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Investigation of the Compositional Raw Mixtures for Preparation of the Sintered Microporous Material and Mineral Feed Additives

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Abstract: The paper presents results of investigation of the compositional raw mixtures, which are manufactured on the basis of the siliceous rock and montmorillonite clay of the Western Kazakhstan for preparation of the sintered microporous ceramics, as well as the mineral raw mixtures, which are used as the therapeutic and prophylactic mixtures for poultry. In accordance with the results of the scientific-experimental investigations, it was proven that amorphous silicon, chalk, and montmorillonite, which are contained in the compositional mineral raw mixtures, ensure growth and tissue strengthening during the period of development and formation of skeleton. The amorphous silicon takes part in the bone mineralisation process even in the case of deficiency of calcium, phosphorus, chlorine, fluorine, sodium, sulphur, and other chemical elements. It was established that the limits of the proposed compositions and the proposed method of preparation of the proposed compositional mineral raw mix ensure therapeutic and prophylactic action, as well as bioactive influence upon the healthy growth and development of organism of broiler chickens. It was proven that proposed compositional mineral feed additives are characterised by high biological activity and substantial pharmacological effect, which are manifested as improvement of morphological and biochemical parameters of the poultry blood.

Keywords: siliceous rock-gaize, montmorillonite clay, physical and mechanical properties, biological activity, raw material components

1. Introduction

With the continuous advancement of industrial technologies, the utilization of natural and technology-related raw materials has expanded across various sectors. As new products based on these resources are introduced and developed, the need for efficient compositional materials becomes increasingly significant. The pressing challenge lies in obtaining such materials through a unified technology. Implementing and perfecting a unified technology enables the production of multiple product types within the same enterprise. Therefore, the development and adoption of a single technology hold great potential for meeting the demand for diverse compositional materials in an efficient and streamlined manner. The development of composite raw material blends to produce sintered microporous material and mineral feed additives using a single technology is key to

the production process, as it increases productivity while reducing the cost of raw materials and thus costs. It also ensures consistent product quality, contributes to the environmental sustainability of the production process by reducing waste and resources, and provides the flexibility to adjust the characteristics of the final product to meet market needs. The composition of the feedstock plays an important role in shaping the final properties of the sintered microporous material. The mineral composition of the feedstock affects the thermal properties of the sintering process, while chemical components such as aluminum and silicon affect the sintering temperature and reaction rate. In addition, the particle size distribution and moisture content of the raw material can affect the sintering uniformity and porosity of the final material. Optimization of these parameters is important for the production of sintered microporous materials with high

technological characteristics. Given these circumstances, it becomes feasible to employ a single technology for the production of multiple product types across different sectors of the economy. The Republic of Kazakhstan has great resources of the natural raw materials (siliceous rocks/gaizes, montmorillonite clays, and coal), on the basis of which it is possible to produce many kinds of products for various branches. This fact is proved by many papers of scientists of all countries of the world within this sphere of knowledge, as well as by wide application of these resources in various branches.

The siliceous opal-cristobalite rocks, which are characterised by very specific material composition and fine-pored structure, are widely used in different branches of industry¹⁾⁻⁴⁾. Because of the siliceous rocks consist (for the most part) of the amorphous activated silica, they are used as the great natural hydraulic admixtures in the puzzolan portland cements and in the lime-tripoli binding substances. In addition, they are used as the raw materials for manufacture of liquid glass, ceramic wall tiles, and refractory materials⁵⁾⁻⁹⁾. Adsorption and catalytic properties of the gaizes, diatomites, tripoli powders, and montmorillonite clays (bentonites) make it possible to use them widely as the filling materials in the course of manufacture of various filtering materials, which are used in order to clean syrups, edible, and industrial oils, as well as in order to ensure dehydration and desalting of crude oil, dehydration of gases and so on¹⁰⁾⁻¹⁵⁾. At the present day, various kinds of application of the siliceous rocks-gaizes and montmorillonite clays (bentonites) become more topical and the most important directions, because of these substances are actively used in the course of manufacture of the mineral feed additives for livestock animals and poultry. Various compositions of the mineral feed additives exert positive influence on the growth and development of the livestock animals and poultry. Mineral feed additives have salutiferous effect on digestive processes, they remove toxins from the body and normalize activity of the reproductive system organs¹⁶⁾⁻²¹⁾.

Therefore, the above-presented brief analytical review has demonstrated that the siliceous opal-cristobalite rocks-gaizes, and montmorillonite clays are the reserve basis of the raw materials not only for manufacture of construction materials, but also for manufacture of the biologically-active mineral feed additives (therapeutic and prophylactic mixtures) for livestock animals and poultry²²⁾⁻²⁵⁾. Mineral feed additives based on siliceous rocks and montmorillonite clays have many positive effects on the health and productivity of livestock and poultry²⁶⁾⁻²⁸⁾. First and foremost, these supplements are a source of important minerals such as silicon, potassium, calcium, iron and others that support the growth and development of animals, including bone structure, skin, feathers and hair health. Additionally, montmorillonite clays, in particular, are known for their adsorption properties. They can absorb toxins and harmful substances that may be present in the feed, thereby reducing their

negative impact on animal health. Some studies have also shown that mineral additives based on flinty rocks can improve digestion and promote more efficient nutrient absorption²⁹⁾⁻³⁰⁾.

