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ORIGINAL ARTICLE

Modeling the effect of different dose of selenium additives in compound feed on the efficiency of broiler chicken growth

O.I. Sobolev[1], D.V. Lisohurska[2], P.V. Pyvovar[2], P.P. Topolnytskyi[2], B.V. Gutyj[3], S.V. Sobolieva[1], O.O. Borshch[1], V.A. Liskovich[1], M.M. Verkholiuk[3], O.Y. Petryszak[3], O.V. Kuliaba[3], I.P. Golodiuk[3], O.S. Naumjuk[3], R.A. Petryszak[3], H.I. Dutka[3]

[1]Bila Tserkva National Agrarian University, Bila Tserkva, Ukraine
[2]Polissia National University, Zhytomyr, Ukraine
[3] Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine
**Corresponding author E-mail: bvh@ukr.net*
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In recent years, the current standards for introducing trace elements into compound feed for highly productive crosses and poultry breeds have been revising with taking into account new scientific data in many countries around the world. According to modern classification, selenium is recognized as an indispensable biotic ultra microelement. The standards of selenium introduction into compound feed for broiler chickens, which are recommended in different countries of the world and at different times, have specific differences and range from 0.1 to 0.5 mg/kg of feed. The differences are probably that the experiments were conducted under different conditions, against the background of different diets, on different poultry crosses, and using different selenium-containing compounds. Also, norms of selenium additives in compound feed for broiler chickens recommended by foreign and domestic scientists are not always supported by mathematical calculations, and, in our opinion, they should be estimated as indicative, requiring further specification depending on the regional characteristics of poultry feeding. As shown above, the standards of selenium supplements recommended by foreign scientists in complete feed for broiler chickens are contradictory. Mathematical calculations do not always support them. In our opinion, they should be evaluated as indicative, requiring further clarification depending on the regional characteristics of poultry feeding. Two scientific experiments were conducted, which lasted 42 days each, to determine the optimal rate of selenium introduction in compound feed for broiler chickens. The research is conducted on broiler chickens of the Coob 500 cross. In compound feeds for broiler chickens of experimental groups, selenium in doses of 0.2, 0.3, 0.4, and 0.5 mg/kg was additionally introduced. The poultry of the control group did not receive selenium supplementation. Statistical processing of experimental data obtained in two scientific experiments by graphical, variance, and regression analysis methods allows us to conclude that the optimal selenium dose in compound feed for broiler chickens should be considered at 0.3 mg/kg. During the growing period, broiler chickens feeding with compound feeds Se-enriched in this amount contributed to a likely increase in their live weight in the first experiment by 7.8 % (P<0,001), in the second experiment by 5.1 % (P<0.01), compared with the control group. Higher doses of selenium are (0.4 and 0.5 mg/kg) in compound feed, as well as a lower dose is (0.2 mg/kg), caused less intensive growth and less of broiler chickens live weight of other experimental groups in comparison with young animals that were fed compound feed with selenium supplement of 0.3 mg/kg.
Keywords: broiler chickens, selenium, optimal rate, compound feed, statistical methods of analysis.

Introduction

The results of numerous scientific research and world experience in the poultry industry show that full-fledged poultry feeding is the key to realizing its genetic potential, high productivity, conservation of livestock, and efficient use of feed. The modern system of normalized poultry feeding provides complete satisfaction of its individual need for energy, nutrients, and biologically active substances, including trace elements (Fisinin et al., 2011; Sychov et al., 2017; Gutyj et al., 2019; Bashchenko et al., 2021).

Trace elements cannot be synthesized in the body or replaced by other substances, and therefore the primary source of their entry into poultry' body is feed (Górniak et al., 2018; Nys et al., 2018). The need to add trace elements to compound feed for poultry is becoming important due to the decrease of their reserves in the soils of some regions and, as a result, in feed. Even if there is no total deficit (at zero levels) of any trace element, their natural content in grain feed does not correspond to the physiological needs of poultry. The possibility of increasing the concentration of trace elements in plant feeds by applying micronutrient fertilizers is quite problematic due to the heterogeneity of climatic and biogeochemical conditions in different regions. Therefore, even today, the issue of the effective use of trace elements in compound feeds for poultry remains relevant.

