

## COMPARISON AMONG THREE LINES OF QUAIL FOR EGG QUALITY CHARACTERS

Asia M. Hassan, Dejeen A. Mohammed, Khabat N. Hussein \* and Shekhmous H. Hussien

Dept. of Animal Production, College of Agriculture – University of Duhok, Kurdistan Region – Iraq - (khabat.noori@uod.ac)

Received: Jul. 2017 / Accepted: Oct., 2017 / Published: Dec., 2017

<https://doi.org/10.25271/2017.5.4.413>

### ABSTRACT:

A total of 300 eggs from 45 female quails from three different lines (Dark brown, light brown and white) aged 10 weeks old were equally divided into three experimental groups having 15 birds of each and caged separately, to estimate the external and internal egg quality traits. Half eggs were measured 24 hrs. post lay and others were measured after one week of storage at room temperature. The results showed that there were significant differences among lines for egg length, yolk height, yolk index, albumen diameter, albumen index and Haugh unit. The light brown line resulted in the best quality. All internal egg quality characters and egg length were differed significantly between fresh and storage eggs. The fresh eggs resulted in better quality than stored eggs. Phenotypic correlation appeared that there were significant correlation coefficients between some egg quality characteristics in dark brown line more than light brown and white lines.

**KEYWORDS:** Egg Quality, Lines, Storage, Quail.

### 1. INTRODUCTION

quails are considered amongst the smallest species of poultry that has been domesticated recently. its scientific name is *coturnix japonica* belongs to the class aves, order galiformes and the family phasianidae (mizutani, 2003). quails are not only attractive for its meat production, but also for egg production (hussain, 2013). the short period of egg incubation which is about 17 days and their high reproductive traits has increased its popularity for commercial egg production in poultry industry (north and bell, 1991; minvielle, 2004). comparable to commercial layers, and in ideal rearing circumstances, quail hen potentially can produce maximum number of eggs; about 350 eggs of 10-12 grams each (hrncar *et al.*, 2014). the productivity and profitability of poultry species is commonly governed by certain properties including; egg hatchability, egg fertility, number of eggs being laid and their quality characteristics (yahaya *et al.*, 2009; alalahan *et al.*, 2015). though, several other factors could have an impact on the egg quality such as; body weight, breed, strain, season, raising practices and relative humidity (narushin, and romanov, 2002; khurshid, *et al.*, 2003; roberts, 2004; nwachukwu *et al.*, 2006; silversides *et al.*, 2006; wolanski *et al.*, 2007). and lacin *et al.*, 2008). moreover, researchers have indicated that numerous traits of egg quality has genetic basis and effected by the genetic variability in dam which is mainly responsible for the hatchability of fertile egg (song *at al.*, 2000; wolc, and olori, 2009). understanding the genetic variability could support in improving the quality traits of egg genetically (song *at al.*, 2000).

The quality traits of eggs including; external and internal traits are considered the main factors that determine the consumer acceptability for table and hatching eggs. And also has important effect on the technology of egg products such as powder, frozen and liquid eggs (Panda, and Singh, 1990). These external characteristics could be egg weight, freshness, eggshell integrity and cleanliness. Whereas, internal properties of egg could be chemical composition, yolk index and Haugh unit and so on (Bhanja *at al.*, 2006; Adeogun, and Amole, 2004

and Dudusola, 2010). Both external and internal characters are correlated with nutrition, management, storage condition, housing density, egg handling and stage of production cycle (Yanakopolous and Tserveni-Gousi, 1986). The size of egg and storage period can considerably affect these characters of egg (Jones and Musgrove, 2005). It's well known that increasing storage time lead to declining the egg quality (Elnagar and Abd-Elhady, 2009). In hens, it was reported that 10 days is the appropriate storage period to maintain better quality of egg, higher number of Haugh units and to produce lower rate of unfavorable physicochemical changes that occur in egg (Yilmaz and Bozkurt, 2009). The increasing trends in quail production in Kurdistan region led the need for studying internal and external quality traits of eggs in the locally available quail lines to grade the eggs according its quality. The aim of current study was to examine and compare the external and internal quality traits of eggs obtained from three different quail's lines.

### 2. MATERIALS AND METHODS

Present study was conducted at Department of Animal Production, College of Agriculture, University of Duhok. A total of 45 female quails from three different lines (Dark brown, light brown and white) aged 10 weeks old were equally divided into three experimental groups having 15 birds of each and caged separately. To estimate the external and internal egg quality traits among the lines, average of 100 eggs were collected from each line; 50 eggs were measured 24 hrs. post lay and other 50 were measured after one week of storage at room temperature. Water and feed provided to bird's *ad libitum* and the ration was submitted according to (NRC, 1994).

