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Interactions of productivity, content of separate amino acids, general protein in blood serum of chickens and tone of the autonomic nervous system

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The regulation of metabolic processes and maintenance of a stable internal environment of the body is the role of the autonomic nervous system (ANS). It influences all systems and organs, thus along with the neuro-humoral system providing control over the metabolism of proteins, fats and carbohydrates. Amino acids, as structural units of any protein molecule, are essential for the metabolism of proteins, enzymes and hormones. Certain amino acids are involved in neutralizing free radicals and are a donor of metal groups, can act as an energy source in case of a deficiency of carbohydrates and fats, and be structural units of connective tissue. Exchange of these compounds and their regulation by ANS have not been studied sufficiently, therefore, it is necessary to carry out research in this direction. The studies were aimed at finding the presence of the regulatory effect of ANS on the content of individual amino acids in the blood serum of 60-day-old Cobb-500 chickens. Determination of the ANS tone in Cobb-500 chickens at the age of 30–35 days was determined by the method of variation pulsometry. Electrocardiographic examination was performed in a quiet room without the use of sedatives. At the age of 60 days, blood was obtained from the saphenous vein of the chickens' shoulder. Blood was sampled from 10 am to 1 pm, after a short fasting (2:00). It was found that sympathicotonic chickens had a higher content of individual amino acids compared to normotonics and vagotonics. In vagotonic chickens, the content of glycine and serine in the blood serum significantly exceeded the rate of chickens with a balanced tone of ANS. Correlative relationships between amino acid content were highly significant in poultry with balanced ANS tone. Vagotonic chickens had the highest correlations between ANS tone, heart rate and amino acid content (trend). Correlative relationships were present between ANS and body weight of chickens of different groups, serum protein. The correlation between total serum protein and body weight of chickens was different depending on the tone of the ANS. Fisher's test revealed a significant effect of balanced ANS tone on the content of valine, serine and glycine and the weight of chickens. The effect of ANS tone on weight in vagotonic birds was high.

Keywords: physiology; higher nervous activity; electrocardiogram; valine; glycine; serine; proline; productivity.

Introduction

Amino acids in the body of animals are a building material for the synthesis of enzymes and hormones, transport compounds (Castro et al., 2019), muscle frame and are involved in the detoxification of toxic compounds of protein metabolism (Holeček & Vodeníčarová, 2018; Kobayashi, 2018) and others. Certain amino acids have antioxidant properties and are able to counteract excessive amounts of free radicals, be donors of methyl groups (Lys & Regeda, 2018) and have hepatoprotective functions. That is why it is extremely important to regulate the metabolic processes in which these substances are involved. It has been repeatedly established that the proper content of amino acids in the diet, sufficient intake and full assimilation in the gastrointestinal tract (Wu et al., 2014) of chickens play a huge role in the growth and development of their body (Castro et al., 2019). The absence or deficiency of at least one amino acid can lead to irreversible changes in animal health and productivity (Bin et al., 2017).

Total serum protein of chickens is one of the main parameters for assessing the condition of the avian organism. Its metabolism takes place in the liver as the main organ, which is responsible for about 11% of the synthesis of all proteins in the body of the bird (Zaefarian et al., 2019). Serum proteins play a major role in maintaining colloidal osmotic pressure, can be a rapid reserve of essential amino acids and act as a plastic material in

gluconeogenesis, transfer biologically active substances (Piotrowska et al., 2011). They are in close interaction with tissue proteins of the animal body, and their content may vary depending on the state of adaptation systems and the tone of the ANS. It has been proven that the content of serum proteins decreases with excessive effects of stress factors on the body of the bird, and under the influence of moderate effects without stress, on the contrary, may increase. The impact of stress on poultry farming is an extremely important factor that directly affects its productivity. Compared to other animals, chickens are more sensitive to any changes in their environment. These may be changes in diet, maintenance, transportation or preventive veterinary measures that cause significant reductions in weight gain, egg production, growth, milk productivity (in cattle) (Kavtarashvili & Kolokolnikova, 2010). The role of maintaining these adaptive functions and preventing the negative effects of stress factors on the body of animals and humans is largely dependent on the sympathetic nervous system.

