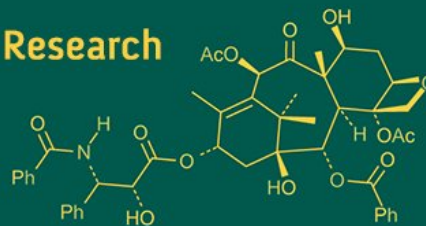


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Efficacy of nutraceutical treatment as an adjunctive therapy in *escherichia coli* associated hemorrhagic Gastroenteritis in Dogs in Patna

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Abstract

Systemic antimicrobial therapy is routinely employed in the management of canine hemorrhagic gastroenteritis, and nutraceuticals such as polyherbal and synbiotics formulations are increasingly used as adjunctive treatments. This study evaluated the effectiveness of these nutraceuticals in improving the clinical course and hemato-biochemical parameters in dogs with *Escherichia coli*-associated hemorrhagic gastroenteritis. Thirty affected dogs were randomly allocated into three groups of ten animals each: Group T1 received standard treatment, Group T2 received a polyherbal formulation alongside standard therapy, and Group T3 received synbiotics in addition to standard therapy for 10 days. Dogs in T1 showed gradual normalization of vital signs and hematological and biochemical variables. Adjunctive polyherbal therapy (T2) accelerated improvement in temperature, heart rate, electrolytes, and blood urea nitrogen, likely due to its anti-inflammatory, antioxidant, and immunomodulatory properties. Synbiotics supplementation (T3) resulted in the most comprehensive recovery, with significant enhancements in erythron indices, lymphocyte counts, serum proteins, glucose, sodium levels, and respiratory rate, reflecting improved gastrointestinal integrity, nutrient absorption, and immune restoration. Although standard therapy alone achieved effective bacterial clearance, metabolic and electrolyte recovery was comparatively slower. Mean recovery times were 5.0, 3.5, and 3.2 days in T1, T2, and T3, respectively. These findings indicate that adjunctive nutraceutical therapies, particularly synbiotics, substantially enhance clinical and biochemical recovery and may be recommended as supportive treatments for rapid restoration of health in dogs with hemorrhagic gastroenteritis.

Keywords: Dog, Hemorrhagic gastroenteritis, polyherbal, synbiotics, Efficacy

Introduction

A life-threatening illness, hemorrhagic gastroenteritis (HGE), is brought on by a number of factors, including bacterial and viral infections, endoparasitic infestations, irritating medications, an improper diet, and the consumption of toxic substances (Enany *et al.*, 2021) [11]. Most often, bacteria or viruses are the infectious agents linked to diarrhea in young dogs (Magne, 2006) [20]. *Salmonella sp.*, *Clostridium difficile*, *Clostridium perfringens*, *Escherichia coli*, *Campylobacter jejuni*, and other possible enteropathogenic bacteria have been linked to bacterial gastroenteritis in dogs (Marks *et al.*, 2011). The excretion of these bacteria occurs in feces, while they are transmitted by direct or indirect contact with feces or to the contaminated food and water, feeding bowls etc. (Turchetto *et al.*, 2015) [30]. *Escherichia coli* are commensal bacterium found in the intestines of many animals and humans. It belongs to the *Enterobacteriaceae* family. Soil and water are common environmental habitats for it. The two types of strains that cause intestinal infections are attaching-and-effacing *E. coli* (AEEC) and enterotoxigenic (ETEC). AEEC are further divided into enteropathogenic (EPEC) and enterohemorrhagic *E. coli* (EHEC). These *E. coli* strains are known to produce shiga toxins (Garcia Navarro, 2014). Human hemolytic-uremic syndrome and hemorrhagic colitis have been linked to multiple strains of Shiga-toxin-producing *E. coli* (STEC) (Mora *et al.*, 2011) [21]. A tentative diagnosis is made mostly on the basis of the patient's history, symptoms, and typical signalment; fecal culture is rarely used. According to Zoran (2008) [40], a definitive diagnosis necessitates fecal culture, PCR

detection of bacterial toxins or DNA, or proof that there is bacterial toxin present in the feces. Dogs with HGE will undergo varying degrees of treatment, dependent on the severity of their clinical symptoms. Dogs with mild to moderate clinical signs may be able to undergo therapy as an outpatient; dogs with severe clinical signs and hypovolemic shock, however, require hospitalization and intensive intravenous fluid treatment. There are now differing views on the use of antibiotics in dogs that have HGE.

Antimicrobial therapy proponents argue that in addition to treating a suspected infectious etiology, antimicrobials should be administered due to the potential for bacterial translocation from the gastrointestinal tract. Evidence from the veterinary literature demonstrates that dogs with suspected hemorrhagic gastroenteritis have high circulating levels of endotoxin in their bloodstream (Wessels *et al.*, 1987) [35]. Although the exact cause of the microbiota alterations remains unknown, it is thought that intestinal dysbiosis contributes to the pathophysiology of both acute and chronic disorders. Therefore, a quick restoration of microbial dysbiosis could be advantageous (Ziese *et al.*, 2018) [39]. Probiotics are live microorganisms that are administered orally and, when given in adequate amounts, have a positive impact on the host's health. Although the exact mechanisms of probiotics are still unclear, a number of studies have suggested that they may improve host health in a variety of ways, including immunomodulation, anti-inflammatory qualities, or competition with potential pathogens for nutrients or adhesion sites (Schmitz and Suchodolski, 2016) [29]. The probiotic strain, mixture, and concentration may have an impact on the results. Prebiotics are nondigestible substrates that selectively promote the host by promoting the growth and/or activity of beneficial gut microbiota specific bacteria, thereby enhancing host health (Gibson *et al.*, 2017) [13]. Synbiotics are formulations combining probiotics and prebiotics that act synergistically to enhance probiotic survival and activity in the gastrointestinal tract, thereby providing greater health benefits than either component alone. The purpose of synbiotics is to overcome some possible difficulties in the survival of probiotics in the gastrointestinal tract (Rioux *et al.*, 2005; Bengmark, 2005) [3, 27].

