Acta Scientific Veterinary Sciences (ISSN: 2582-3183)

Volume 7 Issue 10 October 2025

Research Article

Hematological, Biochemical and Zootechnical Changes of Broiler-Chickens Treated Distantly by Weak Non-Thermal Pulsed Electromagnetic Fields

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Received: August 29, 2025

Published: September 17, 2025

Abstract

In this article, the effect of electromagnetic field (EMF) on the body of broiler chickens was studied. Two studies were conducted on poultry. The first study was conducted on small stock from one day old to 56 days old. During the study, data were obtained on the effect of EMF on zootechnical indicators and morpho-biochemical composition of poultry blood. In parallel, the second experiment was conducted on a large number of poultry at one of the poultry farms in Russia. The application of this type of treatment in both cases led to improved feed conversion, an increase in the live weight of chickens and an increase in the economic efficiency of production, as well as better preservation of the flock due to increased immunity of broilers. The results of the study showed that the application of low-level electromagnetic radiation had a noticeable effect on the chickens. This suggests that this technology can be effectively used to increase productivity in poultry farming in a short time.

Keywords: Hematological; Biochemical; Zootechnical; Broiler-Chickens; Electromagnetic Fields

Introduction

In modern conditions of agriculture, many countries experience sustainable development of poultry farming. World and domestic broiler poultry is the basis for the production of dietary meat. Significant progress achieved in the industry over the past decades by the large-scale implementation of scientific achievements, has turned it into one of the most important sources of replenishment of food resources [1]. Modern technologies for broiler chicken meat production provide high growth rates, and each subsequent stage of increasing the rate of business growth requires even greater consolidation of the avian genetic structure with external factors, which is not always economically justified [2,3]. Today, in the context of economic sanctions and import substitution policies in the Russian Federation, the issue of ensuring national food security is extremely relevant. In this regard, the availability of high-quality protein on the market, such as poultry meat, is one of the optimal responses to international challenges [4]. In order to intensify production, increase live weight yield and production volumes, it is necessary to develop innovative practical solutions [5]. For instance, traditionally exploited sources of chemical elements in poultry feeding have a potentiality of environmental pollution along with production waste, and may also have high toxicity and low assimilability (e.g., microelements in inorganic form, hormones, antibiotics and heavy metals) [6].

An important and often crucial factor causing economic damage to poultry farms are infectious diseases accompanied by a decrease in the resistance of the bird's organism [7]. Some authors believe that under the influence of various conditions, broiler chickens exhibit certain and significant deviations in blood parameters. It is known from the literature that heat stress, for example, causes changes in many blood parameters, including an increase in the ratio of heterophils to lymphocytes and a decrease in the levels of substances that react with thiobarbituric acid. Adding different lev-

els of protein to the diet also leads to changes in basic haematological parameters such as leukocyte, erythrocyte, haemoglobin and haematocrit levels [8,9], since blood is a kind of effective indicator reflecting various aspects of metabolism [10]. Blood cells participate in maintaining the organism homeostasis, directly or indirectly involving in many physiological and pathological processes. The metabolic activity of the broiler organisms is influenced by both internal and external factors, including electromagnetic fields [11].

The mechanism of the effect of weak electromagnetic fields on the body of broilers has not been studied enough. However, along with traditional technologies and methods for increasing the productivity of agricultural poultry, electromagnetic wave technologies for treating broiler stocks are in progress to date [12]. For many decades, the chicken has been considered an ideal model for studying a large number of vital processes in various fields of biology, in particular, when studying the interactions between growing tissues and organs, as well as the influence of chemicals or physical factors [13]. We have previously shown that electromagnetic radiation (EMR) has a positive effect on the development of poultry and does not cause undesirable side effects in the development of internal organs and tissues; therefore, it is safe for use in poultry farming. [14]. In addition, studies have demonstrated a positive effect on the immune status of chicken blood [15]. In this regard, the aim of this study was to investigate changes in biochemical, hematological and zootechnical parameters in broiler chickens as a result of remote exposure to non-ionizing non-thermal electromagnetic fields.

Materials and Methods

Experiment 1

The studies were carried out in the laboratory of physiology of the Federal Scientific Center "VNITIP" in the vivarium of the Selective Genetic Centre "Zagorskoye Experimental Breeding Farm" (SRC "Zagorskoye EPH" - a branch of the Federal Scientific Center "VNITIP") in 2023. The object of the study was 80 broiler chickens of the "Smena 9" cross from a day-old to 56-day-old age. The chickens were housed in floor boxes with 40 chickens in each group. Feeding and housing conditions met all requirements for this poultry cross [16].

