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Effect of Primary and Active Shungite on the Quality of Feed, Meat and Eggs of Broilers

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ABSTRACT

The main purpose of this study was to assess the impact of primary and active Shungite in the diet of Arbor Acres cross broilers on the quality of feed, eggs, and meat. A total of 180 chickens aged 21 weeks were used in the experiment and randomly divided into three groups of 60 chickens each. The first (control) group was fed the basic diet. The second group received the basic diet with 5% primary Shungite in powder. The third group received the basic diet with 5% active Shungite. Sample collection and laboratory analysis were carried out following regulatory documents. Based on the results, the authors determined the positive effects of primary and active Shungite on the total content of mineral elements in feed, meat, and eggs. Based on the analysis of meat, the protein content in the eggs from the third group significantly increased (by 8.3%) compared to the control group. The difference between the second and third groups was insignificant. The ash content increased in the muscles and eggs in the experimental groups, leading to a higher content of mineral elements. Including active Shungite in the diet of Arbor Acres cross broilers has significantly enhanced the quality of meat and eggs. This improvement was marked by increased protein and ash content and higher levels of essential macro- and microelements, demonstrating the potential of Shungite as a valuable dietary supplement for poultry.

Key words: Broiler, Chemical composition, Feed additive, Macroelements, Microelements, Veterinary and sanitary assessment

INTRODUCTION

Poultry farming is a rapidly advancing sector within agriculture (Omer et al. 2019). Its extensive development can be attributed to several factors: 1) the greater profitability of producing eggs and meat in poultry compared to other animal species, 2) the dietary and nutritional benefits of poultry products and 3) the rapid growth and breeding capabilities of poultry, which enhance the productivity of meat and egg production (Nkukwana 2018; Buyarov et al. 2019).

The feeds of plant and animal origin used in poultry farming do not always meet biological safety requirements. These are subject to spoilage by mycotoxin-producing fungi causing enormous economic damage (Matuszek and Królczyk 2017). Feed additives based on natural minerals can neutralize mycotoxins, enrich feed with minerals, improve the digestibility of nutrients, reduce the toxicological burden on the body, increase safety and productivity, and improve the composition and ecological purity of products (Atabayeva et al. 2018; Zhyrgalova et al. 2024). In the last decade, non-traditional mineral feed sources, including Shungite, have been increasingly used.

Shungite is a rare natural black mineral. It grinds well, has many unique properties and contains 31 chemical elements, 17 of which can be added to animal diets (Erenko et al. 2024; Tkeshelashvili and Bobozhonova 2024).

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Fullerenes, new forms of carbon in the form of spherical ions, have been found in it. Shungite has high activity in redox processes and sorption and catalytic properties, which opens up prospects for its use in various fields of production, medicine, and veterinary medicine (Shevchenko et al. 2023).

The mineral form of Shungite is a non-graphitized, fullerene-like carbon distinct from graphite in terms of its supramolecular, atomic and electronic (ribbon) structure (Obradović et al. 2019). Research on Shungite has been conducted for more than 200 years (Skrypnik et al. 2021). Shungite can be utilized in various economic sectors in several ways, including the production of water filters, serving as an antioxidant and anti-inflammatory agent in veterinary medicine, and being used as a sorbent and feed additive (Sajo et al. 2017; Mooste et al. 2021).

By delving deeper into the molecular composition of Shungite, researchers can uncover new and valuable properties that can be harnessed in various industrial processes. This exploration can advance cutting-edge filtration systems and environmental remediation techniques that leverage Shungite's multifaceted capabilities. In addition to water purification, Shungite's properties make it suitable for medical treatments and air purification and as a component in advanced materials for technological applications. The versatility and efficiency of Shungite not only address current environmental challenges but also pave the way for sustainable solutions in multiple fields, demonstrating its vast potential beyond traditional uses (Skrypnik et al. 2021).

All known Shungite deposits in Kazakhstan belong to the black shale regional metamorphic type—the estimated Shungite raw materials in Kazakhstan amount to millions of tons. There are several Shungite deposits in Kazakhstan, such as Koksu, Mayak, Akbalshyk, Shandashinskoye, Klubnichnoe, Ilchebekskoye, Eskenzhol, Konnozavodskoye, Zaborovskoye, Gavrilovskoye, Bakyrchik, etc. (Agibaeva 2006).

The main raw material source is Shungite rocks from the Bakyrchik deposit in the East Kazakhstan region. According to geological exploration data, the reserves of Shungite rock today amount to about 30 million tons (Rozhkova et al. 2020). The results of the elemental analysis show that in the samples of Shungite rocks of the Bakyrchik deposit, the content of C, N, H, and Na significantly increases, and the content of Se, Al, Mg, K, Ca, and Fe decreases after flotation (Bulegenova et al. 2014).

Research on Kazakh Shungite and its application is at an early stage, but now we can talk about significant interest in this mineral from the scientific community. Researchers actively study the properties of Shungite and the opportunities for its use in various fields. This study aimed to analyze the effect of primary (PS) and active Shungite (AS) in the amount of 5% in the diets of broiler chickens of the Arbor Acres cross on the quality of feed, meat, and eggs.

MATERIALS AND METHODS

Ethical approval

The research adhered to ethical standards set by the EU Directive 2010/63/EU (2010) on protecting animals used in scientific research.

AS composition

Shungite rock, a carbon-mineral raw material, was utilized to produce AS. This contact ore was discovered during the extraction of polymetallic ore at the Bakyrchik deposit. AS was obtained in two stages. In the first stage, to ensure uniform carbon distribution, work was carried out to stabilize the composition of Shungite materials by flotation enrichment on an FM-0.2M machine (Gornye Machiny JSC, Russia). Previously, the PS was crushed into fractions of up to 0.3mm and enriched by froth flotation on carbon. Flotation was carried out in one stage in an aqueous medium. The Shungite carbon concentrate was dried at 105±5°C for 3 hours with occasional stirring, reducing the moisture content to no more than 3.0%. The carbon concentrate was then briquettes. Wood chemical and coal tar were used as a binder, and the diameter of the die of the extruder was 1.7mm.

In the second stage, the resulting carbon concentrate of Shungite was subjected to additional drying, carbonation (in argon medium) at 700-750°C, and activation by jet water steam at 850-900°C. The elemental composition of the PS from the Bakyrchik deposit: C: 17.7; S: 0.2; N: 0.3; H: 0.02; SiO_2: 52.0; Na_2O: 1.4; MgO: 2.2; K_2O: 0.1; CaO: 1.1; Fe_2O_3+FeO: 4.2; Al_2O_3: 16.3; TiO_2: 0.7 (Efremov et al. 2013). The elemental composition of AS: C: 22.5; S: 0.0; N: 0.0; H: 0.0; SiO_2: 40.1; Na_2O: 0.7; MgO: 1.9; K_2O: 4.7; CaO: 2.5; Fe_2O_3+FeO: 10.3; Al_2O_3: 16.4; TiO_2: 0.9.

Based on the data from the elemental analysis of the studied Shungite (Table 1), after flotation enrichment of the PS, the carbon content significantly increases; in AS, which lacks sulfur, hydrogen, and N, we observed a decrease. Compared to the PS, SiO_2 and Na_2O oxides in AS decrease (in addition to carbon), and the content of metal oxides K, Ca, Fe, Al, and Ti increases significantly (Kazankapova et al. 2019).