Conventional management relies on supportive care, fluid therapy, and antimicrobials when indicated, but adjunctive herbal therapies have been explored for their potential antidiarrheal effects. *Punica granatum* (pomegranate) exhibits astringent, antioxidant, antimicrobial, and anti-secretory properties, showing reduced diarrhoea and inhibition of enteric pathogens (Singh *et al.*, 2011). *Tinospora cordifolia* (giloy) demonstrates immunomodulatory and anti-inflammatory activity,

enhancing gut immunity and reducing inflammation (Kumar *et al.*, 2015) [17]. *Cyperus rotundus* (nutgrass) has been shown to reduce intestinal motility and secretion and possesses antidiarrhoeal and anti-giardial effects (Rathi *et al.*, 2012) [24]. *Acacia catechu* provides astringent, antimicrobial, and anti-inflammatory benefits (Singh & Sharma, 2011). *Plantago ovata* (psyllium husk) has demonstrated clinical efficacy in dogs, improving stool consistency in cases of chronic diarrhoea (Vahabzadeh and Schultze, 2010) [32]. Collectively, these findings support the potential of these botanicals as adjunctive interventions in diarrhoeal conditions, though most evidence remains preclinical.

Keeping the above facts in view, the study was designed to know the impact of oral polyherbal and synbiotics as an adjunctive therapy for the treatment of Hemorrhagic Gastroenteritis (HGE) in dogs

Materials and Methods

Ethical approval

The present study was undertaken at Bihar Animal Sciences University, Patna, Bihar, India with approval of Institutional Animal Ethics Committee (IAEC) under project number IAEC/BVC/2024/27 following the ethical guidelines.

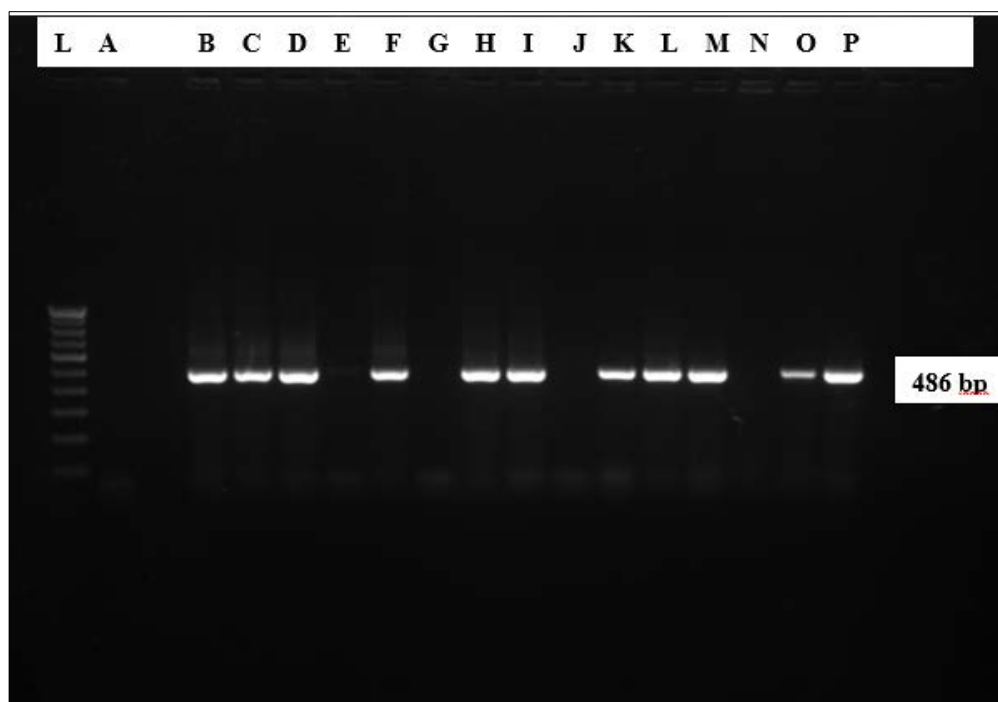
Animals

This present study was conducted in Department of Veterinary Medicine, Bihar Veterinary College, Patna, from June 2024 to May 2025. Dogs presented to the Veterinary Clinical Complex were included. Preliminary diagnosis was based on modified canine HGE activity index as described by Unterer *et al.*, 2011 (Table 1) [31].

Animals that did not meet the study's inclusion criteria such as compliance issue with owners, pretreatment with antibiotics or had concomitant diseases capable of causing hemorrhagic gastrointestinal symptoms were excluded. Exclusion was confirmed through fecal antigen detection (SNAP Canine Parvovirus Antigen Test Kit) and fecal smear examination for parvovirus and parasitological cases respectively. Cases of sudden death were also excluded.

Screening of animals for *e. coli* associated canine hemorrhagic gastroenteritis

Approximately 1–2 g of fresh fecal samples were aseptically collected from dogs suffering from HGE into sterile, disposable sample collection vials, following standard protocols for the isolation and characterization of *E. coli*. Samples were inoculated in pre-sterilized MacConkey broth in ratio 1:10, and incubated for 24 hours at 37°C. Isolation, biochemical characterization and molecular characterization by polymerase chain reaction targeting species specific *uidA* gene as per procedure described by El-Badawy *et al.*, 2017 (Table 2, figure 1) [10].



L: Ladder (100bp)
A: Negative control
B, C, D, F, H, I, K, L, M, O and P: Positive amplification of 486 bp
Fig 1: PCR amplification of species specific *uidA* gene to confirm *E. coli*

Selection of the antimicrobial agent

Amikacin was selected as the antimicrobial agent based on the resistance profile determined using the Kirby–Bauer disk diffusion method, conducted according to standard protocols.

Therapeutic trial

A total of 30 dogs were enrolled in the present study and allocated into three groups: 10 *HGE*-positive dogs in the standard treatment group (T1), 10 in the polyherbal adjunctive therapy group (T2), and 10 in the synbiotics adjunctive therapy group (T3), all receiving standard treatment. Allocation of *HGE*-positive dogs to each group was performed using a randomization method. The details of the animals included in the study are summarized in Table 3.

Dogs selected for the present study were provided with the treatment for a period of 10 days as per table 3. Blood samples were collected on day 0, 5 and 10 post-treatment for therapeutic evaluation.

Clinical signs

Day 0 was defined as the day of clinical presentation and study inclusion. For 10 days, clinical signs were assessed and quantified using the Modified canine HGE activity index (Table 1). The index includes the parameters appetite, vomiting (times/day), stool consistency, stool frequency (times/day), dehydration and level of consciousness. Each parameter was scored from 0 to 3; and the sum of scores yielded a total cumulative score.

