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## Morphometric variables for breed differentiation

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# DIFFERENTIATION OF QUAIL (*Coturnix japonica*) BREEDS BASED ON THE MORPHOLOGICAL PARAMETERS OF EGGS

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Abstract

For quail breeding in Russia, a variety of populations is characteristic in which the pedigree of individuals is often unknown. Advanced breeding with quails (*Coturnix japonica*) requires identification of breeds, including the common origin. Egg weight is a mandatory descriptive attribute when testing poultry breeds and lines for distinctness, uniformity and stability. This paper is the first to provide data for quail breeds' differentiation by egg morphological parameters and estimates the influence of the quail breed on the parameters under consideration. The work aimed to study if it is possible to discriminate quail breeds by origin based on the morphological characteristics of eggs. Eggs were collected in the breeding herds of Japanese quail ($n$ = 240), Omsk quail ($n$ = 720), Pharaon ($n$ = 720), and Texas white quail ($n$ = 360) of 238-242 days of age (Siberian Research Institute of Poultry — a Branch of the Omsk Agrarian Scientific Center, Omsk). Three successively laid eggs were taken from each laying hen. Morphological parameters of eggs included large diameter (mm), small diameter (mm), egg weight (g), absolute weight of shell (g), yolk (g), and albumen with fractionation (g), albumen height (mm), yolk height (mm), shell thickness (μm) at the sharp pole, at the equator and at the blunt pole. All parameters were assessed according to the "Methodology for anatomical cutting of carcasses and organoleptic assessment of the quality of meat and eggs" (Sergiev Posad, 2013). Statistical analysis was performed using IBM SPSS Statistics v.23 software. Breed affiliation was considered as a factor influencing the egg morphological composition. The strength of the influence of the breed ($\eta^2$) was assessed using analysis of variance (ANOVA). As breeds deviated towards meat productivity, the weight of an egg and its components increased. Purposeful selection of Japanese, Omsk, Pharaon and Texas White quails for economically useful traits led to their significant differences in egg weight ($\eta^2$ = 0.723; p < 0.001). Quail egg weigh depended largely on albumen mass ($r$ = 0.897-0.911; p < 0.01). Distinctiveness of egg weight as a breed trait is due to breed differences in a set of morphological characteristics. These are the weight of the outer liquid layer of the albumen ($\eta^2$ = 0.642; p < 0.001) and outer dense layer of the albumen ($\eta^2$ = 0.796; p < 0.001); the height of the dense layer albumen ($\eta^2$ = 0.627; p < 0.001); large and small diameters ($\eta^2$ = 0.776 and $\eta^2$ = 0.852, respectively; p < 0.001). Breed clustering based on the morphological parameters of the eggs, corresponds to the similarity of genotypes. Our findings allow us to suggest the morphological analysis of eggs as a methodology to preliminarily discriminate the relatedness of quail breeds.

Keywords: *Coturnix japonica*, quail, egg morphological characteristics, analysis of variance, breed influence, degree of relationship

The global trend of modern quail breeding is the organization of production based on industrial technologies. As many years of experience in chicken and turkey breeding show, an increase in productivity is achieved through the use of poultry crosses namely, a complex of combined lines [1].

A feature of domestic quail breeding is the diversity of populations, often of unknown origin. This creates a breeding problem, since in order to obtain quail lines, it is necessary to study the productive qualities of the gene pool available in

Russia and to identify promising specialized (egg and meat) breeds. To increase the genetic diversity of the constituent breeds or lines, it is necessary to know the degree of their relationship, that is, to identify existing breeds and populations (2).

Egg weight is one of the obligatory features when testing poultry breeds and lines for distinctness, uniformity and stability [3, 4].

The bird egg is a complex and highly differentiated germ cell containing the nutrients necessary for the development of the embryo. Egg mass and properties are influenced by genotypic and paratypic factors [5). The body of the bird reacts to the conditions of feeding and keeping, which affects the reproductive system. Under the influence of these factors, components of the egg, the albumen, yolk and shell undergo quantitative and qualitative changes [6-8].

