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A comparative study of the therapeutic effect of zinc oxide nanoparticle and aloe vera extract on an induced ulcerative colitis in rats

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Abstract
This study aims to detect the therapeutic effect of zinc oxide nanoparticles, and to compare it with the therapeutic effect of aloe vera extract alone, in a laboratory rat model of ulcerative colitis induced using acetic acid. The rats were divided into five groups: a negative control group, a positive control group (untreated), a zinc oxide nanoparticle-treated group, and a group treated with aloe vera extract**.**Therapeutic efficacy was evaluated by measuring a set of immunological and physiological parameters, including levels of interleukin-10 (IL-10), nitric oxide (NO), and total antioxidant capacity (TAC). The results showed that treatment with zinc oxide nanoparticles led to a significant improvement in the studied values compared to the other groups, with higher levels of interleukin-10 and higher antioxidant capacity, along with a significant decrease in nitric oxide levels, indicating a high efficacy in reducing inflammation and oxidative stress. The aloe vera extract group also showed significant improvement compared to the positive control group, but it was less effective than the zinc oxide nanoparticles group**.** These results suggest that zinc oxide nanoparticles may be a promising and effective option for alleviating the severity of ulcerative colitis, more effective than treatment with aloe vera extract alone.

Keywords: Psychiatric disorders, suicide, suicide attempt; first admission; recurrent admission; schizophrenia; bipolar disorder; depression; substance abuse disorder

Introduction
Ulcerative colitis UC an inflammatory bowel disease IBD of the large intestine, impacts millions worldwide. Although the pathogenesis of UC is vague, genetic, environmental, autoimmune, and immune-mediated components have been implicated as contributing factors (Porter *et al.*, 2020) [15]. The main symptoms include weight loss, blood in stools, abdominal pain, diarrhoea, increased defecation and colonic bleeding in recent years, the prevalence and incidence of UC have increased worldwide (Ananthakrishnan, 2015) [3]. Evidence suggests that disrupted interactions between the host immune system and gut microbiome contribute to UC pathogenesis (Popov *et al.*, 2021) [14]. Nanotechnology refers to the manipulation of matter at the nano scale, typically between 1 and 100 nanometers, where materials exhibit unique physical, chemical, and biological properties, This technology has significant implications across various fields, including medicine, electronics, and materials science. The development of nano material's enhances the performance of products, leading to innovations in drug delivery systems, cosmetics, and electronics (Malik *et al.*, 2023) [9]. Zinc oxide (ZnO) has emerged as a promising therapeutic agent in the management of ulcerative colitis due to its anti-inflammatory and antioxidant properties. ZnO has been shown to down regulate the expression of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, which are known to play critical roles in the pathogenesis of colitis (Abou Zaid *et al.*, 2023) [1]. Additionally, zinc contributes to the maintenance of intestinal epithelial integrity by promoting cell proliferation and enhancing tight junction proteins, thereby reducing intestinal permeability and preventing further mucosal damage. Its antioxidant capacity also allows it to neutralize reactive oxygen species (ROS), which are key mediators of oxidative stress and tissue injury in inflamed colonic tissue. In animal models of chemically induced colitis, particularly those using ZnO nanoparticles, significant improvements have been observed in clinical symptoms, histopathological scores, and levels of inflammatory markers (Alkushi *et al.*, 2022) [2]. Aloe vera gel is one of the most widely

