CJES

Caspian Journal of Environmental Sciences

Online ISSN: 1735-3866
Print ISSN: 1735-3033

Influence of the ratio of the mass and volume of quail eggs on their morphometric indicators and incubation results

Ziad Ahmad Alabdallah[1, 2]*, Aleksandr Alekseevich Nikishov[1], Peralta Umatambo Angel Daniel[1], Cueva Jimenez Jhonn Lenon[1], Cen Huato Laura Candelaria[1], Ngantou Seunou Danielle Dorcas Stella[1]

1. Peoples Friendship University of Russia (RUDN University) Moscow, Miklukho-Maklaya Street, Russia
2. Al Furat University, Deirez-Zor, Department of Anatomy-Histology and Embryology, College of Veterinary, Syria

** Corresponding author's Email: Zead3133@gmail.com*

ABSTRACT

In industrial quail breeding all hatching eggs are subjected to preliminary selection according to external features and egg weight. This means that the issues of evaluating hatching eggs, increasing hatchability, and the viability of young animals during artificial incubation do not lose their relevance. Comparative assessment was carried out on the quality of incubation eggs of Estonian and Manchurian Golden quail breeds with different mass-to-volume ratios, as well as the results of incubation and the values of electromagnetic impulses during the incubation of quail eggs. The material for the study was the eggs of the Estonian and Manchurian Golden (MG) breeds of quials. Eggs were selected with a shelf life of no more than 7 days. At the first phase, 100 eggs of each breed were opened and morphologically analyzed. At the second, three incubations were carried out. For each incubation, 150 eggs of the Estonian and Manchurian Golden breeds were selected, of those, 50 eggs were opened and a morphological analysis of the eggs of each breed was made. The incubation of quail eggs at the 2nd phase was carried out in IPH-10 incubators. At the 3rd phase, eggs were incubated individually in an R-COM DX-8800XP incubator. During incubation, the development of embryos was monitored by candling eggs on days 6, 11, and 16 of incubation. In the Manchurian Golden breed, 7.5 times fewer eggs fell into the first variation class, and 2.3 times more eggs into the third variation class compared to the Estonian breed ($p < 0.05$). The large diameter of the egg increased on average by 4.3%, while the small one decreased by 3.2%. Egg shape index increased by 3.3% in Manchurian eggs, while by 2.9% in Estonian eggs ($p < 0.05$). The value of the "Haugh unit" index decreased by 4.2% in the eggs of the Manchurian Golden breed, while by 5.9% in the eggs of the Estonian breed ($p < 0.05$). The ratio of mass and volume significantly affected the results of incubation of eggs. In the second and third classes, an average of 6.1 and 2.7% more quials hatched than in the first class. In terms of hatchability of eggs, these differences were more significant and amounted to 15.8 and 14.0%, respectively.

Keywords: Quail, Egg, Morphometric, Electromagnetic, Incubation.
Article type: Research Article.

INTRODUCTION

Poultry farming has always been one of the most efficient branches of agriculture, which creates good opportunities for a quick and effective solution to the problem of protein nutrition (Alabdallah *et al.* 2021). A significant role in the successful functioning of poultry farming is given to issues related to the incubation of eggs. Currently, in industrial poultry farming, the average quail output is only 70-80%. This means that in quail breeding, the issues of evaluating hatching eggs, increasing hatchability, and the viability of young animals during artificial incubation do not lose their relevance (Inci *et al.* 2015). Being one of the most highly productive branches of animal husbandry, quail breeding creates good opportunities for quickly and effectively solving the problem of

Caspian Journal of Environmental Sciences, Vol. 21 No. 3 pp. 629-646 Received: Feb. 05, 2023 Revised: March 16, 2023 Accepted: May 24, 2023
DOI: 10.22124/CJES.2023.6941

Publisher: University of Guilan,

protein nutrition of the population of the whole world (Alabdallah *et al.* 2021). At the present time, zootechnical science has achieved significant success in improving the breeding, feeding and keeping poultry, which has formed a highly productive and highly profitable industry (Genchev *et al.* 2010). In conditions of highly profitable poultry farming, the issue of improving technological parameters and improving product quality at all stages of production becomes the most important (Alabdallah *et al.* 2021). A significant role in the successful functioning of poultry farming is assigned to issues related to the incubation of eggs (Milojević *et al.* 2019). There are many specific features in the incubation of poultry eggs that open up great opportunities in controlling the process of bird reproduction. The modes of incubation are developed and continue to be improved on the basis of the patterns of embryonic development of birds (Reijrink 2010). Currently, in industrial quail breeding, the average value of chick hatching is 70-80% and this is provided that all hatching eggs are subjected to preliminary selection according to external features and egg weight. This means that in industrial quail breeding, the issues of evaluating hatching eggs, increasing hatchability, and the viability of young animals during artificial incubation do not lose their relevance (Narushin & Romanov 2002). The purpose of this work is to evaluate the morphometric characterisics, the results of incubation and the values of electromagnetic impulses during the incubation of quail eggs of different breeds, depending on the ratio of their mass and volumen (Shafey *et al.* 2005; Sampedro *et al.* 2006) Studies conducted in recent years have established the relationship between the morphometric characteristics of a quail egg (including the ratio of mass and volume) with its quality and subsequent results of incubation (Rehman *et al.* 2017; Angel Daniel *et al.* 2022) Despite the stringent requirements for the selection of hatching quail eggs, during their subsequent incubation, the percentage of embryo death varies on average within 15-35%. This may be due to the fact that among the eggs selected for external signs, there are eggs with different qualitative characteristics that have a positive or negative effects on the development of a quail embryo under equal conditions. Therefore, the study of additional characteristics for evaluating eggs selected for incubation is a necessary condition for improving the quality of hatching eggs (Ondrušíková *et al.* 2018; Milojević *et al.* 2019; Nasri *et al.* 2020; Narushin & Romanov 2022). In this work, for the first time, a comparative assessment of the quality of incubation eggs of Estonian and Manchurian quail breeds with different mass-to-volume ratios was carried out, as well as the results of incubation and the values of electromagnetic impulses during the incubation of quail eggs of different breeds.

MATERIAL AND METHODS

The experimental part of the work was carried out in the Department of Veterinary Medicine of the Agrarian and Technological Institute of the Peoples' Friendship University of Russia in the period from 2019 to 2022. The material for the study was the eggs of the Estonian and Manchurian Golden breeds of quails obtained in the conditions of the RUDN vivarium. Eggs were selected with a shelf life of eggs no more than 7 days. At the first stage, 100 eggs of each breed were opened and morphologically analyzed. The mass of eggs was determined on an HR-200 electronic balance (Japan); the egg diameter was measured with a STAYER 34410-150 digital caliper with an accuracy of 0.01 mm. At the second phase, three incubations were carried out: in April, June and September. For each incubation, 150 eggs of the two breeds were selected, of those, 50 eggs were opened and a morphological analysis of the eggs of each breed was made. The incubation of quail eggs at the 2nd phase was carried out in IPH-10 incubators. At the 3rd phase, eggs were incubated individually in an R-COM DX-8800XP incubator. During incubation, the development of embryos was monitored by candling eggs on days 6, 11, and 16 of incubation. According to the results of incubation, the indicators "hatch" and "hatchability" were calculated according to standard methods (Narushin 2005; Narushin *et al.* 2021). The study of electrooscillatory processes was carried out using a two-channel oscilloscope PCS 500A Valleman and a PCG10 Valleman signal generator. Information processing was carried out using a computerized laboratory PC Lab 2000se. To study electromagnetic oscillations, eggs were individually placed in a solenoid an electromagnetic monosyllabic cylindrical coil with a significant inductance and low active resistance and capacitance, the turns of which were wound closely, and the length was much greater than the diameter. The solenoid was characterized by a significant ratio of the length of the winding to the diameter of the mandrel, which, if necessary, allowed us to create a relatively uniform magnetic field inside the coil. The coil consisted of two circuits - primary and secondary winding. The primary winding served to induce a static electromagnetic field and removed the signal from the egg. A signal (3 Hz) was generated on the secondary winding using a PCG10 signal generator to obtain a signal response from the egg. The frequency spectrum of the signal was visualized using a Fourier analyzer. In the recorder mode, single bursts were recorded and slowly changing processes were recorded. Eggs were taken from healthy birds at the age of 20-22 weeks. Statistical processing of the obtained data was carried out in accordance with the guidelines for the presentation of the results of measurement materials and algorithms for processing the material using the data analysis package "MS Excel 2010" and the program "Statistics for Windows" (Alabdallach *et al.* 2020).

RESULTS

First phase of the study

Characterization of morphometric indices of quail hatching eggs

The eggs of the examined quail breeds were an asymmetric ellipse or an oval “Cassinian” in shape, one end of which was somewhat blunter than the other. A standard quail egg had the following characteristics: weight 10.0 g, volume 23 cm^3, density 1.08 g cm^{-3}, long circumference 7.7 cm, short circumference 6.5 cm, shape index 74 (Troscianko 2014) (Table 1).

Table 1. Morphometric parameters of hatching eggs of hens.

Indicators	*Breed*	
	Estonian (n = 100)	*Manchurian (n = 100)*
	Mean ± error	*Mean ± error*
Egg weight, g	11.7 ± 0.32	12.4 ± 0.16
Large diameter (BD; mm)	16.8 ± 0.22	17.6 ± 0.13
Small diameter (MD; mm)	13.3 ± 0.22	14.0 ± 0.07
Form index: DB:MD	1.30 ± 0.023	1.31 ± 0.022
MD: BW × 100	76.6 ± 0.28	75.9 ± 0.22
Egg volume (cm^3)	16.1 ± 0.36	18.2 ± 0.21
The ratio of mass and volume (g cm^{-3})	1.079± 0.043	1.086 ± 0.021

Based on the value of the shape index (average 1.30), it can be stated that the eggs corresponded to the standard ovaloid for eggs. Manchurian eggs were on average larger than Estonian ones. They exceeded the Estonian ones in weight by 0.7 g ($p < 0.05$), in large and small diameters by 0.8 and 0.7 cm, respectively ($p < 0.05$). This, in turn, affected the larger volume of Manchurian eggs (18.2 cm^3) compared to Estonian ones (16.1 cm^3). In terms of the ratio of mass and volume, the eggs of the Manchurian breed exceeded those of the Estonian ones by an average of 0.8%.

