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Formulation of the Enterosorbent Bentorb and Assessment of Its Acute and Chronic Toxicity

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Abstract

This paper presents the findings of multiple investigations into the newly developed Bentorb sorbent, derived from winemaking byproducts, specifically the adhesive residues of yellow blood salt. Elemental analysis revealed that the predominant components of Bentorb include oxygen, carbon, silicon, aluminum, iron, nitrogen, and magnesium, which together make up the majority of the sorbent's composition. Toxicological assessments of Bentorb were conducted using laboratory animals. To evaluate acute toxicity, 60 white mongrel rats, each weighing approximately 237 ± 7 g, were subjected to the substance. The results showed no significant changes in the general clinical condition of rats in either the experimental or control groups, and all animals survived the tests. Chronic toxicity was assessed in 60 white mice and 40 Wistar rats, each weighing 185 ± 12 g. Over the study period, no notable differences in health or survival rates were observed between the experimental and control groups. The effects of Bentorb on gastrointestinal function were examined in piglets aged 40-80 days. Additionally, the potential embryotoxicity of Bentorb was investigated in pregnant Wistar rats weighing 200-240 g. The study also included analyses of body weight and various internal organs in both control and experimental groups that received Bentorb.

Keywords Acute toxicity, Enterosorbent, Sorbent, Chronic toxicity, Sorption, Bentorb

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Introduction

The rapid industrialization of recent years has led to increased environmental pollution from exotoxins [1]. The contamination of air, water, soil, food, and food products with hazardous chemicals has made the chemical factor a key determinant in the extent of environmental degradation [2-4]. Hazardous persistent organic pollutants, such as dioxins and dibenzofurans, are now found ubiquitously in the environment [5]. Many regions are severely contaminated with household waste, heavy metals, and pesticides [6].

Various pollutants that enter the body through inhalation or other routes can trigger a range of diseases of diverse origins [7]. Continuous exposure to harmful environmental factors often leads to metabolic disruptions, resulting in marked clinical changes in metabolism [8]. These environmental concerns have contributed to increased rates of disease and death, as well as reproductive impairments [9]. Given the growing challenges posed by radionuclide contamination and the expanding technological pollution, the development of methods to detoxify the human body has become a critical area of research [10].

Among these methods, intracorporeal enterosorption techniques are gaining popularity [11]. These approaches are favored due to their ease of use, physiological compatibility, minimal complications, and low material costs. The principle of enterosorption involves administering sorbent substances orally, which bind toxic compounds present in the gastrointestinal contents [12].

This paper presents the findings of multiple investigations into the newly developed Bentorb sorbent, derived from winemaking byproducts, specifically the adhesive residues of yellow blood salt.

Materials and Methods

Capillary electrophoresis was utilized to determine the organic acids in the extract derived from the adhesive residues of yellow blood salt, using the “Kapel-105” R52841-2007 device. Data were processed using the Multichrome software for Windows.

To assess the toxicity of yellow blood salt adhesive residues, which serve as the basis for the Bentorb sorbent, a rapid biotesting procedure was conducted using the equidistant paramecia (*Paramecium caudatum*). The toxicity of the finalized Bentorb sorbent was then tested on white mongrel rats and Wistar rats.

For the investigation into the effect of the yellow blood salt adhesive residues on the infusoria, varying dilutions of Lozin-Lozinsky mineral solution were added to the wells of a serological plate (2.5 cm³ volume per well). In each well, 2.0 ml of the yellow blood salt adhesive residue solution and 0.5 ml of a 3-day-old culture of either Paramecia or Stylonychia were introduced, following the experimental setup. A control group was set up in which the Lozin-Lozinsky solution was used without the sorbent, and infusoria were added at the same volume. Exposure durations ranged from fifteen minutes to four days.

Animal studies on the Bentorb sorbent included acute toxicity testing in 60 white mongrel rats (237 ± 7 g) and chronic toxicity testing in 60 white mice and 40 Wistar rats (185 ± 12 g), divided into four groups of 10 animals per group based on body weight. The effects of Bentorb on the digestive system were evaluated in piglets aged 40-80 days. Additionally, the potential embryotoxicity of Bentorb was evaluated in pregnant Wistar rats weighing 200-240 g.

