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Small Egg Diameter as a Selection Criterion of Broilers

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Abstract— **The shape of the egg is directly related to the productive and reproductive qualities of broilers. Large and small egg diameters are characterized by low variability (Cvbd = 4.74%, Cvmd = 2.73%). However, the range of variability of these characters was 9 and 10 mm, respectively; and 64.12% and 75.16%, respectively, of the layers according to these characters are outside the modal classes. The most informative is the small diameter of the egg. The correlation coefficient of the small diameter of the egg with live weight at 28 days of life is 0.734 (P <0.01), with hatchability of 0.270 (P <0.05). In addition, the small diameter of the egg has a significant negative relationship with mortality of embryos during the incubation period. The proportion of genotypic variation in the small diameter of an egg in both fathers and mothers is two times greater than that of a large diameter. Consequently, the small diameter of the egg, which, as a sign of chicken selection, can be another breeding trait increasing the offspring's live weight and reproductive qualities.**

Keywords—broilers, selection, egg shape, productivity, reproductive qualities, correlation coefficients.

I. INTRODUCTION

World meat consumption is growing along with an increase in the population of the planet. Since the 1960s, consumption has increased by 21 kg per capita. According to the FAO, the average person consumes 43 kg of meat per year to date. Poultry confidently takes a leading position in the structure of meat production, leave pork and beef behind. Poultry farming has achieved outstanding biological and economic results, incorporating the achievements of science and business. Meat poultry is developing quite dynamically and is one of the most competitive global industries [1, 2].

The poultry growth rate is still a priority factor in the development of poultry meat production. Despite the improvement of feeding programs and maintenance technologies, the contribution of genetics remains the main determinant [3, 4].

However, the selection of the lines of the Cornish White breed on this basis no longer gives an effect comparable to the costs. A promising solution is to slightly increase the live weight of the White Plymouth Rock hens while maintaining optimal reproductive qualities. At the present stage, a comprehensive assessment of the bird is being improved according to a number of signs that are significant for the

final result. Moreover, the study of the correlative relationships of economically useful traits remains relevant [5-9].

II. LITERATURE REVIEW

Selection of poultry by growth rate affected the quality indicators of eggs. At the same time, the live weight of broilers at the end of the growing period depends on the mass of day old chickens, which is largely determined by the quality of the eggs [10].

It is relevant to use various methods of phenotypic measurements of egg parameters and elucidate their correlations with other zootechnical traits. An important factor is the integrity of the egg shell with the goal of incubation. One of these signs is the shape of the egg, which is determined by the index: the ratio of small/large diameter. Consequently, the egg becomes more rounded with an increase in the small diameter and more elongated with an increase in the large. Despite the importance of morphological indicators for incubation qualities such as egg white and yolk shape index, egg white height, Haugh units, and others (excluding the egg shape index) – they are difficult to use in breeding.

Rounded eggs, compared to elongated ones, have significantly less external liquid egg white, a higher egg white and yolk index, additional Haugh units and, as a rule, slightly more solids and more intense pigmentation of the yolk. Thus, rounded eggs (with a high shape index) are generally more nutritious than elongated ones. A number of authors noted that the shape of the egg does not depend on the methods of managing the hens, nor on the microclimate conditions or on the feeding characteristics, but is associated with the bird genotype [11-16].

A.L. Romanova and A.I. Romanova in their classic work "Bird's egg" noted that "... individual hens lay eggs more or less of the same in shape and outline. In this case, the transverse diameter of the egg is usually more constant. This is due to the fact that the egg is formed in the oviduct, the lumen of which is limited in width" [17].

The aim of the study was to study the relationship of the geometric dimensions of the egg with the zootechnical indicators of meat chicken crosses.

