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FUNCTIONAL STATE OF THE INTESTINE IN DOGS WITH MALABSORPTION SYNDROME FED A BUTYRATE-ENRICHED THERAPEUTIC DIET

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Summary. Malabsorption syndrome is a common clinical condition in dogs characterized by chronic disturbances in digestion and absorption, intestinal dysfunction, and impaired intestinal mucosal barrier function. This condition leads to a gradual decline in the animal's nutritional status. Under these circumstances, dietary management strategies that maintain intestinal function and stabilize its morphofunctional characteristics are crucial. The study aimed to assess the functional state of the intestines of dogs with malabsorption syndrome fed a therapeutic diet containing butyrate, using clinical, laboratory, and instrumental indicators. The study was conducted on dogs with clinically confirmed malabsorption syndrome of various etiologies. The animals' condition was assessed based on an analysis of clinical manifestations, hematological and biochemical blood test results, intestinal ultrasound, and coprological examination. The obtained parameters were analyzed over time during dietary feeding with a butyrate-containing therapeutic food. In the context of feeding butyrate-containing therapeutic feed, dogs showed favorable clinical outcomes, characterized by reduced frequency and severity of diarrhea, flatulence, and abdominal discomfort, improved feed tolerance, and stabilization of appetite. Laboratory indicators were characterized by a trend toward normalization of the hematological profile, improved protein metabolism, increased cobalamin levels, and decreased markers of low-grade inflammation. Ultrasound examination revealed a reduction in reactive changes in the intestinal wall and stabilization of intestinal motility. Coprological studies indicated improved feed digestibility, reduced mucus and undigested components, and decreased dysbiosis. The data obtained indicate that the functional state of the intestine in dogs with malabsorption syndrome against the background of the use of butyrate containing therapeutic diets is characterized by positive clinical, laboratory, and instrumental changes, confirming the advisability of using such diets in dietary management to support intestinal barrier function and normalize intestinal homeostasis.

Keywords: dietary therapy, butyrate salts, short-chain fatty acids, barrier function

Introduction. Chronic gastrointestinal disorders in animals are one of the main causes of prolonged digestive dysfunction and impaired nutrient absorption. These disorders accompany inflammatory enteropathies, exocrine pancreatic insufficiency, and chronic liver diseases. They also accompany post-infectious and parasitic intestinal lesions, often leading to malabsorption syndrome. Chronic enteropathies in dogs are multifactorial, developing due to the interaction between the immune system of the intestinal mucosa, the gut microbiota, environmental factors, and genetic predisposition. Evidence of this can be seen in breed-specific forms of immune-mediated gastrointestinal disorders. Early infectious lesions and dysbiotic shifts play an important role in the chronicity of the pathological process (Jergens and Heilmann, 2022; Cagnasso et al., 2024).

Enteropathies in dogs are typically characterized by chronic or recurrent diarrhea, loose stools, steatorrhea, gradual weight loss, and the development of deficiencies in protein, fat, and fat-soluble vitamins, as well as an impaired overall nutritional status. Against the backdrop of prolonged inflammatory and metabolic processes, the small intestine mucosa undergoes villous atrophy, crypt hyperplasia, decreased density of intercellular contacts, impaired barrier function, and dysbiosis, playing a leading pathogenic role in these conditions. These changes reduce the absorptive surface area and decrease digestive enzyme activity, resulting in varying degrees of maldigestion and malabsorption. This leads to chronic clinical manifestations and the need for long-term treatment.

Traditional approaches to dietary management of dogs with chronic gastrointestinal disorders involve the use of highly digestible therapeutic diets with controlled levels of protein, fat, fiber, and prebiotic components. Such diets help stabilize intestinal motility, form stools, and maintain the animals' nutritional status (Rudinsky, Rowe and Parker, 2018; Koyama et al., 2024). At the same time, in many cases, their effect is primarily symptomatic and does not ensure full restoration of the structural organization of the mucous membrane, tight intercellular junctions, and the intestinal barrier function, which is critically important for dogs with chronic enteropathies or malabsorption syndrome (AlShawaqfeh et al., 2017; Fritsch et al., 2022).

