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Effect of Opoka use on Meat Productivity, Nutritional, Biological Value and Quality of Broiler Meat

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ABSTRACT

Poultry meat production, particularly broiler production, is one of the fastest-growing agricultural sectors worldwide. Rapid growth within the global population and increasing expenditure of protein foods are contributing to the demand for high-quality poultry meat. Broiler meat occupies an important position due to its rapid maturity, nutritional properties, low fat content, and high protein level. This study aims to investigate meat productivity, nutritional, biological value, along with the quality of broiler meat concerning the incorporation of Opoka into the main diet. For the research, two groups of broilers, each consisting of 100 chicks, were formed at one day of age. These chicks were hatched from eggs of the Ross-308 breed. The experiment lasted for 42 days. Broilers of group 2 were supplemented with 20% Opoka to the main diet. Opoka was implemented in the broilers' nutrition from the third day of life until slaughter. The incorporation of Opoka into the feeding regimen has resulted in increased live weight and carcass weight of broilers, as well as enhancements in the composition of vitamins, fatty acids, minerals, amino acids, chemical formulation, overall nutritional value of meat of broiler. A high survival rate of birds was detected in group 2 over the 42-day growth period. The use of Opoka positively influences the quality of broiler meat and enhances its nutritional value. The results of this research can be applied in the development of balanced feeding regimens, highlighting the relevance and significance of this matter.

Key words: Opoka, Broilers, Biological value, Nutritional value, Quality of meat

INTRODUCTION

Avian husbandry plays a key role in ensuring food security on a global scale. Given the growth in the global population and increasing demand for food resources, poultry meat production is becoming one of the most significant sectors of agriculture (Ciptaan et al. 2024). According to UN estimates, by 2050 the global population is expected to achieve 9.7 billion people, which will demand a significant increase in food production, including livestock products (United Nations 2019; Giller et al. 2021; Gržinić et al. 2023).

Poultry meat, especially broiler meat, occupies a leading place among sources of animal protein due to its availability, high nutritional characteristics, and low-fat content. Unlike other types of meat, broiler meat contains all the crucial amino acids, vitamins, and minerals vital for the normal performance of the human body. These qualities make it an important component of the diet in many countries around the world, especially in developing regions where protein deficiency is most acute (Park et al. 2021; Choi et al. 2023; Susalam et al. 2024).

One of the highly productive crosses is the cross "Ross 308" of the holding company Aviagen (USA). Currently, meat chickens of the Ross 308 cross occupy a leading position in the world market, they have become widespread in the USA, as well as in Europe and the Middle East. One of the most important factors that has a decisive influence on the implementation of the genetic ability of productive qualities of broiler chickens is feeding. Feed and feed additives are a source of energy, nutrients, minerals, and bioactive compounds that affect the safety and productivity of broilers (Martínez and Valdivié 2021).

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The Republic of Kazakhstan has large reserves of natural, environmentally friendly, and safe raw materials that can be used as feed additives in livestock and poultry farming. For this purpose, the greatest interest is represented by the Opoka of the Taskala deposit in Western Kazakhstan as a natural, environmentally friendly raw material. Opoka, in geology, is a microgranular microporous siliceous sedimentary rock composed of opal (Montayeva et al. 2021; Montayev et al. 2023).

This publication presents a detailed analysis of the application of the mineral feed additive Opoka in poultry farming. While numerous studies examine the use of various mineral additives in feed, research dedicated exclusively to the study of Opoka is considerably less common and is relatively rare.

In our study, we investigated the effectiveness of using Opoka in poultry farming to determine the output and standard of poultry meat. The composition of vitamins, fatty acids, minerals, amino acids, chemical composition, as well as the energy content of broiler meat were examined in detail. This research will enable a comprehensive and safe assessment, as well as identify new opportunities for further scientific investigations focused on exploring the beneficial properties of Opoka in broiler feeding and analyzing its impact on meat quality.

This study aims to investigate the meat productivity, nutritional, biological value, along with the quality of broiler meat concerning the incorporation of Opoka into the main diet.

