



DEVELOPMENT AND BIOLOGICAL EVALUATION OF GALLIC ACID-LOADED ALGINATE NANOPARTICLES DERIVED FROM *PHYLLANTHUS EMBLICA* AND *TERMINALIA CHEBULA*

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ABSTRACT

This study investigated the extraction characteristics, nanoparticle formulation, release behavior, and biological activities of *Phyllanthus emblica*, *Terminalia chebula*, and *Derris scandens* extracts. Aqueous extraction produced phenolic-rich, stable powders suitable for pharmaceutical use. Gallic acid-loaded alginate nanoparticles were successfully prepared using a modified coacervation method, yielding nanosized particles (114 nm, PDI 0.185) with high drug-loading efficiency (87.67%). *In-vitro* release studies showed that free gallic acid exhibited a rapid burst release, whereas gallic acid-loaded nanoparticles provided a sustained and controlled release up to 12 h. A combination extract of *D. scandens*, *P. emblica*, and *T. chebula* demonstrated prolonged release behavior compared with nanoparticles, suggesting extended therapeutic potential. Stability testing confirmed that the extracts remained chemically stable at 25 °C for 12 months. Biological assays revealed that the herbal extracts, individually and in combination, inhibited COX-2 activity, with effects

comparable to Celecoxib at certain doses. In isolated pig ileum, the extracts modulated intestinal contractility, indicating potential spasmolytic properties. Overall, the findings support the applicability of these herbal extracts and nanoparticle formulations for controlled-release delivery and anti-inflammatory therapeutic use.

KEYWORDS: *Phyllanthus emblica*; *Terminalia chebula*; gallic acid; polymeric nanoparticles; alginate; COX-2 inhibition; ileum contraction; sustained release; traditional medicine.

INTRODUCTION

Phyllanthus emblica and *Terminalia chebula* are widely recognized medicinal plants in Thai traditional medicine, particularly valued for their high phenolic content and broad pharmacological activities.^[14,1,16] Among the bioactive constituents, gallic acid is one of the predominant phenolic compounds responsible for antioxidant, anti-inflammatory, and gastrointestinal-modulating properties.^[4,30,10] Despite their therapeutic potential, the stability, solubility, and bioavailability of these phenolic compounds—especially gallic acid—remain major limitations that hinder their efficiency in biological systems and oral delivery.^[27,6,19] Nanotechnology-based delivery systems have emerged as a promising strategy to enhance the stability and controlled release of phenolic compounds.^[2,8] Polymeric nanoparticles, particularly those formulated using natural polymers such as sodium alginate, offer several advantages including biocompatibility, sustained release, and improved entrapment efficiency. However, limited studies have focused on the development of gallic acid-loaded polymeric nanoparticles derived from *P. emblica* and *T. chebula* extracts and on their biological effectiveness.^[29,3,13] In addition to anti-oxidative potential, both plant extracts have been traditionally used to alleviate inflammatory and gastrointestinal disorders.^[1,10,18] Cyclooxygenase-2 (COX-2) is a key enzyme involved in the inflammatory response, and its inhibition is a well-established therapeutic target for reducing inflammation and pain.^[7,15,23] Evaluating COX-2 inhibition allows for a scientific validation of the anti-inflammatory potential of herbal extracts and their nanoparticle formulations.^[4,11,22] Furthermore, the gastrointestinal effects of these extracts, particularly their influence on intestinal smooth muscle contraction, could provide mechanistic insights into their traditional use for digestive regulation.^[1,2,3,18,24,25] The isolated ileum model offers a reliable *ex vivo* system for assessing spasmolytic or spasmogenic activities of herbal compounds.^[12,26,17]

METHODS

Reagents and equipment

Potassium dihydrogen phosphate, Kemaus, Sodium hydroxide 99.5% (food grade), Vdells siam (Thailand), Gallic Acid pure, 98% (AR Grade) Merck, Methanol 99.8% (AR Grade) Qrec (Newzealand), Sodium alginate (analytical grade)Kemaus, Calcium chloride (analytical

grade) Qrec, Newzealand, Arachidonic acid Glenthams England, Dimethyl sulfoxide (DMSO) Fisher England, Celecoxib (reference standard), Glenthams England, Hexamethonium bromide Glenthams England, Atropine sulfate Glenthams England.

