LIFE SCIENCE REVIEW

p-ISSN 3117-3535
e-ISSN 3117-3543

Review Article

Journal homepage: https://lsr.crcjournals.org/

Natural Products as Sources of Therapeutic Agents and Functional Biomolecules

Janardhan Namdeo Nehul

Department of Botany, Dadapatil Rajale College of Science, Adinathnagar, Tal-Pathardi, Dist-Ahmednagar (M.S.), India

Received 17 September 2025 | Revised 15 October 2025 | Accepted 16 November 2025 | Available Online 13 December 2025

*Corresponding Author: **Janardhan Namdeo Nehul** | Email Address: **jnnehul@gmail.com**

Citation: Janardhan Namdeo Nehul (2025). Natural Products as Sources of Therapeutic Agents and Functional Biomolecules. ***Life Science Review***. **DOI: https://doi.org/10.51470/LSR.2025.09.02.40**

Abstract

Natural products have long served as a foundation for the discovery and development of therapeutic agents and functional biomolecules. Derived from plants, microorganisms, marine organisms, and other natural sources, these compounds exhibit remarkable structural diversity and biological activity. Historically, natural products have played a pivotal role in traditional medicine and continue to inspire modern drug discovery, contributing significantly to the treatment of infectious diseases, cancer, metabolic disorders, and inflammatory conditions. This review provides a comprehensive overview of natural products as sources of bioactive compounds, emphasizing their classification, biosynthetic origins, mechanisms of action, and therapeutic applications. Advances in analytical techniques, biotechnology, and computational approaches that enhance natural product discovery are discussed. Additionally, challenges related to sustainability, standardization, and clinical translation are highlighted, along with future prospects for integrating natural products into modern medicine and functional biomolecule development.

Keywords: *Natural products, bioactive compounds, drug discovery, functional biomolecules, phytochemicals, secondary metabolites.*

1. Introduction

Natural products are chemical compounds synthesized by living organisms that are not directly essential for their primary metabolic processes, such as growth, development, or reproduction, yet they play critical roles in ecological interactions, defense mechanisms, and environmental adaptation. These compounds, often referred to as secondary metabolites, are produced by a wide range of organisms, including plants, microorganisms, marine species, and animals [1]. Historically, natural products have formed the backbone of traditional medicine systems across civilizations, providing remedies for infections, inflammation, pain, and chronic diseases long before the advent of modern synthetic pharmaceuticals.

The significance of natural products in modern medicine is undeniable. A substantial proportion of clinically approved drugs are either natural products, derivatives thereof, or synthetic molecules inspired by natural scaffolds. Antibiotics such as penicillin and streptomycin, anticancer agents including paclitaxel and vincristine, immunosuppressants like cyclosporine, and antimalarial drugs such as artemisinin are all derived from natural sources [2]. These compounds have revolutionized healthcare and significantly reduced morbidity and mortality worldwide.

Their success underscores the immense chemical diversity and biological relevance inherent in natural product chemistry. There has been a renewed and intensified interest in natural products as sources of therapeutic agents and functional biomolecules. One major driving force behind this resurgence is the growing limitation of conventional synthetic chemical libraries [3]. While combinatorial chemistry initially promised vast chemical diversity, many synthetic libraries lack the structural complexity, stereochemical richness, and functional group diversity required for effective interaction with biological targets. In contrast, natural products are shaped by evolutionary pressures, resulting in molecules that are highly optimized for biological activity, target specificity, and bioavailability.