MATERIALS AND METHODS

Ethical approval

All research and studies were undertaken in strict accordance with the requirements of local and worldwide legislation, determined by the recommendations of the European Convention for the Protection of Vertebrate Animals (Ausems 1986). Everything planned as well as conducted studies were thoroughly reviewed and received approval at the meeting of the university's ethics committee (No: WKATU-4/2024, April 11, 2024) at the WKATU named after Zhangir Khan, situated in the city of Uralsk, Republic of Kazakhstan.

Research duration and place

The research was undertaken at the veterinary clinic of the Educational and Scientific Production Center at the WKATU named after Zhangir Khan from April to June 2024, by the research plan. The subjects of our research were broilers of the Ross-308 breed. The analysis and assessment of broiler meat quality were conducted in the Limited Liability Partnership "Nutritest," located within the territory of the Republic of Kazakhstan.

Housing conditions of broilers

The housing conditions for both groups of broilers were identical and fully compliant with established regulatory requirements. Throughout the duration of our research, the broilers exhibited a clinically healthy state: their behavioral indicators, physiological parameters, and appearance remained consistent across both groups and reflected the natural age-related changes.

Experimental design

For the research, two groups of day-old broilers (Fig. 1) (group 1, group 2) were formed, with 100 individuals in each group, following the incubation of Ross-308 broiler eggs. The experiment lasted for a period of 42 days. Following the experimental design, the feeding regimen for both group 2 and group 1 was identical and consisted of a basic high-quality compound feed formulated to meet the daily nutritional requirements per bird. In the group 2, 20% of ground Opoka was added to the main diet of the broilers. Opoka was introduced into the broilers' feed from the third day of life until slaughter (Fig. 2, 3). By the 20th day of life, granulated Opoka was used instead of ground Opoka (Fig. 4, 5).

Fig. 1: Ross 308 broiler chicken.

Fig. 2: Opoka from the Taskalinskoye deposit of the West Kazakhstan Region, Republic of Kazakhstan.

Within this study, three replicates were conducted for each group 2. Upon completing the experiment, the broilers were weighed to assess growth dynamics, as live weight is

an important indicator of housing and feeding conditions. Technological slaughter of the broilers was performed on the 42nd day of the study to determine carcass weight and analyze the composition of vitamins, amino acids, minerals, fatty acids, chemical composition, energy value and quality of the broiler meat.

Fig. 3: Opoka grinding.

Fig. 4: 20-day-old Ross 308 broiler chicken.

At 42 days old, 50 broilers from each category were selected and processed following standard slaughter protocols, in accordance with the specifications outlined in GOST R (52837-2007) along with GOST (25391-82). These procedures ensured adherence to established guidelines for poultry processing and meat quality assessment. Following the slaughter, the broiler carcasses were anatomically dissected in accordance with the guidelines specified in GOST R (52702-2006). From these dissected carcasses, samples were then selected for detailed chemical analysis. The organoleptic assessment and physicochemical analyses of broiler meat were conducted in the Veterinary and Sanitary Expertise at the WKATU named after Zhangir Khan.

Fig. 5: Granulated opoka.

These evaluations were performed following GOST 9959-2015, which outlines the general conditions for organoleptic assessment of meat and meat products and GOST (7702.1-74), which details techniques for the chemical and microscopic examination of meat freshness. The humidity level in the meat was measured utilizing the drying technique, in strict accordance with GOST (9793-2016). The protein level in the meat was analyzed through the Kjeldahl technique, following the procedures outlined in GOST (25011-81). The fat content was assessed following the methodology outlined in GOST (23042-2015). The ash composition was assessed in accordance with the procedures specified in GOST 31727-2012 (ISO 936:1998). The energy content of the broiler meat was estimated following the guidelines established in GOST 34567-2019.

The concentrations of macronutrients and micronutrients were evaluated following the established criteria outlined as follows. The determination of calcium content was performed in accordance with GOST R (55573-2013). The determination of phosphorus content

was conducted in accordance with GOST 32009-2013 (ISO 13730:1996). The proportions of magnesium, sodium, and potassium were quantified following the guidelines set forth in GOST R (55484-2013). The concentration of iron was analyzed by GOST (26928-86).

The analysis of vitamins was conducted in accordance with the "Guidelines for Methods of Quality Control and Safety of Biologically Active Food Supplements" - P 4.1.1672-2003, Chapter 2, Section 1. The fatty acid contents of broiler meat were analyzed using the "Methodology of Gas Chromatographic Determination of Fatty Acids and Cholesterol in Food and Blood Serum" - MVI.MN. 1364-2000. The amino acid components in the meat samples were assessed utilizing the "Method for the Determination of Amino Acids in Food Using High-Performance Liquid Chromatography" - MVI.MN. 1363-2000.

