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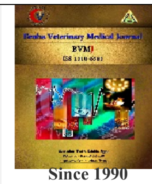

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Effect of feed restriction on some behavioral patterns, productive, and reproductive traits in Japanese quail

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ABSTRACT

The current study was conducted to investigate the impact of feed restriction on behavioral patterns, productive, and reproductive performance of Japanese Quail. Total number of 480 quail aged 6 weeks of both sexes were equally assigned to four groups (3 replicates per group). First Group (G1) was allowed to eat the whole day (control group). Second (G2), Third (G3), and Fourth Group (G4) were allowed to eat two times, three times, and four times per day respectively. All groups were subjected to 16 hours of light per day. Behavior of birds was observed 3 days per week. Body weight, productive performance (egg weight and quality), and reproductive performance (fertility and hatchability) were measured for all groups. Results were analyzed using mixed models in SPSS. Analysis showed that feeding twice a day significantly reduces the body weight ($P<0.057$), frequency of sexual behavior ($P<0.05$), percentage of fertility ($P<0.0001$), hatchability ($P<0.001$), percentage of unhatched fertile eggs ($P<0.0001$), and clear eggs ($P<0.0001$), compared to the control group. While feeding three and four times a day had a significantly higher effect on egg production ($P<0.0001$), egg weight ($P<0.0001$), fertility ($P<0.0001$), and hatchability ($P<0.001$) than feeding twice a day. Results showed that feed restriction could be used to protect the health and welfare of Japanese quail.

1. INTRODUCTION

Animal protein intake deficit and the ever-increasing human population in developing countries are of utmost concern. Quails, in general, and Japanese Quails, in particular, are one of the alternative sources of animal protein. The Japanese quail has a low maintenance cost as well as a short generation interval, which allows it to reach sexual maturity sooner and is more resistant to diseases than other birds (Abbas et al., 2015). Overfeeding laying hens (ad-libitum) leads to overconsumption of energy, and excessive abdominal fat accumulation predisposes layers to heat stress. In addition, high lameness rates and high mortality due to skeletal disorders impact the laying performance of laying hens at the age of 40 weeks (Oyedeji et al., 2007) as the feeding process represents the majority of the production cost (65% - 80%) of chicken meat and eggs. Therefore, restricted feeding would reduce costs, improve egg quality, and reduce mortality in the laying period.

In poultry, especially chickens, feed restriction has been studied and documented (Hester and Stevens, 1990; Lee et al., 1971). The focus of these studies has been on the effects of feed restriction on growth and reproductive variables. These studies have produced contradictory results. There may be a part of the reason for this on the basis of different modes of feed restriction, such as daily restriction (Lee, 1987), skip-a-day feeding (Wilson et al., 1983), and chemical restriction (Pinchasov and Jensen, 1989). In addition, several studies have examined the impact of feed restriction on the performance of the meat birds at different ages (Gebhardt-Henrich and Marks, 1995; Hassan et al., 2003; Lee and Leeson, 2001; Zubair and Leeson, 1994; Zulkifli, 2003). In previous studies, feed restriction has been cited as a critical factor in a good performance in both feed efficiency and growth rate.

Feed restriction programs in broilers may induce compensatory growth, resulting in improved feed efficiency and reducing exposure to suboptimal levels of nutrients, but the efficiency of the usage of those nutrients may be affected (Abbas et al., 2015). There is a common practice of restricting ad-libitum feed consumption by 50-90% to reduce metabolic disorders and improve productivity (Fidan and Kaya, 2014; Najafi et al., 2015). At the onset of lay, feed restriction did not affect body weight, but it did delay the age of first laying. This study aims to investigate the impact of feeding system on behavior, productive, and reproductive performance of Japanese quail.

