Journal of Medicinal Natural Products

Scilight

Article

Thrombolytic and Membrane Stabilizing Activities of *Murraya koenigii* Bark and *Tinospora crispa* Stem

Joy Sarker [1,*] and Mahfuza Rahman [2]

[1] Department of Pharmacy, University of Rajshahi, Rajshahi 6205, Bangladesh
[2] Department of Pharmacy, East West University, Dhaka 1212, Bangladesh
* Correspondence: joyru.ac.bd@gmail.com; Tel.: +880-1701092224
Received: 5 January 2026; Revised: 6 February 2026; Accepted: 4 March 2026; Published: 12 March 2026

Abstract: Thrombosis and inflammation are interrelated pathological processes that play a central role in the development of cardiovascular complications. This study evaluated the thrombolytic and membrane stabilizing activities of the bark of *Murraya koenigii* and the stem of *Tinospora crispa*, two widely used medicinal plants with recognized traditional medicinal value. Crude methanolic extracts of both plant materials were first prepared. These extracts were then subjected to solvent–solvent partitioning to yield petroleum ether, dichloromethane, ethyl acetate, and aqueous fractions. Thrombolytic potential was investigated using an in vitro clot lysis assay, while membrane stabilizing activity was assessed through hypotonic solution and heat-induced hemolysis models employing human erythrocytes. The ethyl acetate fraction of *M. koenigii* bark exhibited the highest thrombolytic activity among the tested samples, whereas fractions derived from *T. crispa* stem demonstrated moderate clot lysis. In membrane stabilization assays, *M. koenigii* bark extracts showed strong inhibition of hypotonic solution–induced hemolysis, while *T. crispa* stem fractions were more effective against heat-induced hemolysis. The observed bioactivities varied across solvent fractions, indicating the influence of solvent polarity on the distribution of active constituents. These findings support the traditional use of *M. koenigii* and *T. crispa* and suggest their potential as sources of plant-derived thrombolytic and membrane stabilizing agents for managing inflammation-associated thrombotic disorders.

Keywords: *Murraya koenigii*; *Tinospora crispa*; thrombolytic activity; membrane stabilizing activity; medicinal plants; inflammation; erythrocyte hemolysis

1. Introduction

Medicinal plants constitute an essential component of traditional healthcare systems and remain a major source of bioactive compounds for modern drug discovery [1]. In developing countries such as Bangladesh, plant-based remedies continue to be extensively used for the prevention and management of various chronic diseases due to their accessibility, cultural acceptance, and perceived safety [2]. Consequently, scientific validation of medicinal plants traditionally used in Bangladesh has gained increasing attention as a rational approach for identifying novel therapeutic agents.

Thrombosis is a critical pathological process underlying numerous cardiovascular and cerebrovascular disorders, including myocardial infarction and ischemic stroke [3]. It results from an imbalance in the hemostatic system and is closely associated with inflammatory responses and oxidative stress. Inflammatory mediators contribute to endothelial dysfunction, platelet activation, and fibrin deposition, thereby promoting thrombus formation [4,5]. Although several thrombolytic drugs such as streptokinase and tissue plasminogen activator are clinically available, their use is often limited by adverse effects, high cost, bleeding complications, and immunogenic reactions [6]. These limitations highlight the need for safer and more affordable thrombolytic agents, particularly from natural sources.

Membrane stabilization represents an important mechanism underlying anti-inflammatory activity. Erythrocyte membrane stabilization models, including hypotonic solution and heat induced hemolysis assays, are widely used to assess the ability of compounds to protect cellular membranes from stress-induced damage [7]. Stabilization of erythrocyte and lysosomal membranes prevents the release of inflammatory enzymes and mediators, thereby contributing to the attenuation of inflammation and inflammation-associated thrombotic events [7,8]. Therefore,

simultaneous evaluation of thrombolytic and membrane stabilizing activities provides meaningful insight into the cardiovascular and anti-inflammatory potential of medicinal plants.

Murraya koenigii (L.) Spreng. is a medicinal plant widely distributed in Bangladesh and traditionally used for the treatment of inflammation, metabolic disorders, gastrointestinal disturbances, and cardiovascular ailments [9,10]. Previous phytochemical investigations have identified a range of bioactive constituents, including carbazole alkaloids, flavonoids, phenolics, and terpenoids, which are associated with antioxidant, anti-inflammatory, antiplatelet, and cardioprotective effects [11,12]. Despite these reported activities, the thrombolytic and erythrocyte membrane stabilizing properties of the bark of *M. koenigii* have not been sufficiently explored.