It should be emphasized that the nervous regulation of physiological processes in animals and humans is carried out by all formations of the nervous system up to the cerebral cortex, which carries out the most subtle adaptation of life to changing environmental conditions. This, in particular, was studied in cattle (Danchuk et al., 2020a) and pigs (Danchuk et al., 2020b). The studies on animals of other species revealed that the processes of protein metabolism and productivity in their body are directly affected

by higher nervous activity (HNA). For example, pigs with a strong type of HNA were characterized by a higher content of total protein, serum albumin had a higher productivity compared with a weak type of cortical regulation. Regarding amino acids, animals with a weak type of HNA were characterized by lower levels of essential amino acids valine, proline and glycine. Other researchers (Trokoz et al., 2013) also found that the strength and mobility of cortical processes dominate and directly cause an increase in total serum protein of pigs in the intact period of rearing compared to animals with a weak and inert type of HNA. Regarding the interaction of ANS tone and strength of cortical processes, it was found that pigs that had the highest strength and balance of cortical processes belonged to the group of normotonics and vagotonics, and animals with a weak type of ANS – sympathicotronics. It is worth noting that in these studies parasympathetic tone of ANS was found not to affect the strength and mobility of cortical processes, while sympathicotonic tone, on the contrary, had a significant effect on the balance ($P < 0.05$) and strength (trend) of cortical processes (Karpovsky et al., 2015). Regarding the effect on metabolism and other substances, the authors' studies (Postoy et al., 2019) did not show an association between ANS tone and cholesterol and triacylglycerol levels in the blood of single sows, but there is a significant effect of different types of ANS on the concentration of these substances.

The autonomic nervous system is considered to be able to regulate metabolic processes in animals and humans directly and indirectly through the endocrine glands (Reutov & Chertok, 2016; Postoi et al., 2020). It consists of two anatomically and functionally separated departments – sympathetic and parasympathetic. Their control centers are at the level of the cortex, hypothalamus and brainstem (Navarro, 2002). Since these structural units of ANS mostly have the opposite effect on tissues, the increase in the activity of one system leads to a simultaneous decrease in the activity of another. This allows for rapid and accurate control of organ and tissue functions (Corry, 2007).

The parasympathetic and sympathetic divisions of the ANS have different effects on metabolism and animal activity (Corry, 2007). The dominant influence of the sympathetic nervous system leads to increase in glucose levels (Karpovsky et al., 2016), increase in blood serum lysozyme and bactericidal activity (Karpovsky et al., 2013). By contrast, the parasympathetic division is activated during rest. Its effect is to preserve and accumulate energy, regulate digestion and urination (Shields, 1993). It has also been shown that the parasympathetic nervous system regulates metabolism in the liver of rainbow trout and increases the use and synthesis of glucose, amino acids, and lipids through the indirect effect of hypothalamic AMPK α 2 (Conde-Sieira et al., 2020).

The use of neuropeptides Y and AgRP has been shown to stimulate the nutrient-sensitive zone of the hypothalamus with activation of the parasympathetic link of the ANS, which in turn caused hyperphagia and weight gain (Grechko et al., 2018).

The role of the autonomic nervous system is especially evident in the work of the heart. A significant number of mechanisms are involved in the regulation of its activities. There may be different types of modulation: automation, transneuronal, transsynaptic, hormonal modulation (Beaulieu & Lambert, 1998). Autonomous regulation of heart rate is provided in two ways. The first way is the effect on the receptors of the cells of the sinoatrial node, which are able to involuntarily be excited and provide the main rhythm of the heart. Another mechanism is less studied, it is a system of certain time mechanisms “coupled-clock”, which provide rhythmic work even without the influence of higher centers (Rosenberg et al., 2020). The heart also involves a large number of different neuronal peptides that act as neurotransmitters or neurohormones. Some of them are formed in the endocrine glands and circulate as hormones, while others are located in cardiac myocytes and perform the functions of modulating the heart rate. There is evidence of such a role especially for locally located neuropeptides Y, natriuretic peptides, etc. (Beaulieu & Lambert, 1998). It is the great importance of the described mechanisms which determines the choice of the method of studying the tone of the autonomic nervous system – variational pulsometry.

The existence of the organism without the interaction of the sympathetic and parasympathetic systems and their mutual regulation is impossible. This can be seen in animals and humans with congenital ANS dysfunction, characterized by stunted growth, dysfunction of the endocrine

and external secretion glands, susceptibility to disease and general weakness (Wehrwein et al., 2016; Zhukov et al., 2020).

