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COMPARISON OF THE BLOOD PARAMETERS WITH THE CHEMICAL COMPOSITION OF THE MUSCLE TISSUE OF MEAT-AND-EGG CHICKEN

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Abstract
Basic blood and muscle tissue parameters have been analyzed in crossbred male Russian White and Cornish hens (♂, RW x CORN, n = 95, slaughtered at 63 days of age). According to BW at slaughter, males (n = 95) were divided into 3 groups (group 1–1,000–1,799 g, n = 31; group 2–1,800–2,099 g, n = 28; group 3–2,100–2,650 g, n = 36). It has been found that with an increase in the live weight at slaughter, the ratio of albumin to globulin (p = 0.038), aspartate aminotransferase (p = 0.003) increased in the serum of birds; the levels of globulins (p = 0.05), glucose (p = 0.02), Ca (p = 0.006), Mg (p = 0.05) decreased. With increasing BW, the crude protein content in thigh muscle decreased (p = 0.019) against a trend towards increasing moisture content in thigh meat (p = 0.058). Comparative assessment of biochemical blood parameters of nitrogen, carbohydrate-lipid, mineral metabolism, antioxidant protection parameters, some clinical blood parameters (hematocrit, erythrocytes and hemoglobin) and chemical composition of the breast and thigh muscle tissue has been carried out. The analysis (Pearson correlation coefficients) has revealed patterns between the concentration of some blood metabolites and the composition of muscle tissue in males. Thus, the accumulation and analysis of data on resource genetic populations is of interest for science and practice in order to establish relationships between blood parameters and the quality of chicken products, as well as to identify biomarkers for predicting poultry productivity in vivo.

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Introduction

Poultry is one of the actively developing branches of animal husbandry. It is quite capable of providing the population with high-quality meat associated with high growth energy and the bird's ability to reproduce quickly [1].

The study of the biochemical status of the bird's body is in great demand for assessing the state of health [2]. The authors have been studying the biochemical parameters of blood in birds of domestic breeds [3] and modern poultry crosses [4].

The high-quality food products are the basis for public health. The need of modern society poses the problem of deepening knowledge in the field of lifetime formation and improving the quality of poultry products. An urgent scientific problem is the fundamental study of the factors, contributed to the formation of the quality of poultry products by the integrated approach, including the complex of molecular genetic, biochemical, microbiological, hormonal mechanisms of homeostasis in the body of poultry [5].

The study of biochemical parameters of blood and their relationship with the antioxidant status and the composition of the poultry products is the most relevant with the advent of new bird genotypes. The modern market requirements determine the advantage of breeds and lines with good viability, high growth rate, good egg and meat qualities [6]. Crossbreeding of different chicken breeds can be a good strategy for the development of poultry farming and improvement of the poultry product quality. It can be useful for studying the biochemical and genetic aspects of product formation and obtaining new biomarkers of the health status and poultry product quality. The local poultry breeds of the meat productivity are promising for crossbreeding. Of particular interest is the assessment of the influence of the effect of heterosis on the biological characteristics of the offspring and the physiological and biochemical aspects of the formation of poultry health and poultry product quality.

An increase in the productive qualities of offspring and improvement in the intensity of live weight gain are among the main tasks of crossing different breeds of poultry. It is also important to obtain high-quality meat rich in biogenic nutrients for a high level of human nutrition. The study of the relationship between blood biochemical parameters and the meat chemical composition in accordance with the intensity of poultry growth is relevant. There are few data in the literature characterizing the correlation between biochemical indicators (including indicators of the antioxidant defense) and the poultry meat composition in accordance with the live weight and other growth indicators.

The influence of biochemical and molecular genetic factors on the poultry meat quality requires further study. The accumulation and analysis of correlations between blood biochemical and genetic parameters and the quality of animal products to identify biomarkers for predicting animals and poultry productivity of various genotypes is very interesting for science and practice.

The purpose of this study was to determine the biochemical and hematological parameters in roosters when crossing the Russian White and Cornish chicken breeds (RW x CORN) and to compare the parameters with the muscle tissue chemical composition.

Objects and methods

Animals

The experiment used meat-and-egg poultry (♂, RW × CORN) at the age of 63 days (n = 95). The birds were kept under the same conditions of feeding and keeping. Roosters (n = 95) were divided into groups according to BW at slaughter (age at slaughter was the same and was 9 weeks or 63 days): 1) 1,000–1,800 g, 2) 1,800–2,100 g, 3) 2,100–2,650 g.

The research was conducted in accordance with the requirements of the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (ETS No. 123, Strasbourg, 1986). The research was approved by the bioethical commission of the L. K. Ernst Federal Research Center for Animal Husbandry (protocol № 3, dated May 27, 2022).

The basis of the diet was industrial feed for young chickens, balanced in terms of nutrients and energy in accordance with modern requirements and the recommended feeding regimen [7]. The composition of feed was as follows: corn 48.0%, wheat 21%, soybean meal 13.0%, sunflower meal 12.0%, fish flour 1.0%, raw materials of animal origin, fish meal, vegetable oil, limestone meal, phosphates, salt, vitamins (including vitamin E analogue), minerals, amino acids, enzymes and other ingredients. The birds had constant access to water.

Analysis of biochemical and hematological variables

Blood collection was carried out when birds were slaughtered at 63 days of age. Two blood samples were transferred to Vacutainer tubes. The first blood sample was collected into 8 ml VACUETTE® serum tube with blood clotting activator (Greiner Bio-One, Austria) and centrifuged within 4 h of collection at 5,000 g for 5 min. The second blood sample was collected in a VACUETTE® tube (Greiner Bio-One, Austria) containing EDTA as the anticoagulant and used for hematological analysis.

Samples were sent to the laboratory (the Department of Physiology and Biochemistry of Farm Animals at the Federal Research Center for Animal Husbandry named after Academy Member L. K. Ernst) and analyzed on an automatic biochemical analyzer ChemWell (Awareness Technology, USA) using reagents from Analyticon Biotechnologies AG (Germany), Spinreact (Spain) and Deacon (Russia).

Methods used were as follows: protein total (TP) — by the biuret method (9104), albumin (ALB) — by the colorimetric method (9136), globulins (GLB) — by calculation, albumin to globulin ratio (ALB / GLB) — by calculation, creatinine (CREA)- by the Jaffe kinetic method (448), alanine aminotransferase (ALT) — by the UV kinetic (1187), aspartate aminotransferase (AST) — by the UV kinetic (1177), alkaline phosphatase (ALP) — by the UV kinetic (1625), glucose (GLU) — by the enzymatic-glucose oxidase (4341), triglycerides (TRIG) — by the enzymatic-colorimetric method (41031), total bilirubin (TBIL) — by the Walters and Gerarde method (804), cholesterol (CHOL) — by the enzymatic-colorimetric method (41021), chlorides (CL) — by the colorimetric method (1001360); calcium (Ca) — by the O-cresolphthalein complexone method (10100), phosphorus (P) — by the colorimetric method (1914), magnesium (Mg) — by the colorimetric method (1001280), iron (I) — by the colorimetric method (1001247). For hematology, hemoglobin (HGB) (spectrophotometric method), hematocrit (HCT), red blood cell (RBC) count were determined, using ABC VET (HORIBA ABX Diagnostics Inc) (France).

