International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

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Effect of Feed Supplements on Blood Biochemical Parameters and Intensity of Metabolic Processes in Cows: the Neural Network Modeling Method

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Abstract

The purpose of this study was to evaluate the effect of internal metabolic processes and feed supplements on the biochemical parameters of cows' blood. Two experiments were conducted on black-and-white cows to study the effect of shungite and humic feed supplements. Blood parameters related to metabolic processes were measured and used as input data for the CompNN neural network model. The model calculated the cognitive significance index, which served as a dimensionless parameter representing the relationship between blood parameters and biometric indicators. The results showed that the inclusion of shungite and humic feed supplements led to an increase in cognitive significance index values. This indicated the stimulation of metabolic processes in the intestines of cows, while the humic preparation had a greater effect. Correlation coefficients between the cognitive significance index and specific blood parameters demonstrated a relationship between the intensity of metabolic processes and changes in the concentration of albumin, phosphorus, creatinine, and urea. The results of this study highlight the potential of using neural network modeling to assess the effect of feed supplements on metabolic processes and blood parameters in cows. The cognitive correlation established using the cognitive significance index provides valuable information about the effect of feed supplements on animal health. As a result of the study, the positive effect of shungite and humic feed supplements on animal health has been shown. Further research in this area can contribute to the development of optimized feeding strategies and the development of sustainable and efficient animal husbandry.

Keywords: Feed supplements, shungite, food security, blood parameters

Full length article **Corresponding Author*, e-mail: *ni.vorobyov@mail.ru*

1. Introduction

Cattle play a crucial role in ensuring food security, especially in the Russian Federation, as they serve as an important source of protein through the production of meat and milk [1-3]. To increase efficiency and sustainability in animal husbandry, the need for environmentally friendly products free of antibiotics and hormones is increasing. One of the promising ways to achieve this goal is the use of biologically active substances as feed supplements. These substances regulate the adaptive and protective functions of the body and reduce sensitivity to adverse environmental factors, technogenic burden, and unbalanced nutrition. The health of highly productive cows is a serious problem all over the world, as the lack of certain nutrients can disrupt metabolic processes and affect the overall well-being of animals. Therefore, ensuring a balanced diet becomes a primary task in industrial animal husbandry, since energy deficiency can significantly affect the vital activity of the body [4-6]. To solve these problems, the inclusion of biologically active substances has become an effective strategy for restoring and maintaining animal health. Among the various approaches, the effect on the rumen proved to be particularly effective for increasing milk production and the nutritional value of the milk. Although antimicrobial feed supplements were used to increase the efficiency of milk production by dairy animals, their subtherapeutic use in livestock diets was prohibited due to a decrease in public recognition and their residual content in animal products [7, 8]. Therefore, microbiologists and animal nutritionists are studying new feed supplements from natural sources to replace antimicrobial feed supplements [9-12]. One such supplement is humate substances. In recent years, interest in the use of humic substances in animal diets has increased. Humic substances (including humic and fulvic acids) are considered safe and natural feed supplements that have a beneficial effect on animal welfare and the quality of animal products. Humic substances are natural organic substances found in the soil, formed during the humification of dead organic matter. They have many physical, chemical, and biological properties that make them suitable for use in animal husbandry. They demonstrate antioxidant and anti-inflammatory effects and support the gastrointestinal tract of animals, accelerating their growth and simultaneously improving immunity and reproductive function [13-16]. In addition, sorbents of both natural and synthetic origin are increasingly used in industrial animal husbandry to mitigate the negative effects of toxic substances contained in the feed. One of these additives is shungite. This is a unique natural mineral. This sorbent can sorption of organic and mineral substances, as well as a high filtering ability [17, 18]. Thus, the introduction of mineral preparations into the diet of animals based on humic acids and shungite minerals can lead to the activation of metabolic processes in the body of animals and accelerated accumulation of biomass by them [19, 20].

The purpose of this study was to evaluate the effect of mineral feed supplements on metabolic processes in the cows' bodies based on biochemical parameters of animal blood and their neural network modeling.

2. Materials and methods

2.1. Materials

We conducted two scientific and production experiments using black-and-white cows to investigate the effects of shungite and humic feed supplements on metabolic processes and blood parameters.

Methods Experiment 1: Shungite Feed Supplements The first experiment was conducted at the experimental and physiological facility of the Federal State Budgetary Scientific Institution "All-Russian Research Institute of Animal Husbandry (VIZh) named after Academician L.K. Ernst." A total of 30 black-and-white cows were selected, and the experiment extended over a duration of 85 days.