The study of the mechanisms of amino acid and total protein metabolism regulation is a crucial scientific issue. Investigation of the effect of ANS tone on the synthesis and metabolism of these compounds in the organism of chickens will shed valuable light on this issue and give impetus for further scientific research.

The objective of this study was determining interdependencies and interactions between the indices of the ANS tone and the content of individual amino acids in the blood serum of chickens.

Materials and methods

All the manipulations with the animals were conducted according to the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (Official Journal of the European Union L276/33, 2010).

The ANS tone in Cobb-500 chickens at the age of 30–35 days was determined by the method of variation pulsometry. The method is based on the fact that the increased tone of the parasympathetic division of the ANS inhibits cardiac activity, and that of the sympathetic, on the contrary, stimulates. For this purpose, the ECG of chickens was recorded with a portable electrocardiograph EK3T 01-“R-D” (Russia). To record cardiac activity, chickens were put in the supine position, standard leads were used (I – left and right thoracic limbs, II – left thoracic and left pelvic limbs and III – right thoracic and left pelvic limbs), tape speed 50 mm/s, amplitude – 1 mV. The ECG study was performed in a quiet room, sedatives were not used. All work was carried out in accordance with the ethical standards and recommendations for the treatment of animals (Albus, 2012). We analyzed 100 consecutive R–R cardio intervals. The mode indicator (Mo) was determined – the duration of the R–R interval, which was most often recorded. If the mode indicator was 0.14–0.16 s – the animal was classified as sympathicotonic (increased tone of the sympathetic division of the ANS); 0.16–0.17 s – normotonic (balanced tone of ANS divisions); 0.18–0.21 s – vagotonic. The mode amplitude (AMo) was used as an additional, clarifying indicator for determining ANS dominant tone. The AMo is the number of Mo indicators from cardiointerval samples, expressed as a percentage. This indicator was >45% in sympathicotronics, 40–45% in normotonics, and <40% in vagotonics. According to the results obtained, the studied chickens were divided into three groups in accordance with the ANS department tone: sympathicotronics (St), normotonics (Nt) and vagotonics (Vt), four animals in each group. At the age of 60 days, blood was drawn from the saphenous vein of the chickens' shoulder (Bayer, 2012). Blood was sampled from 10 am to 1 pm, after a short fasting (2:00). The chickens were put in the supine position, the vein puncture site was treated aseptically and anesthetized with lidocaine gel (Bayer, 2012). The amino acid content in blood serum was determined using “Kapel 105M” (Russia) by capillary electrophoresis.

Data analysis was performed using Statistica 6.0 (StatSoft Inc., USA). The data are presented in the text as $\bar{x} \pm m$ (\bar{x} – standard deviation). Differences between values in the experimental groups were determined using ANOVA and the Kruskal–Wallis criterion, where the differences were considered significant at $P < 0.05$. To determine the relationship and interaction of ANS tone indicators (heart rate, mode and mode amplitude) and the content of amino acids in the blood serum of chickens (valine, glycine, serine and proline), we used a correlation and Fisher's test.

Results

As a result of the conducted electrocardiographic studies, it was found that birds of the sympathetic division of the ANS (St) had lower Mo values and proportionally higher heart rate indicators (Figs. 1, 2). Values of Mo in chickens-St were lower compared with other groups by 0.017 s 10.3% (Nt) and 0.027 s 15.4% (Vt). The difference between normotonics and vagotonics was 0.01 s 5.7%. Heart rate has a high inverse dependence on Mo and was higher in chickens with a predominance of the sympathetic division of the ANS compared with normotonics at 41 beats/min (9.7%) and vagotonics at 58 beats/min (14.4%). The heart rate difference between Vt and Nt was insignificant and amounted to 19 beats/min (5.2%).

