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EFFECTS OF FEEDER SHAPE ON BEHAVIORAL PATTERNS, PERFORMANCE AND EGG QUALITY TRAITS OF JAPANESE QUAIL

Hesham H. Mohammed[1*], Ibrahim F. Rehan[2], Ahmed F. Abou-Elnaga[3], Radi A. Mohamed[4]

[1]Department of Veterinary Public Health, Faculty of Veterinary Medicine, Zagazig University, 44511, Egypt. [2]Department of Animal Behavior and Husbandry, Faculty of Veterinary Medicine, South Valley University, 83523, Egypt, [3]Department of Husbandry and Development of Animal Wealth, Faculty of Veterinary Medicine, Mansoura University, 35516, Egypt. [4]Department of Aquaculture (Animal and Fish Behavior and Welfare), Faculty of Aquatic Sciences and Fisheries, University of Kafrelsheikh, 33511, Egypt

*Corresponding author, E-mail: heshamvet_hosny@yahoo.com

Abstract: Offering the food to Japanese quails may help to reorganize their behavioral needs. However, limited data was reported on the effect of feeder shape on birds' behaviors, welfare, and productivity. Herein, the main objective was to assess the effects of the most available feeder shapes in the Egyptian market on the birds' behaviors. The shape of feeders were longitudinal, vertical-narrow, vertical-wide and round. All the used feeders were made from plastic, marked with a grey color and enriched with a net. A total of 180 one-day old Japanese quail (*Coturnix japonica*) were divided into four experimental groups (three replicates of each). Behavioral patterns of birds were investigated by direct observation and video recording for four days per week using scan sampling technique. The results indicated that there were feeder shape-dependent-differences in quail behaviors demonstrating the highest significant (P<0.001) levels of activity behaviors in a round feeder compared to other groups. Moreover, the highest significant (P<0.001) levels of resting behaviors within a vertical-wide feeder group. Likewise, flying behavior was recorded in the above mentioned group. However, the fear associated responses and alertness were the highest significant level (P<0.001 each) in longitudinal and vertical-wide feeders. Noticeably, the aggressive pecking was the highest significant (P<0.001) levels in birds dealt with a longitudinal feeder. Meanwhile, almost of a quail's egg quality traits demonstrated the highest significant values (P<0.001) during offering round containers for the birds. The results therefore suggested that quails might have a preference to deal more with a round feeder shape than other shapes. These findings may also have great implications to researchers, veterinarians and stakeholders to decide the most economic feeder shape of quails for greater performance and productivity.

Key words: feeder shape; welfare; egg quality; quail

Introduction

Today, the poultry industry is the most popular and enriched sources of animal protein in the form of eggs. Therefore, poultry welfare is

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essential to be deeply understood. Welfare of poultry is mainly regulated by basic principles, among which feeding plays as the most important input for intensive poultry production and has superseded effect on the financial viability of the production cycle (1). Previous and new studies have been done to maximize the feeding efficiency of chickens in areas like ingredients' selection and feed processing methods (2), the effect of feed particle size on flock performance (3), and gut development (4). However, a little data informed the impact and efficiency of different feeder shapes on birds' feeding behavior and/or productivity.

Hence, Japanese quails were inexpensive to keep and had a high immunity against common poultry diseases, we should pay attention to the tool/feeder by which offered the food to realize the birds' behavioral needs toward welfare and productivity (5). Feeding of quail has been studied in several aspects, even though few have compared the different quail feeder design in a collective study. It was reported that design way, such as size, place, geometry, spacing and/or angle of feeders can change the behavior of animals (6). Moreover, nets or partition grids covering feed trays were widely used in the poultry farms to promote a better collection of the birds around the feeders and to reduce feed competition, fighting and wastage (7). The feeder body might be in the form of a channel having a substantially C-, V- or U-shape in cross-section and comprising a passageway extending between the first and the second openings (8). Moreover, the same author stated that the body of animal feeding device may have any suitable cross-sectional shape like circular, triangular, square or oval. Likewise, the most available feeder shapes are linear, vertical and round shape in the Egyptian market. It was given by the fact that the body of the animal/bird feeding device may be designed of any size, type, shape or configuration, and it will be understood that the size of the body will be linked to the animal with which the animal feeding device is intended to be used. Therefore, the patterns of brain activation might be regulated by particular neuropeptides and/or gene expressions like immediate-early gene toward the targeted preferences (9).