2. MATERIAL AND METHODS

The study procedures were approved by animal's care and use ethics committee (No. BUFBTMO 2-08-22) of Faculty of Veterinary Medicine, Benha University, Egypt and were conducted along the period from August to September 2020

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2.1. Birds and Management

At the age of two-weeks, a total of 480 healthy unsexed Japanese quail chicks, with an average body weight of $51.80 \pm 0.66\ grams$, were purchased from a private farm in Kafr El-Sheikh Governorate, Egypt. Following the chick's arrival, they were housed in one room (3.75 m length x 3.50 m width x 3.20 m height) for 3 weeks for adaptation. Then, chicks were randomly divided into 4 groups with a sex ratio of 1:3 (male to female) and reared on deep littered floor pens (3.75 m length × 1.00 m width × 1.00 m height) which had been previously prepared and disinfected. Chicks in each pen were randomly divided into 3 replicates where each replicate conceives the same sex ratio of 1 male to 3 females. The floor of the pen was covered by a layer of wood shaving about 10 cm in depth. Along the experimental period, the average temperature and relative humidity% were 31 ± 1.28 ℃ and 55%-65% respectively and the photoperiod were set to be 16 hours light and 8 hours darkness. Feeders and drinkers were provided before the arrival of the birds. Ingredients and chemical composition of the commercial diet for quail during laying have been summarized in Table 1

Table 1: Composition and Nutrient Content of the Basal Diets

Ingredients (g/kg as fed)	Growing phase	Laying phase
Yellow corn	55.40	57.80
Soybean meal (46%cp)	34.60	24
Corn gluten meal (60% cp)	5.80	6.1
Limestone	1.63	6.0
Wheat bran	0.0	2.4
Soyabean oil	0.3	1.5
Monocalcium phosphate	1.4	1.4
Common salt	0.25	0.25
Vitamin and mineral premix	0.2	0.2
Bicarbonate sodium	0.11	0.11
Lysine HCL	0.13	0.1
dl-methionine	0.08	0.09
Choline chloride	0.1	0.07
Calculated chemical composition (%)		
DM	87.2	87.12
Metabolizable energy (kcal/kg)	2900	2900
Crude protein	24	19.98
Ca	0.94	2.58
Na	0.17	0.17
ca	0.82	2.52
Available phosphorus	0.42	0.41
Na	0.15	0.15
Chloride	0.22	0.22
Lysine	1.3	1.00
Methionine	0.52	0.47

Vitamin and mineral premix: composition per 3kg, vit. A 12,000,000 I.U.; vit. D3 2,000,000 I.U.; vit. E 10.000 mg; vit. K3 1000 mg; vit. B1 1000 mg; vit. B2 5000 mg; vit. B6 1500 mg; vit. B 12 10 mg; niacin 30,000 mg; biotin 50 mg; folic acid 1000 mg; pantothenic acid 10.000 mg; chloride 500,000 mg; zinc 50,000 mg; manganese 60.000 mg; iron 30,000 mg; copper 10,000 mg; selenium 100 mg; cobalt 100 mg; calcium carbonate to 3 kg

2.2. Experimental Design

Quails were allocated randomly to 4 groups, 120 birds each. Each group was divided to 3 replicates (40 birds each) with a sex ratio 1 male: 3 females. Each replicate had one feeder and one drinker according to feeding time restrictions from 6 weeks old. Birds in the first group (G1), the control group, were fed ad libitum for 28 days. Birds in the second group (G2) were fed twice daily (at 7:00 am and 7:00 pm) for 30 minutes each time. Birds in the third group (G3) were fed three times daily (7:00 am, 1:00 pm, and 7:00 pm) for 30 minutes each time. While birds in the fourth group (G4) were fed four times daily (7:00 am, 11:00 am, 3:00 pm, and 7:00 pm) for 30 minutes each time. All groups were subjected to 16 hours of light per day.

