An International Edition

ISBN: 978-93-49938-62-5

ADVANCES IN PLANT AND ANIMAL SCIENCE

Editor
Mrs. Varsha Suprit Yadav
Mr. Vivek Shrikant Netam
Mrs. Snehal Nandakumar Shingate

Nature Light Publications

An International Edited Book *ISBN-978-93-49938-62-5*

ADVANCES IN PLANT AND ANIMAL SCIENCES

Editors

Mrs. Varsha Suprit Yadav
Research Scholer,
Department of Botany,
Rayat Shikshan Sanstha's
Sadguru Gadage Maharaj College, Karad, Satara, (MH), India.

Mr. Vivek Shrikant Netam
Assistant Professor
Department of Zoology,
Balwant College Vita, Tal. Khanapur, Dist. Sangli, (MH), India.

Mrs. Snehal Nandakumar Shingate
Research Scholer,
Department of Zoology,
Rayat Shikshan Sanstha's
Sadguru Gadage Maharaj College, Karad, Satara, (MH), India.

Published By

Nature Light Publications, Pune

Advances in Plant and Animal Sciences

Editors

Mrs. Varsha Suprit Yadav
Mr. Vivek Shrikant Netam
Mrs. Snehal Nandakumar Shingate

First Edition: May, 2025

An International Edited Book

ISBN- 978-93-49938-62-5

9 789349 938625

Published by:

Nature Light Publications, Pune
309 West 11, Manjari VSI Road, Manjari Bk.,
Haveli, Pune- 412 307.
Website: www.naturelightpublications.com
Email: naturelightpublications@gmail.com
Contact No: +91 9822489040 / 9922489040

Preface

Plant and animal sciences have evolved from classical natural observations to cutting-edge interdisciplinary domains that intersect biotechnology, artificial intelligence, and therapeutic research. This edited volume, "Advances in Plant and Animal Science." is a scholarly attempt to explore the diverse, innovative, and integrative developments shaping modern research and applications in these fields.

The book begins with a comprehensive review titled Natural Products from Plants and Animals: A Review of Their Phytochemical and Therapeutic Applications, which sheds light on the age-old wisdom of traditional medicine and pharmacognosy. It explores the biochemical richness of flora and fauna, revealing their significant roles in modern pharmacology and therapeutic innovations. This theme is extended further in the chapter Convolvulus pluricaulis: Traditional Use and Modern Scientific Insights, providing a focused case study on a revered medicinal plant, bridging folk knowledge with evidence-based science.

Technological advancement finds robust representation in the chapter Digital Guardians of Nature: Emerging AI Technologies in Plant and Animal Surveillance. Here, the integration of artificial intelligence and remote sensing technologies is examined in depth, showcasing their transformative role in ecological monitoring, species tracking, and environmental protection.

In the realm of animal science, sustainable development is the focus of Review on Innovations in Animal Nutrition and Feed Technology for Sustainable Livestock Production. This chapter presents modern feed strategies, nutrigenomics, and precision farming tools aimed at reducing environmental impact while enhancing animal productivity. Complementing this, Biotechnological Innovations in Animal Healthcare outlines significant breakthroughs in diagnostics, therapeutics, and vaccines, reflecting the convergence of molecular biology and veterinary science.

The intersection of biology and the arts is explored in chapters such as Music Therapy in Stress Management: Perspectives on Mechanism and The Therapeutic Effect of Music in the Treatment of Diabetes. These contributions present pioneering research on how acoustic stimuli influence physiological processes, hormonal balance, and mental well-being both in humans and animal models indicating the broad therapeutic potential of non-invasive natural remedies.

Environmental biotechnology emerges as a crucial theme in Fungal Enzymes in Green Industrial Biotechnology: From Paper to Bioethanol, where the authors present the latest insights into the application of fungal enzymes for sustainable industrial transformation. This chapter underscores the ecological importance of microbial innovation in addressing global energy challenges.

Addressing global public health concerns, Dengue Virus: Transmission, Diagnosis and Prevention adds a vital perspective by discussing vector biology, disease ecology, and strategies for outbreak management. It aligns with the book's commitment to covering zoonotic interfaces and their relevance in today's interconnected world.

Together, these chapters reflect the multidimensional nature of plant and animal sciences — where traditional knowledge coexists with modern research, and ecological preservation goes hand in hand with biotechnological innovation. The contributors to this volume comprise a diverse group of researchers, academicians, and professionals whose insights and expertise have shaped this scholarly effort.

We hope that this book serves as a valuable resource for students, researchers, and professionals across disciplines — from botany, zoology, and environmental science to biotechnology, pharmacology, and AI in agriculture. It aims to ignite curiosity, inspire interdisciplinary research, and foster sustainable innovations for the well-being of both nature and society.

Editors

Advances in Plant and Animal Sciences

Table of Content

Natural Products from Plants and Animals: A Review of Their Phytochemical and Therapeutic Applications

[1]Yugandhara S. Chandanshive

[2]Varsha D. Jadhav (Rathod)

[1]Research Scholar, Department of Botany, Shivaji University, Kolhapur, (M.S.), India.

[2]Professor, Department of Botany, Shivaji University, Kolhapur, (M.S.), India.

Email: yugandharabotany@gmail.com

Article DOI Link: https://zenodo.org/uploads/15576683

DOI: ***10.5281/zenodo.15576683***

Abstract

Natural products derived from plants and animals have been a cornerstone of traditional medicine for centuries, offering a vast array of bioactive compounds with therapeutic potential. This review aims to provide a comprehensive overview of the phytochemical and therapeutic applications of natural products from plants and animals. We discuss the diverse range of phytochemicals, including alkaloids, glycosides, and terpenes, and animal-derived compounds, such as Omega-3-fatty acid, chitin, chitosan, that have been isolated and characterized. The therapeutic applications of these natural products are vast, ranging from antimicrobial and anti-inflammatory to anticancer and neuroprotective effects. Recent advances in analytical techniques and bioinformatics tools have facilitated the identification and characterization of novel natural products, enabling researchers to explore their therapeutic potential. Plant-derived compounds like curcumin and resveratrol have shown promise in treating various diseases, while animal-derived compounds like bee venom and omega-3 fatty acids have demonstrated anti-inflammatory and cardioprotective effects. The review highlights the importance of natural products in drug discovery and development, as well as their potential to provide novel leads for the treatment of various diseases. We also discuss the challenges and opportunities in harnessing the therapeutic potential of natural products, including issues related to sustainability, standardization, and regulatory frameworks. In conclusion, natural products from plants and animals offer a rich source of bioactive compounds with therapeutic potential, and continued research in this area is likely to yield novel and effective treatments for various diseases.

Keywords: Natural products, phytochemicals, animal-derived compounds, therapeutic applications, bioactive compounds.

Introduction

Natural products have emerged as a vital source of inspiration for the development of novel therapeutics, providing a diverse array of bioactive compounds that hold promise for addressing the complexities of chronic disorders and other pressing medical needs (Atanasov, et al. 2021). The intricate relationships within nature have yielded a vast array of bioactive compounds from plants, animals, and minerals, which have served as a foundation for developing therapeutic strategies to combat human diseases (Firenzuoli & Gori, 2007). Plants are fundamental to ecosystem functioning, providing essential services that support life on Earth. Medicinal plants, in particular, have played a pivotal role in human health, serving as a primary source of therapeutic agents throughout history. The complex interactions between plant constituents can yield synergistic effects, enhancing their medicinal properties and mitigating adverse effects. Plant-derived compounds have shown remarkable potential in treating challenging diseases, such as cancer, and preventing disease onset. The growing concern over the toxicity and side effects of conventional pharmaceuticals has fuelled interest in herbal medicine, driving demand for plant-based therapeutics and contributing to the expansion of the herbal medicine industry (Halberstein, 2005; Rasool, 2012; Jack, 1997). A substantial proportion of modern pharmaceuticals are derived from natural products, which comprise a vast array of bioactive compounds that exhibit therapeutic efficacy against various disease-causing agents. The structural diversity and pharmacological properties of plant-derived secondary metabolites have been extensively explored, yielding numerous compounds with promising biological activities (Gad, et al. 2013). Plants have been an integral part of human existence, providing essential nutrients and therapeutic benefits that underpin human health and well-being. The utilization of plants as medicinal agents has been a cornerstone of human civilization, with a rich history of traditional medicine practices continuing to influence contemporary healthcare systems (Yazarlu, et al. 2021; Bano, et al. 2017). This chapter aims to provide a comprehensive overview of the Phytochemical and therapeutic applications of natural product from plant and animals.

Phytochemicals:

Plant-Derived Compounds:

Plant-based bioactive compounds, also known as phytochemicals or secondary metabolites, are a diverse group of molecules that confer disease-protective effects without being essential nutrients. These compounds, found in a variety of plant-based foods including fruits, vegetables, whole grains, seeds, and nuts, can be categorized into several major classes, including phenolics, terpenes, alkaloids, saponins, glycosides, and polysaccharides, based on their biosynthetic origins and structural characteristics (Riaz, et al. 2023). Fig. 1 &2.

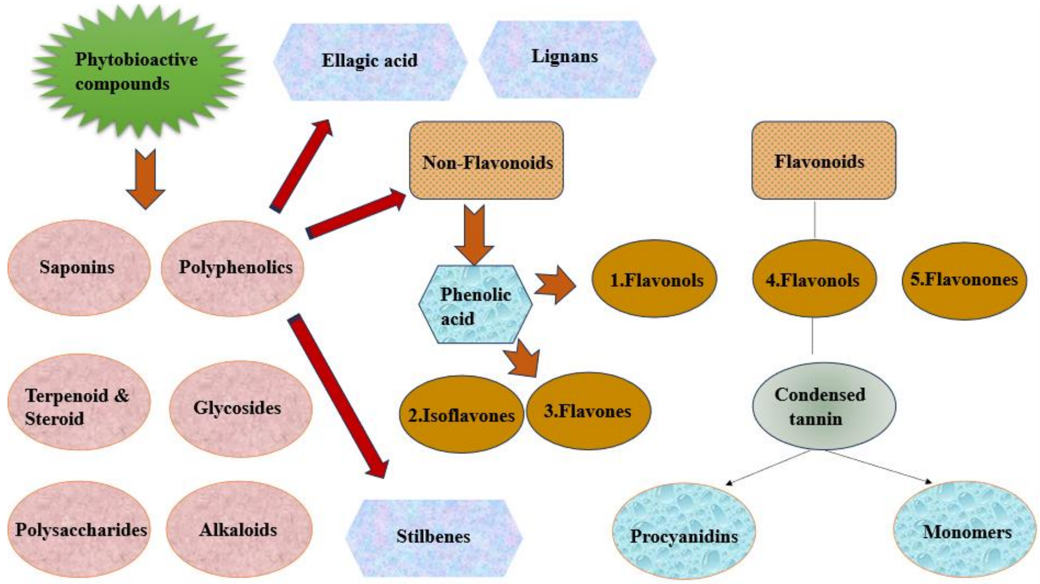

Fig. 1. Plant-Derived Compound Classification (Source: Riaz, et al. 2023)

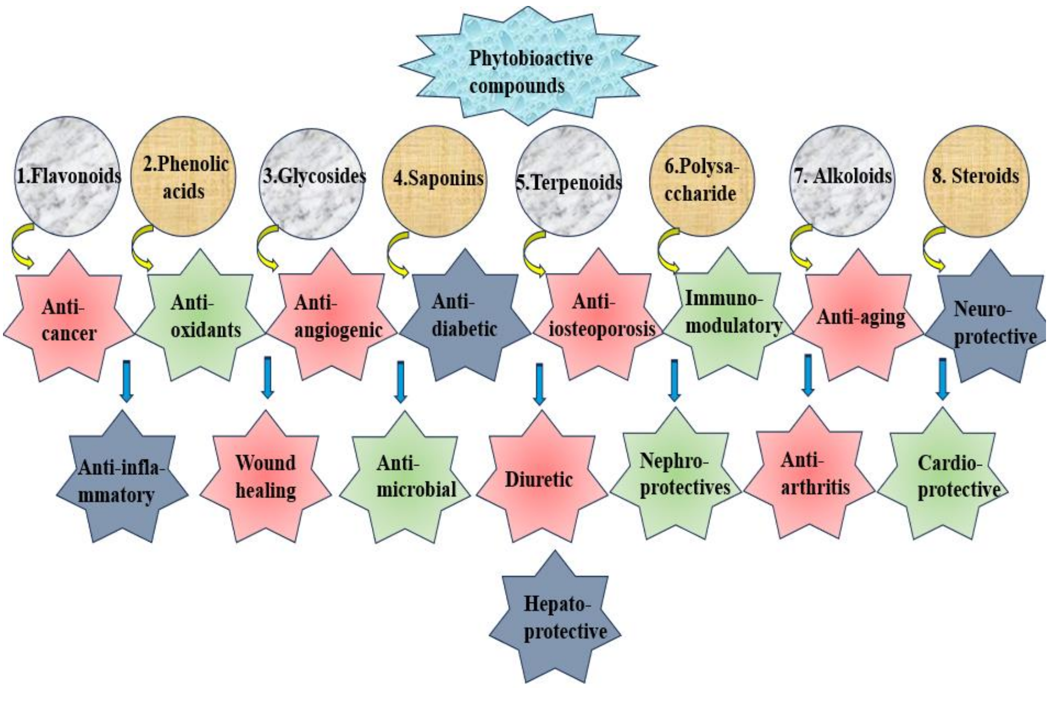

Fig. 2. Therapeutic Applications of Phytobioactives (Source: Riaz, et al. 2023)

1.**Polyphenols**

Polyphenols, a diverse group of plant-derived secondary metabolites, exhibit potent anticancer properties by modulating key signalling pathways and transcription factors involved in carcinogenesis. By scavenging free radicals and inhibiting oxidative stress, polyphenols can suppress the activation of pro-inflammatory proteins, such as NF-κB, COX 2, and iNOS, ultimately reducing the risk of cancer development (Shen, et al. 2017; Ramos, 2008).

A) Phenolic acids: Phenolic acids, characterized by hydroxyl groups attached to aromatic rings, play a multifaceted role in plants, contributing to colour development, pollination, and defense against pathogens. These compounds also exhibit valuable properties, including antimicrobial activity, antioxidant effects, and potential anticancer benefits, making them important for plant and human health (Ayub, et al. 2017; Sharif, et al. 2018).

B) Flavonoids: Flavonoids, a diverse group of polyphenols found in plant-based foods and beverages, comprise over 8,000 identified compounds. These bioactive molecules, including anthocyanins and anthoxanthins, exhibit beneficial effects on human health, such as antioxidant, anticancer, and immunomodulatory properties, with notable compounds like quercetin, kaempferol, and hesperidin contributing to their therapeutic potential (Khairan, et al. 2021).

C) Lignans and stilbenes: Lignans, a class of phenolic compounds found in higher plants and produced by gut microorganisms, exhibit diverse bioactive properties, including antioxidant, antiviral, and insecticidal activities. Rich sources of lignans include sesame seeds, flaxseed, and linseeds, which contain notable compounds like secoisolariciresinol and sesamin (Banwo, et al. 2021).

D) Alkaloids: Alkaloids, a diverse group of plant-derived compounds, exhibit a range of bioactive properties, including defensive effects against pests and pathogens, analgesic, antimalarial, antiviral, and anti-inflammatory activities. Certain alkaloids, such as berberine and tetrahydropalmatine, have been used in traditional medicine for their therapeutic potential, while others, like anabasine and nicotine, have been utilized as insecticides (Fielding, et al. 2020; Jahangir, et al. 2018; Iqbal, et al., 2013; Khadka, et al. 2021).

E) Terpenes: Terpenes, a diverse group of compounds, have extensive applications in various industries, including pharmaceuticals, cosmetics, and food. They exhibit notable therapeutic properties, including anti-inflammatory, antimicrobial, and antioxidant activities, with well-known examples like artemisinin and paclitaxel demonstrating their potential as antimalarial and anticancer agents (Shahid, et al. 2020; Ashraf, et al. 2020; Bhatti, et al. 2013).

F) Saponins: Triterpene saponins, comprising five-ring and four-ring structures, exhibit cardioprotective effects by modulating calcium homeostasis, energy metabolism, and inflammatory responses, ultimately mitigating oxidative stress and promoting cardiovascular health (Chen, et al. 2017).

G) Polysaccharides: Polysaccharides, abundant in fruits and vegetables, have been shown to possess cardioprotective properties through multiple mechanisms, including antioxidant, anti-inflammatory, immunomodulatory, and metabolic regulatory effects, with notable examples including gums and fucoidan (Chen, et al. 2021).

Animal-Derived Bioactive Compounds

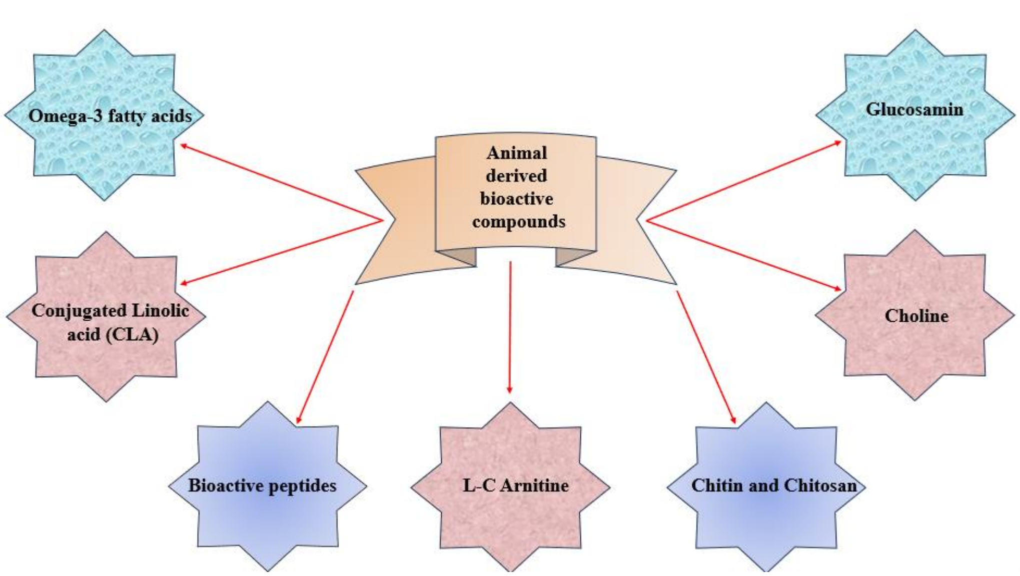

Fig. 3. Animal-Derived Bioactive Compounds (Source: Chaudhary and Garg, 2023).

1. Omega-3-fatty acid

Omega-3 fatty acids, a type of polyunsaturated fatty acid (PUFA), comprise key forms such as alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA), and docosahexaenoic acid (DHA), which are essential for various biological functions. Omega-3 fatty acids offer cardiovascular benefits by reducing heart disease risk and alleviating complications associated with diabetes, such as hypertension and hypertriglyceridemia. Moreover, they play a crucial role in brain function and mental health, with DHA being essential for maintaining brain membrane fluidity and regulating neurotransmitters (Ruxton, et al. 2004).

2. Conjugated Linoleic Acid (CLA)

Conjugated linoleic acid (CLA), a group of linoleic acid isomers found in ruminant-derived meat and dairy products, exhibits diverse bioactive properties, including anti-adipogenic, anti-diabetic, anti-atherosclerotic, and anticarcinogenic effects. CLA has been shown to reduce body weight and adipose tissue mass in animal models, and its anticancer properties have been demonstrated in various cancer models, including skin, stomach, breast, prostate, and colon carcinogenesis (Belury, 2002; Schmid, et al. 2006).

3. Bioactive peptides

Milk-derived bioactive peptides exhibit diverse biological activities, including antiproliferative, apoptosis-inducing, and cell growth-promoting effects, with potential applications in cancer treatment and infant development (Meisel, 2005).

4. L-C Arnitine

Carnitine, synthesized from lysine and methionine primarily in the liver, is found in various animal and dairy products. Research suggests that L-carnitine supplementation may have therapeutic benefits for conditions such as Alzheimer's disease, cardiovascular disease, and obesity, while also improving glucose tolerance and energy expenditure (Flanagan, et al. 2010).

5. Chitin and Chitosan

Chitin and chitosan, biopolymers composed of amino polysaccharides, exhibit unique structural properties, enabling their use in various applications, including food, pharmaceuticals, and water treatment, where they can effectively remove pollutants such as metal ions and dyes (Jeon, et al. 2000).

6. Choline

Choline, an essential nutrient obtained from dietary sources like lecithin and endogenously synthesized, plays a crucial role in human health. Adequate choline intake is vital for preventing diseases, and its deficiency can affect multiple physiological systems. Choline's biological functions include serving as a precursor for acetylcholine, methyl donors, and phospholipids, highlighting its importance in maintaining overall health (Sanders, et al. 2007; Gossell, et al. 2006).

7. Glucosamin

Glucosamine, an amino monosaccharide synthesized from glucose, is crucial for cartilage structure and composition. It serves as a substrate for glycosaminoglycan and proteoglycan synthesis, essential components of cartilage's extracellular matrix, highlighting its importance in maintaining joint health (Anderson, et al. 2005).

Challenges and Opportunities

1. **Bioavailability and Stability Concerns:** Animal-derived peptides face challenges in clinical applications due to rapid degradation and low bioavailability. To overcome these limitations, innovative delivery strategies, including peptide modifications and nanoparticle-based systems, are being developed to enhance their therapeutic efficacy (Fan, 2024).
2. **Ethical Considerations and Regulatory Compliance:** The large-scale extraction of bioactive peptides from natural sources poses ecological and ethical challenges, necessitating sustainable practices, regulatory compliance, and innovative biotechnological solutions to minimize environmental impact and ensure responsible research practices (Duarte, et al. 2023).
3. **Sustainable Conservation Approaches:** The use of animal-derived materials in research raises concerns about contamination, variability, and ethics. To address these issues, researchers must prioritize conservation, adhere to strict regulations, and explore alternatives like controlled breeding programs to ensure sustainable and responsible practices (Smith, et al. 2024).
4. **Cultural and Religious Implications:** The acceptance of animal-derived bioactive is influenced by cultural and religious beliefs, requiring researchers to consider ethical and permissibility aspects, particularly for products derived from animals with dietary restrictions, such as pork or frog, which may be impermissible in certain faiths (Park, 2023).
5. **Innovation and Clinical Translation Opportunities:** Advances in biomaterials, tissue engineering, and peptide synthesis are poised to revolutionize animal-derived bioactive for wound healing, with smart wound dressings and regenerative medicine approaches showing great promise. Regulatory agencies ensure safety and efficacy, while cutting-edge analytical techniques like mass spectrometry and genomics enable characterization and mechanistic insights into these bioactive compounds (Elangwe, et al. 2022).

Conclusion

This comprehensive review highlights the vast therapeutic potential of natural products from plants and animals, showcasing their diverse bioactive compounds and applications in disease prevention and treatment. As research continues to uncover novel insights into these compounds, it is essential to prioritize sustainable practices, regulatory compliance, and innovative biotechnological solutions to harness their full potential and translate them into effective treatments for various diseases.

Acknowledgment

The authors would like to express their sincere gratitude to Nature Light Publication, Pune for providing a platform to share their research findings with the scientific community. We are also grateful to our esteemed guide, Professor (Dr.) Varsha D. Jadhav for their invaluable guidance, support, and expertise throughout the preparation of this review manuscript. Their insightful feedback and suggestions have significantly enhanced the quality of this work.

References

1. Anderson, J. W., Nicolosi, R. J., & Borzelleca, J. F. (2005). Glucosamine effects in humans: A review of effects on glucose metabolism, side effects, safety considerations and efficacy. Food and Chemical Toxicology, 43,187 201.
2. Ashraf, A., Zafar, S., Ashraf, M. Y., Ijaz, M. U., Muzammal, S., Asad, F., Jabeen, F., & Shahid, M. (2020). Phytochemical composition and potent biological activities of Ficus benjamina var. comosa leaves extract. Pakistan Journal of Botany, 52(2), 531– 535.
3. Atanasov, A. G., Zotchev, S. B. R., & Supuran, C. T. (2021). Natural products in drug discovery: advances and opportunities. Nature Reviews Drug Discovery, 20, 200–216.
4. Ayub, M. A., Hussain, A. I., Hanif, M. A., Chatha, S. A. S., Kamal, G. M., Shahid, M., & Janneh, O. (2017). Variation in phenolic profile, β- carotene and flavonoid contents, biological activities of two tagetes species from Pakistani Flora. Chemistry & Biodiversity, 14(6), 1600463.
5. Bano, N., Afzal, M., Abdullah, S., & Shahid, M. (2017). The potential use of citric acid for the improvement in growth of Labeo rohita. International Journal of Agriculture & Biology, 19(2), 363– 366.
6. Banwo, K., Olojede, A. O., Adesulu- Dahunsi, A. T., Verma, D. K., Thakur, M., Tripathy, S., Singh, S., Patel, A. R., Kumar Gupta, A., Noe Aguilar, C., & Aguilar, C. N. (2021). Functional importance of bioactive compounds of foods with potential health benefits: A review on recent trends. Food Bioscience, 43, 101320.
7. Belury, M. A. (2002). Dietary conjugated linoleic acid in health: Physiological effects and mechanisms of action. Annual Review of Nutrition, 22,505.
8. Bhatti, I., Iqbal, M., Anwar, F., Shahid, S., & Shahid, M. (2013). Quality characteristics and microbiological safety evaluation of oils extracted from gamma irradiated almond (Prunus dulcis Mill.) seeds. Grasasy Aceites, 64(1), 68– 76.
9. Chaudhary, M. & Garg, A. P. (2023). Bioactive compounds from plants and animals: A review. International Journal of Advanced Biochemistry Research, 7(1),105-117.
10. Chen, Y., Zeng, L., Yang, J., Wang, Y., Yao, F., Wu, Y., Wang, D., Hu, Y., & Liu, J. (2017). Anti- DHAV- 1 reproduction and immuno- regulatory

effects of a flavonoid prescription on duck virus hepatitis. Pharmaceutical Biology, 55(1), 1545– 1552.

11. Chen, C., Yu, L. T., Cheng, B. R., Xu, J. L., Cai, Y., Jin, J. L., Feng, R. L., Xie, L., Qu, X. Y., Li, D., Liu, J., Li, Y., Cui, X. Y., Lu, J. J., Zhou, K., Lin, Q., & Li, D. (2021). Promising therapeutic candidate for myocardial ischemia/ reperfusion injury: What are the possible mechanisms and roles of phytochemicals? Frontiers in Cardiovascular Medicine, 8, 792592.
12. Duarte, A. C, Costa, E. C., Filipe, H. A. L., Saraiva, S. M., Jacinto, T., Miguel, S. P., Ribeiro, M. P., Coutinho, P. (2023). Animal- derived products in science and current alternatives. Biomaterials Advances,151,213428.
13. Elangwe, C. N., Morozkina, S. N., Olekhnovich, R. O., Krasichkov, A., Polyakova, V. O., & Uspenskaya, M. V. (2022). A Review on Chitosan and Cellulose Hydrogels for Wound Dressings. Polymers (Basel),14,5163.
14. Fan, X., Ye, J., Zhong, W., Shen, H., Li, H., Liu, Z., Bai, J., & Du, S. (2024). The Promoting Effect of Animal Bioactive Proteins and Peptide Components on Wound Healing: A Review. International Journal of Molecular Sciences, 5,12561.
15. Fielding, B. C., Filho, C. D. S. M. B., Ismail, N. S., & Sousa, D. P. D. (2020). Alkaloids: Therapeutic potential against human coronaviruses. Molecules, 25(23), 5496.
16. Firenzuoli, F., & Gori, L. (2007). Herbal medicine today: clinical and research issues. Evidence-Based Complementary and Alternative Medicine, 4(1),37-40.
17. Flanagan, J. L., Simmons, P. A., Vehige, J., Willcox, M. D., & Garrett Q. (2010). Role of carnitine in disease. Nutrition & Metabolism, 7,30.
18. Gad, H. A., El-Ahmady, S. H., Abou-Shoer, M. I., & Al-Azizi, M. M. (2013). Application of chemometrics in authentication of herbal medicines: a review. Phytochemical Analysis, 24(1),1–24.
19. Gossell-Williams, M., & Benjamin, J. (2006). Choline are our university students eating enough? West Indian Medical Journal, 55(3), 197-199.
20. Halberstein, R. A. (2005). Medicinal plants: historical and cross-cultural usage patterns. Annals of Epidemiology, 15(9),686-99.
21. Iqbal, S. Z., Bhatti, I. A., Asi, M. R., Zuber, M., Shahid, M., & Parveen, I. (2013). Effect of γ irradiation on fungal load and aflatoxins reduction in red chillies. Radiation Physics and Chemistry, 82, 80– 84.
22. Jack, D. B. (1997). One hundred years of aspirin. Lancet.350(9075),437-9.
23. Jahangir, M. A., Shehzad, A., Butt, M. S., & Bashir, S. (2018). Influence of supercritical fluid extract of Cinnamomum zeylanicum bark on physical, bioactive and sensory properties of innovative cinnamaldehyde- enriched chocolates. Czech Journal of Food Sciences, 36(1), 28– 36.