Another critical factor contributing to the revival of natural product research is the alarming rise in drug resistance, particularly in infectious diseases and cancer. The emergence of multidrug-resistant pathogens and the reduced efficacy of existing chemotherapeutic agents pose significant challenges to global health. Natural products, with their diverse mechanisms of action and novel molecular frameworks, offer promising alternatives for overcoming resistance and discovering next-generation therapeutics. Many natural compounds act on multiple cellular targets simultaneously, reducing the likelihood of resistance development. Natural products play an increasingly important role as functional biomolecules in food, cosmetics, agriculture, and biotechnology. Bioactive compounds such as polyphenols, flavonoids, carotenoids, alkaloids, peptides, and polysaccharides are widely used in nutraceuticals and functional foods due to their antioxidant, anti-inflammatory, immunomodulatory, and metabolic regulatory properties [4]. These biomolecules contribute to disease prevention, health promotion, and improved quality of life, aligning with the growing global demand for natural and sustainable health solutions.

Advances in analytical chemistry, molecular biology, and computational sciences have significantly transformed natural product research. Modern techniques such as high-resolution mass spectrometry, nuclear magnetic resonance spectroscopy, metabolomics, genomics, and bioinformatics enable rapid identification, structural elucidation, and functional characterization of complex natural compounds. Furthermore, innovations in synthetic biology and metabolic engineering allow for the sustainable production of rare or structurally complex natural products through microbial or plant-based systems, addressing issues related to limited availability and environmental impact. and their immense potential, the development of natural products into clinically approved therapeutics is not without challenges. Issues such as low yield from natural sources, structural complexity, variability in chemical composition, and difficulties in large-scale production often hinder drug development efforts [5]. Regulatory requirements, standardization, and quality control further complicate the translation of natural compounds into pharmaceutical products. Nevertheless, ongoing technological advancements and interdisciplinary approaches continue to mitigate these limitations, making natural products increasingly viable candidates for drug discovery and functional biomolecule development.

The natural products as sources of therapeutic agents and functional biomolecules. It highlights their classification, biosynthetic origins, mechanisms of action, and diverse applications across medicine and biotechnology. An integrating traditional knowledge with modern scientific approaches, this review emphasizes the enduring relevance of natural products and their promising role in addressing current and future health challenges.

2. Classification and Sources of Natural Products

Natural products encompass a wide range of structurally diverse compounds derived from various biological sources. Based on their origin, they are broadly classified into plant-derived, microbial, marine, and animal-derived natural products. Each category contributes uniquely to the pool of bioactive molecules with therapeutic and functional significance [6]. The diversity in chemical structures and biological activities reflects the evolutionary adaptations of organisms to their environments, making natural products an invaluable resource for drug discovery and biotechnology.

2.1 Plant-Derived Natural Products

Plants are the most extensively studied and historically significant sources of natural products. They produce a vast array of secondary metabolites that play essential roles in defense against herbivores, pathogens, and environmental stresses [7]. Major classes of plant-derived natural products include alkaloids, flavonoids, phenolic acids, terpenoids, glycosides, tannins, and saponins. These compounds are synthesized through complex biosynthetic pathways and are often compartmentalized within specific plant tissues.

Alkaloids are nitrogen-containing compounds known for their potent pharmacological activities. Well-known examples include morphine, quinine, atropine, and vincristine, which exhibit analgesic, antimalarial, anticholinergic, and anticancer properties, respectively. Flavonoids and phenolic compounds, widely distributed in fruits, vegetables, and medicinal plants, are recognized for their strong antioxidant, anti-inflammatory, cardioprotective, and anticancer activities. These compounds scavenge free radicals, modulate signaling pathways, and regulate gene expression involved in stress responses and disease progression. Terpenoids represent the largest class of plant secondary metabolites and include monoterpenes, sesquiterpenes, diterpenes, and triterpenes. Many terpenoids, such as artemisinin, taxol, and ginsenosides, have been successfully developed into therapeutic agents due to their antimicrobial, anticancer, and immunomodulatory properties. Saponins and glycosides, characterized by their sugar moieties, exhibit diverse biological activities including cholesterol-lowering, antimicrobial, and anticancer effects. Plant-derived natural products continue to be a major focus of pharmaceutical research due to their accessibility, chemical diversity, and compatibility with human biological systems [8]. Advances in phytochemistry, metabolomics, and plant biotechnology have further enhanced the exploration and utilization of plant-based bioactive compounds.