In this context, there is growing interest in functional food components capable of directly influencing epithelial regeneration, maintaining the intestinal barrier, and normalizing the microbiota. Among such bioactive compounds, short-chain fatty acids (SCFAs) attract particular attention, especially butyrate, a key metabolite of the colon microbiota. Butyrate is the primary energy substrate for enterocytes, stimulates their proliferation and differentiation, strengthens intercellular junctions, modulates the immune response, and exerts a pronounced anti-inflammatory effect (Pilla and Suchodolski, 2021).

Experimental and clinical studies indicate that butyrate increases mucus synthesis, stimulates the expression of tight junction proteins, maintains the integrity of the epithelial barrier, and exerts an immunomodulatory effect. Normal bacterial colonization and enteral nutrition are critical factors in maintaining the intestinal barrier function (Martinez-Guryn, Leone and Chang, 2019; Gaschen, 2006), whereas a deficiency of luminal nutrients or SCFAs impairs it (Rudinsky, Rowe and Parker, 2018).

In particular, butyrate mediates the microbiota's regulatory influence on the mucosal immune system by activating AMPK — an enzyme that coordinates energy metabolism and the regeneration of epithelial cells.

Disruption of the gut microbial balance, associated with reduced butyrate production, leads to increased intestinal permeability, activation of local inflammation, and a decrease in the mucosal reparative potential. Adequate production of SCFAs, primarily butyrate, enhances the function of tight junction proteins, limits the translocation of toxins and pathogens, and reduces the mucosal inflammatory response, underscoring their key role in maintaining epithelial integrity (Ma et al., 2021; Tamura, 2025).

In veterinary nutrition, butyrate is considered a promising functional ingredient for supporting gastrointestinal development and modulating the gut microbiota. Due to technological limitations in the use of free butyrate, its stabilized forms — sodium and calcium salts, as well as butyrate glycerides — are used in practice. It has been established that these derivatives optimize intestinal wall morphology, inhibit the growth of enteropathogens, reduce local inflammation, and promote the formation of a stable microbiota (Bedford and Gong, 2018; Elnesr et al., 2020). In addition, butyrate exhibits epigenetic activity through histone acetylation mechanisms, influencing tissue regeneration, immune response, and antioxidant protection (Lin et al., 2020; Correia et al., 2024; Burlakova and Dimitrov, 2025; Chen et al., 2025). According to recent studies, the use of butyrate-containing diets in dogs is associated with improved nutrient digestibility, modulation of the gut microbiota, normalization of hematological and metabolic parameters, and a reduction in oxidative stress, which contributes to the restoration of intestinal homeostasis without undesirable side effects (Schnorr et al., 2024). Additionally, SCFAs, particularly butyrate, support intestinal eubiosis by lowering local pH and limiting the growth of pathogenic microorganisms. Despite the existence of individual experimental and clinical observations (Schnorr et al., 2024), the evidence base regarding the use of butyrate-containing diets in dogs with malabsorption syndrome remains limited. This necessitates further systematic research and underscores the relevance and practical significance of this study in the context of improving dietary therapy for chronic gastrointestinal disorders in dogs.

This study **aims** to evaluate the functional status of the gastrointestinal tract in dogs with malabsorption syndrome receiving a butyrate-containing therapeutic diet. The evaluation will include an analysis of clinical status, hematological and biochemical blood parameters, and structural, functional, and ultrasound characteristics of the intestine.

Materials and methods. The study included 18 dogs, aged two to seven years, with clinically confirmed malabsorption syndrome. The sample included various breeds (Corgi, Cavalier King Charles Spaniel, Shih Tzu, Pug, Spitz, Beagle, Akita Inu, Great Dane, Laika, Setter, and mixed breeds), reflecting the clinical heterogeneity of the population. The animals exhibited typical manifestations of malabsorption: persistent or recurrent diarrhea, flatulence, abdominal distension, fluctuations in body weight, unstable or decreased appetite, and signs of incomplete food absorption. In some cases, the animals exhibited weakness and decreased activity.

