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STUDY OF THE CORRELATION BETWEEN MORPHOLOGICAL INDICATORS OF EGGS AND EXTERIOR PARAMETERS IN LAYING HENS OF TWO BREEDING LINES AND THEIR SURVIVABILITY

Liubov LIAKHOVICH, Olena BYRKA, Andrii ZAKHARYEV, Yuliia SOBAKAR, Olena KOCHEVENKO

State Biotechnology University, 44, Alchevskikh Street, Kharkiv, Ukraine

Corresponding author email: Liubov.vet@ukr.net

Abstract

The relationship between productive and exterior features and the survival of two breeding lines of laying hens population was studied. A direct correlation was established between two groups of features: 1 - exterior (density, color and shine of feathers; shape, size, color of the comb; height of the legs); 2 - morphological parameters of eggs (shape, size, condition of the cuticle, color of the shell and yolk, condition of the protein). Hens with dense black-pearl and zoz-like plumage, an elongated rose-shaped comb and high legs laid teardrop-shaped eggs of medium size, with a glossy shell, a large bright yolk, and a transparent dense protein. Their survival was 100%. Hens with red and white-black plumage (preserved 95%) had a leaf-shaped or rose-shaped comb, shorter legs and laid larger eggs (including round ones, with weak polar differentiation), dull and poorly mineralized shells, with smaller yolk and a larger zone of thinned protein. Hens with leaf-shaped combs laid fewer number of eggs that had defects in the shell texture in hot conditions.

Key words: *correlation, exterior indicators, laying hens, morphological parameters of egg, survivability.*

INTRODUCTION

The poultry industry plays a key role in meeting the global demand of the human population for substrates valuable for its health in the composition of chicken eggs. Chicken eggs are a valuable protein component of people's food chain all over the world (Khailov, 2018; Hliebova & Vertiichuk, 2014). It is known that, in addition to gastronomic uses, chicken eggs have a powerful biomedical potential. Their components (shell, subshell membrane, albumen and yolk) are used in bone transplantation, tissue engineering, wound healing, drug delivery and biosensors (Mohseni & Zhong, 2025; Usturoi et al., 2025).

Chicken eggs from private mini-farms and organic farms, where environmentally friendly poultry farming technologies are used, are extremely popular with modern consumers (Rahmani et al., 2019; Wägeli et al., 2016; Hidalgo et al., 2008). This technology of production minimizes the harmful impact on the environment. Optimal chicken hybrids are obtained for growing in such conditions because of breeding (Hamzău et al., 2025). Chickens with a meat-egg productivity profile are commercially profitable for mini-farms in rural areas. They are in steady demand among farmers. At the same time, chickens from amateur breeding lines are often used on rural poultry farms (Bondarenko & Khvostyk, 2020; Katerynych et al., 2015; Antos et al., 2013). Such chickens, as a rule, are distinguished by their resistance and high adaptation to environmental conditions. They are an optimal resource of potentially useful genetic parameters for industrial crossbred chickens (Preisinger, 2018; Katerynych et al., 2017; Hocking et al., 2003; Tudorache et al., 2022). Researchers are paying attention to studying the morphological features of local birds, despite the decreasing share of such breeds in the poultry industry of many countries, (Dudusola et al., 2020; Dana et al., 2010; Eganhi et al., 2010).

It is known that laying hens used in commercial poultry farming, as a rule, have solid or monochromatic plumage color. Local breeds of chickens often have a wide range of plumage colors and patterns (Chebo et al., 2023). This is explained by the presence or, conversely, the absence of pigments on the feathers, which is under genetic control (Davoodi et al., 2022). The unique spectrum of plumage pigmentation in local breeds of chickens is a significant genetic resource. Often, due to the uniqueness of the

plumage color, local breeds of chickens, despite the tendency of their population to decrease as a result of the introduction of a large number of commercial crosses, are properly appreciated by farmers and breeders and remain in the poultry sector (Chebo & Nigussie, 2016). Breeders consider the color of the plumage in chickens as a social signal and a tool for identifying breeding. Scientists emphasize the connection of periodic and seasonal fluctuations in the shape, size, texture and pigmentation of feathers in birds with the hormonal background and adaptation of the bird to changing environmental conditions (Widelitz et al., 2018). Investigation on morphological parameters of eggs of amateur breeding hens, depending on exterior characteristics, and their competitiveness in the spectrum of relevant products on the food market, deserve the attention of researchers. Highlighting these indicators and a model of specific experience of specialists and farmers working on optimizing the quality characteristics of chicken eggs will contribute to the development of the poultry industry as a whole. It is possible to optimize the production cycle, objectively investigate the state of egg productivity and morphological parameters of eggs in each breeding line of poultry in the conditions of private poultry farms.