Comparative evaluation of egg volume formulas

In order to identify the optimal formula for calculating the volume of an egg, for the subsequent determination of the indicator "weight and volume ratio", a comparative analysis of the distribution of eggs was carried out according to the theoretically calculated indicator "volume of eggs" (Fig. 1). When it comes to the use of any index to assess the qualitative characteristics of any object, it is desirable that this index has a low intragroup variability. That is, most objects should have similar values of the examined index.

We compared three formulas:

N 1: $V=((\pi LB^2/6) - 0.022(\pi LB^2/6))/1000$; according to Romanoff & Romanoff (Romanoff Alexis & Romanoff Anastasia 1959).

***N 2**: $V = (0.6057 – 0.0018 \times d)\times D \times d \times d/1000$;* according to Narushin V. (Genchev 2012).

N 3: $V=0.523\times D\times d\times d/1000$; according to Narushin V. (Genchev 2012).

The actual egg volume (Vf) was determined by the formula: $Vf = M1–M2$,

where M1 is the mass of the egg in air, M2 is the mass of the egg in distilled water. Data on the calculation of the actual value of egg density and theoretically calculated values of the ratio of mass to volume are given. Fig. 1 shows the data on the deviation of the theoretically calculated values of the “egg volume” index from the actual value (data on the actual value of the egg volume are taken as zero values). In general, it can be stated that the value of deviations did not exceed 10%. The nature of the deviations was almost the same for all formulas, which indicates a good repeatability of calculations. An analysis of the deviations of the theoretically calculated values of the volume from the volume of the egg calculated by the standard method showed that the smallest values were obtained when using the formula of Narushin (2005). to calculate the geometric indies of eggs with a refined constant for brood birds (formula 3). In this case, the average difference was 3.9%. When using formulas 1 and 2, the average deviations were 7.8 and 6.3%, respectively. By using various constants in formula 3, it was possible to increase the accuracy of the calculation to an average of 2.91% and propose the following formula for calculating the volume of quail eggs:

V = 0.485 × D × d × d/ 1000

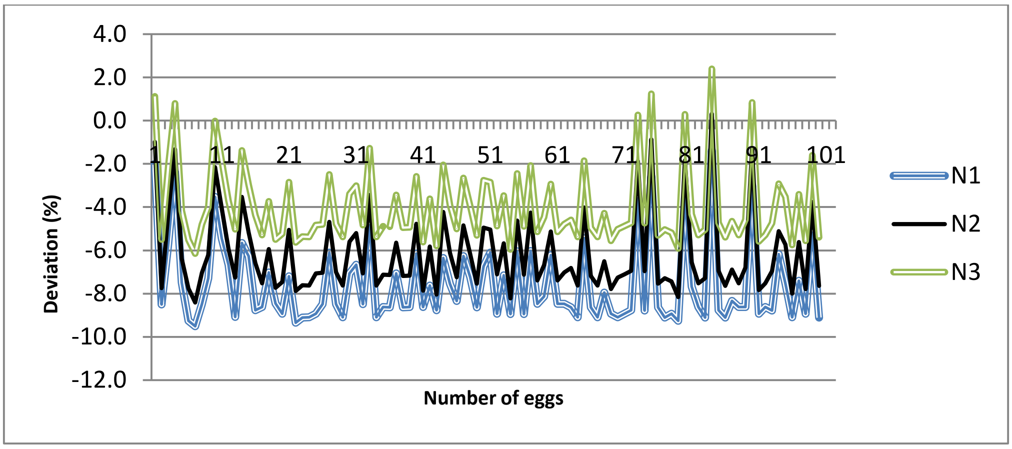


Fig. 1. Deviations of theoretically calculated values of the “egg volume” indicator from the actual value.

where D is the longitudinal diameter of the egg (mm); d is the transverse diameter of the egg (mm).
To use the "mass-to-volume ratio" index in the studies, the "actual egg density" index was determined, calculated on the basis of determining the actual volume of the egg. Figs. 2 and 3 show the data of deviations of the theoretically calculated values of the indicator "mass and volume ratio" from the calculated actual indicators of egg density. The zero value is taken as the actual density of the eggs.

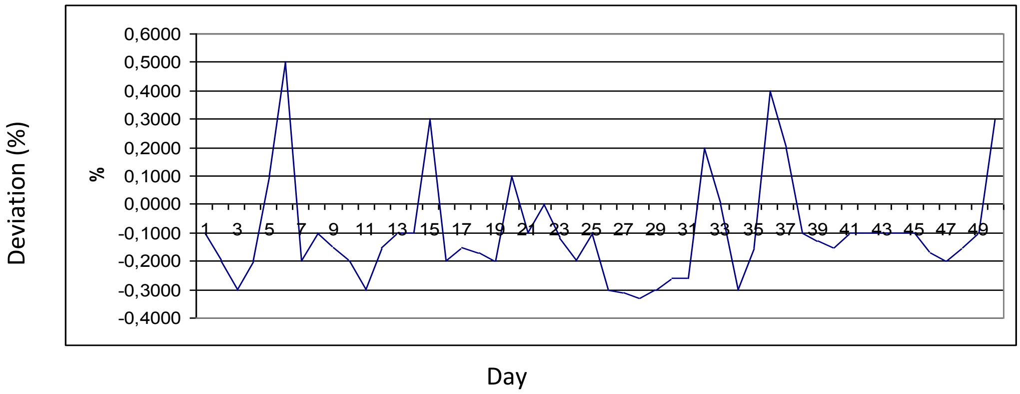


Fig. 2. Deviation of the theoretically calculated ratio of mass and volume of eggs from the actual density value (Manchurian breed).

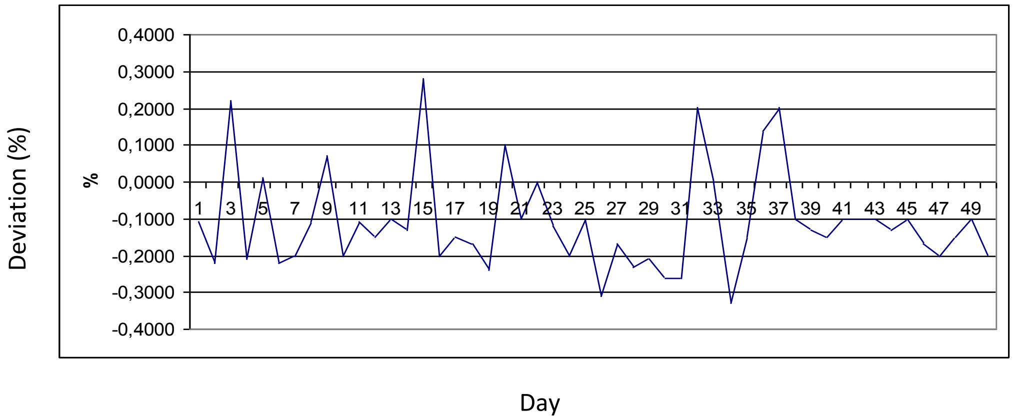
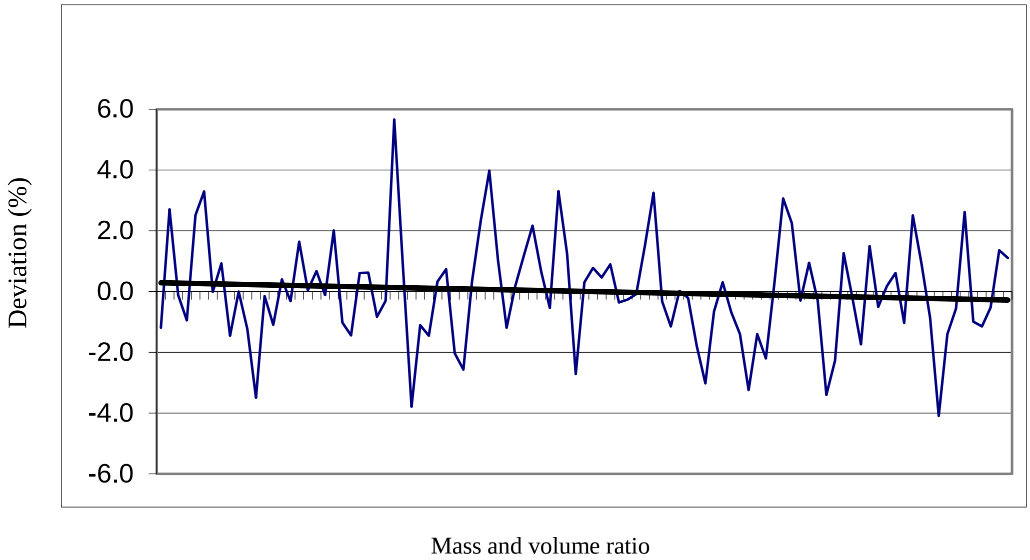


Fig. 3. Deviation of the theoretically calculated ratio of the mass and volume of eggs from the actual density value (Estonian breed).