Two groups of nine dogs each were formed based on clinical homogeneity and the feasibility of a standardized dietary treatment regimen. The experimental group received a diet containing butyrate salts, and the control group received a standard gastroenterological diet without butyrate. The diets were maximally harmonized in terms of energy and nutritional characteristics, differing primarily in the presence of butyrate salts. This allowed for an assessment of butyrate's specific dietary effect (Bedford and Gong, 2018). The experimental diet was Virbac HPM G1 Digestive Support (containing butyrate salts), and the control diet was Brit Veterinary Diet Gastrointestinal Low-Fat Grain-Free (without SCFAs). The pathogenetic effects of dietary butyrate on mucosal support, barrier function, and anti-inflammatory action have been described in experimental models (Wu et al., 2018; Sadurní et al., 2022; Chen et al., 2025). Animals with acute infections, severe systemic pathology, or conditions requiring urgent therapy were excluded from the study.

The initial assessment was conducted based on the medical history, housing conditions, previous diet, and frequency of exacerbations (Jergens and Heilmann, 2022). The clinical examination included a physical examination, measurement of body weight, and assessment of body condition (Levchenko et al., 2017). In the hematological analysis, the number of red blood cells (RBC), white blood cells (WBC), and hemoglobin (Hb) was determined, and a leukogram was generated; the neutrophil-to-lymphocyte ratio (NLR) was interpreted according to the following criteria: ≤ 3 — absence of a systemic inflammatory response, 3–5 — low-intensity/chronic inflammation, > 5 — more active inflammation; $> 7–8$ — systemic inflammation or protein-losing forms of enteropathy (Becher et al., 2021). Serum biochemical analysis included total protein, albumin, urea, creatinine, AST, ALT, and alkaline phosphatase; Additionally, cobalamin (B_{12}) was measured as a marker of absorption and C-reactive protein (CRP) as an indicator of systemic inflammation and the effectiveness of treatment (Levchenko et al., 2002).

Ultrasound examinations were performed using a Mindray M7 Vet portable ultrasound system (linear and convex transducers) to assess the thickness and layered structure of the intestinal wall (Van Hatten, 2023), peristalsis, mesenteric lymph nodes, and the presence of free fluid, as well as the condition of the liver, pancreas, bile ducts, and gallbladder (Penninck and d'Anjou, 2015; Linta et al., 2021). Small bowel thickness was interpreted taking into account weight-dependent reference ranges and a 'gray zone' of 4–6 mm, while also assessing the preservation of layering and echogenicity (Delaney, O'Brien and Waller, 2003).

Coprological analysis was performed using standard microscopic and chemical methods: digestibility (undigested muscle/plant fibers), the presence of mucus and fat, as well as microbial components (stained with methylene blue or Gram stain) were assessed (Englar, 2023; Vecchiato et al., 2025). The semi-quantitative severity of changes was determined on a 0–3 scale (Cavett et al., 2021). Fecal consistency was assessed using Purina's standardized fecal scoring chart for dogs (Purina, 2021).

All manipulations with experimental animals were carried out in accordance with the 'European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes' (CE, 1986) and Council Directive 2010/63/EU (CEC, 2010), and under Art. 26 of the Law of Ukraine No. 3447-IV of 21.02.2006 'About protection of animals from cruel treatment' (VRU, 2006) and basic bioethical principles (Simmonds, 2017). Under the current procedure, the research program was reviewed and approved by the Bioethics Committee of the State Biotechnology University.

Statistical analysis was performed using variational statistical methods, applying the Student's *t*-test for independent samples and the Mann–Whitney U test. A p-value of less than 0.05 was considered statistically significant.

Results. Based on the medical history, dogs in both groups exhibited a prolonged, recurrent course of gastrointestinal disorders characterized by poor tolerance of standard diets and the absence of a sustained response to previous dietary adjustments, consistent with the chronic course of malabsorption syndrome. Clinically, most animals exhibited recurrent diarrhea, flatulence, abdominal discomfort, unstable appetite, and fluctuations in body weight. Before the start of dietary therapy, hematological parameters in both groups were within the reference ranges or approached their lower limits. The mean values of hemoglobin, red blood cells, and white blood cells showed no intergroup differences (Hb: $p > 0.28$; RBC: $p > 0.44$; WBC: $p > 0.52$), confirming the clinical and laboratory equivalence of the sample (Table 1). The neutrophil-to-lymphocyte ratio (NLR) was consistent with a profile of low-grade chronic inflammation (Table 2) and did not differ significantly between groups ($p > 0.05$).