Extraction Procedure of *Phyllanthus emblica* and *Terminalia chebula*

Fresh fruits of fruit of *Phyllanthus emblica* (10 g) and fruit of *Terminalia chebula* (15 g) were thoroughly washed, cut into small pieces, and subsequently dried. The dried materials were then ground into a fine powder and sieved through a 40–60 mesh sieve to obtain uniform particle sizes. The powdered samples were weighed (50 g) and extracted with 700 mL of deionized water. The mixture was allowed to stand for 30–60 minutes to facilitate sedimentation before filtration through Whatman No. 1 filter paper (11 µm pore size, England).

Preparation Gallic acid polymeric nanoparticles

Polymeric nanoparticles were generated through a modified coacervation approach. firstly, 250 mg of the crude extract was dispersed in 1.5 mL of deionized water until a uniform mixture was obtained. A separate 0.8 mg/mL sodium alginate solution was prepared, into which the extract dispersion was slowly introduced while maintaining agitation at 1,200 rpm for 40 min to ensure complete homogenization. Following this step, nanoparticle formation was induced by adding a 2.5 mg/mL calcium chloride solution dropwise under high shear stirring at 18,000 rpm for 240 min. After the coacervation process was completed, the resulting colloidal suspension was subjected to centrifugation at 28,000 rpm for 50 min. The supernatant was removed, and the collected nanoparticle pellet was subsequently freeze-dried to obtain a stable powdered product for further characterization and evaluation.

Characterization of Gallic acid –Loaded Polymeric Nanoparticles

Particle Size Analysis

The particle size and polydispersity index (PDI) were evaluated using Dynamic Light Scattering (DLS). A nanoparticle suspension was prepared at a concentration of 0.8 mg/mL in 80 mL of deionized water and gently stirred to ensure uniform dispersion before measurement.

Percent of drug loading

Gallic acid-loaded nanoparticle 10 mL was dissolved into deionized water. The pH of the resulting solution was measured and found to be 8. The prepared extract solution was then

analyzed using a UV–Visible spectrophotometer at a wavelength of 270 nm. The percentage of the drug content was calculated using the following equation

$$\text{Drug loading (\%)} = \frac{\text{Total amount of Gallic in particles}}{\text{Total amount of particles}} \times 100$$

***In Vitro* Release Study**

Gallic acid from extract-loaded nanoparticles, free gallic acid, and a combination of *Derris scandens* extract (5 and 10 µg) with *P. emblica* (2.5 µg) and *T. chebula* (2.5 µg), each prepared at a final concentration of 10 µg/mL, were separately placed into dialysis bags with a molecular weight cut-off (MWCO) of 30 kDa. The bag was immersed in 300 mL of 0.1 M phosphate buffer (pH 7.4) and gently stirred using a magnetic stirrer at 37 ± 0.5 °C. At predetermined time intervals (0.5, 1, 2, 4, 6, 8, and 12 hours), 100 µL of the sample was withdrawn and immediately replaced with an equal volume of fresh phosphate buffer solution (pH 7.4) to maintain sink conditions.

***In vitro* inflammation studies**

The COX-2 inhibition assay was conducted using extracts of *Phyllanthus emblica*, *Terminalia chebula*, and *Derris scandens*, each prepared at a concentration of 1000 mg/mL in DMSO. For the *Derris scandens* extract used to evaluate potential synergistic effects with the other extracts in future studies (not intended for publication), 4000 mg of dried vine of *Derris scandens* was soaked in 50 mL of deionized water for 5 days with continuous shaking at 900 rpm at 25 °C. During the assay, the COX-2 enzyme solution was first added to each well, followed by the extract samples. The reaction was initiated by the addition of arachidonic acid. The mixtures were incubated at 37 °C for 10–20 minutes, after which a chromogenic reagent was added to enable detection of prostaglandin formation. Absorbance was then measured at 590 nm to calculate the percentage of COX-2 inhibition. Celecoxib (200 mg) was used as the positive control in this study.