24. Jeon, Y. J., Shahidi, F., & Kim, S. K. (2000). Preparation of chitin and chitosan oligomers physiological and functional their foods. International, 16(2),159-176.
25. Khairan, K., Idroes, R., Tallei, T. E., Nasim, M. J., & Jacob, C. (2021). Bioactive compounds from medicinal plants and their possible effect as therapeutic agents against COVID- 19: A review. Current Nutrition & Food Science, 17(6), 621– 633.
26. Khadka, D., Dhamala, M. K., Li, F., Aryal, P. C., Magar, P. R., Bhatta, S., Thakur, M. S., Basnet, A., Cui, D., & Shi, S. (2021). The use of medicinal plants to prevent COVID- 19 in Nepal. Journal of Ethnobiology and Ethnomedicine, 17(1), 1– 17.
27. Meisel, H. (2005). Biochemical properties of peptides encrypted in bovine milk proteins. Current Medicinal Chemistry, 12(16):1905-1919.
28. Park, J. K., & Do, Y. (2023). Current State of Conservation Physiology for Amphibians: Major Research Topics and Physiological Parameters. Animals, 13,3162.
29. Chaudhary, M., & Garg, A. P. (2013). Bioactive compounds from plants and animals: A review. International Journal of Advanced Biochemistry Research, 7(1),105-117.
30. Ramos, S. (2008). Cancer chemoprevention and chemotherapy: Dietary polyphenols and signalling pathways. Molecular Nutrition & Food Research, 52(5), 507– 526.
31. Rasool-Hassan, B. A. (2012). Medicinal plants (importance and uses). Pharmaceutica Analytica Acta, 3, 139.
32. Riaz, M., Khalid, R. Afzal, M., Anjum, F., Fatima, H., Zia, S., Rasool, G., Egbuna, C., Mtewa, A. G., Uche, C. Z., & Aslam, M. A (2023). Phytobioactive compounds as therapeutic agents for human diseases: A review. Food Science and Nutrition, 11, 2500–2529.
33. Ruxton, C. H. S., Reed, S. C., & Simpson, M. J. A. (2004). Millington KJ. The health benefits of omega- 3 polyunsaturated fatty acids: A review of the evidence. Journal of Human Nutrition and Dietetics,17,449-459.
34. Sanders, L. M., & Zeisel, S. H. (2007). Choline: dietary requirements and role in brain development. Nutrition Today, 42(4),181-186.
35. Schmid, A., Collomb, M., Sieber, R., & Bee, G. (2006). Conjugated linoleic acid in meat and meat products: A review. Meat Science, 73,29-41.
36. Sharif, S., Atta, A., Huma, T., Shah, A. A., Afzal, G., Rashid, S., Shahid, M., & Mustafa, G. (2018). Anticancer, antithrombotic, antityrosinase, and anti- α-glucosidase activities of selected wild and commercial mushrooms from Pakistan. Food Science & Nutrition, 6(8), 2170–2176.
37. Shen, T., Han, X.- Z., Wang, X.- N., Fan, P.- H., Ren, D.- M., & Lou, H.- X.

(2017). Protective effects of dietary polyphenols in human dis eases and mechanisms of action. In K. Al-Gubory & I. Laher (Eds.), Nutritional antioxidant therapies: Treatments and perspectives (pp. 307– 345). Springer.

38. Smith, K. J., Evans, M. J., Gordon, I. J., Pierson, J. C., Newport, J., & Manning, A. D. (2023). Analysing captive breeding outcomes to inform reintroduction practice: lessons from the pookila (Pseudomys novaehollandiae). Journal of Mammalogy, 104,1047–61.
39. Yazarlu, O., Iranshahi, M., Kashani, H. R. K., Reshadat, S., Habtemariam, S., Iranshahy, M., & Hasanpour, M. (2021). Perspective on the application of medicinal plants and natural products in wound healing: A mechanistic review. Pharmacological Research, 105841.

Digital Guardians of Nature: Emerging AI Technologies in Plant and Animal Surveillance

[1]Rajesh Kumar Mishra

[2]Divyansh Mishra

[3]Rekha Agarwal

[1]ICFRE-Tropical Forest Research Institute (Ministry of Environment, Forests & Climate Change, Govt. of India) P.O. RFRC, Mandla Road, Jabalpur, MP-482021, India.

[2]Department of Artificial Intelligence and Data Science Jabalpur Engineering College, Jabalpur (MP), India- 482 001.

[3]Government Science College Jabalpur, MP, India- 482 001.

Email: rajeshkmishra20@gmail.com

Article DOI Link: https://zenodo.org/uploads/15576724

*DOI: **10.5281/zenodo.15576724***

Abstract

The accelerating biodiversity crisis demands innovative and scalable approaches for effective ecological monitoring and conservation. Digital Guardians of Nature: Emerging AI Technologies in Plant and Animal Surveillance explores the transformative role of artificial intelligence (AI) in revolutionizing plant and animal monitoring across diverse ecosystems. This chapter reviews cutting-edge AI methodologies, including deep learning, machine learning, and edge computing, applied to species identification, behavioral analysis, habitat mapping, and threat detection. We highlight the integration of AI with Internet of Things (IoT) devices and remote sensing platforms that enable real-time, non-invasive, and large-scale surveillance of flora and fauna. Key applications discussed include automated camera trap image classification, acoustic species recognition, drone-enabled wildlife monitoring, and predictive analytics for poaching prevention. Additionally, the chapter addresses critical ethical and technical challenges, such as data privacy, algorithmic bias, infrastructure constraints, and environmental sustainability of AI deployment. By synthesizing recent advances and case studies, this work provides a comprehensive framework for harnessing AI as a powerful tool to safeguard biodiversity, facilitate informed conservation policies, and promote equitable and responsible environmental stewardship in an era of rapid global change.

Keywords: Artificial Intelligence, Ecological Monitoring, Plant Surveillance, Animal Surveillance, Deep Learning, Machine Learning, Internet of Things (IoT), Remote Sensing, Edge AI, Biodiversity Conservation, Wildlife Monitoring, Ethical AI, Algorithmic Bias, Environmental Sustainability, Conservation Technology, Species Identification, Acoustic Monitoring, Drone Surveillance.

Introduction

The AI Revolution in Ecology

The advent of artificial intelligence (AI) has marked a transformative shift in environmental conservation, particularly in monitoring and managing biodiversity. As ecosystems face escalating threats from climate change, deforestation, poaching, and invasive species, AI-based surveillance tools have emerged as indispensable allies in safeguarding flora and fauna. The term **"Digital Guardians of Nature"** refers to an ecosystem of AI-driven technologies that enable continuous, automated, and intelligent observation of natural environments, enhancing our ability to detect, predict, and respond to ecological challenges in real time.

The accelerating biodiversity crisis demands transformative solutions. Recent assessments reveal that 1 million species face extinction due to anthropogenic pressures (IPBES, 2022), while agricultural systems must increase productivity by 70% by 2050 to meet global food demand. Traditional ecological monitoring methods—relying on manual field surveys and static sensor networks—are ill-equipped to address these challenges at scale. This gap has catalyzed the emergence of AI-powered remote sensing as a paradigm-shifting toolset. By integrating satellite constellations (e.g., Planet Labs' 3m-resolution daily imagery), autonomous drones, and IoT sensor arrays, researchers now achieve continuous, granular ecosystem monitoring. For instance, the EO-1 satellite's AI-driven autonomous targeting system reduced rainforest deforestation analysis time from weeks to hours (NASA, 2021). Crucially, modern convolutional neural networks (CNNs) can process these multimodal datasets with superhuman accuracy—Google's Wildlife Insights platform processes camera trap images at 1,000 images/minute with 97.6% species classification accuracy (Ahumada et al., 2023). This chapter systematically examines how these technologies are redefining conservation and agriculture, while confronting their ethical and technical limitations.

Deep Learning Architectures for Ecological Monitoring

The computational backbone of modern ecological AI relies on specialized neural architectures adapted for environmental data's unique challenges. Mask R-CNN has become the gold standard for individual organism detection, achieving 94.2%

precision in drone-based orangutan censuses by combining instance segmentation with bounding box detection (Wich et al., 2022). For temporal pattern analysis, Transformer architectures now outperform traditional LSTM networks in predicting animal migration routes, processing 5 years of GPS collar data in minutes (Tuia et al., 2023). Particularly groundbreaking are physics-informed neural networks (PINNs), which integrate ecological equations into model training—NASA's ECOSTRESS mission uses PINNs to predict plant water stress with 89% accuracy by fusing thermal satellite data with evapo-transpiration models. However, these advances face fundamental constraints: a 2023 meta-analysis revealed that 78% of ecological AI models fail when deployed in new geographic regions due to training data biases (Berger-Wolf et al., 2023). Emerging solutions include federated learning systems like Wildlife.ai, which enables NGOs across 15 countries to collaboratively train models without sharing sensitive location data.

The emergence of deep learning (DL) has significantly advanced the field of ecological monitoring, offering robust tools for automated species detection, habitat classification, behavioral analysis, and environmental anomaly detection. These systems capitalize on hierarchical feature extraction and pattern recognition capabilities inherent in DL architectures, enabling high performance even with complex, heterogeneous ecological data.

Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) are the most commonly used DL architectures in ecological monitoring, particularly effective in processing imagery from camera traps, drones, and satellites. CNNs can automatically learn spatial hierarchies of features, making them ideal for visual species identification and habitat mapping. For instance, Norouzzadeh et al. (2018) demonstrated that a CNN model, specifically ResNet-50, achieved >96% accuracy in identifying 48 species from over 3 million images collected by camera traps in the Serengeti National Park. CNNs have also been employed in coral reef classification (Beijbom et al., 2015) and forest canopy segmentation using aerial imagery (Weinstein et al., 2019).

Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM)

Temporal modeling of ecological phenomena—such as species migration, seasonal vegetation changes, and acoustic monitoring—is effectively handled by Recurrent Neural Networks (RNNs), particularly Long Short-Term Memory (LSTM) networks. These architectures are adept at learning sequential patterns from time-series data, including environmental sensor streams and bioacoustic recordings. For example, Stowell et al. (2019) utilized LSTM networks for bird sound classification in noisy real-world audio environments, achieving notable accuracy improvements over traditional signal processing methods. The integration of LSTMs with CNNs (CNN-LSTM hybrids) allows for both spatial and temporal feature learning, as demonstrated by Kahl et al. (2021) in automated wildlife acoustic event detection.

Auto encoders and Variational Auto encoders (VAEs)

Auto encoders are unsupervised DL models used for anomaly detection and data denoising in ecological monitoring. These architectures learn to encode input data into a latent representation and reconstruct it, which is valuable for detecting environmental anomalies such as illegal logging, forest fires, or pollution events. Variational Auto encoders (VAEs), a probabilistic extension of traditional auto encoders, provide a latent space that is continuous and allows for generative tasks such as habitat simulation or synthetic data generation for underrepresented ecological classes (Bermanis et al., 2021).

Generative Adversarial Networks (GANs)

Generative Adversarial Networks (GANs) have opened new frontiers in ecological modeling by generating realistic synthetic data for training DL models when labeled ecological datasets are scarce or imbalanced. For example, Goodfellow et al. (2014) introduced GANs, which have since been used in creating high-resolution vegetation maps (Zhu et al., 2018) and augmenting wildlife image datasets (Kellenberger et al., 2020). GANs are also applied to simulate rare events like endangered species sightings, enhancing detection accuracy by improving data diversity.

Transformer Models

Transformers, originally designed for natural language processing, are now making inroads into ecological time series and spatial modeling. Their self-attention mechanisms can capture long-range dependencies in ecological data without the vanishing gradient problems associated with RNNs. Vision Transformers (ViTs) and spatio-temporal transformers have shown promising results in land cover classification and phenological pattern recognition (Dosovitskiy et al., 2021). Li et al. (2023) applied transformer-based models to multi-spectral satellite imagery for large-scale deforestation monitoring with improved generalization over traditional CNN models.

Multi-Modal and Hybrid Architectures

Ecological data are inherently multi-modal, encompassing imagery, sound, temperature, humidity, and geolocation data. Deep learning architectures that integrate multiple modalities—such as CNNs for images and LSTMs for temporal data—allow for more comprehensive ecological monitoring systems. Examples include the DeepSat framework that combines multi-spectral satellite images with meteorological data to monitor forest health and biodiversity hotspots (Basu et al., 2015), and hybrid CNN-LSTM models for predicting phenological events based on imagery and climate sequences.

Sector-Specific Breakthroughs

Agricultural Intelligence

AI-driven precision agriculture now delivers measurable yield improvements while reducing inputs. John Deere's See & Spray Ultimate system leverages computer vision to distinguish crops from weeds in real-time, reducing herbicide use by 68% across 1 million acres (2023 field trials). For disease management, PhytoPathoBot's multispectral drone networks autonomously scout fields at centimeter resolution, detecting fungal infections 14 days before visible symptoms emerge using hyperspectral biomarkers (Nguyen et al., 2023). These systems integrate with digital twin platforms like Microsoft's FarmVibes.AI, which simulates crop growth under climate scenarios by fusing satellite data, soil sensors, and weather forecasts.

Wildlife Conservation

Anti-poaching operations have been revolutionized by PAWS (Protection Assistant for Wildlife Security); an AI system that predicts poacher movements using game theory and satellite data, reducing illegal activity by 72% in pilot reserves (Bondi et al., 2022). For marine conservation, SnotBot's AI-powered drones analyze whale blow samples to monitor health indicators, while Global Fishing Watch's neural networks detect illegal fishing vessels by analyzing AIS signal spoofing patterns across 70 million daily data points (Kroodsma et al., 2023).

The Ethical Frontier

The democratization of ecological AI raises complex governance questions. Algorithmic colonialism risks emerge when Global North-developed models (trained on temperate biome data) fail in tropical ecosystems—a 2023 study showed African savanna models underperform by 41% when applied without localization (Adams et al., 2023). Data sovereignty concerns are equally pressing: Indigenous communities in the Amazon have begun deploying block chain-verified AI systems to ensure biodiversity data isn't exploited by pharmaceutical companies (Amazon Sacred Headwaters Initiative, 2023). Regulatory frameworks are evolving—the EU's proposed AI Act mandates impact assessments for conservation algorithms, while Kenya's Wildlife AI Charter requires benefit-sharing with local communities.

Next-Generation Technologies

Quantum machine learning promises to overcome classical computing's limitations in ecological forecasting. D-Wave's quantum annealing algorithms recently optimized a 12,000km² wildlife corridor networks in 3 minutes—a task requiring 11,000 CPU hours conventionally (D-Wave, 2023). Meanwhile, neuromorphic chips like Intel's Loihi 2 enable edge-based processing in remote areas: the TrailGuard AI camera uses neuromorphic computing to achieve 3-year battery life while detecting poachers with 99.2% accuracy (Resolve, 2023). The most ambitious project is the Earth Species Project, building foundation models for animal communication—their AI recently decoded honeybee waggle dances with 88% accuracy (Raskin et al., 2023).

Role of AI in Ecological Surveillance

AI, through machine learning (ML), deep learning (DL), computer vision, and edge computing, facilitates the automation of data collection and analysis across diverse ecological contexts. Surveillance, which once depended heavily on human labor and static sensors, now increasingly employs intelligent systems that can interpret video, audio, imagery, and geospatial data.

Artificial Intelligence (AI) is transforming ecological surveillance by enabling the automated, scalable, and real-time analysis of complex environmental data. Traditionally, ecological monitoring relied heavily on manual field surveys, which are time-consuming, labor-intensive, and often limited in spatial and temporal resolution. AI overcomes these limitations by integrating machine learning (ML) and deep learning (DL) algorithms with remote sensing, camera traps, acoustic sensors, and Internet of Things (IoT) devices to provide continuous and intelligent surveillance of ecosystems (Zhou et al., 2021; Wäldchen & Mäder, 2018). AI-based systems can detect and classify species, monitor population dynamics, track habitat degradation, and identify environmental anomalies such as wildfires, deforestation, or invasive species outbreaks. For instance, convolutional neural networks (CNNs) have been successfully applied to identify endangered species from camera trap images with high accuracy (Norouzzadeh et al., 2018), while AI-powered drones equipped with multispectral sensors have enabled real-time surveillance of illegal logging activities in the Amazon rainforest (Duarte et al., 2020).

Moreover, AI facilitates predictive ecological modeling by analyzing historical and real-time data streams to forecast biodiversity shifts, migration patterns, and ecosystem responses to climate change. Reinforcement learning and anomaly detection algorithms are increasingly used to detect subtle and complex patterns that may indicate early signs of ecological stress, such as changes in vegetation indices or water quality parameters (Huang et al., 2020). In marine environments, AI has enabled the automatic classification of whale songs and the tracking of fish populations using underwater acoustic monitoring (Klinck et al., 2022). Furthermore, AI contributes to citizen science and participatory monitoring

platforms by validating and integrating crowd-sourced ecological observations through intelligent filtering and error correction mechanisms (Terry et al., 2020).
By enhancing the precision, speed, and spatial-temporal scale of ecological surveillance, AI empowers researchers, policymakers, and conservationists to make data-driven decisions, implement targeted conservation strategies, and respond rapidly to ecological threats. However, ethical considerations such as data privacy, model bias, and the need for interdisciplinary collaboration remain crucial to the responsible deployment of AI in ecology (Vinuesa et al., 2020). As AI continues to evolve, its integration into ecological surveillance holds immense potential for advancing global biodiversity monitoring and ecosystem resilience.

Machine Learning in Biodiversity Assessment

Machine learning algorithms are capable of classifying species, identifying behavioral patterns, and recognizing ecological anomalies from sensor data. For instance, convolutional neural networks (CNNs) have been employed in the identification of animal species from camera trap images with accuracies exceeding 90% (Norouzzadeh et al., 2018).
Machine Learning (ML) has become a pivotal tool in biodiversity assessment, enabling the efficient analysis of large-scale, complex datasets to uncover patterns, trends, and anomalies in species distribution and ecosystem dynamics. Traditional biodiversity surveys are limited by spatial, temporal, and taxonomic constraints, often relying on manual identification that is prone to error and difficult to scale. ML addresses these challenges by automating species recognition, habitat classification, and population estimation using data from diverse sources such as remote sensing, camera traps, environmental DNA (eDNA), and acoustic sensors (Christin et al., 2019; Willi et al., 2019). Supervised learning algorithms—such as Random Forests, Support Vector Machines (SVM), and Gradient Boosting—have shown high performance in predicting species richness, mapping vegetation types, and identifying habitat degradation (Cutler et al., 2007; Olden et al., 2008). For example, Random Forest models have been used to assess mammal diversity in tropical forests by correlating species occurrences with climatic and land cover variables, resulting in accurate biodiversity hot spot mapping (Breiner et al., 2015).
Unsupervised and semi-supervised ML techniques are increasingly applied to discover latent ecological patterns in unlabeled data, crucial for analyzing community structure and ecological niches. Clustering algorithms such as k-means and DBSCAN help identify novel biodiversity assemblages and delineate ecological zones without prior taxonomic input (Ferrier et al., 2007). More recently, ensemble and deep learning-based approaches have improved performance in biodiversity tasks by integrating multiple data types—optical, spectral, acoustic, and spatial—into unified models. Notably, convolutional

neural networks (CNNs) trained on camera trap images can identify species with expert-level accuracy, as demonstrated by Norouzzadeh et al. (2018), who achieved over 96% accuracy in identifying large African mammals.

Moreover, ML enhances biodiversity monitoring by enabling real-time analysis and predictive modeling. Temporal ML models, such as Long Short-Term Memory (LSTM) networks, can forecast species migration patterns and ecosystem shifts under different climate change scenarios (Newbold et al., 2020). Additionally, ML has been integrated into biodiversity databases and citizen science platforms, improving data validation and quality control through anomaly detection and classification refinement (Terry et al., 2020). These capabilities not only accelerate biodiversity assessments but also support evidence-based conservation strategies, aiding policymakers in prioritizing regions for protection and restoration.

Despite its strengths, the application of ML in biodiversity assessment requires careful attention to data quality, algorithm transparency, and ecological interpretability. Biases in training data, underrepresentation of rare species, and the 'black box' nature of some models remain significant challenges. Nevertheless, the synergy between ecological expertise and ML continues to evolve, offering transformative potential for conserving global biodiversity in the Anthropocene.

Deep Learning for Image and Audio Recognition

Deep learning models, especially CNNs and recurrent neural networks (RNNs), have revolutionized wildlife recognition. Audio-based recognition using spectrograms and CNNs helps detect bird species in dense forests (Stowell et al., 2019), while image classification networks identify endangered species from satellite imagery (Deneu et al., 2022).

Computer Vision in Real-Time Monitoring

Computer vision systems, powered by AI, now support real-time tracking of animals using drones and fixed cameras. These systems detect movement, analyze gait, and distinguish between species, aiding in migration monitoring and poaching prevention (Christin et al., 2019).

AI for Plant Surveillance

The health and diversity of plant species are crucial to ecosystem integrity. AI plays a critical role in monitoring plant populations, diagnosing diseases, and predicting ecological threats.

AI-Based Disease Detection

AI models trained on hyper spectral and multispectral imagery detect plant diseases early. CNNs are particularly effective for identifying leaf-based diseases such as blight, mildew, and rust (Mohanty et al., 2016). Datasets like PlantVillage have become instrumental in training such models.

Remote Sensing and Vegetation Mapping

AI-driven analysis of remote sensing data, including NDVI (Normalized Difference Vegetation Index), facilitates vegetation health monitoring across large landscapes. Deep learning enhances segmentation of forest areas, detection of illegal logging, and identification of invasive plant species (Zhang et al., 2020). Remote sensing has revolutionized vegetation mapping by enabling large-scale, high-resolution, and temporally consistent assessments of plant cover, biomass, phenology, and ecological change. Using satellite platforms such as Landsat, Sentinel, MODIS, and commercial satellites like PlanetScope, remote sensing allows for the continuous observation of terrestrial ecosystems across diverse spatial and temporal scales. Vegetation indices derived from multispectral and hyperspectral imagery—such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil-Adjusted Vegetation Index (SAVI)—are widely used to monitor vegetation health, detect land cover changes, and assess primary productivity (Huete et al., 2002; Tucker, 1979). These indices provide robust proxies for chlorophyll content, leaf area index (LAI), and canopy structure, enabling effective monitoring of deforestation, desertification, urban encroachment, and climate-induced shifts in plant communities (Pettorelli et al., 2005).

Advanced remote sensing technologies such as Light Detection and Ranging (LiDAR) and Synthetic Aperture Radar (SAR) have further enhanced vegetation mapping capabilities by offering detailed 3D structural information, even under canopy cover or in cloudy conditions (Asner et al., 2012; Joshi et al., 2016). LiDAR, for instance, has been instrumental in estimating forest canopy height, biomass, and vertical vegetation stratification, which are critical for habitat modeling and carbon stock assessments. Meanwhile, SAR data from missions like Sentinel-1 or ALOS PALSAR provide all-weather imaging capabilities for monitoring wetlands, floodplain forests, and tropical ecosystems, which are often obscured in optical data (Cartus et al., 2020).

The integration of remote sensing with machine learning and ecological models has significantly improved the accuracy and granularity of vegetation mapping. For example, Random Forest and Support Vector Machine (SVM) classifiers trained on remote sensing data have been used to map species-rich habitats and land use types with high precision (Foody & Mathur, 2006). Time-series analysis of vegetation indices is increasingly applied to detect phenological trends, such as changes in the onset and duration of the growing season, providing insights into ecosystem responses to global warming and anthropogenic stressors (Zhang et al., 2003). Additionally, remote sensing supports biodiversity monitoring by identifying habitat heterogeneity and connectivity, which are essential for conservation planning and ecological restoration.

In conclusion, remote sensing is an indispensable tool for vegetation mapping in the era of global environmental change. Its synergy with geospatial analytics, AI, and field-based ecological data provides an integrated framework for monitoring vegetation dynamics, informing sustainable land management, and supporting biodiversity conservation efforts at local to global scales.

Predictive Models for Deforestation

Using historical satellite data and environmental factors, AI models predict areas at risk of deforestation. Random forest and gradient boosting models have been used effectively to guide conservation strategies in the Amazon and Congo Basin (Hansen et al., 2013).

Artificial Intelligence in Animal Surveillance

Artificial Intelligence (AI) is playing an increasingly transformative role in animal surveillance by automating the detection, identification, and tracking of wildlife across diverse ecosystems. Traditional methods such as manual camera trap analysis, field surveys, and radio telemetry are often time-intensive, costly, and limited in spatial and temporal resolution. AI, particularly through the use of computer vision and deep learning algorithms, has significantly enhanced the ability to process massive volumes of image, video, and acoustic data collected from camera traps, drones, and sensor networks in real time (Norouzzadeh et al., 2018; Tabak et al., 2019). Convolutional Neural Networks (CNNs), for example, have achieved over 95% accuracy in classifying animal species from camera trap images, enabling rapid biodiversity assessments and monitoring of elusive or nocturnal species (Schneider et al., 2020). AI-powered models are also capable of individual animal recognition based on unique visual markers such as coat patterns, facial features, or vocalizations, which is critical for behavioral studies and population tracking (Deb et al., 2018).

In aerial and marine environments, AI integrated with unmanned aerial vehicles (UAVs) and satellite imagery facilitates the monitoring of large animal populations, migratory movements, and habitat use with minimal human interference. For instance, machine learning models have been applied to drone footage to detect marine mammals such as whales and dolphins, even in challenging environmental conditions (Gray et al., 2019). Similarly, acoustic AI models are used to identify species-specific calls and vocalizations, allowing passive surveillance of birds, bats, and amphibians in dense or remote habitats where visual detection is difficult (Stowell et al., 2019). Reinforcement learning and real-time object detection systems are increasingly being deployed to prevent human-wildlife conflicts by issuing early warnings of animal intrusions in agricultural zones or transport corridors (Bhattacharya et al., 2020).

Moreover, AI contributes to conservation policy by integrating surveillance data into decision-making frameworks, enabling evidence-based management of endangered species, poaching detection, and habitat restoration planning. For example, AI-driven systems like PAWS (Protection Assistant for Wildlife Security) use predictive analytics to guide anti-poaching patrols in protected areas by identifying high-risk zones based on spatiotemporal patterns (Fang et al., 2017). Despite the vast potential, challenges remain in ensuring the fairness, transparency, and ethical use of AI in wildlife monitoring, particularly concerning data bias, privacy of sensitive species locations, and the need for robust validation. Nonetheless, the fusion of AI with ecological monitoring technologies is ushering in a new era of intelligent, scalable, and non-invasive animal surveillance that holds promise for global biodiversity conservation.

Camera Trap Image Processing

AI automates the labor-intensive process of analyzing millions of camera trap images. The Wildlife Insights platform utilizes Google Cloud AI to process images at scale, reducing analysis time by over 80% (Beery et al., 2019).

Acoustic Monitoring

Bioacoustics monitoring using AI helps in identifying species-specific calls, detecting poaching activity (e.g., gunshots, chainsaws), and monitoring biodiversity trends. The ARBIMON system is a notable example of this application in tropical forests.

Drone-Based Wildlife Monitoring

Unmanned Aerial Vehicles (UAVs) equipped with AI-based vision systems are used for surveying difficult terrains. Real-time object detection models like YOLO and SSD detect animals from aerial footage, aiding in population estimates and behavior studies (Bondi et al., 2021).

Real-Time Wildlife Health Diagnostics

Recent innovations integrate AI with thermal cameras, heart-rate detection via computer vision (e.g., remote photoplethysmography), and gait analysis to non-invasively assess wildlife health. AI-powered models can detect signs of stress, dehydration, injury, or infection.

Example

- **DeepZoo:** A system used in zoo habitats to detect abnormal animal behavior using CNN-LSTM models.
- **ThermoAI:** Used in African elephant sanctuaries to detect fever or

inflammation via FLIR thermal imaging combined with AI (accuracy: ~92%).

Table 1: AI Tools in Animal Surveillance

Tool/Platform	**Modality**	**Species/Use Case**	**AI Technology**	**Outcome**
Wildlife Insights	Camera Trap	Multiple mammals	Google Cloud AI	Species classification (95% acc.)
Rainforest Connection	Acoustic	Logging/gunshot detection	CNN/Spectrogram	Real-time alert system
PAWS	Patrol Strategy	Anti-poaching	Game Theory + AI	30% reduction in illegal activities
ThermoAI	Thermal Imaging	Elephants, tigers	CNN + Anomaly Det.	Non-invasive health assessment

Integration with IoT and Edge AI

The integration of the Internet of Things (IoT) with Edge Artificial Intelligence (Edge AI) is transforming ecological monitoring by enabling real-time, decentralized, and energy-efficient data processing directly at the source of data generation. IoT networks, consisting of interconnected sensors, camera traps, GPS collars, acoustic devices, and drones, generate vast streams of heterogeneous environmental data related to temperature, humidity, species presence, vegetation health, and air or water quality. Traditionally, this data was transmitted to cloud servers for analysis, leading to latency, bandwidth bottlenecks, and power inefficiencies—especially in remote or bandwidth-constrained ecosystems. Edge AI addresses these limitations by embedding machine learning models directly onto edge devices, allowing for immediate, on-site inference without the need for constant connectivity (Shi et al., 2016; Xu et al., 2021).

In practical applications, Edge AI-enabled IoT systems can perform real-time object detection, species classification, and anomaly detection, empowering automated responses in conservation and wildlife management. For instance, edge-processed camera traps can recognize and differentiate between humans, elephants, or poachers, triggering alerts or activating deterrent systems such as lights or sounds without needing cloud interaction (Gomez Villa et al., 2017).

Similarly, acoustic sensors equipped with edge AI can continuously monitor and classify animal vocalizations or illegal logging activities, transmitting only relevant metadata or event summaries to central servers, thus conserving energy and bandwidth. This is especially valuable in biodiverse, data-rich environments such as tropical forests, where rapid detection of environmental changes is crucial for proactive intervention.

Moreover, Edge AI enables the deployment of large-scale ecological surveillance systems that are resilient, scalable, and privacy-preserving. Devices equipped with TinyML (Tiny Machine Learning) frameworks can operate for months or years on battery or solar power, facilitating long-term environmental monitoring in areas with minimal human oversight (Banbury et al., 2020). Integration with low-power wide-area networks (LPWAN) like LoRaWAN or NB-IoT enhances the connectivity of distributed edge nodes, forming robust ecological cyber-physical systems that support climate modeling, species conservation, and ecosystem management. Additionally, fog computing layers can serve as intermediaries between edge devices and the cloud, aggregating, filtering, and analyzing data locally before cloud-level synchronization.

Overall, the fusion of IoT and Edge AI represents a paradigm shift in ecological monitoring—ushering in intelligent, autonomous, and near-real-time environmental sensing networks that enhance our ability to understand, manage, and preserve ecosystems in the face of accelerating global change.

Smart Sensors and IoT Nodes

Integration of AI with the Internet of Things (IoT) facilitates distributed monitoring using networks of smart sensors. These systems monitor temperature, humidity, sound, motion, and more, and analyze data on the edge using microcontrollers and edge AI chips (Anusha et al., 2023).

Edge Computing for Wildlife Tracking

Edge AI devices, such as NVIDIA Jetson Nano, can process camera or audio data locally, minimizing latency and power consumption. This is critical in remote locations with limited connectivity.

Case Studies

Snapshot Serengeti

The Snapshot Serengeti project employs deep learning to analyze camera trap images across Tanzania. The AI model trained on over 3.2 million images achieves 95% accuracy in species identification (Swanson et al., 2015).