- **Control Variant (C1):** Animals were not administered the shungite preparation.
- **Experimental Variant 1 (E1):** Animals received shungite preparation No. 1 alongside the basic diet (BD) at a concentration of 1% of the mass of concentrated feed.
- **Experimental Variant 2 (E2):** Animals received shungite preparation No. 2 with the BD at a concentration of 1% of the mass of concentrated feed.

Blood parameters related to the metabolic state of the animals were determined, including alanine transaminase (ALT), aspartate transaminase (AST), albumins, total protein, total bilirubin, hematocrit, hemoglobin, glucose, calcium, creatinine, leukocytes, urea, phosphorus, total cholesterol, and erythrocytes [20].

Experiment 2: Humic Feed Supplements The second experiment was carried out on a collective farm in the Vologda region, involving 30 black-and-white cows selected based on their milk yield exceeding 8,000 kg in 305 days. Over a span of 90 days, the Reasil Humic Health humic preparation was incorporated into the animals' diet at a daily dosage of 30 g.

- **Control Variant (C2):** Animals did not receive the humic preparation.
- **Experimental Variant 3 (E3):** Animals were administered the Reasil Humic Health humic preparation (30 g per day) for 30 days.

CompNN Neural Network Model To assess the effectiveness of shungite and humic additives, the CompNN computational component neural network was employed. The model aimed to calculate the cognitive significance index (CSI) of animal blood indicators [22]. This index served as a quantitative indicator of the level of metabolic processes within the animals' bodies. The CSI values were determined based on a set of selected blood parameters.

2.2. Statistical analysis

The statistical analysis involved matrix transformations and computations performed using the CompNN model. The layer of neurons (L1) normalized the initial blood data matrix and calculated the normalized matrix. The layer of computational neurons (L2) computed eigenvalues and eigenvectors of the Correlation (Cor) matrix. The matrix G representing the coordinates of the main components was generated based on matrix transformations. The vector of weighting coefficients (W) was calculated through recurrent calculations. Using the weighting coefficients, the CSI vectors were determined, establishing a parametric relationship between blood parameters and body weight gain. The validation of CompNN was achieved through calculating the correlation coefficient of the CSI vector with animal weight gain coefficients.

3. Results

When processing animal blood indicators, it was assumed that blood indicators reflected changes in biochemical metabolic processes occurring during the digestion of feed in the animal rumen. The level of consistency and accuracy of genomic regulation of biochemical processes is a qualitative characteristic of these processes. Therefore, for the cognitive analysis of changes in the level of consistency of biochemical processes, we proposed using CompNN (Fig. 1) [23-25]. The first task of using CompNN was to select the most significant animal blood parameters (alanine transaminase (ALT), aspartate transaminase (AST), albumins, total protein, total bilirubin, hematocrit, hemoglobin, glucose, calcium, creatinine, leukocytes, urea, phosphorus, total cholesterol, and erythrocytes) to establish a cognitive correlation with the intensity of metabolic processes in the animals' body that determine the speed of development and growth of animals. As a result, four indicators were selected (Table 1). Table 1 and Fig. 1 show the values of the CSI indices for the variants of the experiment and the correlation coefficients of the CSI with the blood parameters of animals and their weight gain.

Table 1. Blood counts of cows in experiments with shungite and humic feed supplements

Animal blood counts	Experiment variants					CSI correlation coefficient
	C1	E1	E2	C2	E3	
1. Albumins, g/l, ± 0.5	28.8	28.9	29.4	34.9	37.5	-0.72
2. Creatinine, microns/l, ± 3	70	71	71	86	85	0.45
3. Urea, mM/l, ± 0.2	4.6	4.5	4.7	4.2	4.0	0.68
4. Phosphorus, mM/l, ± 0.1	3.7	3.6	3.6	2.2	2.2	-0.53
Weight gain of animals compared to C1 and C2	1.00	1.08**	1.02**	1.00	1.34*	0.99
CSI, b/r, ± 0.1	4.5	5.2	3.0	4.6	7.7	

*The gain has been calculated using CompNN.
**The weight gain has been calculated compared to the weight in the control version of the experiment (C1).