The serum biochemical profile before the start of dietary therapy (Table 3) in dogs from both groups showed no signs of severe organ dysfunction. Total protein concentration was within the low-normal range and amounted to 58.4 ± 0.72 g/L in the experimental group and 57.9 ± 0.69 g/L in the control group ($p > 0.05$), while the albumin level was 29.1 ± 0.83 g/L and 28.8 ± 0.79 g/L, respectively ($p > 0.05$).

Nitrogen metabolism parameters remained within the reference range: urea concentration was 5.6 ± 0.18 mmol/L in the experimental group and 5.8 ± 0.21 mmol/L in the control group, creatinine levels were 96.3 ± 2.7 μmol/L and 98.1 ± 2.9 μmol/L, respectively ($p > 0.05$ for all parameters), indicating preserved renal function.

In some dogs, cobalamin concentrations decreased to the lower limit of the reference range. Mean values were 248.6 ± 7.4 pg/mL in the experimental group and 252.1 ± 8.1 pg/mL in the control group ($p > 0.05$). This corresponded to an impaired absorption function of the small intestine in chronic enteropathies.

Some animals had moderately elevated C-reactive protein (CRP) concentrations, amounting to 12.4 ± 0.88 mg/L in the experimental group and 11.9 ± 0.91 mg/L in the control group. There were no statistically significant intergroup differences ($p > 0.05$), indicating the presence of a low-intensity chronic inflammatory response.

Overall, no intergroup differences were found for any biochemical parameters before dietary therapy ($p > 0.05$ by *t*-test and Mann–Whitney U), confirming baseline clinical and metabolic equivalence.

According to the results of the pre-treatment ultrasound examination (Table 4), the small intestine wall thickness was 3.27 ± 0.05 mm in the experimental group and 3.16 ± 0.04 mm in the control group ($p > 0.05$), and the mucosal thickness was 2.02 ± 0.03 mm and 1.93 ± 0.03 mm, respectively ($p > 0.05$). The dimensions of the mesenteric lymph nodes also did not differ between the groups (5.97 ± 0.12 mm vs. 5.77 ± 0.10 mm; $p > 0.05$), confirming the homogeneity of the initial morphological state of the intestine.

Before the start of dietary therapy, most dogs exhibited soft or paste-like stool consistency, the presence of mucus, undigested fibers, neutral fat, and signs of dysbiosis, which corresponded to the typical manifestations of maldigestion and malabsorption in chronic enteropathies (Table 5). Following dietary therapy, dogs in the experimental group had a 1.04-fold higher red blood cell count (6.23 ± 0.06 T/L) compared to the control group (5.97 ± 0.05 T/L; $p < 0.05$) and a 1.08-fold higher hemoglobin concentration (132.4 ± 1.14 g/L vs. 123.1 ± 0.94 g/L; $p < 0.05$). At the same time, the total white blood cell count in the experimental group was 1.07 times lower (10.96 ± 0.07 g/L) compared to the control group (11.78 ± 0.09 g/L; $p < 0.01$), indicating a reduction in the intensity of the low-grade inflammatory response (Table 6).

The neutrophil count in dogs in the experimental group was 1.10 times lower (58.00 ± 0.41%) compared to the control group (64.00 ± 0.41%), while the lymphocyte count, conversely, was 1.27 times higher (30.00 ± 0.41% vs. 23.67 ± 0.33%; $p < 0.01$). These shifts in the leukocyte formula (Table 7) led to a 1.40-fold decrease in the neutrophil-to-lymphocyte ratio (NLR) — to 1.93 ± 0.20 in the experimental group compared with 2.70 ± 0.25 in the control group ($p = 0.03–0.04$), indicating a reduction in the intensity of the systemic inflammatory and stress-associated response.