The feces’ physicochemical characteristics were studied by measuring pH with litmus paper, detecting blood with a benzidine test, evaluating bilirubin with the Fouché test, analyzing bile pigments with the Terquay method, and observing fat and starch under a microscope using Sudan III and Lugol’s solution.

Results and Discussion

The production of sorbents involves utilizing winemaking waste, specifically the adhesive precipitates from yellow blood salt formed during the demetallization process [13].

During the demetallization of wine using potassium hexacyanoferrate(II) (yellow blood salt), the iron content is reduced to below 3 mg/dm³, while copper, lead, zinc, and aluminum ions are also removed. The primary purpose of this process is to eliminate excess heavy metals, particularly iron, which negatively affect the wine’s taste and stability [14].

The organic acid composition in the raw materials used for manufacturing ferrocyanide-bentonite sorbents is provided in Table 1.

Table 1. Concentration of organic acids in adhesive precipitates of yellow blood salt

Name	Acid concentration
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	mg/l	%
Wine Room	1645	78.5%
Apple	67.7	1.5%
Lemon	114.9	2.5%
Dairy+acetic	801.3	17.3%
Total	4629	100.0%

Table 1 shows that tartaric acid is the predominant organic acid in the adhesive precipitates of yellow blood salt, accounting for 78.7%, followed by lactic, acetic, and citric acids in smaller amounts.

This indicates that the adhesive precipitates are primarily composed of trivalent and divalent iron ions, with tartaric acid as the main organic acid.

In wineries using equipment made of ferrous metals, the acidic conditions cause the dissolution of iron ions, leading to their accumulation in wine materials. When these materials are treated with potassium hexacyanoferrate (yellow blood salt), ferrocyanides are generated.

The precipitate produced is a gel-like substance containing ferrocyanides and other mineral and organic components. The waste from winemaking contains around 5%-10% bentonite, 5%-7% yeast, 0.5%-2.5% ferro-ferricyanide, as well as adhesives, dyes, tannins, and alcohols. This sediment has a pH of 4-4.5 and an average moisture content of 85%-93%. Its solid matter makes up 15%-20%, with Prussian blue content ranging from 0.5% to 6%. This mixture is difficult to filter and dry, presenting challenges for its neutralization and disposal [15].

To manufacture sorbents, adhesive precipitates of yellow blood salt are gathered from dumps at primary building material production plants.

The production process for Bentorb sorbent involves several steps: first, drying the raw material to an air-dry state, then grinding it.

For the drying process, the raw material is spread into a uniform 5-10 cm-thick layer under a canopy to prevent exposure to direct sunlight and precipitation. Drying occurs in ambient air at temperatures between 15 and 30 °C for 10-20 days, with periodic mixing to monitor moisture levels. Once the moisture content falls to 2%-5%, the raw material is considered air-dried. Afterward, it is stored at 18-20 °C for no longer than 1 month. If stored for extended periods, the moisture content is checked and, if necessary, the material is further dried.

The requirements for the Bentorb sorbent are listed in **Table 2**, and the results from the laser mass spectrometric analysis of a Bentorb sorbent sample are presented in **Table 3**.

Table 2. Requirements and standards for Bentorb sorbent

Indicator	The norm
Appearance	Fine powder of gray-blue color
Bulk weight (kg/dm ³)	0.6-1.2
Quantitative content (%) of iron (II) iron (III)	0.3-5.0 0.4-10.0

potassium	0.1-15.0
Sorption activity (% not lower)	70

Table 3. Results of laser mass spectrometric analysis of the Bentorb sample

Chemical elements	Content, %	Chemical elements	Content (%)
Boron	3.5×10^{-3}	Scandium	9.0×10^{-4}
Carbon	19.2	Titanium	1.1×10^{-1}
Nitrogen	3.0	Chrome	5.0×10^{-3}
Oxygen	44.2	Manganese	8.4×10^{-2}
Fluorine	7.3×10^{-2}	Iron	3.7
Sodium	3.2×10^{-1}	Cobalt	6.4×10^{-4}
Magnesium	1.3	Nickel	5.5×10^{-3}
Aluminum	5.4	Copper	2.3×10^{-2}
Silicon	14.0	Zinc	6.0×10^{-2}
Phosphorus	2×10^{-1}	Gallium	1.4×10^{-3}
Sulfur	2×10^{-1}	Bromine	2.6×10^{-3}
Chlorine	1.6×10^{-1}	Rubidium	5.6×10^{-2}
Potassium	7.8×10^{-2}	Strontium	2.8×10^{-3}
Calcium	2.0×10^{-1}	Yttrium	5.3×10^{-4}
Barium	6.4×10^{-3}	Zirconium	4.4×10^{-3}
Lanthanum	1.7×10^{-3}	Niobium	4.3×10^{-4}
Cerium	1.0×10^{-3}		