Domestic and foreign experience convincingly proves that the introduction of trace elements in compound feed for poultry in optimal quantities and ratios allows increasing its productivity and vitality and improving feed conversion and product quality. Despite the fact that there are many scientific works on the problem of mineral nutrition of poultry and the list of trace elements used in its diet is clearly insufficient. In recent years, the current standards for the introduction of trace elements into compound feed for highly productive crosses and poultry breeds have been revising with taking into account new scientific data in many countries around the world. According to modern classification, selenium is recognized as an indispensable biotic ultra microelement (Oberlis et al., 2008).

Analysis of the results of scientific research by scientists from different countries of the world has shown that selenium is a trace element with a wide spectrum of biological action (Sobolev et al., 2018). According to the results of numerous scientific research conducted on various species of farm animals and poultry have established that selenium has antioxidant properties (Surai, 2002; Zoidis et al., 2018), anticarcinogenic (Micke et al., 2009; Kuršvietienė et al., 2020), radioprotective (Brown et al., 2010; Graupner et al., 2016), immunostimulatory (Surai &Taylor-Pickard, 2008; Huang et al., 2012), anti-viral (Read-Snyder et al., 2009; Shojadoost et al., 2019), antitoxic (Chena et al., 2014; Mughal et al., 2017), adaptogenic (Habibian et al., 2015; Shakeri et al., 2020) and other properties.

The Discovery of the biological properties of selenium became the basis for its use as a mineral additive in poultry feeding. The inclusion of selenium to the composition of compound feeds improves health, and the egg productivity of industrial and parent poultry flock and feed efficiency increase (Surai, 2002; Liu et al., 2015). Optimization of selenium in poultry nutrition has a positive effect on the incubation qualities of eggs; in particular, it helps to increase their impregnation capacity, hatchability, and hatching chicks (Zia et al., 2017). Aqueous solutions of selenium are used for the pre-incubation treatment of hatchery eggs in order to stimulate the embryogenesis of chickens. The treatment of hatchery eggs with 0.01 % of sodium selenite solution with an exposure of 15 minutes suppresses the growth of pathogenic microflora in the egg, and eliminates edema of the head, neck, brain in embryos, and increases the hatchability of chickens, and subsequently their growth rate and viability (Djachenko & Pogibel'na, 2003).

Selenium supplements in the diet contribute to the enrichment of poultry meat and eggs with this trace element (Sobolev et al., 2020), improve shell quality (reduce the number and degree of structural defects), increase the mass, thickness, and shell strength (Boruta et al., 2007; Pavlović et al., 2009). Selenium use in poultry farming reduces the harmful effects of storing eggs and meat. During egg storage, protein oxidation occurs, which leads to dilution of a protein (a decrease of the Haugh Unit) and, accordingly, to its watery consistency. Selenium supplements to the poultry diet increase glutathione peroxidase activity in the egg, which prevents protein oxidation and thus slows down spoilage processes. These data are of commercial importance because they show the real possibilities of maintaining egg freshness (Baylan et al., 2010; Fernandez et al., 2011). The same thing happens with moisture loss during poultry meat storage. On the one hand, moisture loss occurs due to the destruction of cell membranes; on the other – due to proteins oxidation and a decrease of their moisture-retaining properties (Chegpiha et al., 2005; Wang et al., 2009).

Selenium enrichment of compound feeds for young meat poultry of various poultry species helps increase their growth intensity and safety and reduce feed costs per unit of live weight gain (Nevzorova & Karmackih, 2010; Sobolev, 2011). Optimization of selenium levels in the diet significantly affects the meat productivity of turkeys, chickens, ducklings, and goslings, in particular, increases the slaughter yield and weight of edible parts of the carcass due to better development of muscle tissue, skin with subcutaneous fat, edible entrails and reducing the specific weight of bones. Meat indices are improving (Suhanova & Mahalov, 2007; Sobolev, 2012). There are publications of Ukrainian and foreign authors who believe that some indicators that characterize poultry meat quality depend on selenium level in compound feeds. It is noted that the introduction of selenium in diets of young poultry meat productivity, the moisture loss of meat reduces during slaughter and cooking, the taste and chemical composition of meat improves, in particular, it helps to increase the content of dry matter, protein and fat in the muscles of the chest and legs, as well as increases the nutritional and biological value of poultry meat (Sobolev et al., 2019; Mohamed et al., 2020). It was also established that under the influence of selenium, the content and profile of individual free amino acids in poultry meat changes, which is explained by the influence of this trace element on the metabolism of blood proteins, which are a structural material for building muscle tissue (Rjabchyk, 2009; Shevchenko et al., 2009).