Tinospora crispa (L.) Hook. f. & Thomson is another important medicinal plant available in Bangladesh, traditionally used in folk medicine for the management of fever, inflammation, diabetes, rheumatism, and infectious diseases [13,14]. The stem of *T. crispa* is particularly valued for its therapeutic applications. Phytochemical studies have reported the presence of diterpenoids, alkaloids, glycosides, and phenolic compounds, many of which exhibit anti-inflammatory, antioxidant, immunomodulatory, and vascular protective activities [14]. However, scientific evidence regarding the thrombolytic potential and membrane stabilizing activity of *T. crispa* stem remains limited.

The bark of *M. koenigii* and the stem of *T. crispa* were deliberately selected for the present investigation based on both ethnomedicinal relevance and phytochemical considerations. In traditional medicinal practices, the bark of *M. koenigii* is commonly employed in decoctions for the management of inflammatory conditions, circulatory disorders, and pain-related ailments, suggesting the presence of bioactive constituents with vascular and membrane-protective properties. Likewise, the stem of *T. crispa* is the most frequently utilized plant part in folk medicine and traditional formulations, where it is valued for its anti-inflammatory, antipyretic, and blood-purifying properties. From a phytochemical perspective, bark and stem tissues are known to accumulate higher levels of structural secondary metabolites, including alkaloids, phenolics, and diterpenoids, which are often associated with thrombolytic and membrane stabilizing activities. Furthermore, leaves and roots of these plants have been relatively well explored in previous studies, whereas the bark of *M. koenigii* and stem of *T. crispa* remain comparatively under-investigated, justifying their selection for the present study.

Therefore, this study aimed to evaluate and compare the thrombolytic and membrane stabilizing activities of crude methanolic extracts and solvent fractions of *M. koenigii* bark and *T. crispa* stem. The findings are expected to provide scientific support for their traditional medicinal use and identify potential bioactive fractions for further pharmacological investigation.

2. Materials and Methods

2.1. Plant Material Collection

Fresh plant materials of *Murraya koenigii* and *Tinospora crispa* (L.) Hook.f. & Thomson were collected from the campus of University of Dhaka, Bangladesh, during December 2024 to January 2025. Botanical identification of both species was confirmed by a taxonomist at the Bangladesh National Herbarium, where voucher specimens were deposited under accession numbers 46310 (*M. koenigii*) and 40929 (*T. crispa*). The collected plant materials were thoroughly cleaned to remove extraneous matter before experimental use. The stem was cut into small pieces and samples were then subjected to shade drying for several days, followed by oven drying at a controlled temperature not exceeding 40 °C to prevent thermal degradation of bioactive constituents. Dried materials were subsequently pulverized into coarse powder using a mechanical grinder and stored in airtight containers until extraction.

2.2. Preparation of Crude Extract

Approximately 400 g of powdered bark and stem material from each plant were separately immersed in methanol (1.5 L) in amber-colored glass containers. The mixtures were kept at ambient temperature for 17 days with intermittent agitation to ensure effective solvent penetration and extraction. After maceration, the extracts were filtered initially through cotton wool and then through Whatman No.1 filter paper to remove particulate matter. The resulting filtrates were concentrated under reduced pressure using a rotary evaporator at low temperature to obtain crude methanolic extracts, which were preserved at 4 °C for subsequent analyses. The percentage yield of the crude methanolic extract was calculated relative to the dried plant material and found to be 9.8% (*w*/w*)* for *M. koenigii* bark and 7.6% (*w*/*w*) for *T. crispa* stem.

2.3. Solvent–Solvent Fractionation

Fractionation of the crude methanolic extracts was performed using a modified Kupchan partitioning protocol to obtain fractions of varying polarity [15]. Briefly, 5 g of each crude extract was dissolved in 10% aqueous methanol and successively partitioned with petroleum ether, dichloromethane, and ethyl acetate. The remaining aqueous portion was retained as the final fraction. Each solvent fraction was separately concentrated under reduced pressure to dryness. From 5 g of crude methanolic extract, petroleum ether (0.42 g, 8.4%), dichloromethane (0.68 g, 13.6%), ethyl acetate (1.12 g, 22.4%), and aqueous (2.58 g, 51.6%) fractions were obtained. The overall recovery was approximately 96%, with minor losses attributed to solvent handling and concentration steps. A schematic diagram of the fractionation is presented in Figure 1.