2.3. Behavioral Observations

Behavioral patterns of each group were recorded 3 days weekly, 3 times per day during morning (8:00 – 9:00 am), during afternoon (12:00 – 1:00 pm), during the evening (5:00 –6:00 pm) using scan observation (Cornetto and Estevez, 2001). The behaviors of each replicate were recorded for 10 minutes in the morning, afternoon, and the evening per day. All observations were carried out by one observer who was present at all measurement points in the experiment to familiarize the quails with the presence of humans, we had one week training and acclimation to avoid the effect of the observer on the behaviors of quails. Behavioral patterns were recorded as described by (Dawkins, 2004), and and were presented in Table 2.

Table 2: Behavioral Patterns Observed throughout Experiment

Observed behaviors		Description
Ingestive Behavior	Feeding	Head extended towards available feed troughs
	Drinking	The beak of bird in or above the drinkers
Resting Behavior	crouching	Bird laying on the ground with closed eyes
Body care Behavior		A group of behavioral patterns including preening, feather ruffling, scratching, head shaking, leg and wing stretching, dustbathing.
Pecking Behavior		In this behavior one bird pecks at the body of another bird usually directed to the head, may cause serious injuries such as skin or eyelid lesions or eye loss.
Sexual Behavior	Incomplete Mating	In this behavior the male quail grasps the back of female's head and mounting attempts without vent positioning or ejaculation.
	Complete Mating	In this behavior the male quail grasps the back of female's head and mounting attempts, with vent positioning or ejaculation.

2.4. Growth Performance Parameters (Body Weight)

The individual body weight of 5 females per replicate per group was recorded weekly (Yalçin et al., 1998)

2.5. Productive performance

2.5.1. Estimation of egg production and quality parameters

Eggs were collected daily; the number and the weight of each group were recorded to calculate the egg production rate and average egg size for each group. Weekly egg production was calculated by dividing total egg number on number of female quails (El-Sheikh et al., 2016). A total number of 60 eggs (15 per group) were collected at the end of the experiment to calculate the external and internal egg quality parameters within 24 hours of collection. External egg quality traits included egg weight, egg length, egg width, shape index, shell weight and thickness. The egg and shell weights were recorded by using an electronic scale (mg) while egg length and width (mm) was measured with an electronic digital caliper. Egg shell thickness without membranes was measured at three different regions of the shell (broad, medium, and narrow ends), and the average was recorded. The egg shape index was calculated according to (Ahmed et al., 2005)

$$Egg\ shape\ index = \frac{egg\ width\ (mm)}{egg\ length\ (mm)} * 100.$$

The internal egg quality parameters which included albumin height (AH), albumin weight (AW), albumin diameter, albumin index (AI), yolk height (YH), yolk weight, yolk diameter, yolk index (YI) was measured by breaking each egg gently with a scalpel and placing the contents on a flat surface. All these traits were measured with an electronic digital caliper. The yolk weight (g) was separated from the albumin and weighted. Albumin weight (g) was calculating by subtracting egg weight from both shell and yolk weight. The AI and YI were calculated according to (Taskin et al., 2017) with the following formula

$$AI(\%) = \frac{AH}{\left(\frac{average\ albumin\ length\ +\ width}{2}\right)} \times 100$$

$$YI = \frac{YH}{yolk\ diameter} \times 100$$

2.5.2. Estimation of fertility and hatchability percent

Eggs were daily collected and stored in a refrigerator at 10°C -12°C for 5 days before they were placed in the incubator. The incubation was performed by using automatic paterzime setter under the recommended temperature (37.5°C), RH (65%) with automatic turning every 6 hours for 15 days. During the last two days of incubation, eggs were set on boxes in the floor of incubator for hatching at temperature (36.5°C) RH (75%). On day 17 (the end of incubation period) the newly hatched chicks were counted and weighted, while unhatched eggs were broken to determine infertile eggs and dead embryos. Fertility and hatchability per total and fertile eggs percentage were calculated according to (Dauda et al., 2014) as following

$$Fertility\ (\%) = \left(\frac{number\ of\ fertile\ eggs}{total\ number\ of\ eggs\ set}\right) * 100$$

$$Hatchability\ of\ Total\ Eggs\ set\ (\%) = \left(\frac{number\ of\ hatched\ chicks}{total\ number\ of\ eggs\ set}\right) * 100$$