2.2 Microbial Natural Products

Microorganisms, particularly bacteria, fungi, and actinomycetes, are prolific producers of bioactive natural products. Microbial secondary metabolites have played a transformative role in modern medicine, most notably in the development of antibiotics. Landmark discoveries such as penicillin from *Penicillium* species, streptomycin from *Streptomyces griseus*, and erythromycin from *Saccharopolyspora erythraea* revolutionized the treatment of infectious diseases and significantly reduced global mortality rates [8]. Beyond antibiotics, microbial natural products serve as important sources of anticancer agents, immunosuppressants, enzyme inhibitors, and cholesterol-lowering drugs. Compounds such as doxorubicin, bleomycin, cyclosporine, and lovastatin exemplify the therapeutic versatility of microbial metabolites. These molecules often exhibit complex chemical structures and highly specific mechanisms of action, reflecting their evolutionary role in microbial competition and survival.

Recent advances in genome mining, metagenomics, and synthetic biology have reinvigorated microbial natural product research. Many biosynthetic gene clusters remain silent under standard laboratory conditions, and innovative strategies such as co-culture techniques, epigenetic modulation, and heterologous expression are being employed to unlock cryptic metabolites. Microbial natural products thus remain a rich and largely untapped reservoir for future drug discovery.

2.3 Marine Natural Products

Marine ecosystems represent one of the most chemically diverse environments on Earth, hosting an extraordinary range of organisms adapted to extreme conditions such as high pressure, salinity, and limited light. Marine natural products are derived from algae, cyanobacteria, sponges, tunicates, mollusks, corals, and associated microorganisms [9]. These organisms produce unique secondary metabolites that often exhibit novel chemical scaffolds not found in terrestrial sources.

Marine-derived compounds have demonstrated remarkable biological activities, particularly in anticancer, antiviral, anti-inflammatory, and neuroprotective research. Notable examples include trabectedin from tunicates, cytarabine from marine sponges, and bryostatins from bryozoans, which have shown significant potential in oncology and neurological disorders. Many marine natural products function as chemical defenses against predators and competitors, contributing to their high potency and specificity [10]. The development of marine natural products faces challenges related to sustainable supply, ecological impact, and complex chemical synthesis. However, advances in marine biotechnology, aquaculture, and microbial symbiont cultivation are helping to overcome these limitations. The marine environment continues to be a frontier for the discovery of structurally novel and therapeutically valuable natural products.

2.4 Animal-Derived Natural Products

Animal-derived natural products, although less abundant than plant and microbial metabolites, have provided several important therapeutic leads. These compounds include venoms, toxins, peptides, hormones, and enzymes produced by insects, reptiles, amphibians, marine invertebrates, and mammals. Many of these molecules have evolved to interact with specific molecular targets, making them highly potent and biologically active [11]. Venoms from snakes, scorpions, spiders, and cone snails are rich sources of bioactive peptides and proteins with applications in pain management, cardiovascular therapy, and neurological disorders. For example, captopril, an antihypertensive drug, was developed based on peptides derived from snake venom, while ziconotide, derived from cone snail venom, is used for the treatment of severe chronic pain.

Animal-derived hormones and regulatory peptides have also contributed to therapeutic development, particularly in endocrinology and metabolic disorders. Although ethical, safety, and scalability concerns limit the widespread use of animal-derived natural products, advances in peptide synthesis and recombinant technologies have enabled their safer and more sustainable utilization.