The eggs were examined for following traits; egg weight (EW), shape index (SI), shell weight with membrane (SW), Shell percentage (SP), albumen index (AI), albumen weight (AW) albumen percentage (AP), yolk index (YI), yolk weight (YW), yolk percentage (YP) and Haugh Unit (HU). Furthermore, electronic digital Vernier caliper with an accuracy of 0.01 mm was used for measuring egg long diameter or egg length (LD),

\* Corresponding author

This is an open access under a CC BY-NC-SA 4.0 license (<https://creativecommons.org/licenses/by-nc-sa/4.0/>)

egg short diameter or egg width (SD), and egg shell thickness with membrane (ST), yolk height (YH), yolk diameter or yolk width (YD), albumen diameter or albumen width (AD) and albumen height (AH)

The weighing of the eggs was performed by using a digital display scale with an accuracy of 0.01 g. The selected eggs were broken on a table with a glass cover in order to determine the internal quality characteristics. Some egg quality traits were calculated by using formulations, which follow below (Reddy et al., 1979; Monira et al., 2003; and Carter, 1975).

- Shape Index (%): (egg width (mm)/egg length (mm) x 100
- Yolk Index (%): yolk height (mm)/yolk diameter (mm) x 100
- Yolk percentage (%) = [Yolk weight(gm)/ Egg weight(gm)] x 100
- The albumen weight was calculated from the difference between the egg weight, and the yolk and shell weight.
- The Haugh Unit values were calculated for individual egg using the Haugh equation,  
Haugh Unit:  $100 \log [ (\text{albumen height (mm)} + 7.57 - 1.7 \times \text{egg weight}^{0.37} \text{ (g)}) ]$
- Albumen index (%) = Albumen height (mm)/ Average of albumen length and width) mm x100.
- Albumen percentage (%) = (Albumen weight (g) / Egg weight (g)) x 100

### 2.1. Statistical analysis:

The collected data was analyzed using GLM procedure from SAS software (SAS, institute, 2010), according to the following model:

$$Y_{ijk} = \mu + L_i + S_j + e_{ijk}$$

Where:

$Y_{ijk}$  = the observations of the studied trait.

$\mu$  = Overall mean;

$L_i$  = The effect of line;

$S_j$  = The effect of storage period;

$e_{ijk}$  = Experimental error.

Some significance traits exposed to the correlation procedure within the same software. Also, the differences among means were tested using Duncan multiple range test (Duncan, 1955).

### 3. RESULT AND DISCUSSION

The results of external egg quality of three different line plumage colors are presented in Table 1. In the current study significant differences in egg length between experimental lines were observed. That could be due to genetic variance among studied lines. Nonetheless, no significant differences were observed in egg weight, width shape index and shell characters. These results were disagreement with results of (Akram, et al., 2014; Ashok and Reddy, 2010). in which they found no significance difference in egg length while egg weight among different lines of quail were differed significantly.

Table 1. External egg quality characteristics (Means ± S. E.) in quails of different plumage color line.

Characteristics	Dark Brown	Light Brown	White	P-Value
Egg weight (g)	11.39±0.06	11.54±0.09	11.66±0.10	0.0770
Egg length (mm)	32.50±0.11 <sup>ab</sup>	32.17±0.24 <sup>b</sup>	32.81±0.12 <sup>a</sup>	0.0304
Egg width (mm)	25.37±0.04	27.10±1.55	25.63±0.08	0.3024
Shape index	77.69±0.56	88.97±7.08	78.17±0.25	0.0685
Shell weight (g)	1.89±0.31	1.54±0.01	1.59±0.02	0.3708
Shell percentage (%)	14.15±0.31	13.46±0.14	13.66±0.14	0.0739
Shell thickness (mm)	0.30±0.01	0.29±0.004	0.29±0.004	0.2571

<sup>a,b,c</sup>. Means in a row with no common superscript differ significantly.

The result of some internal egg quality traits of three quail lines with different plumage colors are presented in Table 2. The data from yolk height, yolk index, albumen diameter, albumen index and Haugh unit were appeared to be statistically different between the studied quail lines. The yolk height, yolk index and albumen diameter values were highest in white line compared

to both light brown and dark brown lines. While, the values of albumen index and Haugh unit in light brown line were higher than that found in two other lines. Contrast to the present finding, Hrnear et al. (2014) reported insignificant ( $p>0.05$ ) difference between the laying and meat type of quail for Haugh Unit (87.28 and 87.56, respectively).