The novelty of the study lies in its focus on developing compositional raw mixtures based on siliceous rock-gaize for the production of efficient materials and mineral feed additives for poultry. The objective of this study is to examine the composition of raw mixtures derived from siliceous rock-gaize and montmorillonite clays found in Western Kazakhstan. These mixtures are utilized in the production of sintered microporous ceramics as well as mineral raw mixtures, which are used in the creation of therapeutic and prophylactic mixtures for poultry.

Based on the research objective, the following tasks were set:

1. Study of the composition of raw material mixtures obtained from silicic rock gypsum and montmorillonite clays located in Western Kazakhstan.
2. Analysis of the use of these raw material mixtures in the production of heat-resistant microporous ceramic materials.
3. Evaluation of the use of these raw material mixtures in the creation of mineral raw material mixtures for poultry farming, in particular therapeutic and prophylactic mixtures.
4. Determination of possible advantages and application of the obtained composite raw material mixtures in the production of ceramic materials and mixtures for poultry farming.

The use of raw material mixtures obtained from silicic rock gypsum and montmorillonite clays from Western Kazakhstan can create effective composite mixtures for the production of heat-resistant microporous ceramic materials and mineral mixtures for poultry farming, which will have improved properties and can be used in various industries.

2. Materials and Methods

A comprehensive set of investigations has been organized and executed at the Yuzhno-Kazakhstanskiy State University named in honor of M. Auezov, located in Shymkent, Southern Kazakhstan. The principal objective of these inquiries was to ascertain the chemical and mineralogical composition of the raw materials being examined. Several methods were employed throughout these investigations. The raster electronic microscopy method, specifically the JSM-6390LV brand, was used in combination with energy-dispersion microanalysis to determine the local elemental composition of the gaize specimens. Mass spectrometry, aided by the inductively-coupled plasma method (ICP-MS Agilent 7500cx), was used to define the chemical elemental composition. Finally, the mineralogical composition was identified using the X-ray diffractometry method, specifically the X'Pert PRO MPD brand.

The X-ray phase analysis (XPA) of the specimens has been performed with the help of the special apparatus (brand name: DRON-3). In order to ensure performance of the scientific-experimental investigations, the following substances were used as the raw materials: the siliceous rocks-gaizes of the Taskala field; montmorillonite clay of the Pogadayevo field; chalk of the "Melovyye Gorki" field, and coal of the Karaganda Coal Basin. In accordance with the results of the X-ray phase

analysis (XPA) (Figure 1), it was established that mineralogical composition of the clay is presented (for the most part) by the montmorillonite $d/n=5.06; 4.46; 3.79; 3.06; 2.45; 2.28; 2.12; 1.97; 1.81; 1.67 \text{ \AA}$. In addition, the following substances are present in the composition of the clay: quartz (SiO_2) $d/n=4.24; 3.34; 2.45; 2.28; 2.12; 1.98; 1.81; 1.66; 1.33 \text{ \AA}$; haematite (Fe_2O_3) $d/n= 2.69; 1.83; 1.68; 1.59 \text{ \AA}$ and hydrous mica $d/n= 3.21; 2.57; 2.12; 1.49 \text{ \AA}$.

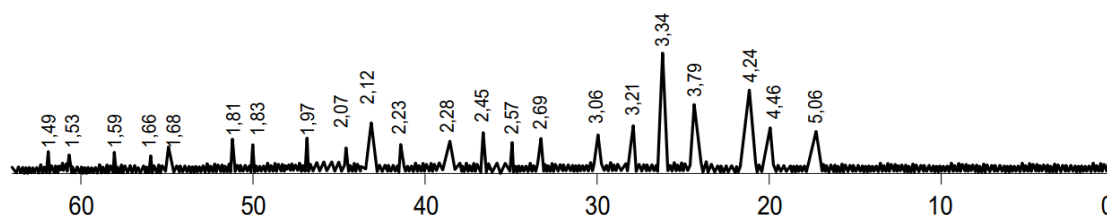


Figure 1. Radiographic appearance of the montmorillonite clay of the Pogadayevo field.

The siliceous rock-gaize of the Taskala field is the light-weight, hard, and microporous rock. In accordance with the geological data, the gaizes are confined to the Paleogene and Cretaceous deposits, the gaizes are usually formed within sea basins due to solidification and cementation of the diatomites and tripoli powders. Values of density of these rocks are within the range from 1.3 up

to 1.5 g/cm^3 . They have a form of white, grey or greenish light-weight rocks along with sporadic fragments of the diatoms algae, radiolarians, and spicules. In accordance with the results of the X-ray phase analysis (Figure 2), it was established that the amorphous silica (SiO_2) is also presented as the principal mineral.