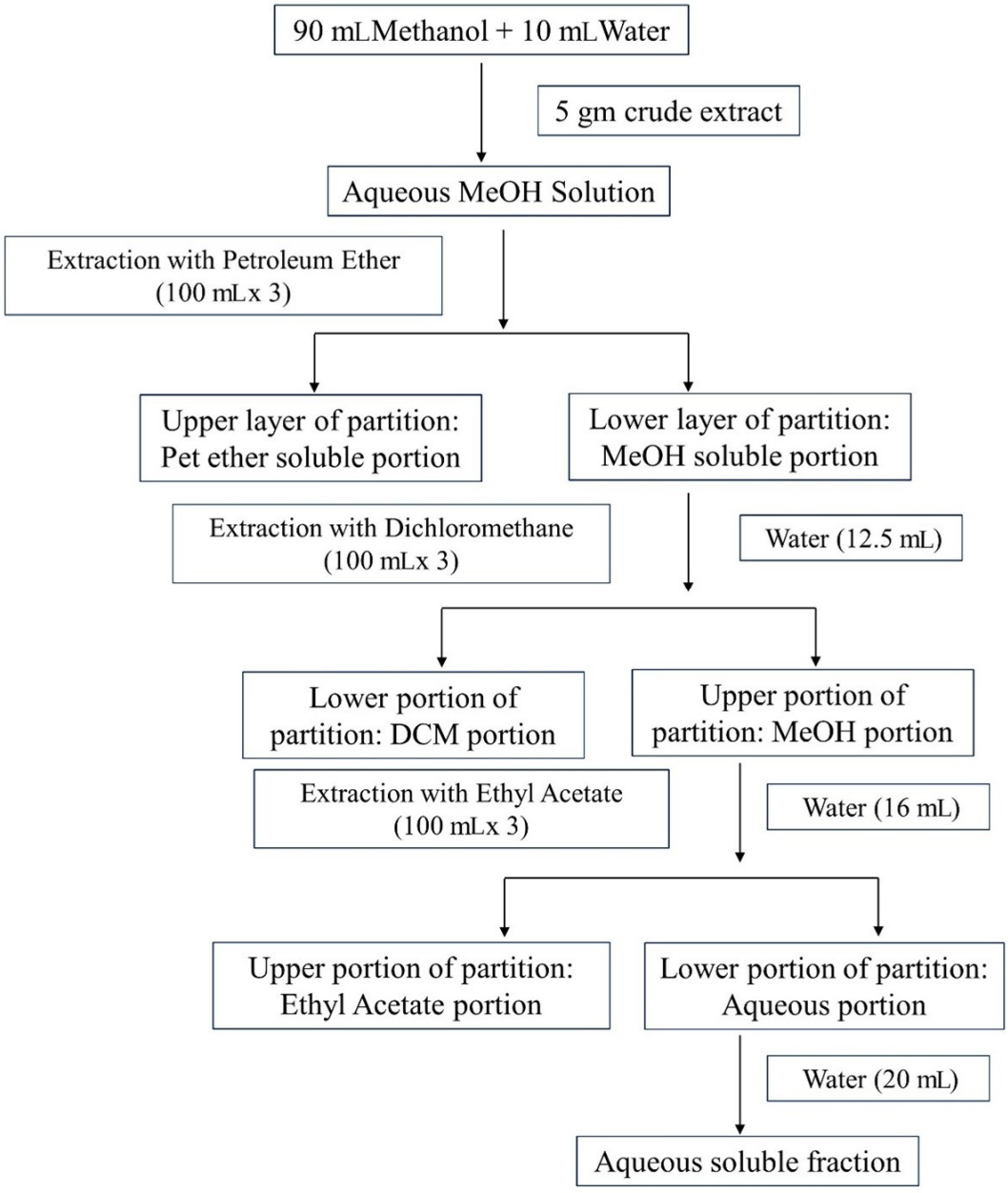

Figure 1. Schematic representation of the modified Kupchan Partitioning of crude extract of bark of *Murraya koenigii* and stem of *Tinospora crispa*.

2.4. Ethical Approval and Consent

The study protocol involving human blood samples was reviewed and approved by the Institutional Ethical Review Committee of the University of Information Technology and Sciences (UITS), Bangladesh (Approval No.: UITS/PHARM/IEC/2025/21). Venous blood was collected from healthy adult volunteers after obtaining written

informed consent, in accordance with the principles outlined in the Declaration of Helsinki. All participants were free from anticoagulant therapy and known hematological disorders at the time of sample collection.