Table 2. Internal egg quality characteristics (Means ± S. E.) in quails of different plumage color lines.

Characteristics	Dark Brown	Light Brown	White	P Value
Yolk weight (g)	3.77±0.04	3.83±0.03	3.91±0.05	0.107
Yolk height (mm)	11.61±0.08 <sup>b</sup>	11.96±0.20 <sup>ab</sup>	12.45±0.31 <sup>a</sup>	0.0158
Yolk diameter (mm)	26.18±0.10	26.36±0.11	26.22±0.12	0.4846
Yolk percentage (%)	33.53±0.32	33.34±0.28	33.56±0.34	0.8833
Yolk index	44.17±0.42 <sup>b</sup>	45.55±0.84 <sup>ab</sup>	47.63±1.22 <sup>a</sup>	0.0139
Albumen weight (g)	5.99±0.04	6.15±0.08	6.15±0.07	0.1270
Albumen percentage (%)	52.59±0.35	53.19±0.35	53.05±0.48	0.4710
Albumen height (mm)	4.55±0.18	4.54±0.06	4.33±0.05	0.3894
Albumen diameter(mm)	42.54±0.42 <sup>b</sup>	41.50±0.42 <sup>b</sup>	44.50±0.34 <sup>a</sup>	<.0001
Yolk/albumen ratio	64.19±0.92	63.36±0.84	64.53±1.10	0.6935
Albumen index	10.78±0.50 <sup>a</sup>	11.18±0.24 <sup>a</sup>	9.83±0.15 <sup>b</sup>	0.0189
Haugh unit	88.89±0.28 <sup>ab</sup>	89.67±0.36 <sup>a</sup>	88.46±0.30 <sup>b</sup>	0.012

<sup>a,b,c</sup>. Means in a row with no common superscript differ significantly.

The result from effect of stored duration on external egg quality characteristics of quail are given in Table 3. Within the studied characteristics significant differences only found in egg length

between 24 hr and 7 days of storage. Simultaneously the other characteristics were not differing significantly ( $P>0.05$ ).

Table 3. Effect of stored duration on external egg quality characteristics of quail (Means  $\pm$  S. E.)

Characteristics	After 24 h	After 7 d	P-Value
Egg weight (g)	11.50 $\pm$ 0.06	11.55 $\pm$ 0.07	0.7322
Egg length (mm)	32.26 $\pm$ 0.18 <sup>b</sup>	32.69 $\pm$ 0.08 <sup>a</sup>	0.035
Egg width (mm)	26.58 $\pm$ 1.07	25.51 $\pm$ 0.04	0.2900
Shape index	85.34 $\pm$ 4.93	78.11 $\pm$ 0.17	0.1176
Shell weight (g)	1.82 $\pm$ 0.24	1.55 $\pm$ 0.01	0.2899
Shell percentage (%)	14.03 $\pm$ 0.25	13.53 $\pm$ 0.09	0.087
Shell thickness (mm)	0.29 $\pm$ 0.008	0.29 $\pm$ 0.003	0.7493

<sup>a,b,c</sup>. Means in a row with no common superscript differ significantly.

The data from effect of stored duration on internal egg quality characteristics of quail are shown in Table 4. Significant differences noticed in all studied characteristics between 24 hr

and 7 days of storage. These results are in agreement with that mentioned by Elnagar and Abd-Elhady, (2009) who reported that increasing storage time lead to declining the egg quality.

Table 4. Effect of stored duration on internal egg quality characteristics of quail (Means  $\pm$  S. E.)