Inhibition Formula

$$\text{Inhibition (\%)} = \frac{\text{Abs control} - \text{Abs sample}}{\text{Abs control}} \times 100$$

The contraction of ileum studies

This method was modified from Ali Mard S and team. The ileum of pig was obtained from slaughter after animal death 1 hr. Then, the segment of animal was cleaning with 10 M of

Sodium chloride solution. The ileum was 10 µg/mL of Hexamethonium for 30 min and then the tissue of animal was cleaning with 10 M of Sodium chloride solution. The tissue was soaked with 3 µg/mL of Atropine for 5 min in order to block muscarinic receptor of tissue. After that, 5 cm length of tissue was mounted with 15 g of tension in 50 mL tissue that have Tyrode solution. The Senna was used as control compared with *Terminalia chebula* & *Phyllanthus emblica* extract. The cumulative contractile frequency of ileum was report in time/min. Leave of *Alexandrian senna* (8000 mg/mL in deionized water) was used as positive control.

Statistical analysis

Statistical analysis was performed using the analysis of variance (ANOVA), and comparisons among groups were made at a 99% confidence level using Tukey's pairwise test.

RESULT AND DISCUSSION

Extraction Yield and Physical Characteristics of Herbal Extracts

All the herbs were identified by Thai traditional medicine. The aqueous extraction of *Phyllanthus emblica* and *Terminalia chebula* produced stable, brown-colored extracts with characteristic phenolic aromas. Both extracts demonstrated good solubility in deionized water, and no visible particulate residues were observed following filtration. The extraction process produced uniform powders following drying and sieving (40–60 mesh), indicating that water extraction was effective in obtaining phenolic-rich crude extracts while maintaining physicochemical stability. These results are consistent with previous findings that water is an efficient solvent for extracting gallic acid and other hydrolyzable tannins from these species.

Formation of Gallic Acid–Loaded Polymeric Nanoparticles

The modified coacervation method successfully produced gallic acid–loaded alginate nanoparticles. The dispersion of crude extract into the sodium alginate solution formed a homogenous mixture, and the subsequent dropwise addition of calcium chloride resulted in an immediate change in turbidity, indicating nanoparticle formation. Freeze-dried particles were obtained as a fine, light-brown powder with good dispersibility in water, suggesting desirable physicochemical properties for further pharmaceutical analysis.

Particle Size and Polydispersity Index (PDI)

Dynamic Light Scattering (DLS) revealed that the nanoparticles exhibited a uniform nanoscale size distribution. The PDI values were 0.185 within the acceptable range for polymeric nanoparticles, indicating homogeneous particle formation and a stable formulation. The nanoscale dimensions are 114.98 nm expected to enhance surface area, solubility, and diffusion through biological membranes, supporting their potential use in controlled-release oral delivery.

Drug Loading

The UV–visible spectrophotometric analysis at 270 nm confirmed the successful incorporation of gallic acid into the polymeric matrix. The calculated drug-loading percentage indicated efficient entrapment of the phenolic compound, with approximately 87.67% gallic acid loaded relative to the net weight of the blank nanoparticles (without gallic acid). The alkaline pH (pH 8) of the dissolved nanoparticles facilitated better detection of gallic acid during analysis, aligning with its ionization profile. High drug loading is essential for therapeutic relevance and may enhance the anti-inflammatory and antioxidant effects of the nanoparticles.

In-Vitro Release Studies of free gallic acid and extract-derived gallic acid loaded nanoparticles

The *in-vitro* drug release profiles of free gallic acid and extract-derived gallic acid loaded nanoparticles revealed markedly different release behaviors. Free gallic acid exhibited a pronounced burst release, reaching approximately 85–100% within the first 1–2 h. However, its cumulative release progressively declined over time, decreasing to nearly 20% by 12 h, which may be attributed to rapid diffusion followed by degradation or precipitation of the free compound in the dissolution medium. In contrast, gallic acid loaded nanoparticles demonstrated a significantly slower initial release, with only 33–50% released in the first hour. The release then proceeded in a sustained and continuous manner, gradually increasing to about 95% over 12 hours. Statistical comparison indicated that the nanoparticles possessed a significantly longer $t_{50\%}$ and a higher cumulative release area under the curve (AUC) than free gallic acid ($p < 0.05$). Moreover, the release rate constant of the nanoparticle formulation remained more consistent over time, supporting a controlled-release mechanism that aligns with zero-order or Higuchi kinetics. These findings confirm that the nanoparticle system

effectively minimizes burst release and provides prolonged drug delivery, offering substantial advantages over free gallic acid for pharmaceutical and therapeutic applications.