The introduction of selenium into poultry compound feed has a positive effect on the development of the digestive system in young poultry, contributes to an increase in the mass and total length of the intestine in general and its departments in particular, as well as the weight of the muscular stomach and liver (Kuleshov, 2010; Sobolev et al., 2019). Selenium supplements in compound feed accelerate and improve the formation of feathers on the back, neck, wings, chest, and lower bird body. From a practical point of view, this fact is essential. Broiler chickens have reduced energy losses, which leads to feeding savings and reduces the probability of pecking in the herd (Edens et al., 2001; Van Emous & Van Krimpen, 2019). The inclusion of selenium in compound feeds significantly affects the feather productivity of poultry; in particular, the quantity and quality of feather products increase in young poultry and adult geese (Djebrov et al., 2006; Suhanova & Nevzorova, 2007).

Many scientists associate the increased productive qualities of poultry with changes in the body's metabolism. Thus, under the influence of selenium, the metabolic energy of feed is used more efficiently (Suhanova, & Mahalov, 2010), the digestibility of nutrients (protein, fat, fiber, BER, ash) improves (Suhanova & Nevzorova, 2007; Kornilova, 2009; Sobolev, 2014), and the deposition and assimilation of nitrogen, calcium, phosphorus and selenium increases (Yoon et al., 2007; Perepjolkina & Krasnoshhjokova, 2008; Sobolev, 2012). This is explained by the increased biosynthesis of selenium-containing proteins in the mucous membrane of the small intestine, which probably leads to an increase in the intensity of absorption and, as a result, to complete extraction of nutrients and minerals from the feed.

Thus, from the point of view of modern concepts, the normal functioning of the poultry's body and the full realization of its genetic potential is impossible without selenium in the diet. The standards of selenium introduction into compound feed for broiler chickens, which are recommended in different countries of the world and at different times, have specific differences and range from 0.15 to 0.5 mg/kg of feed. The differences are probably that the experiments were conducted under different conditions, against the background of different diets, on different poultry crosses, and using different selenium-containing compounds.

Some time ago, American poultry feeding standards noted that broiler chickens should receive selenium supplementation in compound feeding the amount of 0.15 mg/kg during the entire growing period (NRC, 1994).

Today, Russian scientists believe that to achieve high productivity in compound feed for broiler chickens, it is enough to introduce selenium at a dose of 0.2 mg/kg (Fisinin, 2005). The same opinion is shared by scientists from the American company Hubbard (Navidshad et al., 2019). Scientists from the "Coob" company believe that the standard of selenium supplementation to compound feed for broiler chickens should be 0.35 mg/kg (Cobb 500, 2018). Another British poultry company "Aviagen" recommends introducing selenium into compound feed in the amount of 0.3 mg/kg for broiler chickens (Ross Broiler, 2019)

According to the recommendations of Brazilian scientists, the rate of selenium introduction into compound feed for broiler chickens during the growth period of 1-7 days should be 0.375 mg/kg; 8-21 days – 0.33; 22-33 days – 0.30; 34-42 days – 0.225 and 43-49 days – 0.195 mg/kg (Rostagno et al., 2011). According to the recommendations of Belarusian scientists, the selenium level in compound feeds for broiler chickens should be 0.5 mg/kg (Ponomarenko, 2007). In the meantime, Canadian scientists claim that the selenium concentration in compound feeds for broiler chickens should not exceed 0.3 mg/kg (CFIA, 2018).