III. RESEARCH METHODOLOGY

The studies were carried out at the Siberian Research Institute of Poultry (since 2017, the Siberian Research Institute of Poultry branch of the Omsk Agrarian Scientific Center) on hens of the G8 cross breeding herd of the Smena 7 cross breed (White Plymouth Rock breed) at the age of 160-238 days. 471 laying hens were put in control of productivity. Chickens were kept in KBN-1 cages converted for individual maintenance. All birds were individually evaluated for a preliminary production period before picking breeding nests in accordance with the methodological recommendations of the All-Russian Research and Technological Poultry Institute [18]. Puberty was determined by the age of the laying of the first egg. Daily egg quantity, weight (by weighing on the HL-100 with an accuracy of 0.01 g) and defects (by viewing on an ovoscope) were taken into account. At the same time, a large and small egg diameter was established with an electronic digital caliper 31C628 with an accuracy of 0.1 mm, and the shape index was calculated based on the obtained data. The whole set of egg defects was divided into four categories. The main defects are beaten eggs, cracked shell eggs and two-yolk eggs. Eggs with other defects due to their insignificant number were generalized into the category of "other defects" [19]. The live weight was established at the age of 28th day of life (the age of bird evaluation according to live weight and meat-like physique).

According to the results of the selection allotment, chickens are individually evaluated according to their reproductive qualities, as well as by categories of incubation waste. A total of 5858 eggs were incubated. Incubation and biological control were carried out in Stimul-4000 incubation cabinets in accordance with the recommended modes [20, 21].

Heritability coefficients are calculated by the method of hierarchical analysis of variance, the share of influence of one- and two-factor analysis of variance. In order to change the magnitude of the curvilinear connection, the correlation relation (η) was determined [22]. Statistical processing was performed using the SPSS 20.0 software package and Statistica 7.0.

IV. RESEARCH RESULTS AND DISCUSSION

The variability in live weight of 28-day-old chickens was at an average level. However, it should be noted that the range of variation was 390 g. Therefore, extreme variants with a live weight of 892 g and 1282 g were found in the population.

Hens of this line laid quite synchronously, as evidenced by the low coefficient of variation of puberty. Although it was revealed that 22.72% of hens started egg laying before 180 days of life, and 12.31% after 190 days of life. Hens with puberty on 204th day are noted. Late puberty does not allow getting enough offspring. Therefore, even with high live weight during the period of evaluation (28th day of life), it cannot affect the average population due to the limited number of offspring.

Egg weight is one of the key features, as it has a positive correlation with live weight of chickens. At 238th day of age, the egg weight was 60.4 g, which is satisfactory for hens of the Plymouth White breed. But the average weight for the entire study period (160-238 days of life) was lesser by 11.6%.

During the egg laying period up to 238th day of life, the majority of defective eggs were the two-yolk eggs, which is typical for the period when the hens started the egg laying. The

share of beaten and cracked shell eggs amounted to 1.10%. On the one hand, this testifies to the effectiveness of breeding by shell strength, which is one of the priority breeding traits of this line. On the other hand, it is physiologically determined, since the highest shell thickness is observed at this age.

Quantitative features of biological objects are highly variable. This is due to both the influence of external factors and the genetic characteristics of each individual in the population. Determining the degree of variability of the trait, its decomposition into genetic and paratypical components allows you to determine the method of selection. Since a sufficiently large number of breeding characters are used in the selection of broilers, a coefficient of variation expressing this value in percent (Cv) was used to compare the degree of their variability.

Egg laying was characterized by high variability. The variability of live weight of young animals and egg weight were comparable and were at an average level. It is interesting to note the fact that the variability of such an egg defect as beaten egg compared to the cracked shell egg was twice as high with almost the same number.

The variability of the proportion of two-yolk eggs is quite high. But it was noted that although the laying of two-yolk eggs was observed in 242 laying hens, which amounted to more than half of the hens of the entire line (51.38%). Of these, 45.65% of hens laid 1-3 two-yolk eggs, 4.03% laid 4-5 two-yolk eggs and 1.70% laid more than five of two-yolk eggs. This egg defect is characteristic for pullets. It is due to both prolonged selection for an increase in egg production, which led to the formation of a large number of follicles, and the fact that egg laying at this age is not yet synchronized.

Large and small egg diameters were characterized by low variability expressed both in percent (coefficient of variation) and in absolute terms ($\sigma_{bd}=2.59$; $\sigma_{md}=1.14$ mm). On the one hand, this creates certain difficulties for selection. On the other hand, the range of variability of the small and large diameter of the egg is 9 and 10 mm, and 64.12% and 75.16%, respectively, of the laying hens are outside the modal classes according to this pattern (Table 1).