The composition analysis reveals that the most abundant elements in the sample are oxygen, carbon, silicon, aluminum, iron, nitrogen, and magnesium, which together account for 44.2% to 1.3% of the sample. Following these, elements like sodium, phosphorus, sulfur, chlorine, and calcium are present in smaller quantities, ranging from 3.2% to 0.11%. Further trace elements include manganese, potassium, fluorine, zinc, rubidium, and copper, contributing between 8.4% and 0.023%. Additionally, elements such as barium, nickel, chromium, zirconium, boron, bromine, strontium, lanthanum, gallium, and cerium are present in even lower amounts, ranging from 6.4% to 0.001%. Scandium, cobalt, yttrium, and niobium are detected at concentrations between 9.0% and 0.00043%. No traces of arsenic, cadmium, lead, or mercury were found, as their levels fell below 0.0003%.

Evaluation of acute and chronic toxicity

The study of adhesive residues of yellow blood salt demonstrated a beneficial impact on the growth, reproduction, and activity of both *Paramecia* and *Stylonychia*. The optimal concentration for *Stylonychia*'s vitality was found to be $\times 10^{-2}$, with these organisms first settling on the adhesive substrate and later moving energetically in the surrounding medium.

Despite some liquid evaporation from the wells after 72 hours, the population of *Stylonychia* remained unaffected, and cell division was observed, resulting in a 3-to 4-fold increase in their numbers.

Paramecia, in contrast, preferred a lower concentration ($\times 10^{-4}$). Unlike *Stylonychia*, they predominantly inhabit the upper water layers and exhibit more marked negative chemotaxis to organic salts. In the control group, the paramecia displayed decreased activity, but their population did not grow.

These observations indicate that the waste products of wine processing provided a supportive environment for protozoa, as evidenced by increased numbers and greater generational turnover compared to the control.

Further investigation into the microflora of adhesive deposits of yellow blood salt revealed a high abundance of mesophilic aerobic and facultative anaerobic microorganisms, such as *Bacillus subtilis* – *Bac. mesentericus* and *Bac. megaterium*. These species are typically associated with substrates rich in minerals, sulfates, and iron oxides. On bismuth-sulfite medium, colonies with a brownish central area and wrinkled surface were observed, while colonies typical of *E. coli* grew on Endo medium.

Acute toxicity tests with the Bentorb sorbent were conducted on sixty white mongrel rats, each weighing 237 ± 7 g. The sorbent was administered as a 50% aqueous suspension at 400 mg/mL via a probe. Given the small stomach volume of rats, the suspension was administered in 5 ml doses at 1-hour intervals: the second group received a single dose, the third group received two doses, the fourth group received four doses, the fifth group received five doses, and the sixth group received seven doses. The control group received seven 5-mL doses of water. The total dose administered was treated as a single intake. Over a 14-day monitoring period, no significant clinical changes were noted, and all rats survived, as detailed in [Table 4](#).

Table 4. Acute toxicity of Bentorb in rats

Group	Suspension volume (ml)	The amount of the drug (mg/kg)	Number of rats	
			Total	Died
1	5	8370	10	-
2	10	16735	10	-
3	20	33473	10	-
4	15	41841	10	-
5	35	58577	10	-
6	35 (control)		10	-

A two-month chronic toxicity investigation was conducted with 60 white mice, during which each animal received a daily dose of 0.3 ml of Bentorb sorbent suspended in a 2.5% starch-based gel. The mice were divided into several experimental and control groups. Group 1 received Bentorb sorbent stored for 3 years, while group 2 received sorbent preserved for 13 years. Group 3 served as the control and received only the starch gel.