In addition, the components of the egg change with the age of the laying hen: the weight of the egg increases, the thickness of the shell and the quantitative ratio of albumen and yolk decrease, and their biological value regresses [9]. Such variability is within the limits of the reaction norm in accordance with the species, breed and lineage of the bird. In particular, significant differences in egg weight, weight and shell thickness between gray and white quails (*Coturnix japonica*) were found when kept at elevated temperatures [10]. As is known, the egg weight heritability coefficient is one of the highest among quantitative traits, on the basis of which it is assumed that this trait is controlled by a smaller number of genes than other economically useful traits [11-13].

From a biological point of view, a purposeful increase in live weight is a deviation from the natural genetic status of a bird species. Such a deviation entails an increase in the mass and morphological qualities of the egg [14, 15]. The tgg weight correlates with other indicators of productivity, including live weight [16, 17].

In chickens (*Gallus gallus*), a positive and significant phenotypic correlation of egg weight with its geometric dimensions (large and small diameters), as well as with the mass of albumen, yolk and shell, and negative with the shell index [18-20] were revealed. Along with the phenotypic correlation, egg weight has statistically significant ($p < 0.01$) positive genetic correlations with shell weight ($r = 0.73$), albumen weight ($r = 0.73$) and yolk weight ($r = 0.68$), with the height of the yolk ($r = 0.51$), the diameter of the yolk ($r = 0.46$) and its index ($r = 0.42$). Most of the internal qualitative characteristics of the egg varied depending on the change in its mass [21]. Comparison of the morphological features of eggs in birds of the same species, the *G. gallus*, but different breeds (Utrerana and Leghorn) showed significant interbreed differences in egg weight, its geometric dimensions, albumen and yolk weight. For both breeds, it was found that the external features of the egg (mass, small and large diameter) are related to its internal morphology [22].

The accumulated scientific data indicate that the mass of the egg is a determinant of most of its quantitative and qualitative characteristics, which determines the species, breed and lineage of the bird, but research in this area is still fragmentary. For example, it is known that egg mass evolves under the influence of selection in the direction of bird productivity. This sign is considered one of the key ones in the identification of a species, breed, and line. There is also evidence that a change in the mass of an egg entails a modification of its internal structure.

The question naturally arises: which components of the egg change to a greater extent under the influence of selection and whether these morphological characteristics can be applied to determine the degree of similarity of the breed genotype. We suggested that the construction of dendrograms according to the degree of similarity of the complex of morphological features of poultry eggs can be used as a basis for the hierarchical classification of breeds and lines and a preliminary assessment of their proximity in origin. The choice of quail (C. *japonica*) for our study is justified by the fact that it is both an agricultural bird and a model species that is widely used in genetic studies [23-25].

In this paper, for the first time, the results of the analysis of the influence of the breed belonging of quails of different directions of productivity on the morphological characteristics of the egg are presented. It is shown that the selection of quails by live weight to a greater degree affects the geometric dimensions of the egg, its mass as a whole, the mass of its fractions, as well as the thickness of the shell. The possibility of using the morphological characteristics of eggs for preliminary identification of the origin of quail breeds was revealed.

The aim of the work was to study the differentiation of quail breeds and determine the degree of their relationship based on the distinctness of the morphological features of eggs.

*Materials and methods.* The study was carried out on quail eggs of the Japanese ($n$ = 240), Omsk ($n$ = 720), Pharaon ($n$ = 720), Texas White ($n$ = 360) breeds at the age of 238-242 days (SibNIIP, a branch of the Omsk ARC, Omsk, 2020). The diets and conditions of the birds were in accordance with the recommended ones [26].

Three successively laid eggs were taken from each laying hen. The morphological analysis of eggs was carried out in accordance with the methodology of the Federal Scientific Center All-Russian Research Institute of Typology of the RAS [27] for the large egg diameter (mm), small egg diameter (mm), egg weight (g), the absolute shell weight (g), yolk (g), albumen with fractionation (g), albumen height (mm), yolk height (mm), shell thickness (гm). We used an HL 100 electronic scale (A&D Company, Ltd., Japan), a TOPEX 31C628 digital caliper 150 mm, 0.02 mm (Grupa Topex, Poland), and an altimeter.

Data on albumen mass, mass of outer albumen fractions, albumen height, large and small diameters were used for hierarchical classification of the studied breeds with the construction of a dendrogram with sequential association of clusters according to the degree of similarity of the set of features. The convergence of clusters was judged by the Euclidean distance.