2.5. Evaluation of Thrombolytic Activity

The thrombolytic potential of the extracts and fractions was evaluated using an in vitro clot lysis model developed by Prasad et al. [16]. Venous blood samples (5 mL) were collected from six (n = 6) healthy adult volunteers (aged 22–30 years) with no history of anticoagulant use or bleeding disorders. Aliquots of 1 mL blood were transferred into pre-weighed sterile microcentrifuge tubes and incubated at 37 °C for 45 min to allow clot formation. Following clot formation, serum was carefully aspirated without disturbing the clot, and the tubes were reweighed to determine clot mass. Each clot-containing tube received 100 µL of test sample solution (10 mg/mL), resulting in a final assay concentration of 10 mg/mL for all extracts and fractions. Streptokinase (30,000 IU) was used as the positive control, while distilled water served as the negative control. The tubes were incubated at 37 °C for 90 min to facilitate clot dissolution. After incubation, released fluid was removed, and tubes were weighed again. The percentage of clot lysis was calculated using the following equation:

$$\text{Clot lysis (\%)} = \frac{\text{Weight of released clot}}{\text{Initial clot weight}} \times 100$$

2.6. Hypotonic Solution–Induced Hemolysis Assay

Membrane stabilizing activity was assessed using a hypotonic solution–induced hemolysis method developed by Sonter *et al.* [17]. A suspension of human erythrocytes was prepared and mixed with hypotonic saline (50 mM NaCl) in 10 mM phosphate-buffered saline (pH 7.4). Test samples were added to the reaction mixtures to achieve a final concentration of 1.0 mg/mL in the assay system, while acetyl salicylic acid (0.10 mg/mL) was employed as a reference standard. The same final concentration was used for all extracts and fractions. The mixtures were incubated under controlled conditions, followed by centrifugation. The absorbance of the supernatant was measured spectrophotometrically, and the percentage inhibition of hemolysis was calculated as:

$$\text{Inhibition of hemolysis (\%)} = \frac{(\text{OD1} - \text{OD2})}{\text{OD1}} \times 100$$

where OD1 represents the absorbance of the control and OD2 denotes the absorbance of the test sample.

2.7. Heat-Induced Hemolysis Assay

The protective effect of the extracts on erythrocyte membranes under thermal stress was evaluated using a heat-induced hemolysis model [17]. Reaction mixtures containing erythrocyte suspension and test samples were incubated at elevated temperature, while parallel sets were maintained at room temperature. Following incubation, the samples were centrifuged, and the absorbance of the supernatants was recorded. The percentage inhibition of hemolysis was calculated using the following formula:

$$\text{Inhibition of hemolysis (\%)} = 100 \times \left[1 - \frac{(\text{OD2} - \text{OD1})}{(\text{OD3} - \text{OD1})}\right]$$

where OD1, OD2, and OD3 correspond to absorbance values of unheated control, heated test sample, and heated control, respectively.

2.8. Statistical Analysis

All experiments were performed in triplicate (n = 3 independent measurements per sample), and results are expressed as mean ± standard error of the mean (SEM). Statistical analysis and graphical presentation were carried out using GraphPad Prism software (version 9.5.0). Comparisons between each test sample and the negative control were performed using Student's *t*-test (two-tailed). A value of $p < 0.05$ was considered statistically significant.

3. Results

3.1. Thrombolytic Activity

The thrombolytic activity of the crude methanolic extracts and their solvent-partitioned fractions obtained from the bark of *Murraya koenigii* and the stem of *Tinospora crispa* was assessed using an in vitro clot lysis assay. Streptokinase, used as a positive control, produced extensive clot dissolution, whereas distilled water resulted in

minimal clot lysis, confirming assay reliability. Among the *M. koenigii* samples, the ethyl acetate fraction exhibited the highest thrombolytic activity (42.04 ± 0.84%), which was significantly higher than the negative control ($p < 0.001$) and also markedly greater than the other solvent fractions. The methanolic extract and petroleum ether fraction showed moderate but statistically significant clot lysis ($p < 0.01$), while the dichloromethane and aqueous fractions demonstrated lower yet significant activity ($p < 0.05$). In the case of *T. crispa* stem, the aqueous fraction (31.10 ± 0.56%) and dichloromethane fraction (25.13 ± 1.66%) showed significant thrombolytic activity compared to the negative control ($p < 0.01$). The methanolic extract exhibited moderate activity ($p < 0.05$), whereas the petroleum ether fraction did not show a statistically significant effect (ns). The thrombolytic activities of all extracts and fractions are presented in Figure 2.

