DOI: 10.29326/2304-196X-2021-10-4-349-356

Effect of *Chlorella* on hematological parameters and nutrient bioavailability in the diet of rhesus monkeys (*Macaca mulatta*)

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SUMMARY

Chlorella shows a wide spectrum of biological activity, in particular, it exhibits a pronounced antioxidant activity and demonstrates anti-inflammatory, antitumor and antiviral properties. A number of research works have been devoted to studying feed advantages of this unicellular green algae when used in the diets of livestock animals, but the possibility of including different *Chlorella* species in the diet of primates has not been practically studied. The aim of this work was to assess the possibility of replacing high-protein animal and vegetable feeds with *Chlorella*, to calculate the digestibility coefficients for the diet nutrients and the effect of algal dry and suspension forms on hematological and serum biochemical parameters in male rhesus monkeys. The data obtained during the experiment indicate that the inclusion of *Chlorella* in the diet both in the dry form and cell suspension improves nutrient digestibility. Thus, the digestibility of crude protein in the animals receiving algae suspension increased by 4.18% ($p < 0.05$), that of crude fat – by 4.70% ($p < 0.01$), crude fiber – by 4.14% ($p < 0.05$) and crude ash – by 12.32% ($p < 0.001$). The digestibility coefficients of crude protein in the primates receiving compound feed supplemented with *Chlorella* powder were higher by 6.83% ($p < 0.001$), those of crude fiber – by 4.78% ($p < 0.05$) and crude ash – by 18.93% ($p < 0.001$). The hematological study results indicate the absence of side effects from long-term *Chlorella* consumption by primates. The introduction of dry *Chlorella* into the diet increased blood glucose levels to the upper limit of the control values, while *Chlorella* suspension did not produce this effect. Thus, *Chlorella* can be successfully used as a component of a balanced laboratory diet for primates or as a feed additive.

Keywords: *Chlorella*, digestibility, blood composition, biochemical blood test, suspension, primates

For citation: Gaponov N. V., Panchenko Al. V., Panchenko An. V., Chuguev Yu. P. Effect of *Chlorella* on hematological parameters and nutrient bioavailability in the diet of rhesus monkeys (*Macaca mulatta*). *Veterinary Science Today*. 2021; 10 (4): 349–356. DOI: 10.29326/2304-196X-2021-10-4-349-356.

Conflict of interest: The authors declare no conflict of interest.

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УДК 636.978:599.824:636.086.783:612.11/.12

Влияние хлореллы на гематологические показатели и биодоступность питательных веществ рациона у макаков-резусов

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РЕЗЮМЕ

Хлорелла обладает широким спектром биологической активности, в частности, проявляет выраженную антиоксидантную активность, противовоспалительные, противоопухолевые и противовирусные свойства. Изучению кормовых достоинств этой одноклеточной зеленой водоросли при использовании в составе рационов для сельскохозяйственных животных посвящен ряд исследований, однако вопрос возможности включения разных видов *Chlorella* в рацион приматов практически не изучен. Целью данной работы была оценка возможности замещения высокопротеиновых кормов животного и растительного происхождения на хлореллу, определение коэффициентов переваримости питательных веществ рационов и влияния сухой и суспензионной форм водоросли на гематологические, биохимические показатели крови у самцов макаков-резусов. Полученные при проведении эксперимента данные свидетельствуют о том, что включение в рацион хлореллы как в сухом виде, так и в виде клеточной суспензии способствует лучшей усвояемости питательных веществ. Так, в группе животных, получавших суспензию водоросли, усвояемость сырого протеина увеличилась на 4,18% ($p < 0,05$), сырого жира – на 4,70% ($p < 0,01$), сырой клетчатки – на 4,14% ($p < 0,05$) и сырой золы – на 12,32% ($p < 0,001$). У приматов, в рецептуру комбикорма которых был введен порошок хлореллы, коэффициенты переваримости сырого протеина были выше на 6,83% ($p < 0,001$), сырой клетчатки – на 4,78% ($p < 0,05$) и сырой золы – на 18,93% ($p < 0,001$). Результаты гематологических исследований указывают на отсутствие побочных эффектов от длительного употребления хлореллы приматами. Введение в рацион сухой хлореллы способствовало повышению уровня глюкозы в крови до верхней границы контрольных значений, тогда как суспензия хлореллы не оказывала такого эффекта. Таким образом, хлорелла может быть успешно использована в качестве компонента сбалансированного лабораторного рациона для приматов или в качестве кормовой добавки.