Each of the two experimental groups was further divided into subgroups based on dosage concentrations. Subgroups 1.1 and 2.1 received the sorbent at 100 mg/ml; 1.2 and 2.2 received 200 mg/ml; and 1.3 and 2.3 received the highest dosage of 400 mg/ml. The control group received only the vehicle medium without any active substance. Throughout the study period, the primary indicator for evaluating the sorbent's chronic toxicity was the survival rate of the mice under each condition.

Comprehensive data summarizing the outcomes of this chronic toxicity trial are compiled in **Table 5**.

Table 5. Chronic toxicity of Bentorb in mice

Shelf life	Group	Drug quantity		Number of mice	
		Suspension concentration (mg/ml)	Total amount (mg)	Total	Died
3 years	1.1	100	21600	10	2
	1.2	200	43200	10	2
	1.3	400	86400	10	4
13 years	2.1	100	21600	10	2
	2.2	200	43200	10	2
	2.3	400	86400	10	4
Control	3	Starch gel	0	10	4

Throughout the observation period, there were no notable changes in the overall health or behavior of the mice receiving Bentorb compared to the control group. Mortality among the treated mice remained comparable to that observed in animals administered only the starch gel. Post-mortem analysis revealed that the deaths were uniformly caused by mechanical injury from the metal probe, specifically perforation of the gastric wall, rather than the sorbent itself. These findings support the conclusion that Bentorb does not exhibit toxic properties under the tested conditions. Furthermore, survival rates did not differ among mice administered sorbents with different storage durations at the same dosage levels, indicating that extended shelf life does not increase the compound's toxicity.

Additional chronic toxicity assessments were conducted using 40 Wistar rats with an average body mass of 185 ± 12 g. These rats were divided into four equal groups, each comprising 10 subjects. Daily for 60 days, animals in Groups 1 through 3 received oral doses of Bentorb suspended in water at concentrations of 100 mg/ml, 200 mg/ml, and 400 mg/ml, respectively, administered via probe in 5 ml volumes. This regimen resulted in cumulative intakes of 30,000 mg, 60,000 mg, and 120,000 mg per animal. Group 4, serving as the control, received 5 ml of water daily without a sorbent.

Over the two-month experiment, no significant differences were observed between the treated and control groups in survival rates or overall physical condition, further confirming the non-toxic nature of Bentorb when administered chronically under these conditions.

Assessment of the impact of the ferrocyanide-bentonite sorbent bentorb on digestive tract function

A comprehensive investigation into the influence of Bentorb on gastrointestinal function was conducted in piglets aged 40–80 days. The evaluation focused on changes in the physical and chemical characteristics of fecal samples collected at the start of the study and again over the final 20 days. These samples were subjected to sensory analysis, with emphasis on consistency, odor, color, and any visible impurities.

The results demonstrated that both control and test groups exhibited normal defecation behavior, with no signs of discomfort or abnormal posture. The stool samples were well-formed, displayed a cement-gray hue consistent with the sorbent's coloration, and emitted a specific but non-offensive smell. No traces of blood, gas pockets, or mucus were found, and parasitological analysis revealed the absence of helminths and protozoan organisms.

Microscopic evaluation of feces revealed minor digestive residues, including fat droplets and isolated starch granules, indicating normal gastrointestinal enzymatic activity. The pH levels ranged from 7.0 to 7.3, maintaining conditions conducive to a balanced intestinal microbiota. Biochemical assays detected bile pigments within the expected physiological range. Additionally, auscultation revealed stable peristaltic activity in the gastrointestinal tracts of treated animals, suggesting unaltered digestive motility.

Overall, long-term dietary administration of Bentorb at 1% did not cause adverse effects on digestive health, confirming its gastrointestinal safety profile.

Evaluation of embryotoxic and teratogenic effects of bentorb sorbent

To explore potential reproductive toxicity, Bentorb was administered to pregnant Wistar rats weighing 200–240 g. Twenty animals were included, split evenly between two experimental stages—implantation on day 5 and organogenesis on day 10 of gestation. Within each stage, five rats received a single intragastric dose of 10,000 mg/kg Bentorb suspended in 2.5% starch gel, while the remaining five served as controls and were given only the vehicle.

Selected rats from each subgroup (two per group) were euthanized on the 20th gestational day to assess fertility markers, including the number of corpora lutea, early and late resorptions, and fetal viability. Macroscopic examination of the fetuses revealed no malformations, skeletal or organ defects, or significant deviations in embryonic or placental measurements. The proportion of male to female offspring did not differ between groups.

