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Research Article

Effects of Cage Stocking Density on Egg Quality Traits in Japanese Quails

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Abstract

This study was conducted to investigate the effects of different stocking densities on external and internal egg quality traits and to measure the phenotypic correlation coefficients between external and internal egg quality traits. Two hundred and sixteen birds of Japanese quail at 14th week of age were used in this experiment. The birds were divided randomly into three groups, 60, 72 and 84. Each group subdivided into 4 replicates, where the cages floor spaces were 200, 167 and 143 cm^2/bird; respectively. The obtained results revealed that birds housed at 200 cm^2/bird laid heavier egg weight (12.24 g), with significant ($P<0.05$) higher external quality traits, including shell weight (1.27 g), eggshell ratio (10.55%), shell thickness (0.23 mm) and egg shell density (48.70 mg/cm^2). Similarly, internal quality traits, including yolk height (10.72 mm), albumen height (5.67 mm), yolk diameter (24.97 mm), yolk index (43.49%) and Haugh unit (92.77). Shell weight positively correlated with yolk height ($P<0.01$), albumen height ($P<0.01$), albumen weight ($P<0.05$) and haugh unit ($P<0.01$). It was concluded that, housing Japanese quail at low cage floor space associated with depression in external and internal egg quality traits. Moreover there is an economical hazard of housing quails at cage floor space lower than 200 cm^2/bird.

Keywords: *Cage, Egg quality, Stocking density, Quail*

Bıldırcınlarda Kafes Yoğunluğunun Yumurta kalitesi Üzerine Etkileri

Özet

Bu çalışma değişik kafesleme yoğunluklarının iç ve dış yumurta kalitesi üzerine etkisini araştırmak, iç ve dış yumurta kalitelerinin fenotipik korelasyon katsayısını ölçmek amacıyla yapılmıştır. Çalışmada 14 haftalık toplam 216 bıldırcın kullanılmıştır. Hayvanlar rastgele olarak 3 gruba (60, 72 ve 84) ayrıldı. Her bir grup taban alanları sırasıyla 200, 167 ve 143 cm^2/bıldırcın olacak şekilde ayrıca 4 tekrarlı olmak üzere ayrıldı. Çalışma bulguları sonucunda 200 cm^2/bıldırcın olan grupta bıldırcınların daha ağır yumurta verdikleri (12.24 g), anlamlı derecede daha yüksek dış özellikler gösterdikleri; kabuk ağırlığı (1.27 g), kabuk oranı (%10.55), kabuk kalınlığı (0.23 mm) ve kabuk yoğunluğu (48.70 mg/cm^2) belirlendi. Benzer olarak iç kalite özellikleri; yumurta sarısı yüksekliği (10.72 mm), yumurta akı yüksekliği (5.67 mm), yumurta sarısı çapı (24.97 mm), yumurta sarısı indeksi (%43.49) ve Haugh birim (92.77) olarak belirlendi. Kabuk ağırlığı pozitif olarak yumurta sarısı yüksekliği ($P<0.01$), yumurta akı yüksekliği ($P<0.01$), yumurta akı ağırlığı ($P<0.05$) ve Haugh birim ($P<0.01$) ile ilişkiliydi. Çalışma bulguları; bıldırcınların küçük tabanlı alanda yerleştirilmesinin dış ve iç yumurta kalitesini olumsuz etkilediği ortaya koymuştur. Bıldırcınların kafes taban alanının 200 cm^2/bıldırcından daha düşük olmasının ekonomik kayıp oluşturduğu sonucuna varılmıştır.

Anahtar sözcükler: *Kafes, Yumurta kalitesi, Kafes yoğunluğu, Bıldırcın*

INTRODUCTION

Japanese quail (*Coturnix coturnix japonica*) is distributed in many parts of the world, also in Egypt where it could be used as a source of meat and eggs. It has also depicted worldwide usage as laboratory animal [1]. Advantages of Quail as meat animal are: low housing costs and smaller body weight so low floor and/or cage space requirements. In addition to, outcome of waste is low compared with other conventional livestock enterprises, and thus it is not so detrimental to the environment [2].