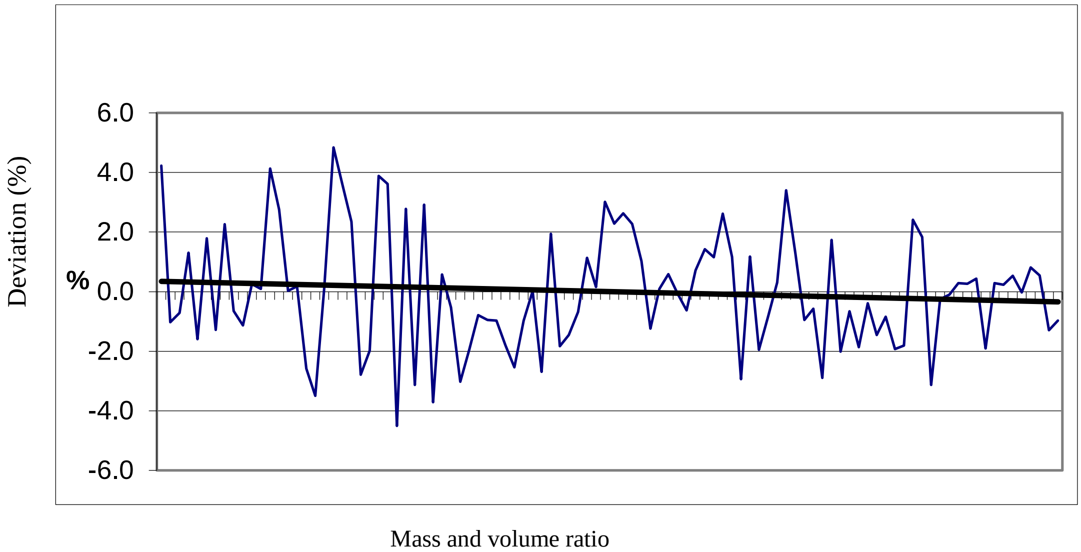
As can be seen from the above data, the deviation of the theoretically calculated values of the "mass-to-volume ratio" was within ± 0.3-0.5%. This indicates that the theoretically calculated mass-to-volume ratio values were very close to the actual density values. The variability was insignificant. The average value of the coefficient of variability (Cv) was 7.6%. Figs. 4 and 5 show graphs of deviations of individual values of the indicator "mass and volume ratio" for each egg from the average group value. As can be seen from Fig. 8, the theoretical values of the "mass-to-volume ratio" index of Manchurian eggs mainly varied within ± 4%, which indicates fairly close egg values for this index and, accordingly, low variability of the trait.



Calculated ratio of the Manchurian breed eggs mass and volume.

Fig. 4. Deviation of the theoretically calculated ratio of the mass and volume of eggs from the average group value (Manchurian breed).

Given the smoothing of the data, based on the trend line, it can be argued that the theoretical distribution of the feature can be within ± 2.0%.



Calculated ratio of the Estonian breed eggs mass and volume.

Fig. 5. Deviation of the theoretically calculated ratio of the mass and volume of eggs from the average group value (Estonian breed).

A similar picture is observed for the eggs of the Estonian breed. Thus, the insignificant amplitude of fluctuations in the studied trait in eggs of different breeds indicates that this index can be used as a fairly objective one for

assessing the quality of eggs. In the calculations, the "three sigma" rule was taken into account. Those. the probability that a random variable deviates from its mathematical expectation by an amount greater than three times the standard deviation (M ± 3σ) is practically zero. With no less than 99.7% certainty, the value of a normally distributed random variable lies within the specified interval. In practice, it is believed that if for any random variable the three-sigma rule is satisfied, then this random variable has a normal distribution. The value of the class interval was 0.09 g cm^{-3}, which corresponded to the average value of the standard deviation. Based on this, in further studies, the eggs were divided into three variation classes in terms of the "mass-to-volume ratio":
the first is the value of the ratio of mass to volume less than 1.01 g cm^{-3},
the second is the value of the ratio of mass to volume from 1.01 to 1.1 g cm^{-3},
the third - the value of the ratio of mass to volume of more than 1.1 g cm^{-3}.
As can be seen, the bulk of the eggs - 86% in the Manchurian breed and 94% in the Estonian one - ranged from 1.01 to 1.1 g cm^{-3}. In both breeds, the eggs were sufficiently consolidated in terms of the "mass-to-volume ratio". However, at the same time, among the hatching eggs in each breed, eggs were found with the index "mass and volume ratio" below the established limit - 1.01 g cm^{-3} (about 3% of eggs) and above the established limit - 1.1 g cm^{-3}(about 6% of eggs).

Second phase of research

Morphometric characteristics of hatching eggs of hens of different variational classes

It was interesting to study how the morphometric characteristics of eggs change depending on the alterations in their ratio of mass and volume. A comparative study of physical indicators makes it possible to evaluate eggs of different variational classes in terms of the "weight-to-volume ratio" according to exterior indices. The arithmetic mean values for the crosses were equal, respectively: eggs of the Estonian breed: 1.078 ± 0.0016 g cm^{-3} , eggs of the Manchurian breed: 1.072 ± 0.0018 g cm^{-3}.

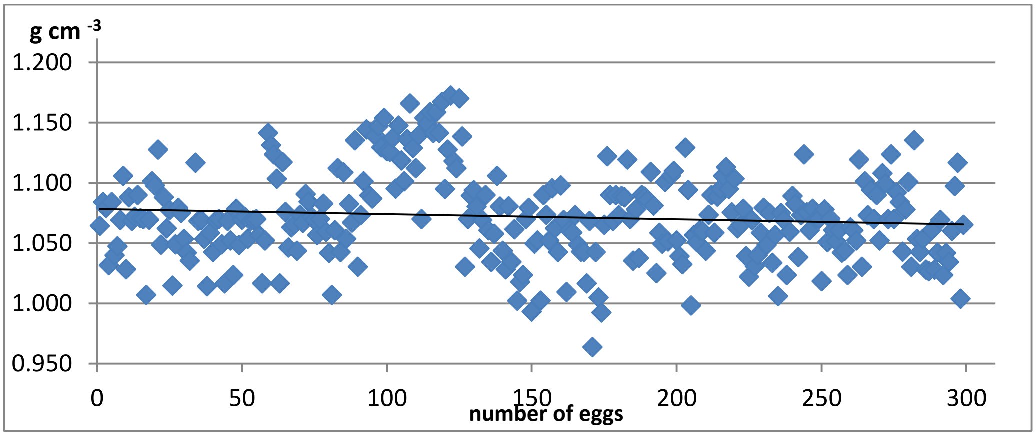


Fig. 6. Distribution of eggs in terms of "mass to volume ratio" (Manchurian breed).

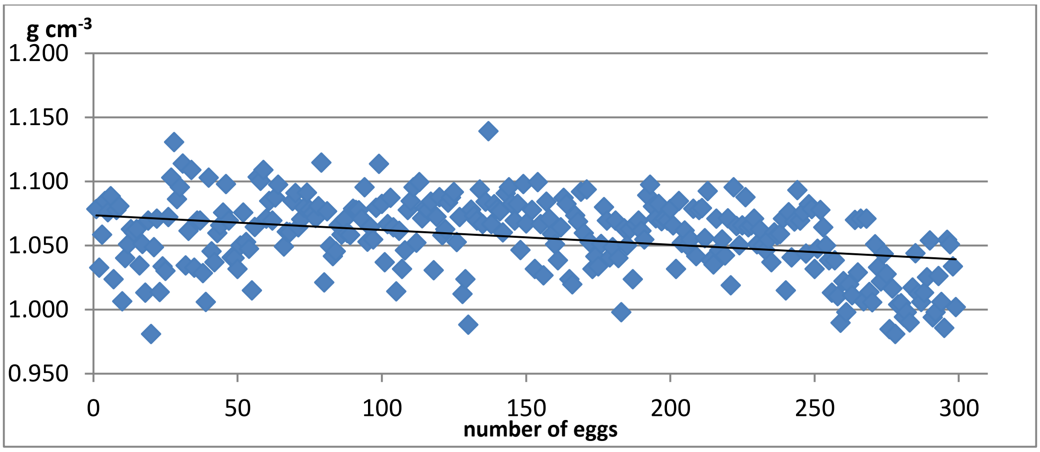


Fig. 7. Distribution of eggs in terms of "mass to volume ratio" (Estonian breed).

By analyzing scatter diagrams and frequency tables, it can be stated that the nature of scatter on the basis of the “mass-to-volume ratio” differs significantly between the eggs of the studied breeds. In the Manchurian breed, hatching eggs, characterized by an average (or most probable) level of manifestation of the quantitative trait "mass-to-volume ratio", are placed in the modal class and account for 83.8% of the total number of eggs that have been studied. Deviations from the modal class to a smaller and larger side amounted to 12.6% and 3.6%, respectively. In the Estonian breed, the distribution of eggs in terms of "mass and volume ratio" was characterized by the following indices: the number of eggs included in the modal class was 90.94%, the deviations to the smaller and larger side were 1.68% and 7.38%, respectively. By analyzing the data obtained, it can be stated that the Estonian breed is characterized by a greater consolidation of hatching eggs in terms of the "mass-to-volume ratio". There were 7.14% more eggs in the Estonian breed that deviated from the mean value by no more than ± 1 standard deviation compared to the Manchurian breed ($p < 0.05$). In variational classes of more than 1.1 g cm^{-3} and less than 1.01 g cm^{-3}, an asymmetric distribution of eggs was observed. In the Estonian breed, 7.5 times fewer eggs fell into the variation class with the value of the “mass-to-volume ratio” higher than 1.1 g cm^{-3} compared to the Manchurian breed ($p < 0.05$). At the same time, 2.1 times more eggs were included in the variation class with the value of the "mass-to-volume ratio" less than 1.01 g cm^{-3} compared to the Manchurian breed ($p < 0.05$). When assessing the mass of eggs (Table 4), it can be noted that larger eggs had approximately 2.7% higher value of the “mass and volume ratio”, which is in line with the data presented by other authors (Reijrink 2010) This trend is observed in eggs obtained from hens of both breeds. It was found that in all variational classes, the average weight of eggs was higher in the Manchurian breed. In the first variation class, the difference in crosses was 1.0 g or 1.70%, while in the second variation class was 0.6 g or 1.02%, and in the third one, 0.91 g or 1.52% ($p < 0.05$). Table 2 show the average values of the main geometric indicators for variation classes.

Table 2. Geometric parameters of hatching eggs of quails.