2.6. Statistical analyses

The SPSS software version 25 (SPSS, 2017) was used to analyze the data. All data were analyzed using analysis of variance (ANOVA). The values were represented as Mean ± S.E of means. The statistical significance was considered at P ≤ 0.05

3. RESULTS

3.1. Behavioral observations

3.1.1. Ingestive and crouching behaviors

The effect of feed restriction on ingestive behavior was presented in Table 3. Feed restriction had a significant effect on feeding behavior (P<0.05) in which the frequency of feeding behavior was significantly higher in those birds exposed to feed restriction of feeding three times per day G3, and four times per day G4 in comparison to control group G1. However, there was no significant effect on drinking behavior (P>0.05). The birds of G2 had a significantly higher frequency of body care in comparison to control G1, G3, and G4 (P=0.05), while birds in G1 had a significantly higher frequency of crouching in comparison to restricted groups (P<0.05). Also, the birds those exposed to feed restriction of feeding only two times per day G2 had a significantly higher frequency of pecking behavior in comparison to other treatment groups including control (P<0.05)

3.1.2. Sexual Behavior

The effect of feed restriction on sexual behavior of Japanese quail is given in Table 4. Feed restriction had a significant effect on the total number of mating, and successful mating (P<0.05). The birds exposed to feed restriction of feeding only two times per day G2 had a significantly lower number of total mating and successful mating compared to control group G1 which fed ad libitum. But there was no significant effect on unsuccessful mating (p>0.05)

Table 3: Effect of Feed Restriction on Ingestive, Body Care, Crouching, and Pecking Behaviors

Group	Feeding	Drinking	Body Care	Crouching	Pecking
G1	3.67 ± 0.55[b]	3.67 ± 0.82	1.44 ± 0.18[b]	1.44 ± 0.18[a]	0.40 ± 0.12[bc]
G2	4.33 ± 1.17[ab]	3.67 ± 0.80	4.00 ± 0.60[a]	0.89 ± 0.20[b]	1.67 ± 0.21[a]
G3	5.44 ± 0.47[a]	3.67 ± 0.80	2.11 ± 0.31[b]	0.50 ± 0.20[c]	0.80 ± 0.17[b]
G4	5.44 ± 0.38[a]	3.56 ± 0.82	2.11 ± 0.35[b]	0.56 ± 0.18[bc]	0.30 ± 0.11[c]
P value	0.004	0.99	<0.001	<0.001	<0.0001

Superscript letters within columns are different between groups which significantly different at (p≤0.05). G1= Fed ad-libitum; G2= Fed twice a day; G3= fed three times a day; G4 = Fed four times a day

Table 4: Effect of Feed Restriction on Sexual Behavior

Group	Number of Mating	Successful Mating	Unsuccessful Mating
G1	3.53 ± 0.46[a]	1.87 ± 0.21[a]	1.67 ± 0.32
G2	2.40 ± 0.25[b]	0.80 ± 0.13[b]	1.50 ± 0.18
G3	3.08 ± 0.32[ab]	1.65 ± 0.20[a]	1.43 ± 0.14
G4	3.10 ± 0.31[ab]	1.63 ± 0.16[a]	1.47 ± 0.16
P value	0.05	<0.0001	0.92

Superscript letters within columns are different between groups which significantly different at (p≤0.05). G1= Fed ad-libitum; G2= Fed twice a day; G3= fed three times a day; G4 = Fed four times a day

3.1.3. Body weight

Results in Table 5 showed the effect of feeding time restriction on female body weight of Japanese quails. During the 6th and 7th weeks, results showed that there was no significant difference in live female body weight among the treatment groups (P<0.05). However, during the 8th and 9th weeks there was highly significant difference in live female body weight among treatment groups in which G2 was significantly lower than other groups (P=0.057) (p=0.044)