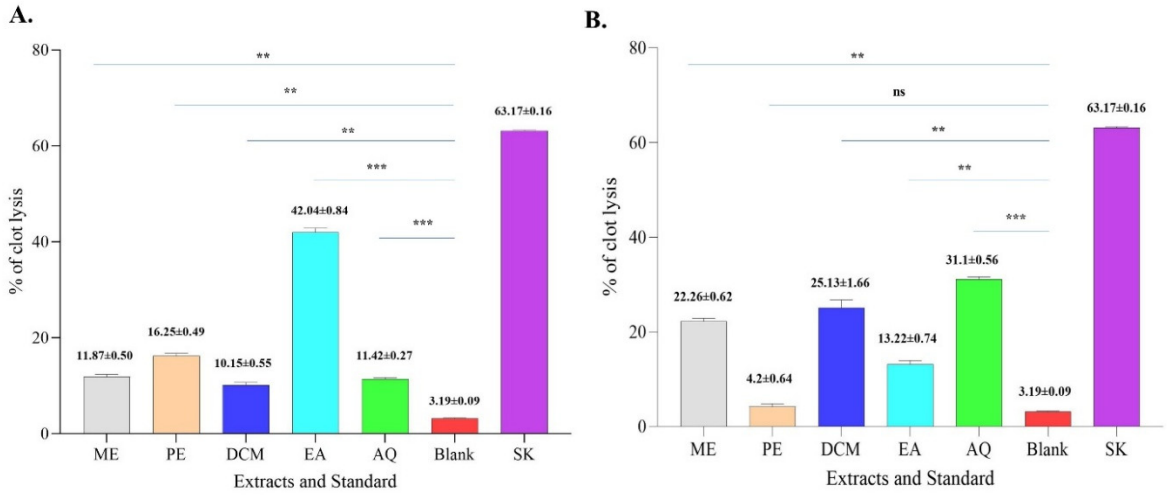

Figure 2. Thrombolytic activity (% clot lysis) of different fractions of crude methanolic extract of (**A**) bark of *Murraya koenigii* and (**B**) stem of *Tinospora crispa*. Data are expressed as mean ± SEM (n = 3). Statistical comparisons were performed against the negative control (Blank: distilled water) using Student's *t*-test (two-tailed). Significance levels are indicated as ** $p < 0.01$; *** $p < 0.001$; ns = not significant. ME = Methanolic extract; PE = Petroleum ether; DCM = Dichloromethane; EA = Ethyl acetate; AQ = Aqueous fraction; SK = Streptokinase.

3.2. Hypotonic Solution–Induced Hemolysis

The membrane stabilizing potential of the extracts was first evaluated under hypotonic stress conditions. In this model, the methanolic extract and aqueous fraction of *M. koenigii* bark showed strong inhibition of erythrocyte hemolysis of 92.65 ± 1.91% and 78.31 ± 0.65%, respectively, as compared to 71.79 ± 0.40% inhibited by acetyl salicylic acid (0.10 mg/mL). The petroleum ether, dichloromethane, and ethyl acetate fractions of *M. koenigii* also exhibited notable membrane stabilization, albeit at lower levels.

In contrast, the extracts and fractions derived from *T. crispa* stem demonstrated comparatively lower inhibition of hemolysis in the hypotonic solution model. Mild membrane stabilizing activity was observed in the dichloromethane (34.52 ± 1.41%) and ethyl acetate fractions (25.43 ± 1.43%), whereas other fractions showed minimal protection. The results are summarized in Table 1.

3.3. Heat-Induced Hemolysis

In the heat-induced hemolysis assay, several fractions from both plant species displayed significant membrane protective effects. The ethyl acetate and petroleum ether fractions of *M. koenigii* bark showed pronounced inhibition of heat-induced erythrocyte lysis of 44.46 ± 1.34% and 32.61 ± 1.01%, comparable to the standard acetyl salicylic acid (41.84 ± 0.41%). Other fractions demonstrated moderate activity.

For *T. crispa* stem, the dichloromethane and ethyl acetate fractions exhibited the highest inhibition of heat-induced hemolysis of 45.18 ± 1.34% and 44.56 ± 1.01%, respectively, while the remaining fractions showed weak to moderate effects. A detailed comparison of membrane stabilizing activities under heat-induced conditions is provided in Table 1.