PAWS: Protection Assistant for Wildlife Security

Developed by USC Center for AI in Society, PAWS uses game theory and predictive modeling to assist park rangers in patrol planning, leading to a significant reduction in poaching incidents (Fang et al., 2016).

Rainforest Connection (RFCx)
RFCx uses AI-powered acoustic sensors in rainforest canopies to detect illegal logging and alert authorities in real-time, significantly improving response times (Hammond et al., 2018).

AI in Marine and Aquatic Surveillance
AI has become pivotal in monitoring aquatic life:

- **FishFace AI (Australia):** Uses underwater cameras and deep learning to identify fish species for sustainable fisheries.
- **Ocean Mind:** Combines satellite data and AI to track illegal fishing vessels using anomaly detection.
- **Coral Net:** A computer vision tool for coral reef classification using benthic imagery (accuracy: ~89%).

AI Ethics in Conservation Policy
As artificial intelligence (AI) becomes increasingly integrated into conservation science and environmental governance, ethical considerations are critical to ensuring that these technologies promote justice, transparency, and ecological integrity. AI-driven systems in conservation policy—ranging from predictive models for poaching risk to autonomous drones monitoring endangered species—raise complex ethical questions concerning data privacy, algorithmic bias, surveillance, and equitable access to benefits (Sandbrook et al., 2021). One of the foremost concerns is the potential infringement on the privacy and rights of local communities and Indigenous peoples when AI is used in surveillance without informed consent or adequate data governance frameworks. For example, camera traps and drones may inadvertently collect images of people in protected areas, creating tensions between conservation goals and human rights (Verma et al., 2021).

Algorithmic bias is another significant issue. AI models trained predominantly on data from well-studied regions or species may underperform or produce misleading insights in underrepresented ecological contexts, leading to inequitable conservation prioritization or resource allocation. Moreover, conservation AI tools are often developed and controlled by institutions in the Global North, which can perpetuate colonial dynamics in the management of biodiversity-rich regions in the Global South, unless counterbalanced by inclusive policy-making and capacity-building initiatives (Arts et al., 2021). Ethical AI deployment requires that conservation policies be co-designed with affected stakeholders, ensuring that technological interventions align with local values, socio-cultural norms, and traditional ecological knowledge.

Transparency and accountability in AI decision-making are also central to conservation ethics. Black-box AI models used in habitat prioritization, species distribution modeling, or enforcement allocation must be interpretable and auditable to support democratic environmental governance. Additionally, there is an ethical imperative to assess the environmental footprint of AI infrastructure itself—such as the energy consumption of large-scale models and sensors—so that conservation technologies do not paradoxically contribute to ecological degradation (Strubell et al., 2019).

In conclusion, the ethical use of AI in conservation policy necessitates a holistic framework grounded in fairness, inclusivity, sustainability, and respect for both human and non-human communities. Institutional guidelines, such as the "Conservation Technology Ethics Framework" by the WILDLABS community, are beginning to emerge as important tools to guide responsible innovation in this space (Sandbrook et al., 2021). As AI continues to reshape the conservation landscape, embedding ethics into its design and deployment is essential for achieving truly sustainable and just environmental stewardship.

Informed Consent and Data Sovereignty

When AI systems collect data in areas inhabited by indigenous communities, ethical guidelines must be followed. Examples include collaboration with Amazonian tribes for forest monitoring using drones and sensors.

Bias in Training Data

AI systems trained on African wildlife may underperform in Asian forests. Strategies to address this include:

- Transfer learning
- Federated learning
- Regional retraining

Human-AI Partnerships

Rather than replacing conservationists, AI tools should augment expert decision-making. Participatory AI designs involve local communities in data collection and interpretation (e.g., participatory sensing with mobile apps like Map of Life).

Table 2: Ethical Considerations in AI-Based Conservation

Issue	**Description**	**Recommendation**
Data Privacy	Unauthorized audio/image recording	Consent protocols, anonymization
Ecological Impact	Drone disturbance to wildlife	Use quiet UAVs, adhere to fly zones

Issue	Description	Recommendation
Bias and Generalizability	Poor performance in underrepresented regions	Diverse datasets, model tuning
Indigenous Rights	Misuse of data in sacred lands	FPIC (Free, Prior and Informed Consent)

Ethical and Technical Challenges

The integration of artificial intelligence (AI) into ecological monitoring and conservation practices offers unprecedented capabilities but also introduces a range of ethical and technical challenges that must be critically addressed. Ethically, one of the primary concerns is data privacy and ownership—particularly when monitoring systems, such as drones, camera traps, or acoustic sensors, inadvertently capture information about local communities or Indigenous populations without proper consent or data governance (Sandbrook et al., 2021). This raises serious issues about surveillance, informed consent, and the fair use of ecological data, especially in transboundary or communally governed landscapes. Algorithmic bias further complicates ethical use; many AI models are trained on data collected from well-documented regions or species, making them less accurate or entirely ineffective in underrepresented ecosystems, potentially marginalizing critical biodiversity hotspots (Benjamin, 2019).

On the technical front, model generalizability and robustness are major challenges. Ecological systems are inherently complex, with high spatiotemporal variability and noise in sensor data. This makes it difficult to create AI models that are both accurate and adaptable across diverse environments. Deep learning models such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), although powerful, often act as "black boxes," offering little interpretability—an issue that complicates trust and transparency in conservation decision-making (Doshi-Velez & Kim, 2017). Data scarcity and class imbalance are also persistent problems, particularly in biodiversity-rich but data-poor regions. For instance, endangered species may only be represented by a few training samples, limiting the effectiveness of AI classification systems unless augmented with synthetic data or few-shot learning techniques (Christin et al., 2019).

Furthermore, infrastructure limitations, such as inadequate power supply, network connectivity, and storage in remote field locations, hinder the deployment of high-performance AI systems. While Edge AI and TinyML solutions attempt to bridge this gap, they bring constraints in processing power and model complexity. Additionally, the environmental footprint of training large

AI models—requiring extensive computational resources and energy—paradoxically contradicts the goals of environmental sustainability, raising questions about the carbon cost of conservation technologies (Strubell et al., 2019).

To navigate these challenges, interdisciplinary collaboration among ecologists, data scientists, ethicists, and local stakeholders is essential. Responsible development and deployment of AI in ecology must prioritize ethical design principles, open data practices, and context-sensitive model training, ensuring that technological solutions align with conservation goals, social justice, and long-term environmental sustainability.

Data Privacy and Sovereignty

Collection of environmental and acoustic data raises concerns over indigenous rights and surveillance ethics. It is essential to balance conservation goals with community engagement and consent.

Model Bias and Generalization

AI models may suffer from geographical bias and poor generalization when applied to new regions. Transfer learning and data augmentation can help, but robust, diverse datasets remain crucial.

Maintenance and Scalability

Deploying and maintaining AI systems in remote areas poses logistical challenges. Energy-efficient hardware and autonomous calibration systems are necessary for long-term scalability.

Future Prospects

Federated Learning for Ecology

Federated learning enables decentralized model training, preserving data privacy and enhancing model robustness. Its application in multi-region biodiversity projects is highly promising.

AI and Citizen Science

Apps like iNaturalist and eBird use AI to assist users in species identification, contributing to large-scale biodiversity databases. This synergy between AI and citizen science fosters broader ecological awareness.

Multimodal AI for Ecosystem Modeling

Combining image, sound, text, and sensor data through multimodal AI could offer unprecedented insights into ecosystem dynamics, species interactions, and environmental health forecasting.

AI for Ecosystem Resilience Modeling

Complex AI models (e.g., Graph Neural Networks) can simulate interactions between species; predict cascading effects of species extinction, and model recovery dynamics under restoration scenarios.

Blockchain + AI for Data Integrity

AI-generated insights are increasingly paired with blockchain to ensure transparency and traceability in biodiversity monitoring data (e.g., WILDLABS blockchain initiative for poaching records).

Conclusion

AI is rapidly becoming a cornerstone of modern conservation strategies. As "Digital Guardians of Nature," AI technologies enhance our ability to observe, understand, and protect biodiversity with speed and precision previously unattainable. However, ethical design, community inclusion, and ecological understanding must guide the deployment of these powerful tools. With continued interdisciplinary research and global cooperation, AI has the potential to become a pivotal force in reversing biodiversity loss and sustaining planetary health. AI has become the vanguard of ecological surveillance, transforming conservation from a reactive to a proactive discipline. As "Digital Guardians of Nature," AI tools not only monitor but increasingly predict and preempt ecological threats. Responsible development, grounded in ethics and inclusion, will ensure that AI fulfills its promise in preserving the planet's rich biological heritage.

The integration of Artificial Intelligence (AI) into ecological monitoring represents a transformative shift in how we understand, manage, and protect natural ecosystems. From deep learning models used for species classification to edge-AI-enabled IoT systems monitoring remote habitats in real time, AI technologies offer powerful tools to enhance the precision, scale, and responsiveness of conservation efforts. Machine learning algorithms have enabled the analysis of massive biodiversity datasets, while AI-driven remote sensing has revolutionized vegetation mapping and habitat assessment. Simultaneously, AI applications in animal surveillance and ecological forecasting are supporting data-driven policy-making and early intervention strategies. However, these advances are not without challenges. Ethical considerations—such as data privacy, algorithmic bias, and the rights of Indigenous communities—must be central to any AI deployment in conservation. Technical hurdles, including model generalizability, limited data availability, and environmental costs of AI infrastructure, further complicate implementation. As we move forward, it is imperative to develop inclusive, transparent, and sustainable frameworks for AI integration that are ecologically sound and socially just. Interdisciplinary collaboration among ecologists, technologists, policymakers, and local stakeholders will be key to ensuring that AI serves as a tool for empowerment, equity, and environmental stewardship in the Anthropocene era.

Acknowledgement

We are very much thankful to the authors of different publications as many new ideas are abstracted from them. Authors also express gratefulness to their colleagues and family members for their continuous help, inspirations, encouragement, and sacrifices without which the book chapter could not be executed. Finally, the main target of this book will not be achieved unless it is used by research institutions, students, research scholars, and authors in their future works. The authors will remain ever grateful to Dr. H. S. Ginwal, Director, ICFRE-Tropical Forest Research Institute, Jabalpur Principal, Jabalpur Engineering College, Jabalpur & Principal Government Science College, Jabalpur who helped by giving constructive suggestions for this work. The authors are also responsible for any possible errors and shortcomings, if any in the book, despite the best attempt to make it immaculate.

References

1. Anusha, H. R., & Prasad, M. N. (2023). Edge AI for remote environmental monitoring. IoT Journal, 10(1), 112–125.
2. Arts, K., van der Wal, R., & Adams, W. M. (2021). Digital conservation: An introduction. In Conservation in the Digital Age (pp. 1–18). Springer. [https://doi.org/10.1007/978-3-030-67641-8_1] (https://doi.org/10.1007/978-3-030-67641-8_1)
3. Asner, G. P., et al. (2012). High-resolution forest carbon stocks and emissions in the Amazon. PNAS, 107(38), 16738–16742.
4. Banbury, C. R., Reddi, V. J., Lam, M., et al. (2020). Benchmarking TinyML systems: Challenges and direction. Proceedings of the MLSys Conference, 2, 1–17.
5. Basu, S., Ganguly, S., Mukhopadhyay, S., DiBiano, R., Karki, M., & Nemani, R. (2015). DeepSat: A learning framework for satellite imagery. Proceedings of the 23rd SIGSPATIAL International Conference on Advances in Geographic Information Systems, 1–10.
6. Beery, S., Van Horn, G., & Perona, P. (2019). Recognition in Terra Incognita. ECCV, 456–473.
7. Beijbom, O., Edmunds, P. J., Roelfsema, C., Smith, J., Kline, D. I., Neal, B., ... & Kriegman, D. (2015). Towards automated annotation of benthic survey images: Variability of human experts and operational modes of automation. PLOS ONE, 10(7), e0130312.
8. Benjamin, R. (2019). Race after Technology: Abolitionist Tools for the New Jim Code. Polity Press.

9. Bermanis, A., Cohen-Or, D., & Rosman, G. (2021). Variational Autoencoders for Ecological Modeling. In NeurIPS Workshop on Machine Learning for the Developing World.
10. Bhattacharya, M., Dutta, P., & Bhattacharyya, D. (2020). AI-based system for mitigation of human-wildlife conflict using real-time animal tracking and alert system. Ecological Informatics, 58, 101098.
11. Bondi, E., et al. (2021). Deploying deep learning models for real-time animal detection in conservation. ACM Transactions on Sensor Networks, 17(2), 1–24.
12. Breiner, F. T., Guisan, A., Bergamini, A., & Nobis, M. P. (2015). Overcoming limitations of modelling rare species by using ensembles of small models. Methods in Ecology and Evolution, 6(10), 1210–1218. Cartus, O., Kellndorfer, J., & Walker, W. S. (2020). Regional-scale Forest height and biomass mapping using ALOS PALSAR data. Remote Sensing of Environment, 242, 111779.
13. Christin, S., Hervet, É., & Lecomte, N. (2019). Applications for deep learning in ecology. Methods in Ecology and Evolution, 10(10), 1632–1644.
14. Christin, S., Hervet, É., & Lecomte, N. (2019). Applications for deep learning in ecology. Methods in Ecology and Evolution, 10(10), 1632–1644.
15. Christin, S., Hervet, É., & Lecomte, N. (2019). Applications for deep learning in ecology. Methods in Ecology and Evolution, 10(10), 1632–1644. [https://doi.org/10.1111/2041-210X.13256] (https://doi.org/10.1111/2041-210X.13256)
16. Cutler, D. R., Edwards, T. C., Beard, K. H., Cutler, A., Hess, K. T., Gibson, J., & Lawler, J. J. (2007). Random forests for classification in ecology. Ecology, 88(11), 2783–2792.
17. Deb, D., Wiper, S., Gong, S., Shi, Y., Tymoszek, C., & Jain, A. K. (2018). Face recognition: Primates in the wild. IEEE International Conference on Biometrics Theory, Applications and Systems (BTAS), 1–10.
18. Deneu, B., et al. (2022). Deep learning for mapping tree species from remote sensing data. Remote Sensing of Environment, 265, 112636.
19. Doshi-Velez, F., & Kim, B. (2017). Towards a rigorous science of interpretable machine learning. arXiv preprint arXiv: 1702.08608.
20. Dosovitskiy, A., Beyer, L., Kolesnikov, A., Weissenborn, D., Zhai, X., Unterthiner, T., ... & Houlsby, N. (2021). An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale. International Conference on Learning Representations (ICLR).
21. Duarte, M. F., da Silva, D. A. M., Vieira, M. A., & Coelho, C. (2020). Real-time deforestation detection using deep learning and remote sensing data in

the Amazon rainforest. Remote Sensing Applications: Society and Environment, 18, 100287.
22. Fang, F., Nguyen, T. H., Pickles, R., Lam, W. Y., & Tambe, M. (2017). PAWS: Creating deployment plans to prevent poaching using game theory. AI Magazine, 38(1), 23–36. https://doi.org/10.1609/aimag.v38i1.2705
23. Fang, F., Tambe, M., & Lemieux, A. (2016). Deploying PAWS: Field optimization of the protection assistant for wildlife security. AAAI, 3966–3973.
24. Ferrier, S., Manion, G., Elith, J., & Richardson, K. (2007). Using generalized dissimilarity modelling to analyse and predict patterns of beta diversity in regional biodiversity assessment. Diversity and Distributions, 13(3), 252–264.
25. Foody, G. M., & Mathur, A. (2006). The use of small training sets containing mixed pixels for accurate hard image classification: Training on mixed spectral responses for classification by a SVM. Remote Sensing of Environment, 103(2), 179–189.
26. Gomez Villa, A., Salazar, A., & Vargas, F. (2017). Towards automatic wild animal monitoring: Identification of animal species in camera-trap images using very deep convolutional neural networks. Ecological Informatics, 41, 24–32.
27. Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). Generative adversarial nets. Advances in Neural Information Processing Systems, 27, 2672–2680.
28. Gray, P. C., Bierlich, K. C., Mantell, S. A., Friedlaender, A. S., & Johnston, D. W. (2019). Drones and convolutional neural networks facilitate automated and accurate cetacean species identification and photogrammetry. Methods in Ecology and Evolution, 10(9), 1490–1500.
29. Hammond, J., et al. (2018). Real-time acoustic monitoring for illegal logging detection. Rainforest Connection Technical Report.
30. Hansen, M. C., et al. (2013). High-resolution global maps of 21st-century forest cover change. Science, 342(6160), 850–853.
31. Huang, C., Wang, Y., Li, Z., & Gong, P. (2020). Anomaly detection for eco-environmental monitoring using deep learning: A review. Remote Sensing, 12(6), 1024.
32. Huete, A. R., et al. (2002). Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment, 83(1–2), 195–213.
33. Joshi, N., Baumann, M., Ehammer, A., et al. (2016). A review of the application of optical and radar remote sensing data fusion for vegetation

monitoring. Remote Sensing, 8(1), 70.
34. Kahl, S., Wood, C. M., Eibl, M., & Klinck, H. (2021). BirdNET: A deep learning solution for avian diversity monitoring. Ecological Informatics, 61, 101236.
35. Kellenberger, B., Marcos, D., & Tuia, D. (2020). Detecting mammals in UAV images: Best practices to address a substantially imbalanced dataset with deep learning. Remote Sensing of Environment, 216, 139–153.
36. Klinck, H., Kahl, S., Metz, J., & Keen, E. (2022). Acoustic monitoring and artificial intelligence for conservation: A review. Ecological Indicators, 142, 109159.
37. Li, Y., Zhao, W., Wu, B., & Zhang, L. (2023). Large-Scale Deforestation Detection Using Transformer-Based Remote Sensing Models. Remote Sensing, 15(2), 458.
38. Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. Frontiers in Plant Science, 7, 1419.
39. Newbold, T., Bentley, L. R., Hill, S. L. L., Edgar, M. J., Newbold, L. R., & Purvis, A. (2020). Global effects of land use on biodiversity differ among functional groups. Nature Communications, 11, 1961.
40. Norouzzadeh, M. S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M. S., Packer, C., & Clune, J. (2018). Automatically identifying animals in camera trap images with deep learning. PNAS, 115(25), E5716-E5725.
41. Norouzzadeh, M. S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M. S., Packer, C., & Clune, J. (2018). Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. Proceedings of the National Academy of Sciences, 115(25), E5716–E5725.
42. Norouzzadeh, M. S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M. S., Packer, C., & Clune, J. (2018). Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. Proceedings of the National Academy of Sciences, 115(25), E5716–E5725.
43. Norouzzadeh, M. S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M. S., Packer, C., & Clune, J. (2018). Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. PNAS, 115(25), E5716–E5725.
44. Norouzzadeh, M. S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M. S., Packer, C., & Clune, J. (2018). Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. PNAS, 115(25), E5716–E5725.
45. Olden, J. D., Lawler, J. J., & Poff, N. L. (2008). Machine learning methods without tears: A primer for ecologists. The Quarterly Review of Biology, 83(2), 171–193.

46. Pettorelli, N., et al. (2005). Using the satellite-derived NDVI to assess ecological responses to environmental change. Trends in Ecology & Evolution, 20(9), 503–510.
47. Sandbrook, C., Dubois, G., Adams, W. M., et al. (2021). Principles for the socially responsible use of conservation monitoring technology and data. Conservation Science and Practice, 3(2), e374.
48. Sandbrook, C., Dubois, G., Adams, W. M., et al. (2021). Principles for the socially responsible use of conservation monitoring technology and data. Conservation Science and Practice, 3(2), e374.
49. Schneider, S., Taylor, G. W., & Kremer, S. C. (2020). Deep learning object detection methods for ecological camera trap data. Methods in Ecology and Evolution, 11(11), 1375–1389.
50. Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge computing: Vision and challenges. IEEE Internet of Things Journal, 3(5), 637–646.
51. Stowell, D., et al. (2019). Automatic acoustic classification of bird species: A review. IEEE/ACM Transactions on Audio, Speech, and Language Processing, 27(5), 829–842.
52. Stowell, D., Wood, M., Pamuła, H., Stylianou, Y., & Glotin, H. (2019). Automatic acoustic detection of birds through deep learning: The first Bird Audio Detection challenge. Methods in Ecology and Evolution, 10(3), 368–380.
53. Stowell, D., Wood, M., Stylianou, Y., Glotin, H., & Sueur, J. (2019). Automatic acoustic detection of birds through deep learning: The first Bird Audio Detection challenge. Methods in Ecology and Evolution, 10(3), 368–380.
54. Strubell, E., Ganesh, A., & McCallum, A. (2019). Energy and policy considerations for deep learning in NLP. Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics, 3645–3650.
55. Strubell, E., Ganesh, A., & McCallum, A. (2019). Energy and policy considerations for deep learning in NLP. ACL Proceedings, 3645–3650.
56. Tabak, M. A., Norouzzadeh, M. S., Wolfson, D. W., Sweeney, S. J., VerCauteren, K. C., Snow, N. P., et al. (2019). Machine learning to classify animal species in camera trap images: Applications in ecology. Methods in Ecology and Evolution, 10(4), 585–590.
57. Terry, J. C. D., Roy, H. E., & August, T. A. (2020). Thinking like a naturalist: Enhancing computer vision of citizen science images by harnessing contextual data. Methods in Ecology and Evolution, 11(2), 303–315.
58. Terry, J. C. D., Roy, H. E., & August, T. A. (2020). Thinking like a naturalist: Enhancing computer vision of citizen science images by harnessing contextual data. Methods in Ecology and Evolution, 11(2), 303–315.

59. Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment, 8(2), 127–150.
60. Verma, R., Wykstra, B., & Overdyke, S. (2021). Surveillance and the ethics of conservation technologies. Oryx, 55(4), 487–489.
61. Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., ... & Nerini, F. F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. Nature Communications, 11, 233.
62. Wäldchen, J., & Mäder, P. (2018). Plant species identification using computer vision techniques: A systematic literature review. Archives of Computational Methods in Engineering, 25, 507–543.
63. Weinstein, B. G., Marconi, S., Bohlman, S., Zare, A., & White, E. P. (2019). Individual tree-crown detection in RGB imagery using semi-supervised deep learning neural networks. Remote Sensing, 11(11), 1309.
64. Willi, M., Pitman, R. T., Cardoso, A. W., Locke, C., Swanson, A., Boyer, A., ... & Fortson, L. (2019). Identifying animal species in camera trap images using deep learning and citizen science. Methods in Ecology and Evolution, 10(1), 80–91.
65. Xu, L. D., He, W., & Li, S. (2021). Internet of Things in industries: A survey. IEEE Transactions on Industrial Informatics, 10(4), 2233–2243.
66. Zhang, X., et al. (2003). Monitoring vegetation phenology using MODIS. Remote Sensing of Environment, 84(3), 471–475.
67. Zhou, S., Chen, W., & Zhang, C. (2021). Artificial intelligence in ecological monitoring: A review and outlook. Ecological Informatics, 64, 101354.
68. Zhu, X. X., Tuia, D., Mou, L., Xia, G. S., Zhang, L., Xu, F., & Fraundorfer, F. (2018). Deep learning in remote sensing: A comprehensive review and list of resources. IEEE Geoscience and Remote Sensing Magazine, 5(4), 8–36.

Review on Innovations in animal nutrition and feed technology for sustainable livestock production

[1]**Datta Ashok Nalle**

[2]**Madhuri Y. Bhande**

[1]Assistant Professor, Department of Zoology & Fishery, Science, Rajarshi Shahu Mahavidyalaya (Autonomous) Latur, (MH), India.

[2]Ph.D. Research Scholar, Research Centre: Department of Zoology, Adarsh Education Society's, Arts, Commerce and Science College, Hingoli, (MH), India.

Email: iprometheous007@gmail.com

Article DOI Link: https://zenodo.org/uploads/15576817

*DOI: **10.5281/zenodo.15576817***

Abstract

This review explores the recent innovations in animal nutrition and feed technology aimed at promoting sustainable livestock and aquaculture production. With rising global demand for animal-derived products and increasing environmental concerns, the livestock and aquaculture sectors are rapidly transforming. Animal nutrition has emerged as a crucial field for enhancing productivity, improving animal health, and minimizing ecological impact. This review highlights advancements such as alternative protein sources, functional feeds, natural additives, and novel feed processing techniques including extrusion, nano-encapsulation, and precision feeding systems. Additionally, the integration of probiotics, enzymes, and fermented feeds has been shown to enhance nutrient bioavailability and disease resistance. By examining these innovations, this review underscores the potential of biotechnological tools, sustainable ingredient sourcing, and smart feeding strategies to build resilient, efficient, and environmentally responsible animal production systems.

Keywords: Sustainable livestock, animal nutrition, feed technology, aquaculture, natural products, feed additives, animal health, precision feeding.

Introduction

Livestock production remains a cornerstone of the global food system, contributing significantly to food security, economic development, and rural livelihoods. With the global population expected to surpass 9 billion by 2050, the demand for animal-based products such as meat, milk, and eggs is projected to rise substantially. However, the livestock sector faces mounting challenges—

including resource scarcity, climate change, and increasing environmental pressures. These challenges demand urgent solutions to ensure that livestock production remains both productive and sustainable. Among the most promising avenues for addressing these challenges are innovations in animal nutrition and feed technology. By enhancing feed efficiency, incorporating sustainable ingredients, and applying emerging scientific insights, it is possible to increase productivity while simultaneously reducing the ecological footprint of animal agriculture.

The animal feed industry is a vital component of global livestock systems, operating in more than 130 countries and supporting a diverse range of animal species raised for meat, milk, eggs, and other products. Feed represents the largest cost input in animal production, often accounting for 60–70% of total operational expenses. Therefore, advancements in feed formulation and technology have a significant impact on overall farm profitability and sustainability.

Trends in Animal Feeds are no longer limited to traditional grains and forages. Modern feed formulations incorporate a wide array of additives that enhance nutritional quality, improve animal performance, and safeguard health. These include amino acids, enzymes, probiotics, phytogenics, and other bioactive compounds that support growth, immunity, and feed efficiency.

Importance of Nutrition in Livestock Production

Nutrition is a critical determinant of livestock performance, health, reproduction, and product quality. Optimal nutrition reduces disease susceptibility, shortens growth cycles, and enhances feed conversion ratios. It also plays a key role in mitigating emissions and waste production.

Energy and Protein Balance that ensuring the right energy-protein ratio is essential for maximizing growth and reproductive efficiency. Micronutrients viz. Minerals and vitamins, though required in smaller amounts, are essential for enzymatic functions, bone development, and immunity further Feed Formulation can dramatically reduce feed costs while meeting nutritional requirements. The processing of feed plays a pivotal role in maintaining or even enhancing its nutritional quality. Technologies such as ensiling, pelleting, and steam-flaking can help preserve nutrients and enhance the efficiency of feed [1] Moreover, bioconversion techniques, including the microbial fermentation of unconventional feedstuffs, have gained attention due to their ability to enhance the value of feed while reducing dependence on traditional, high-cost ingredients [2] The nutritional value of feed varies significantly depending on its source, variety, and processing methods. The quality of forage, including its fiber content, digestibility, and nutrient availability, plays a critical role in the overall health and productivity of ruminants [3]. Animal products are an important source of high-quality, balanced, and highly bioavailable protein and numerous critical micronutrients, including iron, zinc, and vitamins B-12 and A, many of which are deficient in a large portion of the world's population [4–5].

Nutritive Quality Enhancement in Veterinary Nutrition

Enhancing the nutritive quality of animal feed is a critical focus in veterinary nutrition to improve animal health, productivity, and product quality. Nutritive quality can be enhanced by optimizing the balance of essential nutrients such as amino acids, vitamins, minerals, and energy sources. The incorporation of feed additives like enzymes, probiotics, and prebiotics has shown significant benefits in improving nutrient digestibility and gut health in livestock.

Probiotics and prebiotics play a crucial role in improving gut health, which in turn enhances nutrient absorption and strengthens disease resistance in livestock. Recent developments have introduced next-generation probiotics (NGPs) as a promising advancement over conventional strains. Originating from the human gut microbiota, NGPs demonstrate superior therapeutic potential, offering targeted benefits for gastrointestinal, metabolic, and immune-related conditions. These innovations have been made possible through advancements in high-throughput sequencing and bioinformatics, which have facilitated the precise identification of microbial strains with specific health-promoting attributes [6, 7] Advances in biotechnology, including the use of genetically modified crops and precision fermentation, have enabled the development of feed ingredients with improved amino acid profiles and better bioavailability of nutrients [8]. Additionally, techniques like pelleting, extrusion, and fermentation have been employed to reduce anti-nutritional factors and enhance the palatability and safety of animal feed [9]. Such improvements not only support better growth performance but also contribute to sustainable animal production by reducing feed waste and environmental impact.

To enhance the nutritive quality of animal feed, enzyme supplementation and fortification with herbal extracts have emerged as effective strategies in veterinary nutrition.[10] Enzymes such as phytase, xylanase, and protease play a significant role in breaking down complex plant compounds, thereby increasing the bioavailability of nutrients—particularly phosphorus and non-starch polysaccharides—from plant-based feeds [11] This enzymatic enhancement not only improves nutrient absorption but also reduces feed costs and environmental phosphorus excretion. Together, these approaches offer sustainable, health-promoting alternatives that align with the growing demand for antibiotic-free and eco-friendly animal production systems.

Nutritive Quality Enhancement in Aquaculture

Aquaculture nutrition is rapidly advancing to meet the escalating global demand for sustainable and high-quality fish protein. One of the key innovations in this field is the use of alternative protein sources such as insect meal, algae, and microbial biomass to reduce reliance on traditional ingredients like fishmeal and soybean meal, which are associated with environmental and economic concerns [12]. These novel proteins not only provide essential amino acids but also promote circular economy practices in aquaculture. Another major development is the formulation of functional feeds, which are enriched with immunostimulants, antioxidants, and probiotics to enhance disease resistance, improve gut health, and support overall physiological performance in aquatic species [13]. Additionally, water-stable pellet technology has advanced significantly, enabling the production of feeds that maintain their structural integrity in aquatic environments. This reduces nutrient leaching, minimizes feed waste, and enhances feed conversion ratios, contributing to both environmental sustainability and economic efficiency Together, these innovations are transforming aquaculture nutrition into a more resilient, efficient, and eco-friendly system.