used plant extracts in both traditional and modern medicine. It is derived from the inner part of the aloe vera leaf and is rich in biologically active compounds, including polysaccharides, phenolics, anthraquinones, Ulcerative colitis UC an inflammatory bowel disease IBD of the large intestine, impacts millions worldwide. Although the pathogenesis of UC is vague, genetic, environmental, autoimmune, and immune-mediated components have been implicated as contributing factors (Porter *et al.*, 2020) [15]. The main symptoms include weight loss, blood in stools, abdominal pain, diarrhoea, increased defecation and colonic bleeding in recent years, the prevalence and incidence of UC have increased worldwide (Ananthakrishnan, 2015) [3]. Evidence suggests that disrupted interactions between the host immune system and gut microbiome contribute to UC pathogenesis (Popov *et al.*, 2021) [14]. Nanotechnology refers to the manipulation of matter at the nano scale, typically between 1 and 100 nanometers, where materials exhibit unique physical, chemical, and biological properties, This technology has significant implications across various fields, including medicine, electronics, and materials science. The development of nano material's enhances the performance of products, leading to innovations in drug delivery systems, cosmetics, and electronics (Malik *et al.*, 2023) [9]. Zinc oxide (ZnO) has emerged as a promising therapeutic agent in the management of ulcerative colitis due to its anti-inflammatory and antioxidant properties. ZnO has been shown to down regulate the expression of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, which are known to play critical roles in the pathogenesis of colitis (Abou Zaid *et al.*, 2023) [1]. Additionally, zinc contributes to the maintenance of intestinal epithelial integrity by promoting cell proliferation and enhancing tight junction proteins, thereby reducing intestinal permeability and preventing further mucosal damage. Its antioxidant capacity also allows it to neutralize reactive oxygen species (ROS), which are key mediators of oxidative stress and tissue injury in inflamed colonic tissue. In animal models of chemically induced colitis, particularly those using ZnO nanoparticles, significant improvements have been observed in clinical symptoms, histopathological scores, and levels of inflammatory markers (Alkushi *et al.*, 2022) [2]. Aloe vera gel is one of the most widely used plant extracts in both traditional and modern medicine. It is derived from the inner part of the aloe vera leaf and is rich in biologically active compounds, including polysaccharides, phenolics, anthraquinones, vitamins, and minerals, which contribute to its diverse therapeutic potential aloe vera has been known for centuries with its curative and therapeutic properties in addition to the presence of medicinally active constituents like tannins, saponins, phlobbasstannis, steroid, terpenoids, flavonoids, and glycosides (Raad *et al.*, 2020) [17]. Anti-inflammatory properties, Antioxidant effects, Digestive health benefits, Cytokine suppression, Mucosal healing, which may help normalize immune responses and reduce inflammation (Sahoo *et al.*, 2023) [18]. This study aims to comparatively evaluate the effects of zinc oxide nanoparticles and Aloe vera extract on selected physiological parameters in rats with acetic acid-induced colitis.

2. Material and methods

2.1. Plant Sample Collection: Fresh Aloe vera leaves were harvested from local garden in the city of Al-Hillah during the month of December 2024, and confirmation of their classification was done by the National Herbaceous / General Authority for Agricultural Research.

2.2. Preparation of Plant Aqueous Extracts

The leaves were thoroughly washed with distilled water to remove dust and other impurities. After peeling the outer layer, 100 g of the leaf material was manually chopped into small pieces, then ground using an electric blender. The resulting mixture was transferred into a 250 ml glass conical flask containing 100 ml of distilled water. The mixture was placed in a water bath at 90 °C for one hour with continuous stirring using a hot plate with a magnetic stirrer to ensure proper homogenization. After heating, the solution was filtered using Whatman filter papers to remove solid residues and impurities. The obtained extract was collected and stored at room temperature for subsequent experimental applications (Wu *et al.*, 2024) [23].

2.3. Zinc Oxide Nanoparticls

Commercially available zinc acetate with different molarity (0.3M and 0.2M) was used as precursor and sodium hydroxide as reducing agent. (Prakash *et al.*, 2022) [16]. A total 40 male rat Wister albino rat were randomly divided in four groups (n=8) per group each group induced UC with 4% acetic acid intra-rectally except negative control

1. **Control negative group (C-):** animals in this group without any treatment as negative control.
2. **Control positive group (C+):** animals in this group were injected acetic acid 4% intrarectaliy to induced anemiaUC as positive group.
3. **Zinc oxide nanoparticles group (G1):** Treatment of zinc oxide (ZNO) 20 mg\kg BW.
4. **Aloe Vera extract group (G2):** Treatment with Aloe vera extract 400 mg \kg BW.