Lipid peroxidation assay

The lipid peroxidation level in serum samples was measured by the standard method (reaction with the thiobarbituric acid) by kits "Agat-Med" (Russia). The values of the thiobarbituric acid active products (TBA-AP) were expressed. The activity of ceruloplasmin (CP) was measured by the method of Revin [8].

The total amount of water-soluble antioxidants (TAWSA) was measured by the amperometric method using the device "TsvetYauza-01-AA" ("Khimavtomatika", Russia). The TAWSA values were determined by measuring the strength of the electric current arising during the oxidation of molecules on the surface of the working electrode at a potential of ~500 mV. TAWSA was measured in equivalent to gallic acid as in [9]. For this, the "working solutions" were prepared from a gallic acid solution (100 mg/dm^3) for calibration with a mass concentration of 0.2, 0.5, 1.0 and 4.0 mg/dm^3. An amount of 2.2 mmol/dm^3 of the phosphoric acid solution was used as an "eluent". The results of measuring the total antioxidant activity of the samples were statistically processed using the MS Excel program.

The TBK-AP/ CP ratio was calculated by the authors.

Analysis of the chemical composition of meat

Meat samples were analyzed for dry matter (GOST 33319–2015[1]), crude fat (GOST 23042–2015[2]) and ash (ISO 936:1998[3]). Crude protein was calculated.

[1] GOST 33319–2015 "Meat and meat products. Method for determination of moisture content" Moscow: Standartinform, 2019. Retrieved from https://internet-law.ru/gosts/gost/60635/ Accessed December 15, 2022. (In Russian)

[2] GOST 23042–2015 "Meat and meat products. Methods of fat determination" Moscow: Standartinform, 2019. Retrieved from https://docs.cntd.ru/document/1200133107 Accessed December 15, 2022. (In Russian)

[3] ISO 936:1998 "Meat and meat products — Determination of total ash" Technical Committee: ISO/TC34/SC6 Meat, poultry, fish, eggs and their products, 1998. Retrieved from https://www.iso.org/standard/24783.html Accessed December 15, 2022.

Statistical analyses

Descriptive statistics (mean, median, SD, minimum and maximum values) were used with the software packages "Microsoft Office Excel 2003".

An ANOVA was carried out for indicators of blood and meat, taking into account the group of experimental poultry in terms of live weight (program Statistica 13RU, StatSoft, USA).

The Pearson correlation test to determine a relationship between the obtained biochemical parameters and chemical composition of meat was used. All the data were analyzed by using the software packages "Statistica" (Statistica 13RU, StatSoft, USA). The results of the statistical analysis were considered significant at $p < 0.05$.

The significance of the coefficient was determined by t-test, the closeness of connection on the Chaddock scale (0.3 or less — weak connection, 0.4–0.7 — medium, 0.7–0.9 — high connection, 0.9–1 — extremely high).

The calculation of the coefficient of variation (*CV*) was carried out according to the formula:

$$CV = (SD / \text{Median}) \times 100,$$

where *SD* is the standard deviation of the value; *M* — is the median value.

It was believed that when the value of the *CV* was less than 10%, then the spread of data values was insignificant; if from 10% to 20% — medium; greater than 20% and less than or equal to 33% — significant.

Results and discussion

Evaluation of an array of blood and meat indicators in roosters

Obtaining poultry with the highest performance indicators involves crossing poultry of different lines and breeds. This leads to the effect of heterosis with an increase in the scatter of genetic indicators and phenotypic manifestations. This affects blood parameters. It was noted that in CORN × RW poultry hybrids the studied biochemical blood parameters had a significant variation in values (Table 1).

Table 1. Metabolic indicators in roosters (CORN × RW)

Parameter	N	Mean	SEM	SD	Median	Min	Max
TP (g/L)	95	35.13	0.41	4.01	34.70	26.30	47.0
ALB (g/L)	95	13.07	0.36	1.09	13.00	10.30	16.40
GLB (g/L)	95	22.06	0.51	3.47	21.60	14.30	33.30
ALB / GLB	95	0.60	0.008	0.08	0.61	0.41	0.84
TBIL (μmol/L)	95	0.74	0.03	0.30	0.69	0.27	1.74
GLU (mmol/L)	95	14.86	0.16	1.59	14.90	11.27	19.74
CHOL (mmol/L)	95	3.45	0.04	0.76	3.40	2.17	9.98
Ca (mmol/L)	95	2.79	0.03	0.26	2.85	2.11	3.34
P (mmol/L)	95	2.02	0.03	0.35	2.04	0.07	2.89
Ca/P	95	1.75	0.37	3.59	1.38	0.90	36.28
Mg (mmol/L)	95	0.96	0.02	0.15	0.93	0.66	1.51
I (mmol/L)	95	20.41	0.39	3.79	19.90	13.25	32.23
CL (mmol/L)	95	112.95	0.42	4.16	112.50	102.67	122.70
ALT (IU /L)	95	7.35	0.20	2.04	7.10	2.70	13.80
AST (IU /L)	95	220.66	3.82	37.26	214.50	146.80	415.50
AST / ALT	95	31.97	0.97	9.50	30.10	13.27	77.85
ALP (IU /L)	95	1002.86	33.35	325.04	926.00	452.00	2359.00
CREA (mmol/L)	95	31.51	0.51	5.01	31.48	22.25	62.53
TRIG (mmol/L)	95	0.40	0.02	0.20	0.33	0.13	0.96

TRIG, TBIL, ALP, ALT, CHOL had the highest scatter (SD to mean ratio), I, P, AST, CREA, GLB, Mg, TP, GLU had the middle scatter, Ca, ALB, CL had the minimum scatter. The hematologic indices we studied (RBC, HCT, HGB) had average spread values (Table 2).

Table 2. Hematological parameters in roosters (CORN × RW)

Parameter	N	Mean	SEM	SD	Median	Min	Max
RBC (10^{12}/L)	95	3.28	0.06	0.66	3.49	1.50	4.45
HCT (%)	95	46.67	0.99	9.66	48.09	21.19	62.32
HGB (g/L)	95	108.54	1.54	15.01	110.00	9.82	136.00

Lipid peroxidation and antioxidant protection (Table 3) indices had a high scatter of values. With the high scatter of individual blood biochemical parameters (TRIG, TBIL, ALP, ALT, CHOL), it may indicate a high impact of crossbreeding on the stress parameters of hybrid roosters.

Table 3. Lipid peroxidation and antioxidant protection in roosters (CORN × RW)

Parameter	N	Mean	SEM	SD	Median	Min	Max
TBA-AP (μmol/L)	95	2.65	0.07	0.66	2.67	1.33	5.23
CP (mg/L)	95	40.72	1.05	10.31	39.00	23.00	78.00
TAWSA (mg/L)	95	39.80	0.87	9.54	39.34	22.80	69.14
TBA-AP/CP	95	0.07	0.002	0.02	0.07	0.02	0.12

The study of the parameters of the chemical composition showed little variability in dry matter, crude protein and total ash both in thigh meat and breast meat. There was a high scatter of ether extract values (Table 4). The meat chemical composition had less heterogeneity. It allows us to characterize a more stable fixation of these traits.