Statistical analysis was performed using IBM SPSS Statistics v.23 software (https://www.ibm.com/support/pages/down-loading-ibm-spss-statistics-23). Means ($M$) and their standard errors (±SEM) are presented for the measured values. Differences were considered statistically significant at the level of Student's $t$-test $p < 0.05$. The degree of trait variability was assessed by the coefficient of variation (Cv). Variation of the trait was considered weak at $Cv < 10\%$, moderate at $Cv$ 10-20%, and significant at $Cv > 20\%$. Correlation and regression analyzes were used to measure the strength of the interdependence of indicators. Phenotypic correlation coefficients were established based on paired comparisons of traits. As a factor influencing the indicators of the morphological composition of eggs, the breed was taken into account. Analysis of variance (ANOVA) was used to assess the strength of breed influence ($\eta^2$). The influence of the factor was considered significant at the significance level of Fisher's $F$-test from $p < 0.05$ to $p < 0.001$.

*Results.* Large samples of eggs from each breed provides representative results. The egg mass within the breed varied slightly ($Cv < 10\%$). This indicates that the study was conducted on consolidated quail breeds. The direction of productivity was reliably manifested in the difference between breeds in terms of egg weight. The Japanese breed (egg direction) was inferior in egg weight to the meat-and-egg Omsk breed by 6.46%, the meat breeds Pharaon and Texas white by 11.22 and 19.74%, respectively. In turn, in the Omsk breed, the egg weight was less than in the Pharaon and Texas White breeds, by 5.09 and 11.04%, respectively. The Texas white breed, which differs from the other breeds in its greater live weight, also had the highest egg weight (Table 1).

**1. Morphological parameters of eggs in different quail (*Coturnix japonica*) breeds** (Siberian Research Institute of Poultry — a Branch of the Omsk Agrarian Scientific Center, Omsk, 2020)

| Parameter | Japanese quail ($n$ = 240) | | Omsk quail ($n$ = 720) | | Pharaon ($n$ = 720) | | Texas White quail ($n$ = 360) | |
|---|---|---|---|---|---|---|---|---|
| | $M$±SEM | $Cv$, % | $M$±SEM | $Cv$, % | $M$±SEM | $Cv$, % | $M$±SEM | $Cv$, % |
| Absolute mass, g: | | | | | | | | |
| eggs | 12.74±0.111[bcd] | 7,66 | 13,62±0,075[acd] | 7,07 | 14,35±0,079[abd] | 4,53 | 15,31±0,068[abc] | 8,61 |
| shells | 1.28±0.013[bcd] | 9,93 | 1,32±0,007[acd] | 9,40 | 1,36±0,013[abd] | 7,92 | 1,47±0,007[abc] | 9,33 |
| albumen | 7.41±0.049[bcd] | 8,38 | 8,03±0,060[acd] | 8,12 | 8,69±0,060[abd] | 6,05 | 9,18±0,046[abc] | 8,78 |
| yolk | 4.05±0.042[bcd] | 11,39 | 4,27±0,029[acd] | 10,77 | 4,30±0,040[abd] | 7,83 | 4,66±0,028[abc] | 11,76 |
| Absolute mass of albumen layers, g: | | | | | | | | |
| external liquid | 2.84±0.038[bcd] | 22,42 | 3,02±0,031[ad] | 20,75 | 3,09±0,089[ad] | 26,67 | 3,33±0,041[abc] | 23,85 |
| outer dense | 3.10±0.113[bcd] | 12,08 | 3,44±0,051[acd] | 15,76 | 3,60±0,060[abd] | 15,38 | 3,83±0,042[abc] | 11,43 |
| internal liquid | 1.34±0.026[bcd] | 33,44 | 1,42±0,025[acd] | 34,96 | 1,84±0,092[ab] | 40,38 | 1,83±0,019[ab] | 31,30 |
| internal dense | 0.13±0.003[bcd] | 49,16 | 0,15±0,006[ad] | 41,34 | 0,16±0,009[ad] | 44,03 | 0,19±0,011[abc] | 47,86 |
| Egg diameter, mm: | | | | | | | | |
| large | 34.73±0.093[bcd] | 4,91 | 35,11±0,046[acd] | 3,51 | 35,86±0,200[abd] | 4,66 | 37,19±0,084[abc] | 4,40 |
| small | 25.23±0.100[bcd] | 3,44 | 25,62±0,079[acd] | 4,52 | 26,51±0,111[abd] | 3,02 | 27,32±0,079[abc] | 5,60 |
| Shell index, % | 74.54±0.531[b] | 6,28 | 72,97±0,046[acd] | 4,81 | 73,93±0,420[b] | 4,45 | 73,46±0,244[b] | 6,45 |
| Height, microns: | | | | | | | | |
| outer dense albumen | 510±7.5[bcd] | 21,27 | 491±5,7[ad] | 29,53 | 488±4,9[ad] | 24,85 | 457±5,3[abc] | 22,69 |
| yolk | 1111±6.4[bcd] | 5,02 | 1136±5,3[acd] | 9,55 | 1162±5,2[abd] | 7,18 | 1231±4,7[abc] | 7,57 |
| Shell thickness, microns | 186±1.1[bcd] | 7,43 | 192±1,0[acd] | 10,86 | 198±1,1[abd] | 8,83 | 202±0,9[abc] | 9,63 |