Overall egg quality is important for both poultry breeders and for consumers. Poor quality results in substantial economic losses to the worldwide egg industry. For example, losses due to poor eggshell quality have been

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calculated to be in the order of 6-8% [3]. The egg industry is more dependent on high stocking densities for laying hens and quails either during the rearing or laying phases as a tool to reduce housing and equipment costs per bird. The much reduction in the available cage floor space per bird, moreover, feeder and drinker space per bird, may have depressive effects on growth and later performance, so feed intake might decrease which had a worse effect on live weight, and muscular and bone development. Body weight and feed intake are key factors in bird development, egg production, egg size and feed conversion [4].

The phenotypic correlation between any two quantitative traits explained the degree to which individuals above average for one trait tend to be above, below or near the average for the other traits [5]. Knowledge of correlations among productive traits is essential for the construction of selection indices designed to maximize the rate of genetic improvement. Phenotypic characteristic for egg quality traits of external and internal type is important mainly for interest of economy of production [6]. The eggs weight is directly correlated with egg shell quality which has a positive correlation with shell thickness and shell weight [7]. Kul and Seker [8] estimated the phenotypic correlation between internal and external quality traits of eggs in quails. Positive phenotypic correlation was recorded between egg weight and other egg biometrical traits. Ayasan et al.[9] demonstrated high feed conversion ratio, live weight and carcass traits in female quails managed at low stocking density.

The economical importance of stocking density comes from its depressive effect on gain per bird housed and too small profit margins as poultry industry depends on intensive production [10]. Therefore, the objectives of the present investigation were to evaluate the effects of cage density on external and internal egg quality traits and to measure the phenotypic correlation coefficients between external and internal egg quality traits.

MATERIAL and METHODS

Experimental procedures were conducted in accordance with the Zagazig University Animal Ethics Committee guidelines (ANWD-206). Two hundred and sixteen birds of Japanese quails at 14th week of age were used with average initial body weight (173.46 g±1.38). The birds were obtained from experimental unit belonging to Faculty of Agriculture, Zagazig University. The birds were divided randomly into three groups, 60, 72 and 84. Each subdivided into 4 replicates, where the cages floor spaces were 200, 167 and 143 cm^2/bird; respectively. The measures of each cage were 60 x 50 x 37 cm (L x W x H).

Fourteen hours of light per day were provided for quails to maintain maximum egg production and fertility. Supplementary lighting was provided as required to maintain the production [11]. Basic quail's diet was provided ad libitum containing 19.5% crude protein and 2852 k.cal ME/kg. The calculated analysis and ingredients of laying diet were demonstrated in *Table 1*. To assess the egg quality parameters, a total of 240 fresh eggs were randomly collected in 4 sequent weeks, 80 eggs from each stocking density group. Eggs were individually labeled after collection and the following measures of egg quality were taken.

Egg weight measured using the Sartorius 1202 MP balance with accuracy 0.01 g. Egg length and width (mm) measured using an electronic digital caliper. Egg shape index: calculated as egg width/egg length x 100 [12]. Egg shell thickness (mm): measured using an electronic digital caliper, taken as the mean of measures from the equator and both ends of the egg. Egg shell weight (g) was measured, as well as egg shell percentage as shell weight/egg weight x 100. Egg surface area cm^2: calculated as $3.9782W^{0.7056}$, where W = egg weight [13]. Egg shell density mg/cm^2: calculated as shell weight (mg)/egg surface area [14].

