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Editorial: Pharmacological advancements of novel natural-based nanomedicines

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Editorial on the Research Topic
Pharmacological advancements of novel natural-based nanomedicines

Natural-based nanomedicines are increasingly recognized as a transformative approach for enhancing drug delivery, therapeutic precision, and safety profiles through the integration of nanotechnology with biologically derived materials (Spanakis et al., 2014; Li et al., 2022; Azahar et al., 2025; Jahangirian et al., 2017; Manzari-Tavakoli et al., 2024; Ayub et al., 2025; Parvin et al., 2025; Salama et al., 2020). This Research Topic set out to highlight cutting-edge scientific advances that address key pharmacological, biopharmaceutical, and safety challenges in developing advanced drug delivery systems from natural-derived materials, encompassing bioavailability enhancement, sustainable design, and translational strategies.

The central aim was to bridge foundational nanoformulation science with translational pharmacology and regulatory considerations, while presenting multidisciplinary insights into Research Topic such as nano-encapsulation of phytochemicals, biosafety and toxicity assessment, computational prediction of pharmacokinetics, and pragmatic approaches for clinical translation (Parvin et al., 2025; Tripathi et al., 2024; Kim et al., 2025; Ahmad et al., 2022; Saidi et al., 2025). The collected contributions highlight advances spanning metabolic disorders, oncology, wound healing, neurological injury, and emerging nanovesicle technologies, while emphasizing sustainability, mechanistic insight, and translational feasibility.

A central objective of this Research Topic was to demonstrate how nano-engineering can overcome intrinsic limitations of natural compounds that otherwise constrain therapeutic application (Andreani et al., 2024; Han et al., 2022). The study of Moin et al., "*Piperine-loaded solid lipid nanoparticles: a promising nano-phytomedicine for the treatment of non-alcoholic fatty liver disease*" illustrates this principle by encapsulating piperine into solid lipid nanoparticles to enhance oral bioavailability and prolong hepatic circulation. The formulation exhibited sustained release behavior and significantly improved metabolic and hepatic parameters in a hyperlipidaemic mouse model compared with free piperine, underscoring the pharmacological value of nano-encapsulation in improving therapeutic exposure and efficacy.

The therapeutic potential of natural nanoformulations is further exemplified in hepatic disease management. In the work of Hu et al., "*Ursolic acid drug-drug*

nanocrystals ameliorate cholestatic liver injury via inhibiting oxidative stress and regulating bile acid metabolism," co-assembled nanocrystals composed of ursolic acid and α-tocopherol succinate demonstrated enhanced dissolution, improved bioavailability, and restoration of liver function in a cholestatic injury model. Mechanistically, the formulation modulated oxidative stress pathways and bile acid metabolism, highlighting the importance of rational nano-design in targeting disease-specific molecular networks. These findings collectively reinforce the role of nanocarriers in enabling synergistic pharmacodynamics and improving treatment outcomes in liver pathology (Padmanaban et al., 2025; Zhu et al., 2025).

Natural nanomedicine also holds promise in regenerative and neurological contexts. The study "*Unveiling the effects of Rosa canina oligosaccharide liposome on neuropathic pain and motor dysfunction following spinal cord injury in rats*" from Ahmadpour et al., investigates a liposomal nanoformulation designed to mitigate oxidative stress following spinal cord injury. Treatment improved sensory-motor function, enhanced antioxidant defenses, and promoted neuronal survival, demonstrating how nano-delivery systems can support neuroprotection and functional recovery. These findings contribute to the growing evidence supporting antioxidant-based nanotherapies in neurological disorders (Talaat et al., 2025; Li et al., 2020).

Chronic wound management represents another major translational challenge addressed within this Research Topic. The review work from Yadav et al., "*Therapies and delivery systems for diabetic wound care: current insights and future directions*" discusses current understanding of diabetic wound pathophysiology and examines how nano-enabled delivery systems enhance the therapeutic performance of plant-derived bioactive formulations. By integrating phytochemicals with polymeric or metallic nanocarriers, targeted delivery, antimicrobial action, and tissue regeneration may be improved. The review also contextualizes emerging nano-therapies within ongoing clinical and patent developments, bridging experimental innovation with clinical implementation pathways (Psarrou et al., 2023; Ansari and Darvishi, 2024; Kammona et al., 2024; Ahmad et al., 2025; Siafaka et al., 2025).