TABLE I.   ZOOTECHNICAL INDICATORS OF BREEDING STOCK HENS STYLES

Indicator	*Value*	*Cv, %*
Live weight on 28th day, g	1034±3.51	7.36
Puberty, days	184±0.25	2.90
Egg production, pcs.	46.9±0.32	19.10
Average egg weight, g	54.1±0.14	5.70
Egg diameter, mm:		
large	54.6±0.07	4.74
small	41.7±0.05	2.73
Egg shape index, %	76.40±0.10	2.74
Egg flaws, %:		
beaten	0.50±0.06	6.70
cracked shell	0.60±0.06	3.00
other defects	2.76±0.20	3.34
two-yolk eggs	6.03±0.29	7.32

A positive and reliable correlation was found between both egg diameters of different asset and live weight at 28th day of age. The phenotypic correlation coefficient of the small egg diameter with live weight twice as large compared to the large egg diameter and was high. With an average egg weight, the correlation was reliable and equal in strength. A similar trend

was observed with respect to puberty, although the bond strength was half that.

It was found that both egg diameters have a low positive reliable correlation of equal strength with the proportion of two-yolk eggs. Also, the small diameter of the egg had a reliable correlation coefficient with cracked shells, but its value was extremely small. With such an egg defect as beaten eggs in both diameters, the correlation was extremely small and unreliable.

The egg shape index had almost equal correlation coefficients with egg diameters, but with different directions. With a large egg diameter, the correlation dependence was positive, with a small – negative.

The egg shape index was the least informative indicator. Its correlation with zootechnical indicators is extremely low and in most cases unreliable. The reliability of the correlation coefficients of the shape index is established in relation to the average egg weight and the proportion of two-yolk eggs. In the latter case, the bond strength was almost equal to that established for the small and large diameter of the eggs (Table 2).

TABLE II.   CORRELATION COEFFICIENT OF EGG DIAMETERS AND SHAPE INDEX WITH ZOOTECHNICAL INDICATORS (R)

Indicator	Large diameter	Small diameter	Egg shape index
Live weight on 28th day	0.306[a]	0.734[b]	0.142
Puberty	0.297[b]	0.284[b]	-0.014
Egg production	-0.211[b]	-0.216	0.004
Average egg weight	0.403[b]	0.409[b]	0.092[a]
Egg shape index	-0.480[b]	0.461[b]	-
Egg flaws:			
beaten	0.039	0.037	0.043
cracked shell	-0.030	0.094[a]	0.065
other defects	-0.012	0.014	-0.020
two-yolk eggs	0.137[b]	0.132[b]	0.174[b]

a. $P<0.05$

b. $P<0.01$

Since the correlation coefficients of the large and small egg diameters were low in some cases, it became necessary to study the possibility of the curvature of these bonds, for which the correlation ratios (η) were calculated. It is known that for the same sample in the presence of a curvilinear relationship, the correlation coefficient is always less than the correlation ratio. But the smaller their difference is, the closer the relationship to rectilinear.

Correlation coefficients revealed the presence of a significant relationship between large and small diameters with live weight at 28th day of age ($\eta_{bd}=0.553$ and $\eta_{md}=0.857$, respectively). Both values are higher than the correlation coefficient, which indicates the presence of a curvilinear relationship. However, it is worth noting that the difference between the correlation coefficient of the small egg diameter with live weight at 28th day of age and the correlation ratio of these signs is much smaller than for such a large diameter with live weight. As a result, it can be assumed that selection by a small egg diameter will more likely contribute to an increase in live weight at an early age than selection by a large diameter. These calculations were not performed to study the curvilinearity of the relationship between the egg shape index

and live weight due to the lack of reliability of the correlation coefficient between these characters.

The heritability coefficients (h^2_{sd}) of live weight, puberty, egg production, egg weight and shape index were within the limits inherent in these characters [23]. In terms of beaten and cracked shell egg, the inheritance rates for fathers are higher than for mothers. Maternal influence prevailed on the category of "two-yolk eggs".