The measurements of the internal qualities were obtained by gently broken the egg using a scalpel and the contents were taken on flat surface. The yolk was carefully separated from the albumen for weighing. The albumen weight was calculated by subtracting the weight of yolk and shell from the weight of whole egg. The albumen and yolk height and width (mm) were measured using electronic caliper [15]. Yolk weight ratio (%) = yolk weight (g)/egg weight (g) x 100. Similarly, albumen weight ratio

Table 1. *Diet composition in the laying period*
Tablo 1. *Yumurtlama periyodunca kullanılan diyetin içeriği*

Ingredients	Laying Diet
Yellow corn	64.50
Soybean meal (44%)	20.50
Concentrate (52%)	10.00
Di- calcium phosphate	2.31
Limestone	0.96
DL- methionine	0.09
Lysine	0.08
Vitamin and trace mineral	0.30
Premix	1.06
Coccidostate	0.10
Antioxidant	0.10
Calculated Analysis	
ME (K.cal/kg)	2852
Crude protein (cp %)	19.50
Calcium %	2.33
Available phosphorus %	0.66
Lysine %	1.04
Methionine	0.52

(%) = albumen weight (g)/egg weight (g) x 100. Yolk index (%) = yolk height (mm)/yolk diameter (mm) x 100 [16]. Haugh Unit = 100 log (albumen height (mm) + 7.57 - 1.7 x egg weight (g) $^{0.37}$ [17].

Data were analyzed using SAS statistical analysis system package [18]. One way ANOVA was performed using the following model

$Y_{ij} = \mu + L_i + eij$

Where Y_{ij} = egg quality trait; L_i = effect of i^{th} stocking density and e_{ij} = residual. The preliminary effects of replicates were non-significant. Differences among means were compared statistically using Duncan's multiple range tests [19]. Pearson correlations were performed to compute the relationship of the external and internal egg quality traits.

RESULTS

Means ± standard error of external and internal egg quality traits at different stocking densities (200, 167 and 143 cm²/bird) are shown in *Table 2*. It clearly shows that different stocking densities had significant effect on most of egg quality traits.

Phenotypic correlation coefficient between external and internal egg quality are presented in *Table 3*. As it was seen, there were significant correlations among the different egg quality traits.

DISCUSSION

The primary objective of this study was to investigate the effect of cage stocking density on egg quality traits in Japanese quails and to explore the correlations between external and internal egg quality traits. Birds housed at 200 cm²/bird, cage floor space, recorded significant (P<0.05) higher estimates for egg weight (12.24 g), shell weight (1.27 g), eggshell ratio (10.55%), shell thickness (0.23 mm) and egg shell density (48.70 mg/cm²), compared to birds housed at lower cage floor space (167 and 143 cm²/bird). Results revealed that, stocking density had a non-significant effects (P>0.05) on egg length, where the longest egg length had been measured for quails kept at cage floor space of 200 cm²/bird. Birds housed at 200 cm²/bird, cage floor space, had significant (P<0.05) higher estimates for yolk height (10.72 mm), albumen height (5.67 mm), yolk diameter (24.97 mm), yolk index (43.49%) and Haugh unit (92.77), compared to birds housed at lower cage floor space (167 and 143 cm²/bird). However, results cleared that stocking density had a non-significant effects (P>0.05) on yolk weight, yolk ratio, albumen weight and albumen ratio.

The linear lowering in egg weight with each increase in

Table 2. *Effects of different cage stocking densities on the external and the internal egg quality traits of Japanese quails*
Tablo 2. *Bıldırcınlarda kafes yoğunluğunun dış ve iç yumurta kalitesi üzerine etkileri*