The experiments were performed in accordance with the requirements of the European Convention for the Protection of Vertebrate Animals Used for Experiments or Other Scientific Purposes (ETS No. 123, Strasbourg, 1986) [17]. When feeding chickens, three feeding periods were distinguished: starting period (0-10 days), growing period (11-21 days) and finishing period from the 22nd day until slaughter. Composition and nutrition of combined feeds are presented in table 1.

Component, %	Compound feed		
	Starter ration	Grower ration	Finisher ration
Wheat	60,08	58,5	60,27
Soy hulls	24,02	21,2	20,17
Sunflower meal 32%	4,00	7,63	7,78
Vegetable oil	3,32	5,57	6,14
Fish-flour	4,00	2,00	-
Molasses	1,50	1,50	1,50
Calcium superphosphate	1,21	1,03	1,28
Limestone	0,66	0,93	1,14
Premix	0,50	0,50	0,50
Methionine	0,33	0,27	0,27
Lisine	0,53	0,49	0,54
salt	0,27	0,29	0,32
Choline chloride	0,08	0,08	0,08
Total:	100,0	100,0	100,0

100 g contains, %			
Metabolizable energy, Kcal	300,0	305,0	315,0
crude protein	22,00	20,50	19,00
crude fiber	4,00	4,50	4,50
Lisine accessible	1,23	1,09	1,02
Methionine/cystine accessible	0,93	0,84	0,87
Threonine accessible	0,63	0,58	0,53
Calcium	0,96	0,90	0,90
Phosphorus accessible	0,48	0,40	0,40

Table 1: The content and nutritional value of compound feeds in all growing periods.

The chickens were divided into 2 group: control and experimental. For treatment, the TOR non-invasive electromagnetic therapy device (manufactured by JSC Concern GRANIT) was used. The operating principle is based on a weak non-ionizing non-thermal EMF continuously generated by high-voltage pulses with an amplitude of 5-8 kV, capable of influencing the pH of isotonic solutions at a distance of up to 900 m [18], as well as cell cytoplasm. The pulse frequency was 100-150 Hz. Each wave packet with steep rectangular fronts contained frequency modes multiples of 25 kHz. The operating power of the device did not exceed 80 W, which is less than the power of a standard incandescent lamp in rooms [19]. This treatment appeared to be effective in patients with Sars-Cov-2 [20]. Our previous studies also confirm the effectiveness of remote EMF exposure in crop production. According to the results obtained, an improvement in the agrotechnical parameters of grain crops was observed, namely an increase in yield by 7-48%, as well as a reduction in the content of mycotoxins in grain [21].

The poultry were exposed to the EMF of the TOR device for 12 hours a day (from 8.00 to 20.00) according to the following regime: 3 min – EMF exposure, 30 min – break. The average distance from the device to the experimental chickens was at least 3.0 m, the control group was outside the zone of action of the device at a distance of 10 km from the experimental group, due to the fact that the effect of the device can extend to a distance of about 1500 meters. Blood samples for analysis were obtained from each group of broilers at the age of 35 and 56 days from the axillary vein. Sterile vacuum tubes with the lithium-heparin anticoagulant were provided for biochemical studies of blood plasma. To separate the plasma from the blood cells, the samples were centrifuged at 5000 rpm for 5 min. ~~by~~ with an EVA-200 centrifuge (PRC). Biochemical blood tests were performed on a semi-automatic biochemical analyzer SINNOWA BS-3000P (SINNOWA Medical Science and Technology Co., Ltd, China) with certified reagent kits for determining total protein, alkaline phosphatase, calcium, phosphorus, cholesterol and triglycerides (DIAKON-VET, Russia). Hematological blood tests were performed on an automated veterinary haematology analyzer DF50 Vet by Dymind (China). This analyzer used laser flow cytometry to determine: total leukocyte count (WBC), neutrophil count in % (Neu, %), lymphocyte count in % (Lym, %), monocyte count in % (Mon, %), eosinophil count in % (Eos, %), basophil count in % (Bas, %), and the number of neutrophils, lymphocytes, monocytes, eosinophils, and basophils. The number of erythrocytes (RBC) and platelets (PLT) was determined by the conductometric method, haemoglobin concentration (HGB) and haematocrit (HCT) by the photometric method. The analyzer uses 3 reagents: DIL-C, LYC-1, LYC-2. Feed accounting was carried out on daily basis, weighing of broilers was implemented weekly from the first-day to the 56-day.