Innovations in Animal Nutrition and Feed Technology

Recent innovations in animal nutrition have increasingly emphasized the use of natural feed additives due to their effectiveness, safety, and reduced environmental footprint. Plant-based additives, including tannins, saponins, and essential oils, have demonstrated significant benefits in improving nutrient utilization, enhancing digestive enzyme activity, and serving as natural antimicrobial agents, thereby reducing the need for synthetic antibiotics [14]. Additionally, seaweed and algae have gained attention as functional feed ingredients, offering a rich source of minerals, vitamins, and bioactive compounds like polysaccharides and polyphenols that contribute to improved immune response and growth performance in livestock and aquaculture species [15]. Another promising advancement is the use of fermented feed products, which increase the bioavailability of nutrients and promote a healthy gut microbiome by introducing beneficial microorganisms during the fermentation process. These natural solutions align with sustainable livestock production goals and are poised to play a central role in next-generation feed technologies.

Innovations in Animal Feed Technology

Technological advancements in animal feed processing and delivery are revolutionizing the livestock industry by enhancing efficiency, productivity, and animal well-being. One of the most impactful developments is the adoption of precision feeding systems, which utilize artificial intelligence (AI), real-time sensors, and data analytics to tailor nutrient delivery to the specific needs of individual animals, thereby minimizing waste and improving feed conversion efficiency [16]. Additionally, modern extrusion and pelleting technologies have improved the physical and nutritional quality of feeds. These processes enhance the digestibility, palatability, and nutrient density of feed by altering starch structure and inactivating anti-nutritional factors [17]. Another groundbreaking innovation is nano-nutrition, which involves the nano-encapsulation of essential nutrients such as vitamins and minerals. This technique ensures targeted delivery, controlled release, and improved bioavailability, ultimately enhancing growth and immune performance in animals [18]. Together, these technologies are paving the way for more sustainable and precise animal feeding systems.

Future Recommendations

1. **Promote Research on Local and Unconventional Feed Resources:** Support studies on regionally available plants, seaweeds, and agricultural by-products that can serve as low-cost, sustainable feed ingredients.
2. **Scale-Up Precision Nutrition Technologies:** Facilitate the adoption of AI-based feeding systems on small and medium-scale farms through affordable models and government-supported pilot programs.
3. **Strengthen Regulatory Frameworks for Novel Feed Technologies:** Develop safety and quality guidelines for Nano-nutrition and genetically modified feed ingredients to ensure consumer and environmental safety.
4. **Enhance Farmer Education and Knowledge Transfer:** Implement training programs on feed formulation, fermentation techniques, and natural additive usage to help farmers transition to sustainable feeding practices.
5. **Encourage Integration of Circular Economy Models:** Promote the recycling of organic waste (e.g., food waste, insect farming residues) into nutrient-rich feed products to reduce input costs and waste.
6. **Foster Multidisciplinary Collaboration:** Support partnerships among veterinarians, nutritionists, feed technologists, and environmental scientists to develop holistic, science-driven solutions.

Conclusion

Innovations in animal nutrition and feed technology are essential to achieving a more sustainable, productive, and ethical livestock and aquaculture sector. The integration of functional feed ingredients—such as probiotics, enzymes, and phytogenics—with advanced feed processing techniques has significantly enhanced nutrient utilization and animal health. Precision feeding systems, nano-nutrition, and novel protein sources like insect meal and algae have not only improved feed efficiency but also contributed to reducing dependency on traditional, resource-intensive ingredients. These advancements are helping to address major challenges such as rising production costs, environmental degradation, and antibiotic resistance. As the industry moves toward more sustainable practices, continuous research, technology adoption, and collaboration between scientists, producers, and policymakers will be critical in shaping the future of animal nutrition.

References

1. Zhang, L., & Liu, H. (2018). Advances in feed processing technologies for ruminants. Animal Nutrition, 4(2), 137–144.
2. Green, J., & Miller, S. (2019). Bioconversion of unconventional feedstuffs in livestock diets. Sustainable Agriculture, 23, 67–75.
3. De Brito, G. F., McGrath, S. R., Holman, B. W., Friend, M. A., Fowler, S. M., van de Ven, R. J., & Hopkins, D. L. (2016). The effect of forage type on lamb carcass traits, meat quality and sensory traits. Meat Science, 119, 95–101. https://doi.org/10.1016/j.meatsci.2016.04.030
4. World Health Organization. (2003). Diet, nutrition and the prevention of chronic diseases (WHO Technical Report Series No. 916). https://www.who.int/dietphysicalactivity/publications/trs916/en/
5. Randolph, T. F., Schelling, E., Grace, D., Nicholson, C. F., Leroy, J. L., Cole, D. C., Demment, M. W., Omore, A., Zinsstag, J., & Ruel, M. (2007). Invited review: Role of livestock in human nutrition and health for poverty reduction in developing countries. Journal of Animal Science, 85(11), 2788–2800.
6. Bhande, M. Y., & Nalle, D. A. (2025). Beyond gut health: Review on the expanding role of next-generation probiotics in human health. In Current Research Trends in Life Science (1st ed.). Bhumi. https://www.researchgate.net/publication/390836032_BEYOND_GUT_HEALTH_REVIEW_ON_THE_EXPANDING_ROLE_OF_NEXT-GENERATION_PROBIOTICS_IN_HUMAN_HEALTH
7. Dhotre, M. A., Nalle, D. A., & Kadam, S. (2024). Investigation of potential probiotic bacterium (Bacillus subtilis CCI3) in the formulated diets on immunity, growth performance and nutritional quality of Cyprinus carpio. Asian Journal of Fisheries and Aquatic Research, 26(7), 25–42. https://doi.org/10.9734/ajfar/2024/v26i7781
8. Stein, H. H., & Shurson, G. C. (2009). Board-invited review: The use and application of distillers dried grains with solubles in swine diets. Journal of Animal Science, 87(4), 1292–1303. https://doi.org/10.2527/jas.2008-1290
9. Adeola, O., & Cowieson, A. J. (2011). Board-invited review: Opportunities and challenges in using exogenous enzymes to improve nonruminant animal production. Journal of Animal Science, 89(10), 3189–3218. https://doi.org/10.2527/jas.2010-3715
10. Jogdand, S. B., Nalle, D. A. (2025). Evaluating the therapeutic potential of Swertia chirayita extracts against bacterial and fungal fish pathogens.

International Journal of Research and Analytical Reviews, 12(2), 146–152., Available at: http://www.ijrar.org/IJRAR25B1543.pdf

11. Bedford, M. R., & Partridge, G. G. (2010). Enzymes in farm animal nutrition (2nd ed.). CABI. https://doi.org/10.1079/9781845936747.0000
12. Henry, M., Gasco, L., Piccolo, G., & Fountoulaki, E. (2015). Review: Insect meals as sustainable protein sources for fish feeds. Animal Feed Science and Technology, 203, 1–22. https://doi.org/10.1016/j.anifeedsci.2015.03.001
13. Tacon, A. G. J., Hasan, M. R., & Metian, M. (2020). Future directions for aquaculture nutrition: Towards sustainability and beyond. FAO Fisheries and Aquaculture Circular, C1196, 1–30.
14. Greathead, H. (2003). Plants and plant extracts for improving animal productivity. Proceedings of the Nutrition Society, 62(2), 279–290. https://doi.org/10.1079/PNS2002186
15. Holdt, S. L., & Kraan, S. (2011). Bioactive compounds in seaweed: Functional food applications and legislation. Journal of Applied Phycology, 23(3), 543–597. https://doi.org/10.1007/s10811-010-9632-5
16. Ruiz-Ascacibar, I., Stoll, P., Bee, G., & Kreuzer, M. (2019). Precision feeding in livestock: A review of technologies and effects on nutrient utilization. Animal Feed Science and Technology, 248, 1–13. https://doi.org/10.1016/j.anifeedsci.2018.12.001
17. Camire, M. E., Camire, A., & Krumhar, K. (1990). Chemical and nutritional changes in foods during extrusion. Critical Reviews in Food Science & Nutrition, 29(1), 35–57. https://doi.org/10.1080/10408399009527513
18. Kah, M., Kookana, R. S., Gogos, A., & Bucheli, T. D. (2018). A critical evaluation of nanopesticides and nanofertilizers against their conventional analogues. Nature Nanotechnology, 13, 677–684. https://doi.org/10.1038/s41565-018-0131-1

Music Therapy in Stress Management: Perspectives on Mechanism

[1]Nikita Katiyar

[2]Kalpana Singh

Laboratory of Applied Zoology, Department of Zoology, University of Lucknow-226007

Email: singh_kalpana@lkouniv.ac.in

Article DOI Link: https://zenodo.org/uploads/15576853

*DOI: **10.5281/zenodo.15576853***

Abstract

Stress is a pervasive phenomenon with profound implications for both physical and mental health, contributing to conditions such as cardiovascular disease, immune dysfunction, anxiety, and depression. Recognized in basic and clinical neuroscience research, chronic stress is associated with neurobiological disruptions involving the limbic system and prefrontal cortex, and is closely linked to disorders categorized under the ICD-10, including depression and post-traumatic stress disorder. In recent years, music therapy has emerged as a promising complementary approach in stress management. Defined as the clinical application of music interventions to achieve therapeutic goals, music therapy has demonstrated efficacy in reducing physiological stress markers such as cortisol levels, heart rate, and blood pressure, while promoting emotional regulation and psychological well-being. Neuroimaging and psychophysiological studies suggest that music engages neural circuits related to emotion and reward, facilitating stress relief. Furthermore, research highlights music therapy's adaptability across diverse populations and clinical settings, including among healthcare professionals, patients undergoing medical interventions, and individuals with chronic conditions. Key variables such as musical tempo, harmony, and personal preference significantly influence therapeutic outcomes. This review synthesizes contemporary findings to elucidate the mechanisms, effectiveness, and contextual applications of music therapy in stress reduction. The evidence supports music therapy's role as an evidence-based, accessible, and integrative strategy for holistic stress management.

Keywords: Cortisol reduction, emotional regulation, complementary therapy, neuroscience, mental health, limbic system, therapeutic intervention, holistic health.

Introduction

Stress is a universal phenomenon with significant implications for physical and mental health. Prolonged exposure to stress is associated with various adverse outcomes, including increased risks of cardiovascular disease, immune suppression, and psychological disorders such as anxiety and depression (McEwen, 2007). It is widely recognized as a significant concern in both basic and clinical neuroscience research (de Kloet et al., 2005a; McEwen et al., 2015). While this physiological response is essential for survival, it is also closely linked to various brain disorders, including depression, anxiety, and post-traumatic stress disorder, as classified in the International Classification of Diseases, 10th edition (ICD-10) (Ruiz et al., 2007; Heim et al., 2008; Martin et al., 2009; Walsh, 2011; Saveanu and Nemeroff, 2012; Nemeroff, 2016). Investigating the complexities of stress remains a challenge, but research involving both animal and human studies has contributed significantly to our understanding in recent years (Hariri & Holmes, 2015). To advance the field further, it is essential to adopt a translational approach that bridges basic research with clinical practice.

Research studies of stress management strategies consists complementary and alternative therapies that have gained attention, with music therapy. Music therapy, defined as the clinical use of music interventions to achieve individualized therapeutic goals that has demonstrated efficacy in reducing stress markers. Studies have shown that listening to music can lower cortisol levels, heart rate, and blood pressure while improving emotional states (Koelsch et al., 2016; Chanda & Levitin, 2013). Music therapy works by engaging neural pathways associated with emotional regulation and reward, including the limbic system and prefrontal cortex, which are key players in stress modulation (Thoma et al., 2013).

Previous studies on music therapy also highlight the versatility of music therapy in addressing stress across diverse settings and populations. For instance, soothing music interventions have been effective in reducing stress among healthcare workers, patients undergoing medical procedures, and individuals with chronic illnesses (Linnemann et al., 2015; Bradt et al., 2013). The type of music, tempo, and individual preferences all play crucial roles in determining the therapeutic outcomes, with slower tempos and harmonic consonance being particularly effective in eliciting relaxation (Bernardi et al., 2006).

This analysis aims to synthesize findings from recent research to explore the mechanisms underlying music therapy’s stress-relieving effects, its applications in various contexts, and its potential integration into holistic stress management programs. By doing so, it seeks to establish music therapy as a scientifically validated and accessible tool for enhancing well-being.

Stress Pathways: Hypothalamic-Pituitary-Adrenal (HPA) Axis

The human body has evolved intricate mechanisms to cope with environmental stressors, one of the most important of which is the hypothalamic-pituitary-adrenal (HPA) axis. This stress pathway is central to how our body perceives and responds to stress, both physical and psychological. In understanding the HPA axis, it is critical to explore its components, the role of each in stress response, and the impact of chronic stress on health.

Overview of the HPA Axis

The HPA axis is a neuroendocrine system that involves interactions between the hypothalamus, pituitary gland, and adrenal glands. These interactions result in the production of hormones that regulate various body functions, including stress responses. The pathway is activated when the brain perceives a stressor and leads to the release of cortisol, the body's primary stress hormone (Fig., 1.).

1. **Hypothalamus:** The brain perceives a potential signal of threat from stressor during the initiation of stress response. The hypothalamus, a crucial regulatory region located at the base of the brain, serves as the central coordinator of this response. It produces and secretes corticotropin-releasing hormone (CRH), which plays an important role in activating the subsequent stages of the stress pathway.

2. **Pituitary Gland:** In response to CRH, the anterior pituitary gland, located just beneath the hypothalamus, releases adrenocorticotropic hormone (ACTH) into the bloodstream. ACTH is a key hormone in the stress response as it stimulates the adrenal glands to produce cortisol.

3. **Adrenal Glands:** Situated atop the kidneys, the adrenal glands are responsible for producing and releasing cortisol in response to ACTH. Cortisol plays a significant role in regulating metabolism, immune response, and the body's ability to respond to stress.

4. **Negative Feedback Loop:** After cortisol is released, it circulates through the bloodstream, exerting effects on various tissues, including the brain. A critical aspect of the HPA axis is the negative feedback loop. High levels of cortisol signal the hypothalamus and pituitary gland to reduce CRH and ACTH production, helping to prevent excessive cortisol release.

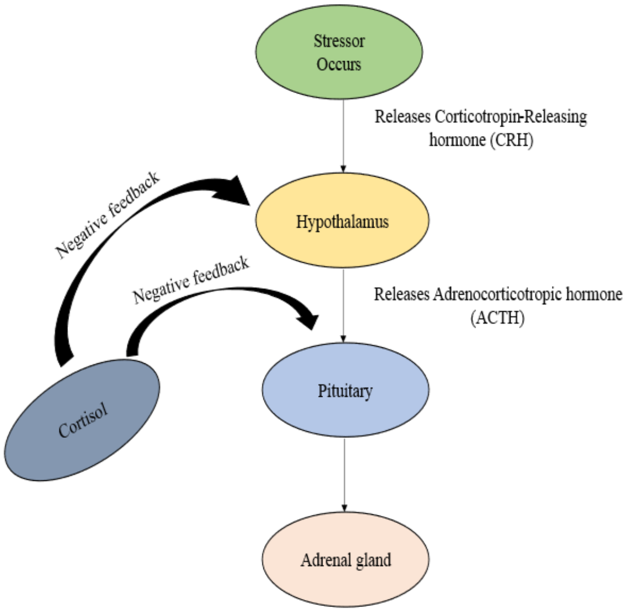

Fig. 1. Hypothalamic- Pituitary- Adrenal (HPA) Axis

The Role of the HPA Axis in Stress Response

The activation of the HPA axis prepares the body for "fight or flight." Cortisol, as the central stress hormone, increases glucose availability, enhances brain function, and supports the body's ability to encounter stress (Lengton et al., 2025). There are some of the key physiological responses to the release of cortisol hormone:

- **Increased blood sugar levels:** Cortisol increases gluconeogenesis (the production of glucose from non-carbohydrate sources), to ensure that the body has enough energy to respond to stress.
- **Suppressed non-essential functions:** Long-term stress can suppress functions that are not immediately essential for survival, such as digestion, immune response, and reproduction.
- **Enhanced brain function:** Cortisol can sharpen memory and focus, helping an individual to react more effectively towards a stressor.
- **Modulation of the immune system:** The acute stress can enhance immune function, but prolonged exposure to high cortisol levels can suppress the immune responses, making the body more susceptible to infections.

Dysregulation of the HPA Axis: Chronic Stress and Its Impact

While acute stress is essential for survival, chronic activation of the HPA axis can have deep effect on health. The activation of the HPA axis for the longer duration leads to sustained high levels of cortisol, which can contribute to a various health issue (Lucassen and Cizza, 2012). Some of the consequences of chronic stress and HPA axis dysregulation include:

1. **Mental Health Disorders:** Chronic activation of the HPA axis has been linked to mental health conditions such as depression and anxiety. James et al., 2023 suggests that longer exposure to elevated cortisol levels can affect the regulation of mood and cognitive function, making individuals more vulnerable to mood disorders.
2. **Cardiovascular Diseases:** Long-term stress can lead to increased blood pressure, higher cholesterol levels, and an elevated risk of heart disease. Elevated cortisol levels can also increase the risk of atherosclerosis by promoting inflammation and increasing fat deposition in arteries.
3. **Immune System Dysfunction:** While short-term cortisol release can enhance immune responses, chronic cortisol elevation suppresses immune function, making individuals more susceptible to infections and possibly delaying the healing process.
4. **Metabolic and Weight Issues:** Chronic stress and the overproduction of cortisol have been associated with increased abdominal fat and obesity. Cortisol affects appetite regulation and can lead to unhealthy eating habits, particularly cravings for high-fat and high-sugar foods.
5. **Neurodegenerative Diseases:** Lupien et al., 1998 demonstrates in their research that the chronic stress and the dysregulation of HPA axis has a contribution in neurodegenerative diseases such as Alzheimer’s disease and the cortisol hormone may play a role in cognitive decline over time on the brain structures like the hippocampus which is involved in memory and learning.

Mechanisms of Music Therapy in Stress Reduction

Music therapy, a well-established therapeutic tool, has increasingly been studied for its effects on stress reduction. This non-invasive approach harnesses the power of music, whether through active engagement (such as playing or singing) or passive listening, to foster emotional, cognitive, and physiological benefits. Understanding the mechanisms behind how music therapy impacts stress requires an exploration of both psychological and neurophysiological processes.

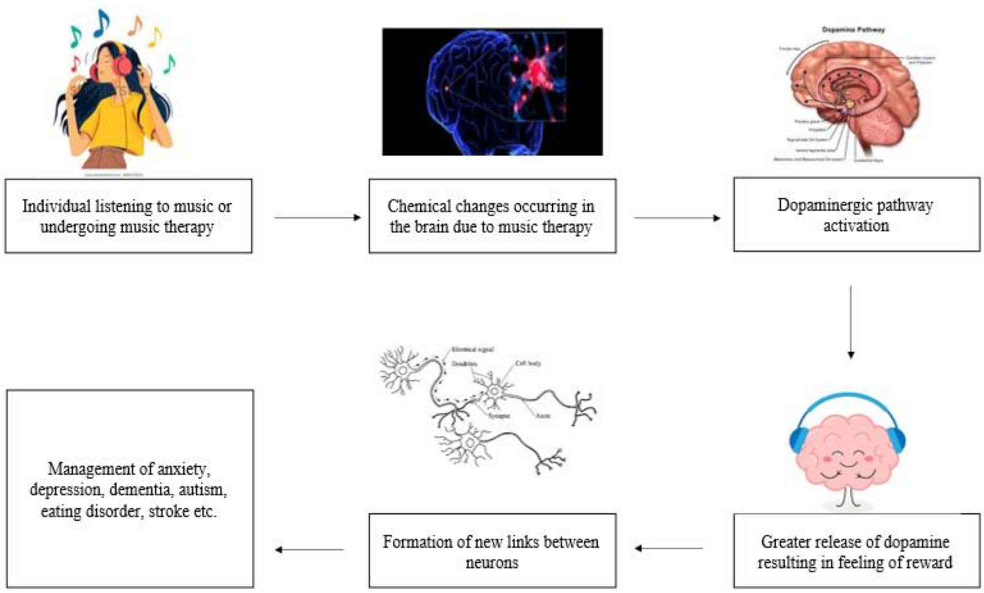

Fig., 2. Mechanism of music therapy in stress reduction

Music can activate key brain regions, regulate autonomic nervous system (ANS) responses, and improve emotional states, making it an effective intervention for stress management (McPherson et al., 2019).

1. Psychological Mechanisms: The regulation of emotional processing

Music has a unique capability to evoke emotional responses, which can be particularly beneficial for individuals experiencing stress. One of the primary ways that music therapy reduces stress is through emotional regulation and expression.

- **Emotional Release and Expression:** Music Listening or creating music provides individuals with a safe outlet for expressing emotions otherwise that may be difficult to articulate. Music can evoke a range of emotions, such as relaxation, joy, nostalgia which in turn can help individuals brain processing and releases stress. According to research by Thoma et al., 2013 music can facilitate emotional regulation by enabling individuals to express feelings they might otherwise suppress, allowing for stress relief.
- **Mood Enhancement:** Music has been shown to activate the reward system in the brain, particularly the release of dopamine, which is associated with feelings of pleasure and relaxation. This response helps reduce negative emotions such as anxiety or frustration, promoting a more relaxed emotional state. Music therapy helps to diminish the negative psychological effects of stress, such as irritability, worry, or sadness by enhancing mood.

2. **Neurophysiological Mechanisms: Brain Activity and Hormonal Regulation**

At a neurobiological level, music therapy has a profound impact on brain function and stress-related pathways, such as the hypothalamic-pituitary-adrenal (HPA) axis and autonomic nervous system (ANS).

- **Activation of the Parasympathetic Nervous System:** The parasympathetic nervous system (PNS), responsible for the function of rest and digest which is often underactive during periods of stress, while the sympathetic nervous system (SNS), which drives the "fight or flight" response, is overactive. Particularly slow-tempo and soothing music, has been shown to stimulate the PNS, which helps to lower heart rate, blood pressure, and respiratory rate. This results in a state of physiological relaxation and reduced stress, as demonstrated in research by Bernardi et al., 2006.
- **Regulation of Cortisol Levels:** Cortisol, a hormone released by the adrenal glands during stress, plays a critical role in the body's stress response. Chronic stress leads to prolonged elevated cortisol levels, which can have detrimental effects on health. Music therapy has been shown to reduce cortisol levels, thus alleviating the harmful effects of stress. For example, a study by Chanda and Levitin, 2013 showed that music listening reduced cortisol levels in participants, helping to mitigate the physiological consequences of chronic stress.
- **Brainwave Entrainment:** Brainwave entrainment refers to the phenomenon where the frequency of external auditory stimuli (such as music) influences brainwave activity. Research has found that certain types of music, particularly slow and rhythmic compositions, can synchronize brainwaves to a frequency associated with relaxation (e.g., alpha or theta waves). This process has been linked to reduced anxiety and stress, as it helps to calm the mind and induce a meditative state, as discussed by Lopez and Engle, 2018.

3. **Cognitive Mechanisms: Attention and Distraction**

One of the cognitive mechanisms by which music therapy alleviates stress is through distraction. Engaging with music or focusing on its elements (melody, rhythm, harmony) provides a form of cognitive distraction from stress-inducing thoughts. This process can help shift attention away from worries, anxieties, or ruminative thinking patterns that contribute to stress.

- **Focused Attention and Mindfulness:** Actively listening to or playing music requires focused attention, which can promote mindfulness—a practice that encourages being fully present in the moment. Mindfulness has been shown to reduce stress by diminishing rumination and helping individuals disengage from negative thought patterns. Studies have demonstrated that mindfulness-based music therapy, which encourages active listening and awareness of the present moment, leads to reduced perceived stress and improved mood (Kenny & Faunce, 2013).

- **Cognitive Restructuring:** Music therapy can also help individuals reframe their experiences of stress by providing a new perspective. For example, individuals may use music as a medium to explore and reframe difficult emotions or stressful situations. Engaging with music creatively can promote cognitive restructuring, leading to healthier emotional responses and less perceived stress.

4. Social Mechanisms: Connection and Support

In many contexts, music therapy is delivered in a group setting, which can have significant social benefits in reducing stress. Group music therapy provides opportunities for social bonding, communication, and shared emotional experiences, which are all known to buffer the effects of stress.

- **Social Support:** Group music-making fosters a sense of community and social support, which is essential for stress relief. Research has shown that social connections reduce cortisol levels and enhance well-being, as social support can provide comfort, validation, and coping mechanisms. Music therapy sessions that emphasize group participation, such as drumming circles or group singing, create an environment where individuals can share emotional experiences, strengthening interpersonal connections and reducing stress.
- **Therapeutic Alliance:** The relationship between the therapist and the participant is another crucial social mechanism in music therapy. A strong therapeutic alliance, where the participant feels understood, supported, and respected, has been shown to enhance the therapeutic benefits of music. Trust between the therapist and the participant allows for a safe space where stressors can be addressed through the medium of music.

5**. Types of Music Therapy Interventions and Their Impact**

There are different forms of music therapy that vary in their application, including active music therapy (where patients engage in making music), passive music therapy (where patients listen to pre-recorded music), and guided imagery and music therapy (where music is paired with visualizations). The choice of intervention can influence the mechanisms of stress reduction:

- **Active Music Therapy:** This involves creating music through singing, playing instruments, or improvisation. Active engagement allows individuals to express themselves creatively, providing an emotional outlet and enhancing feelings of control. Active participation also stimulates the brain's reward pathways, leading to the release of dopamine and other neurochemicals that contribute to stress relief.

- **Passive Music Therapy:** Listening to carefully selected music can have a profound calming effect. Research shows that classical, ambient, or nature sounds often used in passive music therapy reduce anxiety and promote relaxation. Passive music therapy is often used in settings such as hospitals or therapy clinics to induce relaxation in patients.
- **Guided Imagery and Music (GIM):** This type of music therapy involves the use of music to facilitate a meditative or reflective state, often guiding patients through specific visualizations to address stress. GIM has been shown to be effective in helping individuals process traumatic experiences, reduce anxiety, and alleviate stress.

Evidence from Animal Studies: Music Therapy in Preclinical Models

Animal studies have provided significant insight into the underlying mechanisms through which music therapy can reduce stress, regulate biochemical markers, and alter behavioral responses. These studies offer valuable preclinical evidence that helps to validate the therapeutic potential of music for stress reduction and mental health interventions. Research in animal models has explored the biochemical, endocrine, and behavioral outcomes of music therapy in stress-related contexts, providing a basis for further clinical applications.

1. Music Therapy in Preclinical Models

Preclinical studies, particularly those using rodent and other animal models, have examined how music exposure influences stress responses. These studies are critical because they help to establish a biological foundation for music therapy, which can later be tested in humans. Music therapy in animal models is typically implemented in controlled environments where the researchers expose animals to different forms of music and measure various stress markers and behavioral outcomes.

- **Rodent Models:** Rodent models, especially rats and mice, are commonly used in preclinical music therapy studies. Sanyal et al., 2013 demonstrated that exposure to classical music in rats reduced stress and anxiety levels, as evidenced by changes in behavior (such as increased exploration) and biochemical markers (such as decreased levels of corticosterone, a stress hormone). The controlled nature of rodent models allows for precise manipulation of environmental variables and more direct examination of cause-and-effect relationships.
- **Non-human Primates:** Some studies have also extended music therapy to non-human primates, such as monkeys, to explore more complex social and emotional responses to music. For example, a study by Alworth and Buerkle, 2013 showed that primates exposed to soothing music exhibited less

aggressive behavior and lower levels of cortisol, suggesting that music can reduce social stress in primate species. These findings parallel those seen in human studies, supporting the idea that music may have universally beneficial effects on stress.

- **Birds and Other Animals:** Other animal species, such as birds, have also been used to study the impact of music therapy. In birds, exposure to music has been shown to reduce stress behaviors and even influence reproductive success. Williams et al., 2017 found that birds exposed to calming music showed improvements in their social interactions and a reduction in behaviors associated with stress, such as feather-plucking.

2. Effects on Biochemical and Endocrine Markers in Animals

One of the most compelling areas of research in animal models involves the biochemical and endocrine changes that result from music therapy. These markers provide insight into the physiological mechanisms through which music influences stress response pathways.

- **Corticosterone and Cortisol:** Corticosterone (in rodents) and cortisol (in humans) are stress hormones released by the adrenal glands in response to stressors. The activation of the hypothalamic-pituitary-adrenal (HPA) axis triggers the release of these hormones. In various animal models, music therapy has been shown to reduce the secretion of corticosterone. For example, Milbratz de Camargo et al., 2017 found that rats exposed to classical music had significantly lower levels of corticosterone compared to those in a control group. This reduction in stress hormones suggests that music exposure may attenuate the physiological effects of stress at the endocrine level.
- **Serotonin and Dopamine:** Neurotransmitters such as serotonin and dopamine are also impacted by music. Serotonin is often associated with mood regulation, while dopamine is linked to reward and pleasure. Thoma et al., 2013 found that music exposure in rodents increased the release of serotonin and dopamine, potentially explaining the mood-elevating and stress-reducing effects of music. These findings are consistent with the idea that music acts as a positive stimulus that modulates neurochemistry in ways that promote relaxation and stress resilience.
- **Pro-inflammatory Cytokines:** Chronic stress can lead to the release of pro-inflammatory cytokines, which play a role in the development of many stress-related diseases. Wang et al., 2024 examined the effects of music therapy on inflammation and found that music reduced the levels of inflammatory cytokines (e.g., TNF-alpha, IL-6) in stressed animals. These results suggest that music therapy may not only influence the endocrine system but may also

help modulate immune system responses, offering potential therapeutic benefits for stress-related diseases.

3. **Behavioral Outcomes in Animal Stress Models**

In addition to biochemical and endocrine changes, animal studies have also examined how music therapy impacts behavior, particularly in models designed to induce stress or anxiety. These studies offer direct insights into the behavioral outcomes associated with music therapy in animals under stress.