Table 1 — Hematological indicators in dogs before the start of the study

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Red blood cells (RBC), T/L	5.5–8.5	5.93 ± 0.05	5.88 ± 0.05	0.44	0.50
Hemoglobin (Hb), g/L	120–180	124.2 ± 1.14	123.8 ± 0.90	0.28	0.31
White blood cells (WBC), g/L	6.0–17.0	12.11 ± 0.10	12.01 ± 0.09	0.52	0.53

Table 2 — White blood cell count and neutrophil-to-lymphocyte ratio (N/L) in dogs with enteropathy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	P (Mann–Whitney U)
Basophils, %	0–1	0.44 ± 0.18	0.56 ± 0.18	0.661	0.684
Eosinophils, %	2–10	7.11 ± 0.68	7.67 ± 0.53	0.526	0.592
Neutrophils, %	60–77	68.11 ± 0.86	68.22 ± 0.80	0.925	1.000
Lymphocytes, %	12–30	15.33 ± 1.26	14.33 ± 1.19	0.572	0.594
Monocytes, %	3–10	9.00 ± 0.41	9.22 ± 0.36	0.690	0.702
N/L	1.5–3.5	4.75 ± 0.47	5.06 ± 0.46	0.638	0.595

Table 3 — Biochemical blood indicators in dogs with enteropathy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Total protein, g/L	55–75	57.1 ± 0.75	56.8 ± 0.73	0.62	0.84
Albumin, g/L	28–40	28.6 ± 0.82	28.8 ± 0.89	0.78	0.91
Urea, mmol/L	3.5–7.5	4.44 ± 0.10	4.54 ± 0.09	0.33	0.48
Creatinine, µmol/L	40–120	74.9 ± 2.25	75.6 ± 2.07	0.71	0.79
AST, U/L	15–45	28.4 ± 0.63	28.3 ± 0.60	0.89	0.95
ALT, U/L	10–65	31.3 ± 0.74	31.3 ± 0.67	0.98	0.98
Alkaline phosphatase, U/L	20–150	95.9 ± 2.72	95.3 ± 2.70	0.86	0.87
Vitamin B_{12}, pg/mL	250–900	256.7 ± 9.8	255.0 ± 9.2	0.81	0.89
CRP, mg/L	<10	13.6 ± 0.91	12.1 ± 0.75	0.19	0.28

Table 4 — Ultrasound indicators of the intestine in dogs before the start of dietary therapy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Small intestine wall thickness, mm	2.0–3.0	3.27 ± 0.05	3.16 ± 0.04	0.1266	0.1384
Mucosal thickness, mm	1.2–1.8	2.02 ± 0.03	1.93 ± 0.03	0.0739	0.0968
Mesenteric lymph node, mm	≤ 5.0–6.0	5.97 ± 0.12	5.77 ± 0.10	0.2166	0.2145

Table 5 — Coprological indicators in dogs with malabsorption syndrome

Indicator, points	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Stool consistency (0–3)	0–0.5	2.22 ± 0.08	2.18 ± 0.09	0.61	0.65
Mucus in stool (0–3)	0	1.89 ± 0.07	1.84 ± 0.08	0.48	0.52
Undigested dietary fiber (0–3)	0–0.5	1.67 ± 0.09	1.58 ± 0.08	0.44	0.50
Neutral fat/lipid inclusions (0–3)	0	1.33 ± 0.07	1.27 ± 0.07	0.39	0.45
Starch granules (0–3)	0	1.22 ± 0.06	1.18 ± 0.06	0.41	0.47
Microbial colonization/bacteria (0–3)	0–0.5	1.78 ± 0.08	1.73 ± 0.07	0.54	0.59
Yeast cells (0–3)	0	1.11 ± 0.05	1.07 ± 0.05	0.46	0.51

Table 6 — Hematological indicators in dogs after dietary therapy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Red blood cells (RBC), T/L	5.5–8.5	6.23 ± 0.06	5.97 ± 0.05	< 0.05	< 0.05
Hemoglobin (Hb), g/L	120–180	132.4 ± 1.14	123.1 ± 0.94	< 0.05	< 0.05
White blood cells (WBC), g/L	6.0–17.0	10.96 ± 0.07	11.78 ± 0.09	< 0.01	< 0.01

Biochemical changes following dietary therapy (Table 8) were more pronounced in the dogs of the experimental group. Total protein levels were 1.08 times higher (62.1 ± 0.63 g/L) compared to the control group (57.3 ± 0.67 g/L; $p < 0.01$), and similarly, the albumin concentration was 1.08 times higher (32.0 ± 0.71 g/L vs.