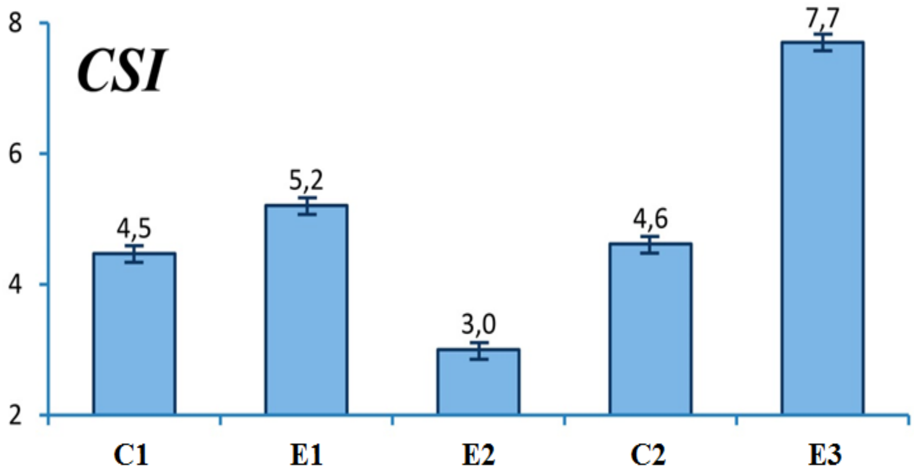

Figure 1. The CSIs of the cognitive significance of animal blood indicators according to the variants of the experiment C1, E1, E2, C2, E3 (Table 1)

3.1. CompNN computing algorithm

Before calculating the CSI of animal blood indicators, a search was conducted for the most informative blood indicators. The total number of possible combinations of four animal blood counts exceeds one thousand. Therefore, previously, using CompNN (Fig. 2), a search was carried out (using the gradient method) for the most informative quarter of animal blood indicators (Table 1).

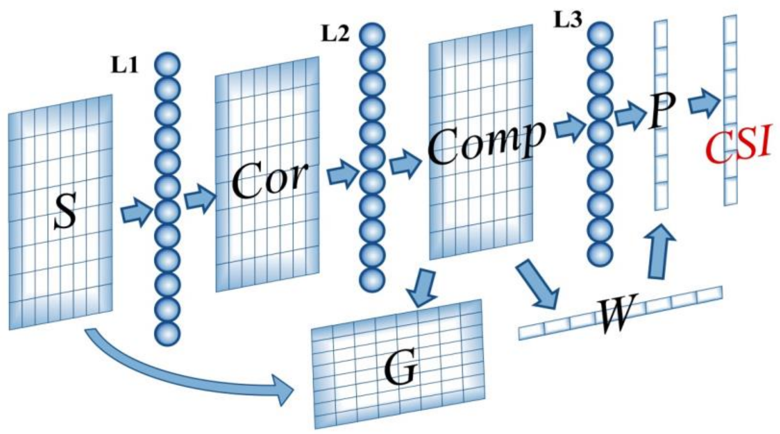

Figure 2. CompNN component neural network designed to calculate the CSI of animal blood indicators. L1, L2, and L3 are layers of artificial neurons performing matrix transformations of numerical data. The description and formulas of transformations are provided in the text.

3.2. Formulas of matrix transformations performed using CompNN

1. The layer of neurons L1 normalizes the initial data of matrix S containing animal blood data (Table. 1) and calculates the normalized matrix D by formulas (1)-(3), and then calculates the Cor matrix by formula (4).

$$D_{jk} = \frac{1}{V_j}\left(S_{jk} - M_j\right) \qquad (1)$$

$$M_j = \frac{1}{5}\sum_{k=1}^{5} S_{jk} \qquad (2)$$

$$V_j = \sqrt{\sum_{k=1}^{5}\left(S_{jk} - M_j\right)^2} \qquad (3)$$

$$Cor_{mn} = CoefficientCorrelation\ (D_{mK1}, D_{mE1}, \ldots, D_{mE3}, D_{nK1}, D_{nE1}, \ldots D_{nE3}) \qquad (4)$$

where S_{jk} are the biochemical parameters of animal blood (Table 1) with ordinal numbers (j,m,n=1,...,4) for experimental variants (C1, E1, E2, C2, E3) with ordinal numbers (k=1,...,5); Coefficient*Correlation()* is a function that calculates the correlation coefficients between a pair of biochemical parameters of animal blood.