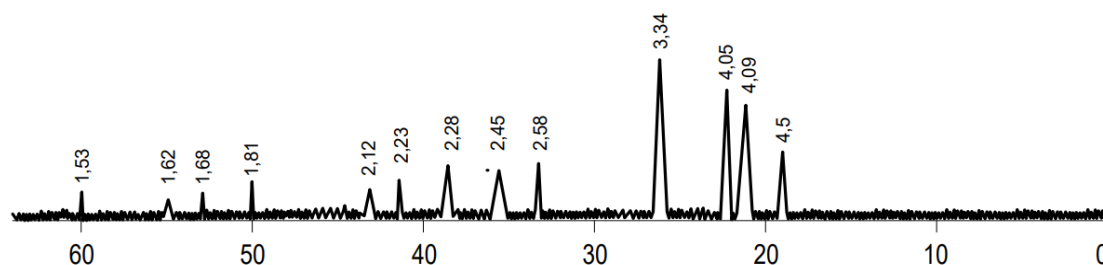


Figure 2. Radiographic appearance of the siliceous rock-gaize of the Taskala field

On the basis of the scientific-experimental investigations, it was established that chalk of the "Melovyye Gorki" field is presented as the unconsolidated rock of white colour. The chalk is clear, it has no any siliceous impurities. In accordance with the results of the X-ray phase analysis (XPA) (Figure 3), it was established that the chalk under investigation consists (for the most part) of the calcium carbonate (CaCO_3) ($d/n = 3.843;$

$3.029; 2.490; 2.277; 2.088; 1.912; 1.869; 1.626 \text{ \AA}$). It has the following chemical composition: $\text{CaCO}_3 - 88.98-95.23\%$, $\text{MgCO}_3 - 0.33-1.57\%$. As concerns chemical composition, this chalk is classified as the chalk of A and B classes. Its ultimate stress limit in dry condition is equal to 11.3 MPa, while the same value in the water-saturated condition is equal to 6.1 MPa.

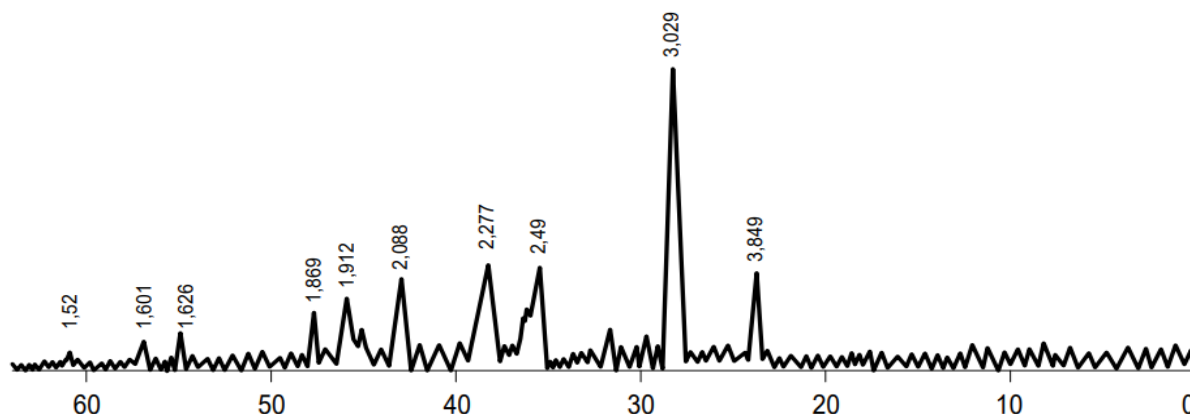


Figure 3. Radiographic appearance of the chalk of the "Melovyie Gorki" field

The pulverised-fuel ash of the Ekibastusz coal-fired thermal power station (hereinafter to be referred to as the Ekibastusz State District Power Plant or as the Ekibastusz SDPP) is the unconsolidated powder-like material of the dark-grey colour, which has the following physical and mechanical properties: specific surface area of ash – 3200-3700 cm²/g; true density – 1.75-1.84 g/cm³; bulk density – 675-740 kg/m³. Granulometric composition of ash (%) at the dimensions of particles (in mm): more than 0.25 – 5.98%; 0.25-0.05 – 34.8%; 0.05-0.01 – 43.07%; 0.01-0.005 – 6.55%; 0.005-0.001 – 6.40%; lesser than 0.001 – 4.35%. It was found that the main crystalline phases that make up this ash are alpha quartz with the chemical formula alpha-Si O₂ and mullite with the chemical formula SiO₂ Al_{1.44} Si_{1.56} O_{9.78}. These findings are important for further studying the possibility of using this ash as a raw material for various technological processes. From the very beginning, raw materials have been dried within the drying closet. Clay and the siliceous rock-gaize were subject to preliminary disintegration with the help of the laboratory jaw breaker. Later on, each substance has been individually crunched within the laboratory ball mill down to the complete transmission through the mesh No. 1,0. The pulverised-fuel of the Ekibastusz state district power plant (SDPP) ash (due to its high dispersion ability) has been used without desintegration. In order to ensure performance of the scientific-experimental investigations, the following selection was made: composition of the raw materials mixture, which were limited by the following maximum component concentrations (in weight percents): gaize 30-50. clay 30-40. ash 10-40 (Table 1)

Table 1. Compositions of the ceramic mixtures under investigation.

