Effect of mineral additives supplementation on Holsteinized Russian Black Pied calves

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Abstract

In this study, the mineral supplementary nutrition complexes Mustala and Mustala-T, based on natural or thermally processed shungite minerals, were used in a mixture with compound feed for Holsteinized Russian Black Pied calves of the preweaning and post-weaning rearing periods as additives in the amount of 1% by weight of concentrates. To obtain the feeding efficiency data for Mustala and Mustala-T, three analogue groups of calves aged 2–5 months were formed. The control group calves were fed the basic diet: whole milk substitute, hay and concentrates in the preweaning period and hay and concentrates in the post-weaning period. The calves of the 1st and 2nd experimental groups were additionally fed 1% Mustala and Mustala-T to the mass of concentrates, respectively. The use of Mustala and Mustala-T contributed to increased body weight gain by 14.1 and 4.2%, respectively. The results of this study were subjected to the calculation of bioconsolidation indices and a neural network analysis based on the biochemical parameters of the blood of calves additionally fed the shungite preparations. Neural network analysis confirmed the high correlation of bioconsolidation indices with indicators of calf productivity and the economic efficiency of the use of shungite preparations in animal feeding.

Keywords: Holsteinized Russian Black Pied calves, Gaussian neural network, Biochemical blood parameters, Biomass indicators, Shungite mineral

Introduction

Improvement of livestock production efficiency includes optimising the fodder base, particularly in young animals (Podstreshnyi and Tereshchenko, 2012; Allen, 2014; Bogolyubova et al. 2014,2018; Fails and Magee, 2018; Terry et al. 2020; Sejrsen et al. 2023). Their subsequent growth, development, environmental adaptation and maximum realization of their genetic potential is key to full productivity (Rexroad et al. 2019; Romanov et al. 2021; Krutikova et al. 2024; Deniskova et al. 2025; Narushin et al. 2025) and disease prevention (Romanov et al. 2016; Medeiros et al. 2022). Gastrointestinal tract (GIT) disorders significantly impede production (Nikonov et al. 2017; Kochish et al. 2018; Marzanova et al. 2023; Grozina et al. 2023), and are caused most commonly by mixed infections often initiated by stress factors, e.g., poor quality colostrum (that may be inappropriately chilled), and improper/untimely newborn feeding. Moreover, violations of sanitary and hygiene regimes (breeding and newborn stock) lead to accumulation of opportunistic and pathogenic microorganisms. Failure to comply with the timing of pregnant cows launch and reduction in the dry period may also result in a decrease in protective immunoglobulins and vitamins in colostrum by 1.4–2x (Nowak et al, 2012; Romanov et al. 2016).

The digestive system in all ruminants forms at 3–5 weeks, and after 2–3 months, nutrient digestion ordinarily occurs in the small intestine, utilising normal flora from the large intestine. Without normal microflora, an intestinal environment favorable for enterobacteria forms, generating toxic products that multiply and block normal metabolic processes, causing diarrhea (Ryadchikov, 2012; Romanov et al. 2016; Li et al. 2021; Litonina et al. 2022) and conditions encouraging common GIT diseases of bacterial and viral origin. Diarrhea-induced calf loss can reach or exceed 50% births and those that recover can be severely stunted, restoring their original weight by about 20 days, but with reduced energy (Ryadchikov, 2012; Romanov et al. 2016; Chen et al. 2022). To manage and treat gastrointestinal disorders, antibacterial drugs are commonly employed but attitudes to them is changing as the negative consequences of their use emerge (Romanov et al. 2022; Laptev et al. 2024a,b,2025; Ben et al. 2022). Antibiotics can accumulate in food products, contribute to the emergence of resistant forms, reduce effectiveness of therapeutic agents, and cause other negative processes (Anisova et al. 2011; Trufanov et al. 2015; Mancuso et al. 2021; Yildirim et al. 2026). Therefore, substitutes have been tested and used (Reddy et al. 2012), including auspicious feed additives e.g., those based on the shungite mineral containing pyrobitumen (Tremasova, 2014; Bogolyubova et al. 2015a,b; Kochish et al. 2020). Their effects are assessed using such novel mathematical and computational approaches as neural network and biosystem consolidation (Vorobyov et al. 2021; Vorobyov and Selina, 2021; Zaikina et al. 2022).

The lack of minerals in calf diets leads to growth retardation and anemia as well as other undesirable metabolic changes, such as general and specific weakening disease (Bogolyubova et al. 2014). Here, we therefore examined the effectiveness of Mustala (based on shungite substance; Bogolyubova et al. 2015c,2016,2017) and Mustala-T (based on thermally processed shungite substance) supplementation in the diets of young cattle using neural network and bioconsolidation analysis (Vorobyov and Selina, 2021; Zaikina et al. 2022).