The experimental part of the study was conducted at one of the largest poultry production facilities located in the south of the Russian Federation. To maintain confidentiality, the name of the poultry farm is not disclosed in accordance with the Non-Disclosure Agreement (NDA). The study was conducted on a territory that included two floor-keeping buildings. The object of the study were 62,082 broiler chickens of the Ross-308 cross (Yaroslavl, Russian

Federation) from one day to 35 days of age. The chickens were divided into two groups, which were kept in two different buildings that were at a large distance from each other. The group exposed to EMF included 30,811 chickens, and the control group included 31,271 chickens. The stocking density was no more than 20 heads per 1 m^2 of the floor of the building. Both groups received the same diet. The chickens were fed with complete compound feeds in 3 periods: the starting period - from the 1st to the 10th day, the growth period - from the 11th to the 20th day and the finishing period - from the 21st to the 35th day. The birds were fed with loose compound feeds according to the standards for broilers, balanced in nutrients, energy, vitamins, microelements (OR) in accordance with the VNITIP standards [22]. In the first period, compound feed PK - 2 was used, in the second - PK-5 and in the third - PK - 6. The chickens had free access to feed and clean water. Distribution of feed and water was automated according to a preset program of the poultry house. The dynamics of changes in the live weight of broiler chickens was count by weighing broiler chickens of the control and experimental groups (n = 100) at the age of day 1, 7, 14, 21, 28, 35 days. Based on the obtained data on live weight in different age periods, the average daily gain (g) was calculated. Feed costs per 1 kg of gain were found as the ratio of feed costs for the entire population to the live weight of broiler chickens up to 35 days of age. Survival was found by subtracting dead broiler chickens from the total number, %; mortality was found by counting dead broiler chickens, %. Control over light, temperature and humidity conditions was carried out in two buildings simultaneously throughout the entire growing period in accordance with the recommendations for this cross of poultry [23].

The effect of EMF on the chickens of the experimental group was carried out using the "TOR" device with the characteristics and exposure scheme specified above in Experiment 1.

Statistical analysis

For statistical processing of the results, STATISTICA 8.0 and Microsoft Office Excel programs were used to calculate the mean (M) and standard deviation (± m). In the groups of experiment 2, the reliability of the differences was determined by the Student's t criterion, the differences were considered statistically significant at $p < 0.05$.

Results

Hematological analysis

As shown in Table 2, at 36 days of age in the experimental group, the total number of leukocytes is lower by 15.1% compared to the control group. At the same time, at 56-day (Table 3) age, an increase in this indicator is observed in the control group up to 60.0 x 10^9/l. In the experimental group the number of leucocytes in this age period was lower by 4.2% compared to the control group.

Haematological indices	Group	
	Control	Test
Leukocytes, 10^9/ l	53,7 ± 1,67	45,6 ± 2,84
Neutrophils, heterophils, %	33,7 ± 2,99	33,4 ± 1,56
Lymphocytes, %	63,6 ± 3,37	63,4 ± 1,95
Eosinophils,%	2,4 ± 0,37	2,8 ± 0,39
Erythrocytes, 10^{12}/ l	2,8 ± 0,04	2,5 ± 0,12
Haemoglobin, g/l	140,2 ± 2,11	126,0 ± 4,44
Haematocrit, %	36,3 ± 0,51	31,8 ± 1,40

Table 2: Comparison of main haematological blood parameters of 36-day-old broiler chickens (n = 5).

*Differences are statistically significant at $p \leq 0.05$ compared to age-matched controls.

The total number of leukocytes in both groups remained almost at the same level throughout the entire growing period.

In most vertebrates, there are five types of leucocytes: lymphocytes (Lym), neutrophils (Neu), eosinophils (Eos), basophils (Bas) and monocytes (Mon). In birds and reptiles, neutrophils are replaced by heterophils (Het), which perform the same immunological function.

Neutrophils/heterophils are the most numerous population of leukocytes that perform a protective function during inflammatory processes. Their main function is defense against infections. The data in Table 2 show that at 36 days of age, the neutrophil content is at the same level of 33% in the control and experimental groups. At 56 days of age (Table 3), a decrease in Het by 20.9% is observed in the experimental group. This may indicate a decrease in inflammatory reactions in the group exposed to the electromagnetic device.