Table 1. Major Classes of Natural Products, Their Sources, and Biological Activities

Class of Natural Product	Primary Source	Representative Examples	Major Biological Activities
Alkaloids	Plants, microorganisms	Morphine, quinine, vincristine	Analgesic, anticancer, antimicrobial, neuroactive
Flavonoids	Plants (fruits, vegetables, herbs)	Quercetin, catechin, kaempferol	Antioxidant, anti-inflammatory, cardioprotective
Phenolic compounds	Plants, fungi	Gallic acid, resveratrol	Antioxidant, anticancer, antimicrobial
Terpenoids	Plants, marine organisms	Paclitaxel, artemisinin	Anticancer, antimalarial, anti-inflammatory
Glycosides	Plants	Digoxin, saponins	Cardioprotective, immunomodulatory
Polysaccharides	Plants, fungi, algae	Chitosan, β-glucans	Immunostimulatory, wound healing
Peptides	Microorganisms, animals	Cyclosporine, antimicrobial peptides	Immunosuppressive, antimicrobial

Table 2. Therapeutic and Functional Applications of Natural Products

Application Area	Natural Product Type	Mechanism of Action	Examples
Antimicrobial therapy	Antibiotics, alkaloids	Inhibition of cell wall synthesis, protein synthesis	Penicillin, streptomycin
Anticancer therapy	Terpenoids, alkaloids	Apoptosis induction, cell cycle arrest	Paclitaxel, vincristine
Anti-inflammatory agents	Polyphenols, flavonoids	Suppression of NF-κB and cytokine signaling	Curcumin, resveratrol
Antioxidants	Phenolics, carotenoids	Free radical scavenging	Quercetin, β-carotene
Functional foods	Polyphenols, peptides	Metabolic regulation, gut health	Catechins, bioactive peptides
Biomaterials	Polysaccharides	Biocompatibility, tissue regeneration	Alginate, chitosan
Neuroprotection	Alkaloids, flavonoids	Reduction of oxidative stress	Galantamine, luteolin

3. Biosynthesis and Chemical Diversity

Natural products are primarily synthesized through specialized or secondary metabolic pathways that operate alongside primary metabolism. These pathways have evolved to produce structurally diverse compounds that confer ecological advantages such as defense, communication, and adaptation to environmental stress.

The remarkable chemical diversity of natural products arises from the combination of core biosynthetic frameworks and extensive post-synthetic modifications [12]. Among the most important biosynthetic systems are the polyketide synthase (PKS) and non-ribosomal peptide synthetase (NRPS) pathways. PKS pathways generate polyketides through the stepwise condensation of simple acyl-CoA units, resulting in complex molecules such as erythromycin, tetracycline, and lovastatin. Similarly, NRPS pathways assemble non-ribosomal peptides independent of messenger RNA templates, producing bioactive compounds such as vancomycin, cyclosporine, and bleomycin. The modular organization of PKS and NRPS enzymes allows for extensive structural variation through domain rearrangement and combinatorial biosynthesis.

Plant-derived natural products are often synthesized through pathways such as the shikimate pathway, responsible for aromatic amino acids and phenolic compounds, and the mevalonate (MVA) and methylerythritol phosphate (MEP) pathways, which generate terpenoids and isoprenoids. These pathways contribute to the biosynthesis of flavonoids, lignins, alkaloids, and terpenes that exhibit wide-ranging biological activities. Enzymatic tailoring reactions—including hydroxylation, methylation, glycosylation, acetylation, and cyclization—further enhance molecular complexity and functional diversity.

The structural complexity of natural products underlies their high specificity and affinity toward biological targets such as enzymes, receptors, ion channels, and nucleic acids. Unlike many synthetic compounds, natural products often possess rigid scaffolds, stereochemical richness, and multiple functional groups, enabling precise molecular interactions. This complexity is a major reason for their success as lead compounds in drug discovery. Recent advances in genomics, transcriptomics, and metabolomics have revolutionized natural product research. The identification of biosynthetic gene clusters through genome mining has revealed a vast number of cryptic pathways with the potential to produce novel compounds. Synthetic biology and metabolic engineering approaches now enable the heterologous expression of these pathways in suitable host organisms, improving yield and facilitating sustainable production [13]. Together, these innovations are expanding access to natural products while overcoming limitations associated with low abundance and environmental impact.