The correlation coefficients calculated by the method of hierarchical analysis of variance allow us to state that the paternal and maternal effects on the sizes of both egg diameters are almost equal. However, the proportion of genotypic variability in the size of the small diameter, both in fathers and in mothers, is twice as large as in large diameter.

The low variability of the small egg diameter ($C_v=2.73\%$) combined with the average value of the heritability coefficient ($h^2_{sd}=0.48$) suggests the effectiveness of the family selection method for this trait, based on an assessment of the offspring' quality [24].

It was found that the coefficients of inheritance of the form index for fathers and mothers were lower compared to the coefficients of inheritance of the small egg diameter, but exceeded those of large diameter (Table 3).

TABLE III.   HERITAGE COEFFICIENTS

Indicator	h^2_s	h^2_d
Live weight on 28th day	0.31[a]	0.22[a]
Puberty	0.11[a]	0.03
Egg production	0.19[a]	0.15[a]
Average egg weight	0.15[a]	0.16[a]
Egg diameter:		
large	0.12[a]	0.10[a]
small	0.24[a]	0.22[a]
Egg shape index	0.19[a]	0.18[a]
Egg flaws:		
beaten	0.17[a]	0.09[a]
cracked shell	0.15[a]	0.07
other defects	0.06	0.04
two-yolk eggs	0.04	0.11[a]

a. $P<0.05$

It should be noted that most often eggs with an egg diameter smaller than that of the modal class are recorded in hens-sisters and hens-daughters obtained from mothers, who also lay eggs with a smaller egg diameter than the average. That is, such eggs are characteristic of the same chickens. Despite this, the complete rejection of such individuals does not provide the expected effect. Apparently, this can be achieved only by prolonged selection and by eliminating the influence of non-genetic factors.

Both egg diameters positively correlate with fertility and hatchability rate and hatchability of live chickens. It was noted that the correlation coefficients of the small diameter are almost twice as large as the correlation coefficients of the large diameter and the shape index.

The geometric dimensions of the egg are negatively correlated with mortality of the embryos. Although the correlation coefficients of small, large egg diameters and shape index with incubation waste vary in magnitude, the trend is the same in all three cases.

To a large extent, the large and small egg diameters and the shape index negatively correlate with the death of the embryos in the first incubation period (the first two days) – the

blood ring and death before end of 48 hours. It is interesting that during this period an intensive transition of water and part of the dissolved nutrients from egg white to yolk is observed, due to which the yolk becomes suitable for nurturing the embryo [25].

The correlation coefficients of the small egg diameter with the embryos mortality rate are much higher compared to the correlation coefficients of the large diameter and the shape index. Based on the degree of reliability of the correlation coefficients, it can be stated that the size of the small egg diameter affects the mortality of embryos to a greater extent during eggs incubation (Table 4).

TABLE IV.   CORRELATION COEFFICIENT OF EGG DIAMETERS AND SHAPE INDEX WITH REPRODUCTIVE INDICATORS (R)

Indicator	Large diameter	Small diameter	Egg shape index
Egg fertilization	0.081	0.089	0.058
Hatchability rate	0.133 [a]	0.270 [b]	0.112 [a]
Hatchability of live chicken	0.127 [a]	0.273 [b]	0.127 [a]
Incubation waste:			
blood ring	-0.105 [a]	-0.266 [b]	-0.133 [a]
dead before end of 48 hours	-0.092 [a]	-0.160 [b]	-0.056
dormant embryos	-0.067	-0.099 [a]	-0.033
dead-in-shell	-0.059	-0.160 [b]	-0.078
weaklings	-0.064	-0.089 [a]	-0.015

a. $P<0.05$

b. $P<0.01$

V. CONCLUSION

As a result of the study, a high positive correlation was established between the small diameter of an egg and live weight at 28th day of age. The coefficient of inheritance of the small diameter of an egg with its low variability allows the family selection method. It was found that the small diameter of an egg has a negative and reliable correlation with embryos mortality. Therefore, the chicken selection by small diameter of eggs at the stage of preliminary assessment of productivity can be another way to increase the live weight of offspring and increase reproductive qualities.

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