Trait	Cage Stocking Density (cm²/bird)			F	P value
	200	167	143		
Egg weight (g)	12.24±0.16^{a}	11.87±0.12^{ab}	11.74±0.14^{b}	3.16	0.04
Egg Length (mm)	33.11±0.19	32.80±0.18	32.95±0.16	0.74	0.47
Egg Width (mm)	25.92±0.14^{a}	25.50±0.15^{b}	26.12±0.13^{a}	4.80	0.00
Egg shape index (%)	78.41±0.48^{ab}	77.87±0.55^{b}	79.35±0.38^{a}	2.43	0.09
Shell weight (g)	1.27±0.01^{a}	1.08±0.01^{b}	1.06±0.01^{b}	59.98	0.00
Eggshell ratio (%)	10.55±0.19^{a}	9.22±0.11^{b}	9.16±0.14^{b}	25.91	0.00
Shell thickness (mm)	0.23±0.009^{a}	0.20±0.003^{b}	0.20±0.002^{b}	39.68	0.00
Egg surface area (cm²)	23.26±0.21^{a}	22.78±0.17^{ab}	22.59±0.19^{b}	3.10	0.04
Eggshell density (mg/cm²)	48.70±0.90^{a}	44.92±0.51^{b}	44.37±0.64^{b}	11.01	0.00
Yolk height (mm)	10.72±0.22^{a}	9.13±0.12^{b}	8.38±0.14^{c}	48.41	0.00
Albumen height (mm)	5.67±0.13^{a}	4.15±0.06^{b}	3.95±0.05^{b}	38.12	0.00
Yolk diameter (mm)	24.97±0.29^{a}	23.86±0.24^{b}	23.58±0.28^{b}	6.99	0.00
Yolk weight (g)	4.31±0.13	4.31±0.13	4.27±0.11	0.03	0.96
Yolk ratio	35.46±1.08	36.57±1.13	36.86±1.01	0.47	0.62
Albumen weight (g)	6.64±0.17	6.41±0.15	6.26±0.15	1.38	0.25
Albumen ratio	53.98±1.10	54.15±1.12	53.34±0.98	0.15	0.85
Yolk index (%)	43.49±1.09^{a}	38.52±0.63^{b}	35.97±0.77^{c}	19.79	0.00
Haugh unit	92.77±0.40^{a}	87.35±0.33^{b}	86.29±0.35^{c}	32.03	0.00

Means within the same row having different superscripts are significantly different

Table 3. *Correlation coefficients among the external and internal egg quality traits in Japanese quails*
Tablo 3. *Bıldırcınlarda dış ve iç yumurta kaliteleri arasındaki korelasyon katsayıları*

Traits	Egg Weight (g)	Egg Length (mm)	Egg Width (mm)	Egg Shape Index (%)	Shell Weight (g)	Eggshell Ratio	Shell Thickness (mm)	Egg Surface Area (cm²)	Eggshell Density (mg/cm²)
Yolk height (mm)	0.004	-0.03	-0.026	0.001	0.244**	0.222**	0.314**	0.004	0.136*
Albumen height (mm)	-0.031	-0.091	-0.175**	-0.087	0.371**	0.380**	0.262**	-0.032	0.265**
Yolk diameter	0.356**	0.244**	0.233**	0.00	0.220**	-0.058	0.174**	0.357**	-0.037
Yolk weight (g)	0.237**	0.026	0.132*	0.105	0.007	-0.164*	0.058	0.237**	-0.138*
Yolk ratio	-0.169*	-0.274**	-0.096	0.153*	-0.103	0.024	0.004	-0.180**	0.003
Albumen weight (g)	0.671**	0.579**	0.336**	-0.190**	0.135*	-0.338**	0.046	0.671**	-0.267**
Albumen ratio	0.225**	0.298**	0.108	-0.161*	0.013	-0.144*	-0.011	0.226**	-0.119
Yolk index (%)	-0.172*	-0.155*	-0.139*	0.007	0.119	0.242**	0.206**	-0.181**	0.151*
Haugh unit	-0.121	-0.196**	-0.182**	-0.001	0.311**	0.380**	0.299**	-0.139*	0.255**

****** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed)*

density from 200 to 143 cm² per bird agreed with findings of Faitarone et al.[20], this can be explained by depression of feed intake and more energy expenditure may be accountable for the reduction in egg weight of quail housed at higher cage stocking density. Davami et al.[21] concluded that hens in lower density cages were allowed more movement within the cage, which may results in less stressful conditions. Food is portioned between body functions, including maintenance, growth, reproduction and health. In stress, most of the consumed food is used to cope with unpleasant conditions [22]. In the present investigation, this condition may explain the reduction in the egg weight in groups with high densities.