In this study, 4% acetic acid solution was freshly prepared by 4% of acid added to 96 mL of distilled water). Each rat received 0.25 mL of the prepared solution via intrarectal administration using a polyethylene catheter (PE-90). The catheter was carefully inserted to a depth of approximately 8 cm into the rectum, and the solution was slowly injected to avoid any potential leakage or backflow. For animals in the negative control group, the same volume (0.25 mL) of distilled water was administered using the same procedure (Bastaki *et al.*, 2016) [4]. Treatment of zinc oxide (ZNO) 20 mg\kg BW and Treatment with Aloe vera extract 400 mg \kg BW and physiological parameters (IL10- Nitric oxide- Total antioxidant).

3. Result and Dissection

3.1 physiological parameters

3.1.1. Interleukin-10 (IL-10)

The presented table summarizes the mean concentrations of interleukin-10 (IL-10) alongside their respective standard deviations across various experimental groups, assessed both pre- and post-treatment. Statistically significant differences between groups ($P \leq 0.05$) are indicated by uppercase letters (A, B, C, D, E), whereas significant intra-group changes over time are denoted by lowercase letters (a, b). Among all groups, the zinc oxide nanoparticle-treated group (G1) demonstrated the most pronounced post-treatment elevation in IL-10 levels, reaching 177.34±6.40 ng/ml and categorized as group B, indicating superior anti-

inflammatory efficacy compared to all other interventions. The Aloe vera-treated group (G2) also exhibited a notable increase in IL-10 levels (157.66±11.08 ng/ml), although this response was comparatively less robust than that observed in the ZnO group. All experimental groups displayed significant increases in IL-10 following treatment, highlighting the immunomodulatory potential of the applied therapies. The calculated least significant difference (LSD) value of 8.61 confirms that intergroup differences exceeding this threshold are statistically meaningful. Collectively, these findings suggest that zinc oxide nanoparticles exert a more potent immunoregulatory effect relative to Aloe vera and the control groups. Nonetheless, further studies with larger sample sizes are warranted to validate these outcomes and to better characterize the variability observed in the Aloe vera group.

Table 1: Effect of ZnONP and Aloe vera extract IL-10 of UC male rats.

Parameters / Groups	IL-10 (ng/ml)	
	At induction	After treatment
C-	112.74±6.43 Bb	132.04±6.13 Ea
C+	121.99±7.05 Ab	164.8±7.49 Da
G1 ZnO chemical	103.95±6.22 Cb	177.34±6.40 Ba
G2 Alovera	114.6±9.11 Bb	157.66±11.08 Ca
LSD	8.61	

Capital letters refer to a relation among groups ($P \leq 0.05$). Small letters refer to a relation within groups ($P \leq 0.05$).