Egg weight, shell weight, shell thickness, weight of albumen and yolk are the most important traits affecting egg quality under a good managemental condition (e.g., feeder shape) and fertility (10). Positive correlations among egg weight, shell weight and shell thickness have also been studied (11). However, poor egg quality results substantial economic losses to the worldwide egg industry (12). Together, it seems likely that the feeder shapes of quails may help to understand their behavioral needs towards the well-being and egg productivity. Therefore, the current study aims to check the influences of four different feeder shapes (longitudinal, vertical-narrow, vertical-wide and round) in relation to the quails' behaviour, performance and egg quality traits. Our finding may give a merit to decide the most attractive feeder shape of quail for economic purposes in quail farms.

Material and methods

This experiment was done after the approval by Ethics and Animal welfare committee of the poultry Research Unit, Faculty of Veterinary Medicine, Zagazig University, Egypt (ANWD-206).

Birds and housing

A total of 180 one-day-old Japanese quail chicks (*Coturnix japonica*), weight 7.43 ± 0.28 g purchased in one batch from Faculty of Agriculture, Zagazig University. The chicks were divided into four groups (45 quails/each) and each group was divided into three replicates (each 15 birds/0.563m^2) kept in brooder house in the same home pen. The experimental groups were categorized according to feeder's shapes (longitudinal, vertical-narrow, vertical-wide and round), as shown in Figure (1). All the used feeders were made of plastic type, marked with a red color and enriched with net to avoid the food wastage. Quail chicks were provided with 35°C ambient temperature during the 1st week of brooding and then gradually decreased by about 3.5°C/week till chicks were entirely feathered at 3-4 weeks. Each pen supplied with

10 cm thickness of sawdust (deep litter system) and hydrated lime was firstly sprinkled before spreading the well dried new litters. Available area per quail was $0.038 m^2$/bird. Quails were supplied with food and water as *ad-libitum* source in a synchronization program twice daily, 7 am and 5 pm, throughout the study. The basic commercial quail's starter diet through the rearing phase contained 24% crude protein and 12.45 MJ/kg metabolizable energy (13). Laying hens in all groups were fed commercial feed mixtures (Table 1), which was formulated to give the typical nutrient requirements (14) of quail contained 20% crude protein, 2.5% calcium and 11.93 MJ/kg metabolizable energy. The lighting system was 16 h of light for the period of rearing and subsequently from the six weeks of age altered to 14 h light with 10 h dark until the end of the study. The group housed quails were marked on their back by using a permanent marker pen to permit individual identification and these marks were refreshed every week throughout the experimental period.

Behavioral observation

Quails behavior was recorded by direct observation through using scan sampling technique (15), where each group was observed 3 times daily (20 min each) for 4 days weekly for the duration of the rearing period at 7 am, 12 pm and 4 pm for reporting the different behavioral patterns (see Table 2). The same individual recorded the behavioral patterns in all experimental groups through standing directly in front of each group and waiting 10 min prior the recording data to avoid any disturbance in the behaviors and to minimize the error factors (16). After scanning, the numbers of quails were counted in the observed pens to calculate the frequencies of behaviors per 1 h. These numbers were important to be used in recording the activities of quails in all treated groups (17).

Growth performance

Growth performance was recorded previously (5), where the quails were weighed on 1st day of age as one-day-old live weight and then live body weights was subsequently estimated weekly until the 4th week of age using digital balance (Sartorius 1202 MP balance, GmbH, Gottingen, Germany). Also, the average feed intake was recorded daily after calculating the feed residues. Body weight gain and feed conversion ratio were also calculated.

Egg quality traits

60 quail's eggs (from the 7th until the 10th weeks of age) were collected (15 eggs from each group). The Sartorius 1202 MP balance measured the weight (g) of whole egg, albumen, yolk and egg shell weight, while electronic digital caliper was used for calculating the whole egg length, its width and shell thickness (mm) (18-21).