Table 1: The composition of the basic diet for broilers

Ingredients	Quantity (%)	Ingredients	Quantity (%)
Corn	35.3	Bone meal	0.6
Wheat	20	Chalk	3
Barley	10	Seashell	3.7
Sunflower meal	13	Table salt	0.4
Fodder yeast	3	P1-2 premix without methionine	1
Fish meal	5	Lysine per 100 kg	0.7
Grass meal	4	Methionine per 100 kg	0.7

Metabolizable energy: 291.3kcal/100g

Experimental design of the study, diet and keeping of chickens

The experimental studies were conducted from September to November 2023 at the commercial poultry farm of TSS Group LLP, Ornek village, Enbekshikazakh district, Almaty region, Kazakhstan. In total, 180 Arbor Acres cross broilers, five months, were used in the experiment. The experiment, which started at 21 weeks and ended at 29 weeks of egg laying, found that their live weight was 3.6kg, with an average egg production of 120 eggs/broiler and an average egg weight of 52.3g. The chickens were randomly assigned to three separate groups. Each group consisted of 60 specimens who received the following diets. The control group (CG) received the basic diet used on the farm without additives. The second group received the basic diet with 5% AS. The third group received the basic diet with 5% PS. The decision to use two experimental groups, each with a 5% inclusion of either AS or PS, was made to focus the study on comparing the effects of these two specific forms of Shungite under identical conditions. The 5% inclusion rate was chosen based on preliminary studies (Mishina et al. 2023), which indicated that this concentration was sufficient to observe measurable effects on broiler meat and egg quality without compromising the birds' health or feed intake.

The additives were introduced into the basic diet as powder by step-by-step mixing. The boilers' basic diet corresponded to commercial recommendations for maintaining and feeding the Arbor Acres breed. The eight-week duration of our study was chosen deliberately to align with the typical commercial broiler production cycle, which is generally completed within 6 to 8 weeks. This period is important for observing the short-term effects of dietary supplements, such as Shungite, on the quality of broiler meat and eggs, which was the primary objective of our research. Extending the study beyond eight weeks could introduce variables related to broiler maturity that were not within the scope of our investigation and may also complicate the maintenance of optimal housing conditions and animal welfare. Additionally, previous studies (Kim et al. 2021; Zou et al. 2022) in poultry nutrition often use a similar timeframe to assess early dietary interventions, ensuring that the results directly apply to industry practices and can be readily implemented.

All broilers were housed in a poultry house equipped with a cage system. The conditions for all three groups were identical, adhering to the technological parameters established for Arbor Acres laying hens. The chickens were kept in three-level cages with adjustable ventilation and lighting, maintaining a consistent lighting duration of 16 hours daily to ensure optimal growth and health.

Sampling and chemical analysis of feed

Feed sampling adhered to the stringent State Standard (GOST) ISO 6497-2014 "Feed. Sampling." The moisture content of the feed samples was determined by drying them at 105°C for 24 hours, using GOST 13496.3-92 "Compound feed, compound feed raw materials. Methods for determining moisture." The ash content was measured following GOST 26226-95: "Feed, compound feed, compound feed raw materials. Methods for the determination of crude ash". A precisely weighed 2g feed sample was placed in a ceramic crucible and ignited in a muffle furnace at 550°C until a constant final ash mass was achieved. The protein mass fraction was determined using the Kjeldahl method, as specified in GOST 13496.4-93: "Feed, compound feed, compound feed raw materials. Methods for determining the content of N and crude protein". The mass fraction of fat was measured according to GOST 13496.15-97: "Feed, compound feed, compound feed raw materials. Methods for determining the crude fat content". Carbohydrates were analyzed following GOST 21176-2019 "Feed, compound feed. Methods for the determination of soluble and easily hydrolyzable carbohydrates". This strict adherence to standards ensures the reliability and accuracy of our chemical analysis.

The analysis of the mineral composition (Fe, Ni, Ca, P, K) of the feed was carried out according to GOST R ISO 27085-2012. The amount of Cu and Zn was determined according to GOST 30692-2000 using a Kvant-Z.ETA atomic absorption spectrometer (LTK, Russia). N was determined according to GOST 13496.4-93. Na was determined according to GOST 13496.1-89. The amount of K and Se was determined according to GOST ISO 6869-2000. The results were examined at the accredited Food Safety Research Institute of the Almaty Technological University (Almaty, Kazakhstan).

Chemical and mineral composition of meat and eggs

At 29 weeks, 30 eggs were randomly selected from each group for chemical analysis. Sampling and examination of egg quality were conducted according to GOST 31654-2012 "Food-quality chicken eggs. Technical conditions". Before starting the study, the selected eggs were weighed on a scale with an accuracy of 0.01g, broken into a porcelain bowl, mixed, and dried at 65°C in a drying cabinet. At 29 weeks, the chickens were slaughtered to study the chemical and mineral meat composition.

The mass fraction of protein was determined according to GOST 25011-2017, "Meat and meat products. Methods of protein determination", using a KFK-3-01 spectrophotometer (NV-Lab, Russia). The mass fraction of fat was determined according to GOST 23042-2015 "Method for determining fat using the Soxhlet extraction apparatus." The amount of moisture and dry substances was determined according to GOST 33319-2015: "Meat and meat products. A method for determining the mass fraction of moisture". The prepared sample (5g) was placed in a weighing cup, mixed, and put in a drying cabinet where it was kept at 103+2°C for 3 hours. Ash was determined according to "GOST31727-2012: Meat and meat products - a method for determining the mass fraction of total ash". The crucible with the sample was heated for 20min in a muffle furnace at 550°C, cooled in a desiccator to room temperature, and weighed on the Gosmetr VL-224V laboratory scales (Gosmeter Research and Production Enterprise, Russia) with an accuracy of 0.1mg.

Fe, Ca, Mg, Na, K, Se, Cu, Zn, Al, and N were determined according to "GOST 32343-2013: Feed, compound feed. Determination of the content of Ca, Cu, Fe, Mg, Mn, K, Na, and Zn by atomic absorption spectrometry" using the Kvant-Z.ETA atomic absorption spectrometer (LTK, Russia). P was determined according to "GOST 9794-2015 Meat products. Methods for determining the total P content". Iodine was determined according to GOST 31660-2012 "Food products. An inversion-voltammetric method for determining the mass concentration of iodine" using the TA-lab voltammetric analyzer (Tomanalit Research and Production Enterprise, Russia).

The energy value (E) of broiler meat was determined using the methodology described by O.I. Sobolev. The calculation was based on the following formula:

$$E=[D-(A+Z)]\times 4.0+(A\times 9.0) \qquad (1)$$

Where S is the dry matter content in meat (%), F is the fat content in meat (%), and A is the ash content in meat (%) (Sobolev et al. 2019).

Measuring tools and analysis

The results are expressed as mean values ± standard errors. The data were analyzed using variational statistical methods in Microsoft Excel, with differences deemed statistically significant at $P<0.05$. This study on poultry was reviewed and approved by the Ethics Committee of the Kazakh National Agrarian Research University (Protocol 77 of September 18, 2023).