Table 1. Membrane stabilizing activities of bark extracts of *M. koenigii* and stem extracts of *T. crispa.*

Plant species	Fraction	Hypotonic Solution–Induced (% Inhibition)	Heat-Induced (% Inhibition)
M. koenigii	ME	92.65 ± 1.91	27.29 ± 0.76
	PE	41.81 ± 0.62	32.61 ± 1.01
	DCM	49.99 ± 0.90	22.34 ± 0.79
	EA	62.46 ± 0.94	44.46 ± 1.34
	AQ	78.31 ± 0.65	18.38 ± 0.64
T. crispa	ME	14.23 ± 0.82	52.00 ± 1.65
	PE	6.92 ± 0.41	12.94 ± 0.88
	DCM	25.43 ± 1.43	45.18 ± 1.34
	EA	34.52 ± 1.41	44.56 ± 1.01
	AQ	9.33 ± 0.37	7.55 ± 0.56
ASA	-	71.79 ± 0.40	41.84 ± 0.41

Note: ME = Methanolic extract; PE = Pet-ether; DCM = Dichloromethane; EA = Ethyl acetate; AQ = Aqueous fraction; ASA = Acetyl salicylic acid.

4. Discussion

Thrombotic disorders are frequently associated with inflammatory processes and oxidative stress, creating an interdependent pathophysiological cycle that accelerates vascular injury [18]. The present study investigated the thrombolytic and membrane stabilizing properties of *M. koenigii* bark and *T. crispa* stem extracts, two widely available plants with longstanding ethnomedicinal relevance.

The notable thrombolytic activity observed in the ethyl acetate fraction of *M. koenigii* bark suggests that semi-polar phytoconstituents play a dominant role in fibrin clot dissolution. Previous phytochemical studies have reported that *M. koenigii* contains carbazole alkaloids, flavonoids, and phenolic compounds, several of which are known to interfere with platelet aggregation and coagulation pathways [19,20]. The moderate thrombolytic activity detected in *T. crispa* fractions may be attributed to essential oils and polyphenolic compounds that influence hemostatic balance indirectly.

Membrane stabilization assays provide valuable insight into the anti-inflammatory potential of test substances by evaluating their ability to protect erythrocytes against physical and osmotic stress [21]. In the hypotonic solution-induced model, *M. koenigii* bark extracts demonstrated superior membrane stabilizing effects compared to *T. crispa* stem. This strong protection against osmotic lysis indicates an enhanced capacity to preserve membrane integrity, possibly through interactions between polyphenolic compounds and membrane proteins or phospholipid bilayers [22].

Despite its ethnomedicinal relevance, several *T. crispa* stem fractions exhibited relatively low membrane stabilizing activity in the hypotonic solution–induced hemolysis model. Notably, the methanolic extract (14.23%) and petroleum ether fraction (6.92%) showed weak protection against osmotic stress. The hypotonic hemolysis assay primarily reflects the ability of test substances to counteract membrane rupture caused by osmotic imbalance, a process often associated with the presence of polar or amphipathic phytoconstituents such as flavonoids and phenolic acids. The limited activity of these *T. crispa* fractions may therefore indicate a lower abundance, reduced accessibility, or weaker membrane affinity of such compounds in the stem, particularly within non-polar and crude extracts.

In contrast, *T. crispa* stem extracts exhibited greater efficacy in the heat-induced hemolysis model than in hypotonic conditions. Heat-induced membrane damage primarily involves protein denaturation and disruption of lipid organization, suggesting that certain constituents of *T. crispa* may be more effective in stabilizing membrane proteins under thermal stress [23]. This differential activity between hypotonic and heat-induced assays highlights the presence of distinct bioactive components acting through different protective mechanisms.

The combined thrombolytic and membrane stabilizing activities observed in this study are pharmacologically significant, as membrane stabilization can suppress the release of inflammatory mediators that contribute to thrombus formation. The fraction-dependent nature of the observed effects underscores the importance of solvent polarity in isolating biologically active constituents and supports the rationale for further bioassay-guided fractionation.

Overall, the findings support the traditional use of *M. koenigii* and *T. crispa* in managing inflammation-related disorders. However, while *M. koenigii* bark exhibited consistently strong thrombolytic and membrane stabilizing activities, the effects of *T. crispa* stem were more variable and generally weaker, particularly in the hypotonic hemolysis model. Nevertheless, selected *T. crispa* fractions demonstrated promising activity against heat-induced hemolysis, indicating their potential as sources of lead compounds for the development of safer, plant-derived thrombolytic and anti-inflammatory agents.

5. Conclusions

The present study demonstrates that the bark of *Murraya koenigii* exhibits consistently strong thrombolytic and membrane stabilizing activities across multiple solvent fractions, particularly in the hypotonic solution–induced hemolysis model. In contrast, the stem of *Tinospora crispa* displayed variable and generally weaker membrane stabilizing activity, with limited effects observed in the hypotonic model but comparatively better protection against heat-induced hemolysis in selected fractions. These findings suggest that while certain fractions of *T. crispa* stem show pharmacological promise, its overall activity in erythrocyte membrane stabilization assays is less pronounced than that of *M. koenigii*. Further bioassay-guided investigations are warranted to isolate and characterize the specific constituents responsible for the observed model-dependent effects.