Clinical parameters

The dogs were clinically examined for:

I. Temperature- rectal temperature was recorded with the help of a digital thermometer.

II. Respiratory Rate -recorded by auscultation of lung field with the help of a stethoscope for 1 minute.

III. Heart Rate- recorded by auscultation between 4-6th intercostal space at the point of maximum intensity (PMI) with the help of a stethoscope for 15 seconds and multiplying the heart rate by 4.

Hemato-biochemical examination

Hematological and biochemical tests will be performed with the collected samples on day 0, day 5 and day 10 post-treatment to compare the findings with different therapeutic regimens.

Haematological parameters

Approximately 1 ml of whole blood sample was collected from cephalic or saphenous vein of each animal in Ethylene Diamine Tetraacetic Acid (EDTA) vial for haematology. The analytical parameters were recorded from Automated Haematology Analyzer (Nihon Kohden India Private Limited) for Complete blood count as per the manufacturer's instructions. Parameters estimated were Total Leucocyte count ($10^3/\mu\text{l}$), Neutrophils (%), Lymphocytes (%), Monocytes (%), Eosinophils (%), Total Erythrocyte Count ($10^6/\mu\text{l}$), Haemoglobin (g/dl) and Packed cell volume (%).

Biochemical parameters

Approximately 3 ml of blood was collected from cephalic or saphenous vein of each animal in clot activator vials for serum biochemistry measured using a semiautomatic analyser, SDS. The biochemical parameters assessed include: Total Protein (g/dl), Albumin (g/dl), Alanine Transaminase (U/L), Aspartate Transaminase (U/L), Blood Urea Nitrogen (mg/dl) and Creatinine (mg/dl), Serum sodium (mmol/l), potassium (mmol/l), chloride (mmol/l) and Glucose (mg/dl)

Statistical analysis

The collected data was statistically analyzed using SPSS software version 29 with Mean $\pm$ SE values determined by the descriptive statistical method. Double-factor analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were applied to compare means among different groups with their respective base values. Additionally, the Kruskal-Wallis test was performed for the statistical analysis of non-parametric data, following the methodology described by Snedecor and Cochran (1994).

Results

Modified canine hemorrhagic activity index

On day 0, median (SD) modified canine HGE activity index in group T1 was 12.5 (2.32), in group T2 it was 13 (2.58) and group T3 12.5 (2.32), which was non-significantly ($p>0.05$) different between groups ($p>0.05$) (Table 18). Compared to day 0, there was a significantly ($p<0.05$) lower index observed on day 5 and 10 ($p<0.05$) in group T3 with median (SD) of 4.0 (0.48) and 2 (0) as compared to group T2 & T3. Within group comparisons showed a significant ($p<0.05$) decrease in median (SD) over time period (Table 4).

Clinical parameters

At day 0, the Mean $\pm$ SE value of temperature in group T2 (100.08 $\pm$ 0.74) was slightly lower than group T1 (100.92 $\pm$ 0.54) and group T3 (101.37 $\pm$ 0.55), but these differences were statistically non-significant. On day 5 and day 10 group T2 (101.68 $\pm$ 0.23, 102.06 $\pm$ 0.25) increased non-significantly as compared to group T1 (101.57 $\pm$ 0.22, 101.94 $\pm$ 0.28) and group T3 (101.62 $\pm$ 0.28, 101.73 $\pm$ 0.20) respectively, though the intergroup differences remained non-significant. Within-group comparisons across days revealed a significant increase over time in group T2 ($p<0.05$), whereas group T1 and T3 did not show significant ($p>0.05$) changes over time.

The Mean $\pm$ SE heart rate values were elevated in *E. coli*-affected dogs on day 0 across all groups, although differences were statistically non-significant. By day 5 and 10, all groups showed a marked decrease and the intergroup differences remained non-significant ($p>0.05$). Within-group comparisons revealed a significant decline over time in all groups: T1 ($p<0.05$), T2 ($p<0.05$), and T3 ($p<0.05$).

On day 0, the Mean $\pm$ SE values of respiratory rate in group T3 (30.40 $\pm$ 1.46) exhibited significantly higher values compared to T1 (24.90 $\pm$ 1.46; $p<0.05$), while T2 (27.90 $\pm$ 1.26) represented an intermediate response that did not differ significantly ($p>0.05$) from either T1 or T3. By days 5 and 10, the values of Group T2 and T3 converged with T1, resulting in non-significant ($p>0.05$) intergroup differences. Within-group analysis demonstrated a significant decline over time in Group T3 ($p<0.05$), whereas Group T1 and T2 did not display statistically significant time-dependent changes (Table 5).

Hematological parameters

At Day 0, the Mean $\pm$ SE values of hemoglobin were higher in group T3 (11.99 $\pm$ 0.45), followed by group T1 (10.33 $\pm$ 0.70) and group T2 (9.90 $\pm$ 1.06); however, the intergroup difference was not statistically significant ($p>0.05$). On Day 5 and 10, the mean values increased across all groups with non-significant ($p>0.05$) intergroup differences. Within-group analysis over time showed no

significant ($p<0.05$) changes in group T1 or group T2. Although group T3 consistently showed higher values, its increase over time was also statistically non-significant ($p>0.05$).

On day 0, the Mean $\pm$ SE values of total erythrocyte counts (TEC) were lower in group T3 (4.95 $\pm$ 0.39) as compared to group T1 (5.74 $\pm$ 0.20) and T2 (5.72 $\pm$ 0.38), but the difference in the values were statistically non-significant ($p>0.05$). On day 5, T3 (5.35 $\pm$ 0.47) remained numerically lower than T1 (5.99 $\pm$ 0.21) and T2 (5.74 $\pm$ 0.49), with non-significant ($p>0.05$) differences among groups. By day 10, T3 (7.15 $\pm$ 0.26) became slightly higher than T1 (6.38 $\pm$ 0.32) and T2 (6.89 $\pm$ 0.28), though intergroup variation remained non-significant ($p>0.05$). Within-group comparisons across days revealed that Group T3 showed a highly significant increase over time ($p<0.05$), whereas T1 ($p>0.05$) and T2 ($p>0.05$) did not exhibit significant changes over time.

At day 0, the Mean $\pm$ SE values of T1 (31.99 $\pm$ 2.06), T2 (32.70 $\pm$ 2.07), and T3 (32.41 $\pm$ 1.14) were lower, with no significant ($p>0.05$) intergroup differences. By day 5 and 10, group T3 increased relative to group T1 and T2, although intergroup differences were not statistically significant ($p>0.05$). Within-group comparisons revealed a significant increase over time in group T3 ($p<0.05$), whereas group T1 and T2 did not show significant temporal changes.