Table 4. Chemical composition of roosters' (CORN × RW) meat,%

Parameter	N	Mean	SEM	SD	Median	Min	Max
Thigh meat							
Dry matter	95	25.93	0.08	0.77	25.86	24.46	28.46
Crude protein	95	21.45	0.07	0.72	21.43	19.21	23.23
Crude fat	95	3.40	0.09	0.90	3.20	1.53	6.22
Total ash	95	1.10	0.005	0.05	1.10	0.91	1.23
Breast meat							
Dry matter	95	26.12	0.08	0.86	26.21	23.93	28.11
Crude fat	95	24.02	0.08	0.81	24.01	21.98	26.28
Ether extract	95	1.01	0.03	0.27	0.95	0.49	2.23
Total ash	95	1.18	0.008	0.08	1.17	1.01	1.51

Correlation of the blood parameters and chemical composition of meat

Pearson correlation coefficients (r) were calculated for the complex of studied blood and meat indicators. Table 5 shows correlations between the indicators in blood and meat of chickens (CORN × RW). High positive correlations between protein, carbohydrate, fat, mineral indicators of metabolism were established indicating a high degree of interconnection (Table 5) and were characterized by commonly known principles. A close positive correlation was established between TP and protein fractions (extremely

Table 5. Correlations of the studied blood and meat parameters (n = 95)

Parameter	TP	ALB	GLB	ALB / GLB	CREA	GLU	TBIL	TRIG	CHOL	ALT	AST	AST / ALT	ALP	Ca	P	Ca / P	Mg	I	CL	RBC	HGB	HCT	TAWSA	CP	TBA-AP	TBA/CP	Moisture of breast meat	Dry matter of breast meat	Crude protein of breast meat	Crude fat of breast meat	Ash of breast meat	Moisture of thigh meat	Dry matter of thigh meat	Crude protein of thigh meat	Crude fat of thigh meat	Ash of thigh meat
TP	1.00																																		
ALB	0.57	1.00																																	
GLB	0.96	0.32	1.00																																
ALB / GLB	–0.62	0.27	–0.81	1.00																															
CREA	0.06	0.12	0.03	0.06	1.00																														
GLU	0.20	0.27	0.14	–0.04	0.06	1.00																													
TBIL	0.14	0.15	0.11	0.02	–0.05	0.08	1.00																												
TRIG	0.21	0.09	0.21	–0.18	–0.39	0.30	0.32	1.00																											
CHOL	0.33	0.34	0.26	–0.06	0.29	0.20	0.11	0.25	1.00																										
ALT	0.05	0.23	–0.02	0.17	0.18	–0.01	0.20	0.05	0.04	1.00																									
AST	0.00	0.14	–0.05	0.15	0.25	–0.14	0.03	–0.04	0.13	0.28	1.00																								
AST/ALT	–0.03	–0.09	–0.01	–0.07	–0.01	0.02	0.23	–0.09	0.06	–0.75	0.28	1.00																							
ALP	0.11	–0.32	0.24	–0.47	–0.27	0.23	0.06	0.31	–0.07	–0.19	–0.27	–0.03	1.00																						
Ca	0.31	0.18	0.30	–0.17	0.13	0.16	0.21	–0.01	0.05	–0.12	–0.26	–0.04	0.13	1.00																					
P	0.14	0.32	0.06	0.15	0.58	0.11	0.02	–0.25	0.22	0.29	0.14	–0.15	–0.29	0.15	1.00																				
Ca / P	0.07	–0.23	0.16	–0.31	–0.44	0.03	0.13	0.23	–0.19	–0.32	–0.32	0.07	0.40	0.48	–0.78	1.00																			
Mg	0.30	0.15	0.30	–0.21	0.25	0.29	0.16	0.43	–0.19	0.15	–0.13	–0.20	0.27	0.09	0.06	0.05	1.00																		
I	0.03	0.09	0.00	0.07	–0.20	–0.07	0.22	0.25	–0.25	0.16	–0.13	–0.23	0.05	0.00	0.03	0.01	0.14	1.00																	
CL	0.03	0.13	–0.01	0.09	–0.35	0.21	0.31	0.37	–0.31	0.12	–0.21	–0.24	0.16	0.25	–0.04	0.21	0.34	0.42	1.00																
RBC	–0.07	–0.23	0.00	–0.10	0.41	–0.05	–0.11	–0.31	0.10	0.06	–0.08	–0.08	–0.08	–0.02	0.32	–0.26	–0.22	–0.14	–0.33	1.00															
HGB	0.26	0.13	0.26	–0.21	0.17	0.28	–0.07	0.09	0.11	0.03	–0.02	–0.01	0.07	0.02	0.15	–0.13	–0.02	–0.05	–0.11	0.27	1.00														
HCT	–0.07	–0.23	0.00	–0.10	0.40	–0.06	–0.08	–0.30	0.06	0.08	–0.09	–0.09	–0.07	0.01	0.30	–0.23	–0.19	–0.15	–0.34	0.99	0.28	1.00													
TAWSA	0.14	0.03	0.16	–0.17	0.03	0.23	0.13	0.14	0.00	0.16	0.07	–0.15	0.33	–0.24	–0.03	–0.08	0.22	0.12	–0.02	–0.26	0.09	–0.26	1.00												
CP	0.45	0.13	0.47	–0.40	0.01	0.25	0.16	0.45	–0.08	–0.07	–0.02	0.08	0.11	0.09	–0.01	–0.34	0.33	0.12	0.16	–0.15	0.15	–0.14	0.19	1.00											
TBA-AP	0.11	0.12	0.09	–0.01	0.32	0.14	–0.16	–0.34	0.31	0.12	0.04	–0.06	–0.07	0.09	0.43	0.08	0.13	–0.36	–0.23	0.37	0.23	0.38	–0.09	0.10	1.00										
TBA / CP	–0.23	0.02	–0.27	0.31	0.25	–0.10	–0.17	–0.57	0.32	0.15	0.08	–0.11	–0.20	0.06	0.34	–0.34	–0.19	–0.37	–0.29	0.35	0.07	0.36	–0.25	–0.69	0.60	1.00									
Moisture of breast meat	0.01	–0.23	0.09	–0.25	0.01	0.29	0.17	0.15	0.03	0.18	–0.01	–0.24	0.29	–0.03	0.04	–0.28	0.16	0.07	0.09	0.03	–0.12	–0.01	0.30	0.05	–0.11	–0.15	1.00								
Dry matter of breast meat	–0.01	0.23	–0.09	0.25	–0.01	–0.29	–0.17	–0.15	–0.03	–0.18	0.01	0.24	–0.29	0.03	–0.04	0.05	–0.16	–0.07	–0.09	–0.03	0.12	0.01	–0.30	–0.05	0.11	0.15	–1.0	1.00							
Crude protein of breast meat	0.01	0.25	–0.07	0.23	0.00	–0.26	–0.21	–0.15	0.00	–0.17	0.02	0.28	–0.29	–0.11	0.00	–0.16	–0.13	–0.01	–0.14	–0.04	0.15	–0.01	–0.22	–0.05	0.11	0.13	–0.94	0.94	1.00						
Crude fat of breast meat	–0.04	0.00	–0.05	0.09	–0.02	–0.08	0.07	–0.05	–0.08	–0.08	–0.06	–0.04	–0.03	0.38	–0.13	0.33	–0.11	–0.20	0.09	0.03	–0.04	0.05	–0.24	–0.02	0.05	0.07	–0.26	0.26	–0.09	1.00					
Ash of breast meat	–0.08	–0.01	–0.08	0.12	0.02	–0.35	0.07	0.02	–0.09	0.05	0.06	–0.07	–0.14	0.10	0.02	–0.01	–0.02	0.08	0.14	0.00	–0.04	0.05	–0.19	0.02	–0.01	0.03	–0.54	0.54	0.43	0.17	1.00				
Moisture of thigh meat	0.05	–0.03	0.06	–0.07	–0.50	–0.01	0.08	0.29	–0.07	0.00	0.08	0.01	0.17	–0.18	–0.37	0.25	0.12	0.06	0.07	–0.22	–0.11	–0.22	0.16	–0.01	–0.30	–0.23	0.41	–0.41	–0.35	–0.22	–0.22	1.00			
Dry matter of thigh meat	–0.05	0.03	–0.06	0.07	0.50	0.01	–0.08	–0.29	0.07	0.00	–0.08	–0.01	–0.17	0.18	0.37	–0.25	–0.12	–0.06	–0.07	0.22	0.11	0.22	–0.16	0.01	0.30	0.23	–0.41	0.41	0.35	0.22	0.22	–1	1.00		
Crude protein of thigh meat	–0.06	–0.14	–0.02	–0.06	0.10	–0.02	–0.13	–0.04	–0.06	0.05	–0.02	0.04	–0.07	–0.13	0.01	–0.08	–0.05	0.05	0.06	0.32	0.12	0.33	–0.16	0.24	0.12	–0.12	–0.18	0.18	0.22	–0.12	0.17	–0.26	0.26	1.00	
Crude fat of thigh meat	–0.02	0.12	–0.06	0.13	0.39	–0.02	0.01	–0.22	0.08	0.05	0.09	–0.05	–0.11	0.22	0.33	–0.19	–0.09	–0.09	–0.13	–0.04	0.00	–0.04	–0.01	–0.19	0.17	0.30	–0.23	0.23	0.14	0.29	0.07	–0.69	0.69	–0.47	1.00
Ash of thigh meat	–0.03	–0.02	–0.02	–0.03	–0.20	0.15	–0.14	–0.03	0.11	–0.13	–0.12	0.06	0.16	0.03	–0.09	0.08	–0.07	–0.12	0.02	–0.10	0.13	–0.09	0.10	–0.08	–0.05	–0.01	–0.06	0.06	0.05	0.00	0.13	–0.07	0.07	0.07	–0.03	1.00