Ключевые слова: хлорелла, переваримость, состав крови, биохимический анализ крови, суспензия, приматы

Для цитирования: Гапонов Н. В., Панченко Ал. В., Панченко Ан. В., Чугуев Ю. П. Влияние хлореллы на гематологические показатели и биодоступность питательных веществ рациона у макаков-резусов. *Ветеринария сегодня*. 2021; 10 (4): 349–356. DOI: 10.29326/2304-196X-2021-10-4-349-356.

Конфликт интересов: Авторы заявляют об отсутствии конфликта интересов.

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INTRODUCTION

Of all freshwater algae, the unicellular green algae *Chlorella* (*Chlorella* spp.) is the most widely used and serves a suitable model for laboratory testing and application in production [1]. The diameter of mononuclear vegetative cells of this alga does not usually exceed 15 microns, the protoplast has one cup-shaped chloroplast with a pyrenoid in the thickened part. *Chlorella* species reproduce exclusively by autospores (generally 4–8 per cell) [2]. *Chlorella* has long been used as a food source, it surpasses all plant feeds and agricultural crops in vitamin content, it contains amino acids, including essential ones, which indicates its prospects as a source of valuable organic matter [3]. In addition, microalgae are cultivated in bioreactors using mineral nutrient media, and the grown suspended plant cell culture is used as a genetically modified platform for the production of heterologous proteins [4, 5].

Chlorella actively produces proteins, carbohydrates, lipids, vitamins with an easily adjustable ratio of these compounds when its cultivation conditions are changed. On average, dried algae contain 45% protein, 20% carbohydrates, 20% fat, 5–10% fiber, zinc, iron, magnesium, calcium, phosphorus, etc. Many of the substances found in *Chlorella* accumulate in the culture medium containing vitamin B1 (thiamine), B2 (riboflavin), B3 (pantothenic acid), B5 (nicotinic acid), B6 (pyridoxine), B12 (cyanocobalamin), folic acid and its derivatives, *para*-aminobenzoic acid, H (biotin), inositol [6, 7]. The amount of these vitamins in the culture fluid significantly exceeds their amount in cells. Therefore, when using C*hlorella* biomass as a feed additive, it is also possible to give animals cell suspension with no loss of vitamins and other biologically active substances in the growth medium.

Chlorella shows a wide range of biological activities, in particular, it exhibits pronounced antioxidant activity and has anti-inflammatory, antitumor and antiviral properties [8]. It was found that the alga protects the INS-1 (832/13) cells in the pancreas from damage by hydrogen peroxide, prevents damage to mitochondrial membranes, restores the adenosine triphosphate levels and reduces the cellular content of reactive oxygen species [9]. The constituents composing the *Chlorella* cell wall have immunostimulating properties, which are manifested in increased activity of NK cells, as well as increased production of interferon-γ, interleukin-12, and interleukin-1β – Th1-associated cytokines [10]. *Chlorella* used in humans with viral hepatitis C helps to reduce virus RNA expression, as well as the level of alanine aminotransferase and aspartate aminotransferase [11]. Dried *Chlorella pyrenoidosa* powder induces a chemopreventive effect on hepatocancerogenesis in rats [12]. Both *Chlorella* extracts [13] and polypeptides exhibit antitumor properties [14]. Clinical trials have shown that supplements containing *Chlorella vulgaris* can alleviate hyperlipidemia, hyperglycemia, protect against oxidative stress, as well as prevent development of cancer and chronic obstructive pulmonary disease [3]. In addition, taking *Chlorella* during pregnancy may reduce dioxin content and increase immunoglobulin content in breast milk [15].