RESULTS

Chemical and mineral composition of the feed in the CG and Experimental Groups (EGs)

The primary nutrients of poultry feed considered in diet formulation include crude protein, moisture, crude fiber, calcium (Ca), and phosphorus (P). Table 2 presents the chemical composition analysis results of broiler chickens' feed samples.

Table 2: Chemical and mineral composition of feed for broilers in the CG and EGs, %

Indicator	Groups		
	I (CG)	II (EG)	III (EG)
Chemical composition (%)			
Mass fraction of protein	28.77±0.06*	21.76±0.07	26.86±0.04
Mass fraction of fat	7.65±0.03*	6.64±0.03	5.28±0.03
Mass fraction of carbohydrates	38.87±0.1	37.54±0.2	33.14±0.2
Mass fraction of moisture	11.32±0.05	9.56±0.05*	10.40±0.44
Dry matter content	88.68±0.43	90.44±0.45*	89.6±0.44*
Mass fraction of ash	1.54±0.0006	1.61±0.007*	1.63±0.008*
Mineral composition (mg/100g)			
Fe	44±0.22	50+0.25*	55+0.3*
Cu	19±0.09	21.3+0.11	20.4+0.102
Zn	162±0.51	159±0.79	168±0.84
Ni	0.032±0.0001	0.033±0.0001	0.031±0.0001
Al	0.75±0.01	0.78±0.01*	0.83±0.01*
N	3.48±0.02	5.24±0.03	4.29±0.02
Ca	0.73±0.004	0.83±0.004*	0.94±0.0003*
Mg	162.45±0.81	175.83±0.88	164.38±0.82
Na	0.18±0.001	0.25±0.001	0.18±0.001
P	0.65±0.003	0.68±0.002	0.65±0.003
K	0.63±0.003*	0.71±0.004	0.78±0.004
Se	104.8±0.5	125.3±0.4	124.5±0.5
I	0.006±0.0001	0.005±0.0001	0.004±0.0001

Values (mean+SD) with asterisk differ significantly ($P<0.05$) in a row. Fe=Ferrous/Iron, Cu=Copper, Zn=Zinc, N=Nickle, Al=Aluminium, N=Nitrogen, Ca=Calcium, Mg=Magnesium, Na=Sodium, P=Phosphorus, K=Potassium, Se=Selenium, and I=Iodine.

The analysis of the feed showed the following composition: the moisture content was 11.32±0.05%, the mass fraction of protein was 32.77±0.06%, the mass fraction of fat was 7.65±0.03%, carbohydrate content was 38.87±0.1%, dry matter content was 88.68±0.43%, and ash was 1.54±0.0006% ($P<0.05$). We observed significant differences in solids and ash content with the basic diet enriched with feed additives. The moisture content in the feed of the EGs was 10.4±0.44 and 9.56±0.05%. The amount of moisture in the EG using PS was 15.5% lower than the CG; in the EG using AS, this indicator was 8.1% lower than the CG.

Crude protein is a crucial nutrient that must be quantified in potential feeds, as it is one of the most expensive components. Protein deficiency significantly impacts poultry growth and productivity, necessitating different diets depending on the stage of poultry breeding. As a rule, starter diets are rich in protein, while breeder diets usually contain less protein since older chickens require less. In this study, the protein mass fraction was 28.77±0.06, 21.76±0.07, and 26.86±0.04%, respectively ($P<0.05$). The mass fraction of protein in the third group was 18.9% higher compared to the second group. However, in both EGs, the protein was lower compared to the CG by 24.3 and 6.6%, respectively.

There was an insignificant difference in the fat content in the broiler feed. The amount of fat was determined on average as 7.65±0.03, 6.64±0.03, and 5.28±0.03%. According to the fat content in the EGs, PS, compared to AS, helps to preserve fat in feed. Fat in the third group was 20.4% lower than in the second group. It was 30.9% lower than in the CG.

The ash content of poultry feed depends on the content of inorganic minerals. In this study, the ash content was found to be, on average, 1.54±0.0006, 1.61±0.007, and 1.63±0.008%. The maximum amount of ash was found in the third group. The mass fraction of ash in the third group was 5.5% higher than in the second group and 4.3% higher than in the control group (CG).

The results of the mineral composition analysis of the feed in the control group (CG) and experimental groups (EGs) are presented in Table 2. The Fe content in the EGs ranged on average from 50+0.25 to 55+0.3mg/100g. These indicators are 12 and 20% higher compared to the CG. The same result was obtained for Al and Ca. The Ca content in the CG was, on average, 0.73±0.004mg/100g. It is 12.1% lower than in the second group and 22.3% lower than in the third group. The difference between the second and third groups was 0.11g/100g. The data on trace elements showed that the high Mg concentration was found in the second group (175.83±0.88mg/100g), and its lowest concentration was found in the CG (162.45±0.81mg/100g). The concentration of Cu in the third group was slightly higher (by 1.4mg/100g). The Zn content in the CG was 162±0.51mg/100g, in the second group 159±0.79mg/100g, and in the third group 168±0.84mg/100g. The indicator in the third group was 3.5% higher compared to the CG. Approximately the same indicators were typical for N, Ni, and Se. The second group had the highest concentration of Na, which was in the range of 0.25±0.001mg/100g. The K content in the third group was 0.78±0.004mg/100g. This indicator is 19.2% higher compared to CG and 8.9% higher compared to the second group ($P<0.05$). I deficiency was noted in the EGs compared to the CG.

The obtained data indicate that it is necessary to add natural minerals to the chicken diet; this balances the trace element content in the diet. Thus, the content of mineral elements in the basic diet only sometimes ensures the necessary concentration and does provide poultry with these elements. When composing diets, it is important to consider the ratio of Ca and P, which is, on average, 2:1.5 according to literature data. If this ratio is not observed, severe disorders of mineral metabolism occur (Kotarev et al. 2019). Balancing bird diets for trace elements can be solved using natural minerals.

Chemical and mineral composition of eggs in the CG and EGs

The chemical composition of eggs is primarily defined by their content of water, nitrogenous substances, lipids, minerals, carbohydrates, and vitamins. These components are crucial indicators of egg quality and are influenced by factors such as poultry species, habitat, and diet. Table 3 presents data on protein, fat, moisture, and ash concentrations in eggs from the control group (CG) and experimental groups (EGs). Analyzing these elements provides insights into the nutritional enhancements achieved through dietary modifications. For instance, eggs' higher protein and mineral content suggest improved nutritional value. In contrast, moisture and fat content variations can impact the eggs' texture and taste, influencing consumer preferences and marketability.

Table 3: Chemical composition of eggs of broilers in the CG and Egs

Indicator name (%)	Groups		
	I	II	III
Mass fraction of protein	13.31±0.07	14.21±0.05	14.51±0.06*
The mass fraction of protein recalculated as dry matter	52.98±0.19	58.06±0.24	58.15±0.31
Mass fraction of fat	11.66±0.06*	9.46±0.05	8.59±0.04
The mass fraction of fat recalculated as dry matter	43.48±0.22	37.86±0.20	37.53±0.18
Mass fraction of moisture	77.11±0.02	75.01±0.02	73.18±0.05
Dry matter content	22.89±0.02	24.99±0.02*	26.82±0.05*
Mass fraction of ash	0.95±0.05	1.02±0.02*	1.01±0.02*

Values (mean+SD) with asterisk differ significantly (P<0.05) in a row

Evaluating the egg quality in these experiments, we found that the mass fraction of protein in the total mass of eggs laid by broilers on the PS diet was, on average, 6.3% higher than in the CG. Specifically, the protein content in the eggs of the third group increased significantly by 8.3% compared to the CG, while the difference between the second and third groups was insignificant.