N o t e. The age of laying hens is 238-242 days. Latin letters [a], [b], [c] and [d] indicate significant differences ($p < 0.05$) with the breeds (Japanese, Omsk, Pharaon and Texas white, respectively).

Differences between breeds in egg mass were reflected in the geometric dimensions of the eggs. The heavier breeds of quails significantly exceeded the light breeds in terms of large and small egg diameters. In the Omsk breed, the large and small egg diameters were larger than in the Japanese breed by 1.08 and 1.52%, in the Pharaon breed vs. the Omsk breed by 2.09 and 3.36%, respectively, in the Texas White breed vs. the Pharaon breed by 3.58 and 2.96% (see Table 1).

There was a tendency for a more noticeable difference between breeds in the small diameter of the egg than in the large one. During statistical processing of the entire data array for four breeds, the determination of the regression coefficient for the mass and diameters of eggs showed that with an increase in egg mass by 1 g, the large egg diameter increases by 0.318 mm, the small one - by 0.363 mm ($p < 0.001$). According to the shell index, only a significant difference between the Omsk breed and the other three breeds was established (see Table 1).

The greatest differences between the breeds were found in albumen mass. Thus, the Japanese breed was inferior to the Omsk, Pharaon and Texas White breeds by 7.72; 14.73 and 19.28%, respectively; Omsk breed to the Pharaon and Texas White breeds by 7.59 and 12.53%; Pharaon to Texas White breed by 5.34%. As the egg mass increased, the difference between the breeds in absolute albumen mass decreased (see Table 1).

Differences between breeds in terms of shell and yolk weight were significant and comparable. In terms of yolk mass, the difference between the Japanese and other breeds was 5.15, 5.81 and 13.09%, respectively, between the Omsk breed and the Pharaon and Texas White breeds 0.70 and 8.37%, between the Pharaon and Texas White breeds 7.73%. Between the Omsk and Pharaon breeds, the difference in yolk weight was unreliable. In the Japanese breed, the weight of the egg shell was less than in the Omsk, Pharaon and Texas White breeds by 3.035.88 and 12.93%, respectively, in the Omsk breed vs. the Pharaon and Texas White breeds by 7.59 and 12.53%, in the Pharaon breed vs. the Texas White by 7.48%.

The data obtained are consistent with the results of A. Taskin et al. [28], who showed that quails, divided into groups by live weight, had differences in egg weight and morphological features, while consistently transmitting these differences to offspring.

In our study, there was a trend towards an increase in shell thickness as breeds deviated towards meat productivity (see Table 1). Omsk breed in terms of egg weight, shell and yolk was more different from the Japanese breed than from the Pharaon breed. This can be explained by the fact that the original population of the Omsk breed was created on the basis of the genetic material of the indicated breeds, but had a $^{3}/_{4}$ blood ratio for the Pharaon breed.

The variability of egg components in quails of all breeds was low (see Table 1). The coefficients of variation in the mass of the shell and albumen were low while of the yolk, it was medium but close to 10%. Of interest is the coefficient of variation in the mass of egg albumen which is less than the variation coefficients for the mass of the shell and yolk. In our previous studies on egg and meat chicken crosses, it was found that the coefficients of variation in egg albumen mass exceeded those for the shell and yolk [29, 30].