Author Contributions: Conceptualization: J.S.; Methodology: M.R. and J.S.; Investigation: M.R.; Data Curation: M.R.; Formal Analysis: M.R.; Software: M.R.; Validation: J.S.; Visualization: J.S.; Writing—Original Draft: J.S.; Writing—Review & Editing: M.R. and J.S.; Supervision: J.S.; Resources: J.S.; Correspondence: J.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This research project has received ethical approval from the Institutional Ethical Review Committee of the University of Information Technology and Sciences (UITS), Bangladesh (Approval No.: UITS/PHARM/IEC/2025/21). Venous blood was collected from healthy adult volunteers after obtaining written informed consent, in accordance with the principles outlined in the Declaration of Helsinki

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors wish to thank the Department of Pharmacy, University of Information Technology and Sciences (UITS), for their kind support in the progress of the research.

Conflicts of Interest: The authors declare no conflict of interest."

Use of AI and AI-Assisted Technologies: During the preparation of this work, the authors used ChatGPT to improve the readability of the article, mainly the introduction and discussion sections. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Abbreviations

ME, Methanolic extract; PE, Petroleum ether fraction; DCM, Dichloromethane fraction; EA, Ethyl acetate fraction; AQ, Aqueous fraction; ASA, Acetyl salicylic acid; SK, Streptokinase; RBC, Red blood cell; OD, Optical density; SEM, Standard error of the mean.

References

1. Newman, D.J.; Cragg, G.M. Natural Products as Sources of New Drugs over the Nearly Four Decades from 01/1981 to 09/2019. *J. Nat. Prod.* **2020**, *83*, 770–803. https://doi.org/10.1021/acs.jnatprod.9b01285.
2. Poli, M.A.; Hossain, M.J.; Kholil, I.; et al. Traditional Medicine Use and Associated Factors in Chronic Patients in Jamalpur, Bangladesh: A Cross-Sectional Study. *Front. Public Health* **2025**, *13*, 1548728. https://doi.org/10.3389/fpubh.2025.1548728.
3. Libby, P.; Ridker, P.M.; Hansson, G.K.; et al. Inflammation in Atherosclerosis: From Pathophysiology to Practice. *J. Am. Coll. Cardiol.* **2009**, *54*, 2129–2138. https://doi.org/10.1016/j.jacc.2009.09.009.
4. Theofilis, P.; Sagris, M.; Antonopoulos, A.S.; et al. Inflammatory Mediators of Platelet Activation: Focus on Atherosclerosis and COVID-19. *Int. J. Mol. Sci.* **2021**, *22*, 11170. https://doi.org/10.3390/ijms222011170.
5. Shebuski, R.J.; Kilgore, K.S. Role of Inflammatory Mediators in Thrombogenesis. *J. Pharmacol. Exp. Ther.* **2002**, *300*, 729–735. https://doi.org/10.1124/jpet.300.3.729.
6. Tisdale, J.E.; Colucci, R.D.; Ujhelyi, M.R.; et al. Evaluation and Comparison of the Adverse Effects of Streptokinase and Alteplase. *Pharmacotherapy* **1992**, *12*, 440–444.
7. Anosike, C.A.; Obidoa, O.; Ezeanyika, L.U. Membrane Stabilization as a Mechanism of the Anti-Inflammatory Activity of Methanol Extract of Garden Egg (*Solanum aethiopicum*). *DARU J. Pharm. Sci.* **2012**, *20*, 76. https://doi.org/10.1186/2008-2231-20-76.
8. Aidoo, D.B.; Konja, D.; Henneh, I.T.; et al. Protective Effect of Bergapten against Human Erythrocyte Hemolysis and Protein Denaturation *In Vitro*. *Int. J. Inflamm.* **2021**, *2021*, 1279359. https://doi.org/10.1155/2021/1279359.
9. Suthar, P.; Kumar, S.; Kumar, V.; et al. *Murraya koenigii* (L.) Spreng: Speculative Ethnobotanical Perspectives of Ubiquitous Herb with Versatile Nutra/Functional Properties. *S. Afr. J. Bot.* **2022**, *145*, 111–134. https://doi.org/10.1016/j.sajb.2021.11.025.
10. Nandy, S.; Das, S. Unveiling the Diverse Medicinal Properties of *Murraya koenigii*. *Sci. Phytochem.* **2023**, *2*, 211–225. https://doi.org/10.58920/sciphy02020107.