Introduction of *Chlorella* suspension in the diet of livestock animals minimizes mortality in young animals, promotes better feed absorption, enhances intestine

peristalsis, preventing stagnation and inflammation of gastrointestinal tract mucosa (diverticulitis), reabsorption of toxic substances, as well as distribution of non-saprophytic microbes [7]. The algae anti-inflammatory and antioxidant properties remove symptoms of ulcerative colitis, irritable bowel syndrome and Crohn's disease. *Chlorella* provides essential nutrients [16, 17], increases body's resistance to infectious diseases, which is especially important when animals are kept outdoors in winter, and is a preventive remedy for vitamin deficiency conditions in the autumn-winter period [7].

Chlorella can be added to the diet of humans and animals in the form of suspension, paste or dry biomass [7]. However, the possibility of including different algae species in the diet of primates has not been practically studied. Taking into account the diverse biological effects of *Chlorella* supplements, it is necessary to evaluate not only the effect on the digestibility of substances, but also on the main hematological and biochemical parameters of the organism.

Thus, the aim of the study was to assess the possibility of replacing high-protein feeds with *Chlorella* of animal and plant origin, to determine the digestibility coefficients for nutrients in diets and the effect of algal dry and suspension forms on hematological and biochemical blood parameters in male rhesus monkeys.

MATERIALS AND METHODS

Animals. Fifteen male rhesus monkeys (*Macaca mulatta*) aged from 7 to 15 years (FSBSI "RIMP" monkey breeding facility) that were kept in individual cells were used in the experiments. According to the method of pairs of analogues and taking into account the age, the animals were divided into three groups – a Control Group and two Experimental Groups (5 animals in each), which received different diets [18].

Animal experiments were performed in accordance with the interstate standards for the maintenance and care of laboratory animals GOST 33215-2014 and GOST 33216-2014, adopted by the Interstate Council for Standardization, Metrology and Certification, as well as in accordance with the requirements of the Helsinki Declaration (2000) and Directive 2010/63/EU of the European Parliament and the Council of the European Union of September 22, 2010 on protection of animals used for scientific purposes. The study was approved by the Bioethical Commission of the FSBSI "RIMP".

The composition of the feed used. Complete granulated compound feed manufactured at the production site of the FSBSI "RIMP" was used in the experiment. In contained wheat – 21.40%, soybean cake – 17.42%, sunflower cake – 13.83%, skimmed milk powder – 14.39%, corn – 13.35%, corn gluten – 11.24%, egg powder – 3.30% and sugar – 4.27%. The diet of the Control Group animals was energetically balanced by adding 0.80% sunflower oil. The biochemical composition of feed and *Chlorella* is shown in Table 1.

Chlorella (*Chlorella vulgaris,* IGF No. C-111 strain) was used in the diets of Experimental Group primates in the form of a suspension at 55–60 million/cm^3 cell concentration (Biocenter Geoflora, LLC, Russia) and dry powder (Green, LLC, Russia). *Chlorella* suspension was administered with drinking water at 2.8 ml/kg of body weight per day in addition to complete compound feed. When *Chlorella* powder was introduced into the diet (13.25%), the content of skimmed milk powder decreased by 90%, and that of egg powder – by 9% in the compound feed formula.

The experimental design is presented in Table 2.

The primates in the first (Control) Group were given complete granulated compound feed and tap water, the animals in the second (Experimental) Group received *Chlorella* suspension included in the diet. The animals in the third (Experimental) Group received compound feed modified with *Chlorella* powder. The experiment lasted 35 days.

At the first stage, the animals were handled to get prepared for the cell keeping conditions for 5 days and the diet was replaced to exclude the influence of previous feeding. The feeding schedule for primates in all groups was the same.