Data analyses

Data were tested for distribution normality, linearity and homogeneity of variance. Data were analyzed using SAS statistical system, Package v9.2, version (22). Data were reported as means ± SEM, compared by one-way ANOVA and the Duncan's multiple range tests was used as a post hoc test. The behavioral variables did not meet the requirements of parametric tests even after transformation, therefore the equivalent non-parametric Kruskal–Wallis test was used to compare between different groups. While, the significant differences among groups were estimated by Mann-Whitney test.

Results

Effect of feeder shape on behavioral patterns

The results showed that there was an effect of feeder shapes on the behavioral patterns and performance of quails (Table 3). The highest levels of eating behavior were recorded in the group dealt with a round feeder compared to the other treatment groups. Moreover, the highest levels of activity (e.g., walking, preening, body shaking, dust pecking, leg stretch and wing stretch) were observed in the same above group ($P<0.001$). Furthermore, the highest level of resting period (e.g., sitting, dust-bathing and sleeping) was recorded in the group dealt with a vertical-wide feeder ($P<0.001$). However, the highest fear response (e.g., stand idle and elimination) were found in the group dealt with a longitudinal feeder (P<0.001, P<0.001) and the quail vices (e.g., feather pecking, loudly sounds) were the highest recoding in the same feeder shape, with a significant level P<0.001 each. Meanwhile, alertness (e.g., drinking, standing) were the highest observations in the group dealt with a vertical-narrow feeder, P≤0.001 each, compared to the other treatment groups.

Effect of feeder shape on bird's performance

There were significant effects of the different feeder shape on quail performance (Table 4). In particular, quail group dealt with a vertical-wide feeder in the 1^{st} and 3^{rd} week (P≤0.05) had the highest body weight in comparison with the other groups. However, the rest of weeks had no significance differences. Moreover, there was no significant difference in feed intake, weight gain and feed conversion ratio between different feeder shapes. While the longitudinal feeder showed the highest weight gain and the lowest feed conversion ratio, and vertical-narrow feeders recorded the lowest feed intake.

Effect of feeder shape on egg quality traits

There were statistical effects of feeder shapes on the external quality (egg weight, width, length, shell weight, and shell thickness) also on the internal quality (albumen and yolk weight) of quail's eggs (see Table 5). The highest levels of egg quality traits (e.g., egg weight, egg width, shell thickness and albumen weight) represented in the group dealt with a vertical-wide feeder (P≤0.001) compared to the other treatment groups. Moreover, the highest level of shell weight demonstrated in the group dealt with a round feeder (P<0.001) compared to the other groups. However, the high levels of egg length and yolk weight shown in the group dealt with a longitudinal feeder (P=0.004, P<0.001, respectively) compared to the other groups.

Relationship between external and internal egg quality traits

There were correlation coefficients among the external and internal egg quality traits in Japanese quail dealt with the analyzed feeder shapes (Table 6). Albumin weight was positive correlated with all external traits except shell weight, which was negatively correlated with yolk weight. Furthermore, there was negative correlation between yolk weight and shell quality (shell weight and thickness), while yolk weight correlated positively with other external egg quality.

Table 1: Ingredients of the experimental diet (kg/100kg)

Ingredients	Kg	Calculated analysis	
Yellow corn	65	Metabolized energy	11.93 MJ/kg
Soybean meal (44%)	20	Crude protein	20%
Corn gluten	5.2	Calcium	2.5%
Calcium carbohydrate & phosphate	2.1		
Soybean oil	0.2		
Premix and common salts	0.7		
Other feed additives	0.6		

Table 2: Definition of recorded behaviors

Behaviors	Definition
Eat	Head extended towards available feed resources while beak in or above the drinker appears to be manipulating or ingesting feed
Drink	Beak in contact with water in or above the drinker and appears to be drinking water
Walk	Moves forward taking one or more steps
Sitting	Head rested on something (litter or another bird) while sitting
Dust bathing	Bathing the dust with the use of wings, head, neck and legs performing vertical wing-shaking
Preen	Beak related behavior that beak touches the plumage of the bird itself
Stand	The abdomen is not touching the litter and the bird is motionless with no apparent movement of legs
Idl	Standing with motionless
Sleeping	Bird's neck is fully recumbent and the eyes permanently closed while lying
Body shaking	Raise feathers and shake body
Elemination	Dropping of fecal materials
Dust pecking	Peck floor with feet usually associated with eating behavior
Leg stretching	Extending one leg at the same side of the body
Wing stretching	Extending one wing at the same side of the body
Fly	By forcing wings displacement from one place to another
Feather pecking	Birds pecks the feather of another birds
Sound	Call or vocalization given by the bird