2. The layer of computational neurons L2 calculates the eigenvalues (λ_j) and the matrix of eigenvectors $Comp_{mn}$ for the Cor matrix by the algorithm developed by [26], using the formulas (5) and (6).

$$\lambda_j = EigenValue\left(Cor_{j.k}\right) \qquad (5)$$

$$Comp_{j.k} = EigenVectors\left(Cor_{j.k}\right) \qquad (6)$$

where j, k = 1, 2, 3, 4 are the ordinal numbers of blood biochemical parameters (Table 1).

3. The initial data can be represented in the coordinates of the main components, in the form of a matrix G (Fig. 1) using the formula of the product of the Comp and D matrices (7).

$$G = Comp \times D \qquad (7)$$

The *Comp* eigenvectors and the λ_k eigenvalues of the $Cor_{j.k}$ matrix are distinguished by a monotonous decrease in the numbers λ_j with an increase in the ordinal number of the main component.

4. The vector of weighting coefficients W is calculated by repeated recurrent calculations of the W2 vector and replacing the W1 vector with the W2 vector. Recurrent calculations continue until the condition (8) is met with a given accuracy. After that, W=W2.

$$CoefficientCorrelation\ (W1; W2 = C \times C^T \times W1) = 1 \qquad (8)$$

where C and C^T are the main and transposed matrices obtained after the normalization of the Comp matrix by rows.

5. Using the vector W data, the CSI vectors are calculated using the formula (9).

$$CSI_k = W_k \cdot b + 5 \qquad (9)$$

where b=3.43; k=1,...,5 are the ordinal numbers of the experience variants C1, E1, E2, C2, E3.

6. Validation of CompNN was carried out by calculating the correlation coefficient of the data of the CSI vector with animal weight gain coefficients (r=0.99, Table 1). In the initial data of experiment No. 2, there is no information about the weight gain of animals in the E3 variant. Therefore, the neural network presented the expected increase in the weight of animals who had received humic preparations with the feed (1.34, Table 1).

The results of calculations using CompNN are shown in Table 1 and Fig. 1.

1. The CSI establishes the parametric dependence of the selected animal blood parameters on it, on the one hand, and the weight biometric indicators of animals, on the other hand. Such a parametric relationship allows for predicting their biometric data based on animal blood parameters, depending on the conditions of their keeping, feeding, and the used feed supplements. At the same time, reducing the number of necessary blood parameters allows monitoring the condition of animals without additional costs and without risks of reducing animal health.

2. When using shungite preparation No. 1 in experiment No. 1 and humic preparation in experiment No. 2, an increase in the CSI is observed compared with control variants (variants C1, E1: CSI =4.5; 5.2; variants C2, E3: CSI=4.6;7.7). This means that the humic preparation stimulated metabolic processes in the intestines of animals to a greater extent than the shungite preparation No. 2.

3. The correlation coefficients of the CSI with animal blood indicators have a different sign (r=-0.72; 0.45; 0.68; -0.53; Table 1). This means that with increasing metabolic processes in the body of animals, the concentration of albumins and phosphorus decreases, and the concentration of creatinine and urea increases. Perhaps this is a consequence of the activation of some biochemical processes in the intestines of animals.

4. Conclusions

By performing two scientific experiments, we noticed that the inclusion of shungite and humic preparations in the diet of cows led to an increase in the CSI, which indicated an increase in the activity of metabolic processes. The CompNN computational component neural network allowed us to establish a cognitive correlation between the values of the CSI in the blood of animals and their body weight gain, acting as a valuable quantitative indicator of metabolic processes in the body of animals.

It was found that the humic preparation stimulated metabolic processes in the intestines of cows to a greater extent compared with shungite preparations. The correlation coefficients between the CSI and blood parameters indicated the association of increased metabolic processes with increased concentrations of creatinine and urea with a decrease in albumin and phosphorus concentrations.

These results highlight the potential of mineral feed supplements, especially humic substances, in maintaining animal well-being, improving the quality of animal products, and improving metabolic functions.

5. Acknowledgments

The study was funded with grant No. 23-26-00234 of the Russian Science Foundation, https://rscf.ru/project/23-26-00234/

References

[1] R.N. Lyashuk, O.A. Mikhailova, S.V. Moshkina, & D.A. Samoilov (2017). Zootechnical evaluation of cows using feed additives. Bulletin of Kursk State Agrarian Academy, 3: 23-28.