- **Anxiety and Exploration:** One of the most commonly used behavioral assays to measure anxiety in animal models is the open-field test and the elevated plus-maze test, which assess animals' willingness to explore new environments. Animals exposed to stressors, such as forced swimming or mild shock, exhibit reduced exploration and increased anxious behavior. However, in studies by Kim et al., 2018, animals exposed to calming music displayed increased exploration in these tests, indicating that music reduces anxiety-like behavior. This enhanced exploration is often interpreted as a sign of reduced anxiety and a return to a more relaxed, exploratory state.
- **Fear Conditioning:** Fear conditioning is another behavioral paradigm used to study stress and anxiety in animals. In this model, animals are exposed to a neutral stimulus (e.g., a sound or light) paired with an aversive stimulus (e.g., a mild shock). Over time, animals will exhibit fearful responses to the neutral stimulus. However, music therapy has been shown to reduce the intensity of conditioned fear responses. Chen et al., 2019 found that rats exposed to music during fear conditioning trials exhibited less freezing behavior (a sign of fear) compared to control animals, suggesting that music therapy may be effective in modulating the emotional response to traumatic stimuli.
- **Social Behaviors and Aggression:** In some animal models, music therapy has been shown to reduce stress-induced aggression and promote prosocial behaviors. Veenema, 2009 observed that animals subjected to stress (e.g., social isolation) exhibited increased aggression when exposed to environmental stressors. However, animals exposed to soothing music in this context demonstrated fewer aggressive behaviors and more cooperative social interactions, suggesting that music therapy could serve as a useful intervention in stress-related aggression.
- **Memory and Cognitive Function:** Chronic stress can impair cognitive functions, including memory and learning. In rodent models, exposure to music has been shown to mitigate some of these cognitive deficits. Chanda and Levitin, 2013 reported that rats exposed to classical music performed better in memory tasks compared to those in control groups. This finding suggests that music therapy might have protective effects on cognitive functions that are typically compromised under conditions of chronic stress.

Music therapy has been extensively studied for its potential to alleviate stress, both in acute situations and over the long term. Research has also compared its effectiveness to other stress management techniques.

Conclusion

Music therapy has emerged as an effective, evidence-based approach to stress management. Research indicates that listening to music, especially calming genres, can significantly reduce stress-related physiological markers such as cortisol levels, heart rate, and blood pressure. Additionally, music therapy enhances parasympathetic nervous system activity, promoting relaxation and emotional balance. Beyond its physiological effects, music therapy also plays a crucial role in mental well-being by alleviating anxiety, depression, and emotional distress. Studies suggest that music stimulates dopamine release, fostering positive emotions and improved mood. Both active (singing, playing instruments) and passive (listening) forms of music therapy have been successfully used in various settings, from healthcare to workplace stress management.

As a non-invasive, cost-effective, and widely accessible intervention, music therapy offers a promising tool for stress reduction. Future research should explore individualized music therapy approaches and investigate its long-term effects. Integrating music therapy with conventional stress management techniques may provide a comprehensive strategy for enhancing overall well-being.

Acknowledgements

The Authors are grateful to Head, Department of Zoology for providing necessary research facilities and Research and Development Scheme of Higher Education department of Government of Uttar Pradesh for providing research grant via letter sankhya-79/2024/1041/sattar-4-2024-001-4-(33)/2023 dtd. 25 September 2024.

References

1. McEwen, B. S. (2007). Physiology and neurobiology of stress and adaptation: central role of the brain. Physiological reviews, 87(3), 873-904.
2. De Kloet, E. R., Joëls, M., & Holsboer, F. (2005). Stress and the brain: from adaptation to disease. Nature reviews neuroscience, 6(6), 463-475.
3. McEwen, B. S., Bowles, N. P., Gray, J. D., Hill, M. N., Hunter, R. G., Karatsoreos, I. N., & Nasca, C. (2015). Mechanisms of stress in the brain. Nature neuroscience, 18(10), 1353-1363.
4. Heim, C., Newport, D. J., Mletzko, T., Miller, A. H., & Nemeroff, C. B. (2008). The link between childhood trauma and depression: insights from HPA axis studies in humans. Psychoneuroendocrinology, 33(6), 693-710.

5. Walsh, R. (2011). Lifestyle and mental health. American psychologist, 66(7), 579.
6. Saveanu, R. V., & Nemeroff, C. B. (2012). Etiology of depression: genetic and environmental factors. Psychiatric clinics, 35(1), 51-71.
7. Nemeroff, C. B. (2016). Paradise lost: the neurobiological and clinical consequences of child abuse and neglect. Neuron, 89(5), 892-909.
8. Hariri, A. R., & Holmes, A. (2015). Finding translation in stress research. Nature neuroscience, 18(10), 1347-1352.
9. Koelsch, S., Boehlig, A., Hohenadel, M., Nitsche, I., Bauer, K., & Sack, U. (2016). The impact of acute stress on hormones and cytokines and how their recovery is affected by music-evoked positive mood. Scientific reports, 6(1), 23008.
10. Chanda, M. L., & Levitin, D. J. (2013). The neurochemistry of music. Trends in cognitive sciences, 17(4), 179-193.
11. Thoma, M. V., La Marca, R., Brönnimann, R., Finkel, L., Ehlert, U., & Nater, U. M. (2013). The effect of music on the human stress response. PloS one, 8(8), e70156.
12. Linnemann, A., Ditzen, B., Strahler, J., Doerr, J. M., & Nater, U. M. (2015). Music listening as a means of stress reduction in daily life. Psychoneuroendocrinology, 60, 82-90.
13. Bradt, J., Dileo, C., & Potvin, N. (2013). Music for stress and anxiety reduction in coronary heart disease patients. Cochrane Database of Systematic Reviews, (12).
14. Bernardi, L., Porta, C., & Sleight, P. (2006). Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. Heart, 92(4), 445-452.
15. Lengton, R., Schoenmakers, M., Penninx, B. W., Boon, M. R., & van Rossum, E. F. (2025). Glucocorticoids and HPA axis regulation in the stress–obesity connection: A comprehensive overview of biological, physiological and behavioural dimensions. Clinical Obesity, 15(2), e12725.
16. Lucassen, E. A., & Cizza, G. (2012). The hypothalamic-pituitary-adrenal axis, obesity, and chronic stress exposure: sleep and the HPA axis in obesity. Current obesity reports, 1, 208-215.
17. James, K. A., Stromin, J. I., Steenkamp, N., & Combrinck, M. I. (2023). Understanding the relationships between physiological and psychosocial stress, cortisol and cognition. Frontiers in endocrinology, 14, 1085950.
18. Lupien, S. J., De Leon, M., De Santi, S., Convit, A., Tarshish, C., Nair, N. P. V., ... & Meaney, M. J. (1998). Cortisol levels during human aging predict hippocampal atrophy and memory deficits. Nature neuroscience, 1(1), 69-73.

19. McPherson, T., Berger, D., Alagapan, S., & Fröhlich, F. (2019). Active and passive rhythmic music therapy interventions differentially modulate sympathetic autonomic nervous system activity. Journal of music therapy, 56(3), 240-264.
20. Sanyal, T., Kumar, V., Nag, T. C., Jain, S., Sreenivas, V., & Wadhwa, S. (2013). Prenatal loud music and noise: differential impact on physiological arousal, hippocampal synaptogenesis and spatial behavior in one-day-old chicks. PLoS One, 8(7), e67347.
21. Alworth, L. C., & Buerkle, S. C. (2013). The effects of music on animal physiology, behavior and welfare. Lab animal, 42(2), 54-61.
22. Williams, I., Hoppitt, W., & Grant, R. (2017). The effect of auditory enrichment, rearing method and social environment on the behavior of zoo-housed psittacines (Aves: Psittaciformes); implications for welfare. Applied Animal Behaviour Science, 186, 85-92.
23. Milbratz de Camargo, A., Henriquebonde, D. D. D. M., Delwing de Lima, D., & Coutinho de Azevedo Campanella, L. (2017). Cocoa and classical music: effect on anxiety and antioxidant activity in Wistar rats. Archivos Latinoamericanos de Nutrición, 67(2), 106-115.
24. Wang, H., Chai, Y., Xu, Y., Wang, Y., Li, J., Zhang, R., & Bao, J. (2024). Long-term music stimulating alleviated the inflammatory responses caused by acute noise stress on the immune organs of broilers by NF-κB signaling pathway. Ecotoxicology and Environmental Safety, 273, 116131.
25. Kim, K. J., Lee, S. N., & Lee, B. H. (2018). Music therapy inhibits morphine-seeking behavior via GABA receptor and attenuates anxiety-like behavior induced by extinction from chronic morphine use. Neuroscience letters, 674, 81-87.
26. Chen, S., Liang, T., Zhou, F. H., Cao, Y., Wang, C., Wang, F. Y., Zhou, X. F., Zhang, J. Y., & Li, C. Q. (2019). Regular music exposure in juvenile rats facilitates conditioned fear extinction and reduces anxiety after foot shock in adulthood. BioMed Research International, 2019(1), 8740674.
27. Veenema, A. H. (2009). Early life stress, the development of aggression and neuroendocrine and neurobiological correlates: what can we learn from animal models? Frontiers in neuroendocrinology, 30(4), 497-518.

Fungal Enzymes in Green Industrial Biotechnology: From Paper to Bioethanol

[1]Cherkupally Rama Raju

[2]Dinaker Chinna T

[3]Shankar T

[1]Assistant Professor of Botany, Government Degree College, Badangpet. Dist: Ranga Reddy, Osmania University, Hyderabad, Telangana.

[2]Assistant Professor of Botany, Governmenrt Arts & Science College (A) Kamareddy, Dist: Kamareddy, Telangana University, Telangana.

[3]Associate Professor of Botany, Government Degree College, Sircilla, Dist: Rajanna Sircilla, Satavahana University, Telangana.

Email: praveenaramaraju@gmail.com

Article DOI Link: https://zenodo.org/uploads/15576972

*DOI: **10.5281/zenodo.15576972***

Abstract

Fungi are vital decomposers in nature because of their capacity to produce a vast array of enzymes. In terms of biotechnology, these enzymes provide environmentally friendly alternatives to industrial processes that rely heavily on chemicals. The yield and stability have increased due to recent advancements in genetic engineering, fermentation, and enzyme immobilization. In the paper and pulp industry, lignin-degrading enzymes reduce the amount of chemicals used; in the bioethanol production process, cellulases aid in the saccharification of biomass; in pharmaceuticals, proteases and β-glucanases aid in the formulation of drugs; in agriculture, chitinases aid in biocontrol; and in environmental remediation, laccases and peroxidases break down pollutants. The commercial potential, ecological significance, and adaptability of fungal enzymes in advancing green industrial biotechnology are highlighted by a careful review of the literature.

Keywords: Fungal enzymes, Green biotechnology, Industrial applications, Bioethanol, Environmental remediation

Introduction

In nature, fungi are among the major producers of enzymes-a process necessary to decompose and recycle organic matter. Utilizing enzyme production by fungi has found many applications, especially in green industrial biotechnology. As the world moves towards sustainability and eco-friendly technologies, fungal enzymes appear to be promising alternatives to chemical processes in industries such as biofuel production, paper, pharmaceuticals, agriculture, and environmental cleanup (Chan et al., 2018).

The advent of biotechnology has created a revolution in industrial production and waste management. With the advent of the present-day techniques of genetic modification, fermentation methods, and enzyme immobilization, fungal enzymes are being produced with higher yields, specificity, and stability, thus harmonistically implementing the concept of circular bioeconomy-a marriage of industrial processes with ecological sustainability (Bugg et al., 2011).

Within paper and pulp and related sectors, lignin-degrading enzymes such as laccases, lignin peroxidases, and xylanases are used instead of harsh chemicals during biobleaching and deinking processes, thus reducing pollution and saving energy (Kirk & Farrell, 1987).

Fungal enzymes, mostly cellulases and hemicellulases from *Trichoderma reesei* and *Aspergillus niger*, are important in the bioethanol industry to convert lignocellulosic biomass into sugars, leading to the production of second-generation biofuels (Sukumaran et al., 2005).

Another field where fungal enzymes are of utmost importance is pharmaceutical drug formulation, biotransformation, and diagnostic areas. Proteases, lipases, and β-glucanases have antimicrobial, anti-inflammatory, and antitumor qualities, with other actions relating to drug delivery systems (Polizeli et al., 2005).

Fungal enzymes find application in the agriculture sector for biocontrol, composting, and soil health. For instance, chitinases and proteases work against harmful microbes and promote sustainable plant vitality. Fungal enzymes are being increasingly incorporated in probiotic formulations to enhance nutrient absorption and plant strength (Harman et al., 2004). Trichoderma isolates, known for their ability to break down lignin, cellulose, and starch, hold promise as biocontrol agents in agriculture, potentially leading to disease control and enhanced crop yield and production (Ramaraju et al., 2017).

Fungal enzymes are also famous in environmental cleanup. N-lactases and peroxidases are capable of destroying pollutants such as dyes, pesticides, and endocrine-disrupting chemicals. The fungi considered for mycoremediation for their wide enzymatic capacity include *Pleurotus ostreatus* and *Phanerochaete chrysosporium* (Pointing, 2001).

Fungal proteases and keratinases also present eco-friendly options in leather industries for de hairing and bating in place of harsh chemicals.

Objectives

This chapter intetent to study the prominent role of fungal enzymes in advancing green industrial biotechnology, with a particular focus on their application in the paper, pulp, and bioethanol production industries. It aims to clarify the ways in which these biocatalysts can offer sustainable substitutes for traditional chemical-intensive processes in these industries. By looking closely at what fungal enzymes can do, this study hopes to encourage their use in creating more sustainable and environmentally friendly practices as we move from making paper to producing bioethanol.

Materials And Methods

Literature Review

A comprehensive literature review was carried out utilizing peer-reviewed journals, books, and databases such as Science Direct, Pub Med, Springer Link, and Google Scholar. The keywords used during the search process were: fungal enzymes, industrial biotechnology, bioethanol production, laccase, cellulase, mycoremediation, and green chemistry.

Selection Criteria

Priority was given to new publications of about the last 15 years with experimental studies, industrial case reports, and reviews related to fungal enzyme applications. They were selected mainly based on their sustainability potential and economic viability, with interdisciplinary significance taken into consideration.

Data Collection and Analysis

Information related to sources of enzyme, their modes of action, substrate specificity, industrial applications, and environmental benefits was organized into six thematic categories: paper industry, bioethanol production, pharmaceuticals, agriculture, environmental remediation, and other applications. The comparative data was analyzed to ascertain the efficacy of fungal enzymes in contrast to existing methods.

Limitations

Being a meta-analysis of pre-existing data, no experimental validation was conducted. Furthermore, this study encompasses only publicly accessible literature, excluding proprietary industrial data.

Results And Discussion

Paper and Pulp Industry

Xylanases and laccases of fungal origin actively involved in pulping processes, particularly in bleaching and deinking. Their use minimizes the need for chemicals, reduces energy usage, and improves the brightness of the paper.

Studies show a reduction of up to 30% in the use of chlorine-based chemicals when fungal enzymes are applied (Kirk & Farrell, 1987).

Bioethanol Production

Cellulases and hemicellulases obtained from *T. reesei* augment the saccharification of lignocellulosic biomass. Accompanied by fermentation bacteria such as Saccharomyces cerevisiae, ethanol is produced and yields improve along with reduced processing times. The combination of enzymes also improves value (Sukumaran et al., 2005; Gusakov, 2011).

Medicine and Pharmacy

Aspergillus and *Penicillium fungi* manufacture enzymes that of active pharmaceutical ingredients, drug delivery systems as well as diagnostics devices. Antimicrobial peptides derived from fungi show a lot of promise for new antibiotic drugs (Polizeli et al., 2005; Gupta et al., 2002).

Agriculture

Fungal chitinases assist in biocontrol by integrating chitin in pests and pathogens, while proteases increase the fertility of the soil. Crop yield is further enhanced by formulations rich in fungal enzymes which promote sustainable agriculture.

Other Industrial Applications

Fungal enzymes are used in diverse fields:

Enzyme	**Fungal Source**	**Application Field**	**Function**	**Reference**
Laccase	*Trametes versicolor*	Paper, Bioremediation	Lignin degradation, dye decolorization	Baldrian (2006)
Xylanase	*Aspergillus niger*	Pulp and Paper	Hemicellulose breakdown, pulp bleaching	Polizeli et al. (2005)
Cellulase	*Trichoderma reesei*	Bioethanol, Textile	Cellulose degradation for saccharification	Gusakov (2011)
Lignin Peroxidase	*Phanerochaete chrysosporium*	Pulp, Bioremediation	Oxidation of lignin and pollutants	Arora & Sharma (2010)

Enzyme	**Fungal Source**	**Application Field**	**Function**	**Reference**
Protease	*Aspergillus oryzae*	Detergent, Leather, Pharma	Protein hydrolysis, dehairing, drug formulation	Gupta et al. (2002)
Chitinase	*Trichoderma harzianum*	Agriculture	Degrades chitin in pests and fungi	Harman et al. (2004)
β-Glucanase	*Penicillium funiculosum*	Pharmaceuticals, Feed	Degrades β-glucans, improves digestibility	Singh et al. (2000)
Lipase	*Rhizopus oryzae*	Food, Pharma, Detergent	Fat hydrolysis, biodiesel production	Hasan et al. (2006)
Amylase	*Aspergillus oryzae*	Food, Brewing	Starch hydrolysis into sugars	de Souza & Magalhães (2010)
Tyrosinase	*Agaricus bisporus*	Cosmetics	Regulates melanin synthesis	Chang (2009)
Keratinase	*Aspergillus flavus*	Leather, Waste Management	Degrades keratin (e.g., feathers)	Gradisar et al. (2005)
Tannase	*Penicillium chrysogenum*	Leather, Beverage	Tannin degradation, juice clarification	Aguilar et al. (2007)
Phytase	*Aspergillus ficuum*	Animal Feed	Liberates phosphate from phytate	Vohra & Satyanarayana (2003)

Enzyme	**Fungal Source**	**Application Field**	**Function**	**Reference**
Glucoamylase	*Aspergillus niger*	Fermentation	Converts starch to glucose	Pandey et al. (2000)
Catalase	*Microsporum* spp.	Medicine, Diagnostics	Breaks down hydrogen peroxide	Chelikani et al. (2004)
Peroxidase	*Pleurotus ostreatus*	Wastewater Treatment	Oxidizes phenolic compounds	Pointing (2001)
Inulinase	*Kluyveromyces marxianus*	Bioethanol, Sweeteners	Converts inulin to fructose	Pandey et al. (1999)
Glucose Oxidase	*Penicillium notatum*	Biosensors, Pharma	Glucose monitoring, antibacterial applications	Bankar et al. (2009)
Aryl Alcohol Oxidase	*Pleurotus eryngii*	Bioremediation	Oxidation of aryl alcohols	Hernández-Ortega et al. (2012)
Urease	*Cryptococcus humicola*	Agriculture	Urea hydrolysis, nitrogen cycling	Mobley et al. (1995)

Conclusion

Fungal enzymes represent a valuable resource for green industrial biotechnology, providing sustainable and efficient alternatives to chemical-heavy processes in numerous sectors. Their successful applications in paper manufacturing, bioethanol production, pharmaceuticals, agriculture, and environmental remediation highlight their adaptability. Future studies should prioritize enhancing enzyme cost-effectiveness, stability, recovery, and scalability. Strengthening partnerships between academic institutions and industries will be crucial for addressing commercialization challenges. As sectors transition toward environmentally friendly solutions, fungal enzymes will continue to play a key role in biotechnological advancements.

References

1. Aguilar, C. N., Gutiérrez-Sánchez, G., Rodríguez, R., et al. (2007). Microbial tannases: advances and perspectives. Applied Microbiology and Biotechnology, 76(1), 47–59.
2. Arora, D. S., & Sharma, R. K. (2010). Ligninolytic fungal laccases and their biotechnological applications. Applied Biochemistry and Biotechnology, 160(6), 1760–1788.
3. Baldrian, P. (2006). Fungal laccases – Occurrence and properties. FEMS Microbiology Reviews, 30(2), 215–242.
4. Bankar, S. B., Bule, M. V., Singhal, R. S., & Ananthanarayan, L. (2009). Glucose oxidase—An overview. Biotechnology Advances, 27(4), 489–501.
5. Bugg, T. D., Ahmad, M., Hardiman, E. M., & Singh, R. (2011). The emerging role for bacteria in lignin degradation and bio-product formation. Current Opinion in Biotechnology, 22(3), 394–400. https://doi.org/10.1016/j.copbio.2010.10.009
6. Chan, L.G.; Cohen, J.L.; Bell, J.M.L.N.d.M. Conversion of Agricultural Streams and Food-Processing By-Products to Value-Added Compounds Using Filamentous Fungi. Annu. Rev. Food Sci. Technol. 2018, 9, 503–523.
7. Chang, T. S. (2009). An updated review of tyrosinase inhibitors. International Journal of Molecular Sciences, 10(6), 2440–2475.
8. Chelikani, P., Fita, I., & Loewen, P. C. (2004). Diversity of structures and properties among catalases. Cellular and Molecular Life Sciences, 61(2), 192–208.
9. Cherkupally Ramaraju, Hindumathi A., and Reddy B.N. (2017). In vitro antagonistic activity of Trichoderma species against Fusarium oxysporum f. sp. melongenae. International Journal of Applied Agricultural Research, 12, 1 pp. 87-95
10. de Souza, P. M., & Magalhães, P. O. (2010). Application of microbial α-amylase in industry—A review. Brazilian Journal of Microbiology, 41(4), 850–861.
11. Gradisar, H., Kern, S., & Friedrich, J. (2005). Keratinase of Doratomyces microsporus. Applied Microbiology and Biotechnology, 67(1), 116–123.
12. Gupta, R., Beg, Q. K., & Lorenz, P. (2002). Bacterial alkaline proteases: molecular approaches and industrial applications. Applied Microbiology and Biotechnology, 59(1), 15–32. https://doi.org/10.1007/s00253-002-0975-y
13. Gusakov, A. V. (2011). Alternatives to Trichoderma reesei in biofuel production. Trends in Biotechnology, 29(9), 419–425.
14. Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., & Lorito, M. (2004). Trichoderma species—opportunistic, avirulent plant symbionts. Nature Reviews Microbiology, 2(1), 43–56. https://doi.org/10.1038/nrmicro797

15. Hasan, F., Shah, A. A., & Hameed, A. (2006). Industrial applications of microbial lipases. Enzyme and Microbial Technology, 39(2), 235–251.
16. Hernández-Ortega, A., et al. (2012). Aryl-alcohol oxidase: A fungal flavoenzyme involved in lignin degradation. Applied Microbiology and Biotechnology, 93(3), 977–991.
17. Hernández-Ortega, A., Ferreira, P., & Martínez, A. T. (2012). Fungal aryl-alcohol oxidase: A peroxide-producing flavoenzyme involved in lignin degradation. Applied Microbiology and Biotechnology, 93(4), 1395–1410.
18. Kirk, T. K., & Farrell, R. L. (1987). Enzymatic "combustion": the microbial degradation of lignin. Annual Review of Microbiology, 41(1), 465–505. https://doi.org/10.1146/annurev.mi.41.100187.002341
19. Mobley, H. L. T., et al. (1995). Molecular biology of microbial ureases. Microbiological Reviews, 59(3), 451–480.
20. Pandey, A., et al. (1999). Production, purification and properties of microbial inulinases: A review. Process Biochemistry, 35(1–2), 135–152.
21. Pandey, A., et al. (2000). Glucoamylase research: A review. Food Technology and Biotechnology, 38(3), 173–186.
22. Pandey, A., et al. (2000). Glucoamylases: characteristics and applications. Process Biochemistry, 35(6), 525–534.
23. Pointing, S. B. (2001). Feasibility of bioremediation by white-rot fungi. Applied Microbiology and Biotechnology, 57(1–2), 20–33.
24. Polizeli, M. L. T. M., et al. (2005). Xylanases from fungi: Properties and industrial applications. Applied Microbiology and Biotechnology, 67(5), 577–591.
25. Singh, S., et al. (2000). β-Glucanase from Penicillium funiculosum: production, purification, and characterization. Process Biochemistry, 35(3-4), 235–243.
26. Singh, S., Madlala, A. M., & Prior, B. A. (2000). Thermomyces lanuginosus: Properties of strains and their hemicellulases. FEMS Microbiology Reviews, 24(3), 411–456.
27. Sukumaran, R. K., Singhania, R. R., & Pandey, A. (2005). Microbial cellulases—production, applications and challenges. Journal of Scientific & Industrial Research, 64(11), 832–844.
28. Vohra, A., & Satyanarayana, T. (2003). Phytases: Microbial sources, production, purification, and potential biotechnological applications. Critical Reviews in Biotechnology, 23(1), 29–60.

The Therapeutic Effect of Music in the Treatment of Diabetes

Rohit Yadav

Kalpana Singh

Department of Zoology, University of Lucknow, Lucknow (UP), India.

Email: biomusicology.india@gmail.com

Article DOI Link: https://zenodo.org/uploads/15577026

*DOI: **10.5281/zenodo.15577026***

Abstract

Diabetes mellitus, a chronic metabolic disorder characterized by persistent hyperglycemia, poses a significant global health challenge, affecting approximately 537 million individuals worldwide in 2021. The disease, stemming from impaired insulin secretion or action, is associated with severe complications, including cardiovascular diseases, renal failure, and neuropathy, alongside substantial psychological and economic burdens. Despite advancements in therapeutic interventions, effective diabetes management remains complex, necessitating innovative approaches to address both physiological and psychological dimensions of the disease. Music therapy, an evidence-based clinical intervention, has emerged as a promising adjunctive therapy, leveraging its ability to modulate stress, enhance emotional well-being, and improve glycemic control. By engaging neural pathways and regulating stress-induced hormonal responses, music therapy offers a holistic approach to diabetes care, potentially mitigating the disease's multifaceted impact on patients' quality of life. This chapter explores the therapeutic potential of music therapy in diabetes management, emphasizing its role in stress reduction, psychological support, and overall health improvement.

Keywords: Diabetes mellitus, music therapy, glycaemic control, stress reduction, hyperglycemia, insulin resistance, psychological well-being.

Introduction

Diabetes mellitus is a chronic metabolic condition marked by prolonged hyperglycaemia due to defects in insulin secretion, insulin action, or both. In the year 2021, around 537 million people worldwide were affected by this disorder, highlighting its status as a major global health issue (Saeedi et al., 2019). The disease significantly impacts patients' quality of life and is linked to numerous complications, including increased morbidity, mortality rates, and substantial healthcare costs. Despite progress in research that has improved our understanding of its pathophysiology, treatment options, and long-term outcomes, managing diabetes effectively remains a complex and ongoing challenge (Aschner et al., 2021). Globally, an estimated 415 million adults, representing 9% of the adult population, live with diabetes, with nearly half of these cases remaining undiagnosed (Jaacks et al., 2016). The prevalence of diabetes has been steadily rising, with 6.4% of adults affected in 2010, equating to 285 million individuals, and projections suggesting an increase to 439 million by 2030. During this period, developing countries are expected to see a 69% rise in diabetes prevalence, while developed nations will experience a 20% increase. A primary driver of this pandemic is the growing prevalence of obesity, particularly in Europe and the United States, where obesity accounts for 70–90% of diabetes cases among adults (Ginter et al., 2013). According to the World Health Organization (WHO), diabetes is projected to become the seventh leading cause of death globally by 2030 (Sheriff et al., 2019). Diabetes is a heterogeneous metabolic disorder encompassing several primary classifications, each distinguished by unique clinical manifestations, symptoms, and pathophysiological mechanisms. Type 1 diabetes, typically diagnosed during childhood or early adulthood but potentially occurring at any age, is an autoimmune condition characterized by the destruction of pancreatic beta cells responsible for insulin production. This results in an absolute insulin deficiency, necessitating lifelong exogenous insulin administration for management (Atkinson et al., 2014). Type 2 Diabetes mellitus (T2DM) represents the most common form, accounting for approximately 90–95% of all diabetes cases (Centres for Disease Control and Prevention, 2022). Its pathogenesis involves a combination of insulin resistance and progressive beta-cell dysfunction, with modifiable risk factors such as poor dietary habits, obesity, and sedentary behaviour significantly contributing to its development (Kahn et al., 2014). Gestational Diabetes mellitus (GDM) arises during pregnancy due to hormonal changes that induce insulin resistance (Catalano & Shankar, 2017). Women with a history of GDM are at a higher risk of developing T2DM in subsequent years. Monogenic diabetes, including maturity-onset diabetes of the young (MODY), is caused by inherited genetic mutations that disrupt insulin secretion (Hattersley et al., 2018). Other variants include secondary diabetes, which may result from underlying conditions such as cystic fibrosis or the use of specific pharmacological agents, including glucocorticoids.

Impact of Diabetes

The impact of diabetes is extensive, affecting nearly every organ system in the body and significantly impairing quality of life.

1. **Physical Health Consequences:** Diabetes is a leading risk factor for

cardiovascular diseases, contributing to heart attacks and strokes through mechanisms such as chronic inflammation and lipid abnormalities (Emerging Risk Factors Collaboration, 2010). Diabetes is the most common cause of end-stage renal disease worldwide (Coresh et al., 2013). Persistent hyperglycaemia damages the kidney's filtration system, leading to proteinuria and eventual renal failure. Peripheral and autonomic neuropathies are frequent complications, resulting in symptoms such as pain, numbness, and gastrointestinal issues (Pop-Busui et al., 2017).

2. **Psychological and Emotional Impact:** The constant need for blood glucose monitoring, medication adherence, and fear of complications leads to psychological distress. Studies have shown high rates of anxiety, depression, and diabetes distress among patients with diabetes (Fisher et al., 2012).
3. **Economic and Social Burden:** Diabetes imposes a significant economic burden on individuals and healthcare systems. The annual global healthcare expenditure on diabetes was estimated at $966 billion in 2021, an increase of 316% over the last 15 years (International Diabetes Federation, 2021). This burden is compounded by productivity losses due to disability and premature death (Bommer et al., 2017).
4. **Impact on Quality of Life:** The chronic nature of diabetes and its complications significantly reduce the quality of life. Limitations in physical activity, dietary restrictions, and social stigma further exacerbate the disease burden (Al Hayek et al., 2014).

Diabetes is a multifaceted disease with widespread impacts on health, psychology, and society. Its classification into distinct types underscores the need for tailored treatment approaches. The global burden of diabetes necessitates ongoing research into innovative therapies and management strategies. Complementary interventions, such as music therapy, are gaining attention for their potential to address both the physical and psychological aspects of diabetes, providing a holistic approach to improving patient outcomes.

Understanding Music Therapy

Music therapy is a clinical and evidence-based practice that uses music to achieve therapeutic goals. It is implemented by trained professionals to address physical, emotional, cognitive, and social needs. The therapeutic use of music is gaining increasing attention for its role in managing chronic diseases, including diabetes, due to its ability to modulate stress and hormonal responses, enhance emotional well-being, and improve quality of life.