The Mean $\pm$ SE values of total leucocyte count (TLC) were lower in *E. coli*-affected dogs in all treatment groups on day 0, but the differences in mean values were statistically non-significant ($p>0.05$). On day 5, T2 (13.15 $\pm$ 0.44) and T3 (13.12 $\pm$ 1.05) showed a numerical increase compared with T1 (11.23 $\pm$ 1.01), though the intergroup differences remained non-significant ($p>0.05$). By day 10, T2 (14.09 $\pm$ 0.32) and T3 (15.46 $\pm$ 0.67) were higher than T1 (12.70 $\pm$ 0.75), with a significant difference observed among groups ($p<0.05$), indicating that T3 increased the most over time compared with T1 and T2. Within-group comparisons across days revealed that T3 experienced a significant increase from day 0 to day 10 ($p<0.05$), whereas T1 and T2 did not show significant changes over time period.

The Mean $\pm$ SE values of neutrophils were higher in all treatment groups at day 0. At day 0, Group T1 (78.70 $\pm$ 1.40) and T3 (80.80 $\pm$ 1.08) were significantly higher than T2 (68.80 $\pm$ 4.85, $p<0.05$), indicating that T2 started at a lower baseline compared with the other groups. On day 5, although T1 (72.10 $\pm$ 1.59) and T3 (70.60 $\pm$ 3.60) remained numerically higher than T2 (63.60 $\pm$ 5.06), the intergroup differences were not significant ($p>0.05$). By day 10, all groups declined further, with T1 (62.10 $\pm$ 2.92) and T3 (55.20 $\pm$ 1.92) slightly higher and lower than T2 (57.30 $\pm$ 3.75), respectively, but these differences remained non-significant ($p>0.05$). Within-group comparisons across days revealed a significant decline in T1 ($p<0.05$) and T3 ($p<0.05$) over time, whereas T2 did not show a significant ($p>0.05$) change over time.

At day 0 and day 5, the Mean $\pm$ SE values of lymphocytes in Group T2 was numerically higher than T1 and T3, but the differences were not statistically ($p>0.05$) significant. By day 10, T2 (36.60 $\pm$ 3.60) showed the highest value, followed by T3 (34.90 $\pm$ 4.26) and T1 (25.10 $\pm$ 1.81), with the intergroup difference reaching significance ($p<0.05$). Within-group comparisons across days revealed a significant increase over time in T1 ($p<0.05$) and T3

($p < 0.05$), while T2 showed a non-significant ($p > 0.05$) upward trend.

At day 0, 5 and 10, the Mean $\pm$ SE values of monocytes among different treatment groups were statistically non-significant ($p > 0.05$). Within-group comparisons across days revealed non-significant ($p > 0.05$) changes over time in all treatment groups.

At day 0, 5 and 10, the Mean $\pm$ SE values of eosinophils among different treatment groups were statistically non-significant ($p > 0.05$). Within-group comparisons over time revealed a significant decrease in T2 ($p < 0.05$), as compared to T1 and T3, that did not show significant ($p > 0.05$) changes over time period (Table 6).

Biochemical parameters

At day 0, 5 and 10, the Mean $\pm$ SE values of total protein in all treatment groups were statistically non-significant ($p > 0.05$). Within-group comparisons across days revealed a significant increase over time in T3 ($p = 0.012$), as compared to group T1 and T2, that did not show significant ($p > 0.05$) temporal changes.

At day 0, the Mean $\pm$ SE values of albumin in Group T3 (2.72 ± 0.27) was slightly higher than T1 (2.17 ± 0.05) and T2 (2.33 ± 0.27), but the differences were not statistically significant. On day 5, T3 (2.87 ± 0.15) remained higher than T1 (2.59 ± 0.14) and T2 (2.35 ± 0.10), and the intergroup differences became significant ($p < 0.05$), with T3 showing the largest increase. By day 10, T3 (3.14 ± 0.14) remained the highest among the groups, followed by T2 (2.88 ± 0.15) and T1 (2.57 ± 0.14), and intergroup differences remained significant ($p < 0.05$). Within-group comparisons across days revealed a significant increase over time in T1 ($p < 0.05$), whereas T2 and T3 did not show statistically significant changes across the study period.

No significant differences were recorded in the mean concentration of ALT and AST either between the groups or within groups at different observation periods of study.

At day 0 and day 5, the mean $\pm$ SE values of blood urea nitrogen in group T1, T2 and T3 were similar, with no significant (> 0.05) differences among groups. On day 10, group T1 (28.50 ± 1.65) was higher than group T2 (18.20 ± 1.24) and T3 (8.80 ± 0.29), and the intergroup differences became highly significant (< 0.05). Within-group comparisons across days revealed a significant decline over time in all groups: T1 ($p = 0.005$), T2 ($p < 0.001$), and T3 ($p < 0.001$).

No significant differences were recorded in the mean concentration of creatinine either between the groups or within groups at different observation periods of study.

At day 0, the Mean $\pm$ SE values of sodium in Group T1 (136.40 ± 2.0) was slightly higher than T2 (127.10 ± 2.54) and T3 (133.60 ± 2.99), with the difference reaching significance ($p < 0.05$). On day 5, T2 (140.50 ± 1.73) increased and slightly surpassed T1 (139.80 ± 1.83) and T3 (136.30 ± 2.74), though intergroup differences were not significant ($p > 0.05$). By day 10, T3 (145.30 ± 1.69) became the highest among groups, followed by T1 (140.60 ± 1.73) and T2 (140.20 ± 1.42), with intergroup differences approaching significance ($p = 0.05$). Within-group comparisons across days revealed a significant increase over time in T2 ($p < 0.05$) and T3 ($p < 0.05$), whereas T1 did not show significant changes over time. At day 0, 5 and 10, the Mean $\pm$ SE values of potassium in all treatment groups were statistically non-significant ($p > 0.05$). Within-group comparisons across days revealed a significant increase over

time in T1 ($p < 0.05$), whereas T2 and T3 did not show significant ($p > 0.05$) changes over time.

At day 0, 5 and 10, the Mean $\pm$ SE values of chloride in all treatment groups were statistically non significant ($p > 0.05$). Within-group comparisons across days revealed a significant increase over time in T1 ($p < 0.05$), whereas T2 and T3 did not show significant changes over time.