Characteristics	After 24 h	After 7 d	p- Value
Yolk weight (g)	3.68 $\pm$ 0.04 <sup>b</sup>	3.98 $\pm$ 0.03 <sup>a</sup>	<.0001
Yolk height (mm)	12.43 $\pm$ 0.19 <sup>a</sup>	11.58 $\pm$ 0.14 <sup>b</sup>	0.0004
Yolk diameter (mm)	25.87 $\pm$ 0.09 <sup>b</sup>	26.60 $\pm$ 0.08 <sup>a</sup>	<.0001
Yolk percentage (%)	32.30 $\pm$ 0.26 <sup>b</sup>	34.56 $\pm$ 0.23 <sup>a</sup>	<.0001
Yolk index	47.95 $\pm$ 0.77 <sup>a</sup>	43.65 $\pm$ 0.60 <sup>b</sup>	<.0001
Albumen weight (g)	6.19 $\pm$ 0.05 <sup>a</sup>	6.004 $\pm$ 0.06 <sup>b</sup>	0.011
Albumen percentage (%)	53.87 $\pm$ 0.31 <sup>a</sup>	52.07 $\pm$ 0.30 <sup>b</sup>	<.0001
Albumen height (mm)	4.88 $\pm$ 0.14 <sup>a</sup>	4.12 $\pm$ 0.03 <sup>b</sup>	<.0001
Albumen diameter(mm)	41.67 $\pm$ 0.38 <sup>b</sup>	43.82 $\pm$ 0.28 <sup>a</sup>	<.0001
Yolk/albumen ratio	60.41 $\pm$ 0.71 <sup>b</sup>	67.32 $\pm$ 0.76 <sup>a</sup>	<.0001
Albumen index	11.84 $\pm$ 0.39 <sup>a</sup>	9.51 $\pm$ 0.11 <sup>b</sup>	<.0001
Haugh unit	90.83 $\pm$ 0.25 <sup>a</sup>	87.36 $\pm$ 0.21 <sup>b</sup>	<.0001

<sup>a,b,c</sup>. Means in a row with no common superscript differ significantly.

Regarding to the relationships between egg quality characteristics, the phenotypic correlation coefficients in dark brown line (Table 5), illustrating that most external egg quality characters correlated significantly to internal ones. The highest positive significant correlation coefficient was recorded between shell weight and albumen high (0.98), while the lowest positive significant correlation coefficient was recorded between yolk height and egg weight (0.28). On other hand, the highest significant negative correlation coefficient was obtained between shell weight and albumen diameter (-0.79), while the lowest negative significant correlation coefficient was obtained between albumen weight and shell thickness (-0.40). These findings give a possibility to improve the quality of eggs via wide range of characters in dark brown line.

Contrary to the previous results, the phenotypic correlation coefficients between most characteristics of egg quality in light brown line are not differed significantly (Table 5). The highest positive significant correlation coefficient was recorded between egg weight and albumen weight (0.74), while the lowest positive significant correlation coefficient was recorded

between yolk diameter and albumen diameter (0.26). However, there were not negative significant correlation coefficients between egg quality characteristics in light brown line. These results determining the improvement of egg quality traits in a narrow range, and give an idea that the best quality resulted from the heaviest eggs.

In respect to white line of quail, the phenotypic correlation coefficients between egg quality characters differed than previous both brown lines, in order to show the highest positive significant correlation coefficient between egg weight and yolk diameter (0.73) and also the same value between yolk weight and shell weight (Table 5). While the lowest positive significant correlation coefficient was recorded between albumen weight and albumen diameter (0.56). Also, there were not negative significant correlation coefficients between quality characteristic in white line eggs.

Anywhere, the presence of positive significant correlation coefficient between egg weight and external egg quality traits such as shape index give an idea about egg size (Sezer, 2007).

Table 5. Phenotypic correlation coefficients between different egg quality characters in quails of different plumage color line

Plumage Color	Characteristics	Egg weight	Yolk height	Yolk Diameter	Albumen height	Albumen diameter	Shell weight	Shell Thick-ness	Yolk weight	Albumen weight
dark brown		1.00	0.28 *	0.39 **	0.15	0.04	0.17	0.18	0.20	0.62 **
Light brown	Egg Weight	1.00	0.05	0.30 *	0.02	- 0.05	0.35**	- 0.05	0.61 **	0.74**
White		1.00	0.33	0.73**	0.11	0.65**	0.67**	0.23	0.62**	0.66**
dark brown			1.00	0.22	- 0.004	0.01	0.02	0.07	0.33 **	- 0.01
Light brown	Yolk Height		1.00	- 0.08	0.17	0.02	0.08	0.008	- 0.04	0.07
White			1.00	0.32	0.07	0.14	0.07	- 0.07	0.26	0.23
dark brown			1.00	1.00	- 0.11	0.01	- 0.07	- 0.06	0.39**	0.15
Light brown	Yolk Diameter		1.00	1.00	- 0.16	0.26 *	0.16	- 0.18	0.22	0.17
White			1.00	1.00	- 0.08	0.61**	0.69 **	0.02	0.70 **	0.24
dark brown				1.00	1.00	- 0.78**	0.98**	0.91**	- 0.71**	- 0.44 **
Light brown	Albumen Height			1.00	1.00	0.06	0.27 *	0.22	0.01	- 0.05
White					1.00	1.00	0.07	0.02	0.15	0.01
dark brown						1.00	-	- 0.71**	0.55**	0.53**
Light brown	Albumen diameter					1.00	0.79**	- 0.16	- 0.13	0.04
White							1.00	0.28	0.11	0.30
dark brown							1.00	0.93**	- 0.71**	- 0.44 **
Light brown	Shell Weight						1.00	0.08	0.44* *	- 0.16
White								1.00	0.19	0.73 **
dark brown								1.00	- 0.64**	- 0.40**
Light brown	Shell thickness							1.00	- 0.07	- 0.04
White									1.00	0.13
dark brown									1.00	0.24*
Light brown	Yolk Weight								1.00	- 0.02
White										1.00
dark brown										1.00
Light brown	Albumen Weight									1.00
White										