The percentage of fat in the yolk was 11.66±0.06% in the CG, 9.46±0.05% in the second group, and 8.59±0.04% in the third group. The mass fraction of fat decreased by 18.8% and 21.3% (P<0.05) in the second and third groups, respectively, compared to the CG.

The moisture content of the EGs was significantly lower than that of the CG, resulting in a higher dry matter content in the eggs of EG broilers.

The ash content in EG eggs was almost at the same level (1.02±0.02 and 1.01±0.02%). However, the amount of ash in the CG was significantly lower (by 6.8% compared to the second group and by 5.9% compared to the third group) (P<0.05).

Thus, the analysis of the chemical composition of broiler eggs with the addition of PS and AS showed a positive effect on some indicators of egg quality. There was a higher protein and ash content. This allowed us to conclude that the observed high nutritional value indicated that the tested feed additives can be used to produce high-quality poultry products.

In the second stage of the experiment, we evaluated the effect of PS and AS on the quality of eggs used for food. We studied the mineral composition of the eggs from CG and EG broilers (Table 4). The results indicate that the Shungite samples had specific effects on the mineral composition of the eggs. The Ca and Fe content was higher than in the CG.

Table 4: Mineral composition (mg/100g) of eggs of broilers in the CG and EGs

Indicator name	Groups		
	I	II	III
Fe	2.10±0.05	2.17±0.03*	2.31±0.02*
Ca	58.43±0.03	60.03±0.09*	63.17±0.10*
Mg	10.38±0.04	12.10±0.05*	11.08±0.03
Na	163.74±0.25	165.03±0.22	170.01±0.32
P	200.61±0.14	205.16±0.12	201.03±0.08*
K	150.96±0.29	152.83±0.38	153.43±0.49
Se	-	-	-
I	0.014±0.002	0.016±0.002*	0.014±0.002
Cu	0.047±0.002	0.050±0.002	0.054±0.002*
Zn	1.12±0.02	1.16±0.2	1.10±0.03
Al	-	-	-

The footnote remains the same as that of Table 2.

The data showed that a large proportion of Ca was found in the third group (63.17±0.10mg/100g). This indicator was 7.5% higher on average compared to the CG and 4.9% higher than the second group. Low P retention was found in the CG (200.61±0.14mg/100g), and a high amount was found in the second group (205.16±0.12). The second group exceeded the third group by 2.1% (P<0.05).

Na was mainly found in the third group (170.01±0.32mg/100g) and was 4.7% higher than in the second group. Mg was concentrated primarily in the second group (12.10±0.05mg/100g), whose content was 8.4% higher than in the third group. The total K content was higher in the third group (153.43±0.49mg/100g); it was 1.6% lower in the CG. The amount of I in the CG and the third group was the same and averaged 0.014±0.002mg/100g. The highest amount of Cu was found in the third group (0.054±0.002mg/100g); in the CG, this indicator was 12.9% lower, and in the second group, it was 7.4% lower (P<0.05).

Se and Al were not found. The Zn content in CG and EGs did not significantly differ.

Chemical and mineral composition of breast and thigh muscles

Shungite positively influenced the chemical composition of both the breast and thigh muscles (Table 5). In the white meat from the EGs, a significant increase in protein, solids, and ash was observed.

The mass fraction of protein in the samples of breast muscles from the EGs was higher than in the CG by 11.2-15.7%. These values were 1.4 and 0.7% higher in the thigh muscles, respectively. There was more protein in the breast muscle. In the CG, this indicator was, on average, equal to 19.41±0.08%, and in the thigh muscle, 18.84±0.06% (P<0.05).

The amount of fat decreased by 11.6% (P<0.05) in the second group; in the third group, it was 22.1% lower than in the CG. In the thigh muscles, this indicator in the CG was, on average, equal to 4.46±0.05%. Compared to the second group, this indicator was 12.3% lower. The fat content in the thigh muscles of the second group was higher than in the control group (CG).

Table 5: The chemical composition (%) of the breast and thigh muscles of broiler chickens

Indicator name	Groups		
	I	II	III
Breast muscle			
Mass fraction of protein	19.41±0.08	21.86±0.06*	23.05±0.08*
The mass fraction of protein recalculated as dry matter	61.76±0.25	63.53±0.17	71.63±0.05
Mass fraction of fat	4.02±0.05*	3.55±0.03	3.13±0.05
The mass fraction of fat recalculated as dry matter	12.79±0.16	10.32±0.09	6.62±0.15
Mass fraction of moisture	68.57±0.03*	67.82±0.05	65.59±0.03
Dry matter content	31.43±0.03	32.18±0.05	34.41±0.03*
Mass fraction of ash	1.57±0.02	1.58±0.02*	1.74±0.02*
Thigh muscle			
Mass fraction of protein	18.84±0.06	19.10±0.05	18.99±0.06*
The mass fraction of protein recalculated as dry matter	56.58±0.18	51.36±0.13	64.40±0.20
Mass fraction of fat	4.46±0.05	5.09±0.04	4.50±0.03
The mass fraction of fat recalculated as dry matter	13.39±0.15	13.69±0.11	15.26±0.10
Mass fraction of moisture	70.51±0.05*	62.81±0.05	66.70±0.02
Dry matter content	29.49±0.05	37.19±0.05	33.30±0.02*
Mass fraction of ash	1.51±0.03	1.70±0.03*	1.81±0.03*

Values (mean+SD) with asterisk differ significantly ($P<0.05$) in a row.

The maximum moisture content in the red meat was found in the CG (70.51±0.05%), which was 10.9% and 5.4% ($P<0.05$) higher than in the experimental samples. Similar changes were observed in the chemical composition of the breast muscles. The difference between the CG and EGs was within 2.7%.

The thigh muscles from the second group had 7.1% more ash, and in the third group, 3.8% more compared to the breast muscles. The amount of ash in both red and white poultry meat with the addition of Shungite was more significant than in the CG.

Our results indicate that PS and AS positively impact broiler chicken meat's chemical composition and biological value. We studied the effects of PS and AS on the mineral content in the white and red meat of broiler chickens. Analysis of the mineral composition of the breast and thigh muscles showed that PS and AS had a beneficial effect.

AS, as a component of compound feed, contributed to an increase in Fe content by 7.8% ($P<0.05$) in the breast muscle and by 4.8% in the thigh muscle compared to the CG.

The Ca content in the muscles of the breast and thighs increased under the influence of Shungite. In the second group, it increased by 14.4 and 12.1%, respectively, compared to the CG. In the third group, the amounts of this element were higher by 18.5 and 14.3%, respectively.

The Mg content in the breast muscles increased significantly in the second group by 9.7% and in the third group by 15.9% compared to the control group (CG). Shungite led to a slight increase in the Mg content in red meat, with an average increase of 1.4% in the second group and 3.0% in the third group ($P<0.05$) compared to the CG.