The amino acid score was determined by employing the formula:

$$\text{Amino Acid Score} = \frac{(\text{mg of amino acid in 1g of test protein})}{(\text{mg of amino acid in the reference pattern})} \times 100$$

Statistical analysis

The data points were subjected to analysis using Microsoft Excel 2016 (Microsoft Corporation, USA). The findings are expressed as average figures accompanied by their respective mean standard errors. Student's test was employed to evaluate the statistical importance of divisions observed among the average figures. The analysis identifies differences between the evaluated means as significant ($P \leq 0.05$), distinctly significant ($P \leq 0.010$), or very significant ($P \leq 0.001$).

RESULTS

Live weight and carcass weight of broilers

A key metric in avian husbandry is live weight and carcass weight. The data from weighing the broilers in the group 2 on day 42 surpassed the live mass of group 1 – 6.66%, with a measurement of 2852±112.98g. In comparison, the live mass of the poultry in the group 1 was 2674±108.26g. Additionally, by day 42 of the study, group 2 poultry, which had Opoka in their diet, exhibited the highest carcass weight, measuring 2053±85.14g, representing a 7.60% increase evaluated with group 1, which had a carcass weight of 1908± 79,61g.

The sensory analysis of broiler meat

The sensory analysis of broiler meat and broth from all studied groups was conducted by a tasting committee to perform a comparative analysis of the key consumer properties of the finished products. After slaughter, the selected carcasses for the study were stored in a refrigerated chamber for three days under identical conditions, maintaining a temperature range of 0 to 4ºC, which ensured optimal conditions for the natural maturation of the meat.

A veterinary and sanitary evaluation of the carcass meat was performed. Upon external inspection of the broiler carcasses, it was determined that they were well-exsanguinated, clean, and free of feathers, down, or stubs. The muscle tissue, upon cutting, exhibited a slightly moist surface with light pink coloration and was characterized by a firm consistency; when pressed, the indentation quickly returned to its original shape, indicating good meat quality.

The odor of the surface layer of the carcasses corresponded to the typical aroma of fresh poultry meat, with no foreign odors present. Thus, upon external examination, no significant differences were observed in the carcasses of broilers that included Opoka in their diet in comparison to group 1.

Initially, a tasting of the broth prepared from all studied samples of broiler meat was conducted. The outcomes of the organoleptic evaluation of the broth demonstrated great scores across all groups. The samples were characterized by a pronounced aroma, a light straw color, and cleanliness, with no flakes present, indicating high product quality.

The examination was conducted using a 5.0 scale. The highest score of 4.9 was awarded to the broth samples prepared from the meat of group 2 in comparison to group 1, which received a score of 4.7. The tasting committee highlighted these samples for their pronounced aroma and rich flavor. Meanwhile, all presented samples received high marks for juiciness, natural and pleasant taste, as well as for their tender, soft texture, reflecting the high quality of the meat under investigation.

Physicochemical analysis of broiler meat

The investigation of the physicochemical characteristics of broiler meat facilitates the ability to objectively evaluate the freshness and quality of the produced products. Initially, an inspection of the carcasses of all studied groups of broilers was conducted to perform a veterinary and sanitary evaluation, which is an important step in confirming the safety and compliance of the products with sanitary standards.

During the investigation of the hydrogen ion concentration (pH), a shift towards acidity was observed, indicating increased resistance of the meat to putrefactive microorganisms. The differences in pH values among group 2 (5.62) as well as group 1 (5.60) categories were found to be insignificant, with a deviation not exceeding 0.2 units.

To evaluate the freshness of the examined meat samples, several qualitative reactions were performed. One of the key stages was the determination of the acid value of the fat. The values obtained for both groups were within 0.9mg KOH, indicating that the samples meet the established regulatory requirements. The peroxide value of all broiler meat samples was measured at 0.1% iodine, which supports the assertion of the freshness of the meat products from all groups. Samples of meat are classified as fresh if the content of amino-ammoniac nitrogen does not exceed 1.26mg. In this study, the average amino-ammoniac nitrogen level in the samples ranged from 0.79mg (group 2) to 0.80mg (group 1). The qualitative reactions for peroxidase (positive) and copper (II) sulfate (negative) also confirmed the high quality of the examined broiler meat samples.