The weight of the egg depended to a greater extent on the weight of the albumen (for the Japanese, Omsk, Pharaon and Texas white breeds, $r_J = 0.902$, $r_O = 0.903$, $r_P = 0.897$, $r_T = 0.911$; respectively, $p < 0.01$) than on the mass of the shell ($r_J = 0.699$, $r_O = 0.494$, $r_P = 0.557$, $r_T = 0.535$; $p < 0.01$) and yolk weight ($r_J = 0.610$, $r_O = 0.580$, $r_P = 0.702$, $r_T = 0.758$; $p < 0.01$). The indicators of albumen, yolk and shell mass positively correlated with each other. The correlation coefficients were moderate or weak, but significant ($p < 0.01$): for albumen and shell mass $r_J = 0.326$, $r_O = 0.273$, $r_P = 0.405$, $r_T = 0.393$; for the mass of albumen and yolk $r_j = 0.213$. $r_o = 0.182$. $r_p = 0.332$. $r_t = 0.436$; for the weight of the yolk and shell $r_j = 0.300$. $r_o = 0.475$. $r_p = 0.345$. $r_t = 0.379$.

The egg albumen consists of four layers, two outer and two inner. The main share of egg albumen was accounted for by its outer fractions, which accounted for 80% in egg and meat-egg breeds (Japanese and Omsk), and somewhat less in meat breeds (Pharaon and Texas White), 77-78%. Significant differences between all breeds appeared only in the mass of the outer dense albumen. Thus, in the Texas White breed, the albumen content in this layer in the egg was higher than in the Pharaon (by 6.01%), Omsk (by 10.18%), and Japanese (by 19.06%) breeds. In turn, the mass of this albumen layer in the Pharaon breed was greater than in the Omsk (by 4.44%) and Japanese (by 13.89%) breeds. In the Omsk breed, the mass of internal dense albumen was greater than in the Japanese breed (by 9.88%). In terms of the mass of the outer dense layer, the Omsk breed approached the Pharaon breed to a greater extent than the Japanese breed. This trend is consistent with the differences we found between the studied breeds in terms of albumen mass.

In all the breeds studied, we established a positive correlation between egg size and albumen mass and its external fractions. Correlation coefficient values ranged from low to moderate, but were significant ($p < 0.01$). For a large egg diameter, $r$ with albumen mass was from 0.345 to 0.613, with the mass of the outer liquid layer from 0.259 to 0.289, with the mass of the outer dense layer from 0.264 to 0.299. For a small egg diameter, $r$ with albumen mass was from 0.527 to 0.703, with the mass of the outer liquid layer from 0.304 to 0.571, with the mass of the outer dense layer from 0.285 to 0.315.

The incubation quality of eggs is characterized by albumen index and Howe units. In accordance with the mathematical calculation formulas, these indices are directly related to the height of the dense outer layer of the albumen. A comparative analysis of the eggs made it possible to establish the following regularity: as the breeds deviated towards meat productivity, the height of the outer dense albumen layer decreased. This is consistent with the data of P.P. Tsarenko [23] that the eggs of heavy breeds of chickens, ducks, turkeys and geese have a slightly lower albumen height compared to light breeds.

For the rest of the albumen fractions, we have identified the following trends. The Japanese breed was significantly inferior to the other three in terms of the mass of external and internal liquid and internal dense albumen. The mass of these albumen layers in the Omsk breed was significantly less than in the Texas White breed. In terms of the mass of internal liquid albumen, the Pharaon and Texas White breeds were close to each other, in terms of the mass of the external liquid and internal dense albumen, the Omsk and Pharaon breeds were close. In all breeds, we established a negative significant ($p < 0.01$) correlation dependence of moderate strength between the mass of the liquid and dense outer layers of the albumen ($r_j = 0.416$, $r_o = 0.300$, $r_p = 0.605$, $r_t = 0.472$,).

The outer layers of the albumen had significantly less variability compared to the inner layers. The smallest variability in all four quail breeds was noted in relation to the outer dense layer of albumen, which was at an average level, approaching the lower limit in the Japanese and Texas White breeds.

