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IGESTIBILITY OF NUTRIENTS AND ENERGY SUPPLY OF ANIMALS UNDER THE INFLUENCE OF UNIFORMITY OF MIXING FEED

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The article presents data from studies of the influence of the factor of uneven mixing of the feed mixture (corn silage, alfalfa hay and compound feed) on the apparent digestibility of nutrients throughout the gastrointestinal tract of young cattle (9 heifers of the Ukrainian red-motley breed). The studies used a method of modeling the consumption of unevenly mixed rations by animals, where 25 % of the ration consisted of high-energy components of the mixture in the second experiment, and feeds with a low energy concentration in the third. It was found that when consuming a low-concentrate feed mixture with an energy concentration in the diet of 8.9 MJ/kg dry matter and a crude protein concentration of 9.7 % with a mixing uniformity of 75 % compared to the control diet (100 % mixing uniformity), there were implausible changes in the consumption of nutrients by individual animals. Fluctuations in the apparent digestibility of nutrients throughout the gastrointestinal tract of young cattle ranged from 2 % to 6 % when consuming a feed mixture with a mixing uniformity of 75 %. On the high-nutrient diet, the digestibility of crude protein and crude fiber increased by 14% and 9 %, respectively. On the low-nutrient diet, there was a significant ($p < 0.05$) decrease in digestibility by 5 % for dry matter and organic matter and nitrogen-free extractives, and for crude protein (by 12 %), compared to the high-nutrient diet. The provision of animals with energy and protein significantly increased ($p < 0.01$) on the high-nutrient diet by 34.7 % and 11.5 %, respectively. Consumption of the low-nutrient diet had practically no effect on energy content. When feeding a feed mixture with a 75 % mixing uniformity on a low-nutrient diet, a significant increase in alkaline phosphatase activity was observed by 42 %, a high-nutrient diet significantly affected the increase in erythrocyte content by 7.9 %, while most hematological and biochemical blood parameters of heifers fluctuated within the physiological norm for animals of this age.

Keywords: digestibility, feed mixture, energy available for exchange, mixing uniformity, hematological and biochemical blood parameters.



ПЕРЕТРАВНІСТЬ ПОЖИВНИХ РЕЧОВИН І ЗАБЕЗПЕЧЕНІСТЬ ТВАРИН ЕНЕРГІЄЮ ЗА ВПЛИВУ РІВНОМІРНОСТІ ЗМІШУВАННЯ КОРМОСУМІШІ

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У статті наведені дані досліджень впливу фактору нерівномірного змішування кормосуміші (силос кукурудзяний, сіно люцернове та комбікорми) на видимому перетравності поживних речовин по всьому шлунково-кишковому тракту молодняка великої рогатої худоби (9 теличок червоно-рябої української породи). У дослідженнях використовували метод моделювання споживання нерівномірно змішаного раціону тваринами, де 25 % раціону складало у другому досліді високоенергетичні компоненти суміші, а у третьому – корми з низькою концентрацією енергії. Встановлено, що при споживанні нізкоконцентратної кормосуміші при концентрації енергії в раціоні 8,9 МДж/кг сухої речовини і концентрації сирого протеїну 9,7 % з рівномірністю змішування 75 % в порівнянні з контрольним раціоном (100 % рівномірність змішування) відбувалися невірогідні зміни в споживанні поживних речовин окремими тваринами. Коливання видимої перетравності поживних речовин по всьому шлунково-кишковому тракту молодняка великої рогатої худоби становили від 2 % до 6 % при споживанні кормосуміші з рівномірністю змішування 75 %. На високопоживному раціоні переваримість сирого протеїну та сирого клітковини зросла на 14 % і 9 %, відповідно. На нізкопоживному раціоні спостерігалось вірогідне ($p < 0,05$) зниження перетравності на 5 % для сухої і органічної речовини та безазотистих екстрктивних речовин, для сирого протеїну (на 12 %), в порівнянні з високопоживним. Забезпеченість тварин енергією і протеїном значно збільшувалася ($p < 0,01$) на високопоживні раціони на 34,7 % і на 11,5 %, відповідно. Споживання нізкопоживного раціону практично не впливало на вміст енергії. При згодовуванні кормосуміші 75 %-вої рівномірності змішування на нізкопоживному раціоні спостерігалось вірогідне збільшення активності лужної фосфатази на 42 %, високопоживний раціон вірогідно вплинув на збільшення вмісту еритроцитів на 7,9 %, тоді як більшість гематологічних і біохімічних показників крові теличок коливалася в межах фізіологічної норми для тварин даного віку.