11. Tan, M.A.; Sharma, N.; An, S.S.A. Multi-Target Approach of *Murraya koenigii* Leaves in Treating Neurodegenerative Diseases. *Pharmaceuticals* **2022**, *15*, 188. https://doi.org/10.3390/ph15020188.
12. Jachak, S.; Singh, M.; Ahirrao, P.; et al. *Murraya koenigii* (L.) Spreng. as a Natural Intervention for Diabesity: A Review. *Curr. Pharm. Des.* **2024**, *30*, 3255–3275. https://doi.org/10.2174/0113816128304471240801183021.
13. Haque, E.; Bari, M.S.; Khandokar, L.; et al. An Updated and Comprehensive Review on the Ethnomedicinal Uses, Phytochemistry, Pharmacological Activity and Toxicological Profile of *Tinospora crispa* (L.) Hook. f. & Thomson. *Phytochem. Rev.* **2023**, *22*, 211–273. https://doi.org/10.1007/s11101-022-09843-y.
14. Ahmad, W.; Jantan, I.; Bukhari, S.N.A. *Tinospora crispa* (L.) Hook. f. & Thomson: A Review of Its Ethnobotanical, Phytochemical, and Pharmacological Aspects. *Front. Pharmacol.* **2016**, *7*, 59. https://doi.org/10.3389/fphar.2016.00059.
15. Reza, A.S.M.A.; Haque, M.A.; Sarker, J.; et al. Antiproliferative and Antioxidant Potentials of Bioactive Edible Vegetable Fraction of *Achyranthes Ferruginea* Roxb. in Cancer Cell Line. *Food Sci. Nutr.* **2021**, *9*, 3777–3805. https://doi.org/10.1002/fsn3.2343.
16. Prasad, S.; Kashyap, R.S.; Deopujari, J.Y.; et al. Development of an in Vitro Model to Study Clot Lysis Activity of Thrombolytic Drugs. *Thromb. J.* **2006**, *4*, 14. https://doi.org/10.1186/1477-9560-4-14.
17. Sonter, S.; Mishra, S.; Dwivedi, M.K.; Singh, P.K. Chemical Profiling, *In Vitro* Antioxidant, Membrane Stabilizing and Antimicrobial Properties of Wild Growing *Murraya Paniculata* from Amarkantak (M.P.). *Sci. Rep.* **2021**, *11*, 9691, https://doi.org/10.1038/s41598-021-87404-7.
18. Xu, H.; Yang, J.; Wei, Z.; et al. Oxidative Stress in Vascular Surgical Diseases: Mechanisms, Impacts and Therapeutic Perspectives. *Front. Pharmacol.* **2025**, *16*, 1527684. https://doi.org/10.3389/fphar.2025.1527684.
19. Franyoto, Y.D.; Nurrochmad, A.; Fakhrudin, N. *Murraya koenigii* L. Spreng.: An Updated Review of Chemical Composition, Pharmacological Effects, and Toxicity Studies. *J. Appl. Pharm. Sci.* **2024**, *14*, 011–027. https://doi.org/10.7324/JAPS.2024.169254.
20. Balakrishnan, R.; Vijayraja, D.; Jo, S.-H.; et al. Medicinal Profile, Phytochemistry, and Pharmacological Activities of *Murraya koenigii* and Its Primary Bioactive Compounds. *Antioxidants* **2020**, *9*, 101. https://doi.org/10.3390/antiox9020101.
21. Shinde, U.A.; Phadke, A.S.; Nair, A.M.; et al. Membrane Stabilizing Activity—A Possible Mechanism of Action for the Anti-Inflammatory Activity of *Cedrus deodara* Wood Oil. *Fitoterapia* **1999**, *70*, 251–257. https://doi.org/10.1016/S0367-326X(99)00030-1.
22. Arora, A.; Byrem, T.M.; Nair, M.G.; et al. Modulation of Liposomal Membrane Fluidity by Flavonoids and Isoflavonoids. *Arch. Biochem. Biophys.* **2000**, *373*, 102–109. https://doi.org/10.1006/abbi.1999.1525.
23. Niu, Y.; Xiang, Y. An Overview of Biomembrane Functions in Plant Responses to High-Temperature Stress. *Front. Plant Sci.* **2018**, *9*, 915. https://doi.org/10.3389/fpls.2018.00915.