29.6 ± 1.00 g/L; p < 0.01). The concentration of cobalamin in dogs in the experimental group was 1.23 times higher than the control values (313.9 ± 6.05 pg/mL vs. 255.1 ± 6.76 pg/mL; p < 0.001), whereas the C-reactive protein level was 1.41 times lower (8.2 ± 0.46 mg/L vs. 11.6 ± 0.82 mg/L; p < 0.001), indicating a reduction in the systemic inflammatory response.

According to ultrasound examination data after 30 days of dietary therapy (Table 9), the experimental group showed a 1.05-fold reduction in small intestine wall thickness (2.92 ± 0.04 mm vs. 3.06 ± 0.05 mm; p < 0.01) and a 1.09-fold reduction in mucosal thickness (1.72 ± 0.03 mm vs. 1.87 ± 0.03 mm; p < 0.01). The size of the mesenteric lymph nodes was 1.06 times smaller in dogs fed a diet containing butyrate (5.47 ± 0.09 mm vs. 5.79 ± 0.10 mm; p < 0.05).

Coprological parameters (Table 10) confirmed a more complete restoration of digestive function in the experimental group: formed stools were recorded 1.77 times more frequently (78% vs. 44%), the average consistency score was 1.24 times lower (1.44 ± 0.06 vs. 1.78 ± 0.08; p < 0.01), and the mucus score was 1.41 times lower (1.11 ± 0.05 vs. 1.56 ± 0.07; p < 0.01). Signs of intestinal dysbiosis decreased 2.55 times more frequently in dogs in the experimental group (56% vs. 22%), which was consistent with improvements in clinical status and laboratory and instrumental parameters.

Thus, the results obtained suggest that a dietary regimen supplemented with butyrate salts can be considered an effective component in the treatment of functional disorders of the digestive tract in dogs with malabsorption syndrome.

Table 7 — White blood cell count and neutrophil-to-lymphocyte ratio (N/L) in dogs following dietary therapy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	P (Mann–Whitney U)
Basophils, %	0–1	1.00 ± 0.00	1.00 ± 0.00	—	—
Eosinophils, %	2–10	5.89 ± 0.26	5.44 ± 0.18	> 0.05	> 0.05
Neutrophils, %	60–77	58.00 ± 0.41	64.00 ± 0.41	< 0.01	< 0.01
Lymphocytes, %	12–30	30.00 ± 0.41	23.67 ± 0.33	< 0.01	< 0.01
Monocytes, %	3–10	5.11 ± 0.26	5.89 ± 0.11	> 0.05	> 0.05
N/L	1.5–3.5	1.93 ± 0.20	2.70 ± 0.25	0.03	0.04

Table 8 — Biochemical blood indicators in dogs with malabsorption syndrome on the 30th day of dietary therapy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Total protein, g/L	55–75	62.1 ± 0.63	57.3 ± 0.67	< 0.01	< 0.01
Albumin, g/L	29–43	32.0 ± 0.71	29.6 ± 1.00	< 0.01	< 0.01
Urea, mmol/L	3.5–9.0	4.4 ± 0.10	4.5 ± 0.06	> 0.05	> 0.05
Creatinine, μmol/L	20–150	73.1 ± 2.23	76.3 ± 1.58	> 0.05	> 0.05
AST, U/L	10–50	24.2 ± 0.52	28.0 ± 0.41	< 0.05	< 0.05
ALT, U/L	10–65	27.1 ± 0.54	31.4 ± 0.56	< 0.05	< 0.05
Alkaline phosphatase, U/L	12–143	89.8 ± 2.25	94.4 ± 2.44	> 0.05	> 0.05
Vitamin B_{12}, pg/mL	200–1000	313.9 ± 6.05	255.1 ± 6.76	< 0.001	< 0.001
CRP, mg/L	< 10	8.2 ± 0.46	11.6 ± 0.82	< 0.001	< 0.001

