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Hatchability parameters, chick quality traits and progeny subsequent growth performance of Japanese quail (Coturnix Coturnix Japonica) affected by some egg quality traits

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ABSTRCT:

The study was designed to evaluate the effect of egg and shell weights on hatchability parameters, embryonic mortality, malposition, chick quality traits and progeny subsequent growth performance of Japanese quail. A total number of 600 eggs were used in this experiment, where150 eggs were taken to initially evaluate egg quality traits. However, the remaining 450 eggs were accurately weighed and divided into 3 experimental categories (N = 150) according to egg and shell weights, namely SEW and LSW (11.24 g vs. 1.86 g), MEW and MSW (13.05 g vs. 1.87 g), and LEW and HSW (14.46 g vs. 1.98) as average. Each group was subdivided into 3 replicates each with 50 eggs (n = 50). The results showed that LEW recorded ($p \leq 0.05$) a significant superiority in most of egg quality traits compared to SEW or MEW. However, the highest fertility and hatchability percentages were observed for MEW compared to SEW or LEW. Obviously, there is a strong coefficient correlation of the hatchability parameters due to egg and shell weights. Medium-sized eggs resulted in best chick quality traits with better post-growth performance ($p \leq 0.05$) than chicks produced from SEW or LEW. Also, there was a significant positive coefficient correlation ($r = 0.72$) between egg weight and hatch chick weight ($p \leq 0.05$). In conclusion, this study is important in giving information about Japanese quail eggs, where MEW are recommended to obtain better hatchability, lower embryonic mortality and obtain the best progeny subsequent growth performance compared to SEW or LEW.

KEYWORDS: Japanese quail, hatchability parameters, chick quality traits, progeny subsequent growth performance.

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1.INTRODUCTION:

It is well known that quail breeding in Egypt has become very important due to some advantages over other domesticated species **(Kostaman** and **Sopiyana, 2021)**. Interestingly, **Hussain et al. (2019**) reported that Japanese quails are small birds and can gain more than 170 grams of weight in just 28 days and can lay more or less 300 eggs per year. From a product point of view, the physical properties of quail eggs play a crucial role in embryo development and influence hatchability, where these parameters have the ability to meet the requirements of fast-growing quail embryos (**Bai et al., 2016**).The relationship between egg quality and hatchability is a major issue, where egg and shell weights can be a good estimator of quality. Therefore, in earlier reports published by **Narushin** and **Romanov (2002)** indicated that studies on the quality of quail eggs are less than those studies conducted on chicken eggs. While, **Aryee et al. (2020)** pointed out that egg quality can be a common term that refers to a number of criteria that define either internal or external quality, targeting the shape and egg shell cleanliness, texture, whereas internal quality refers to albumin quality, viscosity, air cell size, and yolk strength. Moreover, egg weight affects both hatchability and chick weight (**Iqbal et al., 2016**; **Daikwo et al.**, **2011**). Interestingly, **Hanafy** and **Hegab (2019)** showed that when the large eggs were incubated, they recorded a better hatching rate, lower embryo mortality, and gave a heavier weight to the hatched chicks compared to the small eggs of the Japanese quail. In recent study reported by (**Alvah** and **Niba و2022)** found that hatchability and survivability are associated with egg weight, where the hatchability and survivability were respectively highest in medium eggs weighed 10 -12.9 g (91.66%; 86.11%) and lowest for the small eggs < 10 g (66.66%; 52.78%). However, **Akpinar et al. (2016)** showed that egg shell integrity in the hatching egg plays an important role in the development of the embryo. For this reason, quail producers may choose medium-sized eggs as they can be good for excellent sustainability of Japanese quail production. Indeed, there are limited information and conflicting statements about the effect of egg quality traits, especially with regard to egg and shell weights on hatchability, embryonic mortality, malposition, and chick quality traits and progeny subsequent growth performance. Therefore, this study was conducted to evaluate the effect of egg and shell weights on hatchability parameters, embryonic mortality, malposition, chick quality traits and progeny subsequent growth performance of Japanese quail.

2.MATERIALS AND METHODS:

Site, duration, and the aim of the present study.

This study was carried out at the Poultry Experimental Station, Faculty of Agriculture, belonging to Al–Azhar University, Nasr City, Cairo, A.R.E. Therefore, the main objective of this study was to evaluate the effect of egg and shell weights on hatchability parameters, embryonic mortality, malposition, chick quality traits and progeny subsequent growth performance of Japanese quail.

Experimental design and procedure

A total number of 600 eggs were collected from Japanese quail breeder at 16 weeks of age with a sex ratio of 2:1. Only clean oval shaped eggs with sound shells were used in the study. From this number only 150 fresh eggs were firstly taken to study the egg quality traits according to their weights. External egg quality traits were measured, including egg weight, specific gravity, shell weight, egg shape index, shell thickness and shell weight. Also, internal egg quality traits were also estimated, including yolk weight, albumin weight, albumin height, yolk height, yolk index, albumin index, Haugh unit and yolk color. However, the remaining 450 eggs were accurately weighed and divided into 3 experimental categories (N = 150) according to egg and shell weights, namely small eggs weight (SEW, 11.24 g) with light shell weight (LSW, 1.86 g), medium egg weight (MEW, 13.05g) with medium shell weight (MSW, 1.87 g), and large egg weight (LEW, 14.46 g) with heavy shell weight (HSW, 1.98 g) as average. Each group was subdivided into 3 replicates each with 50 eggs (n = 50).

Measurements of egg quality traits

To measure egg quality traits, a total number of 150 fresh eggs were first taken to examine external and internal traits according to their weights, small egg weight (SEW, 11.24 g), medium egg weight (MEW, 1 3.05 g), and large egg weight (LEW, 14.46 g) as average. The following external traits were assessed: egg weight (g), specific gravity (g/cm^3), egg length (mm), egg width (mm), shell weight (g), shell thickness (mm) and egg shape index (%). While, the internal traits included yolk weight (g), yolk diameter (mm), yolk index (%), albumen weight (g), albumen diameter (mm), albumin index (%), Haugh unit and yolk color score. Eggs were individually weighed using a sensitive electric balance with the accuracy of 0.01g to the nearest 0.1 g. Egg length and diameter were measured using a digital calipers (Mitutoyo, Mizonokuchi, Japan) to the nearest 0.01mm. The egg shape index was performed according to the formula reported by **Anderson et al. (2004)** as given with the following formula: ESI (%) = width/length x 100.