Red color indicates statistically significant values at $p < 0.05$; green color indicates positive (high and average) relations of the indicators, blue color indicates negative (high and average) relations of the indicators.

high between TP and GLB (r = 0.96), medium between TP and ALB (r = 0.57), weak correlation — between ALB and GLB (r = 0.32). The average correlation was established between the protein metabolism indicators with CHOL, the blood content of macro- and microelements (Ca, Ca/P, Mg, I) and between them. There was a negative average relationship between ALP and ALB (r = –0.42). The existing positive relationship (r = 0.99) between RBC and HCT was confirmed. Stress indicators had negative mean relationships with biochemical indices: CP and A/G (r = –0.40). TBA/CP and TRIG (r = –0.57). TBA-AP was positively correlated with blood CREA (r = 0.32). There were positive correlations between TBA-AP and TBA/CP with CHOL (r = 0.31 and r = 0.32, respectively). Stress and antioxidant protection indicators point to a negative effect on protein metabolism, accumulation of lipid peroxidation products during intensive growth of poultry. Correlations between the meat chemical composition and blood biochemical parameters were not as pronounced. The average correlation (r = 0.50) was established between dry matter of thigh meat and CREA. Crude protein (r = 0.94) and ash (r = 0.41) increased with increasing dry matter content of breast meat. Dry matter content of thigh meat had a high positive correlation with crude fat (r = 0.69).

Blood parameters and chemical composition of meat depending on the weight of poultry at slaughter

Crude protein of thigh muscle decreased with increasing slaughter weight (p = 0.019) against the backdrop of a trend towards increasing moisture content in thigh meat (p = 0.058) (Table 6, Figure 2).

Table 6. Metabolic and hematological indicators, meat chemical composition of roosters (CORN × RW)

Parameter	Group (by BW)						*p* -value
	1,000–1,799 g		1,800–2,099 g		2,100–2,650 g		
	n = 31		*n* = 28		*n* = 36		
	M	m	M	m	M	m	
TP (g/L)	36.28	0.85	34.29	0.63	34.79	0.65	0.136
ALB (g/L)	13.01	0.26	13.06	0.19	13.14	0.14	0.89
GLB (g/L)	23.27	0.74	21.23	0.48	21.66	0.57	0.052
ALB / GLB	0.57	0.02	0.62	0.01	0.62	0.01	0.038
CREA (μmol/ L)	30.95	0.65	32.95	1.43	30.87	0.57	0.196
GlU (mmol/L)	15.51	0.27	14.44	0.26	14.62	0.29	0.018
TBIL (μmol/ L)	0.78	0.06	0.70	0.05	0.74	0.05	0.574
TRIG (mmol/L)	0.45	0.05	0.34	0.03	0.38	0.03	0.092
CHOL (mmol/L)	3.45	0.09	3.47	0.07	3.44	0.06	0.958
ALT (IU /L)	6.96	0.41	7.49	0.37	7.58	0.33	0.435
AST (IU /L)	202.44	5.27	228.98	7.08	229.89	6.62	0.003
AST/ALT	31.93	2.16	32.33	1.79	31.73	1.26	0.969
ALP (IU /L)	1091.13	92.01	943.39	30.86	973.11	31.90	0.172
Ca (mmol/L)	2.90	0.04	2.77	0.05	2.70	0.04	0.006
P (mmol/L)	2.10	0.06	2.04	0.09	1.96	0.04	0.282
Ca / P	1.42	0.05	2.58	1.27	1.39	0.03	0.351
Mg (mmol/L)	1.01	0.03	0.93	0.03	0.94	0.02	0.051
I (mmol/L)	20.14	0.55	20.80	0.86	20.34	0.66	0.793
CL (mmol/L)	113.85	0.89	111.58	0.73	113.24	0.60	0.096
RBC (10^{12}/L)	3.43	0.12	3.29	0.11	3.16	0.12	0.262
HGB (g/L)	108.95	2.93	108.68	1.36	108.09	3.15	0.972
HCT (%)	48.05	1.72	45.40	1.61	43.83	1.79	0.202
TAWSA (mg/L)	38.58	1.87	38.99	1.98	41.48	1.50	0.421
CP (mg/L)	43.23	2.15	38.32	1.79	40.42	1.60	0.186
TBA-AP(μmol/L)	2.76	0.15	2.65	0.10	2.57	0.11	0.521
TBA / CP	0.07	0.00	0.07	0.00	0.07	0.00	0.445
Moisture of breast meat (%)	73.89	0.18	73.83	0.14	73.67	0.15	0.556
Dry matter of breast meat (%)	26.11	0.18	26.17	0.14	26.33	0.15	0.556
Crude protein of breast meat (%)	23.89	0.18	24.06	0.13	24.11	0.13	0.527
Crude fat of breast meat (%)	1.06	0.05	0.94	0.05	1.02	0.05	0.259
Ash of breast meat (%)	1.17	0.01	1.17	0.02	1.20	0.01	0.102
Moisture of thigh meat (%)	73.80	0.16	74.14	0.13	74.24	0.12	0.058
Dry matter of thigh meat (%)	26.20	0.16	25.87	0.13	25.76	0.12	0.058
Crude protein of thigh meat (%)	21.73	0.13	21.23	0.14	21.39	0.11	0.019
Crude fat of thigh meat (%)	3.36	0.20	3.54	0.16	3.32	0.13	0.608
Ash of thigh meat (%)	1.10	0.01	1.10	0.01	1.11	0.01	0.730