Chemical content and energy value of broiler meat

Studying the chemical formation of broiler meat tissue allows for an evaluation of the nutritional standard of the produced product. A critical parameter is the animal protein content, which is essential for various biochemical and humoral reactions in the human body.

Analysis of the obtained data indicated an increase in protein content in group 2 in comparison to group 1. As a result of incorporating Opoka, the protein level in the meat of group 2 raised by 2.88% relative to the regulation samples, while fat content rose by 20.90%, ash content by 2.22%, and energy value by 13.31%. Conversely, moisture content decreased by 4.23%. The complete chemical formation of the broiler meat samples is summarized in Table 1.

Mineral content of broiler meat

Mineral substances are essential elements in fundamental physiological processes. For the optimal functioning of the human body, an adequate supply of minerals is necessary. Based on our findings, the study established that the mineral formulation of poultry meat receiving additional Opoka surpasses that of group 1 (Table 2). Specifically, the content of macroelements such as magnesium (16.67%), calcium (8.33%), sodium (11.27%), potassium (1.70%), and phosphorus (5.66%) in the meat from broilers consuming Opoka along with their main feed is higher in comparison to the data from group 1. Additionally, the content of the trace element iron (15.38%) in group 2 also shows a growth.

Vitamin composition in broiler meat

One of the components determining the physiological value of a food product is the vitamins it contains. In broiler meat, these are represented by studies on fat-soluble vitamins (A and E) and water-soluble vitamins (B1, B2, PP, and C). Analysis of our research indicated that the meat from the group 2 of broilers was highly balanced in terms of vitamin content (Table 3).

The vitamin content in the meat of group 2, which added the Opoka along with their main diet, exceeded that of group 1. Specifically, the amount of vitamin A increased by 20.00%, while the levels of other studied vitamins also rose: vitamin E by 7.69%, vitamin B1 by 25.00%, vitamin B2 by 7.14%, vitamin PP by 1.96%, and vitamin C by 5.56%.

Fatty acid content of broiler meat

The important consumer characteristic of meat is its fatty acid composition. In this study, we analyzed samples of broiler meat from all groups to determine the levels of 12 essential fatty acids, which included 4 saturated, 3 monounsaturated, and 5 polyunsaturated fatty acids. The fatty acid content in the group 2 receiving Opoka was considerably greater than group 1 (Table 4).

The findings showed that the addition of Opoka to the main diet increased the levels of the investigated 4 saturated fatty acids: myristic acid (C_{14}:0) increased by 20.37%, palmitic acid (C_{16}:0) by 20.87%, margarinic acid (C_{17}:0) by 19.78%, and stearic acid (C_{18}:0) by 20.89%. Additionally, the 3 monounsaturated fatty acids showed increases: palmitoleic acid (C_{16}:1) by 20.84%, oleic acid (C_{18}:1) by 20.91%, and gadoleic acid (C_{20}:1) by 18.80%. Among the 5 polyunsaturated fatty acids, linoleic acid (C_{18}:2) increased by 20.89%, alpha-linolenic acid (C_{18}:3) by 21.05%, arachidonic acid (C_{20}:4) by 20.83%, eicosapentaenoic acid (C_{20}:5) by 9.68%, and docosahexaenoic acid (C_{22}:6) by 26.09%.

Amino acid content of broiler meat

Examination of the information shown in Table 5 indicates that the incorporation of Opoka into the feeding regimen of broilers results in an increase in amino acid levels in the meat of group 2 in comparison to group 1. The amino acid formation of the nutrient fraction in broiler meat consists of nineteen amino acids, including eight essential and eleven non-essential amino acids.