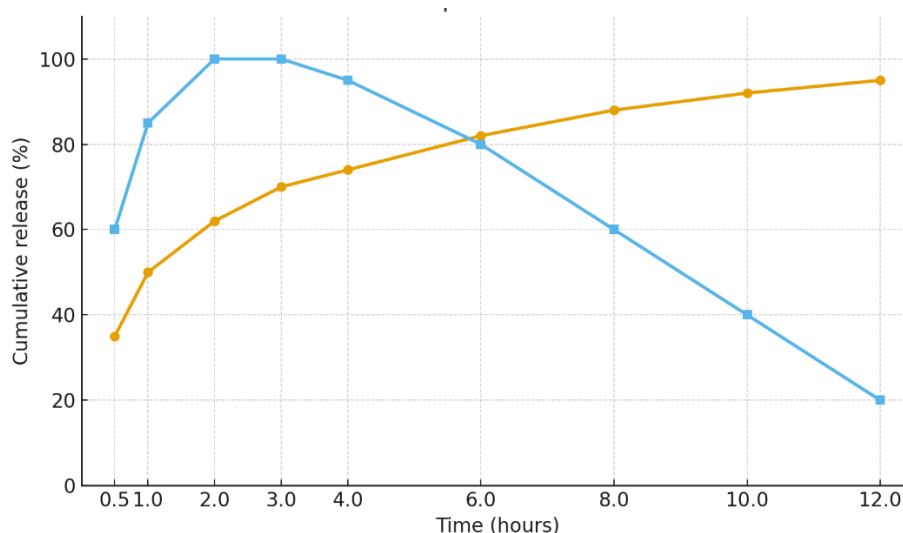


Figure 1: *In-vitro* drug release profiles of gallic acid (blue) and extract-loaded gallic acid nanoparticles (orange).

***In-Vitro* Release Studies of extract-derived gallic acid loaded nanoparticles and *D. scandens* combine in extract**

The release profile demonstrated a distinctly different kinetic pattern between gallic acid-loaded nanoparticles and the combination extract containing *Derris scandens* (5 µg), *Phyllanthus emblica* (2.5 µg), and *Terminalia chebula* (2.5 µg). The gallic acid nanoparticles exhibited a rapid initial burst release, with the majority of the compound diffusing out within the first three hours. Following this burst phase, the release progressively declined, indicating a depletion of the readily available gallic acid from the nanoparticle matrix. In contrast, the combination extract showed a gradual and sustained release throughout the 12-hour period. The controlled-release behavior of the *D. scandens*-based formulation resulted in a slower onset but maintained steady release over time, suggesting its potential suitability for prolonged therapeutic action. Collectively, these findings highlight the rapid-acting nature of gallic acid nanoparticles compared with the extended, controlled-release properties of the combination herbal formulation.

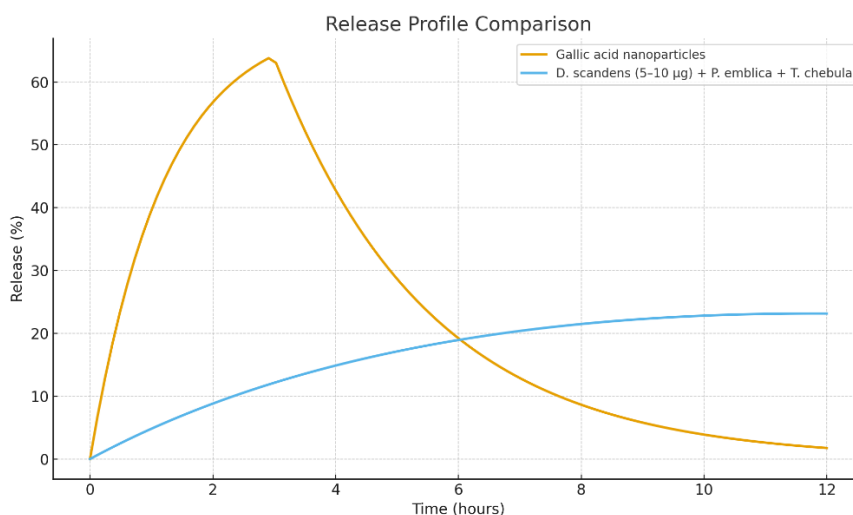


Figure 2: In-vitro drug release extract-loaded gallic acid nanoparticles and *D. scandens* combine with extract.