Table 3: Means (±SEM) of some behavioral patterns of Japanese quail using different shapes of feeders (Numbers of quails/hour)

Behavioral patterns	Shapes of feeders				*P*-Values
	Longitudinal feeder	Vertical narrow feeder	Vertical wide feeder	Round feeder	
Eat	356.58±23.98	343.50±33.89	369.67±33.86	372.17±55.53	0.36
Drink	122.17±1.27^{b}	134.17±1.50^{a}	130.50±2.17^{a}	105.83±1.01^{c}	0.000
Walk	300.00±3.78^{c}	318.67±3.24^{b}	325.83±1.96^{ab}	328.33±2.03^{a}	0.000
Sit	658.67±16.14^{b}	654.83±14.31^{b}	769.75±13.57^{a}	716.75±12.91^{b}	0.000
Dust bath	15.33±1.35^{b}	16.92±1.12^{b}	28.83±0.90^{a}	14.08±0.70^{b}	0.000
Preen	277.08±8.22^{b}	271.00±3.42^{b}	268.63±5.11^{b}	321.00±3.43^{a}	0.000
Stand	332.00±1.95^{a}	336.17±2.47^{a}	229.25±3.26^{c}	275.42±5.56^{b}	0.000
Idle	142.08±3.38^{a}	139.09±2.06^{a}	94.33±1.69^{c}	120.25±2.98^{b}	0.000
Sleep	353.06±8.37^{c}	356.42±3.80^{c}	444.33±2.17^{a}	391.83±3.25^{b}	0.000
Body shaking	25.58±1.93^{a}	14.66±0.56^{b}	17.58±0.76^{b}	25.66±1.26^{a}	0.000
Elimination	3.15±0.36^{a}	2.08±0.28^{b}	0.58±0.22^{c}	.33±0.03^{c}0	0.000
Dust peck	49.66±3.99^{b}	35.58±1.94^{c}	44.66±1.57^{b}	59.00±0.94^{a}	0.000
Leg stretch	47.5±2.36^{b}	51.58±1.82^{b}	46.92±1.31^{b}	60.66±2.15^{a}	0.000
Wing stretch	76.08±2.06^{b}	74.00±1.47^{b}	68.00±2.23^{c}	103.17±1.73^{a}	0.000
Fly	15.50±0.64^{c}	22.16±0,71^{b}	26.5±0.95^{a}	21.5±0.87^{b}	0.000
Feather peck	4.25±0.52	4.00±0.36	3.66±0.33	4.08±0.35	0.77
Sound	3.25±0.56	2.58±0.41	2.00±0.42	2.66±0.48	0.33

^{abc} Means within the same row having different superscripts are significantly different at $P \leq 0.05$

Table 4: Means (± SEM) of growth performance of Japanese quail using different shapes of feeders

Growth performance	Shape of feeders				*P*-Values
	Longitudinal feeder	Vertical narrow feeder	Vertical wide feeder	Round feeder	
Initial body weight (g)	6.76±0.57	7.37±0.32	7.27±0.66	8.32±0.56	0.25
Body weight in 1st week (g)	55.5±2.38^{ab}	54.41±2.08^{ab}	61.58±2.76^{a}	50.16±2.70^{b}	0.02
Body weight in 2nd week (g)	102.68±3.54	96.23±4.41	104.89±3.57	108.19±1.82	0.11
Body weight in 3rd week (g)	138.34±5.06^{ab}	135.72±4.36^{ab}	148.01±4.25^{a}	129.84±4.21^{b}	0.05
Body weight in 4th week (g)	192.20±4.93	186.06±6.92	185.98±5.19	180.11±5.49	0.52
Feed intake (g)	15.58±0.72 a	15.11±0.64 a	15.37±0.65 a	15.91±0.53 b	0.83
Weight gain (g)	185.40±5.00	178.70±6.81	178.70±5.60	171.80±5.50	0.43
Feed conversion ratio	2.38±0.15	2.39±0.13	2.44±0.17	2.62±0.13	0.60