Lymphocytes are the main cellular elements of the immune system, which are formed in the bone marrow and actively function in the lymphoid tissue. Their main function is to recognize foreign antigen and participate in the body's adequate immunological response. The lymphocytes content in the blood of chickens in both groups by 36 days of age was the same - 63%. In the control group, a decrease in the absolute number of these cells was further recorded until the end of rearing. At the age of 56 days their number reached the minimum value - 41.8 %. In the experimental group at 56 days of age, this indicator was 32.5% higher than in the control group. This may indicate an increase in phagocytosis processes in the organism of poultry in this group.

Eosinophils constitute only 0.5-5% of the total number of leucocytes. In our studies, we found an increase in the number of eosinophilic cells in the blood of chickens on the 36th day of growing in the experimental group by 16.7%. Later (56 days), a reliable dynamic of a decrease in eosinophils in the experimental group by 37.9% was observed. It is known from the literature that the period of half-stay of eosinophils in the bloodstream is about 18 hours and this period can vary in different pathological situations. Therefore, this decrease on the 56th day of rearing in the experimental group may indicate that the apoptosis processes of eosinophils were reduced due to reduced corticosteroid release. This may indicate high stress resistance of poultry, as well as the formation of a more stable immune response of the organism under electromagnetic influence.

Haematological Indices	Group	
	Control	Test
Leukocytes, 10^9/l	60,0 ± 4,88	57,5 ± 2,64
Neutrophils, heterophils, %	50,8 ± 3,72	40,2 ± 2,04*
Lymphocytes, %	41,8 ± 4,39	55,4 ± 1,83*
Eosinophils, %	6,6 ± 0,70	4,1 ± 0,25*
Erythrocytes, 10^{12}/l	3,0 ± 0,12	2,9 ± 0,10
Haemoglobin, g/l	152,5 ± 6,67	151,8 ± 4,15
Haematocrit, %	38,7 ± 1,74	38,6 ± 1,17

Table 3: Comparison of main haematological blood parameters of 56-day-old broiler chickens (n = 5).

*Differences are statistically significant at $p \leq 0.05$ compared to age-matched controls.

At the age of 36 days, the experimental group showed a decrease in the number of erythrocytes by 10.7% compared to the control group (Table 2). At the age of 56 days, the number of erythrocytes in the control group was 3.0 x 10^{12}/l. On the contrary, in the experimental group, an insignificant decrease of 3.4% was observed compared to the control group (Table 3).

It is known that the amount of haemoglobin in the blood of birds varies significantly depending on species, age, productivity and feeding. Particularly significant fluctuations can be observed in highly productive poultry. At the age of 36 days, the experimental group broiler chickens showed a decrease in this indicator by 10.1% compared to the control. At the same time, by 56 days of rearing this indicator increased to 152 g/l in both groups (Table 3). Such an increase at the end of rearing may indicate excessive muscle load on the broiler organism due to intensive weight gain.

Similar changes are observed with the hematocrit level in the blood of broilers.

In the experimental group, a decrease of 12.4% is observed at the age of 36 days, and by the age of 56 days, this indicator was also at the same level as the control group (38%). Hematological analysis offers several advantages in assessing the health status of poultry. The use of pathogen-resistant individuals in poultry production allows for a significant increase in the microbiological safety of poultry products reaching the consumer; which can be achieved using new technologies, including electromagnetic exposure.

Biochemical analysis

The serum biochemical parameters in chickens are shown in table 4.

Indicator	Group	
	Control	Experimantal
36-day		
Total protein, g/l	42,0 ± 0,39	39,4 ± 0,66*
Alkaline phosphatase activity, units/l	3830 ± 253,6	3829 ± 147,0
Cholesterol, mmol/l	3,5 ± 0,12	2,5 ± 0,06*
Triglycerides, mmol/l	2,2 ± 0,06	1,5 ± 0,08*
Calcium, mol/l	2,9 ± 0,03	2,9 ± 0,12
Phosphorus, mol/l	3,2 ± 0,09	3,3 ± 0,09
56-day		
Total protein, g/l	43,6 ± 0,94	46,0 ± 0,26*
Alkaline phosphatase activity, units/l	1601 ± 66,5	1603 ± 78,9
Cholesterol, mmol/l	3,5 ± 0,11	4,3 ± 0,22*
Triglycerides, mmol/l	2,1 ± 0,16	2,1 ± 0,04
Calcium, mol/l	3,8 ± 0,05	3,6 ± 0,09
Phosphorus, mol/l	2,8 ± 0,18	2,3 ± 0,11

Table 4: Blood plasma biochemical parameters of 36- and 56-day broilers.