Music therapy is defined by the American Music Therapy Association (AMTA) as "the clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship" (Bradt et al., 2015). It combines music's intrinsic power with therapeutic techniques to promote healing and personal growth. Historically, the use of music as a healing tool dates back to ancient civilizations. In ancient Greece, philosophers like Pythagoras and Plato acknowledged music's therapeutic potential, believing it could restore harmony to the soul and body (Dobrzynska et al., 2021). Similarly, ancient Indian and Chinese medical traditions incorporated music in rituals to treat physical and mental ailments. The modern practice of music therapy began in the 20th century, particularly after World Wars I and II, when music was used to alleviate the psychological and physical trauma of soldiers (Davis et al., 2008).

The formal recognition of music therapy as a profession can be traced to the mid-20th century. The National Association for Music Therapy (NAMT), established in 1950 in the United States, laid the foundation for research and practice standards. Over time, music therapy expanded globally, with institutions and associations forming in Europe, Asia, and Africa (Wigram & Gold, 2006). The evolution of music therapy has been shaped by interdisciplinary research, integrating insights from neuroscience, psychology, and medicine. Advances in brain imaging technologies, such as functional MRI (fMRI), have provided empirical evidence of music's impact on the brain, fostering a deeper understanding of its therapeutic mechanisms (Koelsch, 2010).

Clinical Applications of Music Therapy

Music therapy is widely applied across diverse clinical settings. It is used to treat anxiety, depression, and post-traumatic stress disorder (PTSD), promoting emotional regulation and stress reduction (Maratos et al., 2008). Patients with Parkinson's disease, Alzheimer's, and stroke benefit from music therapy's ability to improve motor coordination and cognitive function (Thaut et al., 2005). Music therapy is increasingly employed in managing chronic illnesses like diabetes and hypertension, with studies highlighting its role in improving glycemic control and reducing cardiovascular risk (Chanda & Levitin, 2013). In surgical and palliative care, music therapy reduces pain perception and the need for analgesics, enhancing overall patient comfort (Lee, 2016).

Music profoundly influences the brain's structure and function, engaging multiple neural networks:

1. **Activation of Reward Pathways:** Listening to music activates the brain's reward system, particularly the mesolimbic dopamine pathway, associated with pleasure and motivation (Salimpoor et al., 2011).
2. **Cognitive Enhancements:** Music engages the prefrontal cortex, hippocampus, and cerebellum, improving memory, attention, and executive functions (Koelsch, 2014).
3. **Neuroplasticity:** Music stimulates neuroplasticity, fostering the brain's

ability to reorganize and adapt, particularly in response to injury or disease (Wan & Schlaug, 2010).

Role of Music Therapy in Modulating Stress and Hormonal Responses

Stress is a significant factor in the progression of chronic diseases, including diabetes, due to its impact on hormonal regulation. Music therapy effectively reduces stress by influencing the hypothalamic-pituitary-adrenal (HPA) axis and autonomic nervous system.

Research shows that listening to calming music decreases cortisol, the primary stress hormone, thereby mitigating the adverse effects of chronic stress on the body (Thoma et al., 2013). Music lowers heart rate and blood pressure by reducing sympathetic nervous system activity, promoting a state of relaxation (Bernardi et al., 2006). Music therapy enhances the release of endorphins and serotonin, neurotransmitters that improve mood and promote a sense of well-being (Kreutz et al., 2004). By alleviating stress and improving sleep quality, music therapy indirectly contributes to better glycemic control, as stress and poor sleep are known to exacerbate insulin resistance (Chanda & Levitin, 2013).

Music therapy represents a promising complementary approach in the management of chronic diseases like diabetes. Its ability to engage neural pathways, regulate stress responses, and enhance emotional well-being makes it a valuable tool for improving patient outcomes. As research continues to unravel its mechanisms, music therapy is poised to play an increasingly significant role in holistic healthcare.

Emotional and Psychological Impact of Diabetes

Diabetes mellitus is a chronic metabolic disorder that imposes significant psychological and emotional challenges on individuals. The constant need for self-management, fear of complications, and societal stigma contribute to emotional distress, anxiety, and depression. Research shows that individuals with diabetes are two to three times more likely to experience depression than the general population (Anderson et al., 2001). Additionally, diabetes distress, a condition characterized by frustration and stress related to diabetes management, is prevalent and adversely affects glycemic control (Fisher et al., 2007). Psychological issues like anxiety and low self-esteem further impact adherence to treatment regimens, resulting in poor health outcomes.

Relation Between Stress and Glycemia

Stress significantly influences glycemic control in individuals with diabetes. Acute stress triggers the release of stress hormones like cortisol and adrenaline, which elevate blood glucose levels by promoting hepatic glucose production and reducing peripheral glucose uptake (Goyal & Jialal, 2021). Chronic stress, on the other hand, exacerbates insulin resistance, making glucose regulation more challenging (Surwit et al., 2002). Studies indicate that psychological stress correlates with increased HbA1c levels, a marker of long-term glycemic control (Lloyd et al., 1999). Stress also disrupts self-care behaviours such as healthy eating, physical activity, and medication adherence, further worsening glycemia. Cortisol, a glucocorticoid hormone, plays a pivotal role in the body's response to stress. It stimulates gluconeogenesis, the breakdown of glycogen into glucose, and inhibits insulin's action, causing hyperglycemia (Kamgang et al., 1989). Similarly, adrenaline (epinephrine), released during the "fight or flight" response, enhances glycogenolysis and suppresses insulin secretion, raising blood glucose levels (Cryer, 1993). In individuals with diabetes, the exaggerated response to these hormones can lead to significant glycemic fluctuations and heightened risk of complications.

Role of Music Therapy in Reducing Stress and Its Impact on Glycemic Control

Music therapy has emerged as a promising non-pharmacological intervention for stress reduction and glycemic control. Listening to calming music has been shown to decrease cortisol levels, heart rate, and blood pressure, thereby mitigating the physiological stress response (Koelsch et al., 2016). A randomized controlled trial by Belmon et al. (2017) demonstrated that music therapy improved psychological well-being and reduced HbA1c levels in individuals with type 2 diabetes. Music's ability to evoke positive emotions and promote relaxation indirectly supports better self-care practices, adherence to treatment, and improved glycemic outcomes. Furthermore, music-based interventions like guided imagery and rhythmic breathing have been found effective in reducing anxiety and depression, which are closely linked to poor diabetes management (Thoma et al., 2013).

Conclusion

The profound therapeutic potential of music therapy in diabetes management. By reducing stress, modulating hormonal responses, and improving emotional well-being, music therapy offers a holistic approach to glycemic control. Its ability to lower cortisol levels and enhance psychological resilience underscores its value as an adjunctive treatment. Integrating music therapy into diabetes care can address both physiological and psychological challenges, ultimately improving patients' quality of life and health outcomes.

Acknowledgement

The authors are grateful to Department of zoology, University of Lucknow, Lucknow for providing the necessary resources and research facilities to conduct this study. Department of Higher Education, Government of Uttar Pradesh is gratefully acknowledged for their financial assistance through research and

development grant scheme.

References

1. Al-Hayek AA, Robert AA, Abbas HM, Itani MB, Al-Saeed AH, Juhani AE, Al-Goudah HS, Al-Sabaan FS. Assessment of health-related quality of life among adolescents with type 1 diabetes mellitus in Saudi Arabia. Saudi Med J. 2014 Jul;35(7):712-7. PMID: 25028228.
2. American Music Therapy Association (2023). Definition of Music Therapy, https://www.musictherapy.org/about/musictherapy/#:~:text=AMTA%20Official%20Definition%20of%20Music,an%20approved%20music%20therapy%20program.
3. Aschner, P., Karuranga, S., James, S., Simmons, D., Basit, A., Shaw, J. E., ... & Saeedi, P. (2021). The International Diabetes Federation's guide for diabetes epidemiological studies. Diabetes research and clinical practice, 172.
4. Atkinson, M. A., Eisenbarth, G. S., & Michels, A. W. (2014). Type 1 diabetes. The lancet, 383(9911), 69-82.
5. Belmon, A. P., & Auxillia, J. (2023). Music therapy: A best way to solve anxiety and depression in diabetes mellitus patients. In Advances in Speech and Music Technology: Computational Aspects and Applications (pp. 237-247). Cham: Springer International Publishing.
6. Bernardi L, Porta C, Sleight P. Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. Heart. 2006 Apr;92(4):445-52. doi: 10.1136/hrt.2005.064600. Epub 2005 Sep 30. PMID: 16199412; PMCID: PMC1860846.
7. Bommer C, Heesemann E, Sagalova V, Manne-Goehler J, Atun R, Bärnighausen T, Vollmer S. The global economic burden of diabetes in adults aged 20-79 years: a cost-of-illness study. Lancet Diabetes Endocrinol. 2017 Jun;5(6):423-430. doi: 10.1016/S2213-8587(17)30097-9. Epub 2017 Apr 26. PMID: 28456416.
8. Bradt J, Dileo C. Music interventions for mechanically ventilated patients. Cochrane Database Syst Rev.2014;2014(12):CD006902. doi:10.1002/14651858. CD006902. Pub3. Epub 2014 Dec 9. PMID: 25490233; PMCID: PMC6517146.
9. Catalano, P. M., & Shankar, K. (2017). Obesity and pregnancy: Mechanisms of short term and longterm adverse consequences for mother and child. BMJ.
10. Centers for Disease Control and Prevention (2022). National Diabetes Statistics Report. https://www.cdc.gov/diabetes/php/data-research/index.html
11. Chanda ML, Levitin DJ. The neurochemistry of music. Trends Cogn Sci. 2013 Apr;17(4):179-93. doi: 10.1016/j.tics.2013.02.007. PMID: 23541122.

12. Chen CT, Tung HH, Fang CJ, Wang JL, Ko NY, Chang YJ, Chen YC. Effect of music therapy on improving sleep quality in older adults: A systematic review and meta-analysis. J Am Geriatr Soc. 2021 Jul;69(7):1925-1932. doi: 10.1111/jgs.17149. Epub 2021 Apr 20. PMID: 33880759.
13. Coresh J, Turin TC, Matsushita K, et al. Decline in Estimated Glomerular Filtration Rate and Subsequent Risk of End-Stage Renal Disease and Mortality. JAMA. 2014;311(24):2518–2531. doi:10.1001/jama.2014.6634
14. Davis, William & Gfeller, Kate & Thaut, Michael. (2008). An Introduction to Music Therapy: Theory and Practice. Third Edition. American Music Therapy Association.
15. Dobrzyńska, Ewelina & Cesarz, Helelna & Rymaszewska, Joanna & Kiejna, Andrzej. (2006). Music Therapy - History, definitions and application. Archives of Psychiatry and Psychotherapy. 8. 47-52.
16. Fiorentino TV, Prioletta A, Zuo P, Folli F. Hyperglycemia-induced oxidative stress and its role in diabetes mellitus related cardiovascular diseases. Curr Pharm Des. 2013;19(32):5695-703. doi: 10.2174/13816128113193200005. PMID: 23448484.
17. Fisher L, Skaff MM, Mullan JT, Arean P, Mohr D, Masharani U, Glasgow R, Laurencin G. Clinical depression versus distress among patients with type 2 diabetes: not just a question of semantics. Diabetes Care. 2007 Mar;30(3):542-8. doi: 10.2337/dc06-1614. PMID: 17327318.
18. Ginter, E., & Simko, V. (2013). Type 2 diabetes mellitus, pandemic in 21st century. Diabetes: an old disease, a new insight, 42-50.
19. Hattersley AT, Patel KA. Precision diabetes: learning from monogenic diabetes. Diabetologia. 2017 May;60(5):769-777. doi: 10.1007/s00125-017-4226-2. Epub 2017 Mar 17. PMID: 28314945; PMCID: PMC5907633
20. Horden, P. (Ed.). (2000). Music as Medicine: The History of Music Therapy Since Antiquity (1st ed.). Routledge. https://doi.org/10.4324/9781315090894
21. Kahn SE, Hull RL, Utzschneider KM. Mechanisms linking obesity to insulin resistance and type 2 diabetes. Nature. 2006 Dec 14;444(7121):840-6. doi: 10.1038/nature05482. PMID: 17167471.
22. Koelsch S. Brain correlates of music-evoked emotions. Nat Rev Neurosci. 2014 Mar;15(3):170-80. doi: 10.1038/nrn3666. PMID: 24552785.
23. Lawrence Fisher, Joseph T. Mullan, Patricia Arean, Russell E. Glasgow, Danielle Hessler, Umesh Masharani; Diabetes Distress but Not Clinical Depression or Depressive Symptoms Is Associated With Glycemic Control in Both Cross-Sectional and Longitudinal Analyses. Diabetes Care 1 January 2010; 33 (1): 23–28.
24. Lee JH. The Effects of Music on Pain: A Meta-Analysis. J Music Ther. 2016 Winter;53(4):430-477. doi: 10.1093/jmt/thw012. Epub 2016 Oct 19. Erratum

in: J Music Ther. 2021 Aug 24;58(3):372. doi: 10.1093/jmt/thab012. PMID: 27760797.
25. Li, X., et al. (2022). Music therapy for diabetes management: A systematic review and meta-analysis. Diabetes Research and Clinical Practice.
26. Magliano, D. J., Boyko, E. J., & Atlas, I. D. (2021). What is diabetes? In IDF DIABETES ATLAS [Internet]. 10th edition. International Diabetes Federation.
27. Mazze RS, Lucido D, Shamoon H. Psychological and social correlates of glycemic control. Diabetes Care. 1984 Jul-Aug;7(4):360-6. doi: 10.2337/diacare.7.4.360. PMID: 6381009.
28. Nilsson U. Soothing music can increase oxytocin levels during bed rest after open-heart surgery: a randomised control trial. J Clin Nurs. 2009 Aug;18(15):2153-61. doi: 10.1111/j.1365-2702.2008.02718.x. PMID: 19583647.
29. PE, C. (2003). Glucose homeostasis and hypoglycemia. Williams Textbook of Endocrinology, 1585-1618.
30. Pop-Busui R, Boulton AJ, Feldman EL, Bril V, Freeman R, Malik RA, Sosenko JM, Ziegler D. Diabetic Neuropathy: A Position Statement by the American Diabetes Association. Diabetes Care. 2017 Jan;40(1):136-154. doi: 10.2337/dc16-2042. PMID: 27999003; PMCID: PMC6977405
31. Rao, M. S., & Saranya, K. (2022). Therapeutic applications of Indian classical music. Journal of Ethnopharmacology.
32. Ryan J. Anderson, Kenneth E. Freedland, Ray E. Clouse, Patrick J. Lustman; The Prevalence of Comorbid Depression in Adults with Diabetes: A meta-analysis. Diabetes Care 1 June 2001; 24 (6): 1069–1078
33. Saeedi, P., et al. (2019). Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas. Diabetes Research and Clinical Practice.
34. Salimpoor VN, Benovoy M, Larcher K, Dagher A, Zatorre RJ. Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. Nat Neurosci. 2011 Feb;14(2):257-62. doi: 10.1038/nn.2726. Epub 2011 Jan 9. PMID: 21217764.
35. Sapolsky, R. M. (2004). Why zebras don't get ulcers: The acclaimed guide to stress, stress-related diseases, and coping. Holt paperbacks.
36. Sheriff, O. L., Olayemi, O., Taofeeq, A. O., Riskat, K. E., Ojochebo, D. E., & Ibukunoluwa, A.O. (2019). A new model for alloxan-induced diabetes mellitus in rats. Journal of Bangladesh Society of Physiologist, 14(2), 56-62.
37. Surwit RS, van Tilburg MA, Zucker N, McCaskill CC, Parekh P, Feinglos MN, Edwards CL, Williams P, Lane JD. Stress management improves long-

term glycemic control in type 2 diabetes. Diabetes Care. 2002 Jan;25(1):30-4. doi: 10.2337/diacare.25.1.30. PMID: 11772897.

38. Thaut, Michael & Abiru, Mutsumi. (2010). Rhythmic Auditory Stimulation in Rehabilitation of Movement Disorders: A Review of Current Research. Music Perception - MUSIC PERCEPT. 27. 263-269. 10.1525/mp.2010.27.4.263.
39. The Emerging Risk Factors Collaboration. (2010). Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. The Lancet, 375(9733), 2215–2222. doi:10.1016/s0140-6736(10)60484-9
40. Thoma MV, La Marca R, Brönnimann R, Finkel L, Ehlert U, Nater UM. The effect of music on the human stress response. PLoS One. 2013 Aug 5;8(8):e70156. doi: 10.1371/journal.pone.0070156. PMID: 23940541; PMCID: PMC3734071
41. Wandja Kamgang, V., Murkwe, M., & Wankeu-Nya, M. (2023). Biological effects of cortisol. IntechOpen. doi: 10.5772/intechopen.1003161
42. Zatorre RJ. Predispositions and plasticity in music and speech learning: neural correlates and implications. Science. 2013 Nov 1;342(6158):585-9. doi: 10.1126/science.1238414. PMID: 24179219.

Dengue Virus: Transmission, Diagnosis and Prevention

Shilpa Nandan

Kalpana Singh

Department of Zoology, University of Lucknow, Lucknow (UP), India.

Email: biomusicology.india@gmail.com

Article DOI Link: https://zenodo.org/uploads/15577103

DOI: 10.5281/zenodo.15577103

Abstract

Dengue fever is an illness caused by a group of viruses spread by mosquitos. Dengue virus (DENV), a member of the Flaviviridae family, is the leading cause of mosquito-borne viral infections in people worldwide. Dengue can affect everyone, but it is more severe in those with weaker immune systems. Dengue hemorrhagic fever is a more severe type of viral infection. Symptoms could involve headache, fever, rash, and bleeding in the body. Dengue fever can lead to serious disease, including dengue shock syndrome, which is potentially fatal. This chapter reviews the causes of disease, diseases mechanism, disease transmission, the virus, the vector, the host, clinical appearance, diagnosis and prevention.

Keywords: Aedes, Mosquito, Vector, Dengue shock syndrome, Flavivirus, Prevention.

Introduction

"Mosquitoes are the greatest mass murderers on planet earth"

-Katherine Applegate

Dengue is the most significant insect pests harming both human and animal health. In addition to irritating humans and animals, biting female mosquitoes can spread a variety of diseases (Cunha, 2017). Dengue fever, also known as "breakbone or dandy fever" is more severe in immunocompromised individuals and can be repeated due to exposure to one of five dengue virus serotypes. Dengue hemorrhagic fever and dengue shock syndrome are severe forms, causing hemorrhages and life-threatening conditions (Howe, 1977). Over the past three centuries, dengue outbreaks have been recorded in temperate, tropical, and subtropical regions of the world. Although an illness similar to dengue has been documented in China as early as 992 A.D, the first dengue outbreak was documented in the French West Indies in 1635 (Gubler, 1997). Epidemics of dengue-like illnesses were reported worldwide in the tropics and some temperate regions throughout the 18th, 19th, and early 20th centuries. When Rush wrote about dengue fever that was happening in Philadelphia in 1780 (Rush, 1789).

Causes of Disease

Dengue virus (DENV) belongs to the Flaviviridae family and Flavivirus genus, with a single-stranded, positive-sense RNA genome. This family includes yellow fever virus, West Nile virus, St. Louis encephalitis virus, Japanese encephalitis virus, tickborne encephalitis virus, Kyasanur Forest sickness virus, and Omsk hemorrhagic fever virus. Arthropods like mosquito and ticks the primary mode of transmission of disease (Gould, 2008). The dengue genome contains around 11,000 nucleotide bases and encodes a single polyprotein. The viral particle consists of three structural protein components (C, prM, and E) and seven nonstructural proteins (NS1, NS2a, NS2b, NS3, NS4a, NS4b, and NS5) are essential for viral replication (Rodenhuis et al., 2010) (Guzman et al., 2010). The virus's five strains (DENV-1, DENV-2, DENV-3, DENV-4, and DENV-5) are classified as serotypes based on their serum antigenicity (WHO 2009).

Disease Mechanism

There is still a lot to learn about DENV's disease mechanism and the host immune response. One of the most noticeable symptoms of the sickness is a capillary leak.

Leukopenia, hemorrhagic tendencies, thrombocytopenia (seen in all forms of DENV infection, but more severe in DHF), and syndrome (plasma leakage induced by DHF-specific endothelial cell failure). The viral envelope (E) glycoprotein binds to host cells and promotes viral replication (Anderson et al.1992). Evidence points to monocytes as the main target (Scott et al.,1980). Infected monocytes produce IFN-a and IFN-b (Kurane et al., 1988).

Disease Transmission

Dengue virus is the most frequent mosquito-borne infection in humans around the world. DENV transmission occurs through the Aedes aegypti and Aedes albopictus (Surasombatpattana et al., 2011). They mainly bite in the early mornings and evenings.

Aedes disease-carrying species include Aedes albopictus, Aedes scutellaris, and Aedes polynesiensis. This virus primarily affects humans, causing even non-human primates. This virus primarily affects humans but can also infect non-human primates. A single bite can cause sickness. A female mosquito draws blood from an infected human. It becomes infected with the virus in its intestine within 2–12 days. After 8-10 days, the virus spreads to various tissues, including the mosquito's salivary glands, before being discharged into the saliva. When it bites another individual, it transmits the virus through saliva (Tomashek et al., 2011). Aedes aegypti is a major threat as it prefers to lay eggs in freshwater containers and near humans. Dengue fever can potentially be contracted through infected blood or organ donation (Teo et al., 2009) (Tan et al., 2005) (Wilder et al., 2009). Vertical transfer from mother to kid during pregnancy or birth has also been demonstrated (Teo et al., 2009). Although rare, other forms of transmission between individuals have been observed (Wiwanitkit et al., 2009).

The Virus

There are five distinct serotypes of DENV, a tiny single-stranded RNA virus (DENV-1 to DENV-5). The viral particle has a diameter of 50 nm and is spherical in shape. The host and viral proteases separate the genome into seven nonstructural proteins (NS) and three structural proteins (capsid C prM, membrane precursor M protein, and envelope E). Dengue viruses exhibit significant genetic variety, with multiple genotypes or lineages discovered within each serotype. However, purifying selection remains a dominating theme in dengue virus evolution, ensuring that only viruses that are "fit" for both people and vectors survive. Severe secondary dengue infections typically involve "European" genotypes DENV-2 and DENV-3 (Simmons et al., 2012; Leitmeyer et al., 1999; Lanciotti et al., 1994).

The Vectors

Infected Aedes mosquitos, specifically Aedes aegypti, transmit different dengue virus serotypes to humans through their bites. This mosquito species is found in tropical and subtropical regions worldwide, primarily between latitudes 35°N and 35°S. These geographical limitations are roughly comparable to the 10°C winter isotherm.

Aedes aegypti was found as far north as 45°N; however, invasions only occurred during warmer months and did not survive the winter. Aedes aegypti is less frequent at elevations above 1000 meters due to cooler temperatures. Embryonic stages are typically seen in water-filled artificial containers near human homes or inside. Research indicates that female Aedes aegypti may spend their lives in or near the homes where adults emerge.

It means that people propagate the virus rapidly within and between communities.

Aedes albopictus, Aedes polynesiensis, and various species of Aedes scutellaris have been linked to outbreak of dengue (Bhattacharya et al 2013). Each species has distinct ecological, behavioral, and geographical distributions. In recent decades, Aedes albopictus has spread from Asia to Africa, the Americas, and Europe, thanks to international traffic in worn tires that contain rainwater, where eggs are deposited. Eggs can survive for several months without water (Ramalingam and Balasubramanian 2020).

The genus Aedes belongs to the family Culicidae and consists of over 950 species, with Aedes aegypti and Aedes albopictus being the most significant in terms of disease transmission. These mosquitoes are distinguished by their black and white striped bodies and legs. The Aedes mosquito undergoes a complete metamorphosis, including egg, larva, pupa, and adult stages. The larvae are primarily aquatic and thrive in stagnant water. Only female Aedes mosquitoes require a blood meal for egg production, whereas males primarily feed on nectar. Aedes aegypti and Aedes albopictus are responsible for transmitting several arboviruses, including dengue, chikungunya, Zika virus, and yellow fever. Transmission occurs when an infected mosquito bites a human host. They typically lay eggs in artificial containers, tree holes, and discarded tires, with eggs capable of surviving desiccation for months before hatching when exposed to water. Aedes mosquitoes are primarily diurnal, with peak feeding times occurring in the early morning and late afternoon.

The Host

The dengue virus infects people and many species of lesser primates. Humans are the major urban habitat for the viruses. Studies in Malaysia and Africa have demonstrated that monkeys are infected and are most likely reservoir hosts. Despite the epidemiological significance of This observation is yet to be established (Gubler, 1997) (Rush, 1789). Dengue virus strains thrive in insect tissue. Cultures and on mammalian cell cultures following adaptation. Infection with any of the four virus serotypes can cause a variety of illnesses after a 4–10-day incubation period. While most infections are asymptomatic or subclinical, primary infection is thought to cause long-term defensive immunity to serotype infections (Messer et al., 2003).

Clinical Appearance

Humans can experience one of three clinical forms: dengue fever (DF), dengue hemorrhagic fever (DHF), or dengue shock syndrome (DSS). Approximately half of DENV infections is asymptomatic, and some are undifferentiated (patients develop fever and moderate symptoms but are not diagnosed with DENV). The intensity of symptoms varies amongst the three clinical signs of the disease, with influenza-like DF being the mildest and DSS being the most serious. Mild febrile DF is typically not lethal, but infections that progress to DHF or DSS can lead to death. Patients with DHF and DSS had viral counts 100- to 1000-fold higher than those with DF from the start of infection (Cardier et al.,2005).

DENV infection is usually more severe in young people than in adults (Vaughn et al., 2000). Signs usually occur after a 3–10-day incubation period (Hammond et al., 2005). Clinical symptoms for dengue hemorrhagic fever and dengue shock syndrome may vary from mild to severe and could be fatal. Predicting the progression of mild indications to severe DHF/DSS remains difficult due to the lack of unique clinical presentation and an insufficient understanding of disease cause and molecular pathways (Chan et al., 2012). WHO defines DF as fever periods (≥40°C for 2-7 days) with symptoms including rash, nausea, vomiting, and headache. Even though the disease affects persons of all ages, from infancy to adulthood (Guha et al., 2005) epidemiological data show that children control the condition better than adults. After 3-7 days, additional symptoms such as stomach pain, mucosal hemorrhage, weakness, and anxiety may develop (Khan et al., 2008).

Diagnosis

Dengue fever symptoms might be similar to those of other infections, such as typhoid fever or malaria, making it tough to identify the condition accurately. Diagnosis can be based on symptoms, medical history, and blood tests (platelet count first, then ELISA, HI assay, and RT-PCR).

Prevention

The first dengue vaccine chimeric yellow fever-dengue-tetravalent dengue vaccine (CYD-TDV or Dengvaxia®) by Sanofi Pasteur was approved in December 2015, following decades of research and clinical trials. Regulatory agencies have acknowledged it in around 20 countries (Vannice et.al., 2018). Clinical studies have shown that CYD-TDV is efficacious and safe for patients who have had prior contact with dengue virus (seropositive). Vaccination increases the risk of severe dengue infection for persons who were previously seronegative. In November 2017, a retrospective investigation analyzed the serostatus at the time of immunization, providing validation (Ramalingam and Balasubramanian 2020). Pre-vaccination screening is the recommended technique for countries seeking vaccination as part of their dengue control program. This technique only vaccinates patients with a history of dengue infection. Implementing a pre-vaccination screening strategy requires careful evaluation at the nationwide level, taking into account test sensitivity and specificity, local priorities, dengue epidemiology, hospitalization levels, and availability of both CYD-TDV and screening tests (WHO 2019). However, prevention relies on monitoring and ensuring the safety of mosquito bites. The major method for monitoring Aedes aegypti is to remove its habitats, which include standing water in urban areas. If destroying habitat is not feasible, using insecticides or biological control agents to standing water is another approach. Reducing open water collecting is the most effective and easily approach of control. General spraying with organophosphate or pyrethroid pesticides is not effective. Mosquito bites can be avoided by wearing clothing that totally covers the skin, using a repellent scarf, or staying in air-conditioned, screened, or nesting places. The frequency of outbreaks in certain areas is increasing due to urbanization, while the range of diseases is expanding due to climate change. However, present methods do not appear to be sufficiently successful (Ramalingam and Balasubramanian 2020).

Conclusion

Dengue fever is a devastating disease with an increasing public health concern. Random development creates extra mosquito breeding areas, increasing exposure to Aedes Aegypti bites. Semi-urban and slum dwellings sometimes lack suitable solid waste disposal services and require household water storage. In recent years, there has been a growing recognition of the need for a cost-effective vaccination for minimizing morbidity and mortality associated with this condition (Ramalingam and Balasubramanian 2020).

Acknowledgements

The authors are grateful to Department of Zoology, University of Lucknow, Lucknow for providing the necessary resources and research facilities to conduct this study.

References

1. Anderson R, King AD, Innis BL (1992). Correlation of E protein binding with cell susceptibility to dengue 4 virus infection. The Journal of General Virology. 73 (8):2155-2159.
2. Bhattacharya MK, Maitra S, Ganguly A, Bhattacharya A, Sinha A (2013). Dengue: A growing menace—A snapshot of recent facts, figures & remedies. International Journal of Biomedical Science. 9(2):61-67.
3. Cardier JE, Marino E, Romano E, Taylor P, Liprandi F, Bosch N (2005). Proinflammatory factors present in sera from patients with acute dengue infection induce activation and apoptosis of human microvascular endothelial cells: Possible role of TNF-alpha in endothelial cell damage in dengue. Cytokine.30(6):359-365.
4. Chan M, Johansson MA (2012). The incubation periods of Dengue viruses. Public Library of Science One. 7(11): 50972.
5. Cunha JP (2017). Dengue fever [Internet]. Medicine Net Available from: https://www.medicinenet.com/dengue_ fever/article.htm [Accessed: 02 January 2020].
6. Gould EA, Solomon T (2008). Pathogenic flaviviruses. The Lancet (London, England). 371(9611):500-509.
7. Gubler DJ (1997). Dengue and dengue haemorrhagic fever: its history and resurgence as a global public health problem. In: Gulber DJ, Kuno G, editors. Dengue and dengue haemorrhagic fever. Wallingford, Oxon: CAB international. p. 1-22.