Nos. of compositions	Name and content of the raw material components, weight%		
	Siliceous rock-gaize	Clay of the Pogodayevo field	Pulverised-fuel of the Ekibastusz SDPP ash

1	30	30	40
2	40	35	25
3	50	40	10

These raw materials have been weighed with the help of the process of weighing in accordance with the compositions under investigation, and then they have been loaded into the laboratory mixing machine in order to perform consolidated mixing operation in dry condition. Upon formation of the homogeneous mixture, water has been usually added into the mixing machine and this product have been thoroughly mixed once again until the moment of formation of the plastic ceramic mixture. Mixing moisture content of this ceramic mixture was within the range from 25 up to 27% of the mass of dry components. Then, special cylindrical specimens (dimensions of which were equal to 50x50x50 mm) have been formed on the basis of this ceramic mixture with the help of the plastic method. The formed cylindrical specimens have been dried within the drying closet down to achievement of the residual moisture content at the level from 8 up to 10%.

3. Results and Discussion

The formed raw cylindrical specimens were subject to the annealing operation at the temperature of 1000 °C within the laboratory muffle furnace with the temperature rise rate at the level of 150 °C per hour. Duration of curing these specimens at the final temperature was equal to 1 hour. Specimens have been hold within the deactivated furnace until the moment of achievement of the room temperature. Then, these heat-treated ceramic cylindrical specimens were subject to physical and mechanical tests in accordance with the rules of standard methodologies. As concerns selections of the properties under investigation, as a rule, the most important physical and mechanical properties of specimens have been selected, that is, the properties, which characterise their efficiency, namely: average density (g/cm³); ultimate compressive

strength (MPa); water absorption capacity (%); total porosity (%), and heat conductivity factor, $W/(m \cdot ^\circ C)$. At the same time, special reference specimens have been formed on the basis of the ceramic mixtures, which were manufactured from the clear sandy clay in order to ensure

performance of the comparative analysis of results of these scientific-experimental investigations. Results of performance of the scientific-experimental investigations are presented in Table 2.

Table 2. Physical and mechanical properties of the ceramic specimens, which were heat-treated at the temperature of 1000 °C.

Seq. numbers of compositions	Average density, g/cm^3	Ultimate compressive strength, MPa	Water absorption capacity, %	Total porosity, %	Heat conductivity factor, $W/(m \cdot ^\circ C)$
1	1.17-1.18	11.2-11.8	32-34	54-56	0.25-0.24
2	1.14-1.16	10.7-10.9	31-32	52-54	0.23-0.24
3	1.12-1.13	10.1-10.3	31-33	51-53	0.19-0.21
Reference specimens on the basis of clear sandy clay	1.85-1.90	7.5-9.4	25	22-25	0.7-0.8

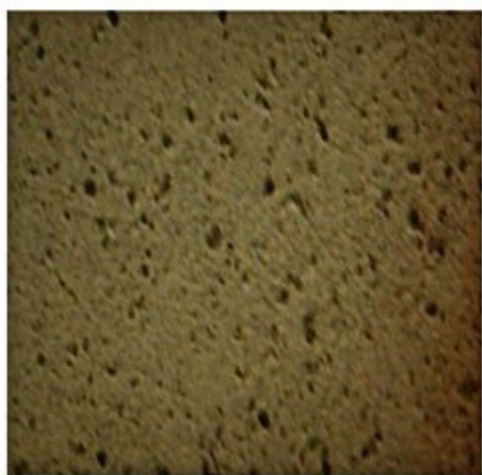
In accordance with results of analysis of physical and mechanical properties of specimens, which were heat-treated at the temperature of 1000 °C, it was possible to establish main regularities of their change depending on the component composition of the raw material system within the area under investigation. As it was demonstrated with the help of analysis of the obtained results, the least parameters in respect of the average density and heat conductivity factor were found in the specimen/composition No. 1 (content of the Ekibastusz SDPP ash is equal to 40%, while content of the siliceous rock-gaize is equal to 30%). In these circumstances, maximum value of total porosity is equal to 54-56%. It is worthy to note that despite high total porosity and low parameters of average density, heat-treated specimens have high parameters of the compressive strength (11.2-11.8 MPa).