At the second stage, the quantity of consumed feed and excreted faeces was recorded for 5 days. Faeces were collected daily at the same time (morning and evening), weighed and ground in a mortar. 50% of the homogenized mass were taken for testing during each sampling. The collected portions were stored in a refrigerator. After the recording period was over, the initial moisture level was determined in the collected faeces samples by drying to constant weight at 60–70 °C.

The non-organic matter in the biochemical composition of the complete compound feed was determined using a wave-dispersive X-ray fluorescence spectrometer SPECTROSCAN MAX-GVM (NPO "SPECTRON", LLC, Russia) in accordance with the "Method of measuring the mass fraction of Mg, Al, Si, Zn, P, S, Cl, K, Ca, Ba, Ti, Cr, Mn, Fe, Ni, Br, Rb, Sr in powder samples of plant materials by X-ray fluorescence method using X-ray devices for spectral analysis SPECTROSCAN MAX (M-049-RM/12)", FR.1.31.2014.17343. The other indicators were determined using the NIRS DS2500F feed spectral analyzer (FOSS, Denmark).

Clinical and biochemical blood tests. Venous blood and the serum thereof were used for testing. Blood samples (2.5–3.0 ml) were taken from the ulnar or femoral vein on an empty stomach before *Chlorella* supplementation and 35 days post the experiment. Whole blood was stabilized with a heparin solution, and hematological analysis was performed using automatic Coulter AcT 5diff CP analyzer (Beckman Coulter, USA). The level of erythrocytes, leukocytes, platelets, hemoglobin concentration, hematocrit, mean erythrocyte volume, erythrocyte anisocytosis were determined. The erythrocyte sedimentation rate (ESR) was evaluated according to Panchenkov's method.

Blood serum was obtained from anticoagulant-free venous blood that was left in a centrifuge glass tube at a temperature of 15–20 °C until a clot was formed. Decanting and centrifugation was performed with a thin glass rod for 10 min at 1,000–1,500 g. Biochemical analysis (the content of total protein, glucose, total bilirubin, calcium, phosphorus) of non-hemolyzed blood sera was carried out within 2–3 hours after submission using commercial test kits (High Technology, Inc., USA) and a semi-automatic biochemistry analyzer (BioChem SA; High Technology, Inc., USA) in accordance with the manufacturer's instructions.

Statistical analysis. The obtained results were processed statistically using the GraphPad Prizm 8.0 Software (USA) and expressed as arithmetic means and standard errors. The statistical significance of the differences was determined using a one-way dispersion analysis of

Table 1
Complete feed and *Chlorella* powder biochemical composition

Parameters (per 1 kg)	Complete compound feed	Complete compound feed with *Chlorella* powder (13.25%)	*Chlorella* powder
Metabolizable energy (primates), MJ	13.36	13.32	21.14
Dry matter, g	818	813	983
Crude protein, g	269	278	500
Digestible protein (primates), g	227	231	–
Lysine, g	88	91	51
Methionine + cystine, g	6.8	9.3	36
Tryptophan, g	3.3	4.3	15.0
Crude fat, g	70	67	259
Crude fiber, g	39	40	10
Nitrogen-free extracts, g	284	280	356
Starch, g	242	241	–
Sugar, g	192	191	–
Calcium, g	16.3	16.4	11.0
Phosphorus, g	8.8	9.6	18.0
Magnesium, g	2.6	2.6	0.7
Potassium, g	5.9	5.8	9.8
Sulfur, g	2.4	2.3	2.5
Ferrum, mg	75	120	528
Copper, mg	14.5	14.7	5.0
Zinc, mg	20.9	19.0	3.0
Manganese, mg	20.1	20.0	2.2
Cobalt, mg	10.5	10.4	0.2
Iodine, mg	0.18	0.42	3.0
Carotene, mg	1.3	1.3	6.5
Vitamin A, IU	800	158	1,700
Vitamin D, IU	15	14	127
Vitamin E, mg	6.1	6.0	8.7
Vitamin B1, mg	5.2	5.2	2.5
Vitamin B2, mg	3.0	2.9	9.6
Vitamin B3, mg	5.4	5.3	2.2
Vitamin B4, mg	735	717	2,175
Vitamin B5, mg	243.4	241.9	1.6
Vitamin B12, μg	14.3	12.0	11.0