Table 1: Influence of Opoka on the chemical composition and nutritional value of broiler meat

Parameters	Measurement	Study groups		Efficiency of Opoka application,+/- (%)	P value
		Group 1 (n=50)	Group 2 (n=50)		
Proteins	g/100g	18.73±0.73	19.27±0.76	+2.88	≤0.05
Fats	g/100g	11.29±0.46	13.65±0.49	+20.90	≤0.001
Moisture	g/100g	69.08±2.78	66.16±2.71	-4.23	≤0.05
Ash	g/100g	0.90±0.037	0.92±0.037	+2.22	≤0.05
Energy value	kcal/100g	176.5±7.28	200.0±7.81	+13.31	≤0.010

Table 2: Influence of Opoka on the mineral composition of broiler meat

Parameters	Measurement	Study groups		Efficiency of Opoka application,+/- (%)	P - value
		Group 1 (n=50)	Group 2 (n=50)		
Sodium	mg	71±2.89	79±3.21	+11.27	≤0.001
Potassium	mg	235±8.30	239±9.84	+1.70	≤0.05
Calcium	mg	12±0.51	13±0.51	+8.33	≤0.010
Magnesium	mg	18±0.95	21±0.86	+16.67	≤0.010
Phosphorus	mg	159±6.46	168±6.75	+5.66	≤0.05
Iron	mg	1.3±0.057	1.5±0.062	+15.38	≤0.001

Table 3: Influence of Opoka on the vitamin composition of broiler meat

Parameters	Measurement	Study groups		Efficiency of Opoka application,+/- (%)	P - value
		Group 1 (n=50)	Group 2 (n=50)		
A	mcg	30±1.46	36±1.45	+20.00	≤0.001
E	mg	0.26±0.010	0.28±0.011	+7.69	≤0.05
B1	mg	0.08±0.004	0.10±0.004	+25.00	≤0.001
B2	mg	0.14±0.006	0.15±0.006	+7.14	≤0.010
PP	mg	6.12±0.251	6.24±0.250	+1.96	≤0.05
C	mg	1.8±0.073	1.9±0.077	+5.56	≤0.05

Table 4: Influence of Opoka on the fatty acid profile of broiler meat

Parameters	Measurement	Study groups		Efficiency of Opoka application,+/- (%)	P - value
		Group; 1 (n=50)	Group 2 (n=50)		
Saturated fatty acid, including:	mg/100g	3494±142.78	4222±169.13	+20.84	≤0.010
$C_{14:0}$	mg/100g	108±4.43	130±5,25	+20.37	≤0.001
$C_{16:0}$	mg/100g	2309±92.41	2791±111.88	+20.87	≤0.001
$C_{17:0}$	mg/100g	91±4.03	109±4.42	+19.78	≤0.001
$C_{18:0}$	mg/100g	986±37.28	1192±48.27	+20.89	≤0.001
Monounsaturated fatty acid, including:	mg/100g	5299±214.96	6404±258.96	+20.85	≤0.010
$C_{16:1}$	mg/100g	830±35.2	1003±42.85	+20.84	≤0.001
$C_{18:1}$	mg/100g	4352±178.08	5262±214.48	+20.91	≤0.001
$C_{20:1}$	mg/100g	117±5.68	139±5.83	+18.80	≤0.001
Polyunsaturated fatty acid, including:	mg/100g	2351±96.04	2840±114.95	+20.80	≤0.010
$C_{18:2}$	mg/100g	2092±86.67	2529±102.17	+20.89	≤0.001
$C_{18:3}$	mg/100g	133±5.92	161±6.86	+21.05	≤0.001
$C_{20:4}$	mg/100g	72±3.08	87±3.77	+20.83	≤0.001
$C_{20:5}$	mg/100g	31±1.33	34±1.34	+9.68	≤0.010
$C_{22:6}$	mg/100g	23±1.42	29±1.22	+26.09	≤0.001
Total fatty acids		11144±471.76	13466±543.61	+20.84	≤0.010