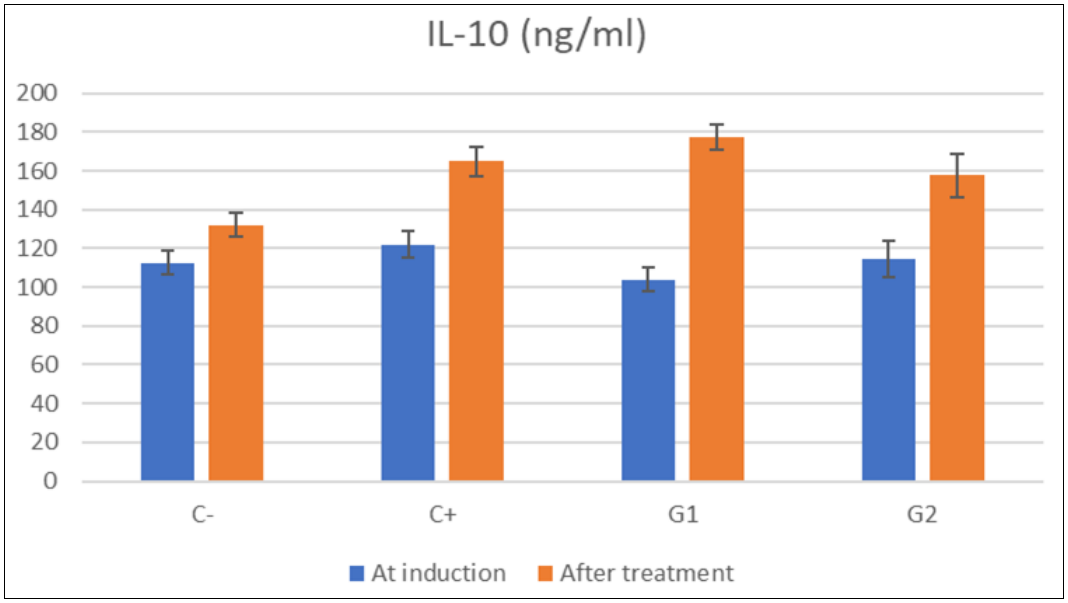

Fig 1: Effect of ZnONP and Aloe Vera extract IL-10 of UC male rats.

The relationship between zinc, IL-10, and intestinal inflammation seems to work together in a beneficial way. Cardoso *et al*. showed that when zinc and IL-10 are used together, they offer better protection against colitis than either one on its own. This suggests a synergistic effect in reducing intestinal inflammation (Cardoso *et al.*, 2018) [5]. This is especially important because patients with inflammatory bowel disease (IBD) often have low levels of zinc and tend to respond positively to zinc supplementation (Siva *et al.*, 2017) [20]. Combination therapies using zinc oxide nanoparticles (ZnO NPs) have been shown to boost IL-10 expression. Park *et al*. found that a drug combining ZnO NPs significantly raised IL-10 levels in colon tissue compared to using the individual components by themselves (Park *et al.*, 2018) [12]. Several studies have shown that zinc oxide nanoparticles (ZnO NPs) and their derivatives can enhance IL-10 expression in models of colitis. For example, Zhang *et al*. discovered that zinc-hyaluronic acid complexes significantly boosted IL-10 levels while also decreasing pro-inflammatory factors like TNF-α and IL-6 (Zhang *et al.*, 2025) [24]. In systemic models found that administering zinc oxide nanoparticles (ZnO NPs) significantly reduced serum levels of both pro-inflammatory cytokines and the anti-inflammatory cytokine IL-10 (Kim *et al.*, 2014) [8]. Multiple studies have shown that Aloe vera extract can boost the production of interleukin-10 (IL-10), an important anti-inflammatory cytokine. In experimental models involving splenocyte cultures stimulated with concanavalin A, Aloe vera peel extract was observed to enhance IL-10 production. This suggests a potential role for Aloe vera in modulating inflammatory responses. This immunomodulatory effect is linked to specific compounds in Aloe vera, especially emodin. Emodin seems to enhance Th2 cytokines, such as IL-10, while simultaneously decreasing Th1 cytokines. This balance may contribute to its anti-inflammatory properties (Samie and Madzie, 2017) [19]. In models of gastrointestinal inflammation, Aloe vera has shown notable effects on IL-10 levels. Research involving gastric ulcer models indicated that Aloe vera treatment increased IL-10 levels while decreasing TNF-alpha and leukocyte adherence. This not only supports ulcer healing but also highlights its role as a gastroprotective agent.(Mani *et al.*, 2015) [10]. This apparent contradiction may stem from variations in experimental conditions, the types of Aloe vera preparations used, or the complex mechanisms by which Aloe vera influences

immune responses in various tissues and disease states (Srivastava *et al.*, 2024) [21].