There was a decrease in Na levels in the breast muscles from the second group by 11.89mg/100g and in the third group by 8.12mg/100g compared to the CG. In the thigh muscles from the CG and the second group, this element was approximately in the same amount (69mg/100g).

The highest P amount in the breast muscle samples was found in the second group (182.5±0.09mg/100g), which was 8.1% higher than in the CG. The lowest P amount was found in the CG, where its value was 6.2% lower than in the third group. This pattern was also noted in samples of the thigh muscle, where the highest concentration of P was found in the second group (182.5±0.09mg/100g). The amount of P in the breast muscle from the third group was 3.5% lower ($P<0.05$) than in the thigh muscle from the third group.

The highest amount of K in the thigh muscle was found in the third group and equaled 295.9±0.09mg/100g. I was not found in the breast muscles of any group or the thigh muscles of the CG. In the second and third groups, its amount in the thigh muscles was 0.005±0.0002mg/100g. In the EGs, the content of this trace element was within the physiological norm. Se and Al were not found in any group's breast and thigh muscles.

The level of Cu in the thigh muscles from the third group decreased by 13.3% and from the second group by 20.0% compared to the CG. AS increased the Cu content in white meat by 4.7% compared to the CG and second group.

The Shungite samples also had a noticeable positive effect on the Zn content in white and red meat. The EGs had more of this trace element. In white meat, the Zn content was 22.3% higher ($P<0.05$) in the third group and 15.8% higher in the second group compared to the CG. In red meat, its content ranged from 1.12±0.03 to 1.39±0.01mg/100g.

The study of the mineral composition of the thigh and breast muscles showed that the level of macro- and microelements in the third group was higher than in the CG and second group.

DISCUSSION

The main problem of industrial poultry farming is the organization of a complete and balanced feed for poultry. The diets of broiler chickens of modern crosses should be strictly normalized according to the level of metabolizable energy, amino acids, vitamins, and macro- and microelements (Fisinin et al. 2016b). Shungite contains a large set of macro- and microelements, which determines its suitability for optimizing the mineral nutrition of poultry. X-ray and radiological examination of Shungite show that the presence of heavy metals and the activity of natural radionuclides do not exceed the standards. Therefore, the mineral is safe and can be used in poultry feeding (Efremov et al. 2021).

According to our results, the positive effect of Shungite on the mineral composition of broiler feed is partly due to the higher content of elements, such as Fe, Zn, Ca, and Mg. However, Na, P, and I concentrations in the third group were lower than in the CG and second group. The studies that were conducted showed that adding AS to the basic poultry diet contributes to significant differences in the concentrations of common forms of elements compared to the second group. The Ca and K concentrations increased significantly when using AS.

Their content was, on average, 11.7 and 8.9% higher than the second group. The Fe content in the third group was 9% higher than in the second group ($P<0.05$). This coincides with the literature data of other researchers.

The concentration of some elements tends to decrease with the use of AS. In the third group, a statistically significant decrease in Cu, Ni, and N concentrations was observed compared to the second group. Shungite has adsorption properties. Egorov et al. (2021) studied the effectiveness of using a combination of sorbents to reduce the effects of imidacloprid on broiler chickens. In the experiment, Shungite was used as a sorbent. According to the results, Shungite reduced the toxic effect of imidacloprid, which positively affected the health of broiler chickens. Determining the chemical composition of eggs is a crucial step in veterinary and sanitary examinations. The chemical composition influences the nutritional value of eggs and determines their physiological role as a source of biologically active substances (Zaheer 2015). By changing the poultry diet accordingly, the nutrient content can be changed.

The analysis of the chemical composition of eggs demonstrated that the inclusion of PS and AS in the compound feed affected their nutritional value. The third group showed the highest protein and ash content, while the control group (CG) recorded the lowest values. Conversely, the CG had the highest moisture and fat levels, with the third group exhibiting the lowest levels. The composition of the nutrients in eggs can be changed by using different types of feed (Nimalaratne et al. 2016). In the EGs, the mineral characteristics recorded during the experimental period significantly differed ($P<0.05$) from the CG. The lowest values of Na, K, Ca, Mg, and P were observed in the CG, and the highest values were in the EGs. The indicators remained almost unchanged in the third group.

The Ca content in the eggs from the third group was 7.5% higher than in the control group (CG), and the second group contained 2.6% more Ca than the CG. The P and Mg content in the eggs was higher in the second group compared to the third group. These values were 2.0 and 8.4% higher, respectively. The K and Na content in the eggs from the third group was 0.4 and 2.9% higher than in the second group. Egg samples from the third group, on average, contained 6.0 and 9.1% more Fe than egg samples from the second group and CG, respectively.

According to the analysis, the mineral composition of the egg samples was significantly improved ($P<0.05$). This can be explained by the higher ash content, which leads to a higher mineral content (Hafeez et al. 2015). Similar results were obtained in the assessment of mineral element content when Shungite was added to the basic diet of laying hens (Sharapova 2010). The results of our study refute the claims of Fisinin et al. (2016a), who noted that the use of Shungite grits in compound feeds for laying hens did not significantly affect the chemical composition of eggs. Thus, eggs enriched with trace elements can be used to make up for the deficiency of trace elements in the human diet. The inclusion of AS in broiler diets improves the quality of eggs by increasing the protein and ash content and the content of macro- and microelements in eggs.

The nutritional value of meat can be estimated based on parameters such as the content and composition of proteins, fat, and mineral content. The chemical composition of poultry meat varies significantly, with notable differences between white and red poultry muscle tissues (Kundryukova et al. 2019). According to our study, broilers' breast and thigh muscles in all groups exhibited significant differences in chemical composition. R.S. Ahmad et al. (2018) emphasize that proteins are the most important components of meat in terms of both nutrition and technology. According to Bychaev (2017), the breast muscles contain up to 22% of proteins, and about 18% are found in the thigh muscles. Based on our results, the protein content in the breast muscles was significantly higher than in the thigh muscles. The differences in protein content between the breast and thigh muscles were very significant ($P<0.05$) in all groups. The protein content in the breast muscles from the CG averaged 19.41±0.08%. This indicator was 5.1% higher in the second group compared to the control group (CG). The application of AS contributed to increased protein content in the muscles. However, the protein content in the thigh muscles of the third group was 17.6% lower. Thus, the breast muscles contain 8-12% more proteins than the thigh muscles. Our results also confirm the conclusions of several other authors. For example, Baeva et al. (2021) researched the effects of the adsorbent Alni-sorb containing the carbon mineral Shungite on the quality of broiler meat. According to the analysis, the adsorbent increased the mass fraction of dry matter and meat proteins in the breast and thigh muscle samples.

Fat is a source of many aromatic substances that influence the taste of meat (Fu et al. 2022). According to Ravindran et al. (2016), a statistically significant negative correlation exists between muscle fat and protein content. This means that the higher the fat content, the less lean meat is present, making it less suitable for human consumption. The trend found for fat was the opposite of the trend for proteins. The fat content in the thigh muscles of broilers was 1.5-2 times higher than in the breast muscles. In a comparative assessment, the fat content in the thigh muscles of the experimental groups of chickens averaged 5.09±0.04% (the second group) and 4.50±0.03% (the third group), while in the breast muscles, the fat content was only 3.55±0.03 and 3.13±0.05%, respectively. The thigh muscles contained 18% more fat than the breast muscles. PS contributed to an increase in muscle fat content. The highest fat content was observed in the CG.