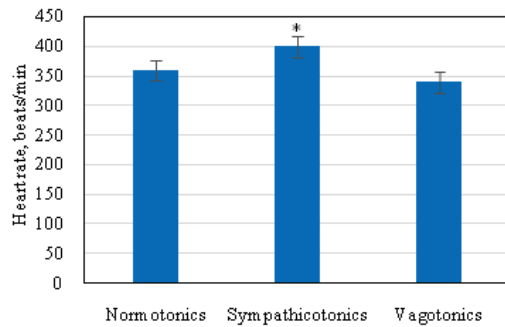


Fig. 1. Heart rate in chickens with different tone of the autonomic nervous system ($x \pm SE$, $n = 4$): * – $P < 0.05$ – compared with normotonics (including Bonferroni correction)

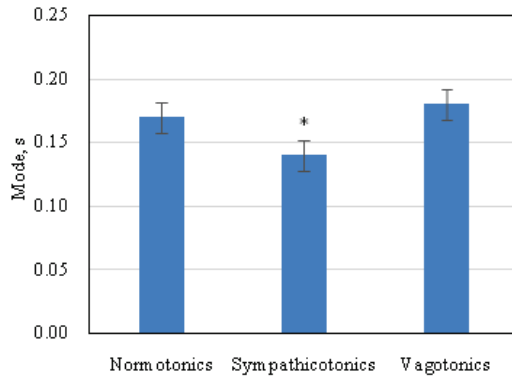


Fig. 2. Mode indicators in chickens with different tone of the autonomic nervous system ($x \pm SE$, $n = 4$): * – $P < 0.05$ – compared with normotonics (including Bonferroni correction)

Besides, sympathicotonic chickens were characterized by the highest AMo value among the groups (Fig. 3), but only at the level of trend. The valine content in serum of these chickens was higher by 11.1 $\mu\text{mol/L}$ (37.2%; $P > 0.05$) and 5.6 $\mu\text{mol/L}$ (18.8%; $P > 0.05$) compared with Nt and Vt, respectively. The difference between the latter groups was

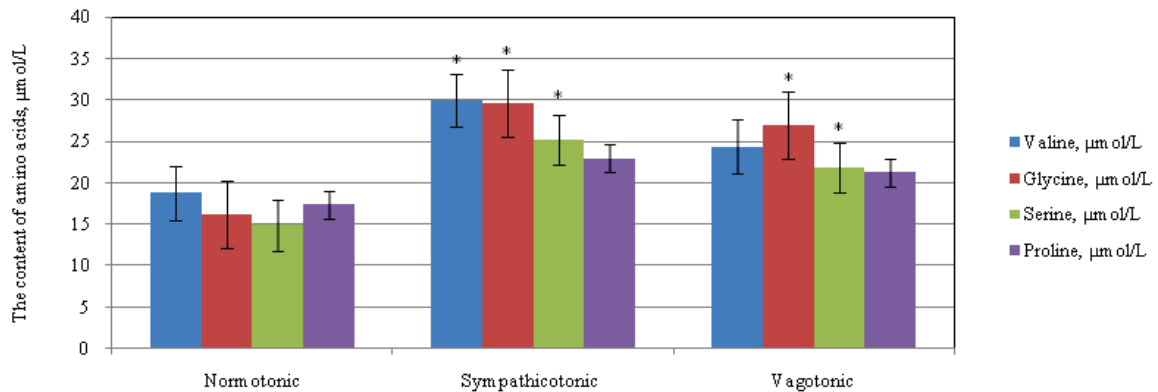


Fig. 4. The content of amino acids in the serum of chickens with different tones of the autonomic nervous ($x \pm SE$, $n = 4$): * – $P < 0.05$ compared with normotonics for each amino acid (including Bonferroni correction)

Table 1

The correlation coefficient between the content of amino acid in blood serum and indicators of autonomic regulation of cardiac activity in sympathicotonic chickens, r ($n = 4$)

Indicators	Mode	Mode amplitude	Heart rate	Total protein	Body weight	Valine	Glycine	Serine
Mode amplitude	-0.983*	–	–	–	–	–	–	–
Heart rate	-1.000***	0.983*	–	–	–	–	–	–
Total protein	0.871	-0.905	-0.871	–	–	–	–	–
Body weight	-0.870	0.845	0.870	-0.944	–	–	–	–
Valine	-0.227	0.116	0.227	0.279	-0.148	–	–	–
Glycine	-0.352	0.205	0.352	-0.321	0.611	0.118	–	–
Serine	-0.121	-0.061	0.121	0.160	0.160	0.614	0.804	–
Proline	-0.446	0.282	0.446	-0.058	0.318	0.797	0.688	0.909

Note: the correlation coefficient is significant at * – $P < 0.05$, *** – $P < 0.001$.