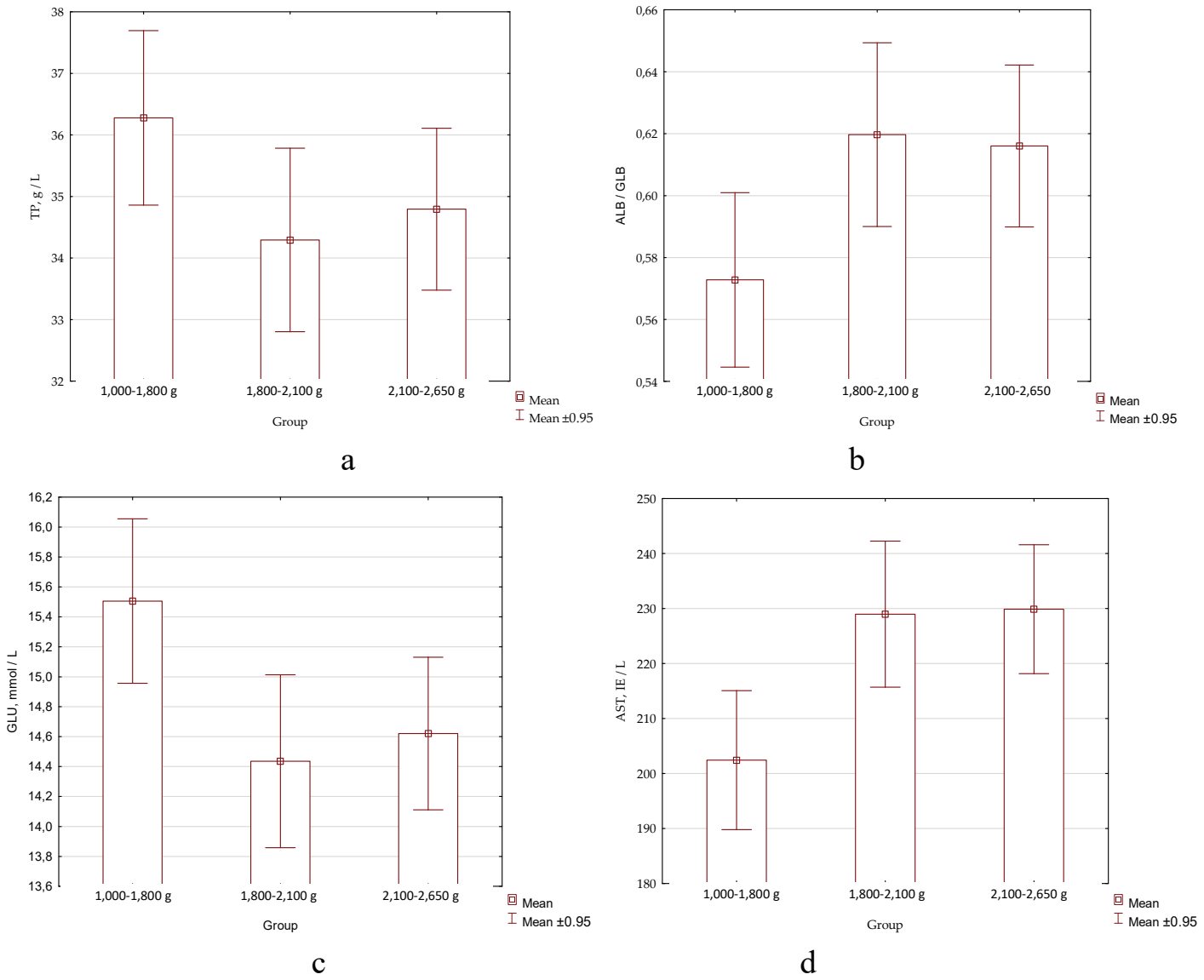

Figure 1. Relationship of indicators and their comparison among poultry groups with different weights (a — GLB, p = 0.052; b — A/G, p = 0.038; c — GLU, p = 0.017; d — AST, p = 0.003). Standard errors of the mean are calculated using the pooled ANOVA variance

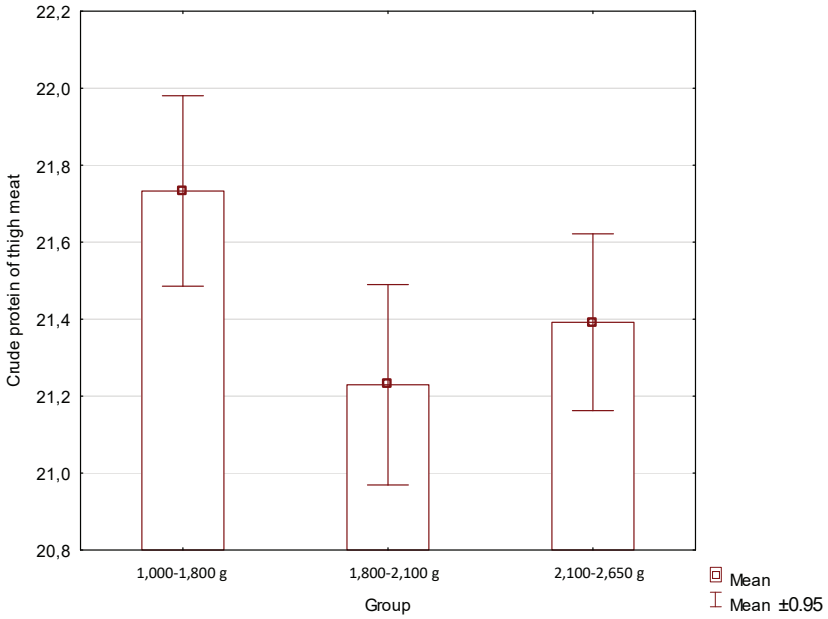

Figure 2. Crude protein of thigh meat in roosters as a function of weight. Standard errors of the mean are calculated using the pooled ANOVA variance

Comparative assessment of blood parameters and chemical composition of meat depending on the weight of poultry at slaughter

Table 7. Correlations of weight with blood parameters and meat chemical composition