At day 0, Mean $\pm$ SE values of glucose Group T2 (84.50 ± 4.30) was slightly higher than T1 (82.50 ± 5.10), and T3 (69.80 ± 5.19) was lower than both, though differences among groups were not statistically significant (> 0.05). On day 5, T2 (87.30 ± 2.59) remained higher than T1 (82.90 ± 2.32) and T3 (81.20 ± 4.71), but intergroup differences were still non-significant (> 0.05). By day 10, T3 (108.80 ± 5.59) showed the highest value, followed by T2 (91.60 ± 4.26) and T1 (88.20 ± 3.06), and the intergroup differences were statistically significant ($p < 0.05$). Within-group comparisons across days revealed a significant increase over time in T3 ($p < 0.05$), whereas T1 and T2 did not show significant ($p > 0.05$) changes over time (Table 7)

Recovery period

The Mean $\pm$ SE number of days required for recovery was highest in group T1 (5.0 ± 0.36), followed by group T2 (3.5 ± 0.22) and group T3 (3.2 ± 0.13). Statistical analysis indicated a significant difference ($p < 0.05$) of group T2 and T3 as compared to T1, with group T1 requiring significantly more time to recover compared to groups T2 and T3. However, no significant ($p > 0.05$) difference was observed between groups T2 and T3 (Table 8).

Discussion

A significant reduction in the modified canine HGE activity index was observed over time in all groups, with the most pronounced improvement in group T3. This indicates that the treatment regimen in group T3 was more effective in accelerating clinical recovery compared to groups T1 and T2. These findings are consistent with those of Unterer *et al.* (2011) [31] and Mortier *et al.* (2015) [22], who also reported a rapid decline in disease severity and earlier clinical recovery. They observed that a significant recovery in PRO was already seen on day 3, while in PLAC it was seen on day 4 compared to baseline. No further differences in severity or duration of clinical signs between PRO and PLAC were seen. The present study thus supports the potential efficacy of the treatment protocol used in group T3 in achieving faster clinical improvement and a more favorable outcome in dogs affected by HGE.

The Mean $\pm$ SE values of temperature were lower in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs on day 0. This lower rectal temperature could be due to severe fluid and electrolyte losses causing hypovolemia, reduced tissue perfusion and metabolic activities. These findings were similar to the findings of Banja *et al.* (2002) [2], Kumar and Kumar, (2017) [16], but their findings were statistically significant. Although intergroup differences at each time point were not statistically significant. Within-group comparisons across days revealed a significant increase over time in group T2, whereas group T1 and T3 did not show significant changes over time. The antioxidant and anti-inflammatory effects of herbs have been shown to modulate cytokine responses, enhance immune function, and improve metabolic regulation (Singh *et al.*, 2011; Kumar *et al.*, 2015) [17]. These properties can help counteract oxidative stress and systemic inflammation commonly associated with *E. coli* infection, thereby contributing to the stabilization of body temperature. The

Mean $\pm$ SE values of heart rate were higher in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs on day 0 and the values differ non significantly. By day 5 and 10, all groups showed a marked decrease and the intergroup differences remained non-significant. Within-group comparisons revealed a significant decline over time in all group. The Mean $\pm$ SE values of respiration rate were higher in *E. coli* associated hemorrhagic gastroenteritis in dogs on day 0 and the values differ significantly. There are non-significant intergroup differences in group T1 & T2 as compared to T3, there was significant decline in group T3 over time. The mean values of heart rate and respiratory rate in the present study were similar to those obtained by Alves *et al.* (2020) but the values were statistically significant. This could be due to dehydration secondary to gastrointestinal loss of fluid and proteins which causes a reduction in the tissue perfusion leading to tachycardia (Prittie, 2004; Schoeman *et al.*, 2013; Rolim *et al.*, 2014) [23, 28].

The observed decrease in hemoglobin (Hb), packed cell volume (PCV), and total erythrocyte count (TEC) in dogs affected with *Escherichia coli*-associated hemorrhagic gastroenteritis may be attributed to hemorrhage and blood loss through feces (Wael, 2011; Bhat *et al.*, 2013) [5, 34]. Additionally, haemodilution resulting from fluid absorption from the intestinal tract and compensatory renal water reabsorption could further contribute to the reduction in these parameters (Collier, 2025) [8].

Over the course of the study, mean TEC and PCV values in group T3 showed a statistically significant increase, indicating progressive recovery of the erythron. This improvement likely reflects stabilization of circulatory volume, resolution of intestinal fluid loss, and restoration of erythropoietic activity. The significant increase in T3 may also be influenced by synbiotic therapy, which improves gut health, reduces ongoing intestinal blood and fluid loss, and supports nutrient absorption necessary for erythropoiesis (Montserrat-Malagariga *et al.*, 2024; Whittemore *et al.*, 2021) [36]. These findings highlight the interplay between fluid-electrolyte balance, gastrointestinal integrity, and haematological recovery during the resolution of hemorrhagic gastroenteritis.

In the present study, Mean $\pm$ SE total leukocyte count (TLC) and lymphocyte values were lower in dogs with *E. coli* associated hemorrhagic gastroenteritis on day 0, although intergroup differences were not statistically significant. By day 10, TLC increased significantly across groups, with group T3 showing a significant within-group increase over time. This rise in leukocyte count may reflect recovery from acute infection and restoration of bone marrow activity. Lymphocyte counts on day 10 differed significantly among groups, while within-group increases over time were observed in T1 and T3, suggesting a gradual reconstitution of adaptive immune cells as the disease resolved (Smith, 2019; Montserrat-Malagariga *et al.*, 2024). The enhanced lymphocyte recovery in T3 may also be linked to synbiotic therapy, which supports gut-associated lymphoid tissue function and systemic immunity (Whittemore *et al.*, 2021) [36].

Neutrophil counts were significantly elevated on day 0 in HGE-positive dogs, likely reflecting acute bacterial infection and inflammatory response. The significant increase is consistent with bacterial involvement, as reported in similar studies by Sharma *et al.* (2003) and Bhat *et al.* (2015) [4], although Dolan and Elias Santo-Domingo (2025) [9] observed neutropenia in contrast. Within-group comparisons revealed a significant decline in neutrophil

counts over time in groups T1 and T2, indicating resolution of acute inflammation and effective host defense mechanisms during recovery. Monocyte counts remained relatively stable throughout the study, with minimal intergroup and intragroup differences. This stability suggests that monocytes were less affected by acute HGE in dogs or that their mobilization remained within a normal physiological range during infection and recovery.