5.5 $\mu\text{mol/L}$ (22.7%) in favour of vagotonics (trend) (Fig. 4). The content of the conditionally essential amino acid glycine in the blood serum of Nt chickens was at a lower level compared with Vt ($P > 0.05$; 39.6%). In St, it was higher in comparison with Nt by 13.3 $\mu\text{mol/L}$ (45.0%). St compared with Vt showed a tendency to higher glycine levels by 2.7 $\mu\text{mol/L}$ (9.0%).

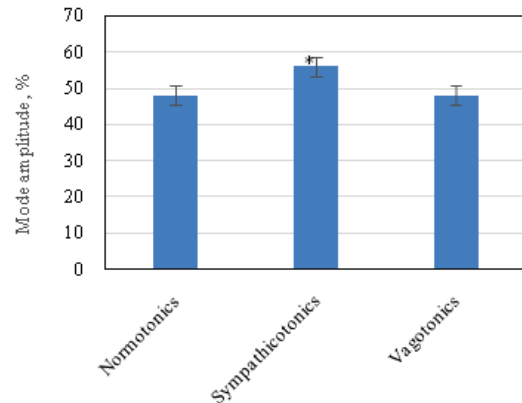


Fig. 3. AMo indicators in chickens with different tone of the autonomic nervous system ($x \pm SE$, $n = 4$): * – $P < 0.05$ – compared with normotonics (taking into account Bonferroni correction)

The serine content in St was $25.21 \pm 3.46 \mu\text{mol/L}$, which was 10.32 $\mu\text{mol/L}$ (40.9%; $P > 0.05$) higher than in Nt chickens, which, within the trend limits, was 3.3 $\mu\text{mol/L}$ (13.1%) higher compared with Vt chickens. The chickens with the dominance of the tone of the parasympathetic division of the ANS (Vt) had higher serine content in the blood serum by 7.02 $\mu\text{mol/L}$ (32.0%; $P > 0.05$) compared with Nt chickens.

The proline content in St chickens was 5.56 $\mu\text{mol/L}$ (24.2%; trend) higher than in Nt chickens and 1.67 $\mu\text{mol/L}$ (7.3%; trend) compared with Vt. In serum of chickens with a dominance of the tone of the parasympathetic division of the ANS, the content of proline was 3.89 $\mu\text{mol/L}$ (18.3%; trend) higher than in Nt. It was determined that individual amino acids in chicken blood serum were interrelated. This is showed by the correlation analysis of experimental data. Thus, in St chickens, a significant positive correlation was seen between the content of serine and proline, and serine and glycine, valine and proline (Table 1).

Table 2

The correlation coefficient between the content of amino acids in serum and indicators of autonomic regulation of cardiac activity in normotonic chickens, r ($n = 4$)

Indicators	Mode	Mode amplitude	Heart rate	Total protein	Body weight	Valine	Glycine	Serine
Mode amplitude	-0.890	–	–	–	–	–	–	–
Heart rate	-0.932	0.990**	–	–	–	–	–	–
Total protein	0.137	0.326	0.230	–	–	–	–	–
Body weight	0.819	-0.984*	-0.971*	-0.453	–	–	–	–
Valine	-0.387	-0.066	0.061	-0.906	0.158	–	–	–
Glycine	-0.567	0.134	0.253	-0.855	-0.029	0.978*	–	–
Serine	-0.180	-0.277	-0.152	-0.933	0.358	0.977*	0.911	–
Proline	-0.137	-0.329	-0.216	-0.980*	0.432	0.954*	0.889	0.985*

Note: the correlation coefficient is significant at * – $P < 0.05$, ** – $P < 0.01$.

Table 3

The correlation coefficient between amino acid content in serum and indicators of autonomic regulation of cardiac activity in vagotonic chickens, r ($n = 4$)

Indicators	Mode	Mode amplitude	Heart rate	Total protein	Body weight	Valine	Glycine	Serine
Mode amplitude	0.991**	–	–	–	–	–	–	–
Heart rate	0.992**	0.985*	–	–	–	–	–	–
Total protein	0.898	-0.948	-0.909	–	–	–	–	–
Body weight	0.954*	-0.914	-0.966*	0.774	–	–	–	–
Valine	0.350	-0.291	-0.236	0.059	0.268	–	–	–
Glycine	0.565	-0.591	-0.466	0.534	0.333	0.768	–	–
Serine	0.509	-0.563	-0.420	0.579	0.241	0.618	0.975*	–
Proline	0.662	-0.665	-0.565	0.555	0.472	0.831	0.981*	0.919

Note: the correlation coefficient is significant at * – $P < 0.05$, ** – $P < 0.01$, *** – $P < 0.001$.