4. Mechanisms of Action and Therapeutic Potential

Natural products exert their therapeutic effects through diverse and often multi-target mechanisms of action. Their ability to modulate complex biological systems makes them valuable not only as drugs but also as functional biomolecules for disease prevention and health promotion.

4.1 Antimicrobial and Antiviral Activities

One of the most significant contributions of natural products to medicine is their role in combating infectious diseases. Many natural compounds inhibit microbial growth by targeting essential cellular processes, including cell wall biosynthesis, protein synthesis, nucleic acid replication, and membrane integrity. For instance, β-lactam antibiotics disrupt bacterial cell wall formation, while aminoglycosides and macrolides interfere with ribosomal function [14]. Natural products also exhibit potent antiviral activity through mechanisms such as inhibition of viral entry into host cells, suppression of viral genome replication, and blockade of viral proteases and polymerases. Flavonoids, alkaloids, and terpenoids have demonstrated activity against a wide range of viruses, including influenza viruses, hepatitis viruses, and emerging viral pathogens. The multi-target nature of these compounds reduces the likelihood of resistance development, making them promising candidates in the era of rising antimicrobial resistance.

4.2 Anticancer Properties

Natural products have played a pivotal role in cancer chemotherapy and continue to be a major source of anticancer agents. These compounds exert anticancer effects through diverse mechanisms, including induction of programmed cell death (apoptosis), inhibition of angiogenesis, disruption of microtubule dynamics, and modulation of key signaling pathways involved in cell proliferation and survival [15]. Classic examples include paclitaxel, which stabilizes microtubules and inhibits mitosis; vincristine, which disrupts microtubule assembly; and camptothecin derivatives, which inhibit DNA topoisomerase I. Many natural compounds also target cancer stem cells and tumor microenvironments, enhancing therapeutic efficacy and reducing recurrence. Their ability to act synergistically with conventional chemotherapeutic agents further underscores their clinical relevance.

4.3 Anti-inflammatory and Immunomodulatory Effects

Chronic inflammation is a central feature of numerous diseases, including cardiovascular disorders, autoimmune conditions, neurodegenerative diseases, and cancer. Natural biomolecules such as polyphenols, terpenoids, and alkaloids exhibit strong anti-inflammatory properties by regulating inflammatory mediators, cytokine production, and immune cell signaling [16]. These compounds often act by inhibiting key pathways such as nuclear factor-kappa B (NF-κB), mitogen-activated protein kinase (MAPK), and cyclooxygenase (COX) pathways. In addition, certain natural products enhance immune surveillance and modulate both innate and adaptive immune responses. Such immunomodulatory effects make natural products valuable for managing inflammatory disorders and improving host defense mechanisms.

4.4 Metabolic and Neuroprotective Effects

Natural products also contribute significantly to metabolic health and neurological protection. Several plant-derived compounds improve glucose and lipid metabolism by enhancing insulin sensitivity, regulating adipogenesis, and modulating energy homeostasis. These properties are particularly relevant in the prevention and management of metabolic disorders such as diabetes and obesity [17]. In the nervous system, natural products exhibit neuroprotective effects by reducing oxidative stress, inhibiting neuroinflammation, and modulating neurotransmitter systems.

Compounds such as polyphenols and alkaloids protect neuronal cells from degeneration and have shown promise in the management of neurodegenerative diseases, including Alzheimer's and Parkinson's disease. Their antioxidant and anti-apoptotic properties further support their role in maintaining neural function and cognitive health.