variance followed by *a posteriori* corrections for multiple comparisons in accordance with Tukey's and Sidak's method. The accepted level of statistical significance was $p < 0.05$ [20].

RESULTS AND DISCUSSION

Changes in the blood system are among the first signs of changes occurring in the body as a whole, which is of great diagnostic importance in alimentary disorders [21]. The results of the hematological analysis of primate blood are presented in Table 3.

It was found that the number of leukocytes in the Experimental Groups slightly exceeded the upper limit of the reference values at the beginning of the experiment. At the end of the experiment, no significant changes in the level of leukocytes were observed. The number of erythrocytes and platelets was within the reference values in all groups, both at the beginning and at the end of the experiment, with no significant differences between the groups. The hemoglobin level and the mean hemoglobin content per erythrocyte did not differ between the groups both at the beginning and at the end of the experiment.

Table 2
Experimental design

Groups	Number of animals	Feeding conditions
I Control	5	Complete compound feed
II Experimental	5	Complete feed + *Chlorella* suspension 2.8 ml/kg of body weight
III Experimental	5	Complete feed + dry *Chlorella* content (13.25%). 90% of milk powder and 9% of egg powder were replaced with dry *Chlorella*

ESR values were within the limits of the physiological norm at the beginning of the experiment as well as following *Chlorella* administration. The ESR and leukocyte levels established in the blood indicate absence of inflammatory processes in experimental animals that received both standard and experimental diets.

Thus, during long-lasting *Chlorella* introduction into the diet in suspension or dry powder forms as part of granular compound feeds, there was no significant change in the hemogram indicators both between groups and in terms of reference values.

Some serum biochemical parameters were determined to assess the *Chlorella* effect on metabolism (Table 4).

The glucose level was within the physiological norm in all groups at the beginning of the experiment. At the end of the experiment there was a statistically significant increase in the glucose level to the upper values of the physiological norm in Experimental Group III following dry *Chlorella* introduction into the diet. The test for digestibility coefficient determination (Table 5) of nitrogen-free extracts (NFE) showed no statistically significant increase ($p > 0.05$) in the carbohydrate intake in Group II animals (79.90 ± 2.03%) as compared to the Control Group (78.05 ± 1.12%). However, the NFE digestibility coefficient was the highest in Group III (82.20 ± 2.03%) as compared to the Control Group ($p > 0.05$). It is known that *Chlorella* and its components can produce a hypoglycemic effect [23, 24] as well as increase blood glucose levels in animals [25]. Perhaps the effect of *Chlorella* intake depends on its rate in the diet. Thus, more detailed studies of dry *Chlorella* effect on carbohydrate metabolism and assessment of how it is correlated with the dose in the diet are required.

At the beginning of the experiment the level of bilirubin derived from hemoglobin in bile pigment cells was within the reference values. At the end of the experiment the mean bilirubin level in Experimental Group III (10.38 ± 5.28 μM/L) as compared to the Control Group (6.98 ± 1.47 μM/L) was 48% higher but the differences did not reach statistical significance ($p > 0.05$).