High stocking density in the cages makes it very difficult for the birds to dissipate their heat [23]. Gou et al.[24] stated that, birds raised in small group size had a lower rectal temperature than those raised in big group size, indicating a facilitating effect of thermoregulation. The birds tend to distance themselves from one another to maximize sensible heat loss. The reduction in reproductive performance associated with heat stress is a well-known phenomenon in domestic birds. This is probably due to the direct debilitating effect of high heat stress on ovarian function in the birds or indirectly through reduction in blood flow to the ovary [25]. Also, Dhaliwal et al.[26] stated a higher stocking density adversely affected egg quality. Negotiated results were demonstrated [27]. They found that albumen index and fresh albumen weight were higher in birds in the lower stocking density than those in other stocking density. On the contrary, non-significant effects of stocking density on egg weight in Japanese quails were reported, and accounted these finding for smaller size of Japanese quails compared to Italian quails [28]. Kakimoto et al.[29] and Bovera et al.[30] enhances these finding, they concluded that, external and internal quality of egg remains unaffected by group size in laying hens. Nagarajan et al.[10] reported that shell thickness was influenced neither by age of the hen nor by stocking density, and the yolk index was superior in the lowest stocking density group. Bandyopadhyay and Ahuja [31] added that cage density significantly affected albumen index, yolk index and internal egg quality, but not egg weight, shape index or shell thickness. In general, yolk index and internal egg quality decreased with increasing cage density; albumen index did not show a definite pattern

Egg weight was positively correlated (P<0.05) with yolk diameter (0.356), yolk weight (0.237), albumen weight (0.671) and albumen ratio (0.225). Egg length was positively correlated with yolk diameter (0.244), albumen weight (0.579) and albumen ratio (0.298). Otherwise, egg weight was negatively correlated with yolk ratio (-0.169), due to lower specific gravity of the yolk which has more lipid content. Shell weight was positively correlated with yolk height (0.244), albumen height (0.371), yolk diameter (0.220) and Haugh unit (0.311). Concretely, shell thickness was observed to be correlated significantly with yolk height (0.314), albumen height (0.262), yolk diameter (0.174), yolk index (0.206) and Haugh unit (0.299). Egg shell density was positively correlated with yolk height (0.136), albumen height (0.265), yolk index (0.151) and Haugh unit (0.255). On the contrary, egg length was negatively correlated (P<0.01) with yolk ratio (-0.274) and haugh unit (-0.196). Similarly, eggshell ratio and eggshell density were negatively correlated (P<0.01) with albumen weight (-0.338 and -0.267).

Results regarding the egg weight were positively correlated with yolk diameter, yolk weight, albumin weight, albumin ratio, which are supported by Zita et al.[32]. They measured positive phenotypic correlations of egg weight with yolk weight, albumen weight and egg shell weight. Also, their finding about negative correlation of egg weight with yolk ratio and egg shell proportion negotiated our experiment. In addition to, positive correlation of egg weight with albumen ratio and negative correlation of albumen weight with eggshell ratio. The findings of

Baumgartner [1] and Minvielle et al.[33] are in the same line with our investigation who estimated high positive correlations between egg weight and the weights of its contents but, Baumgartner et al.[34] found that the correlations between egg weight and the yolk, albumen and eggshell weight were non-significant, low positive estimates (0.432, 0.438 and 0.234; respectively). Yannakopoulos and Tserveni-Gousi [35] demonstrated that egg weight was positively correlated with albumen weight. Kul and Seker [6] and Ozcelik [36] stated that the increase in the egg weight will result in decreased yolk ratio. Kul and Seker [6] reported that yolk and shell ratios negatively correlated with the albumen ratio and albumen index. Ozcelik [36] demonstrated that, egg shape index was negatively correlated with albumen weight and yolk weight. We concluded that, housing Japanese quails at low cage floor space associated with depression in external and internal egg quality traits, reflecting the economical hazards of housing quails at cage floor space lower than 200 cm^2/bird.