However, egg specific gravity (g/cm3) was determined using saline solutions with densities ranging from 1.066 to 1.082 with an increase of 0.004 (**Santos et al., 2015**), according to the following equation: ESG= weight in air / (weight in air-weight in water)

After conducting the external traits, eggs were broken separately on horizontal smooth surface, and egg shells were washed, air-dried and weighed. Albumen weight was calculated as the difference between the weight of the entire egg and the combined weight of the yolk and egg shell. After removing the contents of egg, the shell thickness was determined on both sides in the equatorial region as well as on the blunt and pointed edges with a micrometer to the nearest 0.01 mm. A Vernier caliper was used to measure the length and width of albumen and yolk. The thick albumen and yolk heights were measured to the nearest mm with a tripod micrometer. In addition, parameters of indexes of albumen, yolk and Haugh unit score were calculated according to (**Sari** and **Saatci, 2012)** and **Nasr et al. (2016)** as follows: Albumen index value (%) = (albumen height, mm / average of albumen length, mm and albumen width, mm) x 100

Yolk index (%) value = (yolk height, mm/yolk diameter, mm) x 100

Haugh unit is a measure of egg protein quality based on the height of its egg and it is measured based on the height of the albumen according to the following formula: Haugh unit = 100 x Log (h+7.57) - (1.7 x W 0.37)

Where, h = observed height of the albumen in millimeters, w = weight of egg in grams

Hatchability data recording

A total number of 450 eggs were weighed individually using a sensitive electric balance (Max = 300 g and e = 0.1 mg) and recorded in gram. Eggs were classified and divided into 3 experimental categories (N = 150) according to egg and shell weights, namely SEW and LSW (11.24 g vs. 1.86 g), MEW and MSW (13.05 g vs. 1.87 g), and LEW and HSW (14.46 g vs. 1.98) as average. Each group was subdivided into 3 replicates each with

50 eggs (n = 50) that were incubated in the same incubator. The incubator used was a setter and hatcher and was set by automated incubators at a temperature of 37.5°C and 60% relative humidity. All eggs were sprayed with a 0.5 % Bio-Sentry 904 disinfectant solution. Eggs were incubated for 15 days, where they automatically turned 6 times per day. Then all eggs were transferred to a hatcher, where they were placed in the horizontal position set without turning that was maintained at 36.5°C and 75% relative humidity until hatching. At the end of the incubation period, the hatched chicks were removed according to the method described by (**Randall** and **Bolla, 2008)**, where the numbers of chicks were counted. Finally all unhatched eggs were broken and visually examined to confirm fertilization and embryonic mortality. However, the percentage of egg weight loss was calculated for each individual group alone for each incubation periods, 1-7, 8-15th day and for the total period, according to the following formula: Weight loss (%) =weight loss (g)/ initial weight (g) x100. The hatchability parameters was measured and calculated according to the following equation reported by **Alkan et al. (2008)**: Fertility (%) = (number of fertilized eggs/ total number of eggs placed into incubator) x100

Hatchability (%) of incubated eggs = (number of released chicks /total number of eggs placed incubator) x 100

Hatchability (%) of fertile eggs = (number of released chicks/number of fertilized eggs placed in incubator) x 100

Embryonic mortality and malposition

On the 18th day of incubation, all unhatched eggs were opened and examined macro- scopically to obtain evidence of the stages of embryonic development. Egg types were classified as infertile, early-death (1 to 4 days), intermediate death (5 to 15 days), and late-death (16 to 18 days) embryos, according to **Pedroso et al. (2006)**. All embryos were examined to determine the incidence of malposition, with six embryonic malposition. The following classifications of malposition have been generally accepted and identified by **Dove (1935)** and **Asmundson (1938**) as follows: (I) Head between thighs, (II) Head in small end of the egg (opposite air cell), (III) Head to left instead of right, (IV) Head in normal position but rotated with beak pointed away from air cell, (V) Feet over head, and (VI) Beak or head over right wing.

Chick quality measurements.

Evaluation of quail chick's quality traits is very difficult, although there are a variety of quantitative and qualitative measurement techniques that can be used. Morphological metrics, such as chick hatch weight, chick body length, legs length, activity score, down and appearance score and eyes, brightens are methods used to evaluate chick quality traits according to **Tona et al. (2003**). A total of 50 chicks per treatment group were randomly chosen for scoring body weight, body length, legs length, activity, down and appearance and condition of eyes. To determine chick length, the chick was laid on its ventral side from the tip of the beak to the tip of the middle toe by placing the chick face down on a flat surface and straightening the right leg (**Hill, 2001**). To avoid subjectivity during measurements, all measurements were performed blind, meaning that the measurement of each parameter was done for all chicks, taken in random order from the entire batch of chicks, before the next parameter was measured.

Subsequent growth performance

After all chick quality measurements were performed all chicks hatched from the same egg group were marked and put together in the same group based on their initial treatment to evaluate their subsequent growth performance. The chicks were brooded in battery-wired cages measuring 120×80×50 cm. Brooding temperature was maintained at 35 ºC during the first 3 days of age then decreased by 2 ºC weekly until the end of the brooding period (6 weeks). Thereafter, normal temperature with natural ventilation through the windows was applied up to 42 days of age. Chicks in all experimental treatments were kept under similar management, hygienic and environmental conditions. Artificial lighting was provided over the 23 hours daily during the whole experimental period. One growing diet was formulated to meet the nutrient requirements of growing Japanese quail 24% CP and 3000 kcal ME/kg diet according the **NRC (1994)**. The diet formulation and composition is shown in Table 1, where it fortified with adequate vitamins and minerals. Water and diet were provided ad libitum throughout the experiment. Quails were weighed individually using a sensitive electric balance (Max = 300 g and e = 0.1 mg) on a weekly basis to determine weekly body weight. During the growth period body weight, body weight gain and feed intake were recorded. Also feed conversion ratio was calculated in terms of total feed (g) per (g) of body weight.

Statistical data analysis

Egg quality traits were analyzed by one way ANOVA using the Statistical Package for the Social Sciences (SPSS®) version 16.0. (2010) using the following statistical model: $X_{ij} = \mu + T_i + e_{ij}$.

Where: Xij = value of the observation of the treatment, μ = Overall mean, Ti = Effect of the treatment, eij= stander error.

While, the other parameters were performed in a completely randomized design with 3 × 3 factorial design with three replicates of 50 eggs per replicate by using the following statistical model:

$Y_{ijk} = u + a_i + b_j + (ab)_{ij} + e_{ijk}$

Where:

Y_{ijk}=the hatchability parameters

u =overall men

a_i=the effect of egg weight (EW= 1, 2, 3)

b_j=the effect of shell weight (SW=1, 2, 3)

$(ab)_{ij}$=the interaction between EW x SW

e_{ijk} = stander error

However, Duncan's multiple range test was used to separate the mean difference among the treatments (**Duncan, 1955**). Some parameters were subjected to the pairwise coefficient Pearson correlation analysis to confirm the relationship among the chosen traits. All percentage data were transformed using arcsine square root transformations before analysis. Significance data were based on p≤0.05.

3.RESULTS and DISCUSSION:

Egg quality traits

Table 2 shows the variance of descriptive statistics for exterior and interior egg quality traits and the correlation coefficient of egg weight correlated with the other traits. It was observed that all exterior and interior egg quality traits were significantly affected by egg weight (P≤0.05). Based on this result, Duncan's post hoc revealed that the LEW recorded at 14.46 g had the highest egg quality traits, except shell thickness, yolk index and albumin index (P≤0.05), compared to MEW and SEW. However, egg weight showed a very strong positive significant coefficient correlation for all egg quality traits, except with yolk and albumin index, where a negative correlation was observed. It further implies that the correlation between egg weight and shell weight was high (r = 0.715). Our results clearly showed that external and internal egg quality traits differed significantly among the groups studied.