3.2. Nitric oxide

The current study evaluated nitric oxide (NO) levels across different experimental groups, revealing significant treatment-dependent modulation of NO production. During the induction phase, the positive control group (C+: 51.71±7.61 ng/ml) demonstrated the highest NO concentrations, significantly exceeding those of the other groups ($P \leq 0.05$), and was categorized as group 'A'. Both the Aloe vera-treated group (G2: 42.04±6.22 ng/ml) and the zinc oxide nanoparticle group (G1: 39.22±5.53 ng/ml) exhibited comparably lower NO levels, assigned to group 'B', whereas the negative control group (C−: 18.52±4.49 ng/ml) presented the lowest concentrations and was designated group 'C'. Post-treatment analysis indicated a statistically significant decline in NO levels within all groups (denoted by within-group change from lowercase 'a' to 'b'). The most substantial reduction was observed in the ZnO-treated group (G1), with levels decreasing by 47.2% to 20.71 ng/ml, aligning it with group 'C'. Aloe vera treatment (G2) also resulted in a significant, though more moderate, decrease to 26.99±4.91 ng/ml (group 'B'). The positive control group (C+) showed only a marginal reduction, with post-treatment values of 43.26±6.84 ng/ml, remaining within group 'A'. Statistical validation via Least Significant Difference (LSD) testing (threshold = 5.8) confirmed that all intergroup differences were significant. Collectively, these findings suggest that both zinc oxide nanoparticles and Aloe vera exert down regulatory effects on NO production, albeit with differing magnitudes of efficacy-likely reflecting distinct mechanistic pathways. These outcomes warrant further investigation to elucidate underlying molecular mechanisms and to optimize therapeutic strategies using larger sample sizes and extended treatment durations.

Table 2: Effect of ZnONP and Aloe Vera extract Nitric Oxide of UC male rats.

Parameters / Groups	Nitric oxide(ng/ml)	
	At induction	After treatment
C-	18.52±4.49 Ca	10.09±0.92 Eb
C+	51.71±7.61 Aa	43.26±6.84 Ab
G1 ZnO chemical	39.22±5.53 Ba	20.71±4.05 Cb
G2 Aloe Vera	42.04±6.22 Ba	26.99±4.91 Bb
LSD	5.8	

Capital letters refer to a relation among groups ($P \leq 0.05$).
Small letters refer to a relation within groups ($P \leq 0.05$).

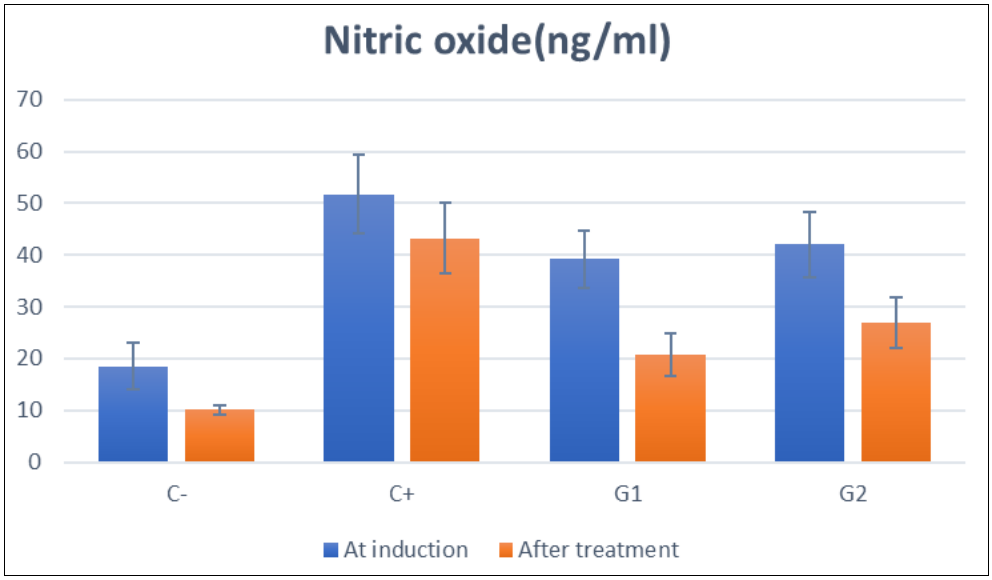

Fig 2: Effect of ZnONP and Aloe Vera extract Nitric Oxide of UC male rats.