Conflict of Interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Baumgartner J: Japanese quail production, breeding and genetics. *World Poult Sci J,* 50, 269-274, 1994.

2. Narahari D, Abdul Mujeer K, Thangavel A, Ramamurthy N, Viswanathan S, Mohan B, Muruganandan B, Sundararasu V: Traits influencing performances of Japanese quail eggs. *Br Poult Sci*, 29, 101-112, 1988.

3. Baylan M, Canogullari S, Ayaşan T, Copur G: Effects of dietary selenium source, storage time and temperature on eggshell internal quality in quail eggs. *Biol Trace Element Res*, 143, 957-964, 2011.

4. Anderson KE, Adams AW: Effects of rearing density and feeder and waterer spaces on the productivity and fearful behavior of layers. *Poult Sci,* 71, 53-58, 1992.

5. Pirchner F: Population Genetics in Animal Breeding. 2nd ed,, pp,274, Plenum Press, New - York and London. 1984.

6. Gihan SF, Ensaf AE: Genetic analysis of clutch and some related production traits in Japanese quail. *Egypt Poult Sci*, 32, 443-456, 2012.

7. Olawumi SO, Ogunalde JT: Phenotypic correlation between some external and internal egg quality traits in the exotic isa brown layer breeders. *Asian J Poult Sci*, 2, 30-35, 2008.

8. Kul S, Seker I: Phenotypic correlations between some external and internal egg quality traits in the Japanese Quail *(Coturnix coturnix japonica)*. *Int J Poult Sci,* 3, 400-405, 2004.

9. Ayaşan T, Baylan M, Uluocak AN, Karasu Ö: Effects of sex and different stocking densities on the fattening characteristics of Japanese quails. *J Poult Res*, 2, 47-50, 2000.

10. Nagarajan S, Narahar LD, Jayaprasad IA, Thyagarajan D: Influence of stocking density and layer age on production traits and egg quality in Japanese quail. *Br Poult Sci,* 32, 243-248, 1991.

11. Randall M, Bolla G: Raising Japanese quail. Primefacts. 602 Second ed., 1-5, 2008.

12. Das SK, Biswas A, Neema RP, Maity B: Effect of soybean meal substitution by different concentrations of sunflower meal on egg quality traits of white and coloured dwarf dam lines. *Br Poult Sci*, 51, 427-433, 2010.

13. Sezer M: Heritability of exterior egg quality traits in Japanese quail. *J App Bio Sci*, 1, 37-40, 2007.

14. Vits A, Weitzenbuerger D, Hamann H, Distl O: Production, egg quality, bone strength, claw length, and keel bone deformities of laying hens housed in furnished cages with different group sizes. *Poult Sci,* 84, 1511-1519, 2005.

15. Reddy PM, Reddy VR, Reddy CV, Rap PSP: Egg weight, shape index and hatchability in khaki Campbell duck egg. *Ind J Poult Sci*, 14, 26-31, 1979.

16. Romanoff AL, Romanoff AJ: The Avian Egg. New York, John Wiley and Sons Inc. 1949.

17. Haugh RR: The Haugh unit for measuring egg quality. *U.S. Egg Poult Mag,* 43, 552-555, 572-573, 1937.

18. SAS: SAS/STAT Users Guide. SAS Institute INC, Cary, NC 27513, USA, 2002.

19. Sokal R, Rohlf FJ: Biometry: The principles and practice of statistics in biological research. San Francisco: W. H. Freeman. pp, 776, 1969.