The following indicators and aspects were studied:

- body weight gain;
- biochemistry/hematology of blood parameters of metabolic processes and nonspecific immunity;
- indices of bioconsolidation of biochemical processes (Vorobyov and Selina, 2021), as a result of processing values of animal blood parameters by a computational neural network (Zaikina et al. 2022);
- effect of shungite preparations on the index of bioconsolidation of biochemical processes;
- correlation of the index of bioconsolidation of biochemical processes with the physiological indicators of blood and with economic indicators of animal feed.

Materials and Methods

To implement the set objectives, a scientific and economic experiment was arranged at the Experimental Physiological Yard of the L. K. Ernst Federal Research Centre for Animal Husbandry and carried out using three groups of calves of the Holsteinized Russian Black Pied cattle breed, which were analogous by age, origin, sex and body weight, with 5 animals each and aged 2–5 months.

The calves of the control group were fed the basic ration diet: whole milk substitute, hay and concentrates. The calves of the 1st and 2nd experimental groups were additionally treated with 1% Mustala and Mustala-T (by weight of concentrates), respectively. Mustala consists of the mineral shungite (Tremasova, 2014; Bogolyubova et al. 2015a, 2015b, 2015c, 2016, 2017) with a particle size of 0.5–1.5 mm, and Mustala-T is a heat-treated form of shungite substance with a particle size of 0.5–1.5 mm.

The studies were carried out from March 17 to June 9, 2017. The duration of the scientific and economic experiment was 85 days. Animals of the control and experimental groups were placed in the same premises.

The chemical composition of the given feed during the period of feeding was determined in the Chemical-analytical Research Laboratory of the L. K. Ernst Federal Research Centre for Animal Husbandry. Body weight gains (gross and average daily) were calculated on the basis of individual weighing of experimental animals (Table 1), followed by calculation of the economic efficiency of the use of feed additives (Table 2).

At the beginning and end of the experiment, blood was sampled from animals of all three experimental groups ($n = 5$) and examined for the determination of indicators characterizing the state of metabolism (total protein, albumins, globulins, creatinine, urea, total bilirubin, total cholesterol, calcium, phosphorus, alkaline phosphatase, glucose, ASAT, ALT), and hematological indicators (hemoglobin, erythrocytes, lymphocytes and hematocrit) (Abdisa, 2017). The blood was studied in the Department of Physiology and Biochemistry of the L. K. Ernst Federal Research Centre for Animal Husbandry.

Table 1. Productivity of calves (biomass indicators).

Indicator	Groups			Correlation coefficients of *IndBcon* indices with biomass indicators
	Control	Experimental 1	Experimental 2	
Body weight, kg				
– at the beginning	82.6±4.8	84.0±4.7	82.3±4.5	0.999
– a month later	104.4±6.3	107.0±5.5	104.2±4.3	0.990
– 2 months later	132.4±4.5	143.8±7.8	134.6±4.3	0.924
– at the experiment end	164.6±7.6	177.6±7.1	167.8±6.5	0.902
Gross body weight gain, kg	82.0±6.9	93.6±5.2	85.5±4.1	0.874
Mean daily gain, g	965.0±82.0	1101.0±61.2	1006.0±49.0	0.874

Table 2. Economic efficiency of the use of feed additives (per 1 animal for the period of experience) at raising calves (economic indicators).

Indicator	Groups			Correlation coefficients of *IndBcon* indices with biomass indicators
	Control	Experimental 1	Experimental 2	
Gross body weight gain, kg	82.0	93.6	85.5	0.874
Conditional price of 1 kg gain, rubles	102.0	102.0	102.0	–
Sum of conditional realization of gain, rubles	8364.0	9547.2	8721.0	0.874
Average consumption of concentrated feed for rearing period, kg	2.25	2.40	2.29	0.892
Feed ration costs for rearing period, rubles	5950.0	6205.0	6035.0	0.857
Cost of diet with additives, rubles	5780.0	6229.5	6073.9	0.874
Excess of the cost of body weight gain over the difference in the cost of feed, rubles	2584.0	3317.7	2647.1	0.616

Results and Discussion

The reflection of metabolism is the state of the internal environment of the body. Blood components provide stabilization (homeostasis) of the internal environment, which is necessary for the vital activity of cells and tissues and ensures the functional unity of the body (Bogolyubova et al. 2014). To study the indicators characterizing the state of nitrogen, lipid and carbohydrate metabolism as well as hematological indicators in the body of experimental animals, blood samples were taken monthly 3 hours after morning feeding.