*The differences are statistically significant at $p < 0.05$ vs the control group.

Serum proteins play an important role in the growth, development, and formation of immunity. Their normal content can vary within a fairly wide range. In the present study (Table 3), this indicator was within the physiological norm. However, in 36-day broilers of the experimental group, a reliable ($p < 0.05$) decrease in whey protein by 6.2% was noted compared to the control group. The obtained data indicate a change in the total protein concentration, which varies depending on age and metabolic processes, associated with the growth and development of broilers in the experimental group. Exposure to EMF led to an increase in the intensity of the poultry growth. A total protein parameter decrease in the experimental group may indicate an accelerated increase in the live weight of broilers. Conversely, in 56-day-old broilers of the experimental group, this indicator increases by 5.5% compared to the control group, which indicates the depletion of the growth potential of broilers exposed to EMF at the final stage of maintenance.

According to the present study results, the enzyme activity of 36- and 56-old day chickens of both groups (Table 3) was at the same level, which indicates a normal course of metabolic processes without inflammatory and destructive reactions.

By the age of 36 days, no significant differences in the calcium and phosphorus content in the blood were observed in all groups. However, at the age of 56 days, the experimental group showed a decrease in calcium levels by 5.26%, and phosphorus levels by 17.8%, respectively, vs control group. A decrease in the content of minerals in the blood plasma indicated a better digestibility of the nutrition elements in EMF-treated broilers.

The biochemical parameters of blood reflecting lipid metabolism are presented in table. 3. In 36-day broilers of the experimental group, the content of triglycerides in the blood plasma was significantly lower by 31.8% ($p < 0.05$) compared to the control group. A similar trend was observed for the cholesterol content. These indicators reflect a higher level of energy supply in the chickens of the experimental group. At the age of 56 days, triglyceride levels in both groups were almost the same. The concentration of cholesterol at this age in the experimental group increased by 22.9% vs the control group, which also indicates an improvement in the intensity of lipid metabolism in EMF-treated poultry.

Zootechnical studies

The results of research and production Experiment 1 are presented in figure 1-5. From the presented data it is evident that the treatment with TOR device affected the live weight of chickens, increasing it compared to the control group.

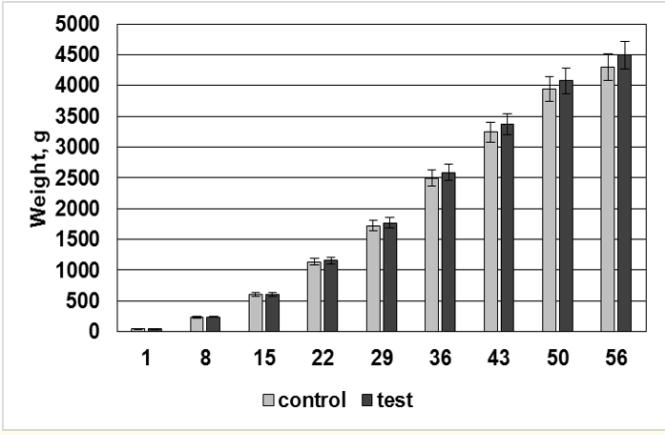

Figure 1: Live weight of broiler chickens from day old to 56 days old, g.

Figure 2 shows that at 8 days of age, the average daily live weight gain in the EMF group was 3.96% higher than in the control group. Feed consumption per 1 head for the period from day-old to 8-day-old in the experimental group was equal to that in the control group (Figure 3). Feed conversion for the 8-day rearing period in the experimental group was 3.7% lower compared to the control group (Figure 4).

Over 15 days of rearing, the live weight in the experimental group was higher by 0.35% compared to the control (Figure 1). Feed consumption and feed expenditure for the first 2 weeks of rearing per head for the period from day-old to 15 days of age in the experimental group was also lower by 1.9% and 1.4%, respectively, compared to the control group (Figure 3,4).