Hatchability parameters

Table 3 and 4 summarize results of the hatchability parameters and coefficient correlations among the examined traits. The results of descriptive statistics indicated that MEW showed a higher fertility and hatchability percentages than the values recorded for LEW and SEW (p≤0.05). While, infertility showed significantly higher trend for LEW than those observed for MEW and SEW. However, egg weight loss data recorded during the different periods of incubation indicated that SEW lost more moisture percentage than either MEW or LEW (p≤0.05). Interestingly, chicks resulted from a group of LEW showed a higher (p≤0.05) hatch chick weight than the groups of MEW or SEW. Regarding the effect of shell weight on the previous traits, statistical analysis indicated that there were insignificant differences among the experimental groups, with the exception of egg weight loss during the first stage of incubation,1-7 d, and the total period 1-18 d, where the groups of LSW and HSW showed a higher trend than the values recorded for the MSW group. The interaction effect indicated that there were significant differences were observed for all measured parameters due to the effect of egg weight and shell weights (p≤0.05). Results of Table 4 indicated that there was a highly significant positive and negative correlation for measured variables, indicated that egg and shell weights plays a very critical role in these parameters.

Embryonic mortality and malposition

The results of embryonic mortality and malposition and coefficient correlation due to the main studied effects are given in Table (5 and 6). It was observed that the embryonic deaths recorded during the three and total periods of incubation were significantly higher (p≤0.05) in SEW than those recorded for LEW and MEW. While, MP1, MP3 and MP5 showed a higher value for LEW than malposition's recorded for MEW and SEW (p≤0.05). While, no observation were observed for the MP2 and MP6 due to the effect of egg weight. However, statistical analysis of embryonic mortality due to the effect of shell weight indicated that eggs with LSW group exhibited higher embryonic mortalities than the values observed for MSW and HSW groups respectively. On the other hand MP1 showed a higher observation for HSW and LSW than the values observed for MSW group. While, insignificant differences observed for MP3 and MP5 due to the effect of shell weight. The results of the interaction effect indicated that the highest embryonic mortalities observed for SEWXHSW, SEWXMSW and SEWXLSW compared to the other interaction groups. However, MP1 and MP5 showed significantly higher values for LEWXHSW, LEWXMSW and LEWXLSW than that observation detected for the other interaction groups (p≤0.05). While the results of MP3 indicated that group with SEWX MSW recorded the highest observation compared to the other interaction groups. Intestinally, it's observed that there were positive strong coefficient correlations among the different variables due to the studied effects as shown in Table (6). From this study it is evident that the quail eggs of MEW could be hatched advantageously than LEW or SEW, where the lowest embryonic mortality and malposition form were observed for MEW compared to LEW or SEW.

Chick quality traits

Mean, standard error, ANOVA, and Duncan test results of hatched chick parameter and coefficient correlation are given in Table (7 and 8). According to the obtained data the chicks that hatched from LEW recorded superior hatch weight, legs and body chick length than the chicks hatched from either MEW or SEW ($p \leq 0.05$). Whereas, ANOVA results indicated converse trend for activity score, down and appearance score and eyes brightens, where the highest score was observed for chicks resulted from MEW followed by LEW and SEW respectively. While, insignificant differences were observed for all chick quality traits due to the effect of shell weight. However, the highest chick body weight and legs length were recorded for the chicks that hatched from the interaction groups LEWXHSW, LEWXMSW and LEWXLSW than the chicks that hatched from the other groups ($p \leq 0.05$). The values of body length showed a significantly higher trend for LEWX HSE and LEW X LSW groups than the values recorded for the other groups. In a converse trend the activity and down and appearance score, exhibited significantly higher trends for MEWXHSE, MEWX MSW and MEW X LSW groups compared to the other interaction groups. The result of eye brightens showed a higher value for MEWXMSW and MEW XLSW groups than the values recorded for the other interaction groups ($p \leq 0.05$). Therefore, in this study the correlation of chick hatch body weight, chick body length and leg length are outlined in Table (8). The correlation analysis indicated that the highest correlation was found among the different measured variables due to the main effects ($p \leq 0.05$).

Subsequent progeny growth performance

The subsequent progeny growth performance results of mixed sex chicks are outlined in Table 9. Analysis of variance indicated that chicks that hatched from LEW recorded a significantly ($p \leq 0.05$) higher body weight, body weight gain and total feed intake along the experimental period than chicks that hatched from MEW and SEW. Conversely, data of feed conversion ratio exhibited the best unit for chicks that hatched from LEW and MEW compared to the chicks hatched from SEW ($p \leq 0.05$). Concerning the effect of shell weight results indicated that all growth performance insignificantly affected due to the effect of egg shell weight ($p \leq 0.05$). On the other hand the data of growth performance as affected by the interaction effect indicated that there were significant differences were observed among the interaction groups due to the main effects ($p \leq 0.05$).

Egg quality traits

Interestingly, egg quality traits have been given great importance in poultry breeding because of their influence on chick quality and subsequently performance. Therefore, differences in results concerning egg quality traits among the literature and our results may be due to the differences in trait calculation and genetic makeup. Our results clearly showed that external and internal egg quality traits differ among quail egg weight categories, reflecting the possibility of achieving their production objectives including nutrition, health and hatching to obtain good chicks. The present results indicated that the egg quality actually was related to the hatchability rate of quail eggs. This statement was in agreement along with **Hrncar et al. (2014)** who stated that egg quality was important in effecting egg hatchability. It was noted that egg weight recorded in this study was found 11.24, 13.05 and 14.46 g for small, medium and large eggs. This results are agree with **Hanusová et al. (2016**) found that the average egg weight of Japanese quail was ranged between 12.20 to13.26 g. The differences in egg size between our results and different literature may arise due to the variations in climatic conditions and differences in feed composition of flock. Obviously, egg size influences the weight of its components, where the average weights of shell, yolk and albumen was around between 1.86 to 1.98; 4.28 to 4.90 and 5.9 to 7.56 g respectively. The result of **Alasahan (2015**) found that albumen and yolk weights of Japanese quail have ranged between 7.76 g and 3.98 g. While, the average of shell thickness in this study was ranged between 22.05 to 22.31 mm. Interestingly, the egg shell is the first element in the assessment of both table and hatching eggs, where egg shell provides protection against mechanical damage and microbiological infection, and it also regulates the water and gas exchange between the embryo and the external environment, as well as constituting the calcium source for the developing embryo (**Drabik et al., 2020**). Therefore, egg shell quality affects fertility, egg weight loss, embryonic mortality, hatchability and early chick growth rates (**Roberts** and **Nolan 2004)**; **Anderson et al., 2004**). The result of (**Ergun** and **Yamak, 2017)** found that the mean egg shell thickness of quail eggs at 23 and 41 weeks of age was 0.28 and 0.29 mm. Results of egg shape index reflect the form of an egg, where the normal ESI for medium eggs could affect the hatchability and fertility because it could determine the amount of albumen index inside the eggs that were important in embryo formation. This finding are observed by **Lotfi et al. (2011**) found that normal ESI resulted a higher hatchability because it can get enough space for embryo placement in a bilateral position, so it is very important for the development of the final embryo. Accordingly, **Sujana et al. (2020)** observed that ESI of quail egg's ranged from 77.871 to 79.622 %. Concerning albumen diameter, albumen length and albumen width the result showed that albumen diameter, albumen length and albumen width were influenced by egg weight **(Aryee et al., 2020)**. Albumen diameter and albumen length increases with increasing egg size. Also, albumen height, yolk index, albumen index, yolk diameter, and yolk height were significantly increased by the increase of egg weight. On the other hand, the average of Haugh unit was ranged from 85.61 to 89.10 and significantly affected by the egg weight. Clearly, Haugh unit is an objective mathematical indicator of albumen quality, it is usually used to measure the degree of albumen deterioration during prolonged egg storage period (**Zita et al., 2013**). The obtained results are inconsistent with the finding of **Hanafy** and **Hegab (2019)** found that Haugh unit was not influenced by egg size in quails. However, egg weight was positively and significantly correlated with all external and internal traits measured. This means that the change of egg weight lead to differences of egg quality traits (**Chimezie et al., 2017**). While, egg weight was negatively correlated with yolk and albumen index (-0.387 vs. -.231). This results are agrees with the report of **Ojedapo (2013)** indicated that positive correlations between egg weight and egg quality traits was found. Also, **Ayeni et al. (2018)** found that there was a coefficient of correlation between egg size and yolk and albumen weights. In general it is interesting to note that egg quality traits were important in terms of influencing the physical traits of quail eggs that play a critical role in fertility , hatchability, embryonic development as well as the quality of the hatched chicks (**Hrncar et al., 2014**; **Ayman, 2011)**.