Ukrainian scientists relatively recently began to recommend compound feed for various poultry species, including broiler chickens and enriched with selenium at the rate of 0.1 mg/kg (Bratishko et al., 2013). However, this does corresponds only to the minimum physiological need of poultry for this trace element. In developing standards for selenium introduction, scientists pay attention to

the recommended maximum acceptable levels of it in compound feed for poultry, which sometimes differ several times in different countries. For example, according to EU law, the selenium level (natural content in feed ingredients + additive) allowed in poultry diets is 0.5 mg/kg (Zoidis et al., 2010). The Canadian Food Inspection Agency (CFIA) has increased the maximum acceptable selenium level in poultry feed from 0.5 to 1.0 mg/kg (CFIA, 2018). The National Research Council of the United States (NRC) has established the maximum acceptable selenium level in compound feed for all farm animals and poultry species at 2 mg/kg (McDowell, 2003). The maximum acceptable selenium level in compound feed for poultry raised for meat in Russia is 1.0 mg/kg (VetPiN, 2003), in the Republic of Belarus, it is 1.0 mg/kg (Postanovlenie, 2011), in Ukraine is 0.5 mg/kg of feed (Order, 2012).
As shown above, the standards of selenium supplements recommended by foreign scientists in compound feed for broiler chickens are contradictory. Mathematical calculations do not always support them. In our opinion, they should be evaluated as indicative, requiring further clarification depending on the regional characteristics of poultry feeding.

Materials and methods

Two scientific experiments were conducted, which lasted 42 days each, to determine the optimal rate of selenium introduction in compound feed for broiler chickens. The research is conducted on broiler chickens of the Coob 500 cross.
According to analogs, the groups of daily young poultry were formed to conduct scientific experiments, taking into account live weight, origin, and physiological state (mobility, umbilical cord state, and featherless).
The poultry of the control group was fed compound feed balanced by the essential nutrients and biologically active substances during the rearing period. The poultry of experimental groups was additionally introduced into compound feed with different amounts of selenium according to the experimental schemes (Table 1). Selenium in feed for broiler chickens was taken as part of the mineral premix. As a source of selenium used sodium selenite.

Table 1. Schemes of experiments.

Group	Number of chickens in the group, heads		Selenium supplement in complete feed, mg/kg
	at the beginning of the experiment	at the end of the experiment	
Scheme of the first scientific experiment			
1 control (D1_1)	100	90	Complete feed – CF
2 experimental (D1_2)	100	91	CF + 0.2
3 experimental (D1_3)	100	95	CF + 0.3
4 experimental (D1_4)	100	94	CF +0.4
Scheme of the second scientific experiment			
1 control (D2_1)	100	95	Complete feed – CF
2 experimental (D2_2)	100	97	CF + 0.3
3 experimental (D2_3)	100	96	CF + 0.4
4 experimental (D2_4)	100	96	CF +0.5

In both experiments, broiler chickens were fed with complete dry compound feeds according to existing standards (Bratyshko et al., 2005). Broiler chickens were raised on a deep litter, with free access to feed and water, in compliance with the technological parameters of amount of floor space per bird, microclimate, and lighting according to existing standards (Galibarenko et al., 2005).
For mathematical processing of research result, a graphical analysis of the experimental results was performed as well as methods of variance and regression analysis implemented in the R software environment (R is a programming language and free software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing) were used.