Ключові слова: перетравність, кормосуміш, доступна для обміну енергія, рівномірність змішування, гематологічні і біохімічні показники крові.

Introduction. One of the main advantages of using feed mixtures is the leveling of differences in the consumption of diet components by individual animals. This property of the feed mixture is directly related to the mixing uniformity of its components. Finding out the optimal mixing uniformity is important from the point of view of saving resources and fully providing productive animals with nutrients.

In the case of poor-quality feed mixture preparation with insufficient mixing or separation of feeds during distribution, selective eating of feeds by individual animals may occur (Amaral-Phillips D. M, et al., Grant R. J. et al, 1990, Kononoff P. J. et al, 2003a and 200b). The uniformity of mixing significantly depends on the degree of



grinding of roughage (Baran M., 1980., Clauss M. et al, 2011, Tafaj M. et al, 1999). Our studies and data from other authors indicate that from a physiological point of view, there are optimal sizes of roughage particles, deviations from which in the direction of increase cause a decrease in dry matter intake and a slowdown in the rate of fractional outflow from the rumen, and deviations in the direction of decrease cause a decrease in the number of chewing movements during chewing and the volume of saliva (Guozhong D., et al., 2011, Lechner I. et al., 2013., Rolf S. et al., 2018), disrupt the specific layered structure of the rumen contents and its motility, contribute to increased acidity in the rumen, and are often accompanied by abomasum displacement and digestive disorders (Kaiyue P. et al., 2022, Golder H. M. et al., 2014, Krause K. M. et al., 2002 and 2003). Finding the optimal size of coarse feed grinding when preparing a feed mixture is a compromise between the negative impact of overgrinding and the negative consequences of insufficiently uniform mixing (Beauchemin K. A. et al., 2003, Maekawa M. et al., 2002, Maulfair D. D. et al., 2011, Vibart R. E. et al., 2010). In our opinion, the provision of animals with nutrients with the same uniformity of mixing of the feed mixture, but with different energy content, can differ significantly (Vasylevskyi M. V. and Yeletska T. O., 2012).

Purpose of the work. To investigate the effect of consuming a feed mixture with a mixing uniformity of 75% by young cattle on the apparent digestibility of nutrients in the diet and the content of energy available for exchange in order to ensure the effective use of feed nutrients and their transformation into livestock products.

Materials and methods. To study the effect of the uniformity of feed mixture mixing on the consumption of nutrients and the energy actually received by the animals from the diet, three experiments were conducted on 9 heifers of the red-and-white breed. The animals were kept tethered, fed twice a day with free access to individual automatic drinkers. The diet consisted of corn silage, alfalfa hay, and mixed feeds.

The studies were conducted using the method of modeling the consumption of an unevenly mixed diet by animals. For this purpose, the content of individual feeds in the main diet and their ratios were calculated. In the first experiment (control), the animals received all the feeds in the form of a feed mixture, which corresponded to a mixing uniformity of 100%. Then, the ratio of feeds was calculated at a uniformity of 75%. For this purpose, it was assumed a priori that 75% uniformity is the actual consumption by animals of a diet in which 75% is represented by 100% uniformly mixed feed mixture, in which the ratio of all components corresponds to the diet of the first experiment. The remaining 25% was replaced in the second experiment with high-energy components of the mixture, and in the third with feeds with a low energy concentration. The content of available energy for metabolism (AEE) was calculated based on apparently digestible nutrients using energy coefficients (Nehring K., 1975). Statistical processing was performed using the method of variance analysis and the method of paired related data (Vasilevskij N. V., 2007). The case was considered probable when the error was less than 5%. Since the purpose of our research was to find the boundary of the zone of influence of negative parameters, the probability analysis was also carried out in the zone of tendency to probability, when the error was in the range from 20% to 5%.

Research results. The amount of feed consumed is presented in Table 1. The consumption of dry and organic matter in our experiments was at the level of 3.5–4.0 kg, respectively.