Table 5: Effect of Feed Restriction on Body Weight of Female Quail

Groups	6th week	7th week	8th week	9th week
G1	214.07 ± 3.94	236.07 ± 7.81	241.00 ± 5.82[a]	255.53 ± 3.00[a]
G2	222.13 ± 7.19	226.53 ± 5.44	223.47 ± 1.14[b]	231.33 ± 1.92[b]
G3	214.80 ± 2.12	224.00 ± 1.17	232.07 ± 0.98[ab]	245.33 ± 9.99[ab]
G4	210.73 ± 6.04	232.67 ± 2.90	236.53 ± 3.99[a]	248.27 ± 1.16[a]
P value	0.503	0.364	0.044	0.057

Superscript letters within columns are different between groups which significantly different at (p≤0.05). G1= Fed ad-libitum; G2= Fed twice a day; G3= fed three times a day; G4 = Fed four times a day

3.2. Egg production and quality Parameters

3.2.1. Egg production

The effect of the feed restriction on egg production of Japanese quail was shown in Table6. In week six, the egg production and weekly egg weight per bird in G1 and G4 were significantly higher than other treatment groups (P<0.05), while in weekly egg number per bird, G1 was significantly higher than other groups (P<0.05). In week seven, eight, and nine, feed restriction had a significant effect on total number of eggs (P<0.05), weekly egg number per bird (P< 0.05), weekly egg weight (gm)/bird in which the highest result was in G1 and the lowest one was in G2

3.2.2. Internal egg quality traits

The effect of the feed restriction on internal egg quality parameters were displayed in Table 7. There was no significant difference among groups in shape index and shell thickness (P>0.05) but increased numerically in restricted groups (G2, G3, and G4) than control group G1. While in yolk index there were significant differences among treatment groups in which, G3 recorded the highest value (P<0.05), while in albumin index G4 were significantly higher than other groups (p<0.05)

3.3. Reproductive performances

Results of the effect of feed restriction on fertility, and hatchability of Japanese quail were shown in Table 8. The fertile and hatched egg percentage were significantly lower in G2 (p<0.05), while G3 had the highest result (p<0.05). While the percentage of the fertile not hatched eggs, G2 was significantly higher than other groups (p<0.05) while G1 had the lowest (p<0.05). Percentage of clear egg G2 was significantly higher than in other groups (p<0.05) and the lowest value was in G3 (p<0.05)

Table 6: Interaction Effect of Feed Restriction and Age of the Bird on Egg Production

Week	Group	Number of Eggs	Num. of Eggs per week / bird	Weight of Eggs per week / bird	Number of Female
6th week	G1	62.00±4.00^{a}	2.05±0.16^{a}	23.45±1.32^{a}	29.33±1.45
	G2	40.00±4.00^{c}	1.38±0.14^{c}	15.58±2.33^{c}	29.00±0.85
	G3	48.00±3.46^{bc}	1.62±0.12^{bc}	18.32±1.48^{bc}	29.67±0.33
	G4	56.67±3.84^{ab}	1.89±0.13^{a}	21.07±0.79^{a}	30.00±0.00
	P value	**0.016**	**0.037**	**0.037**	**0.688**
7th week	G1	116.00±2.31^{a}	4.01±0.16^{a}	44.17±2.17^{a}	29.00±1.00
	G2	84.00±2.31^{b}	3.10±0.20^{b}	34.75±2.71^{b}	27.33±1.76
	G3	114.67±0.88^{a}	3.92±0.03^{a}	43.57±0.58^{a}	29.00±0.00
	G4	112.00±1.00^{a}	3.87±0.09^{a}	44.41±0.63^{a}	29.00±0.58
	P value	**<0.0001**	**<0.006**	**0.014**	**0.404**
8th week	G1	147.00±4.73^{a}	5.08±0.21^{a}	58.89±2.25^{a}	29.00±1.00
	G2	78.67±1.45^{c}	2.96±0.13^{c}	35.41±1.51^{b}	26.67±1.45
	G3	129.33±2.03^{b}	4.51±0.12^{b}	54.27±1.46^{a}	28.67±0.33
	G4	128.33±1.20^{b}	4.49±0.15^{b}	55.06±1.29^{a}	28.67±0.88
	P value	**<0.0001**	**<0.006**	**<0.0001**	**0.390**
9th week	G1	163.85±6.17^{a}	5.65±0.28^{a}	84.45±3.02^{a}	29.00±1.00
	G2	91.67±6.84^{c}	3.43±0.11^{c}	45.42±1.93^{b}	26.67±1.45
	G3	154.33±6.12^{b}	5.39±0.23^{b}	70.80±2.90^{a}	28.67±0.33
	G4	157.00±2.65^{b}	5.56±0.20^{b}	74.89±2.21^{a}	28.33±1.20
	P value	**<0.0001**	**<0.0001**	**<0.0001**	**0.473**