Results and discussion

Graphical analysis was performed for each experiment using the *violin* procedure (Wickham & Chang, 2012), which is used to plot the density distribution of experimental results by groups and determine the marker for the median of data and the distribution of measurements by quartile.
Analysis of the results obtained by processing data from the first experiment (Figure 1, Table 2) indicates a shift in the median towards higher values of live weight of broiler chickens. If we choose not the same average weight (standardization) of broiler chickens as a sign of the effectiveness of selenium supplements but the weight of obtained products, then the experimental group D1_3 is undoubtedly more attractive. At the same time, taking into account descriptive statistics, it should be noted that the peculiarity of this group (D1_3) is a significant dispersion of live weight, which indicates an unequal positive effect of a selenium dose of 0.3 mg/kg on broiler chickens growth.
Analysis of the results obtained by data processing from the second experiment (Figure 2, Table 2), as in the first experiment, indicates an increase in the live weight of broiler chickens when selenium additives are introduced into compound feed. Simultaneously, the most significant increase in live weight of broiler chickens was observed in the experimental group D2_2. However, there is no significant dispersion of the results, which indicates a greater identity of the effect of selenium supplementation on chicken growth. In groups D1_3 and D2_2, the dose of selenium supplementation in compound feed was the same and amounted to 0.3 mg/kg. Descriptive statistics data also evidence the conclusions drawn: arithmetic mean (mean), standard deviation (sd), median (median), trimmed mean (trimmed), the median value of absolute deviation from the median (mad), minimum and maximum values (min, max), range of variation (range). They also indicate that the most effective dose of selenium in compound feed for broiler chicken is 0.3 mg/kg.

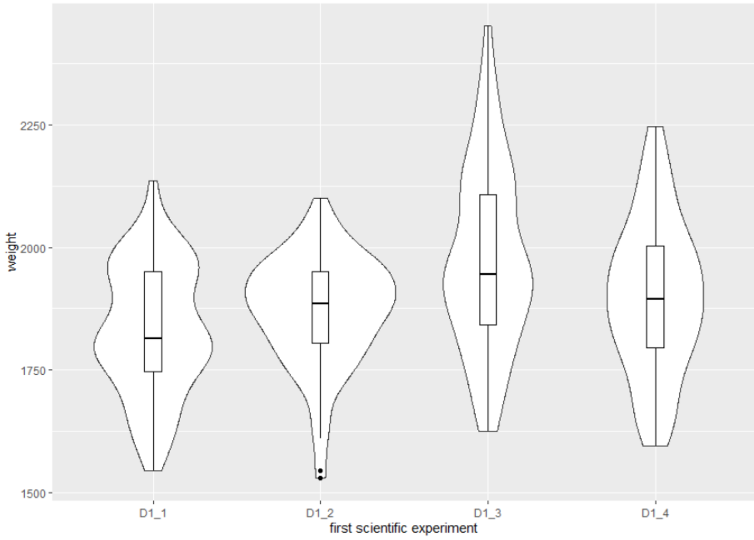

Fig. 1. Violin plot and boxplot for the first scientific experiment.

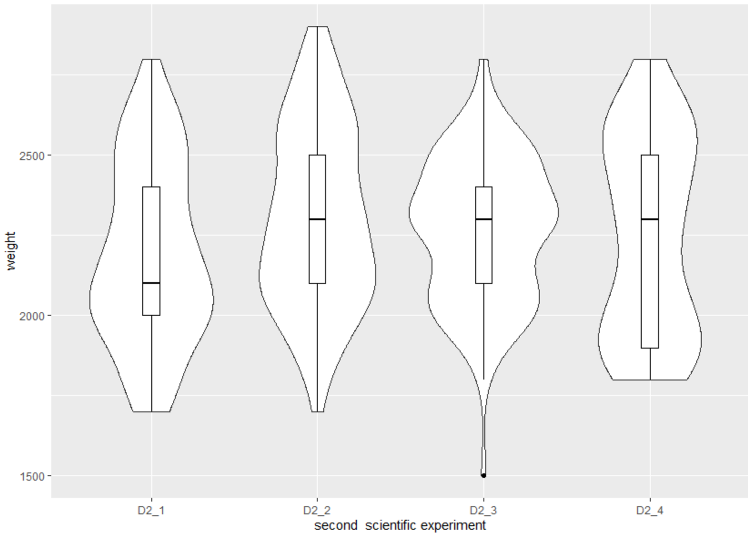

Fig. 2. Violin plot and boxplot for the second scientific experiment.

Table 2. Descriptive ststatistics for the studied groups.