Increase in content of the siliceous rock-gaize up to 50% due to decrease in content of the Ekibastusz SDPP ash down to 10% caused insubstantial increase in the average density and decrease in parameters of the compressive strength. Increase in the average density is in the range from 0.74-0.78 g/cm^3 up to 0.84-0.87 g/cm^3 , while decrease in the ultimate compressive strength is in the range from 11.2-11.8 MPa up to 10.1-10.3 MPa. In these circumstances, total porosity of the specimens is maintained at the level of 51-53%. Increase in parameters of the heat conductivity factor is also insubstantial (0.31-0.34 $W/(m \cdot ^\circ C)$).

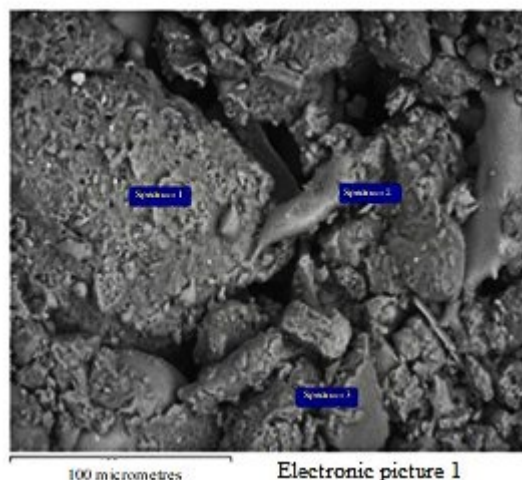
Increase in parameters of the total porosity is also confirmed by increase in parameters of the water

absorption capacity of specimens. At the background of increase in the total porosity, parameters of the water absorption capacity of the specimens are within the limits of 31-34%. The comparative analysis of change in the physical and mechanical properties of specimens of the ceramic mixture compositions under investigation in comparison with the ceramic specimens on the basis of the clear sandy clay has demonstrated substantial changes in all parameters of these properties. Specimens on the basis of the ceramic mixture under investigation have the lowered average density and increased total porosity by more than 2 times. In addition, they are characterised by the lowered heat conductivity factor (0.25-0.34 $W/(m \cdot ^\circ C)$ against 0.7-0.8 $W/(m \cdot ^\circ C)$), and this fact is one of the important energy efficiency criteria of a material. In addition, despite of the high parameters of total porosity, these specimens are characterized by high compressive strength (11.2-11.8 MPa against 7.5-9.4 MPa).

In order to investigate morphology of the porous structure, slices of the ceramic specimens under investigation were made with the help of the relevant cutting tool. Later on, electronic microscopic photographs of these slices were made (Figure 7). With the help of visual examination and examination through the microscope, it was possible to establish that these specimens are the specimens of the strongly-sintered ceramic material of the light-beige color, which have various macro- and microporous structures. Macro- and micropores are uniformly distributed within the entire volume.



a)



b)

Fig. 4: Porous macrostructure (view of the slice surface) of the cylindrical specimens, which were heat-treated at the temperature of 1000 °C. a) view of the slice surface; b) view under an electron microscope (magnification x 550).

The existent changes in the physical and mechanical properties of the ceramic mixtures under investigation are connected, firstly, with chemical and mineralogical characteristics of the applicable raw materials. Low average density and high total porosity of the composition No. 1 is ensured (as it seems) at the expense of content of the Ekibastuz SDPP ash due to burning out of the unburnt residues of the finely-dispersed coal. In addition, these values are connected with the relatively low parameters of average density of the ash itself. As concerns the ceramic mixture No. 3, which is characterized by minimum content of ash in the composition of this substance, the siliceous rock-gaize plays the decisive role in formation of the porous structure and low parameters of the average density. In principle, it has high porosity and low average density. Clay enacts as the binding substance for two nonplastic materials at the stages of formation and subsequent processes of the hard- and liquidphase-sintering at the stage of the annealing operation. In consequence of these stages, the sintered hard-crystalline phase is formed. This substance is characterised by the finely-porous structure, and this fact explains the high strength properties of the specimens, despite of their high total porosity. Therefore, on the basis of the ceramic mixture compositions under investigation it is possible to form the efficient ceramic materials, which would have light weight, required mechanical strength, high total porosity, as well as low parameters of the heat conductivity factor. Sintered microporous materials can be widely used in various industries due to their unique properties. For example, they can be used as filters for purifying gases or liquids, sound absorption materials, catalysts in chemical reactions, and as thermal insulation materials. Mineral feed additives derived from flint and montmorillonite clays can significantly improve the health and performance of livestock and poultry. They

help increase weight and productivity, improve bone health and increase disease resistance. Additionally, such additives can be used to effectively enrich feed with essential minerals, which is especially important in intensive livestock and poultry production³¹⁾⁻³³⁾. The results, which were obtained in the course of these investigations, are the basis for development of the manufacturing technique in order to produce efficient and much-needed construction materials of wide spectrum (ceramic road-building materials, heat-insulation and constructional walling ceramic materials, heat-insulation ceramic veneers, light-weight porous filling materials).