Cross	Variation class	Egg weight (g)	Egg shape index	Large diameter (mm)	Small diameter (mm)
Manchurian breed	<1.01	11.19 ± 0.34	1.27 ± 0.05	17.67 ± 0.45	14.58 ± 0.58
(n = 150)	1.01-1.1	11.83 ± 0.29	1.28 ± 0.04	17.36 ± 0.39	13.82 ± 0.44
	>1.1	12.97 ± 0.77	1.29 ± 0.08	17.8 ± 0.74	13.6 ± 0.62
Estonian breed	<1.01	11.19 ± 0.54	1.27 ± 0.09	15.93 ± 0.65	13.57 ± 0.78
(n = 150)	1.01-1.1	11.23 ± 0.29	1.28 ± 0.04	15.76 ± 0.30	13.65 ± 0.21
	>1.1	12.06 ± 0.73	1.29 ± 0.06	15.21 ± 0.41	13.12 ± 0.55

The assessment of the geometric indices of hatching eggs shows that the eggs according to the above indices met the regulatory requirements for hatching eggs. Once studying the external dimensions of the eggs, it was determined that by an elevation in the “mass-to-volume ratio”, the eggs become more elongated, acquire an elliptical shape. In the ase of metric indices of hatching eggs, it was found that the eggs of all variational classes practically did not differ in geometric indices. One can only note a tendency to a slight elevation in weight and a decline in the small diameter of the egg with an upraised value of the “weight-to-volume ratio”. Once studying the ratio of the mass and volume of eggs, one cannot but investigate such a physical index as the thickness of the shell. From the data presented in Table 3, it follows that the eggs that fell into the variational classes with low values in terms of the "mass-to-volume ratio" also differed in smaller shell thickness values.

Table 3. Results of evaluation of shell thickness, µm.

Cross	variation class (m : V)	Shell thickness (microns)		
		M ± m	σ	Cv (%)
Manchurian breed	<1.01	326.2 ± 16.18	66.4	20.3
n=150	1.01–1.1	348.8 ± 9.32	52.3	14.9
	> 1.1	350.1 ± 12.14	71.9	20.5
Estonian breed	<1.01	334.3 ± 10.25	54.8	16.4
n=150	1.01–1.1	351.2 ± 12.61	60.4	17.2
	>1.1	353.3 ± 18.17	78.2	22.1

Conversely, eggs with high values of shell thickness were assigned to the variation series with the maximum values of "mass-to-volume ratio". The values of the studied features that make up the totality have different values. The differences are sometimes large, sometimes almost imperceptible, however, they always exist, since there is no complete homogeneity within groups of biological objects. In this case, the variability of the "shell thickness" feature is quite pronounced. The range of samples for the Manchurian breed was 23.9 µm, while for the Estonian breed was 19.0 µm. The values of the coefficient of variability of the trait are very close and average 18.6%, which indicates an average degree of variability. The study of the quality indices of hatching eggs showed that the average values of all indices were within the normal range for hatching eggs, although they varied significantly by class. Table 4 shows the data on the evaluation of the weight of shell.

Table 4. The results of the evaluation of the mass of the shell (g)

Cross	Variation class (m : V)	Shell weight		
		M ± m	σ	Cv
Manchurian breed	<1.01	3.2 ± 1.18	1.4	20.3
n = 300	1.01–1.1	4.2 ± 0.92	2.3	14.9
	> 1.1	5.1 ± 2.14	1.9	20.5
Estonian breed	<1.01	3.8 ± 1.25	1.8	16.4
n = 300	1.01–1.1	4.3 ± 1.61	0.4	17.2
	>1.1	5.3 ± 1.17	1.2	22.1

From the data presented in Table 4, it follows that the eggs that fell into the variation classes with a low value in terms of the ratio of mass and volumen, were distinguished by low values of the shell mass. Conversely, eggs with large values of the shell mass were assigned to the variation series with the maximum values of the ratio of mass and volume. The values of the features that make up the set have different values. The differences are sometimes very large, sometimes almost imperceptible, however, they always exist, since there is no complete homogeneity within groups of biological objects. In this case, the variability of the "shell weight" trait is quite pronounced. The range of samples for the Manchurian breed was 1.9 g or 23.1%, while for the Estonian breed was 1.5 g or 18.1%. The values of the coefficient of variability of the traits are very close and averaged 17.6%. It can be seen that in eggs with a mass-to-volume ratio of less than 1.01 g cm^{-3}, there is a deline in the relative mass of protein and shell due to an elevation in the relative mass of the yolk. Eggs with a high mass-to-volume ratio exhibited a larger shell mass. The dynamics of alterations in the thickness and mass of the shell was clearly visible. By an elevated “mass-to-volume ratio”, the thickness and mass of the egg shell upraised significantly. In terms of weight, the difference was on average 16.2%, while that of shell thickness was 10.3%. To study the interior index quality of freshly laid hatching eggs, 100 eggs of each breed were opened. The study of the index quality of quail hatching eggs showed that the average values of all indices were within the normal range, although they varied significantly by varied classes (Table 5). It was noted that the protein index, reflecting the qualitative state of the egg white, was the lowest in eggs with a low value of the ratio of mass and volume (0.070 ± 0.003 in the eggs of the Manchurian breed, while, 0.075 ± 0.004 in those of the Estonian ones), which on average, it was lower by 0.013 or by 7.7% in comparison with eggs assigned to the variation class (with a mass-to-volume ratio of higher than 1.01 g cm^{-3}).

Table 5. Quality indicators of quail eggs.

Cross	variation class (m : V)	Protein index	Yolk index	Haugh units
Manchurian breed	<1.01	0.070 ± 0.001	0.44 ± 0.023	76.67 ± 2.70
n = 100	1.01–1.1	0.078 ± 0.001	0.47 ± 0.027	82.32 ± 1.64
	> 1.1	0.085 ± 0.001	0.48 ± 0.031	78.37 ± 2.66
Estonian breed	<1.01	0.073 ± 0.001	0.44 ± 0.038	77.85 ± 2.31
n = 100	1.01–1.1	0.081 ± 0.001	0.47 ± 0.022	83.86 ± 2.18
	>1.1	0.087 ± 0.001	0.49 ± 0.017	80.01 ± 2.88

The distribution of the Haugh units index showed the same trends as the protein index. By an elevation in the ratio of mass and volume, the value of the Haugh unit index upraised by an average of 4.83 absolute percent for the Manchurian breed, while by 4.93 absolute percent for the Estonian one. The qualitative state of the yolk is reliably characterized by its index. The difference in this indices between the polar variation classes was 0.03, or 6.5%. Thus, it can be stated that there is a tendency towards a decline in the quality of the yolk in eggs with a low weight-to-volume ratio. The ratio of the morphological parts of a quail egg is an important breed trait and largely indirectly determines the qualitative characteristics of the egg. The results of the study of the morphological structure of hatching eggs are presented in Table 6. In this study, 100 eggs of each cross were selected. From the data presented in Table 8, it follows that the eggs laid by Estonian quails exhibited a more optimal ratio between the main morphological parts of the egg. An Estonian quail egg is based on three main components (in %): protein: 57.9; yolk: 30.2; shell: 11.9. These ratios ensure the normal development of the embryo. Eggs laid by Manchurian quails are characterized by the following ratio of the main components: 58.1, 30.3 and 11.6 respetively. notably, by an elevated ratio of mass and volume in the egg, the relative mass of protein upraised, while the mass of the yolk declined. The reason for the deterioration in the quality of eggs may be a violation of calcium metabolism in the body of laying hens. Eggshell quality can be improved by supplementing the diet with vitamin D and especially vitamin C (Świątkiewicz *et al.* 2015; Nowaczewski *et al.* 2010).

Table 6. Morphological structure of hatching eggs.

Cross	Variation class (m : V)	Parts of an egg	Average, g M ± m	Rate (%)
Manchurian breed n = 100	< 1.01	shell	3.4 ± 0.35	10.5
		yolk	9.2 ± 0.66	31.5
		Protein	15.4 ± 1.21	58.0
	1.01–1.1	shell	4.1 ± 0.32	11.7
		yolk	10.9 ± 0.74	29.4
		Protein	15.8 ± 2.22	58.9
	> 1.1	shell	3.4 ± 0.56	12.0
		yolk	11.8 ± 0.83	30.3
		Protein	15.8 ± 1.87	58.4
Estonian breed n = 100	< 1.01	shell	2.9 ± 0.37	11.4
		yolk	11.2 ± 0.53	31.4
		Protein	15.0 ± 1.52	58.1
	1.01–1.1	shell	3.2 ± 0.28	11.9
		yolk	11.5 ± 0.56	30.5
		Protein	15.2 ± 1.42	58.5
	> 1.1	shell	3.7 ± 0.73	12.6
		yolk	11.3 ± 0.55	30.3
		Protein	15.1 ± 1.33	58.2

Relationship between the egg quality indices

The calculated correlation coefficients indicated an average in strength and a direct in direction significant relationship between "shell thickness" and "shell mass" with the sign "mass and volume ratio" (Table 7).

Table 7. Correlation lattice.

Indicators	Egg weight	Form Index	M:V	Protein index	Yolk index	Shell thickness	Shell weight	Haugh units
Egg weight	1.00	0.33	-0.05	0.09	-0.17	0.39	0.55	-0.14
Form Index	0.33	1.00	-0.13	0.27	0.14	0.04	0.21	0.17
M:V	-0.05	-0.13	1.00	0.05	-0.12	0.27	0.29	0.06
Protein index	0.09	0.27	0.05	1.00	0.29	0.16	0.18	0.96
Yolk index	-0.17	0.14	-0.12	0.29	1.00	-0.18	-0.27	0.31
Shell thickness	0.39	0.04	0.27	0.16	-0.18	1.00	0.73	0.05
Shell weight	0.55	0.21	0.29	0.18	-0.27	0.73	1.00	0.05
Haugh units	-0.14	0.17	0.06	0.96	0.31	0.05	0.05	1.00

Note: cells with a statistically significant value of the correlation coefficient ($p < 0.05$) are highlighted in dark color.

Sufficiently high correlation coefficients were noted for egg weight, which is positively related to shell thickness and weight ($p < 0.05$).