Eosinophil counts showed minimal intergroup differences; however, group T2 exhibited a modest but statistically significant decline over time, whereas T1 and T3 remained relatively stable. The reduction in eosinophils in T2 may be attributed to the anti-inflammatory and immunomodulatory effects of the polyherbal formulation, which can modulate leukocyte activity and dampen mild inflammatory responses (Gupta *et al.*, 2024; Li *et al.*, 2022) [19].

Overall, the leukocyte profile indicates an acute inflammatory response at disease onset, characterized by neutrophilia and reduced lymphocyte counts, followed by gradual normalization as treatment and supportive interventions, including polyherbal and synbiotic therapies, facilitated systemic recovery.

In the present study, Mean $\pm$ SE values of total protein (TP) were decreased, though non-significantly, across all groups in dogs affected with *Escherichia coli*-associated hemorrhagic gastroenteritis. Hypoproteinemia may result from anorexia, malabsorption, and ongoing protein loss through damaged capillaries of the intestinal villi (Biswas *et al.*, 2005) [6]. Similarly, decreased TP observed in parvovirus-positive dogs has been attributed to protein-losing enteropathy, intestinal hemorrhage, systemic inflammatory response syndrome (SIRS)-mediated vascular permeability, and effects of rehydration therapy (Van den Broek, 1990) [33]. Impaired intestinal absorption may further reduce uptake of proteins and amino acids, compounding the decline in circulating protein levels (Reeds *et al.*, 2000) [25]. Although intergroup differences remained minimal throughout the study, group T3 exhibited a significant upward trend over time, whereas T1 and T2 remained relatively stable. This improvement in T3 may reflect enhanced gut integrity, nutrient absorption, and modulation of intestinal inflammation through synbiotic therapy (Montserrat-Malagariga *et al.*, 2024; Whittemore *et al.*, 2021) [36].

Mean albumin concentrations on day 0 were also lower in HGE-positive dogs, although differences among groups were not statistically significant. These findings are consistent with previous reports by Bhat *et al.* (2015) [4]; Schoeman *et al.* (2013); Li and Humm (2015) [18]. Group T3 consistently had the highest albumin values and exhibited significant differences relative to the other groups. Within-group analysis revealed a significant increase over time in T1, while T2 and T3 remained relatively stable, suggesting partial restoration of hepatic synthetic function and improved protein nutrition over the course of the study.

Serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) values showed no significant differences either between or within groups at different observation periods. Both intergroup and intragroup differences were minimal, and the parameters remained relatively stable throughout the study period. These results indicate that neither polyherbal (T2) nor synbiotic (T3) supplementation significantly influenced hepatocellular enzyme activity, suggesting the absence of hepatotoxic effects under the study conditions. In the present study, Mean $\pm$ SE values of blood urea nitrogen (BUN) were increased, though non-significantly, in all groups on day 0

in dogs affected with *Escherichia coli*-associated hemorrhagic gastroenteritis. By day 10, BUN values differed significantly among groups, with groups T2 and T3 showing a more pronounced temporal decrease compared with T1. This significant downward trend over the study period suggests that while baseline renal function was similar across groups, polyherbal (T2) and synbiotic (T3) therapies may have contributed to improved nitrogen metabolism and recovery from gastrointestinal-associated azotemia. Elevated BUN in the acute phase may be attributed to dehydration, hypovolemia, and increased protein catabolism resulting from systemic inflammatory stress (Smith, 2019; StatPearls, 2025). The more marked reduction in BUN in T2 and T3 likely reflects improved hydration, restoration of gastrointestinal absorption, and reduced protein catabolism mediated by anti-inflammatory and gut-modulatory effects of the interventions (Gupta *et al.*, 2024; Montserrat-Malagarriaga *et al.*, 2024) [14]. Serum creatinine concentrations, however, did not show significant differences either between groups or within groups over time. The stability of creatinine levels indicates that glomerular filtration and overall renal function were largely preserved throughout the course of hemorrhagic gastroenteritis, and that neither polyherbal nor synbiotic supplementation adversely affected renal parameters. These findings suggest that the renal involvement in this model was mild and primarily functional, related to pre-renal azotemia rather than intrinsic renal injury (Whittemore *et al.*, 2021) [36]. In the present study, Mean $\pm$ SE values of sodium were significantly decreased in all groups on day 0 in dogs affected with *Escherichia coli*-associated hemorrhagic gastroenteritis, reflecting acute sodium depletion due to vomiting, diarrhea, and dehydration (Rewerts & Cohn, 2000; Hoskins, 1998) [15, 26]. Although group T2 started with slightly lower baseline values, it exhibited a significant increase over time, while T3 demonstrated a prominent upward trend by day 10. In contrast, T1 remained relatively stable, suggesting that polyherbal (T2) and synbiotic (T3) interventions may have contributed to improved sodium homeostasis through enhanced fluid absorption, reduced gastrointestinal losses, and modulation of intestinal integrity (Gupta *et al.*, 2024; Montserrat-Malagarriaga *et al.*, 2024) [14]. Mean $\pm$ SE values of potassium were decreased, though non-significantly, in all groups on day 0. While intergroup differences were minimal at each time point, T1 exhibited a pronounced upward trend over the study period, whereas T2 and T3 remained relatively stable. Hypokalemia in HGE- positive