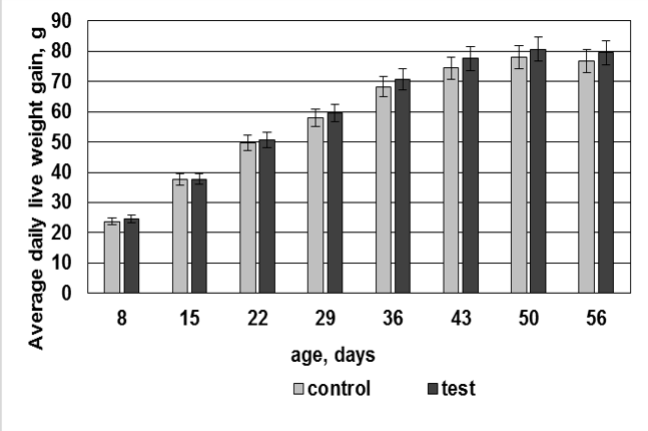

Figure 2: Average daily live weight gain of broiler chickens during the whole growing period, g.

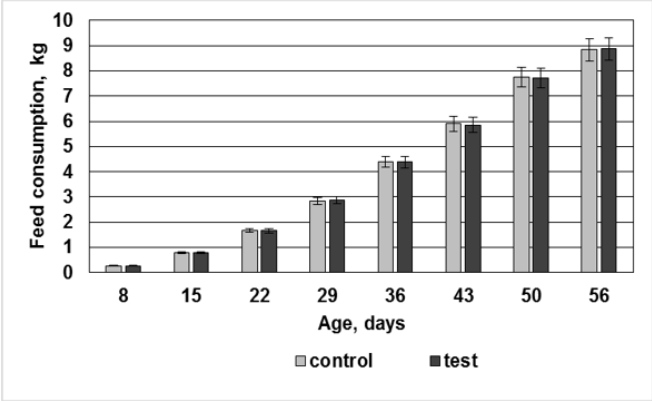

Figure 3: Feed consumption per head for the whole period of broiler chick rearing, kg.

In the third week of rearing (22 days), live weight was higher by 1.77% compared to the control group (Figure 1). A similar pattern was observed in the average daily weight gain: in the experimental group this indicator was higher by 1.87% compared to the control group (Figure 2). During this period of rearing, feed conversion was also better in the experimental group as compared to the control.

In the period from day-old to 29 days old, better results were observed in the experimental group compared to the control. Thus, live weight was higher by 2,61%, the average daily gain was higher by 2,71%, and feed costs per 1 kg of live weight gain were lower by 1,8%.

Over 5 weeks of rearing (from day-old to 36-day-old), the live weight of the experimental group increased by 3.68% compared to the control group, and feed conversion improved by 3.9%.

Similar trends were observed in the experimental group on the 43rd day of rearing: the live weight of the chickens in this group was 4.18% higher than in the control group and feed conversion was 4.89% better.

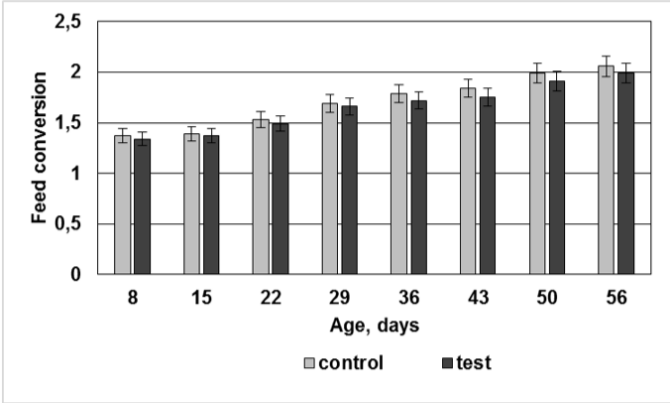

Figure 4: Feed conversion in broiler chickens during rearing periods.

Over the entire rearing period from day-old to 56 days of age, the average daily live weight gain in the experimental group was 3.62% higher compared to the control group (Figure 2). Feed consumption per 1 head over the entire rearing period in both groups was practically at the same level (Figure 3). At the same time, feed conversion in the experimental group was lower by 3.4% compared to the control group (Figure 4).

Experiment 2

Since the results of the zootechnical parameters were obtained on small stock, we decided to test this method on a poultry farm with a large number of poultry. For this purpose, we obtained voluntary consent from the poultry farm management farm to conduct research on production testing. The results of the research are presented in Figures. 5, 6, 7.