[2] P. Galin, A. Galyaveeva, H. Bataev, & V. Safonov (2020). The role of micro-nutrients and vitamins in the prevention and remote treatment of heart failure. Revista Latinoamericana de Hipertension, 15: 26-32.

[3] N. V. Bogolyubova, V. N. Romanov, & V. A. Devyatkin (2015). Progress ovtsevodstva i usvoyaemost pitatelnykh veshchestv s ispolzovaniem mineralnogo shungita v kachestve istochnika ergotropnykh veshchestv [Progress of sheep breeding and digestibility of nutrients using mineral shungite as a source of ergotropic substances]. Bulletin of Samara State Agrarian Academy, 1: 168-117.

[4] T. V. Boyko, E. A. Chaunina, N. A. Buzmakova, & E. A. Zharikova (2021). Biologically active additives for cows as a factor in the production of environmentally friendly products in animal husbandry. IOP Conference Series: Earth and Environmental Science, 624: 012063. http://dx.doi.org/10.1088/1755-1315/624/1/012063

[5] A. A. Aliev (1997). Obmen veshchestv u zhvachnykh zhivotnykh [Metabolism in ruminants]. NITs Inzhener, Moscow, Russia. 420 p.

[6] N. V. Bogolyubova, V. N. Romanov, V. A. Devyatkin, & Yu. K. Kalinin (2014) Optimizatsiya protsessov pishchevareniya i obmena veshchestv v organizme ovets pri ispolzovanii kompleksa ergotropnykh veshchestv v sostave minerala shungita [Optimization of the processes of digestion and metabolism in the body of sheep using a complex of ergotropic substances in the composition of the mineral shungite]. Veterinariya i kormlenie, 5: 88-90.

[7] H. M. El-Zaiat, A. S. Morsy, E. A. El-Wakeel, M. M. Anwer, & S. M. Sallam (2018). Impact of humic acid as an organic additive on ruminal fermentation constituents, blood parameters, and milk production in goats and their kids' growth rate. Journal of Animal and Feed Sciences, 27(2): 105-113. https://doi.org/10.22358/JAFS%2F92074%2F2018

[8] F. A. Musaev, N. I. Torzhkov, Zh. S. Maiorova, & D. A. Blagov (2015). Kormovye dobavki s biologicheski aktivnymi svoistvami v kormlenii skota [Feed supplements with biologically active properties in livestock feeding]. Fundamentalnye issledovaniya, 2(23): 5133-5138.

[9] M. K. S. Chattopadhyay (2014). Use of antibiotics as feed additives: A burning question. Frontiers in Microbiology, 5: 334. https://doi.org/10.3389/fmicb.2014.00334

[10] Yu. M. Smirnova, A. V. Platonov, & A. A. Shamakhov (2022). Pokazateli krovi korov pri vklyuchenii v ratsion dobavki na osnove guminovykh kislot [Blood parameters of cows when supplements based on humic acids are included in the diet]. Vestnik KrasGAU, 8(185): 100-105. https://doi.org/10.36718/1819-4036-2022-8-100-105

[11] A. A. Vasilev, A. P. Korobov, S. P. Moskalenko, L. A. Sivokhina, & M. Yu. Kuznetsov (2018). Znachenie, teoriya i praktika ispolzovaniya guminovykh kislot v zhivotnovodstve [Significance, theory and practice of using humic acids in animal husbandry]. Agrarnyi nauchnyi zhurnal, 1: 3-6.

[12] M. A. Glaskovich, & L. V. Shulga (2010). Kak oboitis bez kormovykh antibiotikov? [How to do without feed antibiotics?], in Pervye mezhdunarodnye Bekkerovskie chteniya: Sbornik nauchnykh trudov po materialam nauchno-prakticheskoi konferentsii, Volgograd, 27-29 maya 2010 g. [First international Becker readings: A collection of research papers based on the materials of the research and practice conference, Volgograd, May 27-29, 2010], Part 2. Volgograd State University, Volgograd, Russia. 90-92.

[13] A. Šamudovská, & M. Demeterová (2010). Effect of diet supplemented with natural humic compounds and sodium humate on performance and selected metabolic variables in broiler chickens. Acta Veterinaria Brno, 79: 385-393. https://doi.org/10.2754/avb201079030385

[14] K. M. S. Islam, A. Schuhmacher, & J. M. Gropp (2005). Humic acid substances in animal agriculture. Pakistan Journal of Nutrition, 4(3): 126-134. http://dx.doi.org/10.3923/pjn.2005.126.134

[15] M. Yu. Kuznetsov (2018). Opyt ispolzovaniya biologicheski aktivnoi dobavki Reasil Humic Health v ratsione doinykh korov [The experiment with Reasil Humic Health dietary supplement in the diet of dairy cows]. Osnovy i perspektivy organicheskikh biotekhnologii, 4: 37-40.