When processing values of animal blood parameters, it is assumed that blood parameters reflect changes in the consistency and genomic organization of biochemical processes that occur during the digestion of feed in the animal rumen with their statistical characteristics. Consistency and genomic organization of biochemical processes is a qualitative rather than quantitative characteristic of these processes. When changing the diet of animal feeding, the control of biochemical processes by the animal metagenome may be disturbed. When the feed is changed, microbial destructive biosystems in the intestines of animals can be rearranged, with different efficiency transforming the organic substances of the feed into nutrient forms of substances for the intestinal microflora and the animal body (Vorobyov et al. 2021; Vorobyov and Selina, 2021). All these phenomena were characterized by us implementing the concept of bioconsolidation of biochemical processes (Vorobyov and Selina, 2021). Herewith, it is assumed that increased bioconsolidation of biochemical processes will mean: (1) a more precise attunement to the joint biochemical activity of intestinal microorganisms of animals; (2) the lowest consumption of material and energy resources of the partners of microbial-organism biosystems; (3) more accurate performance of biochemical transformation operations in time and in accordance with the metagenomic program of the microbial-organismal biosystem; and (4) increased efficiency of the transformative activity of the intestinal microflora of animals, which is reflected in the accelerated gain of biomass by animals.

For quantitative comparison of the level of bioconsolidation of biochemical processes in different variants of the experiment, the index of bioconsolidation (*IndBcon*) of biochemical processes was introduced (Kochish et al. 2020, 2023; Vorobyov and Selina, 2021; Karpenko et al. 2025). *IndBcon* is a dimensionless quantity that takes values in the range 0...1. It is assumed that if *IndBcon* = 1, then the consistency of biochemical processes reaches a maximum and the processes are entirely controlled from a single genomic center, i.e., there is no chaos of biochemical processes. If *IndBcon* = 0, then the coordination of biochemical processes and the control of these processes from a single genomic center of the microbial-organismal biosystem are completely absent, that is, there is a chaos in biochemical processes.

Thus, the main goal of processing values of animal blood parameters by a Gaussian neural network (GaussNN) is to calculate the *IndBcon* index. Hereby, it is assumed that the validation of the applied GaussNN should be carried out on the basis of a study of the intervariant correlation of the *IndBcon* index with animal biomass. Only after that, by comparing the values of *IndBcon*, it is possible to get an answer to the question: at which feeding rations is a higher bioconsolidation of biochemical processes in the animal body achieved and, therefore, a greater biomass is achieved?

Gaussian neural network algorithm

To describe the calculations performed by GaussNN, the data sample for the ALT blood parameter values (Table 3) was used as an example. Processing other blood parameters using a similar neural network is hereby possible.

Table 3. Indicators of ALT (IU/l) in the blood of experimental animals by months.

Month of blood sampling	Groups		
	Control K	Experimental 1 E1	Experimental 2 E2
March	10.1±0.7	10.0±1.2	9.5±0.6
April	13.4±0.5	13.7±1.5	12.4±1.0
May	17.3±0.8	15.5±0.5	17.3±0.5
June	21.7±0.4	19.7±0.9	22.1±0.3

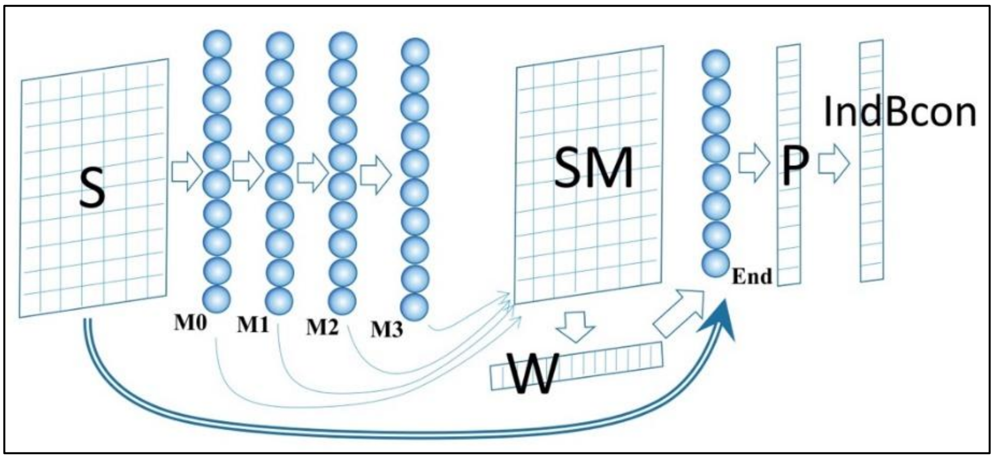

Fig. 1. Gaussian neural network (GaussNN) designed to calculate the IndBcon index based on biochemical parameters of animal blood. M0, M1, M2, M3, End are layers of artificial neurons that perform the necessary transformations of numerical data. Description and transformation formulae are given in the text.