Concerning the dry matter, a significant difference was found between the muscles of the breasts and thighs. The dry matter content in the thigh muscles was significantly higher ($P<0.05$) than in the breast muscles. In the breast muscles of the control group (CG), the average dry matter content was 31.43±0.03%. This indicator was 2.3% higher in the second group and 8.6% higher in the third group. In the thigh muscles, the dry matter content in the CG was 29.49±0.05%; it was 20.7% higher in the second group and 11.4% higher in the third group. Additionally, the dry matter content in the thigh muscles of the second group was 5% higher than in the breast muscles. The ash content in the thigh muscles was also significantly higher ($P<0.05$) compared to the breast muscles. The relative ash content of breast muscles from the CG was 1.57±0.02%, in the third group – 1.74±0.02%; in the thigh muscles, it was 1.51±0.03% (the CG) and 1.81±0.03% (the third group). The third group contains 9.7-16.5% more ash than the muscles from the CG.

Analytical tests conducted on broiler muscles also included the determination of macro- and microelements. Unlike the breast muscles, the Ca content in the thigh muscles tended to increase. We assessed the Mg content in the thigh muscles and concluded that Shungite did not affect the Mg content. According to Czerwonka et al. (2017), the Fe content of meat depends on many factors, such as the species, breed, gender, and anatomical origin of muscles. Lower Fe content was found in the CG. The Fe content in meat is considered an important qualitative characteristic (Esfandiar et al. 2019). In our experiment, the average Fe content in the breast and thigh muscles of the second group was 1.56%. This value is 1.9% lower than the average Fe content in the third group. Other researchers have reported similar results (Kadikov et al. 2020).

The tests showed that the breast and thigh muscles differed in P content. The P content in the thigh muscles is higher than in the breast muscles. In the breast muscles from the third group, P was 178.9±0.10%, whereas this indicator in the thigh muscles averaged 185.4±0.08%. Applying AS to the basic diet increased the level of P in the muscles. We found that the I content in the thigh muscle from the EGs was 0.005±0.0002%. The amount of I in the muscles increased when PS and AS were introduced into the broiler diet. Iodine is a part of hormones that play an important role in regulating metabolism, which in the broiler industry is associated with human health, intermediate cell activity, and cellular oxidation processes (Behroozlak et al. 2020).

In the work by Biktashev et al. (2018), Shungite was added in a dose of 0.5% to the basic poultry diet. According to the results, the productivity of broiler chickens increased by 10.2% due to the antibacterial, oxidative, and reducing properties of Shungite. The research by Mishina et al. (2023) investigates the effects of incorporating Shungite and other sorbents into the diets of 42-day-old broiler chickens exposed to experimental mixed mycotoxicosis. Their veterinary and sanitary examination revealed significant improvements in the quality of chicken meat when these sorbents were used. Specifically, the inclusion of a sorbent in the mycotoxin-contaminated diet elevated the veterinary and sanitary indicators of the chicken meat, bringing them up to par with the control group that was not exposed to mycotoxins (Mishina et al. 2023).

Furthermore, this research underscores the potential of natural sorbents like Shungite in mitigating the adverse effects of mycotoxins in poultry farming. Mycotoxins, which are toxic compounds produced by certain types of fungi, can contaminate feed and pose severe health risks to poultry, leading to significant economic losses (Nasiyev 2016; Serekpayev et al. 2016). By neutralizing these toxins, sorbents not only enhance the safety and quality of poultry products but also improve the overall health and productivity of the birds (Mendybayeva et al. 2023; Smolovskaya et al. 2023).

Ermolaeva et al. (2019) presented the results of the veterinary and sanitary examination of poultry meat in mycotoxicosis against the background of using Shungite. The meat met the requirements for organoleptic, microbiological, and physicochemical parameters. In the studies by Gubeeva et al. (2019), the sorption property of Shungite against a pesticide in Cross COBB 500 broiler chickens was studied. The results of morphological studies provided reassuring evidence that the use of Shungite and zeolite had a significantly positive effect on the histostructure and morphological picture of the liver of broiler chickens exposed to imidacloprid, instilling confidence in the health and well-being of the birds. Kochish et al. (2020) evaluated the effectiveness of Sirtil and Mustala Shungite-based mineral additives as neutralizers of mycotoxins in the feed for egg-laying chickens. The potential of these feed additives to neutralize mycotoxins, sustain and enhance productivity, and improve feed conversion without negatively impacting metabolism has been demonstrated, offering a promising outlook for the future of egg production.

Conclusion

AS positively affected the quality of feed, meat, and eggs. The mineral composition of the broiler muscle and eggs increased. The protein and ash content increased, and the thigh and breast muscles became more nutritious. Adding 5% PS and AS to the basic diet of chickens contributed to its enrichment with macro- and microelements, increasing the total content of meat and eggs. Thus, the enrichment of the broiler diet with AS allows one to obtain poultry products with improved biological and consumer properties.

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Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

Agibaeva LM, 2006. O biomineralnom i organomineralnom syre Kazakhstana [On biomineral and organomineral raw materials of Kazakhstan]. Izvestiya NAN RK. Seriya Geologicheskaya 3: 43-45.

Ahmad RS, Imran A and Hussain MB, 2018. Nutritional Composition of Meat. In: Arshad MS (ed), Meat Science and

Nutrition. InTech, pp: 61-75. http://dx.doi.org/10.5772/intechopen.77045

Atabayeva S, Nurmahanova A, Yernazarova G, Asrandina S, Alybayeva R, Ablaikhanova N, Turasheva S, Tynybekov B and Fei LUI, 2018. Effect of cadmium on mineral composition of rice grain. Research on Crops 19(4): 569–575

Baeva AA, Chabaev MG, Bulatseva SV, Bobyleva LA, Osikina RV, Shugusheva LH and Kozhokov MK, 2021. Effect of mold inhibitor and adsorbent on digestive processes and consumer quality of broiler meat. Journal of Livestock Science 12: 367-371. http://dx.doi.org/10.33259/JLivestSci.2021.367-371

Behroozlak M, Daneshyar M and Farhomand P, 2020. The effects of dietary iodine and its consumption duration on performance, carcass characteristics, meat iodine, thyroid hormones and some blood indices in broiler chickens. Journal of Animal Physiology and Animal Nutrition 104(3): 876-885. https://doi.org/10.1111/jpn.13321

Biktashev RU, Konyukhova VA, Papunidi KKH, Kadikov IR, Zakirova GSH and Gataullin DKH, 2018. Effektivnost shungita i tseolita v ratsionakh tsyplyatbroilerov, kontaminirovannykh kadmiem i svintsom [The effectiveness of Shungite and zeolite in the broiler chicken diets contaminated with cadmium and lead]. Veterinarnaya Farmakologiya s Toksikologiei 6: 16-21.

Bulegenova ZHK, Cakipova ZB and Abdimanova BZH, 2014. Rentgeno-phase analysis of the Shungite extracted from the Bakyrchik ore deposit. Farmatsiya Kazakhstana 5: 49-51.