The outer albumen fractions, compared to the inner ones, had a closer correlation with both the total albumen mass and the egg mass. The degree of correlation between the mass of albumen and eggs with the mass of the outer liquid albumen was moderate, with the mass of the outer dense - moderate and high. Correlation coefficients for internal albumen fractions turned out to be low and, in most cases, unreliable (Table 2).

**2. Correlation coefficients (*r*) between the variables of egg morphological parameters in different quail (*Coturnix japonica*) breeds** (Siberian Research Institute of Poultry — a Branch of the Omsk Agrarian Scientific Center, Omsk, 2020)

| Albumen layer | Japanese quail ($n$ = 240) | | Omsk quail ($n$ = 720) | | Pharaon ($n$ = 720) | | Texas White quail ($n$ = 360) | |
|---|---|---|---|---|---|---|---|---|
| | egg | albumen | egg | albumen | egg | albumen | egg | albumen |
| Outer: | | | | | | | | |
| liquid | 0,219[b] | 0,389[b] | 0,206[b] | 0,400[b] | 0,204[b] | 0,203[b] | 0,309[b] | 0,312[b] |
| dense | 0,379[b] | 0,659[b] | 0,677[b] | 0,841[b] | 0,244[b] | 0,492[b] | 0,381[b] | 0,439[b] |
| Internal: | | | | | | | | |
| liquid | 0,013 | 0,153[b] | 0,257[b] | 0,227[b] | 0,152[b] | 0,189[b] | 0,199[b] | 0,145[b] |
| dense | 0,016 | 0,127[a] | 0,007 | 0,145[b] | 0,005 | 0,101[a] | 0,046 | 0,123[a] |

N o t e. The age of laying hens is 238-242 days. Latin letters [a] and [b] indicate statistically significant correlations at $p < 0.05$ and и $p < 0.01$, respectively.

**3. The influence of the quail (*Coturnix japonica*) breed on egg morphological parameters** (Siberian Research Institute of Poultry — a Branch of the Omsk Agrarian Scientific Center, Omsk, 2020)

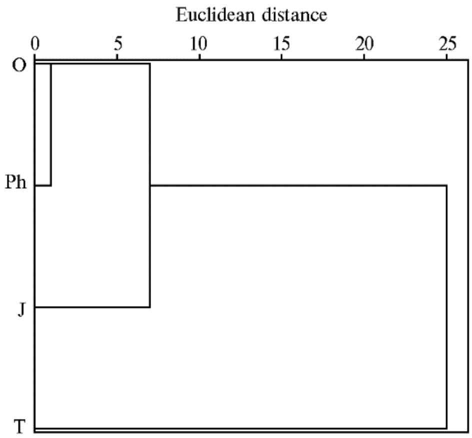
| Parameter | $\eta^2$ | *F* | p |
|---|---|---|---|
| Absolute mass: | | | |
| eggs | 0.723 | 10.908 | 0.000 |
| shells | 0.354 | 8.280 | 0.000 |
| albumen | 0.633 | 10.958 | 0.000 |
| yolk | 0.496 | 7.759 | |
| Absolute mass of albumen layers: | | | |
| external liquid | 0.642 | 7.682 | 0.000 |
| outer dense | 0.796 | 12.418 | 0.000 |
| internal liquid | 0.498 | 7.624 | 0.000 |
| internal dense | 0.058 | 2.260 | 0.086 |
| Height of outer dense albumen, microns | 0.627 | 7.774 | 0.000 |
| Egg diameter: | | | |
| large | 0.776 | 11.434 | 0.000 |
| small | 0.852 | 18.788 | 0.000 |
| Shell index | 0.721 | 8.704 | 0.000 |
| Shell index, % | 0.291 | 8.455 | 0.000 |

N o t e. The age of laying hens is 238-242 days.

We used one-way analysis of variance to establish the reliability of the distinguishability of quail breeds by the morphological structure of eggs. For all the studied morphological characteristics of the egg (except for the mass of the inner dense albumen layer), the influence of the breed factor was statistically significant ($p < 0.001$) (Table 3).