The remaining dams were allowed to deliver, and postnatal development was monitored. No toxic influence on gestation or parturition was detected. Delivery occurred normally between days 23 and 24, and average litter size was nearly identical between treated (12.6 ± 0.653) and control (12.4 ± 0.72) groups. All pups were born alive with no external defects.

Subsequent growth assessments included body weight, tail and ear length, and developmental milestones such as ear unfolding, hair emergence, eye opening, and reflex activity. Initial weights were consistent across groups, averaging 30.2 ± 0.51 g in the test group and 29.9 ± 0.62 g in the control group. Sensory and motor development followed identical timelines: ear detachment by days 4–5, full hair growth by day 16, and eye opening between days 15 and 17.

These findings confirm that exposure to the ferrocyanide-containing sorbent during pregnancy does not impair fetal development, neonate health, or postnatal behavior, and there is no evidence of embryotoxic or teratogenic effects based on macroscopic fetal morphology and developmental outcomes.

Analysis of bentorb sorbent effects on animal organs and general health

A separate study was conducted to examine the systemic impact of Bentorb administration in rats. Fifty animals were assigned to five experimental groups based on dose frequency: group 1 received a single administration of 5 ml; group 2 received two doses spaced an hour apart; group 3 was dosed four times; groups 4 and 5 were administered five and seven doses, respectively, at hourly intervals. An additional group of ten rats served as untreated controls.

Throughout the observation period, no visible signs of toxicity or illness were detected in any group. The rats remained in good health, displaying a clean coat, healthy mucosa, stable appetite, normal activity, and unaltered respiratory function. Regular body weight monitoring showed upward trends across all groups, including the controls, with no statistically significant changes from baseline (Table 6), suggesting that Bentorb did not adversely affect general metabolic or physiological parameters, even at high or repeated doses.

Table 6. Body weight and hematological parameters of rats once treated with Bentorb sorbent (M = m; n = 60)

The duration of the study (days)	Group	Body weight (g)	Leukocytes (thousand/ μ l)	Lymphocytes (thousand/ μ l)	Erythrocytes (million/ μ l)	Platelets (thousand/ μ l)
Before the administration of the drug	1	236.7 $\pm$ 2.0	19.0 $\pm$ 4.1	9.5 $\pm$ 1.9	8.6 $\pm$ 1.4	475 $\pm$ 39
	2	233.3 $\pm$ 16.7	22.6 $\pm$ 2.1	14.0 $\pm$ 1.7	8.6 $\pm$ 1.0	460 $\pm$ 44
	3	233.3 $\pm$ 19.7	20.5 $\pm$ 3.2	12.3 $\pm$ 2.2	7.5 $\pm$ 0.9	393 $\pm$ 60
	4	243 $\pm$ 22.5	19.7 $\pm$ 3.3	11.7 $\pm$ 2.1	7.3 $\pm$ 0.2	338 $\pm$ 13
	5	211.7 $\pm$ 8.2	23.8 $\pm$ 3.5	14.3 $\pm$ 2.0	7.4 $\pm$ 0.4	387 $\pm$ 55
	6	265.0 $\pm$ 40.2	19.6 $\pm$ 3.3	11.1 $\pm$ 3.8	6.6 $\pm$ 0.4	405 $\pm$ 13
1	1	235 $\pm$ 3.5	23.8 $\pm$ 1.4	15.4 $\pm$ 1.8	6.8 $\pm$ 1.2	415 $\pm$ 76
	2	243.3 $\pm$ 24.8	15.8 $\pm$ 0.*	10.5 $\pm$ 1.0	7.2 $\pm$ 0.2	466 $\pm$ 39
	3	233.3 $\pm$ 8.9	16.7 $\pm$ 0.9	10.5 $\pm$ 1.5	6.2 $\pm$ 0.3	323 $\pm$ 20
	4	248.3 $\pm$ 25.6	20.5 $\pm$ 2.1	13.1 $\pm$ 1.5	6.6 $\pm$ 1.1	274 $\pm$ 86
	5	201.7 $\pm$ 8.9	18.6 $\pm$ 1.8	8.8 $\pm$ 1.3	7.3 $\pm$ 0.3	423 $\pm$ 43
	6	256.7 $\pm$ 36.8	15.0 $\pm$ 2.3	9.9 $\pm$ 2.2	7.6 $\pm$ 0.6	333 $\pm$ 45
7	1	230.0 $\pm$ 1.0	27.1 $\pm$ 3.3	16.8 $\pm$ 1.3	7.9 $\pm$ 0.7	463 $\pm$ 45
	2	246.7 $\pm$ 30.9	23.1 $\pm$ 4.7	12.6 $\pm$ 2.7	7.0 $\pm$ 0.5	427 $\pm$ 91
	3	230.0 $\pm$ 3.5	24.6 $\pm$ 2.6	13.3 $\pm$ 4.5	6.4 $\pm$ 0.7	333 $\pm$ 57
	4	251.7 $\pm$ 26.5	26.5 $\pm$ 6.9	16.2 $\pm$ 4.5	7.60.3	32466
	5	206.78.2	20.02.0	13.3 $\pm$ 2.7	7.4 $\pm$ 0.5	349 $\pm$ 30
	6	265.0 $\pm$ 43.4	17.0 $\pm$ 1.8	10.1 $\pm$ 1.5	7.0 $\pm$ 0.5	360 $\pm$ 19
14	1	241.7 $\pm$ 2.0	22.5 $\pm$ 3.8	13.9 $\pm$ 1.6	7.4 $\pm$ 0.4	440 $\pm$ 49
	2	250.0 $\pm$ 28.9	19.6 $\pm$ 3.2	11.6 $\pm$ 1.9	6.6 $\pm$ 0.4	441 $\pm$ 37
	3	240.0 $\pm$ 6.1	24.1 $\pm$ 4.6	12.4 $\pm$ 3.1	6.9 $\pm$ 0.5	343 $\pm$ 27
	4	258.3 $\pm$ 31.7	24.1 $\pm$ 4.9	14.3 $\pm$ 2.8	8.0 $\pm$ 0.6	242 $\pm$ 26
	5	215.0 $\pm$ 9.4	18.9 $\pm$ 2.6	11.6 $\pm$ 2.3	7.1 $\pm$ 0.8	380 $\pm$ 7