In oncology, natural nanomaterials are increasingly explored for targeted therapy and diagnostic applications. The review from Pandey et al., "*Biosynthesis of silver nanoparticles from plant extracts: a comprehensive review focused on anticancer therapy*" provides an extensive overview of plant-mediated silver nanoparticle synthesis and their emerging roles in cancer detection and treatment. By leveraging phytochemicals as reducing and stabilizing agents, green-synthesized nanoparticles offer a sustainable strategy to enhance selectivity and reduce toxicity compared with conventional treatments. Complementing this perspective, the research article of Cui et al., "*Plant-derived extracellular nanovesicles: a promising biomedical approach for effective targeting of triple negative breast cancer cells*" presents experimental data considering the anticancer activity of Citrus limon-derived extracellular nanovesicles. These vesicles demonstrated cellular uptake, suppression of proliferation and migration, and modulation of PI3K/AKT and MAPK/ERK signaling pathways in triple negative breast cancer models. Overall, both findings highlight the convergence of green chemistry, and nanotechnology, as a promising direction for future therapeutic developments in oncology (Bakhshan et al., 2025; Zhang et al., 2026; Zhou et al., 2026; Ion et al., 2021; M et al., 2025; Zango et al., 2023; Fraguas-Sá et al., 2025; Spanakis et al., 2024; Vizirianakis et al., 2016).

Beyond experimental advances, understanding research trajectories is essential for guiding future innovation. The bibliometric analysis "*Unveiling the dynamic trends of plant-derived exosome nanovesicles-based theranostics: through bibliometric and visualized analysis*" from Cao et al., maps the years of scientific activity in plant-derived nanovesicle research. By identifying dominant research themes, contributing institutions, and emerging hotspots, this work provides a strategic overview of the field's evolution and highlights opportunities for interdisciplinary collaboration and translational advancement (Elayaperumal et al., 2025; Barathi et al., 2024; Agrahari and Agrahari, 2018; Xing et al., 2025; Barkat et al., 2020).

Across these contributions, several cross-cutting themes emerge. First, nano-encapsulation consistently enhances pharmacokinetic performance and therapeutic stability of natural compounds, reinforcing the importance of formulation science in maximizing biological activity (Goktas et al., 2020; Shaji and Jayasri, 2023; Sadr et al., 2025; Papadimitriou et al., 2008; Umar et al., 2025). Second, sustainability and biosafety remain essential considerations, particularly in the context of green synthesis and long-term biological interactions of nanomaterials (Bai et al., 2024; Xuan et al., 2023; Oladipupo et al., 2025; Fadeel et al., 2018). Third, mechanistic understanding linking nano-structure to biological function is increasingly emphasized, supporting rational design strategies for targeted therapy (Moyano and Rotello, 2011; Liu and Tang, 2017; Chehelgerdi et al., 2023; Shan et al., 2024; Han et al., 2025). Finally, translational progress will depend on integrating predictive modeling, standardized characterization, and regulatory frameworks to bridge preclinical success with clinical application (Ozbek et al., 2024; Rodríguez-Gó et al., 2025; Bobo et al., 2016; Desai et al., 2025).

In summary, this Research Topic highlights the extent and momentum of natural-based nanomedicine research, spanning fundamental formulation science to disease-specific therapeutic applications. The collected works demonstrate that natural nano-formulations can enhance drug performance, modulate disease pathways, and offer sustainable alternatives to conventional therapies. Continued interdisciplinary collaboration and rigorous translational strategies will be essential to fully realize the clinical potential of these emerging pharmacological technologies.

Author contributions

MS: Conceptualization, Project administration, Resources, Supervision, Visualization, Writing – original draft,

Writing – review and editing. AF: Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review and editing. SP: Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review and editing.