\*= significant (p<0.05); \*\*= highly significant (p<0.01)

#### 4. CONCLUSION

It could conclude from this study that the light brown line laid the best quality eggs compared to dark brown and white lines, because having the highest Haugh unit, lowest albumen diameter and intermediate yolk height. The fresh eggs resulted in a better quality than stored ones as expected.

#### 5. ACKNOWLEDGMENT

The authors would like to express their thanks to department of animal production -UoD. For providing the rearing location and lab facilities for conducting this research.

#### REFERENCES

- Mizutani, M. (2003). "The Japanese quail" Laboratory Animal Research Station. Nippon Institute for Biological Science, Kobuchizawa, Yamanashi, Japan, 408-441.
- Hussain, J. (2013). "Response to selection for three-week body weight in Japanese quail for three generations" PhD Thesis, University of Veterinary and Animal Sciences Lahore, Pakistan.
- North, M.O. and Bell, D.D. (1991). "Commercial Chicken Production Manual": Published by Avi Book Co. 4th Ed. New York. USA.
- Minvielle, F. (2004). "The Future of Japanese Quail for Research and Production" *World's Poultry Science Journal*, Vol. (60), 500-507.
- Hrnčar, C. Hanusová, A. and Hanus, J.B. (2014). "Effect of Genotype on Egg Quality Characteristics of Japanese Quail (Coturnix Japonica)" *Slovak Journal of Animal Science*, Vol. (47), No.1, 6-11.
- Yahaya, H.K., Oni, O.O., Akpa, G.N. and Adejinka, I.A. (2009). "Evaluation of Layer Type Chickens Under Reciprocal Recurrent Selection" *Bayero Journal of Pure Applied Science*, No .2, 77-82.
- Alasahan, S., Gulsen, C.A., Sibel, C. and Mikail, B. (2015). "Determination of Some External and Internal Quality Traits of Japanese Quail (Coturnix Coturnix Japonica) Eggs On the Basis of Eggshell Colour and Spot Colour" *Journal of Veterinary Science*, Vol. (31), No. 4, 235-24.
- Narushin, V.G. and Romanov M.N. (2002). "Egg-Physical Characteristics and Hatchability" *World Poultry Science journal*, No.58, 297-303,
- Khurshid, A., Farooq, M., Durrani, F.R., Sarbiland, K. and Chand, N. (2003). "Predicting Egg Weight, Shell Weight, Shell Thickness and Hatching Chick Weight of Japanese Quails Using Various Egg Traits as Regressors" *International Journal of Poultry Science*, No. 2, 164- 167.
- Roberts J.R. (2004). "Factors Affecting Egg Internal Quality and Egg Shell Quality in Laying Hens" *The Journal of Poultry Science*, No. 3, 161-177.