MATERIALS AND METHODS

The relationship between morphological indicators of eggs and exterior characteristics in amateur breeding chickens and the survival of their population in two mini-farms was studied.

1. Chickens (n = 40) of the 1st mini-farm are the result of 18-year natural selection and selection of local chickens (Ukraine). The owner of the poultry farm is engaged in breeding chickens to form a collection of an ecological poultry farm. He raises chickens for a dual purpose (for decorative use - individuals with colorful feather color); to obtain: meat, eggs, fuzz and feathers. Chickens are obtained from incubation of eggs by hens and are grown in a mini-farm with free range. According to anamnestic data, chickens from this poultry farm are distinguished by endurance and a high level of viability. The owner uses combined individual-family selection based on indicators of families and individuals. The chickens breeders were evaluated based on the quality of the offspring if the line specificity was saved.

The chickens of the first mini-farm are descendants of local chickens (Ukraine): black-emerald, zozulyasty, with lacy, motley and striped feather patterns. The farm owner selected the chickens based on the following parameters: colorfulness and decorativeness of the plumage (shine and lacy and motley patterns of feathers; its density and splendor); resistance of the chickens to the influence of negative factors; high shins (the owner considers long legs in chickens to be a sign of both elegance and endurance, which is important in free-range conditions with wetlands); egg production, average egg size (this parameter, as established during monitoring of chickens of two generations, was inherited by laying hens from the paternal line - from the grandmother through the rooster line) and high yolk content.

The chickens of the first mini-farm are representatives of a breeding line, as they are a group of birds with common genetic traits that have been bred and fixed through selection to achieve certain qualities.

In the context of the modern concept of longevity of laying hens, the owner of the first mini-farm, on the advice of experts, uses a comprehensive approach to optimizing their life cycle: from day zero to the end of egg laying. This contributes to the sustainable and profitable production of high-quality food eggs. Observation of the chicken population lasted from the start of egg laying (at the age of 6 months, 100% of the chickens in the studied group laid eggs) to 70 weeks of age.

2. Chickens (n = 40) of the 2nd mini-farm were obtained as a result of amateur selection carried out by the owner of the farm for seven years. They were obtained from incubation of eggs by hens and grown in a free-range mini-farm. These chickens are descendants of local chickens with red and variegated plumage (Ukraine). The farm owner selected them based on the following characteristics: live weight (selection for live weight was carried out to reduce it to a level at which maximum egg production was achieved); at the same time, the owner selected the chickens based on the indicator of large eggs. Observation of the chicken population lasted from the start of egg laying (at the age of 5.5 months) to 70 weeks of age.

Both farms are located in the same biotope with the same type of relief and soil and plant cover. Chickens are kept in equipped poultry houses with optimal sanitary and hygienic conditions at night and in the cold season. Chickens are free-range during the day (in favorable weather). Nests in the poultry houses are equipped with video cameras to record the egg production of chickens, which makes it possible to carry out its individual accounting. The research was carried out in stages: the first stage included an individual assessment of productivity and morphological indicators of eggs; the second stage included an assessment of the exterior features of each laying hen and their comparison with the macromorphological features of eggs obtained from them. The ration of the studied chickens had significant seasonal differences in the set of feed components and their proportions. According to the analysis, the chickens' diet was dominated by wet mixtures of grain feeds (usually crushed and whole grains of wheat, barley, rolled oats, crushed corn) and crushed root crops (grown by farm owners), crushed mass of boiled beans, peas; periodically the chickens were fed dairy waste from their own farm. The seasonal feeding scheme for chickens was developed taking into account their age and operational characteristics, the corresponding needs of the body and the availability of specific feed sources at different times of the year. The most optimal period is the months from April to mid-November (at this time there are significant resources of grass in the grazing areas). The ambient air temperature, with the exception of hot summer and frosty winter days, allowed the chickens to roam during the day in search of plant and other feed components. The farm owners use a rotational system for keeping chickens: in certain areas, the chickens do not graze for 30 days and during this period the grass grows there. The chickens were fed with cultivated and wild plant species: aegopodium, chenopodium, wheatgrass; chopped radish, cabbage, spinach leaves. In autumn and winter, the chickens were fed wheat microgreens, hay flour, chopped hay of legumes (clover, sainfoin) and wild cereal crops, dandelion leaves, nettle, boiled root vegetables, potatoes, raw pumpkins.