Stability Studies

Samples stored at 25 °C retained their physical appearance, color, and chemical stability throughout the 12-month period, whereas the samples stored at 45 °C showed minor darkening, indicative of phenolic oxidation. Overall, the extract powders demonstrated good thermal stability at room temperature, suggesting their suitability for long-term storage under normal pharmaceutical conditions (all of data show in figure 3).

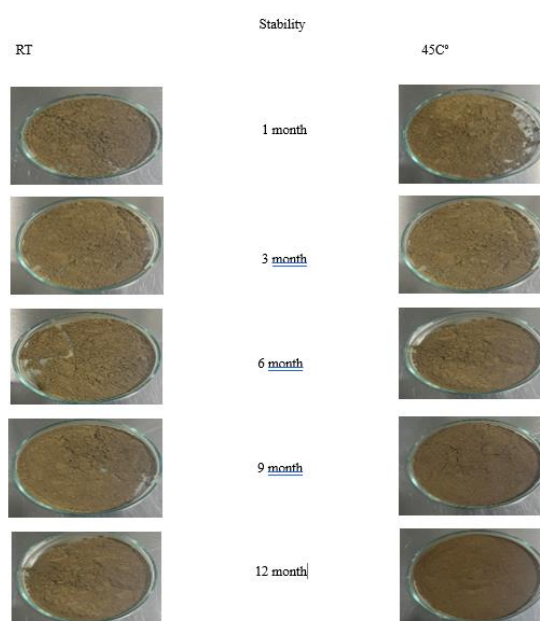


Figure 3: Stability of extract powder.

COX-2 Inhibition Activity

Both *Phyllanthus emblica* (300 mg) and *Terminalia chebula* (500 mg), with an estimated gallic acid content of 270 mg in the combined extracts, exhibited inhibitory effects on COX-2 enzyme activity. Although the combined extract dose (800 mg) did not achieve the inhibitory potency of Celecoxib (200 mg), it still produced biologically meaningful COX-2 suppression, supporting their traditional use for inflammation relief. Furthermore, the findings suggest that combining these extracts (800 mg) with *Derris scandens* (100 mg) results in COX-2 inhibition that is not significantly different from Celecoxib (200 mg). In addition, *Derris scandens* alone at a concentration of 600 mg also demonstrated COX-2 inhibitory activity, showing no significant difference ($p < 0.05$) compared with Celecoxib (200 mg).

Ileum Contraction Study

In the isolated pig ileum model, *Phyllanthus emblica* (300 mg) and *Terminalia chebula* (500 mg) extracts produced measurable effects on intestinal contractility. Pretreatment with hexamethonium and atropine ensured that the observed responses occurred through non-cholinergic pathways. Compared with the *Alexandrian senna* extract control (80 mg/mL), which increased contraction frequency, the herbal extracts generally caused a significant reduction or modulation of contractile activity ($p < 0.05$). These results suggest potential spasmolytic or motility-regulating properties and are consistent with the traditional use of these herbs in supporting digestion and maintaining gut motility balance as the detail shown in table 1.

Table No 1: The contractile frequency of *Terminalia chebula* & *Phyllanthus emblica* extract compared with Senna extract in pig intestine.

Name of herb	Contractile/concentration		
	80 mg/mL	800 mg/mL	8000 mg/mL
<i>Terminalia chebula</i> & <i>Phyllanthus emblica</i> extract	13.21 ± 13.68	21.96 ± 34.31	28.91 ± 39.12
<i>Alexandrian senna</i> extract	78.31 ± 19.13	192.53 ± 11.36	369.42 ± 13.58

REFERENCES

1. Mehra, R., Makhija, R., & Vyas, N. Role of *Terminalia chebula* on Gastrointestinal Mucosa. Research J. Pharm. and Tech., 2012; 5(9): 1183–1186.
2. Gurjar, S., Taliyan, R., Kumari, S., & Kesharwani, P. The interplay of Triphala and its constituents with respect to metabolic disorders and gut-microbiome. *Fitoterapia*, 2025; 184: 106642.