6	273.3 ± 47.5	20.6 ± 1.0	14.8 ± 1.4	7.6 ± 0.4	357 ± 71
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No discernible trends were noted in the variation of erythrocyte and platelet counts between the experimental and control animals. Although a mild increase in leukocyte levels was observed between the first and seventh days, fluctuations in blood cell parameters were not statistically significant. Based on the data in the referenced table, administration of the Bentorb sorbent into the gastrointestinal tract at doses ranging from 2000 to 14000 mg per rat did not produce a marked impact on either overall body mass or hematological indices in peripheral blood, with survival observed across all test subjects. Findings from the evaluation of venous blood cellular profiles in rats—divided into four experimental cohorts of ten animals each and subjected to repeated Bentorb exposure over a 60-day duration—are detailed in [Table 7](#).

Table 7. Hematological parameters of the blood of rats treated with Bentorb for 60 days (M ± m; n = 40)

The duration of the study (days)	Group	Body weight (g)	Leukocytes (thousand/ μ l)	Lymphocytes (thousand/ μ l)	Erythrocytes (million/ μ l)	Platelets (thousand/ μ l)
before administration of the drug	1	261 ± 29	16.4 ± 1.7	11.3 ± 1.6	7.1 ± 0.6	343 ± 64
	2	238 ± 11	14.9 ± 0.9	10.2 ± 0.8	6.8 ± 0.6	255 ± 26
	3	246 ± 8	19.1 ± 2.7	13.4 ± 1.7	7.7 ± 0.3	328 ± 46
	4	238 ± 10	21.6 ± 5.1	12.8 ± 2.8	6.6 ± 0.5	298 ± 43
10	1	265 ± 10	22.0 ± 1.3	15.2 ± 2.0	7.5 ± 0.5	390 ± 51
	2	248 ± 12	18.1 ± 2.3	13.3 ± 2.1	7.4 ± 0.1	380 ± 31
	3	255 ± 6	23.6 ± 4.2	16.0 ± 3.1	6.5 ± 0.3	278 ± 28
	4	265 ± 15	18.9 ± 3.1	13.3 ± 2.9	7.3 ± 0.5	330 ± 57
20	1	255 ± 22	21.4 ± 2.3	13.9 ± 2.1	7.8 ± 0.2	358 ± 41
	2	258 ± 13	13.7 ± 1.7	8.4 ± 0.7	7.1 ± 0.3	350 ± 36
	3	263 ± 9	22.7 ± 6.3	12.4 ± 2.6	7.1 ± 0.5	391 ± 44
	4	269 ± 19	26.3 ± 2.6	18.3 ± 2.3	7.5 ± 0.6	343 ± 22
30	1	261 ± 28	20.1 ± 1.5	12.8 ± 2.4	7.2 ± 0.4	403 ± 29
	2	260 ± 12	17.0 ± 1.1	11.8 ± 1.7	6.9 ± 0.4	360 ± 34
	3	271 ± 8	21.1 ± 1.4	14.0 ± 1.1	7.7 ± 0.4	353 ± 51
	4	261 ± 29	23.0 ± 3.0	13.8 ± 0.83	7.3 ± 0.3	356 ± 31
45	1	253 ± 21	20.6 ± 3.7	14.2 ± 2.9	7.4 ± 0.6	401 ± 22
	2	263 ± 12	13.0 ± 1.0	8.2 ± 0.8	7.8 ± 0.6	391 ± 30
	3	261 ± 5	19.8 ± 2.3	13.9 ± 1.7	8.0 ± 0.8	359 ± 40
	4	248 ± 17	24.9 ± 2.4	18.0 ± 1.5	7.7 ± 0.1	347 ± 66
60	1	249 ± 17	21.6 ± 3.9	14.3 ± 3.9	7.7 ± 0.8	357 ± 35
	2	250 ± 21	14.6 ± 2.0	10.0 ± 1.2	7.5 ± 0.9	297 ± 25

	3	270 ± 7	21.3 ± 5.2	11.0 ± 2.2	7.8 ± 0.7	322 ± 19