The research was made in accordance with the topics of scientific activity of the Department of Morphology of the State Biotechnology University (Kharkiv, Ukraine).

The following methods were used: 1 – daily recording of individual egg productivity of chickens; 2 – method of selective assessment of morphological parameters of eggs (egg mass, thickness, strength and brightness of the shell; condition of the cuticle; proportion and condition of yolk and albumen); 3 – assessment of exterior features of chickens (density and color of plumage, shape, color and size of combs; height of thigh and shin); 4 – statistical analysis of the results obtained; 5 – method of regular chicken counting with calculation of survival rate; 6 – method of autopsy of dead chickens; 7 – method of photography.

For the purpose of selective assessment of morphological parameters of eggs, 5 eggs were selected from each laying hen of both farms aged 52-54 weeks and the egg weight and shell thickness were determined at three points (middle part, sharp end, blunt end), obtaining the average value per individual. 200 eggs were examined from each group of laying hens (total 400 eggs). 1. The weight of the egg and/or its components (g) was determined by weighing on an *Adventurer* laboratory electronic balance. 2. The thickness of the egg shell in the middle part / at the sharp end / at the blunt end (mm) was measured using an ultrasonic thickness gauge (Echometer 1061 device; *Karl Deutsch*; Co. Ltd., Wuppertal, Germany). 3. The strength of the shell was determined by a puncture resistance test (the ability of the shell to withstand a point mechanical impact/pressure of a dissecting metal needle in a certain area was assessed by two indicators: 1 - strong; 2 - fragile). 4. The degree of brightness of the egg shell was determined visually in daylight (in relative units) on the following scale: 1 - the shell is bright, the cuticle is uniform and smooth, reflects light rays in a specular direction; 2 - the shell is moderately shiny, the cuticle has separate matte areas; 3 - the shell is matte, without signs of shine. 5. The condition of the yolk and albumen was determined visually after breaking the shell; the integrity of the yolk and its pigmentation, the degree of protein density were noted. 6. The mass of the albumen and yolk was determined on the Adventurer laboratory electronic balance with the determination of their proportion.

The exterior features of the chickens were evaluated (the color of the plumage was visually determined; the brightness of the plumage was determined visually, in daylight, according to the following scale: 1 - bright plumage, with the presence of shiny black-tar, black-green, purple-pearl feathers; 2 - moderately bright plumage; with individual areas of dull feathers; 3 - dull plumage);
feather density was determined visually and palpated; comb shape (1 – rose-shaped; 2 – leaf-shaped) was determined visually; comb size was determined visually (by comparison in different chickens) and using a flexible laboratory ruler; thigh and shin height (cm) was measured using a laboratory ruler.
The survival rate of chickens on each farm was determined by regularly counting them, calculating the percentage of survival, and analyzing the reasons for their loss (death, culling). The survival rate of chickens was calculated as the ratio between the number of live chickens at the end of the study and their number at the beginning of the study.
Statistical analysis was performed using standard biometric methods using Microsoft *Excel* 2019 (Microsoft Corp., Redmond, WA, USA). Data are presented as mean ± standard deviation (M ± SD). The difference between the performance of chickens from two farms was assessed using Student's t-test for independent samples. The difference was considered statistically significant at $p < 0.05$. M ± SD (mean ± standard deviation; comparison of groups (chickens from two farms) – Student's t-test for independent samples; significance level $p < 0.05$). Correlation analysis was performed within each farm to assess the relationships between egg characteristics and exterior traits. For continuous variables (egg weight; shell thickness; thigh length; shin height), the Pearson correlation coefficient (r) was used. For ordinal brightness scores, the Spearman rank correlation coefficient (ρ) was used.