dogs is likely due to excessive loss of potassium in diarrheic fluid, which is not efficiently conserved by the colon, unlike sodium and bicarbonate (Yoxall and Hird, 1980) [37]. Polyherbal and synbiotic interventions may have moderated potassium fluctuations by supporting intestinal absorption and maintaining fluid-electrolyte balance. Chloride levels were also decreased non-significantly at baseline, reflecting losses from vomiting and diarrheal fluid. T1 exhibited a gradual upward trend over time, while T2 and T3 remained relatively stable. The observed changes in chloride concentration parallel those of sodium, highlighting the close relationship between these electrolytes in extracellular fluid balance and acid-base homeostasis (Rewerts & Cohn, 2000; Hoskins, 1998) [15, 26]. Overall, the electrolyte disturbances observed in the acute phase of *E. coli* associated hemorrhagic gastroenteritis reflect gastrointestinal fluid losses, dehydration, and impaired absorption. The recovery trends in T2 and T3 suggest that polyherbal and synbiotics supplementation may aid in maintaining electrolyte homeostasis and mitigating the severity of hyponatremia and hypochloremia during disease progression. In the present study, Mean $\pm$ SE values of glucose were decreased, though non-significantly, in all groups on day 0 in dogs affected with *E. coli* associated hemorrhagic gastroenteritis. This hypoglycemia is consistent with previous observations (Coles, 1986) [7] and may result from anorexia or inappetence, compounded by malabsorption due to intestinal mucosal damage (Shinde *et al.*, 2000). Impaired nutrient absorption and ongoing gastrointestinal losses contribute to reduced circulating glucose levels during the acute phase of the disease. By day 10, glucose values differed significantly among the groups. Group T3 exhibited a significant within-group increase over time, suggesting a more effective restoration of energy metabolism. This improvement may be attributed to synbiotics therapy, which supports gastrointestinal integrity, enhances nutrient absorption, and reduces systemic inflammatory stress, thereby facilitating normalization of blood glucose (Montserrat-Malagarriaga *et al.*, 2024; Whittemore *et al.*, 2021) [36]. Groups T1 and T2 showed comparatively smaller increases, reflecting partial recovery of glucose homeostasis through supportive therapy and polyherbal intervention, respectively. These findings indicate that synbiotics supplementation may play a beneficial role in restoring energy balance and mitigating hypoglycemia during the recovery phase of hemorrhagic gastroenteritis in dogs.

Table 1: Modified canine HGE activity index

Clinical signs	Grade 0	Grade I	Grade II	Grade III
Appetite	Normal	Mild	Moderate	Severely decreased
Vomiting frequency	No	1 X/day	2-3 X/day	>3 X/day
Stool consistency	Normal	Slightly soft	Very soft	Watery diarrhea
Stool frequency	Normal	2-3 X/day	4-5 X/day	>5 X/day
Dehydration	No	<5%	5-10%	>10%
Level of consciousness	Normal	Mild depression	Moderate depression	Severe depression/recumbency

Total score: 0 $\pm$ 3: clinically insignificant; 4 $\pm$ 5: mild; 6 $\pm$ 8: moderate; >9: severe AHDS

Table 2: Primer used in the study

Primer sequence	Target gene	Product size (BP)	Reference
F:ATCACCGTGGTGACGCATGTCGC	<i>uidA</i> <i>E. coli</i>	486	El-Badawy <i>et al.</i> , 2017 [10]
R:CACCACGATGCCATGTTCATCTGC			

Table 3: Grouping of animals for therapeutic trial

Group T1 (N = 10)	Group T2 (N = 10)	Group T3 (N = 10)
Therapeutic protocol	Therapeutic protocol	Therapeutic protocol
Standard treatment• Inf. Fluid therapy (as per dehydration status)• Inf. Metronidazole @ 15 mg/kg, intravenous, q24hr• Inj. Amikacin @ 20 mg/kg, intravenous, q24hr• Inj. Pantoprazole @ 1 mg/kg, intravenous, q24hr• Inj. Ondansetron @ 0.2–0.5 mg/kg, intramuscular or intravenous, q12hr• Inj. Haemocoagulase @ 0.5–1 ml, intramuscular	Standard treatment plus polyherbal preparation fortified with B vitamins and electrolytes.Each 10 ml contains:Vitamin B1..... 2 mgVitamin B2..... 22 mgVitamin B6..... 1 mgPunica granatum..... 8.33 mgTinospora cordifolia..... 12.5 mgCyperus rotundus..... 8.33 mgAcacia catechu..... 4.16 mgPsyllium husk extract..... 2 mgDextrose..... 100 mgSodium bicarbonate..... 150 mgPotassium chloride..... 50 mgMagnesium sulphate..... 50 mgDosage:Puppies: 2.5 ml twice dailyMedium breeds: 5 ml twice dailyLarge breeds: 10 ml twice daily	Standard treatment plus symbiotic preparation fortified with immunity boosters.Each 10 gm contains:Lactobacillus sporogenes..... 10 × 10 ⁷ CFUBifidobacterium longum..... 10 × 10 ⁷ CFUSaccharomyces boulardii..... 10 × 10 ⁷ CFUSaccharomyces cerevisiae..... 10 × 10 ⁷ CFUAspergillus oryzae..... 10 × 10 ⁷ CFUFructo oligosaccharide (FOS)..... 1 gMannan oligosaccharide (MOS)..... 30 mgSilymarin..... 5 mgBiotin..... 20 mgDL-Methionine..... 20 mgZinc sulphate..... 8 mgCobalt sulphate..... 400 mgCopper sulphate..... 80 mgCichorium intybus..... 10 mgDosage:0–5 kg Body Weight: 2.5 gm twice daily6–15 kg Body Weight: 5 gm twice daily15 kg & above Body Weight: 10 gm twice daily

Table 4: Effect of polyherbal and synbiotic therapy on modified canine HGE activity index in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs

Parameter	Day/ Group	Group T ₁	Group T ₂	Group T ₃
HGE index	Day 0	12.5±2.32 ^A	13±2.58 ^A	12.5±2.32 ^A
	Day 5	6±1.42 ^{BX}	5±1.35 ^{BX}	4±0.48 ^{BY}
	Day 10	3±1.19 ^{CX}	2.5±1.10 ^{CX}	2±0 ^{CY}

Median ± SD within rows represented by X, Y, Z and column represented by A, B, C

Table 5: Effect of polyherbal and synbiotics therapy on clinical parameters in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs

Parameter	Day/ Group	Group T ₁	Group T ₂	Group T ₃
Temperature (°F)	Day 0	100.92±0.54	100.08±0.74 ^y	101.37±0.55
	Day 5	101.57±0.22	101.68±0.23 ^x	101.62±0.28
	Day 10	101.94±0.28	102.06±0.25 ^x	101.73±0.20
Heart rate (bpm)	Day 0	131.30±4.21 ^x	131.50±4.40 ^x	138.20±4.24 ^x
	Day 5	114.40±4.51 ^y	121.50±1.57 ^y	121.20±1.55 ^y
	Day 10	108.40±4.47 ^y	113.50±0.96 ^y	113±2.60 ^y
Respiratory rate (breaths /min)	Day 0	24.90±1.46 ^b	27.90±1.26 ^{ab}	30.40±1.46 ^{ax}
	Day 5	23.80±1.47	24.70±1.71	23.40±0.66 ^y
	Day 10	23±1.36	23.70±1.36	22.40±0.80 ^y

Values (Mean ± SE) within same row represented by a, b, c and within same column represented by x, y, z for a particular parameter differs significantly ($p < 0.05$)