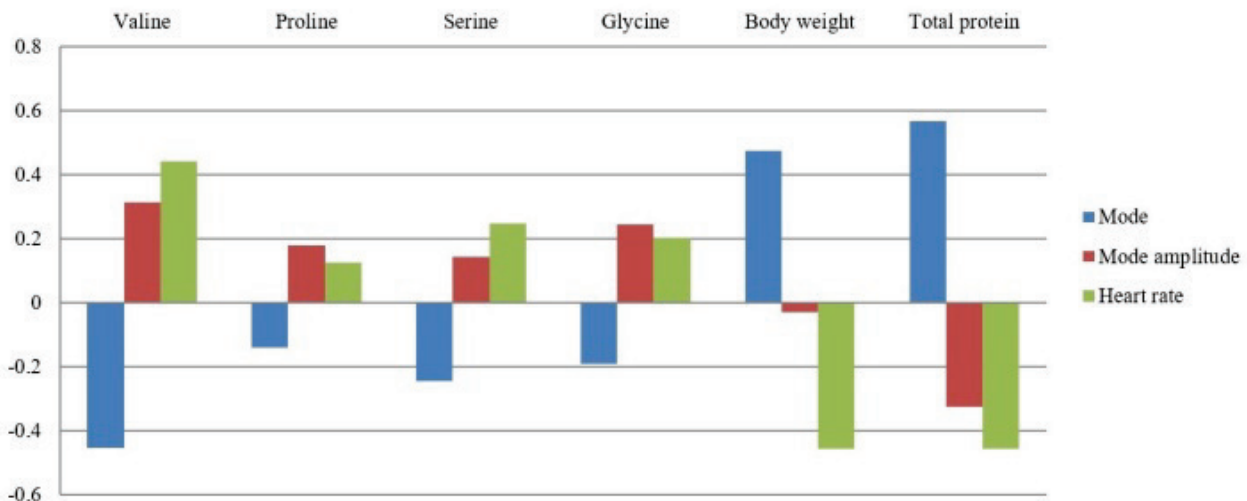


Fig. 5. The correlation coefficient between the content of amino acids and indicators of autonomous regulation of cardiac activity in chickens of all groups, r ($n = 12$)

Negative and positive correlations from weak to moderate were recorded between indicators of Mo, heart rate and the content of individual amino acids. However, such relationships were not confirmed by statistics. They did not exceed the limits of a trend, possibly due to the small number of animals in the group. The mode amplitude had a positive correlation with the mode ($P < 0.05$) and moderate to weak positive correlation with body weight, valine, glycine and proline content (trend).

Correlative negatives and positive linear relationships existed between Mo, Amo and body weight of chickens and their serum protein. A close negative correlation was present between total protein and poultry weight (trend). The relationship between amino acid content and total serum protein, as well as the body weight of chickens, was both positive and negative, and only within the trend between glycine and body weight.

Chickens with balanced ANS tone had close significant ($P < 0.05$) correlations between the content of individual essential and nonessential amino acids (Table 2).

A weak to moderate correlative interaction was found between Mo, heart rate, and the amino acid content of the blood serum of these chickens. A high degree of negative correlation existed between the Mo and AMO indicators. The negative correlation between the mode amplitude and the amino acid content was characterized by a weak to moderate strength. There was a very close negative interaction between the content

of total protein and the amino acid pool of blood (proline – $P < 0.05$). Chicken body weight was correlated with the amino acids proline and serine, but only at the level of the trend. The correlation of this performance indicator with the indicators of cardiac activity was quite close ($P < 0.05$).

In birds with the dominance of the parasympathetic division of the ANS, a high correlation ($P < 0.05$) was observed between the content of almost all amino acids (Table 3).

There was a noticeable positive correlation between Mo and amino acid content. There were from low to moderate relationships between AMO, heart rate and amino acid content. A strong correlation was found between the indicators of Mo and AMO ($P < 0.01$). In this sample of chickens, the closest positive correlation was observed between other groups, between body weight and amino acid content (trend), as well as the content of total serum protein. Similar processes, but with the opposite direction were observed in Nt chickens. In our opinion, the processes that cause this condition in these groups of birds are identical.