In order to achieve the determined goal in respect of investigation of special compositions for the mineral raw mixtures for livestock animals and poultry, the following raw material composition was selected: montmorillonite clay – siliceous rock-gaize – chalk. The compositions under investigation are presented in Table 3.

Table 3. Compositions of the feed additives under investigation.

Nos. of compositions	Name and content of the raw material components, weight %		
	Montmorillonite clay	Siliceous rock-gaize	Chalk
1	30	30	40
2	30	40	30
3	25	35	40

The following procedure is used in order to prepare the compositional mixture. From the very beginning, large pieces of the gaize, montmorillonite clay, and chalk (more than 10 centimetres in dimension) are subject to disintegration with the help of the jaw breaker until the moment of formation of the relevant fraction (from 10 up

to 30 millimetres in dimension) on the condition of the subsequent desintegration with the help of the roll crusher until the moment of formation of the relevant fraction (from 0.3 up to 3.0 millimetres in dimension). Then, the required compositional mixture is manufactured on the basis of the desintegrated raw material components in the following ratio (in weight percents): gaize – 30-40, montmorillonite clay – 20-30, and chalk – 30-40. Later on, this mixture (without any preliminary heat-treating operation) is thoroughly mixed once again within the hermetic mixing machine until the moment of development of the uniformly-distributed mixture. The obtained mixture is usually packed into hermetic sacks or packages (5, 10, 20, 25, and 50 kg in weight) for subsequent use of this mixture as the component of the poultry feed.

The scientific-experimental investigations with the purpose of studying influence of the developed compositions of the raw mixtures upon the poultry organisms have been actually performed in respect of the broiler chickens (of the 30-days age) in the conditions of the Shamshyrak Agricultural Production Co-operative (town of Uralsk). In these circumstances, chickens of the first poultry group (control group) have been obtained feed without compositional raw mineral mixture, while the second poultry group has been obtained the feed with admixture at the rate of 2-3% of dry substance of the daily diet. All experimental poultry groups were clinically healthy. During 30 days, physiological status of the poultry has been assessed in accordance with the results of morphological and biochemical investigations of the poultry blood. These investigations have been performed in order to track out (over time) changes in the metabolic processes of poultry organisms in respect of the following parameters: red blood cell count and haemoglobin level; total protein and protein fractions; glucose; urea; level of the alanine aminotransferase (ALT), aspartate aminotransferase (AST); total calcium and inorganic phosphorus; as well as main micronutrient elements.

Investigation of the chemical composition of blood gives possibility to assess state, direction, and intensity of the metabolic conversion; course of physiological processes in the organism; level of usefulness of feeding the poultry; state of health of the poultry. The investigations, which have been performed, have demonstrated that the proposed compositional mineral feed additives, which were included into composition of the daily diet of the experimental poultry groups, have significant pharmacological effect. Please see below results of the haematological parameters of the experimental broiler chickens (n=5) (Table 4).

Table 4. Haematological parameters of the experimental broiler chickens (n=5).

Parameter	Group	
	control	experimental
Red blood cell count, 10^{12} /litre	2.47+0.012	2.57 +0.011
White blood cells count, 10^9 /litre	34.21+0.16	31.12+0.14
Haemoglobin, g/l	97.04+1.83	104.25+1.81

Results of the performed investigations have demonstrated that there is increase in the content of the red blood cells, as well as increase in the blood hemoglobin concentration in the experimental poultry groups. For example, as concerns the first experimental group (group I), level of the red blood cells increased by 4.45% ($P<0.01$), while level of the haemoglobin increased by 7.43% ($P<0.01$). Level of white blood cells in blood of chickens of the experimental groups decreased by 9.03%. As it seems, the compositional mineral feed additive in the daily diets of broiler chickens occurred positive influence upon their immunity. Morphological composition and chemical composition of blood are parameters of the physiological status of organism and they predetermine productive and adaptational capacities of the agricultural poultry.

The processes, which occur in the organism, influence upon the morphological composition of blood. Therefore, it is possible to assess intensity of the oxidation-reduction processes taking into account the content of the red blood cells, white blood cells, and haemoglobin. In accordance with results of our investigations, it was established that the morphological parameters of blood, which we have investigated in respect of the experimental broiler chickens, were within the limits of the physiological norm (Table 5).

Table 5. Biochemical parameters of blood of broiler chickens (n=5).