^{ab} Means within the same row having different superscripts are significantly different at $P \leq 0.05$. g= gram

Table 5: Means (± SEM) of egg quality traits of Japanese quail using different shapes of feeders

Egg quality	Shape of feeders				*P* Values
	Longitudinal feeder	Vertical narrow feeder	Vertical wide feeder	Round feeder	
Egg weight (g)	11.48±0.18^{a}	10.59±0.23^{b}	11.61±0.15^{a}	10.36±0.16^{b}	0.000
Egg width (mm)	25.53±0.41	24.79±0.22	26.01±0.26	25.26±0.49	0.128
Egg length (mm)	32.20±0.66^{a}	30.64±0.46^{b}	32.09±0.26^{a}	30.06±0.43^{b}	0.004
Shell weight (g)	1.03±0.02^{c}	1.41±0.04^{b}	1.58±0.03^{a}	1.60±0.05^{a}	0.000
Shell thickness (mm)	0.21±0.007^{c}	0.26±0.017^{ab}	0.27±0.004^{a}	0.23±0.009^{bc}	0.001
Albumin weight (g)	6.12±0.07^{a}	5.82±0.16^{a}	6.24±0.12^{a}	5.12±0.22^{b}	0.000
Yolk weight (g)	4.33±0.16^{a}	3.42±0.15^{b}	3.78±0.09^{b}	3.64±0.12^{b}	0.000

^{abc} Means within the same row having different superscripts are significantly different at $P \leq 0.05$.
g= gram mm= millimeter

Table 6: Correlation coefficients among the external and internal egg quality traits in Japanese quails

Egg quality traits	Egg weight (g)	Egg width (mm)	Egg length (mm)	Shell weight (g)	Shell thickness (mm)
Albumin weight (g)	0.786***	0.312*	0.449***	-0.242	0.296*
Yolk weight (g)	0.610***	0.333***	0.375***	-0.362***	-0.291*

The asterisk (*) showed a significance level, $P \leq 0.05$ and the asterisk (***) showed a significance level, $P \leq 0.001$.
G= gram mm=millimeter

Figure 1: Different shape of feeders from left to right longitudinal feeder, vertical-narrow feeder, vertical wide feeder and round feeder.

Discussion

The behavioral patterns reflect a serious of the activities of endocrine and exocrine character for assessing the animal's response to its environment that consequently impairs its welfare and production (23). Herein, for the first time, we examine the influence of feeder shape on the CNS stimuli of quail hens to be targeted on their behavioral responses and production.

As a result shown in Table 3, the eating behavior had no significant difference among all groups. It means that the feeder shapes have no clear influences on feed intake of quails. Meanwhile, the quail hens have been dealt with round shape feeders were the best group to perform several behaviors other than eating, such as, activity behaviors (e.g., walking, preening, leg/wing stretching, pecking and body shaking) and resting behaviors (e.g., sitting, sleeping and dust-bathing). All these behaviors are considered to be 'natural behaviors', and good indicators of welfare of birds (24). However, the quail hens have been dealt with longitudinal/vertical-narrow shape feeders were the groups clearly performed the fear associated responses (e.g., elimination and idle) as well as alertness behaviors (e.g., drinking and standing). By which, these behaviors are considered poor indicators of welfare of birds. Moreover, it's well-known that quails/birds can stay rested up to 70–80% of their time (25). It can be understood that the birds using a vertical-wide feeder somehow felt more comfortable by staying/resting nearby this feeder shape than others.

Changing of the management condition in quail farm might affect the performance of the birds. The result in Table 4 showed that quails dealt with a vertical-wide feeder showed significantly the best body weight, particularly in the 1^{st} and 3^{rd} week of age comparable to the other groups. In spite of the non-significant effects of different feeder shapes on quails' weight in the 4^{th} week, quail dealt with a round feeder showed the best body weight and feed intake compared to the other groups. These results agreed with two other researchers who stated that some management condition can affect the growth performance of quails (26, 27), such as body weight (28) and feed consumption (29). Our results indicated that the vertical-wide and round feeder shapes can positively affect the performance of quails and it can show the good managerial conditions applied in our experiment. This preference of these feeder shapes towards the increasing the activities and performance of quails might relate to the centrally induced appetite by neuropeptide Y (30). Moreover, it is probably regulated by the high genetic expression of immediate-early gene Zenk in Pallial brain structure (9).