Fertility and hatchability traits

There are many factors that affect the fertility and hatchability of quail eggs, but there is a paucity of information on the effect of egg and shell weights. Therefore, **Farooq et al. (2001)** considered egg and shell weight as the two most important factors affecting hatchability. Undoubtedly, the fertility and hatchability are two major factors that greatly affect day-old chicks. Interestingly, fertility and hatchability are the major determinants of profitability in a hatchery enterprise (**Peters et al., 2008**). The finding of this study showed that the highest fertility and hatchability rate was found for medium eggs. This may be attributed to the optimal weight to the development of the quail embryos that occurs within medium egg weight, where the success in the hatching process depends on the several factors including egg quality and egg weight (**Widiyaningrum et al., 2016)**. The discrepancy among literature results may arise from differences in egg weight, as well as in poultry species and breeds (**Alabi et al., 2012**). This results are agree with **Elibol** and **Brake (2008)** found that fertile hatchability decreased in the large egg due to an increased percentage of the late dead. In addition, (**Alvah** and **Niba, 2022)** showed that hatchability percentage was higher in medium sized eggs (91.66%) than those observed for small size egg (66.66%). Also, **Dudusola et al. (2021)** found that medium egg size gave better results in terms of fertility and hatchability of Japanese quail. While, shell weight insignificantly affected fertility and hatchability traits. In the results reported by **Portugal et al. (2014)** explained that the main functions of the eggshell are protection, providing the embryos with calcium and other minerals, and allowing the exchange of gases and water between the embryo and the external environment, which is essential for the success of hatching processes. The results indicated that small-sized eggs lose a greater amount of water than medium-sized or large eggs. This study also showed that the large loss of water in small-sized eggs explains the low hatching rates of these eggs, since if the water loss is high, the growth of the embryo is negatively affected and is exposed to danger, and thus the hatching rate decreases. This effect may be due to the fact that smaller eggs have a larger surface to volume ratio and that there is an increased amount of water removed which ultimately leads to increased egg weight loss (**Abiola et al., 2008; Iqbal et al., 2016**). Therefore, egg weight loss, which occurs during embryonic development, is an important factor affecting hatching results (**Akpinar et al., 2016**). The results of this study indicated that from 9.50 to 12.42% of egg weight loss is necessary during incubation in order to get a good incubation result, where improper evaporation of water from the eggs during the incubation leads to the increased of embryo mortality and consequently decreases of hatching rate. This finding are agree with **Nowaczewski et al. (2010)** investigated relationships between the size of Japanese quail eggs and hatchability and found that their loss of weight until the 15^{th} day of incubation ranged from 9.5 to 11.0%. However, chick hatch-weight are closely related to the weight of the egg, where the chicks hatched from large or medium eggs exhibit higher hatch weight at one day of hatch than small eggs. The increased weight of the chick hatched from large egg may attributed to heavier eggs contained more nutrients than small eggs, and hence, developing embryos from heavier eggs tended to have more nutrients for their growth requirements **(Williams, 1994)**. This finding are in consistent with **Dudusola (2013**) showed that the chick weight of Japanese quail was increased significantly as a result of the increasing egg size. From the correlation result obtained in Table 4, the results indicated that there was a strong correlation for the different measured variables due to the main effects. However, there is a significant positive correlation between egg and chick weight was discovered (**Iqbal et al., 2016**). For this reason, there is a significant correlation between egg weight and the weight of one-day-old chicks. In this connection, **Alkan et al. (2008)** found that hatchling weight was positively correlated to egg weight. Accordingly, **Uddin et al. (1994**) showed that a positive correlation was observed between egg weight and chick weight. In addition **(Hanafy** and **Hegab, 2019)** found that a significant positive correlation was detected between egg weight and hatchability, with heavier chick weight that obtained from large eggs.

Embryonic mortality and malposition

Embryonic mortality and malposition patterns of Japanese quail eggs was similar to that observed in the chickens, in which there are two phases of increased embryonic mortality during the incubation period: the first phase occurs during the first and the second week during the last week of incubation (**Jassim et al., 1996**). Interestingly, the success of embryonic development deepens on egg weight and the functional and structural properties of the egg shell. Our results indicated that in general, embryos seemed to be resistant to death in medium eggs that weighed 13.04 g that have 1.99g of shell weight, followed by small and large eggs. It is observed that embryonic mortality was higher in the late period compared to the first phase of incubation. It is observed that at the early stage (1-4 d) embryonic mortality increased conspicuously in small eggs compared to large or medium eggs. In the light of the above concept, the increase in the embryonic mortality in the two mortality peak periods may be due to the rapid decrease of embryonic vitality and rapid development of embryonic physiological function, metabolic mechanisms in relation to early embryonic development and respiratory metabolism at the critical periods of embryonic metabolism (**Spratt** and **Nelson, 1953**). The explanation for the increased embryonic mortality due to increased egg size was that larger eggs would be expected to have greater difficulty initially achieving sufficient embryonic temperature and subsequently lose embryonic metabolic heat during subsequent incubation (**Lourens et al., 2005**). This finding are agree with **Meijerhof** (**2002**) showed that the high heat production and increased difficulty of heat dissipation in large eggs has been found to result in higher embryo temperatures in large eggs. However, **Tona et al. (2001**) found that in small eggs, the high embryonic mortality could be attributed to increased embryonic metabolic rate, such as lipid utilization and respiration, with embryonic growth and insufficient nutrients and pores, which could affect the embryo development. While the higher rate of embryonic mortality in large eggs may be due to the fact that large eggs do not allow for the optimal ventilation rate and have greater difficulties in removing excess heat from the egg (**French, 1997**), a result of the decrease in the ratio between egg surface and egg content with increasing egg size (**Vogel, 1981**). Therefore, **Bergog et al. (2013)** reported that the physical characteristics of quail eggs play a very crucial role in embryonic development. For example, albumin is one of the main indicators of internal egg quality parameters and the main reservoir of water and protein and regulates water exchange between egg yolk and developing embryos (**Willems et al., 2014**). Therefore, prolonged water loss deteriorates albumin quality which in turn causes the blastoderm to move to near to the eggshell, leading to early embryonic death (**Brake et al., 1993**). In addition, such changes in the physical properties of the egg, especially albumin pH, lead to the movement of nutrients from the albumin to the blastoderm and may reduce resistance to gas flow, potentially damaging embryonic development (**Lapao et al., 1999**). The results reported by **Seker et al. (2004)** indicated that in Japanese quail, embryo mortality was higher in small eggs than in the heavy egg weight. Indeed, **El-Samahy et al. (2017)** showed that the percentage of embryonic mortality, for whole incubation period (1-17 days) was significantly higher for heavy eggs which recorded 22.01%. However, the embryonic mortality is associated with the occurrence of malposition or malformations through the incubation period. In this study it is interesting to note that low incidence of malformation may be attributed to better selection of parent stocks and hatchery management as these factors plays an important role in the incidence of malformations of embryo (**Wannop, 1968**).