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References

Agrahari, V., and Agrahari, V. (2018). Facilitating the translation of nanomedicines to a clinical product: challenges and opportunities. *Drug Discov. Today* 23, 974–991. doi:10.1016/j.drudis.2018.01.047

Ahmad, A., Imran, M., and Sharma, N. (2022). Precision nanotoxicology in drug development: current trends and challenges in safety and toxicity implications of customized multifunctional nanocarriers for drug-delivery applications. *Pharmaceutics* 14, 2463. doi:10.3390/pharmaceutics14112463

Ahmad, U., Hanaffi, W. N. W., Islam, A., Salman, A., Khan, M. M., Shakeel, F., et al. (2025). Cutting edge strategies for diabetic wound care: nanotechnology, bioengineering, and beyond. *BMEMat*, e70033. doi:10.1002/bmm2.70033

Andreani, T., Cheng, R., Elbadri, K., Ferro, C., Menezes, T., dos Santos, M. R., et al. (2024). Natural compounds-based nanomedicines for cancer treatment: future directions and challenges. *Drug Deliv. Transl. Res.* 14, 2845–2916. doi:10.1007/s13346-024-01649-z

Ansari, M., and Darvishi, A. (2024). A review of the current state of natural biomaterials in wound healing applications. *Front. Bioeng. Biotechnol.* 12. doi:10.3389/fbioe.2024.1309541

Ayub, A., Wani, A. K., Malik, S. M., Ayub, M., Singh, R., Chopra, C., et al. (2025). Green nanoscience for healthcare: advancing biomedical innovation through eco-synthesized nanoparticle. *Biotechnol. Rep.* 47, e00913. doi:10.1016/j.btre.2025.e00913

Azahar, N. I., Arifin, M. A., and Mahmood, S. (2025). *Natural product-based nanomedicine. Nanoengineered materials for medical and healthcare applications*, 53–91. doi:10.1002/9781119792192.ch3

Bai, C., liu, J., Zhang, X., Li, Y., Qin, Q., Song, H., et al. (2024). Research status and challenges of plant-derived exosome-like nanoparticles. *Biomed. Pharmacother.* 174, 116543. doi:10.1016/j.biopha.2024.116543

Bakhshan, M. A., Sheikhzadeh, S., Ramezanimoladehi, M., Pourkamalzadeh, M., and Sheikhzadeh, S. (2025). Nano-phytochemical-based formulations as promising opportunities for prostate cancer therapy and management: a comprehensive narrative review. *Med. Oncol.* 42, 510. doi:10.1007/s12032-025-03059-8

Barathi, S., Ramalingam, S., Krishnasamy, G., and Lee, J. (2024). Exploring the biomedical frontiers of plant-derived nanoparticles: synthesis and biological reactions. *Pharmaceutics* 16, 923. doi:10.3390/pharmaceutics16070923

Barkat, M. A., Harshita, D. S. S., Beg, S., and Ahmad, F. J. (2020). Nanotechnology-based phytotherapeutics: current status and challenges. *Nanophytomedicine*, 1–17. doi:10.1007/978-981-15-4909-0_1

Bobo, D., Robinson, K. J., Islam, J., Thurecht, K. J., and Corrie, S. R. (2016). Nanoparticle-based medicines: a review of FDA-approved materials and clinical trials to date. *Pharm. Res.* 33, 2373–2387. doi:10.1007/s11095-016-1958-5

Chehelgerdi, M., Chehelgerdi, M., Allela, O. Q. B., Pecho, R. D. C., Jayasankar, N., Rao, D. P., et al. (2023). Progressing nanotechnology to improve targeted cancer treatment: overcoming hurdles in its clinical implementation. *Mol. Cancer* 22, 169. doi:10.1186/s12943-023-01865-0

Desai, N., Rana, D., Patel, M., Bajwa, N., Prasad, R., and Vora, L. K. (2025). Nanoparticle therapeutics in clinical perspective: classification, marketed products, and regulatory landscape. *Small* 21, 2502315. doi:10.1002/smll.202502315