Table 5: Influence of Opoka on the amino acid composition of broiler meat

Parameters	Measurement	Study groups		Efficiency of Opoka application,+/- (%)	P value
		Group 1 (n=50)	Group 2 (n=50)		
Essential amino acids, including:	mg/100g	6999±278.96	7251±292.03	+3.60	≤0.010
Valine	mg/100g	950±39.00	997±39.45	+4.95	≤0.010
Isoleucine	mg/100g	763±33.52	762±30.41	-0.13	≤0.05
Leucine	mg/100g	1390±57.60	1439±57.28	+3.53	≤0.010
Lysine	mg/100g	1616±69.64	1676±67.31	+3.71	≤0.010
Methionine	mg/100g	465±20.60	489±19.67	+5.16	≤0.010
Threonine	mg/100g	807±35.28	857±35.28	+6.20	≤0.010
Tryptophan	mg/100g	298±12.92	310±13.6	+4.03	≤0.010
Phenylalanine	mg/100g	710±27.40	721±29.84	+1.55	≤0.05
Non-essential amino acids, including:	mg/100g	11608±474.31	12004±483.46	+3.41	≤0.010
Alanine	mg/100g	1178±50.12	1260±50.59	+6.96	≤0.010
Arginine	mg/100g	1212±51.48	1289±50.56	+6.35	≤0.010
Asparagine	mg/100g	1742±65.66	1776±73.03	+1.95	≤0.05
Histidine	mg/100g	545±18.81	551±23.12	+1.10	≤0.05
Glycine	mg/100g	1281±50.23	1287±52.18	+0.47	≤0.05
Glutamic	mg/100g	2964±110.51	2995±120.84	+1.05	≤0.05
Hydroxyproline	mg/100g	163±6.03	172±5.88	+5.52	≤0.010
Proline	mg/100g	911±33.44	964±37.45	+5.82	≤0.010
Serine	mg/100g	817±30.67	861±35.24	+5.39	≤0.010
Tyrosine	mg/100g	598±25.92	643±24.82	+7.53	≤0.010
Cysteine	mg/100g	197±8.04	206±8.11	+4.57	≤0.010
Total amino acids		18607±734.28	19255±772.6	+3.48	≤0.05

Table 6: Influence of Opoka on the amino acid score of broiler meat

Parameters	Measurement	Study groups		Efficiency of Opoka application, +/- (%)	P value
		Group 1 (n=50)	Group 2 (n=50)		
Isoleucine	%	106±4.01	103±4.15	-2.83	≤0.05
Leucine	%	106±4.13	107±4.66	+0.94	≤0.05
Lysine	%	157±5.38	158±6.95	+0.64	≤0.05
Methionine+Cysteine	%	101±4.04	103±4.24	+1.98	≤0.05
Phenylalanine+Tyrosine	%	116±4.51	118±4.82	+1.72	≤0.05
Threonine	%	108±4.23	111±4.51	+2.78	≤0.05
Tryptophan	%	159±5.36	161±6.86	+1.26	≤0.05
Valine	%	101±4.02	103±4.17	+1.98	≤0.05

The findings indicated that the inclusion of Opoka to the main diet enhanced the levels of 7 out of the 8 essential amino acids also indicated rises: valine - 4.95%, leucine - 3.53%, lysine - 3.71%, methionine - 5.16%, threonine - 6.20%, tryptophan - 4.03%, and phenylalanine - 1.55%. All 11 non-essential amino acids also showed increases: alanine - 6.96%, arginine - 6.35%, aspartic acid - 1.95%, histidine - 1.10%, glycine - 0.47%, glutamic acid - 1.05%, hydroxyproline - 5.52%, proline - 5.82%, serine - 5.39%, tyrosine 7.53%, as well as cystine - 4.57%. Only one essential amino acid, isoleucine, showed a slight decrease of 0.13%.

Amino acid score of broiler meat

To determine the biological significance of broiler meat, the amino acid score was calculated. The biological

value of the meat from group 2, which was given Opoka, was considerably greater than group 1, indicating that it aligns with the definition of a highly nutritious and balanced product. The amino acid score levels in the meat of all groups were within the regulated norms. However, the highest amino acid score was observed in the group 2, where we noted increases in the levels of leucine (0.94%), lysine (0.64%), methionine + cystine (1.98%), phenylalanine + tyrosine (1.72%), threonine (2.78%), tryptophan (1.26%), and valine (1.98%). Only a low level of isoleucine (2.83%) was observed in the meat of group 2 in comparison to group 1 (Table 6).

DISCUSSION

At present, mineral feed compounds draw significant focus from experts in the field of fauna nutrition, both domestically and internationally. Utilizing local raw materials for their production is recommended. Natural mineral feed additives possess distinctive properties such as ion exchange, adsorption, and catalytic functions, which enhance the digestibility of feed nutrients, positively affect the physiological well-being, increase body mass gain, and improve the survival rate of young animals (Georgy and Belenkaya 2022).