Table 1

Average consumption of dietary nutrients by animals, (M ± m), n = 3

Experiments	1	2	3
DM, g	3396 ± 148	4406 ± 52	3728 ± 26
Cv, %	7,55	2,05	1,20
OM, g	3193 ± 135	4140 ± 47	3501 ± 23
Cv, %	7,31	1,97	1,15
CFt, g	62,27 ± 1,95	67,38 ± 0,57	69,87 ± 0,41
Cv, %	5,43	1,46	1,02
CP, g	320 ± 12	463 ± 4	340 ± 2
Cv, %	6,39	1,57	1,07
CF,g	1145 ± 44	1486± 17	1248 ± 8
Cv, %	6,65	1,93	1,12
NFE, г	1666 ± 77	2124 ± 26	1843 ± 13
Cv, %	8,01	2,11	1,22
Ca, г	29,79 ± 1,34	46,84 ± 1,74	31,03 ± 0,25
Cv, %	7,76	6,43	1,39
P, г	8,59 ± 0,40	12,24 ± 1,62	9,04 ± 0,07
Cv, %	8,07	22,87	1,29

Note: Here and below: DM – dry matter, OM – organic matter, CF – crude fat, CP – crude protein, CF – crude fiber, NFE – nitrogen-free extractives, Cv – probability coefficient.

The largest spread for the main nutrients was observed in the first experiment (Cv = 6.99 ÷ 7.63%), a significant decrease in the probability coefficient compared to the control was in the second (5.50 ÷ 5.57%) and third experiments (0.71 ÷ 1.00%). Calculation of the significant difference according to Student's t-test in the first and second experiments between the consumption of dry and organic matter, crude protein, crude fiber, nitrogen-free extractives showed a significant difference (p < 0.05 ÷ 0.01) in the consumption of these substances, the change in the consumption of crude fat was at the trend level (Table 2).

There was also a trend level (0.2 > p > 0.05) difference in the consumption of dry and organic matter, crude protein, crude fiber, nitrogen-free extractives between the first and third experiments. A significant difference in the consumption of crude fat was established (p < 0.05). When comparing nutrient intake in the second and third experiments, a significant difference was established for all indicators (p < 0.05 ÷ 0.01). Using the Student's t-test for the same indicators, but by the method of pairwise related dry matter intake, showed a significant difference in the intake of crude fiber and nitrogen-free extractives, for other nutrients - at the level of the trend between the first and third experiments.



Table 2

Difference in nutrient intake of diets with different mixing uniformity

The difference between experiments	1 та 2	1 та 3	2 та 3
DM g	-1010,6	-332,2	678,43
t ₁	-6,44**	2,21*	11,66***
t ₂	-5,20**	2,72*	9,86***
OM, g	-946,9	-308,01	638,93
t ₁	-6,63**	2,25*	12,15***
t ₂	-5,87**	2,76*	10,28***
CFt, g	-5,11	-7,60	-2,49
t ₁	2,51*	3,81**	-3,56**
t ₂	2,26*	4,93**	2,93**
CP, g	-142,99	-20,03	122,97
t ₁	11,43***	1,67	26,25***
t ₂	-10,09***	2,06*	22,19***
CF, g	-341,38	-103,3	238,09
t ₁	-7,27**	2,31*	12,91***
t ₂	-6,39**	35,92***	10,93***
NFE, g	-457,5	-176,8	280,64
t ₁	-5,63**	2,26*	9,71***
t ₂	-5,00**	2,76**	8,20***
Ca, g	-17,05	-1,24	15,81
t ₁	-7,78**	0,91	9,00***
t ₂	-6,50**	1,14	8,43***
P, g	-3,66	-0,45	3,21
t ₁	-2,19*	1,11	1,98*
t ₂	-2,00*	1,35	1,94*

Note. t₁ – calculated indicator based on variance analysis; t₂ – calculated indicator based on pairwise related data on SR consumption; * – probability of differences between the indicators of the experiments at the trend level; ** – probability of differences between the indicators of the experiments at the p < 0.05 level; *** – probability of differences between the indicators of the experiments at the p < 0.01 level.

Such differences between the intakes in the experiments caused a difference in the characteristics of the actually consumed rations (Table 3). It was determined that all these indicators significantly differed between the second and third experiments. A significant difference was established in the concentration of crude protein between the first and second and the first and third experiments. It was established that the excretion of nutrients with feces differed significantly only in the content of nitrogen-free extractives (p < 0.05) in the first and second and in the first and the third experiments.