5. Natural Products as Functional Biomolecules

In addition to their well-established therapeutic applications, natural products function as important biomolecules across diverse sectors, including food, cosmetics, agriculture, and biotechnology. Their multifunctional properties make them valuable ingredients in the development of functional foods, nutraceuticals, and bio-based materials aimed at improving human health and environmental sustainability [18]. Natural antioxidants such as polyphenols, carotenoids, and vitamins derived from plants and microorganisms are widely used to combat oxidative stress, delay food spoilage, and enhance nutritional value. These compounds neutralize free radicals and reduce lipid peroxidation, thereby contributing to the prevention of chronic diseases associated with oxidative damage. Similarly, natural pigments, including anthocyanins, chlorophylls, and carotenoids, serve as eco-friendly colorants in the food and cosmetic industries, replacing synthetic dyes with safer alternatives.

Bioactive peptides, polysaccharides, and secondary metabolites also play key roles as functional biomolecules. Polysaccharides such as chitosan, alginate, and β-glucans exhibit immunomodulatory, antimicrobial, and wound-healing properties, making them suitable for biomedical applications such as drug delivery systems and tissue engineering scaffolds. Enzyme inhibitors and natural preservatives derived from plants and microbes are increasingly employed to improve food safety and shelf life. Natural products are incorporated into dietary supplements and functional foods to support metabolic health, immune function, and gut microbiota balance. The growing consumer preference for natural and plant-based products has further accelerated research into the identification and validation of bioactive natural compounds with health-promoting effects.

6. Technological Advances in Natural Product Discovery

The discovery and development of natural products have been significantly transformed by advances in analytical, computational, and biotechnological tools. Modern high-throughput screening techniques enable the rapid evaluation of large compound libraries for biological activity, reducing time and cost in early-stage drug discovery.

Analytical technologies such as mass spectrometry (MS) and nuclear magnetic resonance (NMR) spectroscopy play a central role in the identification, structural elucidation, and quantification of natural compounds [19]. Coupled with chromatographic techniques, these tools allow detailed characterization of complex natural extracts. Metabolomics approaches provide comprehensive profiling of metabolites, enabling comparative analysis of biological systems under different conditionsBioinformatics and computational tools have further accelerated natural product research. Molecular docking, virtual screening, and quantitative structure–activity relationship (QSAR) modeling help predict biological activity and optimize lead compounds. More recently, machine learning and artificial intelligence have been applied to mine large datasets, identify biosynthetic gene clusters, and predict novel compound structures.

Synthetic biology and metabolic engineering represent transformative approaches for sustainable natural product production. By reconstructing biosynthetic pathways in microbial hosts, it is possible to enhance yield, reduce dependency on natural resources, and enable scalable production of high-value compounds. These technologies collectively address many limitations traditionally associated with natural product research.

9. Conclusion

Natural products remain indispensable sources of therapeutic agents and functional biomolecules. Their extraordinary structural diversity, evolutionary optimization, and broad spectrum of biological activities make them uniquely suited to address complex health challenges and unmet medical needs. From antimicrobial and anticancer drugs to functional foods and biomaterials, natural products continue to shape modern medicine and biotechnology. Ongoing advancements in analytical technologies, computational tools, and biosynthetic strategies are overcoming traditional limitations associated with natural product research. With a strong emphasis on sustainability, innovation, and interdisciplinary collaboration, natural products are poised to play an increasingly prominent role in future drug discovery, disease prevention, and health promotion.

References

1. Dzobo, K. (2022). The role of natural products as sources of therapeutic agents for innovative drug discovery. *Comprehensive pharmacology*, 408.
2. Yeboah, F. K., &Konishi, Y. (2003). Mass spectrometry of biomolecules: Functional foods, nutraceuticals, and natural health products. *Analytical letters*, *36*(15), 3271-3307.
3. Wangchuk, P. (2018). Therapeutic applications of natural products in herbal medicines, biodiscovery programs, and biomedicine. *Journal of Biologically Active Products from Nature*, *8*(1), 1-20.
4. Li, D., Zhou, B., &Lv, B. (2020). Antibacterial therapeutic agents composed of functional biological molecules. *Journal of Chemistry*, *2020*(1), 6578579.
5. Pemmaraju, D. B., Ghosh, A., Gangasani, J. K., Murthy, U. S. N., Naidu, V. G. M., &Rengan, A. K. (2022). Herbal biomolecules as nutraceuticals. *Herbal Biomolecules in Healthcare Applications*, 525-549.