The body weight of the birds had a close negative correlation with Mo, heart rate and Amo ($P < 0.05$), which indicates a direct relationship between weight and tone of the ANS. Thus, in the individual studied groups of chickens, significant relationships were observed between the contents of individual amino acids. However, the interaction between the dominant tone of the sympathetic division of the ANS in chickens and the

content of mentioned amino acids in their blood serum in individual groups cannot be asserted. Instead, there were significant relationships between chicken body weight, total serum protein and ANS tone, and amino acid content. More research is required on this issue. Thus, when identifying the correlation interactions of indicators of all groups of birds, we determined high correlation coefficients between the content of valine in blood serum and indicators of Mo and heart rate. In addition, the AMO indicator had a positive correlation within the trend. The body weight of the chickens was closely correlated with Mo and heart rate, but practically absent with Amo. Serum total protein was closely related to Mo, heart rate and Amo was within the trend (Fig. 5).

Analysis of variance of the experimental data showed the significant effect of the balanced ANS tone (normotonia) on the content of almost all the studied amino acids (except proline) ($P < 0.05$) and body weight ($P < 0.01$). However, this tone did not affect the indicators of Mo, AMO and total protein content.

The increased tone of the sympathetic division of the ANS had insignificantly less effect on the amino acid content. As for the indicator Mo, the indicator of the force of influence of sympathicotonia was quite high ($P < 0.01$). In vagotonic chickens, the effect of ANS on amino acid levels was the smallest among all typological groups; the Mo index depended on the tone of the ANS too ($P < 0.05$). The effect on the body weight of vagotonic animals was significant ($P < 0.01$) and exceeded this figure in birds-Nt by 35.8%. It can be concluded that vagotonic chickens had the highest influence and relationship between ANS and their body weight, a fairly high (trend) correlation between body weight and amino acid content of total serum protein ($P < 0.05$). This suggests that birds with predominance of parasympathetic tone of the ANS are more prone to weight gain and the relationships between the components of protein metabolism.

Discussion

The autonomic nervous system maintains homeostasis and regulates the stability of the internal matrix fluid needed to sustain life. It is found that the indicators of metabolism in the body of farm animals depend on the tone of the autonomic nervous system (Zhurenko et al., 2018). The high level of productivity of poultry depends on the intensity of metabolic processes, which promotes rapid absorption of nutrients, early maturity and high productivity (Kyryliv et al., 2015). However, the management of the poultry industry includes a number of technological operations that cause excessive stress on adaptive systems and the development of stress (Shevchuk et al., 2018).

Our data suggest that sympathicotonic chickens with an increase in heart rate have a simultaneous increase in the amplitude of Mo or vice versa, which is characterized by better and more accurate regulation of the sympathetic nervous system of the heart (Shutov et al., 2021). Body weight also increased (which was typical only for this group of birds) with increasing sympathetic tone of the ANS with a parallel decrease in total serum protein. Such fluctuations can be characterized by increased metabolic processes in the body of the bird during this period of rearing, intensive growth and adaptation to environmental conditions that require large amounts of nutrients (Tothova et al., 2019). The correlation between protein metabolism and balanced ANS tone indicates that chickens in this group are in a state of dynamic equilibrium at the time of the survey. Increased intake of amino acids will affect the negative shift of total blood protein due to oversaturation of the body with these substances and vice versa, reduction in the content of total protein as a plastic material will require more amino acids. A similar pattern was observed with the body weight of these animals. The reduction of the influence of the sympathetic ANS on metabolic processes in the animal and the growth of parasympathetic tone was accompanied by weight gain and the transition to anabolic processes. This property, in our opinion, depends on many factors influencing the ANS, on the consumption and absorption of nutrients from feed, the mobility of animals, the tone of their centers of adaptation to housing conditions.

Research on other species of animals and humans revealed a direct and indirect effect of the parasympathetic system, and especially the centers in the brain on feelings of hunger and, consequently, the amount of food or food consumed (Grechko et al., 2018). Similar data on the meta-

bolism of total protein and amino acids in animals were obtained in experiments on pigs (Trokoz et al., 2013), where the predominance of strong types of HNA determined a higher level of protein in the serum of pigs. Other studies have reported no effect of ANS on serum fat concentrations in pigs with a concomitant positive effect on their content of cortical processes (Postoy et al., 2019).