Parameter	Group (by BW)		
	1,000–1,800 g	1,800–2,100 g	2,100–2,650 g
	n = 31	n = 28	n = 36
ADG	1.000	0.998	1.000
TP	–0.115	0.144	0.115
ALB	0.421	0.110	–0.146
GLB	–0.278	0.144	0.167
ALB / GLB	0.471	–0.113	–0.217
CREA	0.324	–0.124	–0.088
GlU	–0.037	–0.333	–0.077
TBIL	–0.212	0.048	–0.091
TRIG	–0.194	–0.080	0.174
CHOL	0.154	0.165	–0.241
ALT	–0.075	–0.178	0.020
AST	0.302	0.208	0.392
AST/ALT	0.225	0.179	0.258
ALP	–0.460	–0.166	0.052
Ca	–0.251	0.246	–0.208
P	0.498	–0.004	0.112
Ca / P	–0.662	–0.092	–0.300
Mg	–0.292	–0.238	–0.007
I	–0.205	–0.096	0.197
CL	–0.345	0.061	–0.032
RBC	–0.161	–0.308	0.128
HGB	0.121	–0.039	–0.095
HCT	–0.178	–0.288	0.134
TAWSA	–0.153	–0.205	–0.029
CP	–0.060	0.159	0.023
TBA-AP	0.246	0.026	–0.204
TBA / CP	0.337	–0.096	–0.139
Moisture of breast meat	–0.632	–0.069	0.191
Dry matter of breast meat	0.632	0.069	–0.191
Crude protein of breast meat	0.676	–0.060	–0.167
Crude fat of breast meat	–0.236	0.332	–0.165
Ash of breast meat	0.185	0.102	0.098
Moisture of thigh meat	–0.586	0.118	0.135
Dry matter of thigh meat	0.586	–0.118	–0.135
Crude protein of thigh meat	–0.160	–0.042	0.090
Crude fat of thigh meat	0.575	–0.078	–0.034
Ash of thigh meat	–0.086	0.300	–0.221

Red color indicates statistically significant values at $p < 0.05$

The main changes concerned the differences in protein metabolism (Figure 3–5) in low-weight (1,000–1,800 g) roosters. They were associated with different responses of birds to environmental conditions (feeding, stress, etc.).

Serum TP decreased with increasing ADG in the 1,000–1,799 g group (Figure 3), due to a GLB fraction decrease ($p = 0.052$, Table 6, Figure 5). It is shown by the ALB / GLB ratio too ($p = 0.038$, Table 6). The protein metabolism pattern is significantly different in the 2,100–2,650 g group (Figure 3–5). At almost the same serum TP level, there was a GLB fraction increase.

Cross-breeding is important for the development of new breeds and for the production of commercial poultry superior in performance and viability to purebred parental forms. The study of metabolic parameters in relation to meat quality carried out in this work is important to form approaches to obtaining poultry with improved/maintained quality parameters of the parent breeds and to understand the biochemical processes that determine the possible use of feed and production of a given quality.

Maintaining genetic diversity in farm animal and poultry populations has not lost its relevance in recent years [10]. To obtain the effect of heterosis in crossbreeding, birds with genetically determined traits of high productivity are used for the desirable combination and consolidation in the offspring. This is achieved if breeds, lines and individual animals tested for good compatibility with each other are used in crossbreeding. Our studies have allowed us to establish values of blood biochemical parameters in the body of hens when crossing birds of Russian white breed and Cornish. The Russian White breed belongs to the egg production direction; it was bred in the USSR by crossing White Leghorn cocks with local "outbred" hens [11]. The birds of this breed are characterized by high safety (91–96%), well developed and feathered wings, broad chest and back. The live weight of hens is about 1.8 kg, ales 2.3 kg [12]. The Cornish breed is a meat-producing bird based on the Malay and English fighting hens with a red Aseel hen. The bird is short in stature, with a strong and well-proportioned body in front, a large breast and a long back. The meat of the Cornish is tender and tasty, the weight of an adult hen reaches 2.75–3.25 kg, a rooster 3.75–4.5 kg.

The high coefficients of variability in biochemical indices established in our work indicate the cleavage of traits during crossing. Against the background of the heterosis effect, the distribution of phenotypic manifestations increases. There is a need for markers to trace and consolidate the desired effect in productivity, in particular metabolic indicators in the body.

Previously obtained data from biochemical studies have significant differences. This is due to different genetic, feed conditions and environmental factors. Thus, Kaiser J. C. et al. established reference values of biochemical parameters in domestic chickens of different breeds [2]. The results obtained in poultry at different breed combinations and at different age and physiological periods should be further studied, as direct comparison with available data is often incorrect.

Biochemical blood values reflect metabolic processes and depend on many factors, including housing conditions [13]. For example, in a study of biochemical processes in the body of yellow Wannan chickens, it was found that higher levels of CHOL and TRIG closely related to fat deposition were observed in the blood of non-pecked

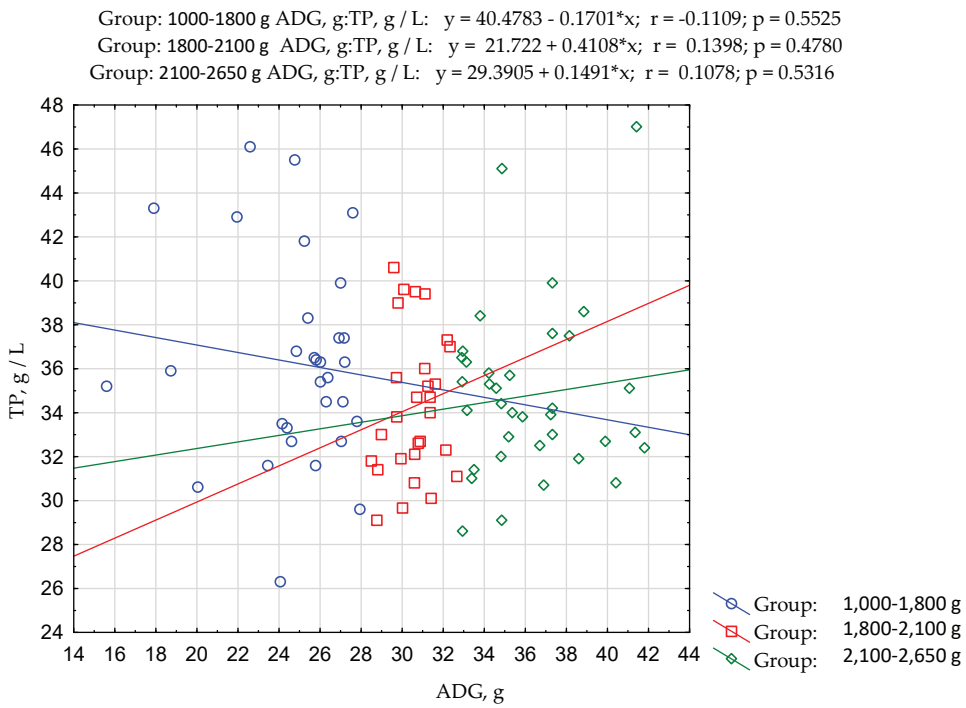

Figure 3. Categorical diagram of the relationship between serum TP and ADG in groups with different weights