Table 6: Effect of polyherbal and synbiotics therapy on hematological parameters in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs

Parameter	Day/ Group	Group T ₁	Group T ₂	Group T ₃
Hb(g/dl)	Day 0	10.32±0.69	9.90±1.06	11.99±0.44
	Day 5	10.44±0.67	11.880±1.15	12.78±1.15
	Day 10	11.61±0.83	12.23±1.17	13.17±1.13
TEC (x10 ⁶ /mm ³)	Day 0	5.74±0.20	5.72±0.38	4.95±0.39 ^y
	Day 5	5.99±0.21	5.74±0.49	5.351±0.47 ^y
	Day 10	6.38±0.32	6.89±0.28	7.15±0.26 ^x
PCV (%)	Day 0	31.99±2.06	32.70±2.07	32.405±1.14 ^y
	Day 5	31.35±2.03	35.68±3.48	38.423±3.45 ^{xy}
	Day 10	35.70±2.61	36.64±3.46	41.86±2.45 ^x
TLC (x10 ³ /mm ³)	Day 0	11.47±1.49	12.13±2.02	11.62±0.90 ^y
	Day 5	11.23±1.01	13.15±0.44	13.12±1.05 ^{xy}
	Day 10	12.70±0.75 ^b	14.09±0.32 ^{ab}	15.46±0.67 ^{ax}
Neutrophils (%)	Day 0	78.70±1.40 ^{ax}	68.800±4.85 ^b	80.80±1.08 ^{ax}
	Day 5	72.10±1.59 ^y	63.60±5.06	70.60±3.60 ^{xy}
	Day 10	62.10±2.92 ^z	57.30±3.75	55.20±1.92 ^z
Lymphocytes (%)	Day 0	16.80±2.90 ^y	24.60±4.66	20.53±2.44 ^y
	Day 5	23.30±1.69 ^y	30.10±4.42	23.50±3.31 ^y
	Day 10	25.10±1.81 ^{xb}	36.60±3.60 ^a	34.90±4.26 ^{ab}
Monocytes (%)	Day 0	5.10±0.88	5.10±0.80	4.2±0.75
	Day 5	3.60±0.56	5±0.74	3.60±0.52
	Day 10	3.30±0.55	3.80±0.59	3.40±0.60
Eosinophils (%)	Day 0	1.40±0.26	1.50±0.22 ^x	1±00
	Day 5	1±0.21	1±00 ^y	1.50±0.30
	Day 10	1.20±0.20	1±0.14 ^y	1.30±0.30

Values (Mean ± SE) within same row represented by a, b, c and within same column represented by x, y, z for a particular parameter differs significantly ($p < 0.05$)

Table 7: Effect of polyherbal and synbiotic therapy on biochemical parameters in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs

Parameter	Day/ Group	Group T ₁	Group T ₂	Group T ₃
Total Protein (g/dl)	Day 0	5.69±0.36	5.08±0.58	4.07±0.64 ^y
	Day 5	6.05±0.37	5.83±0.49	5.57±0.52 ^{xy}
	Day 10	6.67±0.24	6.17±0.42	6.46±0.37 ^x
Albumin(g/dl)	Day 0	2.17±0.05 ^y	2.33±0.27	2.72±0.27
	Day 5	2.59±0.14 ^{abx}	2.35±0.10 ^b	2.87±0.15 ^a
	Day 10	2.57±0.14 ^{bx}	2.88±0.15 ^{ab}	3.14±0.14 ^a
ALT(U/L)	Day 0	60.27±3.73	50.28±5.22	67.42±14.41
	Day 5	56.90±6.19	47.70±5.02	59.90±8.649
	Day 10	57.60±5.54	45.70±2.37	53.40±7.72
AST(U/L)	Day 0	45.48±3.07	54.55±8.06	52±11.83
	Day 5	42.20±1.95	46.35±8.76	50.73±10.88
	Day 10	47.20±2.73	45.15±7.88	55.70±8.98
BUN (mg/dl)	Day 0	37.70±2.40 ^x	37.10±2.35 ^x	38.20±2.08 ^x
	Day 5	29.40±1.82 ^y	28±1.59 ^y	27.20±1.46 ^y
	Day 10	28.50±1.65 ^{ay}	18.20±1.24 ^{bz}	8.80±0.29 ^{cz}
Creatinine (mg/dl)	Day 0	1.08±0.06	1.19±0.07	0.94±0.09
	Day 5	0.90±0.10	0.99±0.10	0.87±0.08
	Day 10	0.83±0.71	0.99±0.11	0.79±0.62
Sodium (mmol/l)	Day 0	136.40±2.0 ^a	127.10±2.54 ^{by}	133.60±2.99 ^{aby}
	Day 5	139.80±1.83	140.50±1.73 ^x	136.30±2.74 ^y
	Day 10	140.60±1.73 ^b	140.20±1.42 ^{abx}	145.30±1.69 ^{ax}
Potassium (mmol/l)	Day 0	3.79±0.12 ^y	3.95±0.12	3.91±0.30
	Day 5	4.11±0.11 ^{xy}	3.99±0.15	4.09±0.16
	Day 10	4.24±0.10 ^x	4.19±0.11	4.15±0.17
Chloride (mmol/l)	Day 0	106.50±1.34 ^z	109.80±2.38	103.90±6.98
	Day 5	111±1.56 ^y	113.80±2.75	112.40±1.72
	Day 10	119.20±1.41 ^x	114.80±2.62	116±1.12
Glucose (mg/dl)	Day 0	82.50±5.10	84.50±4.30	69.80±5.19 ^y
	Day 5	82.90±2.32	87.30±2.59	81.20±4.71 ^y
	Day 10	88.20±3.06 ^b	91.60±4.26 ^b	108.80±5.59 ^{ax}

Values (Mean ± SE) within same row represented by a, b, c and within same column represented by x, y, z for a particular parameter differs significantly ($p < 0.05$)

Table 8: Effect of polyherbal and synbiotic therapy on recovery period (in days) in *Escherichia coli* associated hemorrhagic gastroenteritis in dogs

Group	Mean (days)	SE	P- value
Group T ₁	5	0.36	<0.05
Group T ₂	3.5	0.22	
Group T ₃	3.2	0.13	

Conclusion

Our study demonstrated that adjunctive therapies, particularly synbiotics, significantly enhanced both the rate and extent of clinical, haematological, and biochemical recovery, underscoring their value as effective supportive treatments when used alongside conventional antibiotic therapy.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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