20. Faitarone ABG, Pavan AC, Mori C, Batista LS, Oliveira RP, Garcia EA, Pizzolante CC, Mendes AA, Sherer MR: Economic traits and performance of *italian* quails reared at different cage stocking densities. *Braz J Poult Sci*, 7, 19-22, 2005.

21. Davami A, Wineland MJ, Jones WT, Ilardi RL, Peterson RA: Effects of population size, floor space, and feeder space upon productive performance, external appearance, and plasma corticosterone concentration of laying hens. *Poult Sci*, 66, 251- 257, 1987.

22. Siegel PB, Gross WB: Livestock handling and transport. **In,** Grandin T (Ed): General Principles of Stress and Wellbeing. 2nd ed., pp.27-41,CAB International, Wallingham, 2000.

23. Metheringham J, Hubrecht DR: Poultry in transit A cause for concern? *Br Vet J,* 152, 247-249, 1996.

24. Guo YY, Song ZG, Jiao HC, Song QQ, Lin H: The effect of group size and stocking density on the welfare and performance of hens housed in furnished cages during summer. *Anim Welfare,* 21, 41-49, 2012.

25. Rozenboim I, Tako E, GAL-Garber O, Proudman JA, Uni Z : The effect of heat stress on ovarian function of laying hens. *Poult Sci,* 86, 1760-1765, 2007.

26. Dhaliwal APS, Nagra SS, Brah GS: Effect of cage stocking density and season on laying performance of Japanese quail *(Coturnix coturnix japonica)*. *Ind J Poult Sci*, 42, 243-247, 2007.

27. Waheda P, Rabbani MG, Howlider MAR, Wahid MA: Interaction of group size and stocking density on egg production performance of Japanese quail. *Bang Vet*, 16, 29-33, 1999.

28. Garcia EA, Mendes AA, Gonzales E, Silva ABP, Saldanha ESPB: Productive and economic performance of laying Japanese quails under different stocking density. *Bolet Indúst Anim*, 55, 185-188, 1998.

29. Kakimoto SK, Pizzolante CC, Saldanha ÉSPB, Moraes JE, Laganá C, Madeira LA, Denadai JC: Acidulating in water of Japanese quail *(Coturnix japonica)* housed under different densities. *PUBVET*, 5, NO 37, Unpaginated, 2011.

30. Bovera F, Iannaccone F, Piccolo G, Di Meo C, Russo F, Piscitelli D, Attia YA, Hassan SSA, Nizza A: Effect of group size on performance and egg quality of laying hens during 20 to 36 weeks of age. *Italian J Anim Sci,* 13, 2015-220, 2014.

31. Bandyopadhyay UK, Ahuja SD: Effect of cage density on some of the egg quality traits in Japanese quail. *Ind J Poult Sci*, 25, 59-162, 1990.

32. Zita L, Ledvinka Z, Klesalová L: The effect of the age of Japanese quails on certain egg quality traits and their relationships. *Vet Arch*, 83, 223-232, 2013.

33. Minvielle F, Monvoisin JL, Costa J, Frenot A: Quail lines selected for egg number based on pureline or crossbred performance. *Proceedings of the 12th Symposium on Current Problems in Avian Genetics (Aviagen), Pruhonice (Czech Republic)*. pp.99-103, 1997.

34. Baumgartner J, Koncekova J, Benkova J, Peskovicova D,

Simenovova J, Scuka J: Changes in egg quality traits associated with long-term selection for lower yolk cholesterol content in Japanese quail. *Czech J Anim Sci*, 53, 119-127. 2008.

35. Yannakopoulos AL, Tserveni-Gousi AS: Effect of breeder quail age and egg weight on chick weight. *Poult Sci*, 9, 1558-1560, 1987.

36. Ozcelik M: The phenotypic correlations among some external and internal quality characteristics in Japanese quail eggs. *Ankara Univ Vet Fak Derg*, 49, 67-72, 2002.