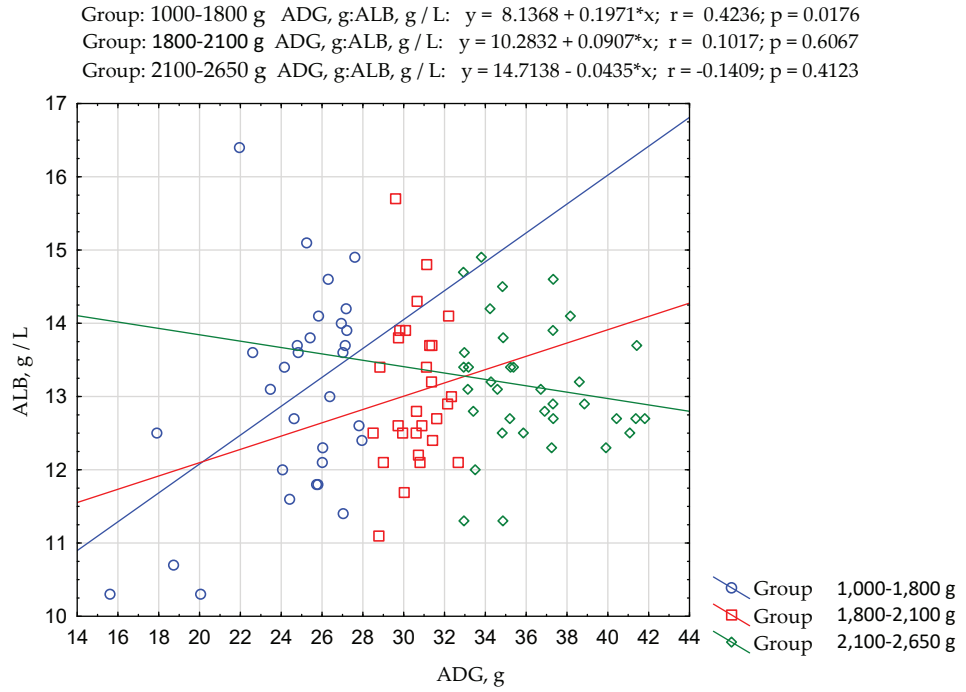

Figure 4. Categorical diagram of the relationship between serum ALB and ADG in groups with different weights

birds [14]. It was found that the activity of three enzymes (lactate dehydrogenase, aspartate aminotransferase and gamma-glutamyltransferase) was increased in the blood when the density increased above the standards (up to 25.3 birds/m^2). Further overpopulation of chickens up to 26.7 birds/m^2 is accompanied by increased serum glucose and creatinine levels, decreased calcium to phosphorus ratio, confirmed by increased alkaline phosphatase activity [15].

In our study of biochemical parameters, we found that TRIG and TBIL had the greatest variation (> 50%) (Table 1). It has been reported that TBIL increases after a long period of exercise due to accelerated erythrocyte destruction induced by exercise stress [16]. Lipolysis in muscle and adipose tissue and TRIG synthesis in the liver are increased due to reduced oxidative capacity of fat utilization during exercise. TRIGs also play an important role in replenishing intramuscular fat. Lipid metabolism is known to be one of the most important parts of adaptation, including the stress-releasing mechanism in birds. In stress-sensitive birds, compared to stress-resistant birds, there is a more pronounced increase in TRIG and CHOL concentrations due to the predominance of cholesterol included in very low density lipoproteins and a decrease in cholesterol included in low and high density lipoproteins [17]. ALP is involved in phosphoric acid metabolism, breaking it down

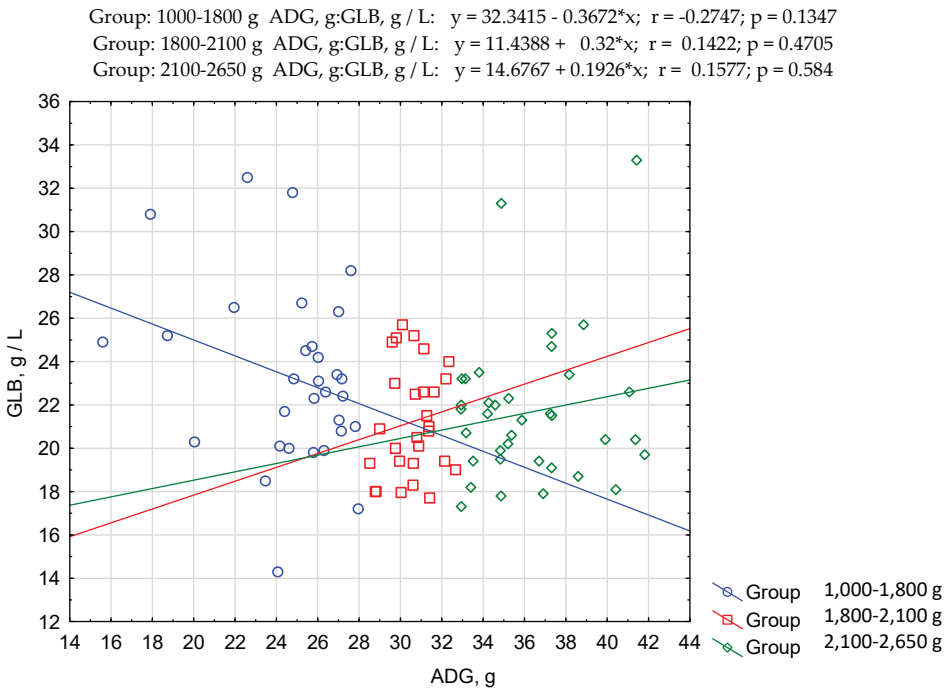

Figure 5. Categorical diagram of the relationship between serum GLB and ADG in groups with different weights

from organic compounds and contributes to phosphorus transport in the body, it affects bone growth, so its content is higher in intensively growing organisms. In turn, we have found that ALP, ALT and CHOL also had a high scatter of values in the studied livestock. In connection with the fact that these parameters (especially TRIG and TBIL) can be markers of the birds' condition, including their reaction to stress, we believe that the established differences should be considered in further work with poultry and in selecting them for further work based on the values of these biochemical parameters.

Carbohydrate metabolism is the key in energy metabolism in poultry [18]. During prolonged exercise, insulin sensitivity and glucose uptake increase, leading to a decrease in blood glucose levels, even if they remain at physiological levels [19]. According to our data, GLU had an average range of values, which generally corresponded to normal values, confirming that the birds were under standard rearing conditions, while the crossed birds, in addition to the effect of heterosis, had a high range of values for individual stress markers, indicating the display of susceptibility of individuals to environmental and nutritional conditions. This is also evidenced by the increased heterogeneity of antioxidant defence indicators (> 20%). The AOS data should also be taken into account when selecting birds for further work, as this may serve as an important factor in selecting birds with the best adaptogenic properties.

The TP level in the blood of the animals we studied was 35.13 g/l, GLB was 13.07 g/l. These indicators of protein metabolism differ greatly from the results of Fedorova et al. [20]. The authors studied adult Pushkin breed chickens (combined direction of productivity). According to the authors, these values were 52.59 and 34.64 g/l, respectively. The level of CREA, according to the authors, was 62.8 μmol/l, which is almost 2 times higher than in our study (31.51 μmol/l). This difference is due to both genetic differences and differences in the age of the poultry and once again confirms the need for separate studies for poultry of different breeds and combinations, as well as the direction of productivity and age.