Chick quality traits

In recent years, researchers have indicated that chick quality is the main factor that has a direct effect on hatchery economics, production and production characteristics. Obviously, visual score, Tuna or Pascar score, and day-old chick weight are commonly used to measure chick quality traits (**Tuna et al., 2004**). Interestingly, high quality chicks should have bright and active eyes and no edema, lesion or similar swelling in their bodies (**Narinç** and **Aydemir, 2021**). It is very important to note that evaluation of quail chick quality is very difficult, due to the difficulty of handling the chick. However, chick weight is the most commonly used indicator to evaluate the quality of day-old chicks (**Decuypere et al., 2002**).The results of this study indicated that the deterioration in quality may be related to the internal quality of eggs, especially albumin. Accordingly, egg weight could be a major determinant of chick weight at hatch. Therefore, a high-quality chick should show optimal development during incubation, high viability, good post-hatch development, and production quality that meets industry standards. Accordingly, **Reijrink et al. (2010**) indicated that egg weight is the main determinant of chick weight at hatching. Therefore, a high-quality chick must show optimal development during incubation, high viability, good post-hatch development, and production quality that meets industry standards. Interestingly, (**Narin** and **Genc, 2022)** showed that the chick quality is a major factor that has a direct impact on the profitability of both hatcheries and producers. In this context the results indicated that chick quality traits are significantly affected by egg weight, where the best quality was observed for chicks that hatched from medium eggs. While, shell weight was insignificantly affected all measured chick quality traits. These results are in accordance with **Tona et al. (2004)** found that the differences observed in hatch weight may have been mainly influenced by initial egg weight. Also, **(Alvah** and **Niba, 2022)** found that the egg weight significantly affected chick weight in Japanese quails. In addition, **Iqbal et al.**

(2016) found that egg size had a significant ($P < 0.05$) effect on chick weight and chick length. In our study a positive strong coefficient correlation was found between chick weight and length (r=0.68), which implied that the two traits are associated with each other and are controlled by linked-genes. The pairwise coefficient correlations Pearson analysis showed that the correlation between chick weight and chick length was significant. In line with the correlation found between chick weight and chick length and the correlation between egg weight and chick length was found to be significant. The results of **Nahm (2001)** showed that there are strong positive correlations between pre-incubation egg weight and chick weight and subsequent performance of chickens. Also, **Tona et al. (2003)** reported that chick weight was positively correlated with the egg weight at setting. However, (**Decuypere** and **Bruggeman, 2007)** reported that there was a weak but significant correlation (r=0.20) was observed between chick length at hatch and body weight at 6 week of age, indicating that chick length could be a tool for predicting chick growth potential. In other reports, **Petek et al. (2010)** found that there is highly positive relationship between body weight and chick length suggesting that the use of chick length measurement of day-old chick can be used to make prediction on the chick quality. Also, **Dudusola et al. (2021)** showed that egg weight is positively correlated with leg length and chick weight. It is observed that with the existing correlation between chick weight and chick length, it was also found that the relationship between egg weight and chick length was statistically significant.

Progeny subsequent growth performance

In this study, it is observed that chick weight was significantly affected due to egg weight ($p \leq 0.05$). Therefore, performance potential depends, in part, on egg quality, where egg quality is an important parameter for embryogenesis as well as the quality and growth of day-old chicks. However, egg weight could be a major determinant of chick weight at hatch. It is clear that the newly hatched chick quality is a major factor in determining its livability, growth, and health, where no mortality recorded during the experiment. Obviously, chick weight and progeny subsequent growth performance of the chicks are closely correlated to egg weight. The weight of the chicks also increased significantly when incubating large eggs compared to the weight of small or medium eggs. This phenomenon may be due to the fact that heavier eggs contain more nutrients than smaller eggs (**Williams, 1994**), resulting in embryos developing from heavier eggs that contain more nutrients for their growth requirements. However, total feed intake showed a higher value for chicks hatched from large eggs compared to medium or small-sized eggs. The results also showed that the progeny subsequent growth performance of chicks is closely related to egg weight, where chicks hatched from small or large eggs showed a lower growth rates (**Uluocak et al., 1995**). This finding is confirmed by **(Alvah** and **Niba, 2022)** indicated that chick weights and weight gain were significantly affected by egg weight. Also, **Ayeni et al. (2018)** found that chick weight was significantly higher when hatched from large egg sized compared with medium and small egg. However, **Abiola et al. (2011)** showed that medium sized eggs are ideal for setting in order to obtain good hatchability and best result of body weight gain. On the other hand, **Abiola et al. (2008)** observed that daily feed intake of chickens increased as chick weight increased. The increase of feed intake as birds grew is due to the increasing demand for protein and energy needed for growth (**Mwale et al., 2008**). However, **Dewitt** and **Schwalbach (2004)** found that the feed conversion ratio was better in chicks hatched from medium-sized eggs in New Hampshire and Rhode Island Red than in those hatched from large-sized eggs. Conversely, **Mateos et al. (2012**) reported that feed conversion ratio was not affected by egg weight because feed conversion ratio is mostly related to environmental factor such as age, sex, air temperature, stress, diet form, and diet components such as fiber intake. In terms of survival rate, the present study is consistent with most studies obtained by **Egbeyale et al. (2011)** and **Alabi et al. (2012**) which reported that there was a non-significant effect of egg weight on survival rate. In general, both egg weight and shell weight are important factors that have a direct impact on chick weight and hatching performance if other management conditions and fertility are not the determining factors (**Khurshid et al., 2003)**.

Conclusion and application: Based on the findings of this study, it is recommended that egg quality traits, especially egg and shell weights, are very important parameters required for obtain good incubation. Therefore, it is important before introducing eggs into hatcheries to classify and grade eggs in order to use medium-sized eggs in hatching, while small and large eggs are marketed for human consumption or for other purposes. However, medium sized eggs are recommended for better hatchability and lower embryo mortality compared to small or large eggs.

Table 1. The composition of the growing experimental diet.