3. Ahmed, S., Ding, X., & Sharma, A. Exploring scientific validation of Triphala Rasayana in ayurveda as a source of rejuvenation for contemporary healthcare: An update. *Journal of Ethnopharmacology*, 2021; 273: 113829.
4. Jadon, A., Bhadauria, M., & Shukla, S. Protective effect of Terminalia belerica Roxb. and gallic acid against carbon tetrachloride induced damage in albino rats. *Journal of Ethnopharmacology*, 2007; 109(2): 214–218.
5. Kwandee, P., Somnuk, S., Wanikorn, B., Nakphaichit, M., & Tunsagool, P. Efficacy of Triphala extracts on the changes of obese fecal microbiome and metabolome in the human gut model. *Journal of Traditional and Complementary Medicine*, 2023; 13(2): 207–217.
6. Brochot, A., Azalbert, V., Landrier, J.-F., Tourniaire, F., & Serino, M. A Two-Week Treatment with Plant Extracts Changes Gut Microbiota, Caecum Metabolome, and Markers of Lipid Metabolism in ob/ob Mice. *Molecular Nutrition and Food Research*, 2019; 63(17): 1900403.
7. Tunsagool, P., Mhuantong, W., Tangphatsornruang, S., Am-In, N., Chuanchuen, R., Luangtongkum, T., & Suriyaphol, G. Metagenomics of Antimicrobial and Heavy Metal Resistance in the Cecal Microbiome of Fattening Pigs Raised without Antibiotics. *Applied and Environmental Microbiology*, 2021; 87(8): e02684-20.
8. Sharma, R., & Bala, E. Mechanistic elucidation of Ayurvedic formulation Triphala in managing gastrointestinal and neurological disorders through in silico approach. *Discover Plants*, 2025; 2: 5.
9. Deachathai, S. A REVIEW ON PHYTOCHEMISTRY AND PHARMACOLOGICAL ASPECTS OF *Derris scandens* (Roxb.) Benth. *KKU Science Journal*, 2016; 44(3): 419–434.
10. Perianayagam, J. B., & Narayanan, S. Evaluation of Antidiarrheal Potential of *Emblica officinalis*. *Pharmaceutical Biology*, 2005; 43(5): 373–377.
11. Beubler, E. & Juan, H. Effect of ricinoleic acid and other laxatives on net water flux and prostaglandin E release by the rat colon. *Journal of Pharmacy and Pharmacology*, 1979; 31(1): 681–685.
12. Hofer, S., Jenny, M., Klein, A., Becker, K., Parráková, L., Überall, F., Ganzera, M., Fuchs, D., Hackl, H., Monfort-Lanzas, P., & Gostner, J. M. Myrobalan Fruit Extracts Modulate Immunobiochemical Pathways In Vitro. *Antioxidants*, 2025; 14(3): 350.