Table 3

Characteristics of rations, (M±m), n=3

Experiments	Exchangeable energy (EE), MJ EA	Concentration EE, MJ/kgDM	Feeding level, MJ/W ^{0,75}	Concentration CP, %	CP/EE, g/MJ
1	30,09 ± 2,24	8,86 ± 0,66	0,59 ± 2,41	9,42 ± 0,07	10,70 ± 0,57
2	40,54 ± 6,47** ^{1,2}	9,20 ± 2,66	0,77 ± 6,07* ^{1,2}	10,50 ± 45,99*** ^{1,2}	11,43 ± 2,51
3	31,89 ± 0,80*** ^{2,3}	8,55 ± 0,64** ^{2,3}	0,61 ± 0,27*** ^{2,3}	9,11 ± 4,62*** ^{1,2; **1,3;***2,3}	10,62 ± 0,11*** ^{2,3}

Note: * - probability of differences between experimental indicators at the trend level; ** - probability of differences between experimental indicators at the $p < 0.05$ level; *** - probability of differences between experimental indicators at the $p < 0.01$ level.

Based on the data on the consumption and excretion of nutrients, their digestibility was calculated (Fig. 1).

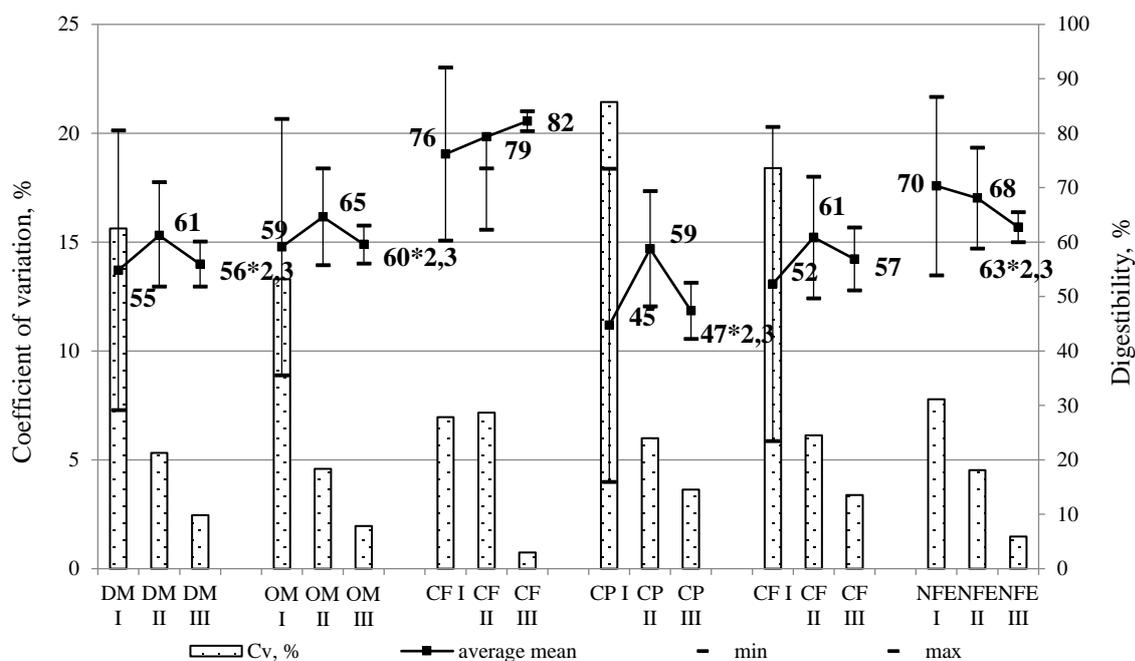


Fig. 1. Nutrient digestibility of diets with 75 % uniformity of mixing.

The fluctuations of this indicator between experiments ranged from 2 % to 6 %. But in the second experiment, compared to the control, the digestibility of crude protein and crude fiber increased by 14 and 9 %, respectively. The apparent digestibility throughout the gastrointestinal tract of the experimental animals due to the uneven mixing of the components in the second and third experiments, compared to the control, did not significantly change. When comparing the second and third experiments, a decrease in digestibility by 5 % was observed for dry matter, organic matter and nitrogen-free extractives, as well as a significant decrease in digestibility of crude protein (by 12 %) ($p < 0.05$).