Group	n	mean	sd	median	trimmed	mad	min	max	range
First scientific experiment									
1 control (D1_1)	94	1831.70	131.19	1815	1833.88	159.38	1545	2135	590
2 experimental (D1_2)	93	1870.38	111.52	1885	1877.73	96.37	1530	2100	570
3 experimental (D1_3)	95	1974.79	184.65	1945	1968.90	214.98	1625	2450	825
4 experimental (D1_4)	95	1899.47	156.03	1895	1897.60	155.67	1595	2245	650
Second scientific experiment									
1 control (D2_1)	95	2188.42	280.53	2100	2183.12	296.52	1700	2800	1100
2 experimental (D2_2)	97	2301.03	278.95	2300	2296.20	296.52	1700	2900	1200
3 experimental (D2_3)	96	2263.54	227.17	2300	2266.67	296.52	1500	2800	1300
4 experimental (D2_4)	96	2245.83	311.50	2300	2242.31	444.78	1800	2800	1000

To verify the conclusions drawn by graphical analysis, an analysis of variance of the experimental results was performed. The main prerequisites for applying analysis of variance are the following requirements: firstly, observations obey the common distribution law; secondly, the variances in groups are approximately equal. The quantitative value in the experiments is the live weight of broiler chickens; it is for it that we will test the hypothesis of normality. The Shapiro-Wilk test was used to test the hypothesis (Hanusz et al., 2016). The verification results are presented in Table 3. The table for each group shows the W- a value of the criterion and the significance level of *the p-value*. As can be seen from the data in Table 3, *the p-value* for the results of experiments in all groups of the first experiment lies in the range of 0.102–0.3434 and the second experiment – in the range of 0.09168–0.1836 at the significance level P=0.05. *The p-value* in all groups is higher than the significance level; respectively, the hypothesis of distribution normality is accepted. Therefore, we can apply analysis of variance.

Table 3. Parameters for checking the normality of research results.

Group	W	p-value
	First scientific experiment	
1 control (D1_1)	0.97648	0.102
2 experimental (D1_2)	0.9838	0.3198
3 experimental (D1_3)	0.98113	0.18178
4 experimental (D1_4)	0.9847	0.3434
	Second scientific experiment	
1 control (D2_1)	0.9801	0.1836
2 experimental (D2_2)	0.97604	0.09489
3 experimental (D2_3)	0.97583	0.09168
4 experimental (D2_4)	0.97706	0.1121

Application of analysis of variance is carried out to study the significance of the difference between the average values of live weight of poultry in experimental groups. The research was conducted using the AOV (analysis of variance) procedure (Gelman, 2005) in the R software environment. As is know, the test of significance, when using analysis of variance, is based on comparing the variance caused by the intergroup and intra-group spread of measurement results.

The research results were processed using analysis of variance in two steps. Firstly, the effect of selenium additives in compound feed on the live weight of broiler chickens was analyzed for the entire volume of experimental data (Table 3). Secondly, the poultry group with the maximum effect of selenium on the parameter under study was determined.

The essence of the first stage of verification is to test the hypothesis H_0 about the equality of the average values of live weight of poultry in the control and experimental samples for two experiments separately. Analysis of the data in Tables 4 and 5 shows that the obtained *p-value* is less than the specified significance level P=0.05. An equality hypothesis of average values is rejected, which allows us to conclude with a high level of statistical significance that selenium supplements in compound feed positively affect broiler chicken's growth.

Table 4. Results of analysis based on the General Dataset for the first scientific experiment.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
D	3	1039570	346523	15.69	1.25e-09	***
Residual	373	8237909	22086			
Signif. Codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Table 5. Results of analysis based on the General Dataset for the second scientific experiment.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
D	3	632111	210704	2.762	0.0419	*
Residual	380	28987889	76284			
Signif. Codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

We identify the experimental groups with the greatest effect of selenium on the growth of broiler chickens in each experiment. The results of the research are shown in Tables 6 and 7. *The Tukey's test* was used to perform the multiple hypothesis testing procedure (Hoaglin et al., 2000). The Tukey HSD procedure is used in the R environment to test for this criterion (Abdi & Williams, 2010). Analysis of the obtained data allows us to conclude that it is possible to reject an equality hypothesis of the average values of live weight of broiler chickens of the control and experimental groups D1_3 and D2_2 in the first and second experiments, respectively. For these groups, *the p-value* is less than the specified significance level P=0.05.