Table 3
Hematological parameters in rhesus monkeys

Parameters	Control Group I		Experimental Group II		Experimental Group III		Reference values*
	at the beginning of the experiment	at the end of the experiment	at the beginning of the experiment	at the end of the experiment	at the beginning of the experiment	at the end of the experiment	
Leukocytes, $\times 10^9$/L	9.8 ± 1.6	10.8 ± 2.0	12.6 ± 1.0	13.4 ± 1.8	11.5 ± 1.6	10.2 ± 1.4	3.1–12.1
Erythrocytes, $\times 10^{12}$/L	6.30 ± 0.05	6.43 ± 0.17	6.31 ± 0.18	5.84 ± 0.09	6.14 ± 0.39	6.14 ± 0.19	4.39–7.02
Hemoglobin, g/L	143.0 ± 1.0	145.0 ± 1.0	145.0 ± 6.0	137.0 ± 4.0	135.0 ± 9.0	137.0 ± 4.0	96.0–143.0
Hematocrit, L/L	0.43 ± 0.01	0.43 ± 0.00	0.43 ± 0.02	0.41 ± 0.01	0.41 ± 0.03	0.41 ± 0.01	0.26–0.47
Mean corpuscular volume, $\times 10^{-15}$ L	67.8 ± 0.4	68.2 ± 0.4	68.4 ± 1.1	69.8 ± 1.0	66.0 ± 0.8	67.2 ± 0.8	67.6–77.5
Mean hemoglobin content per erythrocyte, pg	22.8 ± 0.3	22.8 ± 0.3	22.9 ± 0.5	23.5 ± 0.4	22.0 ± 0.4	22.3 ± 0.4	18.7–26.0
Anisocytosis of erythrocytes, %	13.0 ± 0.2	13.2 ± 0.3	13.3 ± 0.4	13.1 ± 0.4	13.4 ± 0.3	13.6 ± 0.3	12.7–15.2
Platelets, $\times 10^9$/L	308.0 ± 18.0	316.0 ± 26.0	418.0 ± 23.0	366.0 ± 60.0	292.0 ± 48.0	273.0 ± 27.0	155.0–619.0
Mean platelet volume, $\times 10^{-15}$ L	9.7 ± 0.2	9.9 ± 0.3	9.0 ± 0.4	9.8 ± 0.3	9.5 ± 0.4	10.0 ± 0.5	8.0–14.8
ESR, mm/h	0.9 ± 0.1	0.9 ± 0.1	1.1 ± 0.1	1.5 ± 0.3	0.8 ± 0.1	1.1 ± 0.4	0.5–5.0

Data are presented as mean and standard error, $n = 5$ for all groups.

* reference values are given based on B.-S. Koo et al. [22].

Table 4
Serum biochemical parameters in primates

Parameters	Control Group I		Experimental Group II		Experimental Group III		Reference values*
	at the beginning of the experiment	at the end of the experiment	at the beginning of the experiment	at the end of the experiment	at the beginning of the experiment	at the end of the experiment	
Glucose, mM/L	4.43 ± 0.44	3.32 ± 0.38	5.46 ± 0.78	3.68 ± 0.33	4.59 ± 0.46	6.73±0.51[a,b]	1.83–6.66
Total bilirubin, μM/L	6.99 ± 2.74	6.98 ± 1.47	8.93 ± 2.77	4.16 ± 0.66	6.87 ± 5.11	10.38 ± 5.28	1.71–11.97
Phosphorus, mM/L	1.17 ± 0.19	0.61 ± 0.12	0.88 ± 0.18	0.44 ± 0.14	1.33 ± 0.17	0.77 ± 0.17	1.06–2.13
Calcium, mM/L	2.56 ± 0.06	2.01 ± 0.17	2.47 ± 0.06	2.04 ± 0.10	2.65 ± 0.11	2.75 ± 0.12	1.75–2.45
Total protein, g/L	89.00 ± 8.00	80.00 ± 2.00	86.00 ± 3.00	82.00 ± 5.00	104.00 ± 3.00[c]	89.00 ± 3.00	39.00–78.00

Data are presented as mean and standard error, $n = 5$ for all groups.
* reference values are given based on B.-S. Koo et al. [22];
[a] $p < 0.001$ as compared to Control Group;
[b] $p < 0.05$ as compared to the beginning of the experiment;
[c] $p < 0.05$ as compared to Experimental Group II.