[16] O. A. Ratnykh (2018). Lechebnaya effektivnost gumata kaliya pri gepatoze laktiruyushchikh korov i telyat molochnogo perioda [Therapeutic efficacy of potassium humate in hepatosis of lactating cows and calves of the milk period]: Author's abstract of a Cand. Vet. Sci. dissertation. Saratov State University of Genetics, Biotechnology and Engineering named after N.I. Vavilov, Saratov, Russia. 18 p.

[17] T. V. Dyakova (2006). Ispolzovanie shungita Zazhoginskogo mestorozhdeniya dlya profilaktiki mikotoksikozov u ptitsy [The use of shungite from the Zazhoginsky deposit for the prevention of mycotoxicoses in poultry], in Mat. Pervoi Vserossiiskoi nauchno-prakticheskoi konferentsii "Shungity i bezopasnost zhiznedeyatelnosti cheloveka" [Proceedings of the First All-Russian research and practice conference "Shungites and safety of human life"]. Karbon-Shungit, Petrozavodsk, Russia.

[18] V. G. Ryadchikov (2012). Osnovy pitaniya i kormleniya selskokhozyaistvennykh zhivotnykh: Uchebno-prakt. posobie [Fundamentals of nutrition and feeding of farm animals: A workbook]. Kub.GAU, Krasnodar, Russia. 328 p.

[19] V. N. Romanov, N. V. Bogolyubova, M. G. Chabaev, R. V. Nekrasov, V. A. Devyatkin, G. Yu. Laptev, N. I. Novikova, & L. A. Ilina (2015). Optimizatsiya pishchevaritelnykh, obmennykh protsessov i funktsii pecheni u molochnogo skota [Optimization of digestive and metabolic processes and liver functions in dairy cattle]: A monograph. VIZH im. L.K. Ernsta, Dubrovitsy, Russia. 152 p.

[20] V. I. Georgievskii (1990). Fiziologiya selskokhozyaistvennykh zhivotnykh [Physiology of farm animals]. Agropromizdat, Moscow, USSR. 511 p.

[21] S. P. Moskalenko (2018). Mirovoi opyt ispolzovaniya guminovykh kislot v skotovodstve и svinovodstve [World experience in the use of humic acids in cattle and pig breeding]. Osnovy i perspektivy organicheskikh biotekhnologii, 4: 11-15.

[22] U. Sutrop (2001). List task and a cognitive salience index. Field Methods, 13(3): 263-276. http://dx.doi.org/10.1177/1525822X0101300303

[23] A. S. Zaikina, N. P. Buryakov, N. I. Vorobev, & I. N. Nikonov (2022). Neirosetevoi analiz sootvetstviya mikrobno-organizmennoi biosistemy kishechnika ptitsy fraktalno-stokhasticheskoi modeli [Neural network analysis of the correspondence of the microbial-organismal biosystem of the poultry gut to the fractal-stochastic model]. Permskii agrarnyi vestnik, 4(40): 98-106. https://doi.org/10.47737/2307-2873_2022_40_98

[24] F. M. Gafarov, & A. F. Galimyanov (2018). Iskusstvennye neironnye seti i prilozheniya: Ucheb. Posobie [Artificial neural networks and applications: A manual]. Izd-vo Kazan. un-ta, Kazan, Russia. 121 p.

[25] N. V. Bogolyubova, V. N. Romanov, V. A. Devyatkin, & E. V. Dolgosheva (2016). Primenenie shungita v ratsionakh vysokoproduktivnogo krupnogo rogatogo skota [The use of shungite in the diet of high productive cattle]. Izvestiya SGSKhA, 2: 63-66. https://doi.org/10.12737/19062

[26] L. V. Markova, & E. A. Korchevskaya (2011). Chislennye metody nakhozhdeniya sobstvennykh vektorov i sobstvennykh znachenii matrits [Numerical methods for finding eigenvectors and eigenvalues of matrices]. UO VGU im. P. M. Masherova, Vitebsk, Belarus. 47 p.