Buyarov VS, Golovina SYU and Buyarov AV, 2019. Effektivnost sovremennykh energoresursosberegayushchikh tekhnologii proizvodstva myasa broilerov [Efficiency of modern energy-saving technologies for broiler meat production]. Agrarnyi vestnik Verkhnevolzhya 2(27): 86-98. https://doi.org/10.35523/2307-5872-2019-27-2-86-98

Bychaev AG, 2017. Kachestvo Myasa Broilerov: Tekhnologicheskie Aspekty [Broiler Meat Quality: Technological Aspects]. In: Sukhanova SF, Morozova LA, Uskov GE, Tsopanova AV and Poznyakova NA (eds), Bezopasnost i Kachestvo Selskokhozyaistvennogo Syrya i Produktov Pitaniya: Materialy Vserossiyskoy Nauchno-Prakticheskoy Konferentsii [Safety and Quality of Agricultural Raw Materials and Foodstuffs: Proceedings of the All-Russian Scientific and Practical Conference]. Kurgan State Agricultural Academy named after T.S. Maltsev, Lesnikovo, Russia, pp: 51-54.

Czerwonka M, Czerwonka M and Tokarz A, 2017. Iron in red meat–friend or foe. Meat Science 123: 157-165. https://doi.org/10.1016/j.meatsci.2016.09.012

Directive 2010/63/EU of the European Parliament and of the Council (2010). On the protection of animals used for scientific purposes Text with EEA relevance. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0063

Efremov S, Nechipurenko S, Tokmurzin D, Kaiaidarova A, Kalugin S and Tassibekov KH, 2021. Remediation of soil contaminated by toxic rocket fuel components using modified carbon–mineral adsorbing material produced from Shungite rock modified with Mn4+ and Fe3+. Environmental Technology and Innovation 24: 101962. https://doi.org/10.1016/j.eti.2021.101962

Efremov SA, Nechipurenko SV, Kazankapova MK, Washington B, Tassibekov KS and Nauryzbaev MK, 2013. Physico-chemical characteristics of Shungite rock of Kazakhstan. Eurasian Chemico-Technological Journal 15(3): 241-249. http://dx.doi.org/10.18321/ectj228

Egorov V, Aleyev DV, Malanev AV, Khalikova KF, Galyautdinova GG, Yamalova GR, Tremasova AM, Kadikov IR, Saifutdinov AM, Semenov EI, Shuralev EA and Smolentsev SYU, 2021. The use of sorbents for intoxication of chickens with imidacloprid. International Journal of Pharmaceutical Research 13(1): 3225-3233. https://doi.org/10.31838/ijpr/2021.13.01.497

Erenko E, Ovchinnikov A, Aubakirov M, Kaumenov N, Aisin M, Tegza I, Gabdullin S, Akhmetchina T and Shamgunov N, 2024. Effect of a phytomineral complex and an enzyme preparation on the absorption of nutrients and the energy balance of calves' diet. OnLine Journal of Biological Sciences 24(4): 405-412

Ermolaeva OK, Tanaseva SA, Mokhgarova SL, Semenov EI and Papunidi EK, 2019. Veterinarno-sanitarnaya ekspertiza myasa ptits pri mikotoksikozakh [Veterinary and sanitary examination of poultry meat for mycotoxicosis]. Veterinarnyi Vrach 4: 21-26.

Esfandiar Z, Hosseini-Esfahani F, Mirmiran P, Habibi-Moeini A-S and Azizi F, 2019. Red meat and dietary iron intakes are associated with some components of metabolic syndrome: Tehran lipid and glucose study. Journal of Translational Medicine 17: 313. https://doi.org/10.1186/s12967-019-2059-0

Fisinin V, Egorov IA, Egorova TV, Shevyakov AN, Bolgov AE and Leri NA, 2016a. Shungit v ratsione kur-nesushek [Shungite in the diet of laying hens]. Kombikorma 2: 64-66.

Fisinin VI, Egorov IA, Egorova TV, Shevyakov AN, Bolgov AE and Leri NA, 2016b. Snizhenie toksichnosti kombikormov dlya tsyplyat-broilerov pri ispolzovanii shungita [Reducing the toxicity of compound feed for broiler chickens using Shungite]. Ptitsevodstvo 2: 23-27.

Fu Y, Cao S, Yang L and Li Z, 2022. Flavor formation based on lipid in meat and meat products: A review. Journal of Food Biochemistry 46(12): e14439. https://doi.org/10.1111/jfbc.14439

Gubeeva EG, Khalikova KF, Aleev DV, Egorov VI, Saitov VR and Papunidi KKH, 2019. Izuchenie gistostruktury pecheni tsyplyat-broilerov pri khronicheskoi intoksikatsii imidaklopridom na fone primeneniya sorbentov [Study of the histostructure of the liver of broiler chickens during chronic intoxication with imidacloprid against the background of the use of sorbents]. Veterinarnyi Vrach 1: 8-12.

Hafeez A, Mader A, Ruhnke I, Röhe I, Boroojeni FG, Yousaf MS, Männer K and Zentek J, 2015. Implication of milling methods, thermal treatment, and particle size of feed in layers on mineral digestibility and retention of minerals in egg contents. Poultry Science 94(2): 240-248. http://dx.doi.org/10.3382/ps/peu070

Kadikov IR, Biktashev RU, Konyukhova VA, Papunidi KH, Zakirova GSH and Gubeeva EG, 2020. Primenenie shungita i tseolita tsyplyatam-broileram na fone otravleniya tyazhelymi metallami [Use of Shungite and zeolite for broiler chickens against the background of heavy metal poisoning]. Veterinariya 2: 60-64. https://doi.org/10.30896/0042-4846.2020.23.2.60-64

Kazankapova MK, Nauryzbaev MK, Efremov SA, Ermagambet BT, Nurgaliyev NU and Nechipurenko SV, 2019. Preparation of activated Shungite and characterization of its chemical composition and adsorption properties. Solid Fuel Chemistry 53: 241-247. https://doi.org/10.3103/S0361521919040086

Kim B, Bang HT, Jeong JY, Kim M, Kim KH, Chun JL and Ji SY, 2021. Effects of Dietary Supplementation of Black Soldier Fly (Hermetia illucens) Larvae Oil on Broiler Health. The Journal of Poultry Science 58(4): 222–229. https://doi.org/10.2141/jpsa.0200070

Kochish II, Romanov MN and Nikonov IN, 2020. Puti Povysheniya Produktivnykh Pokazatelei Kur (na Primere Ispolzovaniya Kormovoi Dobavki na Osnove Shungita [Ways to Increase the Productive Performance of Chickens (Using the Example of Using a Shungite-Based Feed Additive]. In: Materialy 19-Mezhdunarodnoi Nauchno-

Prakticheskoi Konferentsii "Sovremennye Tendentsii Selskokhozyaistvennogo Proizvodstva v Mirovoi Ekonomike" [Proceedings of the 19th International Research and Practice Conference "Modern Trends in Agricultural Production in the Global Economy"]. Kuzbass State Agricultural Academy, Kemerovo, Russia, pp: 37-44.