RESULTS AND DISCUSSIONS

Research on egg productivity, morphological parameters of eggs, exterior features and safety of laying hens with black-pearl and lace-striped plumage of farm №. 1

Parameters of egg productivity of the first mini-farm hens: age of laying the first egg – 175-180 days; age of reaching peak egg production – 29-31 weeks; egg production for 52 weeks of productivity (for one calendar year) – 245-260 eggs; egg weight at 52 weeks – 57-64 g; safety of hens – 100%. Live weight of adult laying hens – 2.1-2.3 kg. With daily monitoring and visual examination of all eggs laid by hens on the mini-farm, a connection between their morphological parameters and exterior features of the bird was established. Laying hens that had thick, lush black-pearl and black-emerald plumage stable and rhythmic laid eggs (except during the molting period) (Figure 1).



Figure 1. Appearance of part of the plumage of a domestic chicken of local selection: dense shiny black-emerald-pearl plumage in the area of the right wing (own source)

It is known that in nature the color of plumage in birds undergoes seasonal changes. In the studied chickens, the pigmentation of feathers acquired a particularly colorful appearance (to attract the male). Variations in the color of plumage in the studied chickens depended on primary and secondary color patterns and in some individuals were unique. The primary pattern depended on the distribution of colored feathers in different parts of the chicken's body, and the secondary pattern - on the distribution of pigment on individual feathers.
In the studied hens with dense lacy-zolaceous plumage, the eggs were also distinguished by 100% condition. It is known that in birds, feathers and skin are the first line of defense and play an important role in maintaining a stable internal temperature. Lush dense plumage helps maintain normal body temperature, regardless of the season (protects against hypothermia in the cold season and provides cooling in the heat). Elongated bright red rose-shaped combs, wide pectoral part, high shins were no less important exterior features that distinguished the studied hens with stable egg production (Figure 2).

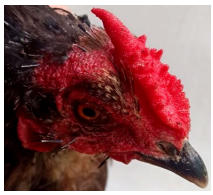


Figure 2. Appearance of a chicken's head with an elongated, bright rose-shaped comb (own source)

It is known, combs in birds play an important role in the prevention of heat stress (Hester et al., 2015; Hamzău et al., 2025). This depends on their shape and volume. The rose-shaped comb, in conditions of overheating of the bird, due to its specific volumetric structure, contributes to its faster cooling, dissipating heat from its surface, than the leaf-shaped one. The exterior features of the 1st farm chickens ensured and supported the adaptation of their organism to different conditions. The result of this was rhythmic egg laying, which indicates a high reproductive status, because it is a component of the reproductive cycle.

Results of visual assessment of the condition of the egg cuticle. The quality of the cuticle in individual egg specimens was consistently distinguished. Eggs from hens with dense colorful plumage (black-blue-pearl, with a metallic sheen and lacy-zulaceous) had a perfectly smooth cuticle. The best appearance was given to eggs from hens with the largest body and high legs. Their shells were shiny (Figure 3).



Figure 3. Appearance of an egg with a glossy (shiny) shell from a laying hen of local amateur breeding (own source)

It is known that gloss is conventionally defined as the specular component of light reflected from an object (Rasmussen & Dyck, 2000). Light is mostly reflected from a smooth glossy surface in a specular direction.

The appearance of a glossy, uniform eggshell was a successful sensory and marketing indicator: they were highly valued by buyers and consumers. It is known that the gloss of eggshells depends on the nanostructure. The shade and level of gloss of the eggshells of individual hens changed over time. But in general, eggs from hens from the first poultry farm had a uniform thickness of glossy golden-cream and pink-beige shells. (Figure 4).



Figure 4. Appearance of eggs from a hen with black-tarnish (on the left) and a hen with zozolish (on the right) plumage (own source)

In addition to marketing value, the uniform thickness of the eggshell ensured their high quality and long-term preservation.