A feed additive can stimulate animal growth, effectively compensate for the lack of nutrients in feed, reduce cholesterol levels, improve the retention and use of trace elements in the bird's body, increase the immune response of animals to stress, and form reactions resistant to diseases and immune reactions (Alagawany and Abd El-Hack 2020).

Mineral elements play a significant role in metabolic processes carried out in the body of animals at the cellular level. They maintain homeostasis, acid-base balance, and osmotic pressure. Deficiency of mineral elements leads to disruption of metabolic processes, decreased productivity, and increased incidence of poultry diseases. Mineral feed additives increase live weight, reduce feed consumption, and improve meat yield in broilers (Poberezhets et al. 2023; Poberezhets et al. 2024). Mineral feed additives are widely used in various agricultural sectors worldwide. Silica, a naturally occurring silicate mineral, has attracted attention as a potential feed additive in animal and poultry nutrition due to its beneficial properties. However, its application in other agricultural sectors other than poultry is extremely rare.

Our research demonstrated that the incorporation of Opoka into the feeding regimen of broilers leads to an increase in both live weight and carcass weight, as well as positively impacting flock survival rates. Mortality was observed during the first week of rearing, primarily due to stress associated with transplantation and the culling of injured and slow-growing chicks. The group 2 exhibited a high survival rate of 96% over the 42-day rearing period, in contrast to 84% seen in group 1.

The organoleptic evaluation of broiler meat demonstrated that incorporating Opoka to the main nutrition of the poultry enhances the flavor characteristics of both the meat and the broth. Furthermore, this significantly increases the product's appeal due to its rich aroma. The texture of the finished product across all samples was characterized by tenderness. The introduction of Opoka did not affect the color characteristics of the product. Thus, the high consumer qualities of the final product remain at a level consistent with standards.

The results of the physicochemical analyses of broiler meat showed that incorporating Opoka into the birds' diet does not adversely affect the quality of the meat or its shelf life. This data indicates that the use of Opoka can be safe and effective in meat production while preserving its organoleptic and nutritional characteristics.

The application of Opoka resulted in an increased protein level in the meat of group 2 in comparison to the regulation samples, along with corresponding increases in fat, ash, as well as energy content. Only the moisture components decreased. In terms of macro and micronutrient composition, the meat from broilers receiving additional Opoka surpassed the group 1. Our analysis of vitamin composition revealed that the meat from the group 2 was well-balanced in terms of vitamins. The fatty acid composition in group 2 receiving Opoka was considerably greater compared to group 1, with increases noted in all twelve examined essential fatty acids. The addition of Opoka to the main diet enhanced the levels of seven out of eight essential amino acids and all eleven non-essential amino acids, with only a slight decrease observed in isoleucine. The amino acid score levels in the meat of all groups remained within regulated norms; however, the highest scores were recorded in the group 2.

Overall, the incorporation of Opoka into the feeding regimen resulted in increased body mass and slaughter mass of the broilers, as well as improvements in the vitamin, amino acid, mineral, fatty acid, chemical formation, and energy quality of the product. Additionally, calm temperament was noted among the birds consuming Opoka alongside their main feed.

This mineral can improve livestock health and performance by improving nutrient digestibility and modulating gut microbiota, which is critical for optimal growth and health in various animal species. Research by Lee et al. (2020) suggests that silicate minerals, including those derived from silica, can positively influence livestock growth performance and health. A study demonstrated that dietary silicate supplementation in pigs resulted in increased leukocyte proliferation, indicating enhanced immune function. In addition, silicate supplementation improved nutrient digestibility and reduced harmful gas emissions in pigs, indicating a dual benefit of promoting growth while mitigating environmental impacts. In addition to growth performance, silicate minerals have been shown to influence biochemical parameters in livestock.

Moreover, the inclusion of silicate minerals in animal diets has been associated with improved feed efficiency. According to Xu et al. (2017), mixed rations (TMRs) that can include silicate minerals promote better feed intake and growth in Tibetan sheep and yaks, especially during the colder season. This suggests that silica flocks may similarly improve the nutritional profile of ruminant diets, leading to improved overall performance.

The mechanisms by which silica fume exerts its beneficial effects may include its role in improving the gut microbiome. Results from Akhter et al. (2015) showed that probiotics and prebiotics improve gut health and nutrient absorption, and silicate minerals may act synergistically

with these supplements to further improve animal health. Modulation of the gut microbiota may improve rumen fermentation processes, thereby increasing nutrient availability to the host animal.