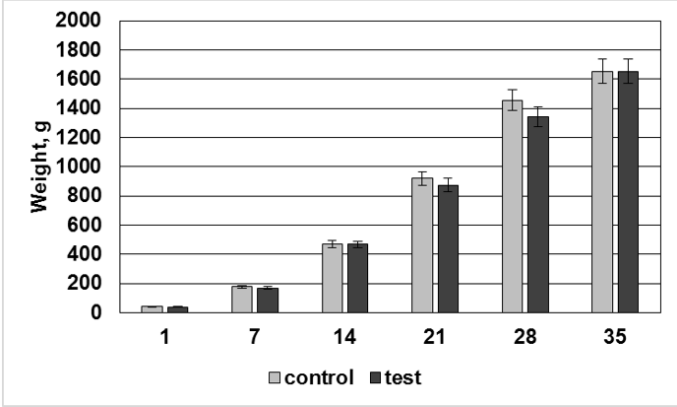

Figure 5: Live weight of broiler chickens in experiment 2.

In the course of Experiment 2, it was found that at the day-one age the average weight of the experimental group was 2 g less compared to the control group, and during the whole rearing period this indicator remained insignificantly lower (Figure 5). However, by the end of the rearing period (35 days), the live weight in both groups became similar. We assume that if the average daily live weight of all chicks in both groups was the same as in Experiment 1, we could also obtain an increase in this indicator in Experiment 2 using EMF.

The data presented in Figure 6 show that up to 28 days of age, the average daily gain of the chickens was lower than that of the control group. At 7 days of age, it was 4.8% lower in the experimental group, and at 14 days, it was 2.1% higher than in the control group. At 21 days and 28 days of age, the average daily gain was again lower by 10.8% and 14.5%, respectively, compared to the control group. However, at 35 days of age, a significant increase of 57.6% ($p < 0.001$) was observed in the experimental group compared to the control group.

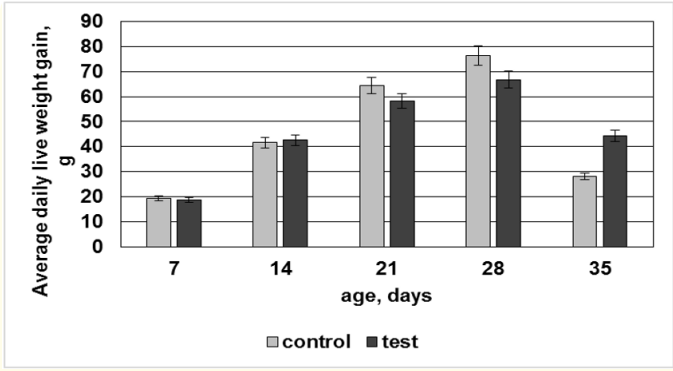

Figure 6: Average daily live weight gain of broiler chickens for the whole growing period in experiment 2, g.

The main zootechnical parameters of broiler chickens from daily to 35 days of age are presented in figure 7. For better visualization of the material feed conversion and poultry mortality in the figure were enlarged 10 times.

From figure 7 shows that by the end of rearing (35 days of age), the safety of the birds in the experimental group was higher by 8.0% compared to the control group. Feed conversion in the experimental group was also lower by 9.8%.

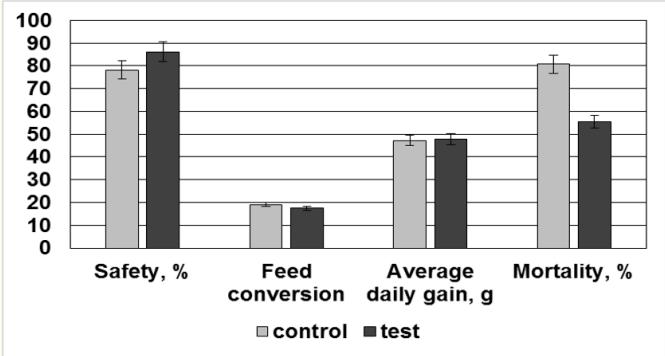

Figure 7: Zootechnical indicators of broiler chickens for the whole period of growing in experiment 2.

The average daily live weight gain by the end of rearing in the experimental group was slightly higher by 1.3%. Under the influence of EMF, there was a decrease in mortality by 2.52% compared to the control group.