Parameter	Group	
	control	experimental
Total protein, g/l	40.37 +0.50	42.65 +0.62
Albumins, g/l	21.31+ 0.44	23.12 + 0.33
Relative, %	52.13 + 0.20	53.24 + 0.18
Globulins, g/l	19.78 + 0.18	20.12 + 0.22
Relative, %	47.08 + 0.34	46.12 + 0.28
Including: α	16.54 + 0.26	16.34 + 0.50
β	6.73 + 0.31	5.14 + 1.16
γ	4.55 + 0.40	5.12+ 1.16
AST, unit/litre	217.4 + 2.72	236.3 + 3.10
ALT, unit/litre	3.39 + 0.22	3.49 + 0.34
Glucose, mmol/litre	6.87 + 0.16	7.29 + 0.14

Total lipides, g/l	4.16 + 0.08	4.12 + 0.07
Alkaline phosphatase, unit/litre	1150 + 8.45	1883 + 9.12

Results of our investigations have demonstrated that proposed compositional mineral admixture occurred positive influence upon the protein metabolism of broiler chickens of the experimental groups. For example, content of the total protein in the blood serum of chickens of the experimental group was higher as compared with the same value of the control group by 2.28g/l or by 5.3% ($P<0.05$) (Table 6). This fact confirms that there exist more intensive oxidation-reduction processes in the poultry organisms of the experimental groups. In addition to the increase in the level of the total protein, it is also possible to observe relevant increase in the content of the albumin fraction in the blood serum of chickens of the experimental groups by 1.81 g/l (or by 7.82%; $P<0.05$). As concerns absolute content of globulins in the blood serum of broiler chickens of the experimental groups, results of our investigations confirm that level of globulins in the course of growth and development of these chickens increased by 0.34 g/l or by 1.68% in respect of the control group of chickens. As concerns protein fractions, γ -globulin is the most interesting substance for investigation, because of this substance is the carrier of antibodies and it ensures immune protection of organism. In the course of our investigations, it was established that content of γ -globulins was higher for the chickens of the experimental groups by 0.57 g/l or by 11.1% ($P<0.05$) as compared with the chickens of the control group. The highest level of the γ -globulin fraction was found in the blood serum of chickens of those experimental groups, which have obtained compositional mineral feed admixture along with the amorphous silicon, and this fact confirms better immunobiological activity of the organism. As concerns factors of the protein metabolism, the following substances play the most important role: aspartate aminotransferase and alanine aminotransferase. These substances act as catalysts of the processes, which are connected with the protein metabolism in organisms of the livestock animals. Changes in the content of the AST and ALT are closely connected with the process of transamination of amino acids, and these changes are the most important biochemical markers in the pathology of liver. Parameters of activity of the aminotransferases in the course of our investigations were within the limits of the physiological norm and they characterise normal function of liver for the experimental chicken groups. In addition, in the course of our investigations it was established that activity of the AST among the broiler chickens of the experimental group has increased by 18.9 unit/litre (by 8.6%; $P<0.05$) as compared with the control group. This fact confirms the higher intensity of the protein metabolism. Activity of the ALT for the chickens

of the experimental groups has been practically equal to the level of the control group.

It should be also noted the stable increase in activity of the alkaline phosphatase in the experimental groups as compared with the control group. This fact confirms substantial increase in the mineral metabolism within the organism. For example, activity of the alkaline phosphatase in the experimental group has increased by 63.7% ($P<0.001$). No critical differences in respect of content of the glucose and total lipides in the blood serum of chickens of the experimental groups were established. Process of the metabolic conversion requires presence of certain microelements within tissues of organisms of the livestock animals. Lack or excess of such microelements impedes processes of synthesis of the biologically active compounds. Mineral substances are components of all tissues of animal organisms, they take part in the energetic, carbohydrate, water kinds of metabolism, in the metabolism of fats, and they exert influence upon growth and development of organism³⁴⁾⁻³⁶⁾. In connection with this fact, there exists great scientific and practical interest in studying the influence of the compositional mineral raw mixtures upon the biochemical parameters of blood, because of these parameters characterise the chicken's metabolism and exchange of macro- and microelements. In the course of these investigations, it was established that broiler chickens of the experimental groups, which have been obtained this admixture, had the higher concentration of macro- and microelements in blood (Table 6).

Table 6. Content of mineral elements in blood of the experimental broiler chickens, mmol/litre (n=5).

Parameter	Group	
	control	experimental
Calcium (Ca)	2.27 + 0.020	2.51 + 0.25
Phosphorus (P)	2.18 + 0.022	2.31 + 0.021
Magnesium (Mg)	0.96 + 0.034	1.05 + 0.028
Sodium (Na)	158.45 + 1.48	159.43 + 1.52
Potassium (K)	4.29 + 0.022	4.46 + 0.032
Cuprum (Cu)	3.53 + 0.07	3.55 + 0.08
Zinc (Zn)	24.17 + 0.17	25.98 + 0.18

Blood of chickens of the experimental group in comparison with the chickens of the control group: content of calcium was higher by 10.5% ($P<0.05$), phosphorus by 5.96% ($P<0.05$), magnesium by 9.37% ($P<0.05$), zinc by 7.48% ($P<0.05$), and potassium by 3.96% ($P<0.05$), respectively. Low levels of the immunological reactivity and natural resistance of organism is one of the main reasons of decrease in productivity and viability of the poultry. Because silicon and calcium are interconnected with these elements in many metabolic processes, it is possible to make conclusion on positive influence of the silicon-containing and calcium-containing groups of minerals, as well as of

the group of the alumino-silicate containing minerals (such as, for example, montmorillonite) upon acceleration of these processes, as well as upon increase in digestibility of nutritional substances within the feed by chickens of the experimental groups and (as the consequence) upon their growth and development. In the course of these investigations, substantial intergroup differences in respect of parameters of the live weight have been established. By the end of raising, live weight of chickens in the experimental group was higher than the same parameter of chickens in the control group by 275 grammes or by 12.15% ($P < 0.001$).