Zinc oxide nanoparticles (ZnO NPs) exert significant effects on nitric oxide (NO) production, which has important implications for their therapeutic potential in ulcerative colitis, Studies have demonstrated that ZnO NPs can reduce NO levels by inhibiting inducible nitric oxide synthase activity in activated macrophages, thereby protecting against the production of reactive oxygen and nitrogen species that contribute to cellular damage in inflammatory bowel conditions (Piątek-Guziewicz *et al.*, 2021) [13]. Aloe vera extract administration significantly reduced serum nitric oxide levels, decreasing from 24 to approximately 9 µm/mL. This reduction was dose-dependent and varied by the route of administration. The most effective method was rectal administration at a dose of 400 mg/kg, compared to oral administration (Naini *et al.*, 2021) [11]. This anti-inflammatory effect was also noted by Wang *et al.*, who highlighted that Aloe vera ethanol extracts significantly suppressed the secretion of NO in rats with -induced colitis (Wang *et al.*, 2023) [22].

3.3. Total antioxidant

The study assessed of total antioxidant capacity (TAO) revealed statistically significant variations among the experimental groups both prior to and following treatment, underscoring the differential efficacy of the applied interventions in modulating oxidative stress within the acetic acid-induced colitis model. The negative control group (C−) exhibited the highest TAO levels at both time points (19.31±2.01 U/ml at induction and 23.23±0.53 U/ml post-treatment), with a significant intra-group increase (Ab to Aa), reflecting a preserved and robust endogenous antioxidant defense in non-inflamed animals. Conversely, the positive control group (C+), characterized by colitis induction without therapeutic intervention, displayed

markedly suppressed TAO values (6.22±0.93 to 8.50±1.34 U/ml), remaining the lowest across all groups and indicating impaired redox homeostasis due to inflammatory insult. Notably, administration of zinc oxide nanoparticles (G1) elicited the most pronounced enhancement in TAO levels, with a significant elevation from 5.38±0.32 to 13.57±1.99 U/ml (Bb to Ca), surpassing the established least significant difference (LSD = 3.4), thereby demonstrating potent antioxidant-restorative capacity. Aloe vera treatment (G2) also significantly elevated TAO levels (8.07±1.03 to 14.04±0.97 U/ml), albeit to a slightly lesser extent than ZnO, suggesting a moderate but notable therapeutic effect. Collectively, these findings indicate that both zinc oxide nanoparticles and Aloe vera exert beneficial effects on oxidative stress modulation in experimental colitis, with ZnO exhibiting superior efficacy, potentially attributable to its nanoscale properties and mechanistic action on redox pathways.

Table 3: Effect of ZnONP and Aloe Vera extract TAO of UC male rats.

Parameters / Groups	TAO (U/ml)	
	At induction	After treatment
C-	19.31±2.01 Ab	23.23±0.53 Aa
C+	6.22±0.93 Ba	8.50±1.34 Da
G**1** ZnO chemical	5.38±0.32 Bb	13.57±1.99 Ca
G**2** Aloe Vera	8.07±1.03 Bb	14.04±0.97 Ca
LSD	3.4	

Capital letters refer to a relation among groups (P≤ 0.05). Small letters refer to a relation within groups (P≤ 0.05).