8. Guha-Sapir D, Schimmer B (2005). Dengue fever: New paradigms for a changing epidemiology. Emerging Themes in Epidemiology. 2(1):1.
9. Guzman MG, Halstead SB, Artsob H, Buchy P, Farrar J, Gubler DJ (2010). Dengue: A continuing global threat. Nature Reviews. Microbiology. 8(12): S7-S16.
10. Hammond SN, Balmaseda A, Perez L, Tellez Y, Saborio SI, Mercado JC (2005). Differences in dengue severity in infants, children, and adults in a 3-year hospital-based study in Nicaragua. The American Journal of Tropical Medicine and Hygiene.73(6):1063-1070
11. Howe GM (1977). A world geography of human diseases. New York: Academic Press p. 302-17.
12. Khan NA, Azhar EI, El-Fiky S, Madani HH, Abuljadial MA, Ashshi AM, Abduhafiz M Turkistani, Esam A Hamouh (2008). Clinical profile and outcome of hospitalized patients during first outbreak of dengue in Makkah, Saudi Arabia. Acta Tropica. 105(1):39-44.
13. Kurane I, Ennis FA (1988). Production of interferon alpha by dengue virus infected human monocytes. The Journal of General Virology. 69(2):445- 449.
14. Lanciotti RS, Lewis JG, Gubler DJ, Trent DW (1994). Molecular evolution and epidemiology of dengue-3 viruses. The Journal of General Virology. 75(1):65-75.
15. Leitmeyer KC, Vaughn DW, Watts DM, Salas R, Villalobos I, de Chacon (1999). Dengue virus structural differences that correlate with pathogenesis. Journal of Virology. 73(6):4738-4747.
16. Messer WB, Gubler DJ, Harris E, Sivananthan K, de Silva AM (2003). Emergence and global spread of a dengue serotype 3, subtype III virus. Emerging Infectious Diseases. 9(7):800-809.
17. Ramalingam Kothai and Balasubramanian Arul (2020). Dengue Fever: An Overview. DOI: http://dx.doi.org/10.5772/intechopen.92315
18. Rodenhuis-Zybert IA, Wilschut J, Smit JM (2010). Dengue virus life cycle: Viral and host factors modulating infectivity. Cellular and Molecular Life Sciences. 67(16):2773-2786.
19. Rush B (1789). An account of the bilious remitting fever, as it appeared in Philadelphia in the summer and autumn in the year 1780. In: Rush B, editor. Medical inquiries and observations. Philadelphia: Pritchard & Hall. p. 89-100.
20. Scott RM, Nisalak A, Cheamudon U, Seridhoranakul S, Nimmannitya S (1980). Isolation of dengue viruses from peripheral blood leukocytes of patients with hemorrhagic fever. The Journal of Infectious Diseases.141(1):1-6.

21. Simmons CP, Farrar JJ, van Vinh CN, Wills B (2012). Dengue. The New England Journal of Medicine. 366(15):1423-1432.
22. Surasombatpattana P, Hamel R, Patramool S, Luplertlop N, Thomas F, Despres P (2011). Dengue virus replication in infected human keratinocytes leads to activation of antiviral innate immune responses. Infection. Genetics and Evolution.11(7):1664-1673.
23. Tan FL-S, Loh DLSK, Prabhakaran K, Tambyah PA, Yap H-K (2005). Dengue haemorrhagic fever after living donor renal transplantation. Nephrology, Dialysis, Transplantation. 20(2):447-448.
24. Teo D, Ng LC, Lam S (2009). Is dengue a threat to the blood supply? Transfusion Medicine 19(2):66-77.
25. Tomashek KM (2012). Dengue fever. In: CDC Health Information for International Travel: The Yellow Book. USA: Oxford University Press; 2011.
26. Vannice KS, Wilder-Smith A, Barrett ADT, Carrijo K, Cavaleri M, de Silva A, Anna P Durbin, Tim Endy, Eva Harris, Bruse L Innis, Leah C Katzelnick, Peter G Smith, Willington Sun, Stephen J Thompsan, Joachim Hombach (2018). Clinical development and regulatory points for consideration for second-generation live attenuated dengue vaccines. Vaccine. 36(24):3411-3417.
27. Vaughn DW, Green S, Kalayanarooj S, Innis BL, Nimmannitya S, Suntayakorn S (2000). Dengue viremia titer, antibody response pattern, and virus serotype correlate with disease severity. The Journal of Infectious Diseases.181(1):2-9.
28. WHO (2009). Epidemiology, burden of disease and transmission. In: Dengue: Guidelines for Diagnosis, Treatment, Prevention and Control. Geneva: World Health Organization. pp. 3-25
29. WHO (2019). Dengue vaccine: WHO position paper, September 2018-Recommendations. Vaccine. 37(35):4848-4849.
30. Wilder-Smith A, Chen LH, Massad E, Wilson ME (2009). Threat of dengue to blood safety in dengue endemic countries. Emerging Infectious Diseases. 15(1):8-11.
31. Wiwanitkit V (2009). Unusual mode of transmission of dengue. Journal of Infection in Developing Countries. 4(1):51-54.

Convolvulus pluricaulis: Traditional Use and Modern Scientific Insights

Kinjal P. Patel

Sweta Besh

Sivendra Verma

Rahul Trivedi

Department of Pharmacy, Sumandeep Vidyapeeth Deemed to be University, Piparia, Vadodara-391760, Gujarat.

Email: kinjalpatel54@gmail.com

Article DOI Link: https://zenodo.org/uploads/15577199

*DOI: **10.5281/zenodo.15577199***

Abstract

Convolvulus pluricaulis, commonly known as Shankhpushpi, is a well-recognized ayurvedic herb belonging to the family Convolvulaceae, traditionally used to manage neurological and psychological ailments. This comprehensive review explores its botanical characteristics, cultivation practices, therapeutic uses, and pharmacological properties. Cultivated in semi-arid regions with minimal agronomic input, *C. pluricaulis* thrives in sandy soils under full sunlight. The plant exhibits a wide range of bioactivities including neuro-protective, antioxidant, anti-inflammatory, anxiolytic, antidepressant, antiepileptic, hepatoprotective, antimicrobial, and cardiovascular effects. Bioactive compounds such as convolamine, β-sitosterol, valeric acid, squalene, and ascorbic acid contribute to its pharmacological potential. Empirical data from various preclinical and clinical studies support its traditional use, particularly in managing anxiety, depression, cognitive dysfunction, and oxidative stress. This review underscores the need for further mechanistic and clinical studies to fully elucidate its therapeutic efficacy and safety profile.

***Keywords**:* *Convolvulus pluricaulis*; Shankhpushpi, neuroprotective, antioxidant,Anxiolytic, cognitive enhancement; traditional herb; pharmacological activity

Introduction

Convolvulus pluricaulis this is the old herbal drug, and these are generally used for treatment of the mental health disorder. *Convolvulus pluricaulis*, a member of the Convolvulaceae family, is also referred to as Shankhpushpi in certain Indian languages. Shankhpushpi is a highly prized plant because of its potent therapeutic properties and distinctive scent. Fresh Shankhpushpi plants produce a pale-yellow oil through steam distillation and have a distinct smell. It is frequently referred to as morning glory.1It grows and is widely dispersed over northern India, including Punjab, Bihar, and Chhota Nagpur. The whole plant's methanolic extract lowers total serum cholesterol, phosphatide, and free fatty acids while also having an anxiolytic effect. Autumn herb blooms range in color from white to pale pink.

Shankhpushpi is regarded as a highly significant herb in Ayurveda. Learning, memory, and behaviour are improved. The roots of the Shankhpushpi plant are used to treat infantile fever, the leaves are traditionally used to treat asthma and chronic bronchitis, and the plant itself encourages hair development it aids in nourishing the skin while enhancing its appearance. The herb's antifungal, antibacterial, antidepressant, antiulcer, antistress, antipyretic, and anthelmintic properties have been discovered through research. As to how beneficial it is in reducing the symptoms of an overactive thyroid. Fever and also used as an alternative tonic for the brain that increases mental alertness, substitutes, and is commonly used to treat weakness, insomnia, weariness, low energy, and gastric mucosa ulcers. Studies on the pharmacological properties of the Shankhpushpi plant have shown that it has sedative and blood pressure-lowering properties. Studies in the clinical setting have shown beneficial outcomes for individuals with anxiety disorder. The plant Shankhpushpi is non-poisonous and does not cause any adverse effects. Conversely, it might cause one to feel more robust, healthy, and energized while simultaneously gaining weight. *Convolvulus pluricaulis choisy* is a common plant found throughout northern India that is employed as a medicinal agent in Ayurvedic medicine. *Convolvulus pluricaulis* is also known for its ameliorative effect on neurodegenerative diseases like Alzheimer's disease. *Convolvulus pluricaulis* entire extracts have also been demonstrated to be efficacious against a range of pathologic or sub-pathologic diseases, including ulcers, bacterial and viral infections, and liver toxicity, in both in vitro and animal models.1-3

The focus of *Convolvulus pluricaulis* research lately has been on its function in lipid control. Generally, in in vivo models of diabetes and hyperlipidemia. In fact, *Convolvulus pluricaulis* methanolic extract has been demonstrated to be beneficial in controlling a number of lipid characteristics. In an animal model of hyperlipidemia and to exhibit notable hypolipidemic effects in a rat model of streptozotocin-induced diabetes. *Convolvulus pluricaulis,* a member of the Convolvulaceae family.1,2This new perspective's significance is closely linked to the interactions between hyperlipidemia, diabetes, and cardiovascular diseases, which are now widely recognized, as is the significance of regulating glycemia and lipid parameters to lower cardiovascular morbidity and death. Preclinical research has previously demonstrated the efficacy of herbal remedies in this regard by using *Convolvulus pluricaulis* to treat high blood pressure. This impact can be attributed to the reduction of non-esterified fatty acid levels, which are an essential part of the pathophysiology of cardiovascular illnesses.4 Increased levels of plasma lipids trigger the body's natural process of activating the intracellular receptors that control lipid metabolism, storage, and even transport. Numerous research works have pointed out the function of the intracellular receptor known as PPARγ (Peroxisome Proliferator-Activated Receptor γ), which is a part of the nuclear receptor superfamily. Generally, this is recognized as a crucial modulator of adipocyte development and, as a result, of the balance between fat and glucose. Since PPARγ has been shown to inhibit macrophage activation and cytokine production, as well as to have a secondary positive effect on insulin signaling and, ultimately, metabolic control, its significance in adipose tissue as a fundamental regulator of both adipocyte and stromal macrophage function has become abundantly evident. 2,4

Furthermore, PPARγ is increasingly being referred to as an anti-inflammatory gene, which plays a crucial role in controlling inflammation in a variety of illnesses, including multiple sclerosis, ulcerative colitis, acute neurological conditions, such as stroke or spinal cord/brain injury, chronic conditions, such as Parkinson's disease and Alzheimer's disease, and, surprisingly, both diabetes and atherosclerosis.5 PPARγ can be activated by various natural or synthetic ligands, solely because of their role in fat/glucose metabolism; among these are anti-diabetic medications like thiazolidinediones. It is now known that some terpenoids, flavonoids, and alkaloids are among the naturally occurring PPARγ agonists. In fat tissue, the genes PPARγ activate and promote lipogenesis and lipid recovery. However, these plants have shown promise in the field of central nervous system research. cardiovascular action, antiulcer, and anticatatonic qualities; relaxing, neurodegenerative, analgesic, hypolipidemic, immunomodulatory, anxiolytic, antidepressant, antioxidant, and antidiabetic. In addition to hydroxyl cinnamic acid, studies on the phytochemistry of the entire plant have found the presence of glucose, sucrose, phenols, coumarins, flavonoids, and alkaloids.5,6

Taxonomy of *Concolculus pluricaulis*6

1	Kingdom	Planet
2	Sub-kingdom	Tracheobionta
3	Divisnion	Magnoliophyta
4	Class	Dicotyledonae
5	Sub-Class	Asteridae
6	Order	Solanaled
7	Family	Gentianaceae
8	Genus	Convolvulus
9	Speciecs	Pluricaulis

Figure No. 01 Taxonomy

Synonyms

The synonym of *Convolvulus pluricaulis* also has the following synonyms, and these are as follows, and generally these are also known as the different names known in the 5 different states.7,8

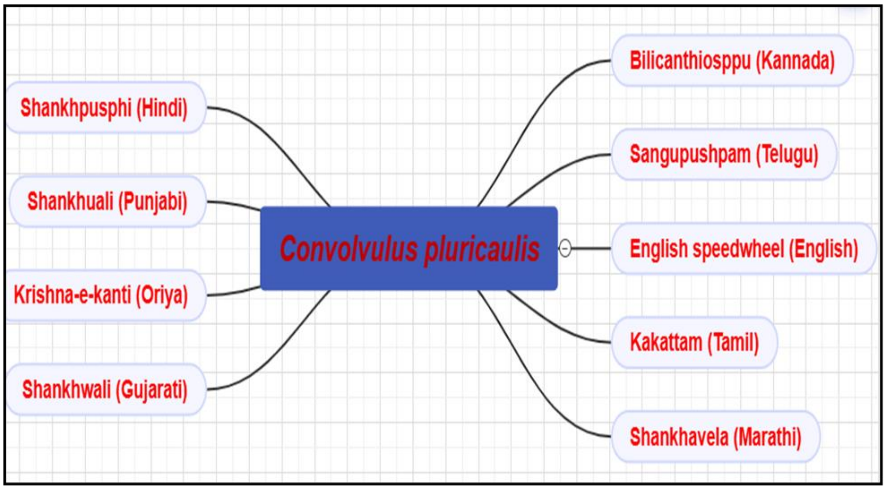

Figure No. 02 Synonym of Convolvulus pluricaulis

Botanical Description

The stem of Shankhpushpi is light green and cylindrical, with noticeable hairy internodes and nodes. Its thickness is 0.1 cm or less. A single-layered epidermis with thick cuticles, unicellular hairs, and a cortex is seen when the stem is examined under a microscope. The plant is divided into two zones: one or two lower parenchymatous layers and two to three higher collenchymatous layers. The leaves are long, round, or oval in shape, with convex and concave midribs. The vascular bundles are made up of four to five layers of parenchymatous cells and contain phloem and xylem components.9

A two-layered palisade, bicollateral vascular bundles, epidermis, and single-cell hairs are all found in the spongy parenchyma on each side of the lamina. With stomatal numbers of 185-247 and 202-238 per sq. mm, respectively, the bottom surface had a stomatal index of 16.9-19.8, while the top layer had a stomatal index of 13.8-17.0. The pale green foliage is It is sharp, petiolate, linear-lanceolate, and has hairy surfaces. They are between 0.2 and 0.5 cm wide and 0.5 and 0.5 cm long. Blooms on the leaf axil might be single or in pairs, white or pink, sessile or sub-sessile. The ovary is superior and bicarpellary. The fruits are rectangular and capsule-shaped, with a coriaceous, pale brown pericarp.9,10

The roots and seeds have a yellowish-brown color and are brown. The root typically contains irregular, rough stem nodules, small secondary roots, branching, cylindrical, and ribbed, in addition to the tiny puberulous seeds. It is 1 to 5 cm long, 0.1 to 0.4 cm thick, and has a yellowish-brown to light brown hue. The cork and major phloem are separated by 10 to 15 layers, giving the root a spherical appearance under a microscope. *Convolvulus pluricaulis* secondary roots are 0.1–0.4 cm thick, 1–5 cm long, and light brown to yellowish-brown in color. The root appears spherical under a microscope, with 10–15 layers separating the primary phloem from the cork.10,11

Figure No. 03 Diagrammatic representation of Convolvulus pluricaulis

Chemical Constituent

The plant has a variety of bioactive compounds that have therapeutic benefits, particularly in terms of improving mental health and brain function. Some of the primary chemical constituents of *Convolvulus pluricaulis* include the following.11

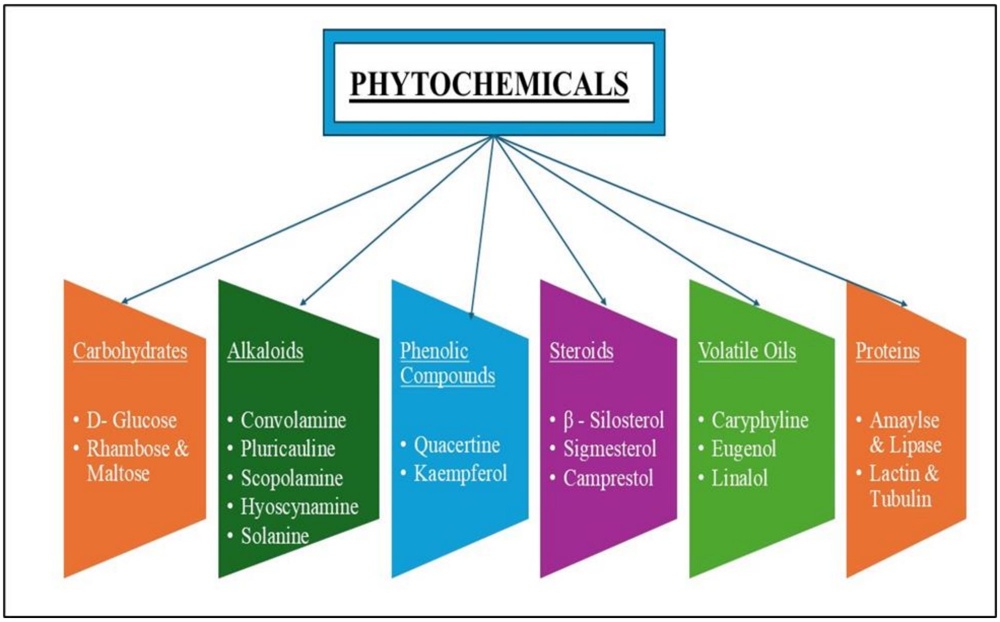

Figure No. 04 Chemical constituent of Convolvulus pluricaulis

These compounds are assumed to be responsible for the plant's putative memory and cognitive function-enhancing properties. Research is ongoing to completely understand the mechanisms and advantages of these substances.

Pharmacological activities of *Convolvulus Pluricaulis*

Neuroprotective Activity

Various studies, such as P. Rachitha, K. et al. in 2018, and SW Bihaqi, et al. in 2009, have also proved that cinnamic acid and convolamine are the active chemical constituents of the *Convolvulus pluricaulis*, and they produce neuroprotective effects at doses ranging from 500 mg/kg to 1000 mg/kg. *Convolvulus pluricaulis* is a versatile herb with numerous traditional therapeutic applications, such as stress reduction and cognitive wellbeing. It is a favorite among gardeners because of its beautiful flowers and ease of growth. This is used to treat a number of CNS conditions, much like any other herbal remedyincluding anxiety, psychosis, dementia, depression, Parkinson's disease, and others.12

Antioxidant Activity

S. Verma, et al. (2012) and P. Agarwal, B. et al. (2014). Their research indicates that at dosages between (500mg/kg) and (750 mg/kg), these substances demonstrate notable antioxidant benefits. As antioxidants, they aid in lowering oxidative stress, which is a major factor in the development of many illnesses and the aging process. These results highlight *Convolvulus pluricaulis's* potential as a treatment for oxidative reactive stress. Squalene and ascorbic acid, two important chemical components of *Convolvulus pluricaulis*, have been shown to have antioxidant qualities by a number of studies.6,13

Anti-inflammatory Activity

N. Jain, et al. (2021) and S.S. Yadav et al. (2022). According to their research, β-sitosterol has notable anti-inflammatory properties at dosages between (750 mg/kg) and (1000 mg/kg). By lowering the synthesis of pro-inflammatory cytokines and mediators like TNF-α and IL-6, *Convolvulus pluricaulis* seems to regulate inflammatory pathways. These results imply that the plant might be useful as a treatment for inflammatory diseases. According to several researches, β-sitosterol is the main active chemical ingredient in Convolvulus pluricaulis.14,15

Anti-anxiety Activity

K. Sharma, et al. (2009) and R. Sharma, R.K. Singla et al. (2022). In addition to convolamine, *Convolvulus pluricaulis* includes a wide range of other bioactive substances, including glycosides, alkaloids, and flavonoids. Together, these substances provide the plant its wide range of therapeutic benefits. Consequently, *Convolvulus pluricaulis* exhibits potential for the treatment of anxiety and numerous other illnesses. Many studies have shown that Convolamine, a major active constituent in *Convolvulus pluricaulis*, has strong antianxiety benefits, especially at doses ranging from 750 mg/kg to 1000 mg/kg.15,16

Antidepressant Activity

G.L. Gupta, et al. (2022) and P. Agarwal, et al (2014) have shown that the main active chemical constituents of *Convolvulus pluricaulis*, convolidine and convolamine, have strong antidepressant effects at dosages between 1000 mg/kg and 1500 mg/kg. It is thought that these substances work by preventing serotonin from being reabsorbed from the postsynaptic neuron, which raises serotonin levels in the brain. *Convolvulus pluricaulis* may have therapeutic promise as a treatment for depression and related mood disorders, according to this mechanism.17

Anti- epeileptic Activity

R.Sharmaet al. (2022) and P. Agarwal, et al. (2014) have shown that the main active chemical constituents of *Convolvulus pluricaulis*, convolidine and convolamine, have strong antidepressant effects at dosages between 1000 mg/kg and 1500 mg/kg. It is thought that these substances work by preventing serotonin from being reabsorbed from the postsynaptic neuron, which raises serotonin levels in the brain. *Convolvulus pluricaulis* may have therapeutic promise as a treatment for depression and related mood disorders, according to this mechanism.18

Hepatoprotective Activity

VD Ravichandra, et al. in 2013 and P. Agarwal, et al. in 2014 evaluated these substances have shown hepatoprotective effects, particularly when taken in dosages between 1500 and 2000 mg/kg. They have specifically been demonstrated to protect against hepatic cell damage, confirming the plant's traditional use to maintain liver function and treat liver-related conditions. Kaempferol and squalene are active chemical components of Convolvulus pluricaulis, a plant recognized for its therapeutic potential, according to data presented by a number of researchers.6,19

Antibacterial Activity

S. Vermaet al. (2011) and P. Rachitha, et al. (2019 evaluated the plant's antibacterial properties, which work well at dosages between 1000 and 1500 mg/kg. It is believed that the chemicals' capacity to target the development and integrity of bacterial cell walls a crucial element for bacterial survival is what causes the antibacterial actions.Therefore, since numerous microbes cannot survive without a completely intact cell wall, *Convolvulus pluricaulis* is especially helpful in treating bacterial infections.Numerous studies have demonstrated that *Convolvulus pluricaulis* also includes squalene and ascorbic acid, which are likewise in charge of the antibacterial activity.20

Anti-hypertensive Activity

G Sharma, et al. in 2021 and K Somarathinam, et al. in 2023 suggested doses between 750 mg/kg and 1000 mg/kg produce these effects. Because of its ability to reduce blood triglyceride levels, prevent blood clots in veins and arteries, and demonstrate antihypertensive qualities, linolenic acid in particular has been emphasized as a useful substance for controlling high blood pressure and enhancing cardiovascular health. Numerous research studies have demonstrated that linolenic acid and ascorbic acid are active chemical elements of *Convolvulus pluricaulis*, contributing to its antihypertensive benefits.21

Anti-diabetic Activity

According to P. Agarwal, et al. (2014) and E. Melloni, et al. (2023), *Convolvulus pluricaulis*'s primary chemical constituent, decanoic acid, is essential for its antidiabetic properties. According to the study, blood glucose levels are considerably lowered by extract dosages ranging from 1000 mg/kg to 1500 mg/kg, indicating that it may be a useful treatment for diabetes. Studies continuously show that decanoic acid has a major effect on controlling blood sugar levels, supporting its potential as a treatment for diabetes.21,22

Anti-demential Activity

Numerous researchers have shown that valeric acid is an active chemical component of *Convolvulus pluricaulis*, including B. Sharma, et al. in 2022 and D. Bhowmik, et al. in 2021. According to their research, when given at levels between 1000 and 1500 mg/kg, valeric acid demonstrates antidementia qualities. This collection of research demonstrates the important role that valeric acid plays in generating these positive effects and supports the potential of Convolvulus pluricaulis as a medicinal agent for the treatment of dementia.21,22

Anti-emetic Activity

A.K. Verma, et al. (2011) and P. Kaushik, et al. (2023) are two among the many researchers that have shown that phthalic acid and squalene are active chemical constituents of *Convolvulus pluricaulis*. Their study demonstrates that both substances, at effective dosages ranging from 1000 mg/kg to 1200 mg/kg, contribute to the plant's antiemetic properties. These results highlight *Convolvulus pluricaulis's* therapeutic potential in reducing nausea and vomiting, with squalene and phthalic acid playing important roles in this positive outcome. 22,23

Anti ulcerant Activity

Numerous investigations, such as those conducted in 2023 by P. Agarwal, et al., and in 2022 by D. Bhowmik,et al.in (2021) have verified that β-sitosterol is an active chemical component of *Convolvulus pluricalus*. According to their findings, β-sitosterol exhibits notable antiulcerant properties at dosages between 1000 and 1500 mg/kg. These results demonstrate *Convolvulus pluricaulis's* potential as a therapeutic agent for ulcer treatment, with β-sitosterol being a key component of its gastrointestinal system-protective actions.6,23

Anti-Parkinsonism Activity

Several researchers have shown that valeric acid and Convolvulus pluricaulis are active chemical ingredients that contribute to its antiparkinsonian properties. These researchers include P.K. Perera, et al. in 2021 and V. Ravindranath, et al. in 2006. According to their research, dosages between 750 mg/kg and 1000 mg/kg can effectively result in notable reductions in the symptoms of Parkinson's disease. These results highlight the neuroprotective qualities of valeric acid and *Convolvulus pluricaulis* and highlight their potential as therapeutic agents for the management of Parkinson's disease.24,25

Antihyperlipidemic Activity

Numerous studies have shown that ascorbic acid and linolenic acid are active chemical elements of *Convolvulus pluricaulis* that display antihyperlipidemic activity. These researchers include D. Iyer, et al. in 2023 and P. Agarwal, et al. in 2014. According to their research, the plant may be useful in treating hyperlipidemia because doses between 1000 and 1500 mg/kg successfully reduce lipid levels. These results demonstrate the medicinal advantages of *Convolvulus pluricaulis* in controlling lipid metabolism, with linolenic acid and ascorbic acid being key contributors to its cholesterol-lowering properties.5,6

Analgesic Activity

Numerous investigations have shown that convolamine, a chemical component of *Convolvulus pluricaulis*, has notable analgesic effects. These research studies include those conducted by B. Sharma, et al. in 2014 and R. Sinha, et al. in 2022. Their findings demonstrate the potential of *Convolvulus pluricaulis* as a natural analgesic drug by showing that doses between 600 mg/kg and 1200 mg/kg are effective in reducing pain. These results further confirm the plant's therapeutic usefulness by highlighting convolvamine's role in pain relief. 6,26

Sedative Activity

K. Sharma, et al. in 2009 and B. Sharma, et al. in 2014 explained doses ranging from 1000 mg/kg to 1500 mg/kg effectively create sedative effects, research suggests that the plant may be utilized as a natural cure for anxiety and sleep difficulties. These results demonstrate the important roles that convulvuline and valeric acid play in generating the relaxing effects linked to *Convolvulus pluricaulis*. Numerous researchers have shown that convulvuline and valeric acid are active components of *Convolvulus pluricaulis* that provide sedative effects.26

Discussion

The present review highlights the multidimensional therapeutic potential of *Convolvulus pluricaulis*, a cornerstone herb in traditional Indian medicine. The pharmacological attributes of this plant are largely attributed to its diverse phytochemical profile, comprising alkaloids, flavonoids, glycosides, and essential fatty acids. Its neuroprotective efficacy, observed in several animal studies, suggests significant promise in the management of central nervous system (CNS) disorders such as Alzheimer’s disease, Parkinsonism, anxiety, and epilepsy. Compounds like convolamine and convolidine exert beneficial effects through modulation of neurotransmitter levels, inhibition of oxidative stress pathways, and anti-inflammatory mechanisms. Antioxidant and anti-inflammatory actions were consistently reported at various dosages, supporting the herb’s potential in preventing oxidative cellular damage and chronic inflammatory conditions. The antiulcer, hepatoprotective, and antimicrobial activities suggest its broader systemic benefits beyond neurological functions. Its antihypertensive, antihyperlipidemic, and antidiabetic effects further indicate a role in metabolic syndrome management. Agronomically, *C. pluricaulis* requires minimal input, making it a sustainable crop for large-scale cultivation, particularly in resource-limited settings. Its drought-resistant nature and adaptability to sandy, alkaline soils provide additional advantages.Despite promising preclinical results, standardization of extracts, dose optimization, and controlled clinical studies remain key to validating its medicinal efficacy. Further exploration into its pharmacokinetics, safety profile, and long-term effects is warranted. Integrating modern analytical tools and molecular techniques will enhance the understanding of its mechanisms of action, paving the way for its inclusion in evidence-based phytotherapeutics.

References

1. Agarwa, P., Sharma, B., Fatima, A., & Jain, S. K. (2014). An update on Ayurvedic herb Convolvulus pluricaulis Choisy. Asian Pacific Journal of Tropical Biomedicine, 4(3), 245–252.
2. Mishra, S. H., & Sethiya, N. K. (2010). Review on ethnomedicinal uses and phytopharmacology of memory boosting herb Convolvulus pluricaulis Choisy. Australian Journal of Medical Herbalism, 22(1), 19–25
3. Bhowmik, D., Kumar, K. S., Paswan, S., Srivastava, S., & Dutta, A. (2012). Traditional Indian herbs Convolvulus pluricaulis and its medicinal importance. Journal of Pharmacognosy and Phytochemistry, 1(1), 44–51.
4. Rachitha, P., Krupashree, K., Jayashree, G. V., Kandikattu, H. K., Amruta, N., Gopalan, N., et al. (2018). Chemical composition, antioxidant potential, macromolecule damage and neuroprotective activity of Convolvulus pluricaulis. Journal of Traditional and Complementary Medicine, 8(4), 483–496.
5. Verma, S., Sinha, R., Kumar, P., Amin, F., Jain, J., & Tanwar, S. (2012). Study of Convolvulus pluricaulis for antioxidant and anticonvulsant activity. Central Nervous System Agents in Medicinal Chemistry, 12(1), 55–59.
6. Yadav, S., Hemke, A., & Umekar, M. (2018). Convolvulaceae, a morning glory plant review. International Journal of Pharmaceutical Sciences Review and Research, 51(1), 103–117.
7. Jaiswal, R. K., Dikshit, M., Tiwari, R. C., Singh, A. K., & Sharma, V. B. (2023). A conceptual study of Convolvulus pluricaulis Choisy. World Journal of Pharmacy and Pharmaceutical Sciences, 8(10), 1046–1058.
8. Aparna, K., Prasad, D. X., Prabosh, G., Surbhi, G., & Franco, S. (2023). A review study on medicinal significance Convolvulus pluricaulis. i-Manager's Journal on Chemical Sciences, 3(3).