Results of the performed scientific-experimental investigations demonstrate that introduction of the compositional mineral raw mixtures into the feed composition exerts therapeutic and prophylactic influence upon organisms of broiler chickens in the experimental groups. These positive effects are connected with the unique properties of the minerals, which are included into compositional mineral raw mixtures. Presence of silicon in the composition of minerals of such compositional additives ensures formation of the colloidal systems, which are electrically charged and which have the unique property. They are capable "to glue" on the viruses and disease-inducing microorganisms, which are not characteristic for poultry, and remove them from the organism. At the same time, normal gut microflora has no property "to glue" with the colloidal systems of silicon and it continues to stay within the gut. Presence of silicon (Si) and calcium (Ca) (these substances are introduced along with the gaize and chaulk) is extremely necessary in order to ensure: growth and development of broiler chickens; formation of the bone and connective tissues; normal metabolism of fats, protein and carbohydrate metabolism, as well as metabolism of vitamins, macro- and microelements³⁷⁾⁻³⁸⁾.

It was experimentally proved that the above-listed minerals exert influence upon the lipid metabolism, metabolism of phosphorus and other mineral elements. Natural mineral sorbents in the form of the siliceous rock-gaize of the Taskala field, as well as in the form of the montmorillonite clay of the Pogadayevo field (these sorbents include, for the main part, highly-dispersed silica and montmorillonite) ensure efficient sorption of the following substances: mycotoxins, salts of heavy metals, chemical toxins, radionuclides, gases and other metabolic products (due to large sorbing surface of such sorbents). In addition, amorphous silicon, chalk, and montmorillonite, which are contained in the compositional mineral raw mixtures, ensure growth and tissue strengthening during the period of development and formation of skeleton and take part in the bone mineralisation process even in the case of deficiency of calcium, phosphorus, chlorine, fluorine, sodium, sulphur, and other chemical elements³⁹⁾⁻⁴⁰⁾. Limits of the proposed compositions, as well as the proposed method of preparation of the compositional mineral raw mixtures

ensure therapeutic, prophylactic, as well as bioactive action, which is necessary for the comprehensive growth and development of organisms of the broiler chickens. Therefore, the proposed compositional mineral feed additive has high biological activity and substantial pharmacological effect, which are manifested as improvement of morphological and biochemical parameters of the blood of cows.

4. Conclusions

The conducted investigations involved several key activities and analyses. Firstly, the necessity for developing compositional raw mixtures based on siliceous rock-gaize was identified as crucial for producing efficient materials and mineral feed additives for poultry. Secondly, the physical and mechanical properties of heat-treated specimens were examined within specific concentration limits of gaize, clay, and ash components. The changes observed in these properties were linked to the chemical and mineralogical characteristics of the raw materials. Additionally, the role of amorphous silicon, chalk, and montmorillonite in promoting growth, tissue strengthening, and bone mineralization processes in poultry was established. The proposed compositional mineral raw mixtures were found to exhibit therapeutic, prophylactic, and bioactive effects, supporting comprehensive growth and development in broiler chickens. Lastly, the high biological activity and significant pharmacological effects of the compositional mineral feed additive were proven through improvements in morphological and biochemical parameters of poultry blood.

The results, which were obtained in the course of these investigations, are the basis for development of the manufacturing technique of the efficient and much-needed construction materials and mineral feed additives (therapeutic and prophylactic mixtures) for poultry. Amorphous silicon, chalk and montmorillonite play an important role in the development and strengthening of tissues and bone mineralization in broiler chickens. Silicon is an important trace element that contributes to the formation of collagen, a key protein that provides strength and elasticity of bones, cartilage, joints and skin, and is involved in the process of bone mineralization. Chalk, as a source of calcium, is important for bone growth and strength, and promotes cellular growth and development. Montmorillonite, also known as bentonite, is used as a feed additive due to its adsorption properties. It binds toxins in the intestines, preventing them from affecting animal health, and improves the efficiency of digestion and absorption of nutrients, including important minerals for bone development. The research is of great importance for industry, as it allows optimizing the composition of raw materials for the production of sintered microporous materials with desirable properties that can be used in areas such as filtration, sound insulation, and construction. In addition, the creation of

mineral feed additives based on these materials can help improve the health and productivity of livestock and poultry. The implementation of the results of this research into large-scale production processes is possible and opens the way to reducing costs and improving production efficiency.

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