Ingredients	Quantity (kg)
Ground yellow corn (8.5%)	55.55
Soybean meal (44%)	30.50
Gluten meal (60%)	09.72
Wheat bran (15.7%)	01.00
Calcium carbonate ($CaCo_3$)	01.34
Di-calcium phosphate(Ca_2HPO_4)	00.88
Sodium chloride (NaCl)	00.25
Choline chloride	00.14
DL-Methionine	00.09
L-Lysine (Hcl)	00.23
Pre-mix*	00.30
Total (kg)	100.0
Calculated diet analysis:	
Crude protein (%)	24.10
Metabolizable energy (kcal/kg)	2913
Calcium (%)	00.80
Available phosphorus (%).	00.31
Ether extract (%)	02.59
Crude fiber (%)	03.24
Lysine (%)	01.32
Methionine (%)	00.54
Methionine + Systine (%)	00.86

*The premix (Vit& Min) was added at a rate of 3kg per ton of diet and supplied as following (as mg or I.U. per kg of diet): Vit A 12000 I.U., Vit D3 2000 I.U., Vit E 40 mg, Vit. K 34 mg, Vit. B l 3 mg, Vit. B2 6 mg, Vit. B6 4 mg, Vit. B12 0.03 mg, Niacin 30 mg, Biotin 0.08, mg, Pantothenic acid 12 mg , Folic acid 1.5 mg, Choline chloride 700 mg, Mn 80 mg , Cu 10 mg, Se. 0.2 mg, Fe 40 mg, Zn 70 mg and Co . 0.25mg.

Table 2. Means of egg quality traits and Pearson's correlation coefficient (Means ± SE)
[a-d] Values in the same row with different superscripts are significantly different ($p \leq 0.05$).

Traits	Egg weight (g)			Statics			
	LEW[1]	MEW[2]	SEW[3]	Sig.	P. value	F. Value	Overall correlation coefficient(r)[3]
Egg weight(g)	14.46±0.06[a]	13.05±0.03[b]	11.24±0.03[c]	*	0.000	2.51	1.0
Specific gravity (g/cm^3)	1.069±0.003[a]	1.068±0.002[b]	1.065±0.04 [c]	*	0.000	43.17	0.392**
Yolk weight (g)	4.9±0.03[a]	4.37±0.02[b]	2.8±0.02[c]	*	0.000	19.80	0.441**
Albumin weight(g)	7.56±0.01[a]	6.08±0.03[b]	5.09±0.02[c]	*	0.000	2.44	0.958**
Shell weight(g)	1.98±0.01[a]	1.87±0.01[b]	1.86±0.01[b]	*	0.000	56.58	0.715**
Shell thickness (mm)	22.09±0.022[b]	22.31±0.015[a]	22.05±0.02[b]	*	0.000	53.514	0.094*
Egg long diameter(mm)	33.96±0.08[a]	33.02±0.03[b]	32.37±0.05[c]	*	0.000	172.80	0.661**
Egg short diameter(mm)	27.89±0.01[a]	26.65±0.02[b]	25.61±0.02[c]	*	0.000	2.64	0.917**
Egg shape index (%)	82.20±0.19[a]	80.70±0.12[b]	79.13±0.13[c]	*	0.000	96.40	0.490**
Yolk diameter (mm)	26.89±0.02[a]	26.12±0.02[b]	23.61±0.06[c]	*	0.000	1.68	0.889**
Yolk high (mm)	9.89±0.03[a]	9.74±0.02[b]	9.15±0.05[c]	*	0.000	107.3	0.529**
Yolk index (%)	36.08±0.12[c]	37.30±0.09[b]	38.8±0.22[a]	*	0.000	42.68	-0.387**
Yolk color score	4.86±0.04[a]	4.74±0.03[b]	4.72±0.03[b]	*	0.000	3.86	0.1*
Albumin diameter (mm)	25.67±0.03[a]	25.01±0.02[b]	24.18±0.04[c]	*	0.000	437.9	0.791**
Albumin high (mm)	4.74±0.01[a]	4.69±0.01[b]	4.56±0.02[c]	*	0.000	44.09	0.394**
Albumin index (%)	18.48±0.03[b]	18.79±0.05[a]	18.90±0.08[a]	*	0.000	12.63	-0.231**
Haugh unit score	89.10±0.01[a]	87.63±0.06[b]	85.61±0.08[c]	*	0.000	760.76	0.852**

1-LEW= large egg weight
2-MEW=medium egg weight
3-SEW=small egg weight
4-**Correlation coefficient at the 0.05 level

Table 3. The effects of egg and shell weights on fertility, egg weight loss, hatchability and chick weight of Japanese quail (Means ±SE).

Treatments	Variables							
	Fertility %	Infertility %	Egg weight loss (%)			Hatchability %		Chick weigh (g)
			P1[1]	P2[2]	Total	Sci.[3]	Com.[4]	
Egg weight (EW)								
LEW[5]	80.03[c]	19.97[a]	3.72[c]	5.77[c]	9.50[c]	75.82[b]	60.60[b]	10.14[a]
MEW[6]	83.32[a]	16.67[c]	4.74[b]	6.63[b]	11.38[b]	84.02[a]	70.04[a]	9.62[b]
SEW[7]	82.03[b]	17.96[b]	5.45[a]	6.96[a]	12.42[a]	70.71[b]	58.01[c]	8.42[c]
SEM	0.003	0.03	0.39	0.037	0.051	0.002	0.002	0.002
F. value	3.525	3.525	493.76	273.30	858.25	1.945	1.587	3.372
P. value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sig.	*	*	*	*	*	*	*	*
Shell weight (SW):								
HSW[8]	81.79	18.21	4.73[a]	6.48	11.21[a]	76.85	62.88	9.39
MSW[9]	81.80	18.20	4.60[b]	6.39	11.00[b]	76.85	62.88	9.40
LSW[10]	81.80	18.20	4.59[b]	6.49	11.08[ab]	76.85	62.89	9.40
SEM[11]	0.003	0.003	0.39	0.37	0.051	0.002	0.002	0.002
F. value	2.30	2.30	4.155	2.145	4.629	1.629	2.002	3.577
P. value	0.101	0.101	0.016	0.118	0.010	0.197	0.136	0. 290
Sig.	NS	NS	*	NS	*	NS	NS	NS
Interaction effect (EWXSW)								
LEWX HSW	80.82[c]	19.97[a]	3.77[a]	5.88[e]	9.65[g]	75.82[b]	60.60[b]	10.15[a]
LEWXMSW	80.02 [c]	19.97[a]	3.62[a]	5.78[f]	9.40[h]	75.81[b]	60.60[b]	10.13[a]
LEWXTSW	80.03[c]	19.96[a]	3.76[a]	5.67[g]	9.44[h]	75.82[b]	60.60[b]	10.15[a]
MEWXHSW	83.31[a]	16.68[c]	4.91[b]	6.66[c]	11.48[d]	84.02[a]	70.03[a]	9.62[b]
MEWXMSW	83.32[a]	16.67[c]	4.72[b]	6.67[c]	11.40[e]	84.02[a]	70.04[a]	9.63[b]
MEWXTSW	83.33[a]	16.67[c]	4.69[b]	6.58[d]	11.26[f]	84.02[a]	70.04[a]	9.62[b]
SEWXHSW	82.02[b]	17.97[b]	5.61[c]	6.90[b]	12.51[a]	70.72[c]	58.01[c]	9.42[c]
SEWXMSW	82.03[b]	17.96[b]	5.41[c]	7.05[a]	12.46[b]	70.71[c]	58.02[c]	8.44[c]
SEWXTSW	82.03[b]	17.96[b]	5.34[c]	6.94[b]	12.24[c]	70.71[c]	58.01[c]	8.43[c]
SEM	0.005	0.005	4.147	0.064	0.088	0.003	0.003	0.003
F. value	3.581	3.581	1.147	1.372	0.577	3.234	1.613	21.321
P. value	0.000	0.000	0.000	0.243	0.679	0.012	0.015	0.000
Sig.	*	*	*	*	*	*	*	*