6. Bernitsa, S., Dayan, R., Stephanou, A., Tzvetanova, I. D., &Patrikios, I. S. (2023). Natural biomolecules and derivatives as anticancer immunomodulatory agents. *Frontiers in Immunology*, *13*, 1070367.
7. Chandana, B. S., Syed, S. A., Khanum, S. J., Abdurahman, S., Purohit, M. N., Vishwanath, P. M., & Achar, R. R. (2024). Structures and functions of biomolecules. In *Biochemical and Molecular Pharmacology in Drug Discovery* (pp. 3-19). Elsevier.
8. Abdullahi, A., Tijjani, A., Abubakar, A. I., Khairulmazmi, A., & Ismail, M. R. (2022). Plant biomolecule antimicrobials: An alternative control measures for food security and safety. In *Herbal biomolecules in healthcare applications* (pp. 381-406). Academic Press.
9. Mushtaq, S., Abbasi, B. H., Uzair, B., & Abbasi, R. (2018). Natural products as reservoirs of novel therapeutic agents. *EXCLI journal*, *17*, 420.
10. Péter, Beatrix, ImreBoldizsár, Gábor M. Kovács, Anna Erdei, ZsuzsaBajtay, Alexandra Vörös, Jeremy J. Ramsden, IldikóSzabó, SzilviaBősze, and Robert Horvath. "Natural compounds as target biomolecules in cellular adhesion and migration: from biomolecular stimulation to label-free discovery and bioactivity-based isolation." *Biomedicines* 9, no. 12 (2021): 1781.
11. Olaniyan, O. T., &Adetunji, C. O. (2021). Biological, biochemical, and biodiversity of biomolecules from marine-based beneficial microorganisms: industrial perspective. In *Microbial Rejuvenation of Polluted Environment: Volume 3* (pp. 57-81). Singapore: Springer Singapore.
12. Riaz, M., Khalid, R., Afzal, M., Anjum, F., Fatima, H., Zia, S., ... & Aslam, M. A. (2023). Phytobioactive compounds as therapeutic agents for human diseases: A review. *Food science & nutrition*, *11*(6), 2500-2529.
13. Cragg, G. M., Grothaus, P. G., & Newman, D. J. (2009). Impact of natural products on developing new anti-cancer agents. *Chemical reviews*, *109*(7), 3012-3043.
14. Bathula, S. R., Akondi, S. M., Mainkar, P. S., & Chandrasekhar, S. (2015). "Pruning of biomolecules and natural products (PBNP)": an innovative paradigm in drug discovery. *Organic & Biomolecular Chemistry*, *13*(23), 6432-6448.
15. Purohit, K., Reddy, N., & Sunna, A. (2024). Exploring the potential of bioactive peptides: From natural sources to therapeutics. *International Journal of Molecular Sciences*, *25*(3), 1391.
16. Chaachouay, N., & Zidane, L. (2024). Plant-derived natural products: a source for drug discovery and development. *Drugs and Drug Candidates*, *3*(1), 184-207.
17. Bernardini, S., Tiezzi, A., LaghezzaMasci, V., &Ovidi, E. (2018). Natural products for human health: an historical overview of the drug discovery approaches. *Natural product research*, *32*(16), 1926-1950.
18. Mitrea, D. M., Mittasch, M., Gomes, B. F., Klein, I. A., &Murcko, M. A. (2022). Modulating biomolecular condensates: a novel approach to drug discovery. *Nature Reviews Drug Discovery*, *21*(11), 841-862.
19. Tvrdá, E., Benko, F., Slanina, T., & du Plessis, S. S. (2021). The role of selected natural biomolecules in sperm production and functionality. *Molecules*, *26*(17), 5196.