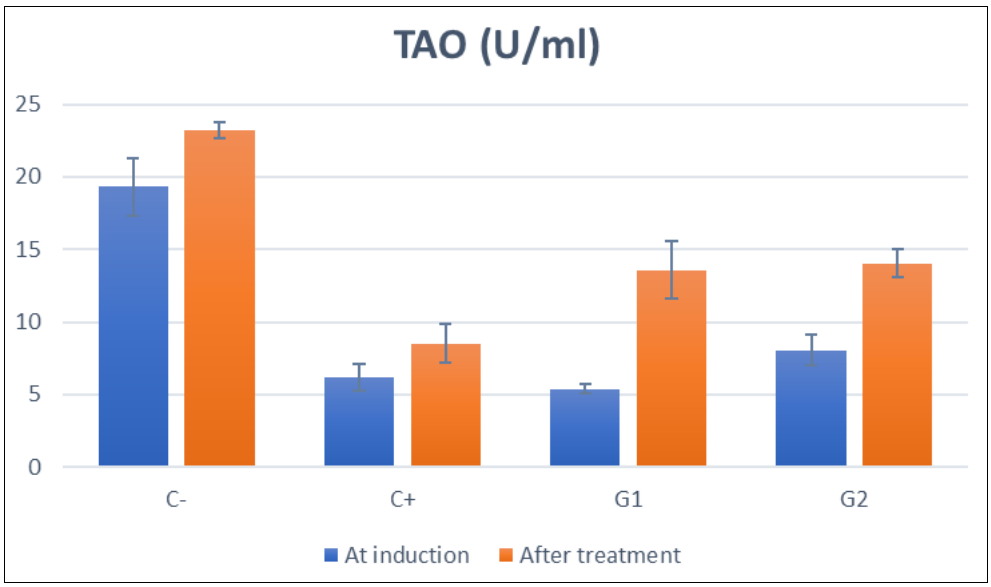

Fig 3: Effect of ZnONP and Aloe Vera extract TAO of UC male rats.

The addition of TOA during synthesis also affects the surface charge characteristics of ZnO nanoparticles. While all spherical ZnO nanoparticles tend to exhibit positive zeta potential, those synthesized with TOA/OD mixtures show a smaller zeta potential compared to nanoparticles prepared from pure OD This alteration in surface charge properties can influence the interactions between nanoparticles and their surrounding environment, potentially affecting their stability in colloidal suspensions and their interactions with biological systems (Gong *et al.*, 2007) [6]. The surface properties modified by TOA can also influence the assembly behavior of ZnO nanoparticles. Studies investigating the mechanisms of oriented attachment of nanoparticles suggest that surface characteristics, rather than dipolar interactions between particles, may be the dominant driving force in nanoparticle organization. When analyzing the assembly of similar nanocrystals under electric fields, researchers found no significant influence of the electric field on particle organization, leading to the conclusion that surface reduction, possibly driven by Coulombic interaction, may be a more important mechanism for the oriented attachment process than dipolar interactions (Hapiuk *et al.*, 2013) [7].

References

1. Abou Zaid ES, Mansour SZ, El-Sonbaty SM, Moawed FS, Kandil EI, Haroun RA-H. Boswellic acid coated zinc nanoparticles attenuate NF-κB-mediated inflammation in DSS-induced ulcerative colitis in rats. International Journal of Immunopathology and Pharmacology. 2023;37:03946320221150720.
2. Alkushi AG, Abdelfattah-Hassan A, Eldoumani H, Elazab ST, Mohamed SA, Metwally AS, *et al*. Probiotics-loaded nanoparticles attenuated colon inflammation, oxidative stress, and apoptosis in colitis. Scientific Reports. 2022;12(1):5116.
3. Ananthakrishnan AN. Epidemiology and risk factors for IBD. Nature Reviews Gastroenterology & Hepatology. 2015;12(4):205-217.
4. Bastaki SM, Al Ahmed MM, Al Zaabi A, Amir N, Adeghate E. Effect of turmeric on colon histology, body weight, ulcer, IL-23, MPO and glutathione in acetic-acid-induced inflammatory bowel disease in rats. BMC Complementary and Alternative Medicine. 2016;16:1-14.
5. Cardoso A, Gil Castro A, Martins AC, Carriche GM, Murigneux V, Castro I, *et al*. The dynamics of