Calcium and phosphorus levels in the blood of animals in all three groups were within the reference values at the beginning of the experiment. By the end of the experiment these parameters did not change statistically significantly, but the phosphorus level was below the reference limits in all groups (Table 4) despite higher phosphorus digestibility coefficients in Groups II and III (Table 5).

The protein levels in the blood of animals both at the beginning and at the end of the experiment were higher than the reference values in all groups (Table 4). At the beginning of the experiment higher protein levels were observed in sera of Group III (104.00 ± 3.00 g/L) animals as compared to the Control Group (89.00 ± 8.00 g/L, $p > 0.05$). Increased serum protein levels in Group II at the beginning of the experiment were probably transient and were not associated with *Chlorella* action in the diet of animals.

Daily feed intake and excreted feces were recorded and the chemical composition thereof was analyzed allowing to determine the nutrient digestibility coefficients of various diets (Table 5).

This indicator in the primates of the Experimental Groups was statistically significantly higher than that in the Control Group animals (Table 5). Thus, the digestibility coefficients of crude protein were higher by 4.18% ($p < 0.05$), those of crude fat – by 4.70% ($p < 0.01$), crude fiber – by 4.14% ($p < 0.05$), crude ash – by 12.32% ($p < 0.001$) in Group II animals that received *Chlorella* suspension. In Group III where *Chlorella* powder was included in the diet composition the digestibility coefficients of crude protein were higher by 6.83% ($p < 0.001$), crude fiber – by 4.78% ($p < 0.05$), crude ash – by 18.93% ($p < 0.001$).

The obtained results indicate that the nutrient digestibility improved when *Chlorella* was introduced in the diet of primates (as compared to traditional feed); these results are consistent with the published study results available on nutrient digestibility when adding *Chlorella vulgaris* microalgae into the diet of Boer goats [25], as well as comply with the previously obtained data on increasing the digestibility of crude protein, crude fiber and calcium accessibility when the diet is enriched with *Chlorella* powder or suspension [26]. Enhancing the digestibility of crude protein, which is the most valuable part of the feed, is the most important effect of introducing *Chlorella* into the diet [27].

CONCLUSION

Thus, the inclusion of dry *Chlorella* as a substitute for high-protein feeds of plant and animal origin in the primate diet composition had a positive effect on the nutrient

Table 5
Digestibility coefficients

Groups	Crude protein, %	Crude fat, %	Crude fiber, %	Crude ash, %	Crude NFE, %	Calcium, %	Phosphorus, %
I (Control)	65.34 ± 1.04	38.09 ± 0.98	25.88 ± 1.01	41.58 ± 0.88	78.05 ± 1.12	44.37 ± 1.94	59.79 ± 2.01
II (Experimental)	69.52 ± 0.95*	42.79 ± 0.79**	30.02 ± 0.90*	53.90 ± 1.00***	79.90 ± 2.03	53.66 ± 1.58**	60.51 ± 1.61
III (Experimental)	72.17 ± 0.96***	40.70 ± 0.87	30.66 ± 1.12*	60.51 ± 1.21***	82.20 ± 2.03	58.17 ± 1.96***	67.86 ± 3.12

Data obtained by averaging five measurements for each animal and the mean for the group ($n = 5$).
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ as compared to Control Group. Data are presented as mean and standard error.

digestibility. At the same time, the hematological test results generally indicate the safety of long-term (35 days) *Chlorella* supplementation in primates. The preparation of complete granular compound feeds supplemented with *Chlorella* powder allows balancing the diet in terms of nutrients and biologically active substances. Similar patterns are typical for *Chlorella* suspension supplementation: the experiments conducted in this regard showed best results for digestibility parameters, indicating that the use of this green algae suspension can significantly increase the metabolism level.

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Received 20.04.2021
Revised 01.06.2021
Accepted 31.08.2021

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