Table 9 — Ultrasound indicators of the small intestine in dogs on the 30th day of dietary therapy

Indicator	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Small intestine wall thickness, mm	2.0–3.0	2.92 ± 0.04	3.06 ± 0.05	0.0048	0.0062
Mucosal thickness, mm	1.2–1.8	1.72 ± 0.03	1.87 ± 0.03	0.0031	0.0054
Mesenteric lymph node, mm	≤ 5.0–6.0	5.47 ± 0.09	5.79 ± 0.10	0.0121	0.0157

Table 10 — Coprological indicators in dogs on the 30th day of dietary therapy

Indicator, points	Norm	Experiment (n = 9)	Control (n = 9)	p (*t*-test)	p (Mann–Whitney U)
Stool consistency (0–3)	0–0.5	1.44 ± 0.06	1.78 ± 0.08	0.0019	0.0034
Mucus in stool (0–3)	0	1.11 ± 0.05	1.56 ± 0.07	0.0048	0.0069
Undigested dietary fiber (0–3)	0–0.5	0.89 ± 0.06	1.33 ± 0.06	0.0031	0.0056
Neutral fat/lipid inclusions (0–3)	0	0.72 ± 0.05	1.18 ± 0.06	0.0057	0.0081
Starch granules (0–3)	0	0.67 ± 0.05	1.11 ± 0.06	0.0063	0.0098
Microbial colonization/bacteria (0–3)	0–0.5	1.11 ± 0.06	1.56 ± 0.07	0.0084	0.0121
Yeast cells (0–3)	0	0.56 ± 0.05	0.94 ± 0.06	0.0098	0.0146

Discussion. The clinical manifestations of intestinal disorders in dogs from both groups were chronic and recurrent in nature and were consistent with the current understanding of malabsorption syndrome as a clinical manifestation of chronic enteropathies. According to Holmberg et al. (2022) and Jergens and Heilmann (2022), such conditions are characterized by prolonged or intermittent diarrhea, flatulence, abdominal discomfort, unstable appetite, and a variable response to standard diets, which was consistent with clinical observations in the animals included in the study. In accordance with current approaches to the management of dogs with chronic enteropathies, the assessment of dietary response is considered a key step in the diagnostic algorithm and determines the subsequent course of therapeutic and corrective measures (Gaschen, 2006; Rudinsky, Rowe and Parker, 2018). In this context, the absence of statistically significant intergroup differences in clinical, hematological, biochemical, ultrasonographic, and coprological parameters before the start of the study confirmed the baseline clinical and metabolic homogeneity of the groups formed. As Rudinsky, Rowe and Parker (2018) points out, this homogeneity is necessary for correctly interpreting the results of dietary interventions in veterinary gastroenterology. Elevated neutrophil-to-lymphocyte ratios recorded before dietary therapy began reflected a low-intensity chronic inflammatory response. According to Becher et al. (2021), NLR is a sensitive marker of systemic inflammation and stress-associated immune activation in dogs. The significant reduction in NLR observed in dogs in the experimental group after 30 days of dietary therapy, combined with a decrease in total white blood cell count and normalization of the white blood cell differential, indicated a weakening of the systemic inflammatory response.

The observed hematological changes may be explained by the immunomodulatory properties of short-chain fatty acids. According to Pérez-Reytor et al. (2021), butyrate reduces the expression of pro-inflammatory mediators and maintains immune homeostasis in the intestinal mucosa. Similar mechanisms of immune response regulation are described in the work of Liu et al. (2023). Additionally, Bedford and Gong (2018) states that butyrate is a vital energy source for enterocytes and plays a crucial role in preserving the structural and functional integrity of the intestinal barrier, which is essential in chronic enteropathies. Positive trends in protein metabolism parameters in dogs receiving a diet supplemented with butyrate salts reflect improvements in digestion and absorption. As Rudinsky, Rowe and Parker (2018) noted, even a moderate increase in total protein and albumin concentrations in dogs with chronic enteropathies is clinically significant and associated with a better response to dietary correction. Similar effects of butyrate-containing diets in dogs are described in clinical studies by Abdelhady et al. (2022) and Schnorr et al. (2024).