9. Ganie, S. H., Ali, Z., Das, S., Srivastava, P. S., & Sharma, M. P. (2015). Genetic diversity and chemical profiling of different populations of Convolvulus pluricaulis (Convolvulaceae): an important herb of Ayurvedic medicine. Biotech, 5, 295–302.
10. Khan, S., Kala, C., Goyal, M., Yadav, S. K., & Taleuzzaman, M. (2023). Evaluation of CNS depressant and anti-anxiety activities of leaves of Convolvulus pluricaulis. Central Nervous System Agents in Medicinal Chemistry, 23(1), 48–56.
11. Bihaqi, S. W., Sharma, M., Singh, A. P., & Tiwari, M. (2009). Neuroprotective role of Convolvulus pluricaulis on aluminium-induced neurotoxicity in rat brain. Journal of Ethnopharmacology, 124(3), 409–415.
12. Iyer, D., Jain, N., & Patil, U. K. (2023). Antihyperlipidemic bioactivity guided isolation and structural elucidation of isolated phytoconstituents from Convolvulus pluricaulis Choisy. European Journal of Medicinal Plants, 34(11–12), 81–91.
13. Irshad, S., Ali, M. A., Makbul, S. A., & Shamsi, S. (2024). Effect of Convolvulus pluricaulis (Shankhpushpi) and Bacopa monnieri (Brahmi) on aging-related diseases and memory deficits. In Medicinal Plants for the Management of Neurodegenerative Diseases (pp. 85–98).
14. Sharma, K., Arora, V., Rana, A. C., & Bhatnagar, M. (2009). Anxiolytic effect of Convolvulus pluricaulis Choisy petals on elevated plus maze model of anxiety in mice. Journal of Herbal Medicine and Toxicology, 3(1), 41–46.
15. Sharma, R., Singla, R. K., Banerjee, S., Sinha, B., Shen, B., & Sharma, R. (2022). Role of Shankhpushpi (Convolvulus pluricaulis) in neurological disorders: An umbrella review covering evidence from ethnopharmacology to clinical studies. Neuroscience & Biobehavioral Reviews, 140, 104795.
16. Gupta, G. L., & Fernandes, J. (2019). Protective effect of Convolvulus pluricaulis against neuroinflammation-associated depressive behavior induced by chronic unpredictable mild stress in rat. Biomedicine & Pharmacotherapy, 109, 1698–1708.
17. Amin, H., Sharma, R., Vyas, M., Prajapati, P. K., & Dhiman, K. (2014). Shankhapushpi (Convolvulus pluricaulis): Validation of the Ayurvedic therapeutic claims through contemporary studies. International Journal of Green Pharmacy, 8(4).
18. Ravichandra, V. D., Ramesh, C., & Sridhar, K. A. (2013). Hepatoprotective potentials of aqueous extract of Convolvulus pluricaulis against thioacetamide-induced liver damage in rats. Biomedicine & Aging Pathology, 3(3), 131–135.
19. Mudgal, V. (1975). Studies on medicinal properties of Convolvulus pluricaulis and Boerhaavia diffusa. Planta Medica, 28(5), 62–68.

20. Somarathinam, K., Gunalan, S., Sailapathi, A., Pannerselvam, B., Mohanasundari, M., Balaraman, A. K., et al. (2023). Antihypertensive effects of pentacyclic triterpenoid from Convolvulus pluricaulis and its plausible mechanism of action hypothesizing its selectivity targeting mineralocorticoid receptor of RAAS. Phytomedicine Plus, 3(1), 100408.
21. Melloni, E., Grassilli, S., Romani, A., Rimondi, E., Marcuzzi, A., Zauli, E., et al. (2023). Convolvulus pluricaulis Choisy's extraction, chemical characterization and evaluation of the potential effects on glycaemic balance in a 3T3-L1 adipocyte cell model. Nutrients, 15(7), 1727.
22. Verma, A. K., & Dubey, G. P. (2011). Effect of Convolvulus pluricaulis and triflupromazine on rat brain and blood biogenic amines. Research Journal of Pharmacy and Technology, 4(4), 549–551.
23. Irshad, S., Ali, M. A., Makbul, S. A. A., & Shamsi, S. (2024). Effect of Convolvulus pluricaulis (Shankhpushpi) and Bacopa Monnieri (Brahmi) on aging-related diseases and memory deficits. Medicinal Plants for the Management of Neurodegenerative Diseases, 85-98.
24. Perera, P. K., Meedeniya, A. C., & Chamikara, N. H. (2021). Traditional medicinal plants of Sri Lanka and their derivatives of benefit to the nervous system. In Medicinal Herbs and Fungi: Neurotoxicity vs. Neuroprotection (pp. 315–346).
25. Sharma, M., Sahu, S., Khemani, N., & Kaur, R. (2013). Ayurvedic medicinal plants as psychotherapeutic agents: A review. International Journal of Applied Biology and Pharmaceutical Technology, 9(2), 214–218.
26. Singh, U. P., Singh, N. P., Murphy, E. A., Price, R. L., Fayad, R., Nagarkatti, M., & Nagarkatti, P. S. (2016). Chemokine and cytokine levels in inflammatory bowel disease patients. Cytokine, 77, 44–49.
27. Guimbaud, R., Bertrand, V., Chauvelot-Moachon, L., Quartier, G., Vidon, N., Giroud, J. P., et al. (1998). Network of inflammatory cytokines and correlation with disease activity in ulcerative colitis. American Journal of Gastroenterology, 93(12), 2397–2404.

Biotechnological Innovations in Animal Healthcare: Advances, Applications, and Future Prospects

[1]Anup Kumar Verma

[2]Dr. Reema Sonker

[1]Dr. Abhinav Singh

[1]Dept of Zoology, Acharya Narendra Dev Kisan P.G. College, Babhnan, Gonda, U.P.

[2]Dept of Zoology, K.S. Saket P.G. College, Ayodhya, UP.

Email: kavrnprjmt2130@gmail.com

Article DOI Link: https://zenodo.org/uploads/15577338

*DOI: **10.5281/zenodo.15577338***

Abstract

Biotechnology has allowed us to handle animal health with dependable, effective and lasting solutions to stop, diagnose and treat diseases. Progress in the field of genetic engineering, molecular diagnostics and creating vaccines is why veterinary research today is done using more advanced and targeted methods. The ways biotechnology supports animal health such as genetically improved vaccines, diagnostic devices such as PCR and ELISA, treatments with monoclonal antibodies and stem cell therapy and genomics for picking new breed lines are all considered in this study. The report covers ethics and future outlooks, mainly in relation to One Health and the spread of diseases from animals to humans.

Keywords: Animal biotechnology; Veterinary medicine; Molecular diagnostics; Recombinant vaccines; Monoclonal antibodies; Genetic engineering; Zoonotic diseases; One Health.

Introduction

Biotechnology is a wide phrase that refers to the use of living things or chemicals to make a product better or to change it in some way, as well as to improve animals or plants or to develop microorganisms for specific goals. Biotechnology is the study of how to change the genetic and reproductive systems of plants and animals. Biotechnology was initially used in 1917 to talk to procedures that employ live things to generate something or do something, such industrial fermentation. There are eight primary fields of biotechnology. 1) Genetic engineering and 2) Biotechnology for farming 3) Biotechnology in Industry 4) Biotechnology for the Environment 5) Molecular Biotechnology 6)

Bioinformatics, 7) Pharmacogenomics, and 8) Synthetic biotechnology (Mittal et al., 2013; Kharissova et al., 2013; Ghorbanpour et al., 2020).

In veterinary medicine, biotechnology is employed for purpose of diagnosing, treating and preventing animal diseases, increasing their productivity, making them reproduce more successfully and to guarantee that food made from animals is safe (Thacker, 2006). Relying on these applications, veterinary science is now based on solid evidence, accuracy and effectiveness. Biotechnology has greatly improved animal health with its ability to diagnose diseases. Thanks to PCR, ELISA and NGS, it is much simpler and speedier to diagnose infectious agents, allowing diseases to be controlled more efficiently. Because to these technologies, animals become healthier and zoonotic diseases which can be passed from animals to humans, do not develop. They are becoming a bigger issue in many different places. The process of making vaccines has been changed by biotechnology which affects our ways of preventing diseases. While the old serums did work, there was a good chance they would change or become dirty. The newest type of vaccines, recombinant, subunit and DNA, produce safer and more specific immune responses. They play a role in protecting animals such as when used to prevent rabies, foot-and-mouth disease and avian influenza (Meeusen et al., 2007). Treating diseases and creating animals that are resistant to them has been possible in recent years mostly thanks to monoclonal antibody therapy and CRISPR-Cas9 gene editing (Whitworth et al., 2016; Viola et al., 2016). Biotechnology is used in significant ways to grow animals and ensure that food is safe. Both marker-based (MAS) and genomic approaches assist breeders in identifying animals with desired traits, for example, disease resistance, efficient use of food and reproduction. Because of this, farmers can improve livestock quickly and sustain production for many years (Goddard and Hayes, 2009). Biotechnology has improved the genetic quality and the reproductive ability of animals by using artificial insemination, in vitro fertilization and embryo transfer. It also benefits the One Health initiative which looks at the health of people, animals and the environment. Using biotechnology is important for the health of countries, since it helps stop infectious diseases in animals and improves food safety by managing diseases and antimicrobial stewardship (World Health Organisation, 2017). To sum up, biotechnology is not merely a tool that helps; it is also a driving factor in modern animal health care. Its uses have broadened the field of veterinary research, leading to new ideas that are changing how illnesses are recognised, treated, and avoided in animals. This is good for both animals and people.

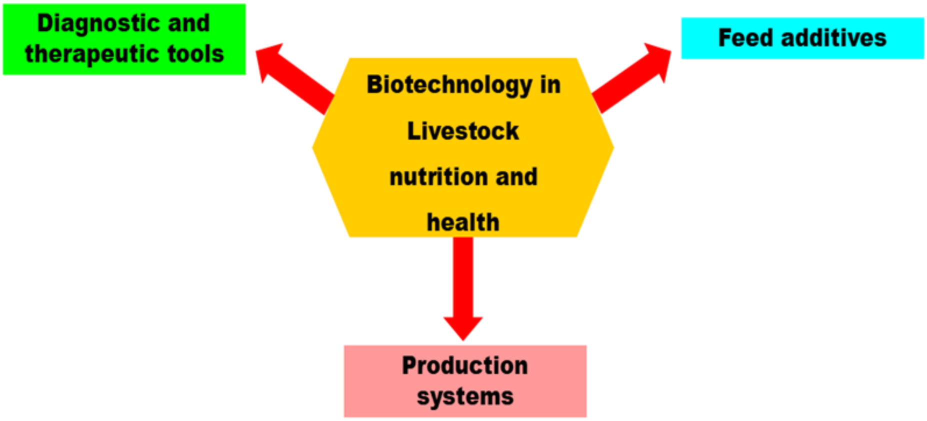

Figure 1: Major biotechnological domains in livestock improvement.

Biotechnological Tools in Animal Disease Diagnosis

Molecular Diagnostics

Molecular diagnostics are an important part of current veterinary biotechnology because they provide quick, sensitive, and precise ways to find diseases at the molecular level. These methods are especially helpful for finding and keeping an eye on infectious diseases early on, which lets doctors start treatment sooner and stop the spread of the disease.

Polymerase Chain Reaction (PCR) is one of the most used molecular diagnostic methods used in animal health care. It makes certain DNA sequences bigger, which lets us find very little amounts of pathogen DNA or RNA in clinical samples. A lot of people utilise this approach to find infections including foot-and-mouth disease (FMD), classical swine fever, and Mycobacterium bovis in bovine TB (OIE, 2021).

Real-time PCR (qPCR) takes this method to the next level by counting the amount of pathogen DNA in a sample. This makes it perfect for keeping an eye on viral load and figuring out how well a therapy is working. For example, qPCR is now the standard method for finding and counting equine herpesvirus and avian influenza virus in infected groups (Spackman et al., 2002).

LAMP, or Loop-Mediated Isothermal Amplification

LAMP is a technique for amplifying nucleic acids at a constant temperature that is becoming more popular in veterinary diagnostics since it is fast, sensitive, and can be used in the field. LAMP doesn't need heat cycling as PCR does, therefore it's good for places with less resources. It has worked well to find pathogens such Brucella spp., Trypanosoma evansi, and Theileria annulata (Notomi et al., 2000).

Microarrays and nucleic acid hybridization

With nucleic acid hybridization methods like DNA microarrays, you may find more than one pathogen at a time in one test. Microarray technology can find co-infections, find novel or emerging pathogens, and assist keep an eye on disease outbreaks in cattle and poultry (Thekisoe et al., 2005).

The Enzyme-Linked Immunosorbent Assay (ELISA)

ELISA is not a molecular technique in and of itself, but it is an important immunological diagnostic tool that is often employed with molecular diagnostics. ELISA is a test that looks for certain antigens or antibodies. It is often used to find illnesses including brucellosis, avian influenza, Newcastle disease, and bovine leukaemia virus (Nielsen and Yu, 2010). It is good for routine screening programmes since it is cheap, fast, and flexible.

Biosensors

Biosensors are analytical tools that turn a biological reaction into a quantitative signal. They provide quick, real-time diagnostics with little sample preparation. They use biological recognition components, like enzymes, antibodies, or nucleic acids, together with physical transducers, like optical, electrochemical, or piezoelectric ones.

Application in Animal Disease Detection

Biosensors are becoming more used in animal healthcare for on-site or point-of-care diagnostics. For instance, electrochemical biosensors have been made that can find Staphylococcus aureus, a significant cause of bovine mastitis, directly in milk samples (Velusamy et al., 2010). In the same way, optical biosensors that employ surface plasmon resonance (SPR) have been used to find Mycobacterium bovis, the bacteria that causes bovine TB, with a lot of accuracy (Tobiszewski and Namieśnik, 2012).

Advantages and Innovations

Recent advances in nanotechnology have made biosensors more sensitive and easier to carry. Nanoparticle-enhanced biosensors can find infections at very low levels, which is important for early identification of illnesses like avian influenza and swine fever (Wang et al., 2014).

Also, lab-on-a-chip (LOC) technologies are being added to biosensor platforms so that many tests may be done in the field. These small devices can analyse and process samples in less than an hour, making them good for usage in rural or distant veterinary clinics (Zhao et al., 2014).

Future Prospects

Combining biosensors with smartphones and wireless data transmission might make it possible to monitor diseases and respond to outbreaks in real time. In places where there aren't enough resources, these kinds of technologies are quite important (Nastasijevic et al., 2021).

Vaccines and Immunotherapy

Biotechnology has greatly improved both immunotherapy and vaccine development for pets and animals by providing new and powerful treatments. Because of recombinant DNA and molecular immunology, safer and more effective vaccines and biologics made for certain species are now possible. In general, this has meant people have more food, animals are better protected and there is better control over diseases.

Recombinant and DNA Vaccines

Recombinant vaccines are made by inserting the pathogen's antigen-producing gene into another virus, bacterium or yeast. It means fewer organisms are used and more of the antigen can be made to help the immune response. The use of recombinant technology is especially recognized for its rabies vaccine. An expression of the rabies glycoprotein gene happens through use of a canarypox viral vector. Compared to traditional rabies vaccines, this one is safer and gives stronger protection to pets and wild animals (Lodmell et al., 2001).

Another type of genetic engineering uses DNA vaccines which inject plasmid DNA containing antigenic protein directly into the host. It is the host cells that produce antigens which then trigger both humoral and cellular immune responses. They are easy to keep, safe and may protect people for a long time. A good example of an aquaculture vaccine is the DNA vaccine that protects salmonids against the infectious hematopoietic necrosis virus (IHNV). With few adverse effects on the environment, the IHNV vaccine which was developed and approved in places like Canada, has decreased outbreaks of the disease in fish farms (Corbeil et al., 1999). Because they have worked well in water species, DNA vaccines are being tested on land animals for diseases like avian influenza and bovine respiratory disease. Besides, recombinant and DNA vaccines are made with DIVA technologies, helping to detect infected animals and leading to the elimination of classical swine fever and foot-and-mouth disease (Cassidy, 2006).

Monoclonal Antibodies and Therapeutic Proteins

In addition, biotechnology is allowing the creation of monoclonal antibodies (mAbs) and therapeutic proteins that can be used in veterinary medicine. Certain mAbs which are special antibodies, stick to particular antigens. THERE is an increasing use of EOs for treating a variety of inflammation, allergy and infection problems in farm animals and dogs. Veterinary medicine uses monoclonal antibodies mainly for treating atopic dermatitis in dogs. The main reason for the itching is interleukin-31 (IL-31) and lokivetmab is able to reduce symptoms by targeting this factor. It is safe and good at decreasing inflammation and itching and it has been authorized for animal use (Banovic et al., 2018). While monoclonal antibodies are not meant for emergency situations, they are safer to take over time than corticosteroids or immunosuppressants. Studies are taking place to see if using mAbs instead of antibiotics can effectively treat and prevent infections in animals. When monoclonal antibodies work against Escherichia coli K88 fimbriae in newborn pigs, it helps stop diarrheal diseases, Sharma et al. (2020) say. It is common to give recombinant treatments such as bovine granulocyte colony-stimulating factor (bG-CSF) to cows to help their immune systems and cut down on infections that occur during giving birth (Shoshani et al., 2014). There is an expectation that the future years will see a rise in biosimilar veterinary biologics, based on human medicines. Animals with complicated illnesses will now be cared for more effectively by veterinarians. The next-generation proteins that are developed with the help of phage display technology, hybridoma technology and CRISPR-based editing are also expected to be choosier about what they work on, thus less likely to set off an immune response.

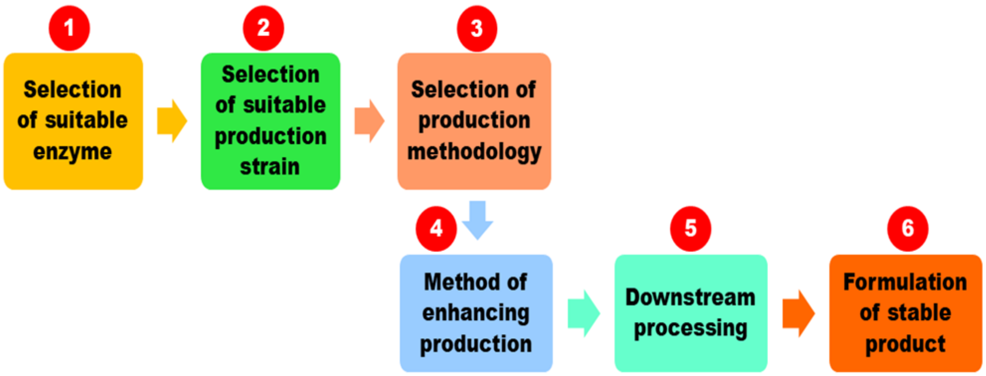

Figure 2: Steps involved in microbially derived commercial enzyme production.

Genomics and genetic engineering

Animals That Have Been Genetically Modified

Genetic manipulation makes it possible to make livestock that are resistant to disease. For example, pigs that are resistant to porcine reproductive and respiratory disease (Whitworth et al., 2016) and cows that are resistant to bovine tuberculosis (Viola et al., 2016).

Selection Using Markers

Genomic techniques like SNP chips make it possible to choose qualities like disease resistance, productivity, and reproductive efficiency with the help of markers. This method helps animal breeding plans that are better for the environment (Goddard and Hayes, 2009).

Regenerative Medicine and Stem Cell Therapy

Veterinary medicine now uses mesenchymal stem cells (MSCs) due to biotechnology, particularly for helping horses and dogs with bone and joint issues. Guest et al. (2008) claim that such interventions can encourage growth in tissues, despite limiting how the immune system reacts.

Biotechnology in Zoonotic Disease Control

Work in biotechnology is helping to deal with zoonotic diseases by rapidly finding new pathogens, producing vaccines and establishing policies for bio-monitoring. As explained by One Health, the way to preserve human, animal and environmental health is through unified efforts (World Health Organization, 2017).

Ethical and Regulatory Considerations

Changing animals' genes using biotechnology raises debate about animal care, safety of the food and ethics. It is important that people are confident in the system and that animals remain safe and this can be achieved by clearly outlining such challenges (Rollin, 2006).

Conclusion

Biotechnology plays a key role in modern animal health care. It has altered the ways diseases are identified, cured and prevented in numerous animals. The use of biotechnology has made a big difference in improving how well animals do. So, using techniques like PCR, biosensors and other molecular diagnostics help us identify diseases fast and accurately. Vaccines made using new approaches like those based on recombination or DNA, as well as monoclonal antibodies, have made a difference. With the aid of these technologies, animals are more productive and healthier and public health initiatives are supported by stopping the spread of illnesses from animals to people. The use of biotechnology in vet clinics cuts down on the use of antibiotics because more specific treatments can be applied. The field will develop further if research is continually financed, ethical rules are obeyed and if there is good communication among veterinarians, scientists, leaders and members of the business. Following these guiding topics can improve the well-being of animals and people according to the One Health program.

References

1. Banovic, F., Jerry, C., & Howerth, E. (2018). Tacrolimus therapy for dermal arteritis of the nasal philtrum refractory to surgery and anti-inflammatory therapy (doxycycline/niacinamide and topical fluocinolone) in a dog. Veterinary Dermatology, 29(1), 85-e35.
2. Cassidy, J. P. (2006). The pathogenesis and pathology of bovine tuberculosis with insights from studies of tuberculosis in humans and laboratory animal models. Veterinary microbiology, 112(2-4), 151-161.
3. Corbeil, S., LaPatra, S. E., Anderson, E. D., Jones, J., Vincent, B., Hsu, Y. L., & Kurath, G. (1999). Evaluation of the protective immunogenicity of the N, P, M, NV and G proteins of infectious hematopoietic necrosis virus in rainbow trout Oncorhynchus mykiss using DNA vaccines. Diseases of Aquatic Organisms, 39(1), 29-36.
4. Cosgrove, S., & Curtis, B. (2017). Understanding global poverty. Taylor & Francis.
5. Ghorbanpour, M., Bhargava, P., Varma, A., & Choudhary, D. K. (Eds.). (2020). Biogenic nano-particles and their use in agro-ecosystems (pp. 1-606). Singapore: Springer.
6. Goddard, M. E., & Hayes, B. J. (2009). Mapping genes for complex traits in domestic animals and their use in breeding programmes. Nature Reviews Genetics, 10(6), 381-391.
7. Guest, D. J., Smith, M. R. W., & Allen, W. R. (2010). Equine embryonic stem-like cells and mesenchymal stromal cells have different survival rates and migration patterns following their injection into damaged superficial digital flexor tendon. Equine veterinary journal, 42(7), 636-642.
8. Kharissova, O. V., Dias, H. R., Kharisov, B. I., Pérez, B. O., & Pérez, V. M. J. (2013). The greener synthesis of nanoparticles. Trends in biotechnology, 31(4), 240-248.
9. Lodmell, D. L., & Ewalt, L. C. (2001). Post-exposure DNA vaccination protects mice against rabies virus. Vaccine, 19(17-19), 2468-2473.
10. Meeusen, E. N., Walker, J., Peters, A., Pastoret, P. P., & Jungersen, G. (2007). Current status of veterinary vaccines. Clinical microbiology reviews, 20(3), 489-510.
11. Mittal, A. K., Chisti, Y., & Banerjee, U. C. (2013). Synthesis of metallic nanoparticles using plant extracts. Biotechnology advances, 31(2), 346-356.
12. Nastasijevic, I., Mitrovic, R., & Jankovic, S. (2021). Biosensors for animal health and meat safety monitoring: Farm-to-slaughterhouse continuum. In IOP Conference Series: Earth and Environmental Science (Vol. 854, No. 1, p. 012063). IOP Publishing.

13. Nielsen, K., & Yu, W. L. (2010). Serological diagnosis of brucellosis. Prilozi, 31(1), 65-89.
14. Notomi, T., Okayama, H., Masubuchi, H., Yonekawa, T., Watanabe, K., Amino, N., & Hase, T. (2000). Loop-mediated isothermal amplification of DNA. Nucleic acids research, 28(12), e63-e63.
15. OIE (World Organisation for Animal Health). (2021). Manual of diagnostic tests and vaccines for terrestrial animals. https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-manual-online-access/
16. Rollin, B. E. (2006). Science and ethics. Cambridge University Press.
17. Sharma, D. K., Paul, S., & Gururaj, K. (2020). Gastrointestinal helminthic challenges in sheep and goats in afro-asian region: a review. Journal of Animal Research, 10(1), 1-18.
18. Shoshani, E., Rozen, S., & Doekes, J. J. (2014). Effect of a short dry period on milk yield and content, colostrum quality, fertility, and metabolic status of Holstein cows. Journal of dairy science, 97(5), 2909-2922.
19. Spackman, E., Senne, D. A., Myers, T. J., Bulaga, L. L., Garber, L. P., Perdue, M. L., & Suarez, D. L. (2002). Development of a real-time reverse transcriptase PCR assay for type A influenza virus and the avian H5 and H7 hemagglutinin subtypes. Journal of clinical microbiology, 40(9), 3256-3260.
20. Tobiszewski, M., & Namieśnik, J. (2012). Direct chromatographic methods in the context of green analytical chemistry. TrAC Trends in Analytical Chemistry, 35, 67-73.
21. Tóro, R. M., Gessner, A. A., Furtado, N. A., Ceccarelli, P. S., de Albuquerque, S., & Bastos, J. K. (2003). Activity of the Pinus elliottii resin compounds against Lernaea cyprinacea in vitro. Veterinary parasitology, 118(1-2), 143-149.
22. Velusamy, V., Arshak, K., Korostynska, O., Oliwa, K., & Adley, C. (2010). An overview of foodborne pathogen detection: In the perspective of biosensors. Biotechnology advances, 28(2), 232-254.
23. Viola, G., Scheiber, T., Fredin, O., Zwingmann, H., Margreth, A., & Knies, J. (2016). Deconvoluting complex structural histories archived in brittle fault zones. Nature Communications, 7(1), 13448.
24. Wang, Y., Ye, Z., Ping, J., Jing, S., & Ying, Y. (2014). Development of an aptamer-based impedimetric bioassay using microfluidic system and magnetic separation for protein detection. Biosensors and Bioelectronics, 59, 106-111.
25. Whitworth, K. M., Rowland, R. R., Ewen, C. L., Trible, B. R., Kerrigan, M. A., Cino-Ozuna, A. G., & Prather, R. S. (2016). Gene-edited pigs are protected from porcine reproductive and respiratory syndrome virus. Nature biotechnology, 34(1), 20-22.

26. World Health Organization. (2017). One Health. https://www.who.int/news-room/questions-and-answers/item/one-health
27. Zhao, X., Lin, C. W., Wang, J., & Oh, D. H. (2014). Advances in rapid detection methods for foodborne pathogens. Journal of microbiology and biotechnology, 24(3), 297-312.

ABOUT THE EDITORS

Mrs. Varsha Suprit Yadav

Varsha Suprit Yadav is a dedicated researcher and academician pursuing her Ph.D. in Botany. With a strong academic foundation, she has established herself as a promising scholar in the field of plant sciences. She has completed M.Sc in Botany (2014) Gained a degree of B.Ed. (2015) and is pursuing a PhD in Botany. Also she has Qualified State Eligibility Test (SET) in Life Science (2024). Varsha's research interests lie in the field of botany, with a focus on (Plant Physiology and Plant Biotechnology). Her passion for understanding plant biology and its applications drives her research endeavors. As a budding researcher, Varsha aims to contribute significantly to the field of botany, advancing our understanding of plant sciences and its applications. Her academic excellence, coupled with her research potential, makes her a promising figure in the scientific community.

Mr. Vivek Shrikant Netam

Mr. Vivek Shrikant Netam is a dynamic academician and researcher with over six years of teaching experience and five years of research expertise in the fields of biopesticides, entomology, and sericulture. He holds a Master's degree in Animal Physiology and has qualified the State Eligibility Test (SET) in Life Sciences. He is currently pursuing a Ph.D., further deepening his contribution to the scientific community. Actively participated in academic projects, having completed two minor research projects as a Co-Investigator. He has authored six research papers published in reputed Scopus-indexed and UGC CARE-listed journals, reflecting his commitment to high-quality scientific communication. His innovative work is further demonstrated through three patents in his name. As a recognized academician, he has been invited as a chief guest and resource person for several academic and student-centered programs, including career guidance lectures. His dedication to teaching, research, and student development positions him as an asset in the academic publishing sphere. With a passion for scientific advancement and education, Mr Netam now contributes his editorial acumen and subject matter expertise as a book editor, ensuring the dissemination of quality scholarly content in the field of life sciences.

Mrs. Snehal Nandakumar Shingate

Mrs. Snehal Nandakumar Shingate is currently pursuing a Ph.D. in Life Sciences, building upon her strong academic foundation. She has completed her Master of Science (M.Sc.) in Cell and Molecular Biology, demonstrating a deep understanding of the intricate mechanisms of life at the cellular and molecular levels. Further highlighting her academic excellence, she has qualified the State Eligibility Test (SET) in Life Sciences. Her dedication to research and education reflects her commitment to contributing meaningfully to the scientific community. With a strong foundation in scientific principles and a keen interest in advancing biological research, Mrs. Shingate is committed to making valuable contributions to the scientific and academic community. Her dedication to continuous learning, research, and knowledge dissemination highlights her role not just as a student, but as a future leader in the field of life sciences.

Nature- 45

Nature Light Publications

309 West 11, Manjari VSI Road, Manjari Bk.,
Haveli, Pune- 412 307.
Website: www.naturelightpublications.com
Email: naturelightpublications@gmail.com
Contact No: +919822489040 / 9922489040

ISBN: 978-93-49938-62-5

Price- 720/-