Table 6. Results of analysis of variance by experimental groups for the first scientific experiment.

	diff	Lwr.	Upr.	p adj
D1_2–D1_1	38.67422	-17.41747	94.76590	0.2849208
D1_3–D1_1	143.08735	87.29325	198.88145	0.0000000
D1_4–D1_1	67.77156	11.97746	123.56566	0.0099937

Table 7. Results of analysis of variance by experimental groups for the second scientific experiment.

	diff	Lwr.	Upr.	p adj
D2_2–D2_1	112.60988	9.734285	215.48547	0.0255663
D2_3–D2_1	75.12061	-28.019750	178.26098	0.2386250
D2_4–D2_1	57.41228	-45.728083	160.55264	0.4774159

Thus, the analysis of variance showed that the maximum effect of using selenium supplements in broiler chicken feeding was observed in the experimental groups D1_3 and D2_2. The poultry of these groups was fed Se-enriched compound feed at 0.3 mg/kg during the rearing period. To confirm the results of graphical analysis and analysis of variance, we will perform a regression analysis of obtained experimental data. The results of the research are shown in Tables 8 and 9.

Table 8. Results of regression analysis by experimental groups for the first scientific experiment.

Residual:						
	Min	1Q	Median	3Q	Max	
	-349.79	-94.79	-0.38	104.62	475.21	
Coefficients:						
	Estimate	Std. Error	t value	Pr(>|t|)		
(Intersept)	1831.70	15.33	119.499	<2e-16		***
DD1_2	38.67	21.74	1.779	0.07600		.
DD1_3	143.09	21.62	6.618	1.27e-10		***
DD1_4	67.77	21.62	3.135	0.00186		**
Signif. Codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Residual standard error: 148.6 on 373 degrees of freedom						
Multiple R-squared: 0.1121, Adjusted R-squared: 0.1049						
F-statistic: 15.69 on 3 and 373 DF, p-value: 1.249e-09						

Table 9. Results of regression analysis by experimental groups for the second scientific experiment.

Residual:						
	Min	1Q	Median	3Q	Max	
	-763.54	-201.03	11.58	236.46	611.58	
Coefficients:						
	Estimate	Std. Error	t value	Pr(>|t|)		
(Intersept)	2188.42	28.34	77.228	<2e-16		***
DD2_2	112.61	39.87	2.825	0.00498		**
DD2_3	75.12	39.97	1.879	0.06095		.
DD2_4	57.41	39.97	1.436	0.15172		
Signif. Codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Residual standard error: 276.2 on 380 degrees of freedom						
Multiple R-squared: 0.02134, Adjusted R-squared: 0.01361						
F-statistic: 2.762 on 3 and 380 DF, p-value: 0.0419						

The regression analysis of the results from the first experiment (Table 8) shows the greatest effect of selenium supplementation on the live weight of broiler chickens of the experimental group D1_3 and high statistical significance of the obtained model p-value=1.27 e-10 at the significance level P=0.05. Analysis of the results of regression analysis of data from the second experiment indicates the greatest positive effect of selenium on a similar indicator in the experimental group D2_2 and high statistical significance of the obtained model p-value=0.00498 at the significance level P=0.05.

Conclusions

Statistical processing of experimental data obtained in two scientific experiments by graphical, variance, and regression analysis methods allows us to conclude that the optimal selenium dose in compound feed for broiler chickens should be considered at 0.3 mg/kg. During the growing period, broiler chickens feeding with compound feeds Se-enriched in this amount contributed to a likely increase in their live weight in the first experiment by 7.8 % (P<0.001), in the second experiment by 5.1 % (P<0.01), compared with the control group. Higher doses of selenium are (0.4 and 0.5 mg/kg) in compound feed, as well as a lower dose is (0.2 mg/kg), caused less intensive growth and less of broiler chickens live weight of other experimental groups in comparison with young animals that were fed compound feed with selenium supplement of 0.3 mg/kg. The most acceptable way to Se-enriched compound feed for broiler chickens is to include it in mineral premixes.

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