[a-d] Values in the same column with different superscripts are significantly different ($p \leq 0.05$).
1-P1=Egg weight loss during the first period of incubation (1-7 d)
2-P2= Egg weight loss during the second period of incubation (8-15 d)
3-Sci.=Scientific hatchability
4-Com. =Commercial hatchability
5-LEM=Large egg weight.
6-MEW=Medium egg weight.
7-SEW= Small egg weight.
8-HSW= Heavy shell weight.
9-MSW= Medium shell weight.
10-LSW= Large egg shell weight.
11-SEM= Stander error of mean.

Table 4. Pairwise coefficient correlations of the variable traits of Japanese quail eggs.

Variables	Fertility (%)	Egg weight loss(%)	Chick weight (g)	Hatchability % Sci.[1]	Com.[2]
Fertility (%)	1.0	-0.413	-0.410**	-0.508**	-0.687**
Sig.	0.000	0.000	0.000	0.000	0.000
Egg weight loss (%)	-0.413**	1.0	0.887**	-0.468**	0.322**
Sig.	0.000	0.000	0.000	0.000	0.000
Chick weight(g)	0.410**	0.887**	1.0	0.576**	0.417**
Sig.	0.000	0.000	0.000	0.000	0.000
Sci. [1]	0.508**	0.468**	0.576**	1.0	0.985**
Sig.	0.000	0.000	0.000	0.000	0.000
Com.[2]	0.657**	0.322**	0.47**	0.963**	1.0
Sig.	0.000	0.000	0.000	0.000	0.000

Values on upper diagonal are for egg weight while those on lower diagonal are for shell weight.
Correlation coefficient at the 0.05 level** (2-tailed)
1-Sci.=Scientific hatchability
2-Com. =Commercial hatchability

Table 5. The effects of egg and shell weights on the embryonic mortality and malposition of Japanese quail eggs (Means ±SE).

Treatments	Variables						
	Embryonic mortality %				Malposition		
	EM1[1]	EM2[2]	EM3[3]	Total	MP1[4]	MP3[5]	MP5[6]
Egg weight (EW)							
LEW	8.59[b]	6.001[b]	4.60[b]	19.19[b]	7.30[a]	1.195[a]	2.55[a]
MEW	8.20[c]	4.60[c]	4.30[c]	17.10[c]	5.29[c]	0.655[b]	2.07[b]
SEW	10.0[a]	8.60[a]	5.30[a]	23.90[a]	6.42[b]	1.194[a]	2.55[c]
SEM	0.002	000	0.000	0.002	0.014	0.020	0.005
F .value	3.968	1.174	4.86	6.664	5.460	234.033	4.038
P. Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sig.	*	*	*	*	*	*	*
Shell weight (SW)							
HSW	8.93[b]	6.40[b]	4.40[b]	19.73[b]	6.39[a]	1.02	2.36
MSW	8.92[c]	6.39[c]	4.39[c]	19.70[c]	6.24[b]	1.02	2.36
LSW	8.94[a]	6.41[a]	4.41[a]	19.76[a]	6.37[a]	1.02	2.36
SEM	0.002	000	0.000	0.002	0.014	0.020	0.005
F. value	56.917	2.861	4.722	424.49	35.59	1.000	0.002
P .value	0.000	0.000	0.000	0.000	0.000	0.000	0.998
Sig.	*	*	*	*	*	NS	NS
Interaction effects (EWXSW)							
LEWX HSW	8.60[c]	6.00[b]	4.60[b]	19.20[b]	7.30[a]	1.12[b]	2.55[a]
LEWXMSW	8.59[c]	5.99[b]	4.59[b]	19.16[b]	7.30[a]	1.12[b]	2.55[a]
LEWXLSW	8.61[c]	6.01[b]	4.61[b]	19.23[b]	7.30[a]	1.12[b]	2.55[a]
MEWXHSW	8.20[d]	4.60[c]	4.30[c]	16.10[c]	5.29[d]	0.65[c]	2.00[c]
MEWXMSW	8.19[d]	4.59[c]	3.29[d]	16.07[d]	5.29[d]	0.65[c]	2.00[c]
MEWXLSW	8.21[d]	4.61[c]	3.31[d]	16.13[c]	5.29[d]	0.65[c]	2.00[c]
SEWXHSW	10.0[a]	8.60[a]	5.30[a]	23.90[a]	6.59[b]	1.19[b]	2.55[b]
SEWXMSW	9.90[b]	8.59[a]	5.29[a]	23.87[a]	6.14[c]	1.93[a]	2.55[b]
SEWXLSW	10.01[a]	8.61[a]	5.31[a]	23.93[a]	6.53[b]	1.19[b]	2.55[b]
SEM	0.003	0.000	0.000	0.003	0.000	0.035	0.009
F. value	1.000	2.197	3.425	1.941	1.0	0.000	0.002
P. value	0.000	0.000	0.004	0.000	35.38	1.000	1.00
Sig.	*	*	*	*	NS	*	NS

[a-d] Values in the same column with different superscripts are significantly different ($p \leq 0.05$).

Embryonic mortality

1-EM1= Embryonic mortality during the first period of incubation (1-4 d)

2-EM2= Embryonic mortality during the second period of incubation (4-15 d)

3-EM3= Embryonic mortality during the last period of incubation (16-18 d), according to (**Pedroso et al., 2006)**

Malposition

4-MP1= Head between thighs.

5-MP3=Head to left instead of right.

6-MP5= Feet over head.

Table 6. Pairwise coefficient correlation among the variable traits.

Variables	Total embryonic mortality (%)	Malposition [1] (%)	Maplsition[2] (%)	Maplsition[3] (%)
Total embryonic mortality (%)	1.0	0.450**	0.575**	0.780
Sig.	0.000	0.000	0.000	0.000
Malposition [1]	0.450**	1.0	0.629**	0.853**
Sig.	0.000	0.000	0.000	0.000
Maplsition[2]	0.575**	0.629**	1.0	0.737**
Sig.	0.000	0.000	0.000	0.000
Maplsition[3]	0.780**	0.853**	0.757**	1.0
Sig.	0.000	0.000	0.000	0.000

Correlation coefficient at the 0.05 level** (2-tailed)
MP1= Head between thighs.
MP2=Head to left instead of right.
MP3= Feet over head.