Our data also somewhat explain the published results of studies in cattle, where cows with a predominance of the parasympathetic autonomic system had higher measurements, body weight and its indices compared to animals in which other departments of the ANS predominated. (Demus, 2010; Dimitriev et al., 2012). Note that long-term exposure to vagotonia can cause irreversible health problems, because in contrast to the trophic functions of the parasympathetic, the sympathetic nervous system counteracts stressors (Morozova et al., 2016) as the root causes of growth retardation, weight loss body and productivity, susceptibility to disease (Kavtarashvili & Kolokolnikova, 2010). As a result, any technological stress, lack of adaptation can lead to large economic losses in livestock farms. The content of amino acids in the blood serum of chickens can vary depending on the period of cultivation and the composition of the diet, the need for them also depends on age and metabolic rate. Each amino acid has a unique function. Valine in the body of poultry and animals is a substrate for anabolism and catabolism of muscles, neutralization of excess amounts of protein metabolism products (Holeček & Vodeníčarová, 2018), and an increase in its content in blood serum may indicate an increase in these processes under the influence of an increased tone of the sympathetic division of the ANS. Glycine is a part of supporting tissues, cartilage, ligaments, down and feathers, therefore it plays an important role in the development of the body of young poultry. Its content is inversely related to the content in the diet and directly affects the exchange of nitrogen in the body of animals (Krivenok et al., 2017).

Serine is a nonessential amino acid, which in animals and poultry can be derived from glycine and tryptophan, or conversely, be a source for the glycine formation. Pyruvate is synthesized from serine, which in turn is the source of adenosine triphosphate (ATP) in the Krebs cycle or is converted to glucose (Gonskyi & Maksimchuk, 2001). Serine also promotes the accumulation of glycogen in the liver and muscles, and is involved in the formation of nerve fibers (Shleper et al., 2005). In serum of chickens with a dominance of the tone of the parasympathetic division of the ANS, the content of proline was higher than in that of Nt chickens. This amino acid is conditional. Due to its cyclic group, it is a structural unit of collagen – a connective tissue protein, where concentrates in large amounts. Proline strengthens the connective tissue, and concentrates in tendons, ligaments and joints, and takes part in skin regeneration (Lysikov, 2012).

Our studies revealed a significant difference in amino acid content in different groups of chickens. This indicates that the effect of increased tone of the parasympathetic division of the ANS, possibly through the humoral system (Shaikhelislamova et al., 2008) accelerates the catabolism of proteins and their use for the body. It was found that the influence of the parasympathetic division of the autonomic nervous system promotes the accumulation and absorption of nutrients from the intestine (Shields, 1993; Grechko et al., 2018), which is accompanied by a higher content of amino acids in the serum of chickens compared to normotonics.

The regulation of the metabolism of amino acids, total protein and body weight by the autonomic nervous system depends on a large number of neuro-humoral mechanisms, which in turn are subordinate to each other, are hierarchically influenced and do not act autonomously (Beaulieu & Lambert, 1998; Reutov & Chertok, 2016; Postoi et al., 2020).

Thus, the parasympathetic nervous system affects the performance and heart rate. Amino acid metabolism depends to a greater extent on the balanced tone of the ANS. Sympathicotonia affects the rhythm and frequency of heart muscle contractions and the content of certain amino acids in the serum.

Conclusion

The research directly determined the effect of different ANS tone on the content of amino acids in the serum, mode and amplitude of the mode in chickens. Sympathicotonic chickens differed significantly from other animals in heart rate and Mo. The balanced tone of the ANS (normotonia)

provides a strong relationship between amino acids and significantly affects their content in the serum of chickens. In contrast, sympathicotonic chickens are characterized by the lowest correlation between amino acids and the average effect of ANS on their content compared with chickens of other types of autonomic nervous regulation. In chickens with a predominance of parasympathetic ANS tone, there was no effect on the content of amino acids in the serum, but there was a significant average effect on Mo. The correlation between the content of amino acids in the serum and the duration of the cardiac cycle in these chickens was quite high and had a positive direction.

Therefore, the increased tone of the sympathetic part of the ANS had the highest effect on the amino acid content in the blood serum of chickens. Normotonia had provided balance of catabolic and anabolic processes that in turn provided a close relationship between individual amino acids and their content in the chickens' body. The body weight of chickens largely depended on the increased tone of the parasympathetic division of the ANS.

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