Evaluation of incubation results

The development of the bird embryo occurs mainly outside the mother's body, and only the initial phase takes place from the moment of fertilization in the genital tract of the laying hen. Embryo development was monitored on days 6, 10, and 16. In the first 6 days of development in eggs of the Estonian breed, the shell with a volume-to-weight ratio of less than 1.01 g cm^{-3}, on average, 6.4 and 2.7%, fewer normally developing embryos were noted compared to with 2 and 3 variation classes ($p < 0.05$). For brown-shelled eggs, a similar picture was observed - the difference was 4.5 and 5.3%, respectively ($p < 0.05$). When assessing the development of quial embryos on the 10^{th} day of incubation, the overall picture of changes was preserved. In our studies, eggs of the variational class with an indicator of "mass-to-volume ratio" from 1.01 to 1.1 g cm^{-3} were characterized by consistently high rates in the development of embryos. It was established that during this period of development of embryos in eggs belonging to the modal class, there was the highest number of normally developing embryos (91.7% in eggs of the Estonian breed and 90.8% in those of Manchurian one), while the minimum number of embryos with developmental delay, 7.8 and 8.0% respectively ($p < 0.05$). When candling eggs on the 19th day of incubation, similar materials were obtained. The worst results were noted in eggs with a low ratio of mass and volume. The differences in normally developing embryos between the 1st and 2nd variation classes were 8.0% and 10% for eggs of the Estonian and Manchurian breeds, respectively ($P<0.01$). Hatchery results were measured by the ratio of the number of healthy-day-old hatchlings hatched as a percentage of the total number of eggs incubated (hatching) and the number of fertilized eggs (hatchability). According to the results of egg incubation, presented in Table 8, it can be seen that the best indices of hatching and hatchability are noted in eggs with a mass-to-volume ratio of 1.01 to 1.1 g cm^{-3} (modal variation class).

Table 8. Results of incubation of quail eggs.

Variation class	Set for incubation	Unfertilized eggs	Fertilized eggs (pcs.)	Died, (pcs.)	Turned out, goal.	Conclusion (%)	Hatchability (%)
			Estonian breed				
less than 1.01	32	0	32	7	25	77.8	77.8
1,01 < x < 1,1	205	33	172	11	161	83.9	93.6
1.1 or more	63	8	55	5	50	79.4	90.9
Total	300	41	259	23	236	78.7	91.1
			Manchurian				
less than 1.01	34	1	33	8	26	76.5	78.8
1.01 < x < 1.1	197	29	168	12	156	79.2	92.8
1.1 or more	69	7	62	7	55	79.7	88.7
Total	300	37	263	27	237	79.0	90.1

Low results are obtained in eggs with a minimum value of the ratio of mass and volume. In the variation class with a value of less than 1.01 g cm^{-3}, 6.1% fewer perpellets were hatched from eggs obtained from Estonian quails compared to the modal class. In the Manchurian breed, similar results were 2.7%. It can be seen that the best hatching rates were noted in eggs with a mass-to-volume ratio of higher than 1.01. In the second and third classes, an average of 7.8 and 8.1% more quials were hatched compared to the first class ($p < 0.05$). The modal class included eggs with a well-structured shell, with an average shell thickness of 348.8-351.2 microns. Probably, larger eggs had a larger supply of nutrients, which exhibited a positive effect on the development of the embryo. In terms of hatchability, these differences were even more significant and amounted to 15.8% and 14.0%, respectively ($p < 0.01$). Eggs with different ratios of mass and volume also differed in the time of embryo development. It can be seen that the duration of the incubation in the first class quials was on average 5-8 hours less. In eggs of the first variational class, a decline in incubation time by an average of 1.8% was noted. In eggs from the second and third variational classes, the longer duration of incubation was probably associated initially with a relatively large supply of nutrients in the eggs. To control the growth and development of embryos, simultaneously with candling, the eggs lost their original weight. (Domatskiy 2019) noted that in the first 11 days of incubation, the eggs should lose as little as possible, and in the last 10 days as much as possible of their own weight. This indicates that the embryo is developing well, metabolic processes are at a fairly high level. In general, it can be stated that over the entire period of incubation in the modal class with a volume-to-weight ratio in the range of 1.01-1.1 g cm^{-3}, egg weight loss was within the normal range (12.1-12.4%). In eggs with a high value of the ratio of mass and volume, weight loss was 13.4%. Twelve hours after hatching, a qualitative assessment of the quials in all study groups was made. The largest number of quails of the 1st category (98.9%) in the Estonian breed was in the modal class, which was 4.3% more than in the first variation class and 1.1% more than in variation class 3. Similar data for the Manchurian breed amounted to 96.5%, 6.2% and 3.4%, respectively.

Third phase of research

Investigation of the bioelectric impulses of eggs during incubation

The study of bioelectric impulses (electric field strength) was carried out using a PCG10 Valleman signal generator and a two-channel oscilloscope PCS 500A Valleman. The data obtained during the experiments show that, depending on the theoretical value of the eggs "weight and volume ratio" index, the development of embryos was stimulated or inhibited. The most optimal level of development of embryos was noted in the modal (2nd) variation class in terms of the eggs "ratio of mass and volume". In eggs of this variational class, the most stable signal was noted. In the future, this trend determined the development of embryos. Embryos in the 2nd variational class exhibited a well-developed circulatory system of the yolk sac, and the allantois closed at the sharp end of the egg already on the 11th day of incubation. Embryos of the 3rd variational class, where the ratio of mass and volume was above average, showed a slight lag in development during 6 and 11 days of incubation, however, displayed almost the same developmental trend as in the 2nd variational series. In the first variation class, a delayed development of a larger number of embryos was noted compared to embryos of the 2nd and 3rd variational classes. The results of studying the strength of the electric field created as a result of the interaction of the static electromagnetic field of the coil with the developing embryo in the first 6 days of development are shown in Fig. 8.

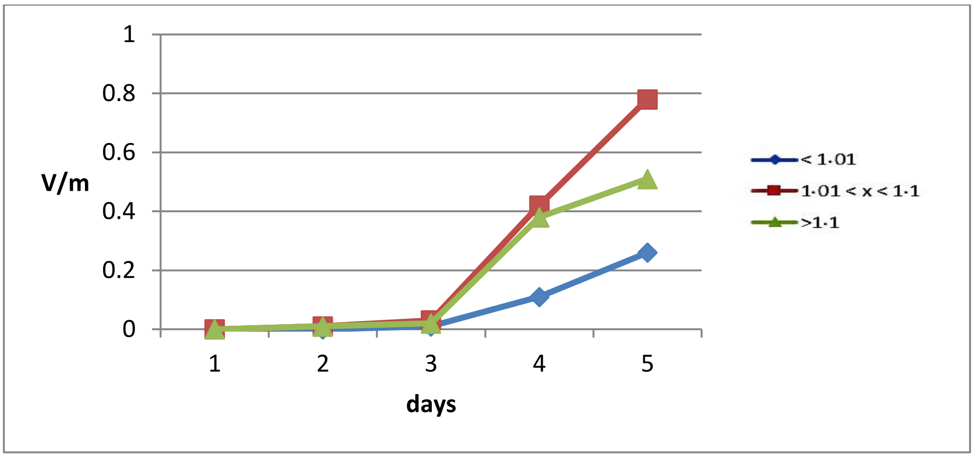


Fig. 8. The value of bioelectric impulses (1-6 days of incubation).

It was established that the eggs of the 2nd variational class significantly exceeded the eggs of the 3rd and, especially, the 1st class in terms of the strength of bioelectric impulses. Thus, the magnitude of the electric field strength created by embryos in the eggs of the modal class was 6.9% ($p < 0.05$) higher compared to the 1st variational one. The same regularity was observed in relation to the 3rd one. A significant jump was observed on days 7-8 of development. During this period of time, the strength of the captured bioelectric impulse (changes in the intensity of the electrostatic field) increased by 1.3 times. This, apparently, is due to the active formation of the fundamental systems and organs of the body (Fig. 9).

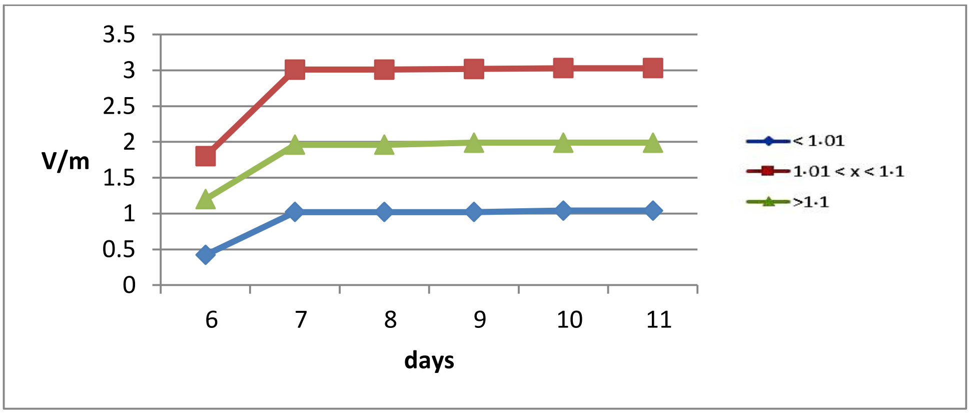


Fig. 9. The value of bioelectric impulses (7-10 days of incubation).

In continuation of the experiment, we studied the dynamics of changes in bioelectric impulses (electric field strength) on days 11-17 of incubation. It was established that the eggs of the 2nd variational class significantly exceeded the eggs of the 1st one in terms of the magnitude of the electric field strength during this period. The same regularity was observed in relation to the 3rd one (Fig. 10).

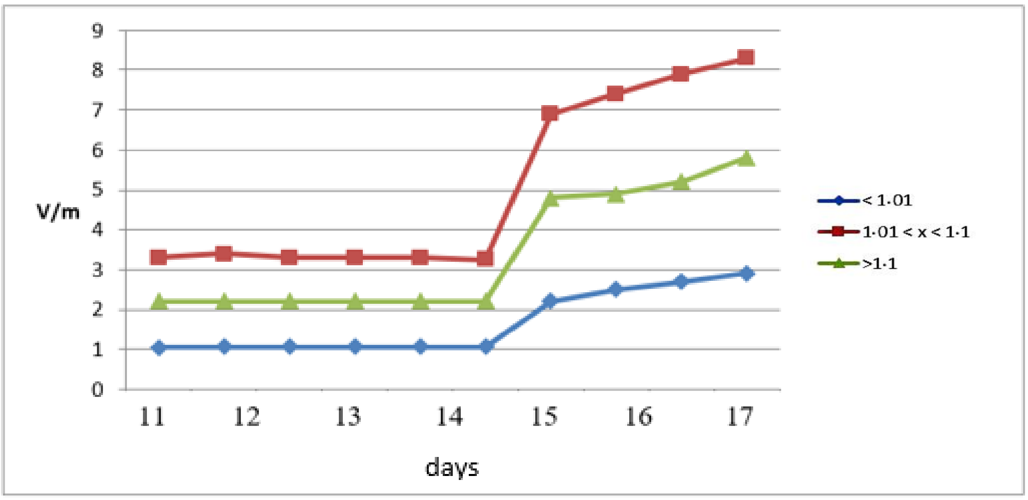


Fig. 10. The value of bioelectric impulses (11-17 days of incubation).