It is known that the physiological state of the animal, its age, feeding conditions, productivity and other factors affect the composition of the animal's blood. Thus, the



results of biochemical studies (Table 4) of selected blood samples showed that the content of total protein, as the main indicator of its use in the body, was higher in the third experiment, in the second experiment this indicator had an intermediate value.

The content of albumins in the serum of heifers for all experimental groups of animals was within the normal range and was approximately the same - 39 ÷ 40 %. The content of globulins went beyond the limits of physiological fluctuations (29 ÷ 49 %) - an increase of 22.7 % in the first experiment, 23.1 % - in the second and 25.2 % - in the third. It can be noted that the urea content was within the physiological range (3.7 - 4.13 mmol / l).

Table 4

Biochemical indicators of blood of experimental animals, (M±m), n = 3

Tests		1	2	3
Total protein, g/l		62,73±0,31	66,87±1,89	69,67±0,94
Albumin,%		40,37±0,95	40,17±0,27	39,13±0,96
Total globulins,%		59,63±0,95	59,83±0,27	60,87±0,96
a/g		0,67±0,03	0,70±0,01	0,63±0,03
globulins, %	α-1	5,0±1,26	4,37±0,82	2,77±0,33
	α-2	14,63±3,36	14,80±0,95	14,90±2,60
	β	14,83±1,31	15,67±1,72	16,70±1,47
	γ	25,17±0,17	25,03±0,55	26,50±0,87
Glucose, mol/l		4,50±0,12	4,80±0,19	4,90±0,17
lysozyme activity, 10 ⁻³ g/l		0,70±0	1,39±0,61	0,70±0,12
alkaline reserve, mg%		254,67±18,42	227,67±18,41	272,33±22,32
Urea, mmol/l		3,77±0,23	3,80±0,06	3,70±0,15
AST, units/l		40,00±1,15	41,33±0,88	38,00±1,15
ALT, units/l		27,67±2,03	32,33±0,67	31,67±1,33
Creatinine, kmol/l		156,17±1,56	142,60±0,60* ^{1,2}	150,87±2,14* ^{2,3}
Alkaline phosphatase, units/l		211,33±22,67	214,67±26,69	300,00±5,77* ^{1,3;2,3}

Note. * – probability of differences between the indicators of the experiments at the p <0.05 level.

The glucose content (the norm for young cattle is 2.5–3.5 mol/l) in the experimental animals increased – from 4.5 mol/l in the first experiment to 4.8 mol/l in the second and to 4.9 mol/l in the third experiment. The alkaline reserve of blood serum, according to our data, was: 255 mg%, 228 and 272 mg%, respectively. This is below the norm (460 – 580 mg%): in the first experiment – by 44.6 %, in the second – by 50.4 % and in the third – by 40.9 %, respectively. A significant increase in alkaline phosphatase activity was found by 42 % in the third experiment (before control) and by 40 % between the second and third experiments.

Analysis of hematological parameters (Table 5) showed that in all experiments an increase in the content of erythrocytes was observed, in the third experiment the number of leukocytes increased slightly. The hemoglobin content in the blood of animals ranged from 121.67 to 129.33 g/l.



Table 5

Hematological parameters of the blood of experimental animals, (M±m), n=3

Tests		1	2	3
Erythrocytes, 10 ¹² /g/l		7,63±0,69	8,23±0,62* ^{1,2}	8,43±0,09
Hemoglobin, g/l		121,67±5,61	129,33±8,65	128,33±5,78
Leukocytes, g/l		8,73±1,16	9,73±0,16	12,47±3,03
Phagocytic	Activity, %	52,00±9,24	42,67±7,42	50,67±1,33
	index	3,40±0,12	4,70±0,46	4,07±0,62
	number	1,73±0,30	2,03±0,50	2,07±0,27
	capacity	5,53±0,86	6,80±1,66	7,07±0,50
Neutrophils, %	young	0	0	0
	rodnucleate	3,33±0,88	2,67±0,67	4,33±1,86
	segmentnucleate	34,67±4,33	32,67±2,93	27,00±9,61
Eosinophils		4,0±0,58	6,33±1,20	7,67±2,19
Basophils		0,33±0,33	0,67±0,67	0,67±0,33
Monocytes		0	0	0
Lymphocytes		56,00±4,62	55,33±3,39	58,33±6,69
Monocytes		1,33±0,33	2,33±0,88	2,00±1,00

Note. * – probability of differences between the experimental indicators at the $p < 0.05$ level.