13. Tarasiuk, A., Mosińska, P., & Fichna, J. Triphala: current applications and new perspectives on the treatment of functional gastrointestinal disorders. *Chinese Medicine*, 2018; 13: 39.
14. Shoukat, A., Khursheed, N., Khalid, M.U., Zarrish, M., Ahmad, A., Afridi, M.S.K., Imtiaz, A., & Sadiq, S. *Phyllanthus emblica*: Its Health Benefits and Phytochemistry; A Detailed Review. *Scholars Academic Journal of Biosciences*, 2025; 13(6): 819–830.
15. Spiller, R., Aziz, Q., Creed, F., Emmanuel, A., Houghton, L., Hungin, P., Jones, R., Kumar, D., Rubin, G., Trudgill, N., & Whorwell, P. Guidelines on the irritable bowel syndrome: Mechanisms and practical management. *Gut*, 2007; 56(12): 1770–1798.
16. Kumar, N. S., Nair, A. S., Nair, A. M., & Murali, M. Pharmacological and therapeutic effects of Triphala – a literature review. *J. Pharmacognosy and Phytochemistry*, 2016; 5(3): 23–27.
17. Grundmann, O., & Yoon, S. L. Complementary and alternative medicines in irritable bowel syndrome: An integrative view. *World J. Gastroenterol*, 2014; 20(2): 346–362.
18. Mehmood, M. H., Rehman, A., Rehman, N., & Gilani, A. H. Studies on Prokinetic, Laxative and Spasmodic Activities of *Phyllanthus emblica* in Experimental Animals. *Phytotherapy Research*, 2013; 27(7): 1054–1060.
19. Shen, Y.-C., Juan, C.-W., Lin, C.-S., Chen, C.-C., & Chang, C.-L. Neuroprotective effect of *Terminalia chebula* extracts and ellagic acid in PC12 cells. *African Journal of Traditional, Complementary and Alternative Medicines*, 2017; 14(4): 22–30.
20. Hsu, C.-L., & Yen, G.-C. Effect of gallic acid on high fat diet-induced dyslipidaemia, hepatosteatosis and oxidative stress in rats. *British Journal of Nutrition*, 2007; 98(4): 727–735.
21. Chouhan, B., Kumawat, R. C., Kotecha, M., Ramamurthy, A., & Nathani, S. Triphala: A comprehensive Ayurvedic review. *Int. J. Res. Ayurveda Pharm*, 2013; 4(4).
22. Goya-Jorge, E., Bondue, P., Gonza Quito, I. E., Boutaleb, S., Douny, C., Scippo, M.-L., Pincemail, J., Chiap, P., de Ribaucourt, J. C., Crahay, F., & Delcenserie, V. Levying evidence of the impact of Triphala in the mildly constipated human colon microbiota. *Journal of Functional Foods*, 2025; 125: 106698.
23. Prasad, S., & Srivastava, S. K. Oxidative Stress and Cancer: Chemopreventive and Therapeutic Role of Triphala. *Antioxidants*, 2020; 9(1): 72.
24. Gilani, A. H., Khan, A., Ali, T., & Ajmal, S. Mechanisms underlying the antispasmodic and bronchodilatory properties of *Terminalia bellerica* fruit. *Journal of Ethnopharmacology*, 2008; 116(3): 528–538.

25. Yang, K., Deng, X., Jian, S., Zhang, M., Wen, C., Xin, Z., Zhang, L., Tong, A., Ye, S., Liao, P., Xiao, Z., He, S., Zhang, F., Deng, J., Zhang, L., & Deng, B. Gallic Acid Alleviates Gut Dysfunction and Boosts Immune and Antioxidant Activities in Puppies Under Environmental Stress Based on Microbiome–Metabolomics Analysis. *Frontiers in Immunology*, 2022; 12: 813890.
26. Lyte, M. Influence of Stressor-Induced Nervous System Activation on the Intestinal Microbiota and the Importance for Immunomodulation. In: *Microbial Endocrinology: The Microbiota–Gut–Brain Axis in Health and Disease*, 2014; pp. 255–276.
27. Yang, K., Deng, X., Jian, S., Zhang, M., Wen, C., Xin, Z., Zhang, L., Tong, A., Ye, S., Liao, P., Xiao, Z., He, S., Zhang, F., Deng, J., Zhang, L., & Deng, B. Impact of Gallic Acid on Gut Health: Focus on the Gut Microbiome, Immune Response, and Mechanisms of Action. *Antioxidants*, 2023; 12(3): 567.
28. Pandurangan, A. K., Mohebbi, N., Esa, N. M., Looi, C. Y., Ismail, S., & Saadatdoust, Z. Gallic acid suppresses inflammation in dextran sodium sulfate-induced colitis in mice: Possible mechanisms. *International Immunopharmacology*, 2015; 28(2): 1034–1043.
29. Bairwa, V.K., Kashyap, A.K., Meena, P., & Jain, B.P. Triphala's characteristics and potential therapeutic uses in modern health. *International Journal of Physiology, Pathophysiology and Pharmacology*, 2025; 17(2): 19–36.
30. Mukherjee, P.K., Rai, S., Bhattacharyya, S., Debnath, P.K., Biswas, T.K., Jana, U., Pandit, S., Saha, B.P., & Paul, P.K. Clinical Study of 'Triphala' – A Well Known Phytomedicine from India. *International Journal of Pharmacology and Therapeutics*, 2006.