian steroidogenesis, and oviduct development during the onset of sexual maturity (Saraswati *et al.*, 2013; Rehman *et al.*, 2020). Furthermore, birds maintained under free-feeding conditions exhibited higher ovarian weights than those subjected to time-restricted feeding, suggesting that unrestricted feed availability may support ovarian development and follicular growth (Reddish *et al.*, 2003; Arora & Samples, 2011).

The significant interaction effects observed for ovarian weight and gonadotropin concentrations further suggest that magnetized water may partially counteract the physiological limitations imposed by feed restriction. By enhancing feed utilization efficiency and reducing stress-induced corticosterone secretion, magnetized water may promote activation of the hypothalamic–pituitary–gonadal (HPG) axis, leading to increased secretion of FSH and LH and consequently driving ovarian follicular development and structural hypertrophy. Adequate nutrient intake under free-feeding conditions may also enhance pituitary sensitivity to hypothalamic stimulation and improve ovarian responsiveness to circulating gonadotropins. Conversely, unmitigated feed restriction may reduce endocrine efficiency and limit hormone

secretion from the anterior pituitary gland (Renema *et al.*, 1999; Hill *et al.*, 2008; Deviche *et al.*, 2010).

Overall, the integrated responses observed in both sexes indicate that magnetized water exerts a consistent positive influence on reproductive physiology through dual pathways of metabolic optimization, stress mitigation, and neuroendocrine regulation. Although the 5-hour daily time-restricted feeding regimen alone maintained homeostatic baseline values without markedly compromising reproductive parameters, its interaction with water quality demonstrated synergistic benefits that supported gonadal growth and endocrine activity. These findings highlight the importance of optimizing both nutritional and environmental management practices to enhance reproductive efficiency in Japanese quail, particularly under conditions where stress and growth dynamics may influence activation of the reproductive axis.

CONCLUSION

The findings indicate that magnetized water had a positive effect on reproductive and hormonal traits in Japanese quail, particularly by improving testicular and ovarian weights and enhancing reproductive hormone concentrations. In contrast, time-restricted feeding had limited effects in males but negatively affected ovarian weight and reproductive hormone concentrations in females. The interaction between the two factors further demonstrated the beneficial influence of magnetized water on reproductive performance. Overall, magnetized water appeared to have a greater positive influence on reproductive and hormonal traits than time-restricted feeding.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

تأثير استخدام الماء الممغنط والتقنين الغذائي الزمني في بعض المؤشرات التناسلية والهرمونية لدى طيور السمان الياباني (*Coturnix japonica*)

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الخلاصة

هدف البحث إلى دراسة تأثير استخدام الماء الممغنط والتقنين الغذائي الزمني في بعض المؤشرات التناسلية والهرمونية لدى طيور السمان الياباني (*coturnix japonica*)، إذ استُخدم في التجربة 312 فرخاً من فراخ الفري الياباني غير مجنسة بعمر يوم واحد، وزعت الأفراخ عشوائياً إلى أربع معاملات كل منها ضمت 78 فرخاً وهي (T1 معاملة الماء غير الممغنط والتغذية الحرة، T2 معاملة الماء غير الممغنط والتقنين الغذائي لمدة 5 ساعات يومياً، T3 معاملة الماء الممغنط والتغذية الحرة، T4 معاملة الماء الممغنط والتقنين الغذائي لمدة 5

ساعات)، وضمت كل معاملة ثلاثة مكررات في كل منها 26 فرخاً، مع توحيد ظروف الإيواء والرعاية والتغذية لجميع المعاملات.

أظهرت النتائج ارتفاعاً معنوياً ($P \leq 0.05$) في وزن الخصى وتركيز هرمون التستوستيرون لدى ذكور معاملات الماء الممغنط بالمقارنة مع الذكور التي استهلكت الماء غير الممغنط، كما أظهرت الإناث التي استهلكت الماء الممغنط زيادة معنوية ($P \leq 0.05$) في وزن المبيض وتركيز هرمونات LH و FSH. لم يُظهر التقنين الغذائي تأثيراً معنوياً في وزن الخصى أو تركيز التستوستيرون بين ذكور المعاملتين، بينما تفوقت إناث التغذية الحرة معنوياً ($P \leq 0.05$) في وزن المبيض وتركيز LH و FSH مقارنة بإناث التقنين الغذائي. وأشارت نتائج التداخل إلى تفوق معنوي ($P \leq 0.05$) في وزن الخصى وتركيز هرمون التستوستيرون لدى ذكور معاملات T3 و T4 بالمقارنة مع معاملات T1 و T2، كما تفوقت إناث معاملات الماء الممغنط T3 و T4 في وزن المبيض وتركيز FSH بالمقارنة مع إناث معاملات T1 و T2، بينما سجلت معاملة T3 أعلى تركيز لهرمون LH. وأظهرت هذه النتائج أهمية استخدام الماء الممغنط منفرداً أو بالتداخل مع التقنين الغذائي ودوره في تحسين بعض المؤشرات التناسلية والهرمونية للطيور.

كلمات مفتاحية: وزن الخصى، وزن المبيض، مستوى التستوستيرون، الهرمونات المحفزة للمناسل، الهرمونات التناسلية.

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