Discussion. Optimal uniformity of mixing ensures the same consumption of all components of the diet by all animals, which should ensure, on the one hand, the same nutritional value of the feed in all parts of its volume, and on the other hand, it is unacceptable to grind coarse feed too densely. The use of mixtures of heterogeneous composition for feeding animals significantly reduces their productive effect (Raab L., 2009, Maekawa M. et al, 2002). Feeding young cattle with a feed mixture with a mixing uniformity of 75 % in our studies had a slight effect on nutrient intake. As for the apparent digestibility of nutrients throughout the gastrointestinal tract of experimental animals, it varied depending on the nutritional value of the diet. Thus, an increase in the digestibility of crude protein and crude fiber was observed when feeding a highly nutritious diet, while feeding a low-nutrient diet led to a decrease in the digestibility of dry and organic matter, crude protein, and nitrogen-free extractives. Feeding highly nutritious diets significantly increased the provision of animals with energy and protein. And when consuming a low-nutrient diet by young cattle, there was practically no effect on energy content, which is consistent with our previous studies, where we indicated that the consumption of high- and low-nutrient diets with increasing uneven mixing will lead to significant differences in the intake of energy and nutrients from the feed by individual animals (Yeletska T.O., 2014).

The indicators of most blood metabolites were within normal limits, and only some of them slightly deviated beyond the physiologically permissible values. Thus, an increase in the content of globulins may indicate an increase in the protective function of the body, and an increase in the content of glucose may be associated with an increase in the somatotropic function of the pituitary gland and other hyperglycemic hormones. (Yousefinejad S. et al., 2021). An indicator of the state of the blood plasma buffer system is the alkaline reserve. A decrease in this indicator, according to our data, indicates a limited buffer capacity to counteract acidification, which can be explained by the same type of feeding with a predominance of corn silage in the diet, imbalanced mineral nutrition and insufficient level of physiological mechanisms for regulating acid-base balance due to long-term feeding of animals with unbalanced diets, which is indicated in



the works (Nasrollahi S. M. et al., 2019, Lukashynskyi V., 1987). The increase in alkaline phosphatase activity when replacing 100% of the uniformly mixed feed mixture with feed with an unevenly mixed fourth fraction is probably the result of inadequate feeding with carbohydrate-containing feeds with easily absorbable bases (Utama D.T. et al., 2018). As a result of the analysis of hematological indicators, it was found that as a result of the experiment, both in the first and in the second and third experiments, moderate erythrocytosis and physiological leukopenia were observed. A slight lymphocytosis was also observed. This can be explained by the fact that in young growing organisms, which have significant growth energy, the percentage of lymphocytes is always higher than in adults. The hemoglobin content in the blood of animals corresponds to the physiological norm for a given age (Peredriy N.N. et al., 2017).

Conclusions

1. It was found that when consuming a low-concentrate feed mixture with an energy concentration in the diet of 8.9 MJ/kg dry matter and a crude protein concentration of 9.7 % with a mixing uniformity of 75 % compared to the control diet (100 % mixing uniformity), there were improbable changes in the consumption of nutrients by individual animals.

2. When consuming a feed mixture with a mixing uniformity of 75 %, the fluctuations in the apparent digestibility of nutrients throughout the gastrointestinal tract of young cattle ranged from 2 % to 6 %. On a highly nutritious diet, the digestibility of crude protein and crude fiber increased by 14 % and 9 %, respectively. On the low-nutrient diet, there was a significant ($p < 0.05$) decrease in digestibility by 5 % for dry matter, organic matter and nitrogen-free extractives, for crude protein (by 12 %), compared to the high-nutrient diet.

3. The energy and protein intake of animals increased significantly ($p < 0.01$) on the high-nutrient diet by 34.7 % and 11.5 %, respectively. Consumption of the low-nutrient diet had virtually no effect on energy content.

4. Consumption of a 75 % uniform feed mixture led to a significant increase in phosphatase activity by 42 % on the low-nutrient diet. Feeding a highly nutritious diet significantly increased the content of erythrocytes by 7.9 %, while most hematological and biochemical blood parameters fluctuated within the physiological norm for a given age of animals.

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