Researchers note the nanostructural basis of the shine of the shell of chicken eggs and indicate the dependence of this trait on the breed and age of the laying hens (Li et al., 2020; Li et al., 2019; Yan et al., 2014). Researchers Lichovníková & Zeman (2008) note the influence of the housing system on the calcium needs of laying hens and the quality of eggshells. At the same time, scientists believe that the shine of the eggshell can potentially be integrated into the selection index as a moderate hereditary characteristic to achieve higher egg attractiveness.

Therefore, we consider the trait of the shine of the eggshell in chickens of the first farm to be extremely valuable and recommend that the owner use it as a breeding trait in chicken breeding programs. Researchers note that the hatchability of eggs depends on the quality of bioceramic calcite layers and the surface glycoprotein film of the egg (cuticle) (Bordunova et al., 2024).

Scientists Johnsson et al. (2012) indicate that calcium is more easily mobilized into the eggshell when hens have larger combs. At the same time, the heterogeneity of the thickness of the egg shell is a diagnostic criterion for a probable deficiency of minerals (calcium, phosphorus, etc.), vitamins of group *D* in the poultry diet and the influence of stressors

(Yenice, et al., 2025; Liakhovich et al., 2024; Liulin et al., 2023; Liakhovich et al., 2023).
Among the useful and husbandry traits in the chickens of the farm №1, it is important to note the indicator of long legs. The owner selected chickens, in particular, according to this trait, which is justified in free-range conditions.
Chickens with long legs move freely and quickly around the territory of the enclosure, compared to chickens with short legs. Long legs and distinctive camouflage plumage color variations (Figure 5) helped protect free-range chickens from predators.



Figure 5. Appearance of a chicken with camouflage lace plumage of beige-gray-brown shades (own source)

The survival rate of chickens on farm №. 1 was 100%.

Research on egg productivity, morphological parameters of eggs, exterior features and survival of hens with red-white and white-black plumage of amateur breeding of farm №. 2.
Parameters of egg productivity of hens of the second mini-farm: age of laying the first egg – 160-165 days; age of reaching peak egg production – 28-30 weeks; egg production for 52 weeks of productivity – 265-290 eggs; egg weight at 52 weeks – 57-67 g; survival rate of hens – 95.6%. The live weight of adult laying hens was 2.3-2.7 kg.
Hens with lush white and black plumage, a rose-shaped comb, an elongated body on medium-length legs, laid eggs with a white-cream shell. The shape of these eggs was distinguished by an elongated upper part and a smooth transition from the equatorial part to the rounded lower pole (Figure 6).



Figure 6. Appearance of an egg from a hen with white and black plumage with a rose-shaped comb, an elongated body on medium-length legs (own source)

Hens with lush red-and-white plumage, a short and thickened rose-like comb (Figure 7), and short legs laid relatively large eggs. These hens had a longer delay in feather regrowth after moulting compared to hens from the first farm. Hens from the farm №. 2 also had paler combs than hens from the farm №. 1.



Figure 7. Appearance of the head of a hen with red-and-white plumage and a short thickened light pink rose-like comb (own source)

The large eggs had rounded poles without clear differentiation, and their shells were often depigmented and dull (Figure 8).



Figure 8. Appearance of a large egg from a hen with red and white fluffy plumage: depigmentation and dullness of the shell, weak differentiation of the upper and lower poles (own source)

It was difficult to establish the basic color of the shell of such eggs, which is characteristic of chickens of certain crosses and breeds. Due to the large size of the egg and the squat body

structure, painful egg laying was observed in these chickens.

Daily recording of egg production, systematic visual assessment of the texture and pigmentation of the egg shell made it possible to establish the influence of specific factors that can change the indicated indicators. In chickens with a leaf-shaped comb (Figure 9), under conditions of comfortable summer temperatures, the color and texture of the egg shell were conditioned. And, at temperatures above 30°C, regardless of the color of the plumage of these chickens, their egg production decreased sharply (by 50-65%).