Elayaperumal, S., Sivamani, Y., Agarwal, P., and Srivastava, N. (2025). Plant-based nanotherapeutics: a new frontier in disease management and prevention. *Nano TransMed* 4, 100086. doi:10.1016/j.ntm.2025.100086

Fadeel, B., Farcal, L., Hardy, B., Vázquez-Campos, S., Hristozov, D., Marcomini, A., et al. (2018). Advanced tools for the safety assessment of nanomaterials. *Nat. Nanotechnol.* 13, 537–543. doi:10.1038/s41565-018-0185-0

Fraguas-Sánchez, A. I., Martín-Sabroso, C., Lozza, I., and Torres-Suárez, A. I. (2025). *Nanomedicine applications in cancer treatment*, 205–241. doi:10.1007/978-3-032-00773-5_294

Goktas, Z., Zu, Y., Abbasi, M., Galyean, S., Wu, D., Fan, Z., et al. (2020). Recent advances in nanoencapsulation of phytochemicals to combat obesity and its comorbidities. *J. Agric. Food Chem.* 68, 8119–8131. doi:10.1021/acs.jafc.0c00131

Han, H. S., Koo, S. Y., and Choi, K. Y. (2022). Emerging nanoformulation strategies for phytocompounds and applications from drug delivery to phototherapy to imaging. *Bioact. Mater.* 14, 182–205. doi:10.1016/j.bioactmat.2021.11.027

Han, Y., Kim, D. H., and Pack, S. P. (2025). Nanomaterials in drug delivery: leveraging artificial intelligence and big data for predictive design. *Int. J. Mol. Sci.* 26, 11121. doi:10.3390/ijms262211121

Ion, D., Niculescu, A. G., Păduraru, D. N., Andronic, O., Muşat, F., Grumezescu, A. M., et al. (2021). An up-to-date review of natural nanoparticles for cancer management. *Pharmaceutics* 14, 18. doi:10.3390/pharmaceutics14010018

Jahangirian, H., Lemraski, E. G., Webster, T. J., Rafiee-Moghaddam, R., and Abdollahi, Y. (2017). A review of drug delivery systems based on nanotechnology and green chemistry: green nanomedicine. *Int. J. Nanomedicine* 12, 2957–2978. doi:10.2147/IJN.S127683

Kammona, O., Vamvakaki, M., and Tamerler, C. (2024). Editorial: biomaterials for chronic wound healing. *Front. Bioeng. Biotechnol.* 12, 1430646. doi:10.3389/fbioe.2024.1430646

Kim, H. K., Kim, S. J., Gil, W. J., and Yang, C. S. (2025). Exploring the therapeutic potential of phytochemicals: challenges and strategies for clinical translation. *Phytomedicine* 145, 157090. doi:10.1016/j.phymed.2025.157090

Li, C. W., Li, L. L., Chen, S., Zhang, J. X., and Lu, W. L. (2020). Antioxidant nanotherapies for the treatment of inflammatory diseases. *Front. Bioeng. Biotechnol.* 8, 525724. doi:10.3389/fbioe.2020.00200

Li, Z., Zhao, T., Li, J., Yu, Q., Feng, Y., Xie, Y., et al. (2022). Nanomedicine based on natural products: improving clinical application potential. *J. Nanomater* 2022, 3066613. doi:10.1155/2022/3066613

Liu, X. Q., and Tang, R. Z. (2017). Biological responses to nanomaterials: understanding nano-bio effects on cell behaviors. *Drug Deliv.* 24, 1–15. doi:10.1080/10717544.2017.1375577

M, M., Sagadevan, S., Suryadevara, P. R., Sudhan, H. H., Rao Burle, G. S., Ruokolainen, J., et al. (2025). Cytotoxicity and targeted drug delivery of green synthesized metallic nanoparticles against oral cancer: a review. *Inorg. Chem. Commun.* 173, 113806. doi:10.1016/j.inoche.2024.113806