Our biochemical results are close to those of the experiment on Ross × Ross 308 broiler chickens at 35 days of age, except for AST [21]. The AST activity in broiler chickens was 328 U/L. The mean value of the AST activity in our results was 220.66 IU/l.

Our work has established high positive correlations between indicators of protein, carbohydrate, fat and mineral metabolism, indicating a high degree of correlation between the studied parameters (Table 5). Of particular interest is the study of correlations between biochemical blood parameters and stress indicators. Stress markers had negative mean associations with biochemical parameters in our studies: CP and A/G (r = –0.40). TBA/CP and TRIG (r = –0.57). The TBA/CP ratio indicates a conjugation of lipid peroxidation and antioxidant defence. An increase in this index points to a decrease in the level of antioxidant protection and an increase in the synthesis of stress hormones.

TBA-AP was positively correlated with blood levels of CREA (r = 0.32). CP levels were negatively correlated with A/G. This may be due to the fact that decreased antioxidant protection leads to increased synthesis and secretion of corticoid hormones, as well as protein catabolism, and consequently to increased albumin levels, which determine A/G. An increase in TAS levels may lead to an increase in albumin and total serum protein. The weak positive correlations detected between TBA-AP and TBA/CP with CHOL (r = 0.31 and r = 0.32, respectively) are consistent with results obtained previously by researchers [22].

A significant correlation between serum biochemical indices and meat quality of farm animals has been reported previously. Serum biochemical indices determine the animal's resistance strength and oxygen transport and have a significant influence on growth intensity and metabolic specificity [23,24].

The study of the chemical composition of meat from the poultry stock we studied showed that these parameters had less heterogeneity, which allows us to characterize a more stable fixation of these traits in the production of offspring. Against this background, weak correlations were found between the chemical composition of meat and biochemical blood parameters. A medium correlation ($r = 0.50$) was found between the dry matter of thigh meat and serum CREA levels. The raw protein ($r = 0.94$) and ash content ($r = 0.41$) increased with increasing dry matter of thigh meat. Dry matter of thigh meat had a high positive correlation with the crude fat content ($r = 0.69$). CREA is an indicator of energy metabolism and is related to live weight of animals and poultry. This fact is probably the reason for the positive correlation between dry matter of thigh meat and serum CREA and in the future this parameter can be taken into account when predicting meat quality and when selecting poultry.

Studies by other authors have described the influence of factors on poultry meat quality, including the effect of the season of the year [5]. The influence of some biochemical indicators (stress markers) on poultry meat quality is shown in [25]. Different blood metabolites (stress biomarkers) and meat quality are evaluated in [26]. A correlation between serum biochemical indices and meat quality attributes based on pH, meat color and a number of other parameters has recently been reported [27]. The correlation between meat quality and serum biochemical indices has been studied in [28]. Albumin and serum water-holding capacity, serum somatotropin and pH1 (45–60 min after slaughter) were significantly and positively correlated with each other [29].

Thus, it is necessary to take into account correlations characterizing the interdependence of biochemical processes with quality parameters of meat, while expanding the range of studied parameters, including stress and AOS markers.

We have assessed blood biochemical parameters characterizing nitrogen, carbohydrate-lipid and mineral metabolism, antioxidant protection, hematological parameters (RBC, HCT, HGB), chemical composition of breast and thigh of 63-day-old cockerels ($n = 95$) depending on slaughter live weight. There were significant changes in the blood values (Table 6, Figure 1). A/G ($p = 0.038$) increased in animals with increasing slaughter weight. AST ($p = 0.003$); GLB ($p = 0.052$), GLU ($p = 0.018$), Ca ($p = 0.006$), Mg ($p = 0.051$) levels decreased. There was a downward trend in serum TRIG ($p = 0.092$), CL ($p = 0.096$). These figures indicate the important role of the study of stress tolerance in poultry and the peculiarities of the indication of the normal course of biochemical processes.

Analysis of the relationship between slaughter weight and blood parameters and the chemical composition of meat shows significant ($p < 0.05$) correlations mainly in the group of roosters with the low slaughter weight (1,000–1,800 g) (Table 7). Positive moderate correlations were observed between weight and protein metabolism, P, dry matter of breast and thigh meat, crude protein of breast meat, and crude fat of thigh meat. Negative correlations were observed between slaughter live weight and ALP, Ca/P. Against the background of low weight gain and increased protein content in meat, there was a decrease in blood ALB/GLB ratio and an increase in ALP (Tables 6, 7). Thus, these indicators can serve as markers for evaluating poultry growth.

The decrease in body weight was primarily characterised by differences in protein metabolism (Figures 3–5) in the group of roosters with the low body weight (1,000–1,799 g) related to the different responses of the birds to environmental conditions (feeding, housing, possible stress, etc.). In the group of animals with maximum slaughter weight, a significant positive correlation was observed between the live weight and serum AST activity. The increased activity of these enzymes may indicate activation of protein and amino acid metabolism, increased load on the liver and cardiovascular system [30]. The poultry live weight increases the load on these important functions and systems, causing an increase in the serum AST activity. Previously, ALT and ALB levels have been found to be of practical importance in predicting carcass quality in animals on the day of slaughter. ALB levels were moderately positively correlated with the live weight, hot carcass weight, cold carcass weight and dorsal fat thickness. Serum ALT levels were moderately positively correlated with the live weight, hot carcass weight and cold carcass weight [31].

Conclusion

Our study reaffirmed the importance of studying an extended range of biochemistry parameters (including AOS and stress markers) and in the relationship with meat quality parameters and growth intensity, which can serve as a basis for predicting growth parameters and as additional criteria for selecting poultry with given productivity parameters.

The metabolic status ($N = 95$), comparison of the biochemical blood indices characterizing the nitrogen, carbohydrate-lipid and mineral metabolism, antioxidant protection, some clinical blood indices (hemoglobin, erythrocytes, hematocrit), chemical composition of the breast and thigh meat of cockerels (♂ RW × CORN) at the age of 63 days have been analyzed. High positive correlations between the indices of protein, carbohydrate, fat and mineral metabolism have been established, indicating a high degree of interrelation and characterized in general by the commonly known principles. Correlations between biochemical parameters of protein, carbohydrate and lipid metabolism and stress markers have been established (first

of all, attention should be paid to protein metabolism parameters, but also to CHOL, TRIG and TBIL).

At the current stage of research, no highly significant links have been found between biochemical blood values and the chemical composition of meat. This indicates the importance of searching for additional markers for *in vivo* evaluation of the composition and quality of poultry products. Correlations have been established between cockerel body weight, blood parameters (TP, ALB/GLB, CREA, ALP, Ca/P and others) and the chemical composition of meat (primarily protein and fat content) in the poultry group with a slaughter weight of 1,000–1,799 g.

In the future, it is planned to expand the range of studying the relationships between biochemical, antioxidant, hormonal blood parameters, expression of antioxidant protection and immunity genes with regard to meat quality of modern chicken breeds to obtain new knowledge about the genetic determination of productivity traits. Development of express methods of predicting the biochemical composition of poultry products and health status of poultry based on extended analysis of blood biochemical composition is one of the priority tasks of practical approbation of our research in the future.

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