Figure 9. Appearance of hen head with a leaf-like comb that, under heat stress, laid eggs with defective shell texture (own source)

At the same time, eggs from hens with a leaf-shaped comb (in those individuals that maintained egg production in hot weather conditions) had a dull, depigmented and defective shell texture due to rough calcareous tubercles on the surface (Figure 10).



Figure 10. Appearance of an egg with a rough and depigmented shell from a hen with a leaf-shaped comb of amateur selection, laid at the background of heat stress (own source)

Researchers have found variability in some physical characteristics of chicken eggs and their shell quality throughout the entire laying cycle (Sirri, et al., 2018; Johnston & Gous, 2007). Regarding changes in internal and external egg quality parameters, scientists point out, first of all, their connection with the housing system, environmental temperature, age and genotype of the hens (Tumova & Gous, 2012; Tumova, 2011).

Data on the average egg weight from hens from both farms are given in Table 1.

Table 1. Egg mass of hens from two farms

Indicator	Farm 1 (n = 40)	Farm 2 (n = 40)	p
Egg mass (g)	59.88 ± 1.88	60.78 ± 2.69	0.087

As can be seen from the data in Table 1, the egg mass of chickens from the two farms is not statistically different.

Data on the thickness of the eggshells from chickens from both farms are given in Table 2.

Table 2. Eggshell thickness of chickens

Shell thickness (mm)	Farm 1 (M ± SD)	Farm 2 (M ± SD)	p
in the middle of the egg	0.332 ± 0.004	0.325 ± 0.012	0.001
at the sharp end	0.335 ± 0.004	0.328 ± 0.011	0.0004
at the blunt end	0.323 ± 0.005	0.317 ± 0.011	0.0013

The data in Table 2 show that the thickness of the eggshell at all three measurement points is significantly higher in chickens from the farm № 1; the differences are highly significant ($p < 0.01$).

Data on morphological and phenotypic indicators of chickens from the two farms are given in Table 3.

Table 3. Morphological and phenotypic indicators of chickens

Indicator	Farm 1 (M ± SD)	Farm 2 (M ± SD)	p
Brightness of the shell (relative units)	2.75 ± 0.44	1.65 ± 0.48	<0.001
Length of the thigh (cm)	14.97 ± 0.08	14.06 ± 0.15	<0.001
Height of the shin (cm)	8.14 ± 0.08	7.13 ± 0.14	<0.001
Brightness of the plumage (relative units)	2.70 ± 0.46	1.48 ± 0.51	<0.001

As can be seen from the data in Table 3, the brightness of the shell in chickens from the farm №1 is significantly higher than in chickens from the second farm; the length of the thigh and the height of the shin are also significantly higher in chickens from the farm №1; the brightness of the plumage is statistically higher in chickens from the first farm. In all cases, the differences are highly significant ($p < 0.001$).

The data of the correlation analysis within each farm to assess the relationships between egg characteristics and exterior traits of chickens are given in Table 4.

Table 4. Key correlations of indicators in chickens of farm 1 (n = 40)

Pair of indicators	Method / Coefficient (Pearson r; Spearman ρ)/	p
Egg mass ↔ Shell thickness (middle of egg)	r / −0.803	4.6×10^{-10}
Egg mass ↔ Shell thickness (sharp end of egg)	r / −0.703	4.1×10^{-7}
Egg mass ↔ Shell thickness (blunt end of egg)	r / −0.820	9.4×10^{-11}
Shell thickness middle of egg ↔ sharp end of egg	r / +0.851	3.5×10^{-12}
Shell thickness middle of egg ↔ blunt end	r / +0.667	2.6×10^{-6}
Shell thickness sharp end of egg ↔ blunt end	r / +0.768	7.3×10^{-9}
Thigh length ↔ Tibia height	r / +0.338	0.0327
Shell brightness ↔ Plumage brightness	ρ / +0.756	1.7×10^{-8}
Shell brightness ↔ Egg mass	ρ / −0.753	2.0×10^{-8}
Plumage brightness ↔ Egg mass	ρ / −0.764	9.4×10^{-9}

According to the results presented in Table 4, there is a strong negative relationship between the indicators “egg weight / shell thickness” in chickens of farm №. 1 (at all 3 measurement points).