The above data give us the opportunity to say that eggs with a theoretical ratio of mass and volume in the range from 1.01 to 1.1 were distinguished by the most active signals during this observation period. This can be explained by the optimal mode, in which the qualitative and quantitative indices of incubation improve.

Investigation of electromagnetic pulses in eggs during incubation

Electromagnetic fields are currently considered to be the same important component of the biosphere as air and water. By varying intensity, such fields are emitted by all material objects. We set the task to study in dynamics during the period of incubation the frequency of electromagnetic signals emitted by the developing embryo. Once laid for incubation, the egg practically did not emit electromagnetic oscillations. The blastodisc was no more than 3-5 mm in diameter and the metabolic processes are insignificant (Fig. 11).

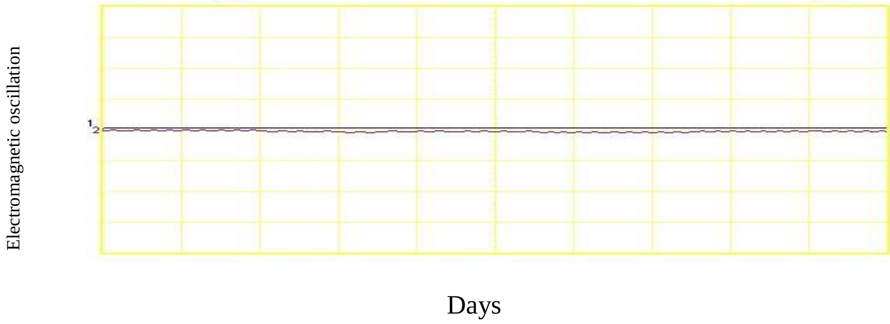


Fig. 11. Electromagnetic impulses on the 2nd day of incubation.

On days 6-7, farms usually carry out the first stage of biological control - unfertilized eggs are detected. The study of electromagnetic oscillations on the 6th day showed that their values can be estimated using a two-channel oscilloscope. The fluctuation values ranged from 0.01 to 0.04 kHz, averaging 0.028 kHz (Fig. 12).

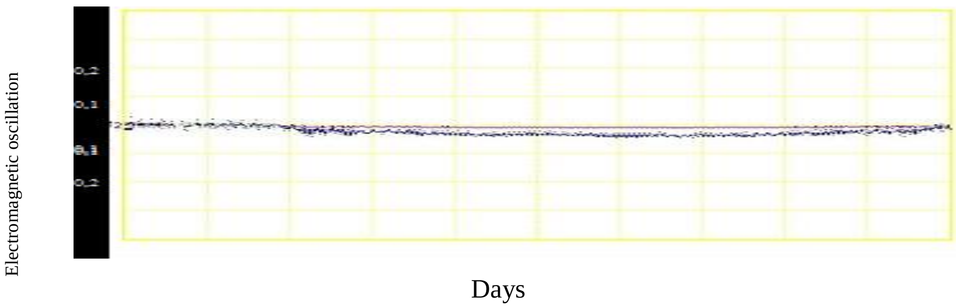


Fig. 12. Electromagnetic impulses on the 6th day of incubation.

On the day 11, all systems and organs were practically formed in the embryo. At this time, there was a good response of devices to the values of electromagnetic oscillations. The limits of fluctuations at this time were from 0.05 to 0.21 kHz, on average 0.184 kHz (Fig. 13).

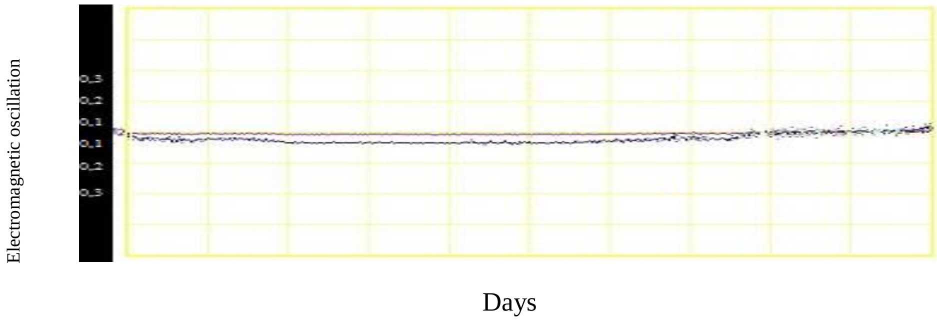


Fig. 13. Electromagnetic impulses on the 10th day of incubation.

On the day 11, the average value of electromagnetic oscillations was 0.325 kHz. Peaks related to the work of the heart were already visible on the electromagnetic curve (Fig. 14).

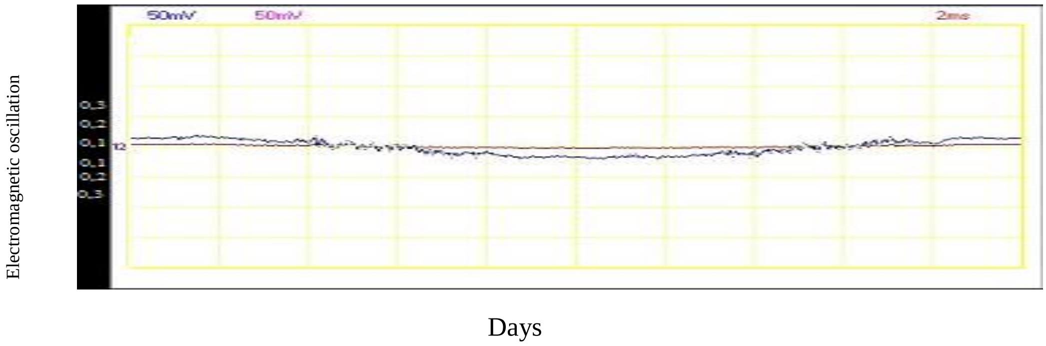


Fig. 14. Electromagnetic impulses on the 12th day of incubation.

At the end of incubation, intensive growth of organs occurs and the response of electromagnetic oscillations varied within the following limits: on the day 16 from 0.32 to 0.48 kHz, and on day 19 from 0.56 to 0.74 kHz (Fig. 15 and 16).

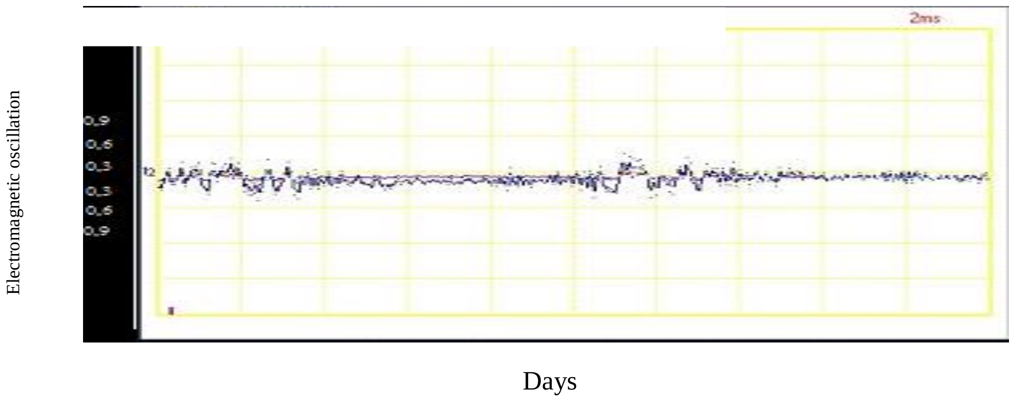


Fig. 15. Electromagnetic impulses on the 14th day of incubation.

In the first three days, the fluctuation frequency indicators were equal to zero, which indicates a low signal level, and, possibly, insufficient sensitivity of the device. On the 4th day, there was a noticeable increase in the size of the membranes and the formation of the limbs begins, which can already be fixed by the device. In the future, there is a gradual increase in the electrical signal. Several periods could be noted: 6-7, 9-10 and 14-15 days when a significant increase in signal was observed. Basically, this was due to the movement (turning) of the embryo inside the egg and a significant structural reorganization of tissues and organs in the body of the embryo during these age periods. Note that different levels of tension (static stress) have the same effect on the duration of embryonic development and hatching of quails. So, in the 2nd and 3rd variation classes, the durations of embryonic development in eggs with white color, were 488 and 489 hours, respectively: which were 6-7 hours higher than in the 1st class. In the case of eggs with brown shells, were 492 and 495 hours, which were 9 and 10 hours higher than in the 1st class. The hatching of quails in the 1st class was unfriendly, the quails were small. The verification of the adequacy of the adopted model for determining the frequency of pulse oscillations was verified using the Fisher F-criterion. The error in the results of experiments carried out with a certainty of 95% did not exceed the level of 3%.

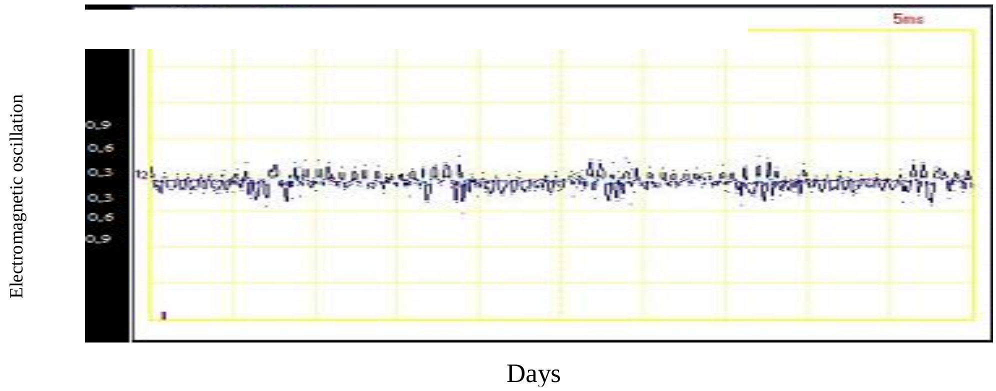


Fig. 16. Electromagnetic impulses on the 16th day of incubation.