Kotarev VI, Lyadova LV, Morozova EE, Bessonova LP, Denisenko LI and Belousov DA, 2019. Monitoring kaltsii-fosfornogo sootnosheniya v polnoratsionnykh kombikormakh dlya kur v Voronezhskoi oblasti [Monitoring the calcium and phosphorus ratio in complete feed for chickens in the Voronezh region]. Veterinarnyi Farmakologicheskii Vestnik 2(7): 78-90. https://doi.org/10.17238/issn2541-8203.2019.2.78

Kundryukova U, Drozdova L, Beikin Ya and Pichugova S, 2019. Comparative Ultrastructure of Skeletal Muscles of Broiler Chickens and Quails. In: International Scientific and Practical Conference "Digital agriculture-development strategy" (ISPC 2019). Atlantis Press, pp: 422-425. https://doi.org/10.2991/ispc-19.2019.94

Matuszek DB and Królczyk JB, 2017. Aspects of safety in production of feeds – A review. Animal Nutrition and Feed Technology 17(2): 367-385. http://dx.doi.org/10.5958/0974-181X.2017.00036.1

Mendybayeva A, Abilova Z, Bulashev A and Rychshanova R, 2023. Prevalence and resistance to antibacterial agents in Salmonella enterica strains isolated from poultry products in Northern Kazakhstan. Veterinary World 16(3): 657–667. https://doi.org/10.14202/vetworld.2023.657-667

Mishina NN, Semenov EI, Malaniev AV, Yamalova GR, Aleev DV, Khalikova KF, Galyautdinova GG and Valiev AR, 2023. Veterinary and sanitary examination of broiler chicken meat when usung a fourcomponent sorbent in feed for mycotoxicosis. Problemy Veterinarnoy Sanitarii, Gigiyeny i Ekologii 2(46): 174-179. https://doi.org/10.36871/vet.san.hyg.ecol.202302007

Mooste M, Tkesheliadze T, Kozlova J, Kikas A, Kisand V, Treshchalov A, Tamm A, Aruväli J, Zagal JH, Kannan AM and Tammeveski K, 2021. Transition metal phthalocyanine-modified Shungite-based cathode catalysts for alkaline membrane fuel cell. International Journal of Hydrogen Energy 46(5): 4365-4377. http://dx.doi.org/10.1016/j.ijhydene.2020.10.231

Nasiyev B, 2016. The study of the processes, degradation factors and the selection of crops for the restoration of bioresources capacity of the grassland of semi-desert zones. Research Journal of Pharmaceutical, Biological and Chemical Sciences 7(3): 2637-2646.

Nimalaratne C, Schieber A and Wu J, 2016. Effects of storage and cooking on the antioxidant capacity of laying hen eggs. Food Chemistry 194: 111-116. http://dx.doi.org/10.1016/j.foodchem.2015.07.116

Nkukwana TT, 2018. Global poultry production: Current impact and future outlook on the South African poultry industry. South African Journal of Animal Science 48(5): 869-884. https://doi.org/10.4314/sajas.v48i5.7

Obradović NN, Gigov M, Djordjevic A and Pavlovic VB, 2019. Shungite - A carbon-mineral rock material: Its sinterability and possible applications. Processing and Application of Ceramics 13: 89-97. https://doi.org/10.2298/PAC190108 90

Omer HAA, El-Mallah GMH, Abdel-Magid SS, Bassuony NI, Ahmed SM and El-Ghamry AKA, 2019. Impact of adding natural bioactive mixture composed of lemon, onion, and garlic juice at different levels on productive performance, egg quality, and some blood parameters of commercial laying hens. Bulletin of the National Research Centre 43: 137. https://doi.org/10.1186/s42269-019-0160-4

Ravindran V, Tancharoenrat P, Zaefarian F and Ravindran G, 2016. Fats in poultry nutrition: Digestive physiology and factors influencing their utilisation. Animal Feed Science and Technology 213: 1-21. http://dx.doi.org/10.1016/j.anifeedsci.2016.01.012

Rozhkova NN, Goryunov AS and Rozhkov SS, 2020. Mechanisms of Shungite Nanocarbon Interactions with Biological Molecules. In: Proceedings - International Conference Laser Optics 2020. IEEE, pp: 1-1. https://doi.org/10.1109/ICLO48556.2020.9285424

Sajo MEJ, Kim C-S, Kim S-K, Shim KY, Kang T-Y and Lee K-J, 2017. Antioxidant and anti-inflammatory effects of Shungite against ultraviolet b irradiation-induced skin damage in hairless mice. Oxidative Medicine and Cellular Longevity 2017: 7340143. https://doi.org/10.1155/2017/7340143

Serekpayev N, Popov V, Stybayev G, Nogayev A and Ansabayeva A, 2016. Agroecological Aspects of Chickpea Growing in the Dry Steppe Zone of Akmola Region, Northern Kazakhstan. Biotechnology Research Asia 13(3): 1341-1351.

Sharapova VYU, 2010. Ispolzovanie shungita v kormlenii kur-nesushek [Use of Shungite in feeding laying hens]. Ptitsevodstvo 9: 31-33.

Shevchenko TV, Ustinova YV, Ermolaeva EO, Popov AM and Uzunov GB, 2023. Extending the storage life of foods using Shungite. Advances in Life Sciences 10(2): 152-156

Skrypnik L, Babich O, Sukhikh S, Shishko O, Ivanova S, Mozhei O, Kochish I and Nikonov I, 2021. A study of the antioxidant, cytotoxic activity and adsorption properties of Karelian Shungite by physicochemical methods. Antioxidants 10(7): 1121. https://doi.org/10.3390/antiox10071121

Smolovskaya O, Pleshkov V, Zubova T and Bormina L, 2023. Probiotics in Industrial Poultry Farming. American Journal of Animal and Veterinary Sciences 18(1): 1-8

Sobolev OI, Gutyj BV, Sobolieva SV, Borshch OO, Liskovich VA, Prystupa OI, Demus NV, Paladiychuk OR, Fedorovych OV, Fedorovych EI, Khariv II, Vasiv RO, Levkivska ND, Leskiv KY and Guta ZA, 2019. Chemical composition, energy and biological value of broiler chicken meat caused by various doses of Se. Ukrainian Journal of Ecology 9(4): 622-627. https://doi.org/10.15421/2019_799

Tkeshelashvili M and Bobozhonova G, 2024. Enhancing gerodietic nutrition: Innovative technology for developing health-promoting feed. Advances in Life Sciences 11(1): 112-118.

Zaheer K, 2015. An updated review on chicken eggs: Production, consumption, management aspects and nutritional benefits to human health. Food and Nutrition Sciences 6(13): 1208-1220. http://dx.doi.org/10.4236/fns.2015.613127

Zhyrgalova A, Yelemessov S, Ablaikhan B, Aitkhozhayeva G and Zhildikbayeva A, 2024. Assessment of potential ecological risk of heavy metal contamination of agricultural soils in Kazakhstan. Brazilian Journal of Biology, 84: e280583 https://doi.org/10.1590/1519-6984.280583

Zou Q, Fan X, Xu Y, Wang T and Li D, 2022. Effects of dietary supplementation probiotic complex on growth performance, blood parameters, fecal harmful gas, and fecal microbiota in AA+ male broilers. Frontiers in Microbiology 13: 1088179. https://doi.org/10.3389/fmicb.2022.1088179