To assess the relationships between morphometric parameters (thigh length, shin height, plumage brightness) and egg quality indicators (egg weight, shell thickness at three different points and its brightness), a correlation analysis was conducted. It showed the presence of a number of statistically significant relationships between morphometric characteristics of birds and egg quality indicators in hens of the farm №. 1.

The most pronounced relationships were found between egg mass and shell thickness, where a strong negative correlation was observed. Thus, the correlation coefficient between egg mass and shell thickness in the middle part was $r = -0.80$ ($p < 0.01$), at the sharp end of the egg $r = -0.70$ ($p < 0.01$), and at the blunt end $r = -0.82$ ($p < 0.01$). This indicates that with increasing egg mass there is a tendency for shell thickness to decrease. Shell thickness indicators in different parts of the egg demonstrate a high positive correlation with each other ($r = 0.67–0.85$; $p < 0.01$), which indicates the consistency of shell formation processes over the entire surface of the egg.

A strong positive correlation was also found between the brightness of the shell and the brightness of the plumage ($r = 0.76$; $p < 0.01$). A moderate positive relationship was found between the length of the thigh and the height of the shin ($r = 0.34$; $p < 0.05$), reflecting the overall proportionality of the development of the limbs in the studied chickens.

Correlation analysis of productivity indicators and morphometric characteristics of chickens of the farm № 2 revealed a number of statistically significant relationships between the studied traits. The most pronounced correlations were found between egg mass and shell thickness. A strong negative correlation was established between egg mass and shell thickness in the middle part of the egg ($r = -0.77$; $p < 0.01$), at the sharp end ($r = -0.73$; $p < 0.01$) and at the blunt end ($r = -0.79$; $p < 0.01$).

The results obtained indicate that with increasing egg mass there is a tendency for the shell thickness to decrease. Such a dependence may be due to the redistribution of mineral substances during the formation of larger eggs, which leads to a relative decrease in shell thickness. Strong positive correlations were found between shell thickness values measured in different parts of the egg. The correlation coefficient between shell thickness in the middle part of the egg and at the sharp end was $r = 0.88$ ($p < 0.01$), between the middle part and the blunt end - $r = 0.74$ ($p < 0.01$), and between the sharp

and blunt ends - r = 0. These results indicate a high consistency of shell formation processes across the entire surface of the egg and confirm the integrity of the shell mineralization mechanism.

A strong positive correlation was found between the brightness of the shell and the brightness of the plumage ($r = 0.73$; $p < 0.01$).

This may indicate common physiological or genetic mechanisms of pigmentation formation in birds, which are manifested both in the coloring of the plumage and the eggshell. Morphometric parameters in chickens of farm № 2 demonstrated a moderate positive relationship between the length of the thigh and the height of the shin ($r = 0.31$; $p < 0.05$), which reflects the proportionality of the development of the skeleton of the limbs in the studied birds.

At the same time, in chickens of farm № 2, the relationship between morphometric characteristics (thigh length, shin height) and egg quality indicators turned out to be weak or statistically unreliable, which indicates a relatively smaller influence of the bird's body size on the formation of egg quality characteristics in this sample. In general, the results of the correlation analysis show that close relationships are observed between the indicators of the structure of the egg shell, and even between the signs of pigmentation. This confirms the existence of functional and physiological relationships between individual components of egg formation and phenotypic characteristics of birds.

Comparative analysis of the results of the correlation study. Comparison of the results of the correlation analysis showed that in chickens on both farms similar patterns of relationships between egg quality indicators and morphometric characteristics of chickens are observed. In both groups, a strong negative correlation was established between egg weight and shell thickness in different parts of the egg, which indicates a tendency to decrease shell thickness with increasing egg weight.

Also, in chickens from both farms, close positive correlations were found between the shell thickness indicators measured in different parts of the egg, which confirms the consistency of the shell formation processes. In addition, in both groups, a positive relationship was observed between the brightness of the shell and the brightness of the plumage, which may indicate common mechanisms of their pigmentation. In general, the correlations between the studied indicators in chickens from the first and second farms are of a similar nature, which confirms the stability of the identified biological patterns.

Research on the internal content of eggs from chickens from two farms.