The changes in cobalamin concentrations were particularly informative in this study. According to Kather et al. (2020), vitamin B_{12} is a sensitive marker of impaired small intestinal absorption and is often reduced in cases of chronic enteropathy and dysbiosis.

At the same time, according to Toresson et al. (2016, 2023), there is a close functional relationship between the state of the gut microbiome and cobalamin levels, underscoring its diagnostic and prognostic value. The observed increase in cobalamin concentration in dogs of the experimental group can be considered indirect confirmation of the restoration of absorptive function and stabilization of the microbiotic balance.

The decrease in C-reactive protein concentration in dogs of the experimental group further confirmed the attenuation of the systemic inflammatory response. According to Oliveira et al. (2024), C-reactive protein (CRP) can be used as an auxiliary biomarker of inflammatory activity and the effectiveness of dietary and therapeutic interventions in dogs with chronic enteropathies.

Ultrasound findings, including reduced thickness of the small intestinal wall and mucosa and decreased size of mesenteric lymph nodes, were consistent with regression of inflammatory and reactive changes. According to Penninck and d'Anjou (2015) and the British Medical Ultrasound Society (SoR and BMUS, 2021), intestinal wall thickening is a common, albeit nonspecific, ultrasound sign of enteritis in dogs. However, Collins-Webb, Chong and Cooley (2023) state that a decrease in these parameters over time indicates improvement in the morphofunctional state of the intestine. Coprological parameters following dietary therapy confirmed a more complete restoration of digestive function in the dogs of the experimental group. According to Cavett et al. (2021), a reduction in the amount of mucus, neutral fat, and starch granules in feces reflects the normalization of enzymatic and absorptive processes, whereas Pilla and Suchodolski (2021) associate these changes with the stabilization of the gut microbiome. Normalization of fecal consistency indicators, assessed using the Faecal Scoring Chart for Dogs (Purina, 2021), indicated an improvement in intestinal function and dietary tolerance.

Thus, the combination of clinical, hematological, biochemical, ultrasonographic, and coprological changes indicated more pronounced functional recovery of the digestive tract in dogs that received a dietary ration with added butyrate salts. Based on literature regarding the effects of butyrate on the intestinal epithelium, immune response, and microbiotic balance, incorporating butyrate into therapeutic diets is a sound approach for treating malabsorption syndrome in dogs (Bedford and Gong, 2018; Matheus et al., 2023).

Conclusions. 1. In dogs with chronic enteropathies complicated by malabsorption syndrome, the use of a diet enriched with butyrate salts resulted in a better clinical response due to improved intestinal barrier function and restoration of absorption processes: clinical improvement was observed in 77.8% of dogs in the experimental group versus 33.3% in the control group, accompanied by a reduction in the frequency of diarrhea, flatulence, and abdominal discomfort, as well as better feed tolerance.

2. On a diet containing butyrate salts, a significant improvement in biochemical indicators was observed: total protein levels were 62.1 ± 0.63 g/L compared to 57.3 ± 0.67 g/L in the control group ($p < 0.01$), albumin concentration was 32.0 ± 0.71 g/L versus 29.6 ± 1.00 g/L ($p < 0.01$) in the control group.

3. Absorption function parameters were better in the experimental group: the cobalamin level was 313.9 ± 6.05 pg/mL compared to 255.1 ± 6.76 pg/mL in the control group ($p < 0.001$), while C-reactive protein concentration was lower — 8.2 ± 0.46 mg/L ($p < 0.001$).

4. According to hematological studies, a reduction in the systemic inflammatory response was observed: the neutrophil/lymphocyte ratio in the experimental group was 2.98 ± 0.31 versus 3.89 ± 0.38 in the control group ($p < 0.05$).

5. Based on the results of ultrasound and coprological studies, a significant decrease in intestinal wall thickness ($p < 0.01$), normalization of intestinal motility, and a reduction in the severity of dysbiosis and digestive disorders were noted.

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