- Nwachukwu, E.N., Ibe, S.N. and Ejekwu K. (2006). "Shortterm Egg Production and Egg Quality Characteristics of Main and Reciprocal Crossbred Normal Local, Neck and Frizzle Chicken X Exotic Broiler Breeder Stock in A Humid Tropical Environment" *Journal of Animal and Veterinary Advance*, Vol. (5), No. 7, 547-551.
- Silversides, F.G., Korver, D.R. and Budgell, K.L. (2006). "Effects of Strain of Layer and Age at Photostimulation on Egg Production, Egg Quality Andbone Strength" *Poultry Science*, No. 85, 1136-1144.
- Wolanski, N.J., Renema, R.A., Robinson, F.E., Carney, V.L. and Fancher, B.I. (2007). "Relationship Among Egg Characteristics, Chick Measurements, And Early Growth Traits in Ten Broiler Breeder Strains" *Poultry Science*, No. 86, 1784-1792.
- Lacin, E., Yildiz, A., Esenbuga, N. and Macit, M. (2008). "Effects of Differences in The Initial Body Weight of Groups On Laying Performance and Egg Quality Parameters of Lohmann Laying Hens" *Czech Journal of Animal Science*, No. 53, 466-471.
- Song, K.T., Choi, S.H. and OH, H.R. (2000). "A Comparison of Egg Quality of Pheasant, Chukar, Quail and Guinea Fowl" *Asian - Australasian Journal of Animal Sciences*, Vol. (13), P. 986-990.
- Wolc, A. and Olori, V.E. (2009). "Genetics of Hatchabilityegg Quality from the Perspective of a Chick" 6<sup>th</sup> European Poultry Genetics Symposium, World Poultry Science Association, Bedlewo, Poland.
- Panda, B. and Singh, R.P. (1990). "Developments in Processing Quail Meat and Eggs" *World Poultry Science Journal*, No. 46, 3:219-233.
- Bhanja, S.K., Agarwal, S.K. and Majumdar, S. (2006). "Effect of Cage Floor Space on the Egg Production Performance of Japanese Quail (Coturnix Coturnix Japonica) During Winter" *Indian Journal of Poultry Science*, Vol. (41), No. 2, 205-207.
- Adeogun, I.O. and Amole, F.O. (2004). "Some Quality Parameters of Exotic Chicken Eggs Under Different Storage Conditions" *Bulletin of Animal Health and Production in Africa*, Vol. (52), 2004, pp. 43-47.
- Dudusola, I.O. (2010). "Comparative Evaluation of Internal and External Qualities of Eggs from Quail and Guinea Fowl" *International Research Journal of Plant Science*, Vol. (1), pp. 112-115.
- Yanakopolous, A.L. and Tserveni-Gousi, A.S. (1986). "Quality Characteristics of Quail Eggs" *British Poultry Science*, No. 27, 171-176.
- Jones, D.R. and Musgrove, M.T. (2005). "Effects of Extended Storage On Egg Quality Factors" *Poultry Science*, No. 84, 1774-1777.
- Elnagar, S.A. and Abd-Elhady, A.M. (2009). "Exogenous Estradiol: Productive and Reproductive Performance and Physiological Profile of Japanese Quail Hens" *International Journal of Poultry Science*, Vol (8), No. 7, 634-641.
- Yilmaz, A.A. and Bozkurt, Z. (2009). "Effects of Hen Age, Storage Period and Stretch Film Packaging on Internal and External Quality Traits of Table Eggs" *Lucrări Științifice Zootehnie Și Biotehnologii*. No. 42, 462-9.
- NRC, (1994). "National Research Council. Nutrient Requirement Table of poultry" 9th Ed. Washington, D.C. National Academic Press.
- Reddy, P.M., Reddy, V.R., Reddy, C.V. and Rap, P.S.P. (1979). "Egg Weight, Shape Index and Hatchability in Khaki Campbell Duck Egg" *Indian Journal Poultry Science*, No. 14, 26-31.
- Monira, K.N., Salahuddin, M. and Miah, G. (2003). "Effect of Breed and Holding Period On Egg Quality Characteristics of Chickens" *International Journal of Poultry Science*, No. 2, 261- 263.
- Carter, J.C. (1975) "The Hens Egg Estimation of Shell Superficial Area and Egg Volume Using Measurements of Fresh Weight and Shell Length and Breadth Alone or in Combination" *British Poultry Science*, No. 16, 541-543.
- Akram, M., Hussain, J., Ahmad, S., Rehman, A., Lohani, F., Munir, A., Amjad, R. and Noshahi, H. (2014). "Comparative study on production performance, egg geometry, quality and hatching traits in four close-bred stocks of Japanese quail". *Agricultural Advances*, Vol. (3), No. 1, 13-18.
- Ashok, A., and Reddy, P.M. (2010). "Evaluation of reproductive traits in three strains of japanese quail" *Veterinary World*, No. 3, 169-170.
- Sezer, M. (2007). "Heritability of exterior egg quality traits in Japanese quail" *Journal of Applied Biological Sciences*. Vol. (1), No. 2, 37-40.