Efficiency of weight-to-volume assessment of hatching eggs

In agriculture, improving the economic efficiency of animal husbandry means increasing the productivity of farm animals and reducing production costs. In breeding poultry farming, the economic indices of management to a large extent depend on how many daily quails will be received on the farm, and in particular, hens. In addition, it is important to ensure that the hatchery sections are filled with high quality breeding eggs, which will ensure that a sufficient number of day-old young stock are obtained to ensure the profitable operation of the hatchery. To calculate the effectiveness of the results of incubation in the conditions of the RUDN University vivarium, large batches of eggs were laid for incubation. In 2021, 320 eggs were laid for incubation in standard sections of the incubator, 160 eggs of each cross (see Table 9). Before laying for incubation, 50% of the eggs (80 pcs.) of each cross were evaluated by the ratio of mass and volume.

Table 9. efficiency of egg evaluation based on theoretical mass-to-volume ratio.

Indicators	Manchurian breed		Estonian breed	
	with an estimate by the ratio of mass and volume	not assessed by the ratio of mass and volume	with an estimate by the ratio of mass and volume	not assessed by the ratio of mass and volume
Eggs laid for incubation ()pcs.	80	80	80	80
Hatching of day old chicks (%)	95.7	89.9	93.8	87.6
Day-old chicks hatched (heads)	69	64	67	63
including:				
females	38	33	37	33
mails	31	31	30	30
Difference by quails heads	5		4	
Additional hens received per 1000 eggs (heads)	63		50	
The cost of selling 1 head (Ruble).	28-00*		28-00	
The amount of additional products received per 1000 eggs (Ruble).	1764-00**		1400-00	

Note: *. in 2021 prices; **. Without taking into account the costs of sorting eggs according to the ratio of mass and volume.

All eggs that had a theoretically calculated mass-volume ratio below 1.01 g cm^{-3} were discarded and replaced with eggs with a mass-volume ratio greater than 1.01 g cm^{-3}. The remaining 50% of the eggs (80 eggs) were randomly selected and placed for incubation without sorting according to the ratio of mass and volume. Calculations on the efficiency of egg selection in terms of "mass and volume ratio" showed that the use of preliminary sorting of eggs increases the yield of quails for the Manchurian breed by an average of 6.2%, while for the Estonian breed by 5.8%. Based on 1000 eggs, it is possible to obtain an additional 63 daily quails for the Manchurian breed and 50 daily quails for the Estonian one, including 5 and 4 quails heads, respectively. The amount of additional products received (excluding the cost of sorting eggs according to the ratio of mass and volume) per 1000 eggs is 1764-00 rubles for the Manchurian breed, while 1400-00 rubles for the Estonian one.

DISCUSSION

Modern management of industrial poultry farming has reached a qualitatively new level. All over the world, including in the Russian Federation, targeted breeding work is being carried out to increase the potential, both in meat and egg production. The production of quail eggs in the world, according to the FAO, will reach 10 million tons (about 1.5 trillion pieces) by 2025. Egg production is also growing in Russia, which reached 9.0 billion eggs in 2021, while according to the state program, it should exceed 10 billion in 2025 (Barroeta *et al.* 211). Thus, the medical norm of consumption per capita (292 units) will be exceeded. In accordance with the concept for the development of the poultry industry, one of the main components of an effective economy of enterprises should be the rational use of high-quality breeding material. Breeding is an inseparable part of scientific and technological progress and the continuous development of poultry farming. By intensive management of the industry, breeding plants with a small number of livestock cannot ensure the supply of large batches of breeding material to modern large poultry holdings. Creation of selection and genetic centers with wide employment of the best domestic and foreign genetic resources can solve this problem. By such a high concentration of production, an important role is given to assess the quality of breeding material and, in particular, the increasing requirements for the quality of hatching eggs, which is the key to obtaining healthy young. Numerous studies (Nowaczewski *et al.* 2010; Nasri *et al.* 2020) have established the effect of the density of incubation eggs on the indices of hatching of daily quails. The normative index of egg density in breeding poultry farming is 1.055-1.097 g cm^{-3}. It has been established that the high-quality young animals are hatched from eggs with such a density value. At breeding poultry enterprises, when selecting eggs for the purpose of subsequent incubation, a thorough assessment of eggs is carried out according to exterior and, selectively, interior indices. Despite this, the yield of high-quality young animals is, on average, 75-90% (Inci *et al.* 2015; Alikhanov *et al.* 2021). This means that in industrial poultry farming, the issue of evaluating hatching eggs does not lose its relevance. Previously, an analysis was carried out using three formulas for calculating the volume of an egg: the Simpson formula (Narushin *et al.* 2021) A comparative analysis of the formulas for the theoretical calculation of egg volume showed that the results obtained were close. The range of deviations from the actual egg volume was 4-7% with low intragroup variability within 10%. All three formulas can be used to calculate the theoretical egg volume (Rehman *et al.* 2017; Troscianko 2014). In our work, to calculate the ratio of mass and volume, we settled on the formula of Narushin (2005) in their own interpretation, when working with which they obtained the smallest deviations (3.7%) from the instrumental method for determining the volume of an egg. The analysis of scatterplots and frequency tables showed that the nature of scatter according to the trait "mass-to-volume ratio" differs significantly between the eggs of the Manchurian and Estonian breeds. In the Manchurian breed, hatching eggs, characterized by an average (or most probable) level of manifestation of the quantitative trait "mass-to-volume ratio", were concentrated in the modal class and account for 83.8% of the total number of eggs examined. Deviations from the modal class to a smaller and larger sides amounted to 12.6% and 3.6%, respectively. In the Estonian breed, the number of eggs included in the modal class was 90.94%, the deviations to the smaller and larger sides were 1.68% and 7.38%, respectively. The Estonian breed was characterized by a greater consolidation of hatching eggs in terms of the ratio of mass and volume. There were 7.14% more eggs in the Estonian breed that deviated from the mean value by no more than ± 1 standard deviation compared to the Manchurian breed ($p < 0.05$) (Genchev 2012). It has been established that in the polar variation classes (the ratio of mass and volume was higher than 1.1 g cm^{-3} and less than 1.01 g cm^{-3}), an asymmetric distribution of eggs was observed. In the Estonian breed, 7.5 times fewer eggs fell into the variation class with the value of the “mass-to-volume ratio” indicator of higher than 1.1 g cm^{-3} compared to the Manchurian breed ($p < 0.05$) (Song *et al.* 2000; Roriz *et al.* 2016). To the variational class with the value of the exponent “mass-to-volume ratio” less than 1.01 g cm^{-3}, 2.1 times more eggs of the Estonian breed were found compared to the Manchurian breed ($p < 0.05$) (Genchev 2012). The morphometric evaluation of the eggs showed that the arithmetic mean values in terms of the ratio of mass and volume were equal and amounted to 1.078 ± 0.0016 g

cm^{-3} for Estonian breed, and 1.072 ± 0.0018 g cm^{-3} for Manchurian one (Milojević *et al.* 2019) Once studying the external dimensions of the eggs, it was determined that by an elevation in the “mass-to-volume ratio”, the eggs become more elongated, and acquired an elliptical shape. The study of the shell thickness showed that the eggs that fell into the variation class with a low value in terms of "mass and volume ratio" (lower than 1.01 g cm^{-3}) also differed in lower shell thickness values. The range of shell thickness values for the Manchurian breed was 23.9 µm, while for the Estonian one was 19.0 µm. The study of the quality indices of hatching eggs of hens showed that the protein index, reflecting the qualitative state of the egg white, was the lowest in eggs with a low mass-to-volume ratio (0.070 ± 0.003 in the eggs of the Manchurian breed; while 0.075 ± 0.004 in those of the Estonian breed), which was lower by 0.013 or 7.7% compared to the eggs assigned to the variation class with a mass-to-volume ratio of higher than 1.01 g cm^{-3} (Genchev 2012; El Tarabany *et al.* 2015; Adeniyi *et al.* 2016; Grashorn *et al.* 2016). By an increase in the mass-to-volume ratio, the value of the Hay unit index increased by an average of 4.2 absolute percent for the Manchurian breed and by absolute percent for the Estonian one ($p < 0.05$). The conducted studies of the results of incubation showed that the best hatching rates were noted in eggs with a mass-to-volume ratio of higher than 1.01 g cm^{-3}. Eggs assigned to the second and third variation classes hatched 7.8 and 8.1% more quials compared to the 1st class ($p < 0.05$) (Genchev 2012; Milojević *et al.* 2019) In terms of egg hatchability, these differences were even more significant and amounted to 16.3% and 10.7%, respectively ($p < 0.01$) (Tona & Kokou *et al.* 2003; Terčič & Smerdu 2015). The results of the study of the bioelectrical impulses of the egg during the incubation period, which were created in response to a short signal with a frequency of 3 Hz, created by the generator, showed that they changed the intensity of the static electric field, which can be recorded by an oscilloscope. It has been established that the strongest perturbation of the electrostatic field was noted in the eggs of the middle variation class, the minimum - in the eggs of the 1st class (Shafey *et al.* 2005; Sampedro *et al.* 2006). The difference in the frequency of electromagnetic oscillations of eggs of different variational classes placed in an electrostatic field has been established (Troscianko 2014; Youssef *et al.* 2020). The developing embryo generates electromagnetic oscillations with the following parameters: Day 5: 0.028 ± 0.002 kHz, Day 11: 0.184 ± 0.003 kHz, Day 19: 0.589 ± 0.012 kHz (Wang *et al.* 2009; Shafey *et al.* 2015). Prospects for further development of the topic. The results of the pre-incubation assessment of eggs in terms of the ratio of mass and volume can be used at poultry enterprises to increase the yield of daily quails. The proposed scale of values of electromagnetic impulses of a developing embryo during incubation can be used as the basis for the development of technological equipment (non-contact electronic sensor) to control the development of the embryo.