Superscript letters within columns are different between groups which significantly different at (p≤0.05). G1= Fed ad-libitum; G2= Fed twice a day; G3= fed three times a day; G4 = Fed four times a day

Table 7: Effect of Feed Restriction on Internal and External Egg Quality

Group	Shape Index	Yolk index	shell thickness	albumen index
G1	0.81 ± 0.01	0.78 ± 0.01^{bc}	4.62 ± 0.32	0.39 ± 0.01^{c}
G2	0.82 ± 0.01	0.83 ± 0.02^{ab}	4.40 ± 0.27	0.41 ± 0.01^{bc}
G3	0.84 ± 0.01	0.84 ± 0.02^{a}	4.76 ± 0.33	0.43 ± 0.01^{ab}
G4	0.82 ± 0.01	0.77 ± 0.01^{c}	4.91 ± 0.45	0.44 ± 0.01^{a}
P value	0.078	0.011	0.763	0.002

Superscript letters within columns are different between groups which significantly different at (p≤0.05). G1= Fed ad-libitum; G2= Fed twice a day; G3= fed three times a day; G4 = Fed four times a day

Table 8: Effect of Feed Restriction on the Percentage of Fertility and Hatchability

Group	Total Number of Eggs	Percent of Fertile egg	Percent of Hatched egg	Percent of Fertile not hatched egg	Percent of Clear egg
G1	114±3.21^{a}	71.61±0.17^{b}	65.81±0.76^{a}	5.80±0.05^{c}	28.36±0.04^{b}
G2	64±4.16^{c}	65.76±0.75^{c}	54.90±0.02^{c}	10.86±0.20^{a}	34.44±0.69^{a}
G3	92±5.69^{b}	74.72±2.29^{a}	65.85±0.21^{a}	8.87±0.05^{b}	26.29±2.66^{c}
G4	104±4.00^{ab}	70.51±0.33^{b}	62.75±0.05^{b}	8.76±0.09^{b}	28.86±0.56^{b}
P value	<0.0001	0.005	<0.0001	<0.0001	0.018

Superscript letters within columns are different between groups which significantly different at (p≤0.05). G1= Fed ad-libitum; G2= Fed twice a day; G3= fed three times a day; G4 = Fed four times a day

4. DISCUSSION

Behavioral observations showed in Table 3 that the frequency of feeding behavior was higher in feed restricted birds compared to those feed ad-libitum. The differences in feeding behavior could be explained by the sense of hunger and birds tried to eat as much as they can, results were in line with the findings of Trocino et al., (2020) who found that the percentage of feeding behavior was significantly higher in feed restricted broiler chickens compared to birds fed ad libitum. Also, Yan et al., (2021) found that the feeding behavior was more frequent in feed restricted broilers than ad libitum. Meanwhile there was no significant effect on drinking behavior because the water was always available to all groups. Crouching behavior was significantly affected by feed restriction as the lowest frequency was in feed restricted groups. Similarly, Trocino et al., (2020) observed that the percentage of crouching behavior was higher in birds feed ad libitum compared to those on restricted feeding program. The reduced resting behavior in feed restricted birds may be attributed to hunger and increased activity and foraging behaviors to search for food as reported by Dixon et al., (2014) who found that feed restricted broiler breeders show increased activity and foraging behavior. Also, Trocino et al., (2020) reported that pecking behavior was higher in feed restricted group than those fed ad libitum. The increased pecking activity in feed restricted birds could be a sign of stress (Sandilands et al., 2005).