The subshell membrane in eggs from chickens from the first mini-farm was distinguished by its strength and elasticity. In eggs from chickens from the farm №2, the thickness of the subshell membrane was smaller.

The study of the internal contents of eggs from chickens from both farms showed a difference in the proportion and condition of the protein part. A larger proportion of protein was in the eggs of chickens from the farm №2, but the protein was watery and easily spread. Due to the diluted state of the protein part, the central position of the yolk was not preserved (Figure 11).

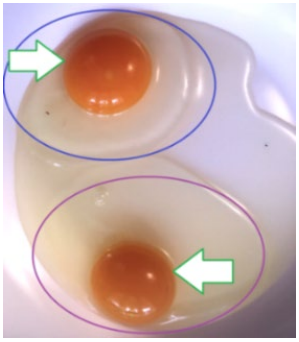


Figure 11. Appearance of the internal contents of eggs from experimental chickens (at the top – bright centrally located yolk and dense egg white from a chicken with black-tarry plumage; at the bottom – dull yolk and watery egg white from a chicken with red plumage) (own source)

The influence of breed and age of hens on the yolk-to-protein ratio in eggs and its differences in different genetic lines of poultry are known (Suk & Park, 2001). The mentioned traits are also influenced by the way the hens are kept, the length of the egg-laying cycle and many other factors (Sokołowicz et al., 2018; Ketta & Tumova, 2016).

The yolks in the eggs of the farm №1 chickens were consistently richer and brighter. At the

same time, the yolks in the eggs from chickens with glossy shells were the most pigmented.
Eggs from chickens with red-white and white-black plumage were heavier due to the albumen part and shell. And eggs from chickens with black-tarry and sable plumage had the most massive yolks. (Figure 12).



Figure 12 . Appearance of egg yolks on the left – a smaller yolk of an egg from a chicken with red-white plumage; on the right – a large yolk of an egg from a chicken with black-pearl plumage (own source)

At the same time, the proportion of yolk was the highest in eggs from hens with rich pitch-black plumage and reached 35% of the egg mass.
The feasibility of keeping hens with rose-shaped combs and long legs in free range is being investigated. A rose-shaped comb provides faster cooling of the hen's body than a leaf-shaped oneIn conditions of overheating. Accordingly, hens with a rose-shaped comb have a lower risk of heat stress. This contributes to the well-being of hens and their stable productivity.
Of the 40 chickens on farm №. 2, two chickens (5% of the initial population) died during the study period. This mortality rate is not statistically significant. It was determined that the deaths of two chickens were due to critical injuries sustained while free-range (one chicken was attacked by a hawk; the other chicken was attacked by a ferret). These incidents were recorded by surveillance cameras.
During the autopsy of one of the dead chickens, a formed egg was found in the oviduct. Hyperemia of the mucous membrane of the oviduct and stretching of its wall were detected (Figure 13), as well as a clear gradation of follicles in the ovary, which indicates the sudden death of the chicken at the moment of readiness for laying.
The difference in the survival rate of chickens on both farms (100% - farm № 1 and 95% - farm №. 2) is statistically insignificant.

Given that the two farms of local breeding laying hens where the study was conducted differ in a number of indicators (selection goal, live weight, age of first clutch), it is worth noting its limitations.



Figure 13. Appearance of the ovary and oviduct (with the presence of an egg in the lumen) in a dead hen (own source)

Given the differences in the directions of selection on both farms, it is advisable, first of all, to consider the impact of its consequences on the exterior and productive indicators of chickens. The number of studied chickens is also objectively limited, which accordingly reduces the possibility of wide application of the results obtained. It is advisable to continue research on the exterior and productive indicators of local breeding chickens on a larger population in the long term.

CONCLUSIONS

Laying hens with bright black-greenish-resinous and pearl plumage laid eggs with thicker and brighter shells, larger yolks and denser whites. They had longer thighs and legs. The weight of eggs from hens from the two farms was not statistically different. In hens with white-motley and red plumage, the white was larger and watery, and the yolk was smaller. In hens from both farms, a strong positive correlation was found between the brightness of the shell and the brightness of the feathers. This should be taken into account when selecting hens for breeding. The difference in survival of hens from both farms is statistically insignificant.

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