Manzari-Tavakoli, A., Babajani, A., Tavakoli, M. M., Safaeinejad, F., and Jafari, A. (2024). Integrating natural compounds and nanoparticle-based drug delivery systems: a

novel strategy for enhanced efficacy and selectivity in cancer therapy. *Cancer Med.* 13, e7010. doi:10.1002/cam4.7010

Moyano, D. F., and Rotello, V. M. (2011). Nano meets biology: structure and function at the nanoparticle interface. *Langmuir* 27, 10376–10385. doi:10.1021/la2004535

Oladipupo, S., Rotimi, D. E., Ezenabor, E. H., Ojo, A. B., Akinsola, O. A., and Ojo, O. A. (2025). Harnessing nanoparticles for phytochemical delivery: a comprehensive review of safety and therapeutic potential. *Ther. Deliv.* 16, 1111–1125. doi:10.1080/20415990.2025.2570638

Ozbek, O., Genc, D. E., and Ulgen K, O. (2024). Advances in physiologically based pharmacokinetic (PBPK) modeling of nanomaterials. *ACS Pharmacol. Transl. Sci.* 7, 2251. doi:10.1021/acsptsci.4c00250

Padmanaban, S., Baek, J. W., Chamarthy, S. S., Chandrasekaran, S., Samrot, A. V., Gosu, V., et al. (2025). Nanoparticle-based therapeutic strategies for chronic liver diseases: advances and insights. *Liver Res.* 9, 104–117. doi:10.1016/j.livres.2025.04.002

Papadimitriou, S., Bikiaris, D., Avgoustakis, K., Karavas, E., and Georgarakis, M. (2008). Chitosan nanoparticles loaded with dorzolamide and pramipexole. *Carbohydr. Polym.* 73, 44–54. doi:10.1016/j.carbpol.2007.11.007

Parvin, N., Aslam, M., Joo, S. W., and Mandal, T. K. (2025). Nano-phytomedicine: harnessing plant-derived phytochemicals in nanocarriers for targeted human health applications. *Molecules* 30, 3177. doi:10.3390/molecules30153177

Psarrou, M., Mitraki, A., Vamvakaki, M., and Kokotidou, C. (2023). Stimuli-responsive polysaccharide hydrogels and their composites for wound healing applications. *Polym. (Basel)* 15, 986. doi:10.3390/polym15040986

Rodríguez-Gómez, F. D., Monferrer, D., Penon, O., and Rivera-Gil, P. (2025). Regulatory pathways and guidelines for nanotechnology-enabled health products: a comparative review of EU and US frameworks. *Front. Med. (Lausanne)* 12, 1544393. doi:10.3389/fmed.2025.1544393

Sadr, S., Hajjafari, A., Lotfalizadeh, N., Lotfalizadeh, M., Laein, S. S., Abbasi, A. M., et al. (2025). Phytosome-based nanotechnology for enhanced efficacy of anticancer phytocompounds: challenges and prospects. *J. Drug Deliv. Sci. Technol.* 104, 106543. doi:10.1016/j.jddst.2024.106543

Saidi, A. K. Al, Al-Shannaq, R., Ul-Islam, M., Shehzad, A., Ahmad, M. W., Farid, M., et al. (2025). Future aspects of nanotechnology in therapeutics: a comprehensive review of materials, applications, and future directions. *Mater. Res. Express* 12, 122001. doi:10.1088/2053-1591/ae22c7

Salama, L., Pastor, E. R., Stone, T., and Mousa, S. A. (2020). Emerging nanopharmaceuticals and nanonutraceuticals in cancer management. *Biomedicines* 8, 347. doi:10.3390/BIOMEDICINES8090347

Shaji, A., and Jayasri, M. A. (2023). A review of the role of liposome-encapsulated phytochemicals targeting PPAR ɣ and associated pathways to combat obesity. *3 Biotech.* 13, 313. doi:10.1007/s13205-023-03740-7

Shan, X., Cai, Y., Zhu, B., Zhou, L., Sun, X., Xu, X., et al. (2024). Rational strategies for improving the efficiency of design and discovery of nanomedicines. *Nat. Commun.* 15 (1 2024), 9990. doi:10.1038/s41467-024-54265-3