Species and breeds are one of the main factors limiting the variability of egg mass [31]. In our study, the influence of the breed factor was high. In the constituent parts of the egg, the studied factor determined the mass of the albumen to a greater extent than the mass of the shell and yolk. The genotypic effect on the variability of the masses of the layers turned out to be unequal. The influence of the breed to a greater extent determined the variability of the mass of the outer fractions of the albumen and the height of its outer dense layer. In terms of magnitude, this variability turned out to be comparable to that for the mass of a whole egg. The variability of the inner layers of the albumen, depending on the breed, turned out to be significantly less, although it remained significant. The geometric dimensions of the eggs were also determined by the breed of quails. The effect of the breed factor was stronger for small egg diameter than for large diameter. The shell thickness variability controlled by the breed was low (see Table 3).

In general, it can be stated that the degree of genotypic variability comparable to that for egg weight was characterized by the following morphological features: albumen weight, weight of its outer fractions, large and small diameter of the egg, height of the outer dense albumen layer. Based on the analysis of the share of influence of the breed on the variability of the morphological parameters of the egg, we chose these features for the hierarchical classification of quail breeds (Fig.).




**Hierarchical analysis of egg morphological parameters of quail (*Coturnix japonica*) breeds:** J — Japanese quail, O — Omsk quail, Ph — Pharaon, T — Texas White quail (Siberian Research Institute of Poultry — a Branch of the Omsk Agrarian Scientific Center, Omsk, 2020).

The studied breeds have a common origin. The Omsk quails are 1/4 the Japanese breed and 3/4 the Pharaon breed. The Pharaon breed was bred due to many years of selection with Japanese quails. The Japanese breed was also involvrd in the creation of the Texas White breed [1]. The process of data aggregation went in the direction of reducing the degree of breeds' relatedness. At the first stage, the Pharaon and Omsk breeds were grouped into one cluster. At the next cluster of both breeds merged with the Japanese breed, then at a great distance the three breeds merged with the Texas White breed.

Our study shows that the creation of quail breeds specialized in economically useful traits leads to a change in the weight of the egg and its morphological features. In meat breeds, in comparison with egg and meat-egg breeds, the mass of the egg, its geometric dimensions, the mass of the shell, albumen and yolk are greater. This is consistent with reports that bird breeds have egg-specific morphological features [32-35]. A number of authors indicate that there are statistically significant phenotypic and genetic correlations between the mass of an egg and its internal structure [36-38].

N. Vali [39] gives data on the coefficients of heritability in quails, the: 0.32-0.65 for egg weight, 0.35 for albumen weight, and 0.25-0.60 for shell weight. The proportions of influence of breeds on the corresponding morphological characters established by us were close to these values.

Our study complements the known data with a more in-depth analysis of the influence of the quail breed on such morphological features of eggs as the mass of outer and inner albumen fractions, the height of the outer dense albumen layer. Summarizing the available scientific publications and the results of our own research, we put forward a hypothesis about the possibility of using the morphological composition of eggs to identify quail breeds.

The method of hierarchical classification for determining the degree of relationship is often used in biology. B.S. Iolchiev et al. [40] used body conformation indicators for the preliminary identification of hybrids of argali and domestic sheep with different proportions of blood. D. Deeming [41] using cluster analysis revealed a high similarity of the amino acid composition of egg albumen in duck and goose, as well as in quail, turkey and chicken. In our study, in order to identify quail breeds with a common origin, we applied a hierarchical cluster analysis based on the morphological characteristics of eggs. The breeds were grouped into clusters according to the degree of genotype similarity (see Fig.). The clustering step distance increased as the bloodiness decreased.

Thus, targeted selection of Japanese, Omsk, Pharaoh and Texas White quails for economically useful traits led to significant differences between breeds in egg weight ($\eta^2 = 0.723$; $p < 0.001$). The mass of quail eggs depended to a greater extent on the mass of alnumen (*r* from 0.897 to 0.911; $p < 0.01$). Distinctiveness of egg weight as a breed trait is due to breed differences in such morphological features as the mass of the outer liquid layer of the albumen ($\eta^2 = 0.642$; $p < 0.001$), the outer dense layer of the albumen ($\eta^2 = 0.796$, $p < 0.001$), the height of the dense layer albumen ($\eta^2 = 0.627$, $p < 0.001$), large and small egg diameter ($\eta^2 = 0.776$ and $\eta^2 = 0.852$, respectively; $p < 0.001$). The breeds were grouped into clusters according to the degree of genotype similarity. Our findings allow us to propose the morphological analysis of eggs for the differentiation of quail breeds.

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