	4	245 ± 13	19.4 ± 2.2	13.0 ± 3.2	7.6 ± 0.6	377 ± 25
90	1	250 ± 17	16.6 ± 3.6	11.4 ± 2.8	6.3 ± 0.4	340 ± 48
	2	255 ± 16	16.7 ± 1.5	10.8 ± 0.9	6.3 ± 0.2	357 ± 32
	3	272 ± 7	16.7 ± 4.9	9.8 ± 3.7	7.1 ± 0.4	366 ± 64
	4	250 ± 23	24.5 ± 0.9	17.5 ± 2.5	7.1 ± 0.2	360 ± 68

Analysis of the table reveals that rats in group 1 exhibited a gradual reduction in body mass from day 10 through day 60; however, these changes did not reach statistical significance when compared to baseline measurements. Across all experimental groups, erythrocyte and platelet levels remained within normal ranges, displaying comparable variations with no meaningful deviation from expected physiological norms. By day 10, leukocyte and lymphocyte counts had increased markedly in the treated animals. Despite some fluctuations in venous blood parameters throughout the study, no significant differences were observed compared with the control group. These results support the conclusion that prolonged exposure to Bentorb at cumulative doses of 30,000-120,000 mg per rat does not compromise the rats' physiological condition.

Conclusion

The acute toxicity assessment of the Bentorb sorbent showed no notable alterations in the clinical condition of rats across all study groups, with complete survival. In evaluating chronic toxicity, mortality rates in sorbent-treated mice did not surpass those recorded in the control cohort. Additionally, administering sorbent samples of varying shelf lives at consistent concentrations revealed no differences in survival outcomes, suggesting that extended storage duration does not enhance the sorbent's toxic potential. Over the 60-day observation period in laboratory rats, no substantial differences in survival rates or general health status were observed between the treated and control groups.

Investigations into the sorbent's impact on digestive function confirmed that sustained dietary inclusion of Bentorb at 1% did not impair gastrointestinal activity.

Morphological evaluations of both external and internal fetal structures confirmed the absence of embryotoxic or teratogenic effects resulting from exposure to the ferrocyanide-containing sorbent in pregnant rats.

Furthermore, repeated administration of Bentorb in cumulative doses ranging from 30,000 to 120,000 mg per animal had no discernible impact on the physiological condition of rats, reinforcing the product's safety profile over prolonged use.

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