Table 7. The effects of egg and shell weights on the chick quality traits of Japanese quail (Means ±SE)

Treatments	Chick quality traits					
	Body weight	**Leg length**	**Body length**	**Activity**	**Down and appearance**	**eye brightens**
Egg weight (EW)						
LEW	10.15^{a}	10.34^{a}	16.13^{a}	4.95^{b}	7.95^{b}	7.09^{b}
MEW	9.62^{b}	9.75^{b}	15.94^{b}	5.92^{a}	9.95^{a}	15.95^{a}
SEW	8.42^{c}	8.95^{c}	15.05^{c}	3.95^{c}	7.95^{b}	7.95^{b}
SEM	0.002	0.002	0.002	0.008	0.004	0.004
F value	3.372	1.759	9.210	1.393	7.851	1.255
P value	0.000	0.000	0.000	0.000	0.000	0.000
Sig.	*	*	*	*	*	*
Shell weight (SW)						
HSW	9.39	9.67	15.71	4.945	8.617	10.618
MSW	9.40	9.68	15.70	4.945	8.618	10.617
LSW	9.40	9.68	15.72	4.940	8.619	10.617
SEM	0.002	0.002	0.002	0.008	0.004	0.004
F. value	3.577	8.035	4.912	0.103	0.026	0.009
P. value	0.292	0.391	0.822	0.902	0.74	0.991
Sig.	NS	NS	NS	NS	NS	NS
Interaction effect (EWX SW)						
LEWX HSW	10.15^{a}	10.33^{a}	16.14^{a}	4.950^{b}	7.95^{b}	7.95^{b}
LEWXMSW	10.12^{a}	10.33^{a}	16.11^{b}	4.950^{b}	7.95^{b}	7.95^{b}
LEWXLSW	10.15^{a}	10.35^{a}	16.14^{a}	4.952^{b}	7.95^{b}	7.95^{b}
MEWXHSW	9.62^{b}	9.75^{b}	15.94^{b}	5.934^{a}	9.95^{a}	15.95^{a}
MEWXMSW	9.62^{b}	9.76^{b}	15.94^{b}	5.934^{a}	9.95^{a}	15.95^{a}
MEWXLSW	9.62^{b}	9.75^{b}	15.94^{b}	5.918^{a}	9.95^{a}	7.95^{c}
SEWXHSW	8.42^{c}	8.94^{c}	15.04^{c}	3.950^{c}	7.95^{b}	7.95^{c}
SEWXMSW	8.44^{c}	8.94^{c}	15.05^{c}	3.950^{c}	7.95^{b}	7.95^{c}
SEWXLSW	8.42^{c}	8.95^{c}	15.05^{c}	3.950^{c}	7.95^{b}	
SEM	0.003	0.003	0.003	0.015	0.007	0.007
F value	21.321	2.174	7.883	0.154	0.013	0.022
P value	0.000	0.071	0.000	0.961	1.00	0.999
Sig.	*	*	*	*	*	*

[a-d] Values in the same column with different superscripts are significantly different ($p \leq 0.05$).

Table 8. Pairwise coefficient correlation for the chick quality traits parameter.

Variables	Body weight	Body length	Legs length
Body weight	1.0	0.990**	0.999**
Sig.	0.000	0.000	0.000
Body length	0.989**	0.962**	1.0
Sig.	0.000	0.000	-
Legs length	0.990**	1.0	0.962**
Sig.	0.000	-	0.000

Correlation Coefficient at the 0.05 level** (2-tailed)

Table 9. The effect of egg and shell weights on subsequent growth performance of Japanese quail (Means ±SE)

Treatments	Traits							
	Body weight (g)			Body weight gain (g)			TFI[1] (g)	FCR[2]
	0 day	3 weeks	6 weeks	1-3	3-6	1-6		
Egg weight (EW)								
LEW	10.15^{a}	100.52^{a}	224.59^{a}	90.38^{a}	124.07^{a}	214.44^{a}	533.50^{a}	2.37^{b}
MEW	9.63^{b}	99.23^{b}	221.53^{b}	89.60^{b}	122.29^{b}	211.90^{b}	526.50^{b}	2.38^{b}
SEW	8.43^{c}	95.75^{c}	215.03^{c}	87.32^{c}	119.28^{c}	206.60^{c}	521.40^{c}	2.42^{a}
SEM	0.002	0.002	0.109	0.003	0.109	0.109	0.00	0.001
F value	3.420	1.560	1.999	3.446	491.41	1.343	4.151	530.55
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sig	*	*	*	*	*	*	*	*
Shell weight (SW)								
HSW	9.40	98.50	220.42	89.09	121.93	211.03	527.13	2.39
MSW	9.40	98.50	220.22	89.09	121.92	210.02	527.09	2.39
LSW	9.40	98.50	220.49	89.10	121.79	211.89	527.17	2.39
SEM	0.002	0.002	0.109	0.003	0.109	0.109	0.000	0.001
F. value	3.865	4.003	0.474	0.239	0.507	0.507	2.116	2.205
P. value	0.062	0.091	0.623	0.788	0.603	0.603	3.521	0.111
Sig	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect (EWX SW)								
LEWX HSW								
LEWXMSW	10.15^{a}	100.51^{a}	224.73^{a}	90.36^{a}	124.21^{a}	214.58^{a}	533.50^{a}	2.38^{b}
LEWXLSW	10.13^{a}	100.53^{a}	224.71^{a}	90.40^{a}	124.17^{a}	214.58^{a}	533.47^{a}	2.38^{b}
MEWXHSW	10.15^{a}	100.52^{a}	224.32^{b}	90.37^{a}	123.79^{b}	214.17^{b}	533.53^{a}	2.38^{b}
MEWXMSW	9.62^{b}	99.24^{b}	221.52^{c}	89.61^{b}	122.28^{c}	211.90^{c}	526.50^{b}	2.38^{b}
MEWXLSW	9.63^{b}	99.21^{b}	221.52^{c}	89.58^{b}	122.31^{c}	211.90^{c}	526.45^{b}	2.38^{b}
SEWXHSW	9.62^{b}	99.22^{b}	221.53^{c}	89.60^{b}	122.30^{c}	211.90^{c}	526.55^{b}	2.38^{b}
SEWXMSW	8.42^{c}	95.73^{c}	215.03^{d}	87.31^{c}	119.30^{d}	206.61^{d}	521.40^{c}	2.42^{a}
SEWXLSW	8.44^{c}	95.75^{c}	215.03^{d}	87.31^{c}	119.27^{d}	206.58^{d}	521.35^{c}	2.42^{a}
	8.43^{c}	95.75^{c}	215.03^{d}	87.32^{c}	119.28^{d}	206.61^{d}	521.45^{c}	2.43^{a}
SEM	0.003	0.003	0.189	0.005	0.189	0.189	0.00	0.002
F Value	22.359	17.369	0.503	19.82	0.501	0.545	4.950	0.667
P value	0.000	0.000	0.034	0.000	0.035	0.003	0.000	0.015
Sig	*	*	*	*	*	*	*	*

$^{a-d}$ Values in the same column with different superscripts are significantly different ($p \leq 0.05$).

1-TFI=Total feed intake 2-FCR=Feed conversion ratio

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