Undoubtedly, that nowadays it is very difficult to choose a technology for growing completely healthy young poultry, which could play a key role in ensuring high poultry productivity. However, the use of electromagnetic radiation (EMR) in poultry production could potentially lead to increase in live weight, improved flock retention and reduced feed consumption, which is of key importance for large poultry farms.

Discussion

In modern poultry farming, one of the key challenges is to ensure high productivity and viability of commercial poultry. Achieving this goal requires a deep understanding of the biological processes that take place in the animal's body.

The immune system in a living organism plays the vital role in protecting against external stressors. Immune cells are involved in many physiological processes and are responsible for the proper functioning of the entire organism. Particular attention is paid to the role of various biological markers such as leukocytes [24], red blood cells and hemoglobin levels [25] in assessing the health and adaptive capacity of poultry. Any factor capable of inducing immunomodulatory effects may attenuate or enhance the immune response [26]. For example, the results of studies by Arbaga., *et al*. (2023) showed that EMR has a modulatory effect on the development of post-vicinal immune responses in poultry. The authors concluded that it is reasonable to use the method of irradiating industrial poultry with extremely high frequency electromagnetic radiation of non-thermal intensity as an immune corrector acting within physiological limits [27].

The results of our studies also confirm the beneficial effect of EMF on the organism of broiler chickens, reducing inflammatory processes in the body of poultry. In the work of Dobromyslova I.A., *et al*., 2018, it is also stated that electromagnetic irradiation in optimal doses improves the functions of hematopoietic organs: the number of formal elements increases within physiological norms, their biochemical functions are activated - the content of erythrocytes and hemoglobin, the level of total protein. The authors concluded that the increase in hemoglobin and erythrocytes in the blood of irradiated birds indicates stimulation of hematopoietic organs, improved tissue respiration and an increase in the level of basic metabolism. An increase in the number of hemopoietic cells and total protein also provides an increase in the immunobiological capacity of the organism as a whole [28]. Researchers [29] claim that erythrocytes of birds treated with EMF had higher functional capacity compared to control birds due to the effective functioning of respiratory function. This resulted in growth of birds and improvement of physiological parameters, contributed to the optimal functioning of organs, increased metabolism and high productivity of poultry.

According to our results, all changes in the morphological composition of the blood occurred within the physiological norm. The increase in the number of erythrocytes, haemoglobin and leucocytes can be characterized as an increase in the natural resistance of the organism, which is confirmed by a decrease in morbidity, mortality, an increase in average daily gain and a decrease in feed conversion. Achieving maximum productivity by broiler chickens in a short period of keeping under conditions of high metabolic intensity leads to a significant burden on the health of the poultry, which can further lead to defects in a number of functional systems [30,31]. Therefore, in the framework of our study, we assume that pulsed electromagnetic field (EMF) exposure to the poultry body leads to a state of eustress, which in turn has a positive effect on the immune system, a decrease in feed conversion ratio and an increase in body weight of birds after repeated sessions of EMF exposure.

The study features

The present study argued that broiler is extremely sensitive to weak non-ionizing non-thermal electromagnetic fields to great distances which permitted our team to influence on poultry growth and the morpho-biochemical indicators of poultry blood within big areas of poultry farms.

Conclusion

Many issues related to the poultry health require various kinds of intervention to strengthen the chicken immune system. The present research had shown a positive effect of EMF treatment on the broiler immune status. By the poultry keeping final stage (56-th day), the safety of poultry was held 100%, and with respect to the live weight in the experimental group, there was an upward tendency- 3.6% (36th day) and 4.5% (56th day) vs control group. This paper established the EMF treatment potency for poultry farming in the lines of physiological standards. EMF treatments of industrial poultry stocks ceteris paribus may provide their resistance to pathogens, as well as increase the live weight growth and poultry safety.

Positive effects of EMFs on poultry physiology we explained here in terms of eustress provided with enhanced ATP synthesis in cells according to the mentioned above model of ion -radical reactions, sensitive to weak electromagnetic fields [29]. Accelerated ATF synthesis in poultry body cells may be key-point to reach high stability in poultry farming economy.

Based on experience 2, we can conclude that the use of remote EMF treatment technology at large poultry farms with buildings up to 100 meters long and more, as well as floor or cage housing, can reduce the risks of mass mortality of chicks, reduce feed consumption and increase the safety of livestock.

The development of EMF methods to reduce the time required to sanitize the premises prior to the introduction of new chickens is also a promising area.

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