CONCLUSION

It has been established that in the polar variation classes (the ratio of mass and volume is higher than 1.1 g cm^{-3} and less than 1.01 g cm^{-3}), an asymmetric distribution of eggs was observed. In the Manchurian breed, 7.5 times fewer eggs fell into the first variation class, and 2.3 times more eggs into the 3rd class compared to the Estonian breed ($p < 0.05$). By an elevated ratio of mass and volume of eggs, the relative mass of the shell increased by 6.6% and the relative mass of the yolk declined by 4.8% ($p < 0.05$). The ratio of mass and volume significantly affects the results of incubation of eggs. In the 2nd and 3rd classes, on average, 6.1 and 2.7% more quials hatched than in the 1st class ($p < 0.05$). In terms of egg hatchability, these differences were more significant and amounted to 15.8 and 14.0%, respectively ($p < 0.01$).

REFERENCES

Adeniyi, PO, Obatolu, VA & Farinde, EO 2016, "Comparative evaluation of cholesterol content and storage quality of chicken and quail eggs." *World Journal of Nutrition and Health,* 4.1: 5-9. DOI: 10.4172/2155-9600.1000584.

Alabdallach, AZ, Nikishov, AA, Volkova, NA, Vetokh, AN, Rebouh, NY, Semenova, VI, Petrov, AK, Rystsova, EO, Bolshakova, MV, Krotova, EA & Drukovsky, SG 2020, Histological and morphometric characteristics of chicken embryos with different genotypes. *EurAsian Journal of BioSciences*, 14: 719-725, Corpus ID: 219109731.

Alabdallah, Ahmad *et al.* 2021, "Influence of different genders of japanese quail on the functional state of kidneys." *Archives of Razi Institute*, 76.3: 667. DOI: 10.22092/ari.2021.355522.1694.

Alabdallah, ZA, Nikishov, AA & Karamyan, AS 2021, Sex-related of some haematological and serum biochemical changes, fed high-protein diet in Japanese quail (*Coturnix japonica*). *Iranian Journal of Ichthyology*, 8: 150-154.

Alabdallah, Z, Nikishov, A, Vatnikov, Y, Al Ragawi, A & Seleznev, S 2021, The effect of high protein in the feed mixture on the morphological changes in the kidneys of quail birds. *Journal of Chemical Health Risks*, 11: 383-392, DOI: 10.22034/jchr.2021.686023.

Alikhanov, J, Moldazhanov, A, Kulmakhambetova, A, Shynybay, Z, Penchev, SM, Georgieva, TD & Daskalov, PI 2021, Express methods and procedures for determination of the main egg quality indicators. *TEM Journal: Technology, Education, Management, Informatics*, 10: 171-176. DOI: 10.18421/TEM101-21.

Angel Daniel, PU, Jhonn Lenon, CJ, Laura Candelaria, CH, Alabdallah, Z & Nikishov, AA 2022, Alterations in the mass of quail eggs of different densities during storage. *Caspian Journal of Environmental Sciences*, 20: 1163-1166.

Barroeta, AC, Izquierdo, D & Pérez, JF 2011, Brief approach manual to the poultry company for veterinary students. Poultry Farming Manual, Animal Science and Food Department Animal Science Unit, Veterinary Faculty, UAB.

Domatskiy, VN 2019, Differentiated incubation of chicken eggs. *Bulgarian Journal of Agricultural Science*, 25(Suppl. 2), 54-58. Corpus ID: 229378066.

El Tarabany, MS, Abdel-Hamid, TM & Mohammed, HH 2015, Effects of cage stocking density on egg quality traits in Japanese quails. *Kafkas Universitesi Veteriner Fak Ltesi Dergisi*, 1: 13-18. DOI:10.9775/kvfd.2014.11374.

Genchev, A 2012, Comparative investigation of the egg production in two Japanese quail breeds-Pharaoh and Manchurian golden. *Trakia Journal of Sciences*, 10, 48-56, Corpus ID: 85588716.

Genchev, A, Ribarski, S & Zhelyazkov, G 2010, Physicochemical and technological properties of Japanese quail meat. *Trakia Journal of Sciences*, 8: 86-94. http://www.uni-sz.bg.

Grashorn, M, Juergens, A & Bessei, W 2016, Effects of storage conditions on egg quality. *Lohmann Information*, 50: 22-27.

Inci, H, Sogut, B, Sengul, T, Sengul, AY & Taysi, MR 2015, Comparison of fattening performance, carcass characteristics, and egg quality characteristics of Japanese quails with different feather colors. *Revista Brasileira de Zootecnia*, 44: 390-396, http://doi.org/10.1590/S1806-92902015001100003.

Milojević, M, Jokić, Ž & Mitrović, S 2019, Effects of morphometric indicators on incubation values of eggs and sex of the chicks of the light hen hybrids. In Animal Models in Medicine and Biology, p. 219. *IntechOpen*. DOI: 10.5772/intechopen.89191.

Narushin, VG 2005, "Egg geometry calculation using the measurements of length and breadth." *Poultry Science*, 84: 482-484, DOI:10.1093/PS/84.3.482.

Narushin, VG, Romanov, MN & Griffin, DK 2021, Egg and math: introducing a universal formula for egg shape. *Annals of the New York Academy of Sciences*, 1505: 169-177, DOI:10.1111/nyas.14680.

Narushin, VG & Romanov, MN 2002, Egg physical characteristics and hatchability. *World's Poultry Science Journal*, 58: 297-303, DOI:10.1079/WPS20020023.

Nasri, H, van den Brand, H, Najar, T & Bouzouaia, M 2020, Interactions between egg storage duration and breeder age on selected egg quality, hatching results, and chicken quality. *Animals*, 10: 1719. DOI: 10.3390/ani10101719.

Nowaczewski, S, Kontecka, H, Rosiński, A, Koberling, S & Koronowski, P 2010, Egg quality of Japanese quail depends on layer age and storage time. *Folia Biologica*, 58: 201-207, https://doi.org/10.3409/fb58_3-4.201-207.

Nowaczewski, S, Witkiewicz, K, Kontecka, HE, Krystianiak, S & Rosiński, A 2010, Eggs weight of Japanese quail vs. eggs quality after storage time and hatchability results. *Archiv Tierzucht*, 53: 720-730, https://doi.org/10.5194/aab-53-720-2010.

Ondrušíková, S, Nedomová, S, Pytel, R, Cwiková, O & Kumbár, V 2018, Effect of different storage times on japanese quail egg quality characteristics. *Potravinarstvo Slovak Journal of Food Sciences*, 12: 560-565. DOI: https://doi.org/10.5219/949.

Rehman, MS, Mahmud, A, Mehmood, S, Pasha, TN, Hussain, J & Khan, MT 2017, Comparative evaluation of egg morphometry and quality in Aseel hens under different rearing systems. *Journal of Applied Poultry Research*, 26: 401-409, DOI:10.3382/japr/pfx008.

Reijrink, I 2010, Storage of Hatching Eggs: Effects of storage and early incubation conditions on egg characteristics, embryonic development, hatchability, and chicken quality. *Wageningen University and Research*, Corpus ID: 90389599.

Romanoff Alexis, L & Romanoff Anastasia, J 1959, The avian egg. New York, John Wiley, London, Chapman and Hall, 620 p., https://search.rsl.ru/ru/record/01008354345.

Roriz, BC, Sgavioli, S, Garcia, RG, Nääs, IA, Domingues, CHF, Caldara, FR & Bernnecke, K 2016. Storage period affects weight loss of Japanese quail eggs. *Revista Brasileira de Ciência Avícola*, 8: 589-592. https://doi.org/10.1590/1806-9061-2015-0178.

Sampedro, F, Rodrigo, D, Martínez, A, Barbosa Cánovas, GV & Rodrigo, M 2006, Application of pulsed electric fields in egg and egg derivatives. *Food Science and Technology International*, 12: 397-405. DOI: 10.1177/1082013206070430.

Shafey, TM, Al Batshan, HA, Al Hassan, MJ, Al Haidary, AA, Al Faraj, A & Ghannam, MM 2005, Embryonic growth of chicks under the influence of electric field. *International Journal of Poultry Science*, 4: 872-878. DOI: 10.3923/ijps.2005.872.878.

Song, KT, Choi, SH & Oh, HR 2000, A comparison of egg quality of pheasant, chukar, quail and guinea fowl. *Asian-Australasian Journal of Animal Sciences*, 13: 986-990. DOI: 10.5713/ajas.2000.986.

Świątkiewicz, S, Arczewska Włosek, A, Krawczyk, J, Puchała, M & Jozefiak, D 2015, Dietary factors improving eggshell quality: an updated review with special emphasis on microelements and feed additives. *World's Poultry Science Journal*, 71: 83-94, https://doi.org/10.1017/S0043933915000082.

Terčič, D & Smerdu, T 2015, Effect of storage period and egg weight on hatchability in Prelux-G chickens. *Acta Agriculturae Slovenica*, 104: 69-74, DOI: http://dx.doi.org/10.14720/aas.2014.104.2.1.

Tona, K, et al. 2003, Effects of egg storage time on spread of hatch, chick quality, and chick juvenile growth. *Poultry Science*, 82.5: 736-741. DOI: 10.1093/PS/82.5.736.

Troscianko, J 2014, A simple tool for calculating egg shape, volume and surface area from digital images. *Ibis*, 156: 874-878. DOI: 10.1111/ibi.12177.

Wang, Z, Yang, P, Xu, H, Qian, A, Hu, L & Shang, P 2009, Inhibitory effects of a gradient static magnetic field on normal angiogenesis. Bioelectromagnetics: *Journal of the Bioelectromagnetics Society*, *The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association*, 30: 446-453. https://doi.org/10.1002/bem.20501.

Youssef, K, Archonta, D, Kubiseski, TJ, Tandon, A & Rezai, P 2020, Electric egg-laying: Effect of electric field in a microchannel on *C. elegans* egg-laying behavior. *BioRxiv*.

Bibliographic information of this paper for citing:

Alabdallah, ZA, Nikishov, AA, Angel Daniel, PU, Jhonn Lenon, CJ, Laura Candelaria, CH, Dorcas Stella, NSD 2023, Influence of the ratio of the mass and volume of quail eggs on their morphometric indicators and incubation results. Caspian Journal of Environmental Sciences, 21: 629-646.