In this study, the average values of external quality traits of quail's eggs (e.g., egg weight, its width, its length & shell weight and its thickness) in Table 5, indicated similarities with the finding of most researchers (11, 31-35). Likewise, the average of internal quality traits of quail's eggs (e.g., albumen weight and yolk weight) indicated similarities by the finding of above researchers. It seems likely that the slight differences between the results of egg quality traits of this research and the results of the other researchers might have resulted from the genetic structure, health condition, flock age, use of different content diet in feeding, and the differences in the care and management condition of the quails (e.g., feeder shape). We reached the point that offering feeder shapes might change the behavioral patterns of quails and remain an important question whether feeder shape can affect the egg quality traits. In this study (Table 6), statistically significant correlation (M±SEM) was obtained among the average of egg weight, its width, shell weight, and shell thickness, especially in the group dealt with a vertical-wide feeder compared to the other treatment groups. Therefore, the egg weight had an indirect relation with the shell quality of the egg. It has been stated by most of the researchers reported that the shell thickness had a direct relation to egg weight (36, 37), also had a positive correlation to the shell weight (36, 38). It's well-known that shell ratio in the total egg had an opposite relation to the egg weight. It comes from the fact that the increase depending on the egg weight on the shell weight and the shell thickness was less than the increase of other components that formed the egg (35). However, by offering a vertical-wide shape and a round shape feeder to quail hens, the shell weight (1.58±0.03, 1.60±0.05, respectively) and shell thickness (0.27±0.004, 0.23±0.009, respectively) have not been clearly affected by the egg weight. Therefore, the rounded feeders have the best economic value among the other groups. It means that the egg shell quality would be evaluated by using the egg weight values due to the positive relation determined between the egg weight and the shell thickness, and the shell weight. In this study, statistically a significant negative correlation was present between the albumen and yolk weight of the egg particularly in the group dealt with a vertical-wide shape feeder (6.24±0.12, 3.78±0.09, respectively) and the other group dealt with a round shape feeder (5.12±0.22, 3.64±0.12, respectively). It was reported that the housing system can affect egg quality and concentration of cholesterol in egg yolk in hens (39), Thusly, increasing the yolk weight in the whole egg is not preferable for human health and marketing. In this study, the group dealt with a longitudinal feeder had the significant highest yolk weight (4.33±0.16) than the other groups. However, the improvement of the albumen weight indicated the dense albumen quality to perfectly estimate the internal egg quality traits (35). In our study, almost all internal quality traits of the egg were significantly influenced based on the influence occurred in the egg weight with respect to the external quality traits. However, the yolk weight and egg length were negatively correlated to the albumen weight. This case was found to be in conformity with the findings of some researchers (40). The results were in contrast with the results mentioned that there were positive significant differences among egg weight and egg length (41).

Our finding has evidence that the quails had a more prefer to deal with rounded feeder than longitudinal and vertical ones indicating good behaviors and welfare. It has great implications for researchers, veterinarians and stockholders to decide the most economic feeder shape of quails for the maximum performance and productivity.

Conclusion

The different feeder shapes influenced the quails' behavior, welfare and productivity. Herein, the birds have demonstrated significantly the highest behavioral patterns when offering round shape feeder. However, the significant lowest activities have been detected when offering longitudinal/vertical shape feeder. It seems likely that the birds were familiarities to the round shape feeder. The quails' performance and egg quality traits had significant effects due to changes in shapes of feeder types. Therefore, for maintaining a successful and profitable quail farming business, the round feeder container as a recommended.

Contributions

Hesham H. Mohammed and Ibrahim F. Rehan are mutually contributed to this study, designed the survey protocol, supervised data collection procedures and drafted the final version of the manuscript; Ahmed F. Abou-Elnaga and Radi A. Mohamed analyzed the data and shared in experimental protocol. All authors have finalized the experimental design and revised the manuscript and then contributed to, edited, and approved the final manuscript as submitted.

Competing financial interests

The authors declare that they have no competing financial interests and non-financial interests.

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