Regarding to the sexual behavior shown in Table 4, feed restriction had a significant effect on the total number of mating and successful mating behavior that was the lowest in bird fed twice per day (G2), that may be due to the feed restriction decrease sexual hormones level responsible for sexual behavior and due to prolonged periods of hunger effect on sexual activity of birds, while there was no significant effect on unsuccessful mating. The same result was observed by De Beer and Coon, (2007) who found that feed restriction significantly affects the age for sexual maturity of breeder broilers due to lack of required protein and energy. Feed restriction induces multiple physiological changes that affect the sexual behaviors of birds. Feed restriction down regulated the genes that are important for sexual behaviors in both male and female Japanese quails. (HAO et al., 2019) restricted feeding significantly inhibited ovary estrogen receptor, melatonin 1B receptor gene expression at 14 wk., 18 wk. and the first egg.

Table 5 revealed that feed restriction affected the female quail body weight of quail at the 8th and 9th week of age, which may be due to the feed restriction applied lead to reduction in body weight of the restricted groups. The current results agreed with Mahrose et al., (2022) who observed that the group of Japanese quail fed ad libitum had the heaviest BW when compared with birds that received feed restriction. Also, (Butzen et al., 2013; Svihus et al., 2013) reported that broilers fed ad libitum were heavier body weights than those subjected to feed restriction.

Our results showed that feed restriction had a significant effect on the egg production of quail as shown in Table 6. Birds exposed to feed restriction of feeding only two times per day had a significant reduction in egg production, and egg weight compared to control and other treatment groups. Similar to our results, Gebhardt-Henrich and Marks, (1995) reported that early feed restriction reduces egg production in quail. Similar results were observed in turkey (Miles and Leeson, 1990). Cave, (1981) demonstrated that feeding broiler breeder hens three times a day increased egg production during the first 10 weeks compared with hens fed once or twice a day.

The obtained results showed that feed restriction had no significant effect on egg quality except the yolk and albumin index as shown in Table 7. The quail fed three times per day were laid egg with higher yolk and albumin index. Similarly, Mahrose et al., (2022) who found that the feed restriction numerically effects on shell thickness and albumen percentage in quail. Also, Li et al., (2011) found that feed restriction numerically impacted egg quality traits.

Table 8 revealed that feed restriction by feeding laying quail three times per day significantly increases the percentages of fertility, and hatchability. Similarly, Mahrose et al., (2022) found that subjecting Japanese quails to restricted feeding improved fertility and hatchability. Also, Carneiro et al., (2019) concluded that the broiler breeders group subjected to restricted feeding showed higher values of fertility and hatchability than those of the control group. Also, Gebhardt-Henrich and Marks, (1995) found that hatchability of eggs was affected by feed restriction (70% of ad libitum consumption).

5. CONCLUSION

We concluded that feed restriction by feeding laying quail only two times per day significantly reduced BW, frequency of sexual behavior, percentages of fertility and hatchability, and significantly increased the frequency of aggressive pecking behaviors, percentage of unhatched fertile eggs, and clear eggs, in comparison to birds fed ad libitum. However, feed restriction of laying quail fed three or four times per day had significant effect on egg production, and egg weight, fertility, and hatchability in comparison to quail feed two times per day. These results show that feed restriction regimen showed be done carefully to protect the health and welfare of laying Japanese quail.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest for current data

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