Table 4. Matrix S (Fig. 1) of normalized data for ALT indicators (Table 3) in the blood of experimental animals by months.

Month of blood sampling	Groups		
	Control K	Experimental 1 E1	Experimental 2 E2
March	0.663	0.657	0.624
April	0.880	0.900	0.814
May	1.136	1.018	1.136
June	1.425	1.294	1.452

Table 5. Matrix of statistical moments (SM, Fig. 1) of numerical values of blood parameters

Statistical moments		Variants of experiment			Vector W_j
		L = K	E1	E2	
$M_{0.L}$	j = 0	1.026	0.967	1.007	0.854
$M_{1.L}$	1	0.329	0.265	0.364	−0.397
$M_{2.L}$	2	0.387	0.319	0.425	−0.291
$M_{3.L}$	3	0.456	0.379	0.500	−0.166
P vector values		−0.350	−0.307	−0.362	
IndBcon vector values		0.413	0.424	0.410	

Formulae for calculating statistical moments (M0, M1, M2, M3; Table 3, Fig. 1):

1. Calculation of the average value of the data in Table 3. MeanTable3 = 15.23.
2. Normalizing the values of Table 3 by MeanTable3 (Table 4).
3. Calculation of the SV matrix of statistical moments of numerical blood parameters (Table 5, Fig. 1):

$$M_{0,L} = \frac{1}{4} \cdot \sum_{i=1}^{4} S_{i.L} \,, \tag{1}$$

$$M_{1.L} = \sqrt{\frac{1}{3} \cdot \sum_{i=1}^{4} \left(S_{i.L} - M_{0.L} \right)^2} \,, \tag{2}$$

$$M_{2.L} = \sqrt[3]{\frac{1}{2} \cdot \sum_{i=1}^{4} \left(S_{i.L} - M_{0.L} \right)^3} \,, \tag{3}$$

$$M_{3.L} = \sqrt[4]{\sum_{i=1}^{4} \left(S_{i.L} - M_{0.L} \right)^4} \,, \tag{4}$$

where $S_{i.L}$ are normalized blood parameters (Table 5), L = K, E1, E2 are serial numbers of experiment variants.

4. Calculation of the weight vector W for the neural layer End (Fig. 1)

$$W_j = \frac{1}{g_j} \cdot \left(M_{j.K} + M_{j.E1} + M_{j.E2} - m_j \right), \tag{5}$$

$$m_j = \frac{1}{3} \cdot \left(M_{j.K} + M_{j.E1} + M_{j.E2} \right), \tag{6}$$

$$g_j = \sqrt{\left(M_{j.K} - m_j \right)^2 + \left(M_{j.E1} - m_j \right)^2 + \left(M_{j.E2} - m_j \right)^2} \,, \tag{7}$$

where j = 0, 1, 2, 3, 4 are the ordinal numbers of statistical moments (Table 5).

The values of the vector W are given in Table 5.

5. Calculation of the P vector of intermediate data (Fig. 1) using the matrix product of the W vector by the matrix of moments SM:

$$\begin{array}{ccccc} P & & W & & \text{SM} \\ \begin{bmatrix} -0.350 & -0.307 & -0.362 \end{bmatrix} & = & \begin{bmatrix} 0.854 & -0.397 & -0.291 & -0.166 \end{bmatrix} & \times & \begin{bmatrix} 0.663 & 0.657 & 0.624 \\ 0.880 & 0.900 & 0.814 \\ 1.136 & 1.018 & 1.136 \\ 1.425 & 1.294 & 1.452 \end{bmatrix} \end{array}$$

6. *IndBcon* index calculation.

$$IndBcon_L = \left(1 + \exp\left(-P_L \right) \right)^{-1}, \tag{8}$$

where L = K, E1, E2 are the serial numbers of the experiment options; and P_L are the values of the vector P (Table 5).

The results of calculating the *IndBcon* index vector are shown in Table 5.

7. Validation of GaussNN was successful, since the correlation coefficients of the IndBcon index with animal biomass characteristics (r = 0.874…0.999, Table 1) and with some economic indicators (r = 0.874…0.892, Table 2) were close to one.

Conclusion

The prospects of using shungite preparations in animal feed, with a high positive correlation of the index of bioconsolidation of biochemical processes, physiological indicators of animals and economic indicators of the foodstuffs suggest dependence of the efficiency of biochemical processes on the level of their bioconsolidation (e.g., on the control of processes by the animal metagenome). Moreover the effect of bioconsolidation of processes on the full development of animals and their accelerated biomass gain is apparent, as is the fact that the bioconsolidation of biochemical processes manifests itself in the deviation of the statistical parameters of distributions from the Gaussian distribution and not in absolute blood parameters.

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