interleukin-10-afforded protection during dextran sulfate sodium-induced colitis. Frontiers in Immunology. 2018;9:400.
6. Gong Y, Andelman T, Neumark GF, O'Brien S, Kuskovsky IL. Origin of defect-related green emission from ZnO nanoparticles: effect of surface modification. Nanoscale Research Letters. 2007;2:297-302.
7. Hapiuk D, Masenelli B, Masenelli-Varlot K, Tainoff D, Boisron O, Albin C, *et al*. Oriented attachment of ZnO nanocrystals. The Journal of Physical Chemistry C. 2013;117(19):10220-10227.
8. Kim CS, Nguyen HD, Ignacio RM, Kim JH, Cho HC, Maeng EH, *et al*. Immunotoxicity of zinc oxide nanoparticles with different size and electrostatic charge. International Journal of Nanomedicine. 2014;9(Suppl 2):195-205.
9. Malik S, Muhammad K, Waheed Y. Nanotechnology: a revolution in modern industry. Molecules. 2023;28(2):661.
10. Mani P, Neelesh M, Sourabh K, Gaurav M. Treatment and replenishment of GI tract with combined regimen therapy (CRT) of Allopathic (PPIs) and Ayurvedic (Aloe Vera) Medicine in peptic ulcer disease to counteract relapse. Journal of Gastrointestinal & Digestive System. 2015;5(272):2.
11. Naini MA, Zargari-Samadnejad A, Mehrvarz S, Tanideh R, Ghorbani M, Dehghanian A, *et al*. Anti-inflammatory, antioxidant, and healing-promoting effects of Aloe vera extract in the experimental colitis in rats. Evidence-Based Complementary and Alternative Medicine. 2021;2021(1):9945244.
12. Park JS, Choi J, Kwon JY, Jung KA, Yang CW, Park SH, *et al*. A probiotic complex, rosavin, zinc, and prebiotics ameliorate intestinal inflammation in an acute colitis mouse model. Journal of Translational Medicine. 2018;16:1-10.
13. Piątek-Guziewicz A, Paśko P, Wcisło K, Dąbek-Drobny A, Przybylska-Feluś M, Kaczmarczyk O, *et al*. Serum levels of selected micronutrients in patients with inflammatory bowel disease in clinical remission. Polish Archives of Internal Medicine. 2021;131:701-708.
14. Popov J, Caputi V, Nandeesha N, Rodriguez DA, Pai N. Microbiota-immune interactions in ulcerative colitis and colitis associated cancer and emerging microbiota-based therapies. International Journal of Molecular Sciences. 2021;22(21):11365.
15. Porter RJ, Kalla R, Ho G-T. Ulcerative colitis: Recent advances in the understanding of disease pathogenesis. F1000Research. 2020;9:F1000 Faculty Rev-1294.
16. Prakash KK, Vinodkumar T, Prakash V. The green and chemical synthesis, and characterization of ZnO nanoparticles by aqueous leaf extract of aloe vera. IOP Conference Series: Materials Science and Engineering. [Year Missing].
17. Raad B, Ali SS, Rehman KU, Akhtar N, Ullah B, Wali S. Phytochemical screening and biological activities of Aloe vera (L.) Burm. f. Pure and Applied Biology. 2020;10(2):360-367.
18. Sahoo DK, Heilmann RM, Paital B, Patel A, Yadav VK, Wong D, *et al*. Oxidative stress, hormones, and effects of natural antioxidants on intestinal inflammation in inflammatory bowel disease. Frontiers in Endocrinology. 2023;14:1217165.
19. Samie A, Madzie N. Effects of Combretum hereroense and Canthium mundianum water extracts on production and expression of interleukin-4. African Journal of Traditional, Complementary and Alternative Medicines. 2017;14(1):302-309.
20. Siva S, Rubin DT, Gulotta G, Wroblewski K, Pekow J. Zinc deficiency is associated with poor clinical outcomes in patients with inflammatory bowel disease. Inflammatory Bowel Diseases. 2017;23(1):152-157.
21. Srivastava S, Kharkar V-R, More S, Kalsi H-S, Sachdev S-S. Efficacy of a novel combination of aloe vera gel and pineapple extracts in improving post-extraction pain and healing: A randomized controlled trial. Journal of Clinical and Experimental Dentistry. 2024;16(7):e794.
22. Wang Y, Xiong Z, Li C, Liu D, Li X, Xu J, *et al*. Multiple beneficial effects of aloesone from aloe vera on LPS-induced RAW264.7 cells, including the inhibition of oxidative stress, inflammation, M1 polarization, and apoptosis. Molecules. 2023;28(4):1617.
23. Wu C, Zhang T, Ji B, Chou Y, Du X. Green synthesis of zinc oxide nanoparticles using Aloe vera leaf extract and evaluation of the antimicrobial and antioxidant properties of the ZnO/regenerated cellulose film. Cellulose. 2024;31(8):4849-4864.
24. Zhang L, Fu X, Li J, Xiao W, Xiong X, Lv H, *et al*. Treatment of acute ulcerative colitis with zinc hyaluronate in mice. Journal of Microbiology and Biotechnology. 2025;35:e2408050.