Siafaka, P. I., Miliotou, A. N., Okur, M. E., Karaotmarlı Güven, G., Karantas, I. D., and Üstündağ Okur, N. (2025). Nanoformulations loaded with phytochemicals for combating wound infections and promoting wound healing: current applications and innovations. *Appl. Sci.* 15, 5413. doi:10.3390/app15105413

Spanakis, M., Bouropoulos, N., Theodoropoulos, D., Sygellou, L., Ewart, S., Moschovi, A. M., et al. (2014). Controlled release of 5-fluorouracil from microporous zeolites. *Nanomedicine* 10, 197–205. doi:10.1016/j.nano.2013.06.016

Spanakis, M., Tzamali, E., Tzedakis, G., Tsatsakis, A., and Sakkalis, V. (2024). Applying pharmacological models of glioblastoma in the research for novel nanomedicine formulations. *Public Health Toxicol.* 4. doi:10.18332/PHT/191623

Talaat, M., Hassan, H., Mosilhy, E. A., Taha, N. A., Elsaid, M., Sharafeldin, M. N., et al. (2025). Nano-antioxidants for neurodegenerative disorders: a scoping review. *Discov. Nano* 20 (20), 194. doi:10.1186/s11671-025-04320-9

Tripathi, D., Pandey, P., Sharma, S., Rai, A. K., and Prabhu, M. B. H. (2024). Advances in nanomaterials for precision drug delivery: insights into pharmacokinetics and toxicity. *Bioimpacts* 15, 30573. doi:10.34172/bi.30573

Umar, M., Sherazi, T. A., Talha, M., Ramadan, M. F., Ahmed, A. E., Taha, R., et al. (2025). Nanoliposome-based drug delivery systems for the treatment of diabetes mellitus: a review. *RSC Adv.* 15, 49119–49143. doi:10.1039/d5ra07152f

Vizirianakis, I. S., Mystridis, G. A., Avgoustakis, K., Fatouros, D. G., and Spanakis, M. (2016). Enabling personalized cancer medicine decisions: the challenging pharmacological approach of PBPK models for nanomedicine and pharmacogenomics. *Oncol. Rep.* 35, 1891–1904. doi:10.3892/or.2016.4575

Xing, H., Li, G., Qi, C., Zhang, M., Ding, N., and Zhang, X. (2025). Emerging role of plant-derived nanostructures in nanomedicine. *Int. J. Nanomedicine* 20, 12715–12731. doi:10.2147/IJN.S547550

Xuan, L., Ju, Z., Skonieczna, M., Zhou, P. K., and Huang, R. (2023). Nanoparticles-induced potential toxicity on human health: applications, toxicity mechanisms, and evaluation models. *MedComm (Beijing)* 4, e327. doi:10.1002/mco2.327

Zango, U. U., Abubakar, A., Saxena, R., and Arya, V. (2023). Phyto-nanotechnology: enhancing plant based chemical constituent mediated anticancer therapies. *Ther. Drug Targets Phytomedicine Triple Negat. Breast Cancer*, 161–181. doi:10.2174/9789815079784123010011

Zhang, X., Fei, G., Xiujia, S., Ganesan, K., and Chen, J. (2026). Natural compound-nanoparticle therapies for breast cancer: a review from 2018-2025. *Phytomedicine* 150, 157652. doi:10.1016/j.phymed.2025.157652

Zhou, Y., Zhao, X., Li, M., Liu, Y., Wu, Y., Fan, M., et al. (2026). Plant-derived exosomes: an emerging delivery platform for cancer therapy. *J. Nanobiotechnology* 24, 195. doi:10.1186/s12951-026-04059-0

Zhu, Y., Ge, D., Wang, J., Sun, H., Li, W., and Ren, H. (2025). Emerging nanomedicine for liver diseases treatment. *J. Nanobiotechnology* 23, 786. doi:10.1186/s12951-025-03832-x