Savinkov et al. (2023) investigated the influence of a mineral feed supplement on the morpho functional, biological chemical along with immunological blood indicators, as well as the productivity of dairy cows. The findings from the research indicated that the use of the additive leads to an enhancement in the proportion of all calcium in the hematologic system of lactating cows, a decrease in the level of inorganic phosphorus, restoration of the phosphorus-calcium ratio, and a decrease in the function of alkaline phosphatase, aspartate, and alanine aminotransferase. A stable tendency to grow in the production of milk receiving the mineral additive, fat, protein, and dry matter was noted. The tested additive can be used as a means for correcting mineral metabolism disorders with manifestations of alimentary osteodystrophy in lactating cows.

The intake of additives based on silicon-containing natural minerals, processed with innovative technologies, and enriched with amino acids of plant origin, into the organism of dairy cows increases the level of animal productivity, ensures the output of high-quality organic products, and has a prolonging effect, according to Dezhatkina et al. (2022).

The findings from research by Zaineldin et al. (2024) on fish showed that silicate-based detoxifiers can alleviate stress and improve growth in fish exposed to aflatoxins, demonstrating the protective effects of the mineral against food toxins. According to Ponomarev et al. (2019), the addition of sorbents in the feed composition helps to increase the immunity of fish to unfavorable development environments, prevent illnesses, as well as obtain superior and eco-friendly aquaculture goods, and also considerably decreases the expenses of fish meat. The addition of Opoka to the feed—a complex mineral addition—yielded favorable results for the fish-breeding and biological parameters of crustaceans and supported to the betterment of the value of the feed (Shirina et al. 2023). Feed with the addition of Opoka is an adequate feed with a high productive effect, which confirms the 100% survival rate of objects, high growth rate, and satisfactory condition of the body. The introduction of a complex mineral supplement into the feed increases the efficiency of growing tropical crayfish.

The results of the conducted review, analytical and scientific-experimental studies of Montayeva et al. (2023) in poultry farming allowed us to identify the following positive effects from the use of mineral springs in Western Kazakhstan: a preventive measure for gastrointestinal diseases, intoxications of the body of exogenous and endogenous origin, improved feed digestibility, adsorption in the gastrointestinal tract, and the removal of toxins from it has antibacterial effects, boosts immunity, and promotes a higher average daily weight gain.

The studies conducted by Nagimova (2024) showed that the introduction of a mineral supplement - Opoka, supplementing the daily feed of poultry without diminishing the nutritional quality of row protein and metabolizable amino acids, positively influences the protein spectrum of the blood, contributing to an elevation in the amount of whole protein and its fractions. Also, according to the conclusions of studies by Nugmanova et al. (2022), the inclusion of a composite mineral feed additive in the diet allowed for a reduction in feed costs to 0.63kg for ducks and to 0.59kg for drakes, which is 6.3–11.8% lower in comparison with group 1. With identical nutrition consumption in comparison with group 1, the inclusion of a mineral additive allowed an increase in the absolute and standard daily gains and live mass of young ducks in the experimental group.

Conclusion

In summary, it can be asserted that the incorporation of Opoka into the feeding regimen positively impacts the effectiveness and value of broiler meat. There is a notable increase in live weight and carcass weight, as well as improved flock survival rates. Additionally, the introduction of Opoka into the diet has enhanced the vitamin, amino acid, mineral, fatty acid, chemical content, and energy significance of broiler meat. To formulate a comprehensive feeding regimen, it is essential to optimize the compositions of the feeds used and to incorporate various available unconventional feed additives, such as Opoka, which improve the quality of diets and positively affect the animals' health. Consequently, the resulting products will retain their high-quality characteristics while remaining economically viable due to increased meat yield and improved quality.

Competing Interests: The authors declare that they have no competing interests.

Author's Contribution: MN, NG and KAK conceptualized the research study, designed and implemented the experimental protocols. SY, KA, SN, VZ contributed to the data collection and analysis. NG, ZF, NF, KAK and PA interpreted the results and drafted the manuscript. MN, ZF, AI supervised the project. All authors have reviewed and approved the final manuscript for publication.

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