



The future of plant tissue culture biotechnology in dermocosmetics

Innovations in sustainable skincare

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Scientific Foundations and Current Applications

We are pleased to bring insights into one of the most exciting intersections of biotechnology and dermatological science that emerged in the form of plant tissue culture applications in cosmetics and healthcare products. As the global demand for sustainable, safe, and efficacious skincare solutions continues to grow, plant-based biotechnologies are shaping the next generation of cosmetic innovation. Among these, plant tissue culture stands out as a transformative platform offering precision, purity, and performance. The future of plant tissue culture biotechnology in cosmetics and healthcare products is promising, blending advancements in biotechnology with rising consumer demand for natural, sustainable, and highly effective skincare solutions (1–3). This biotechnological approach involves cultivating plant cells, tissues, or organs under sterile, controlled conditions to produce valuable secondary metabolites such as flavonoids and polyphenols. This advanced technique has become increasingly integral to modern skincare and cosmetic formulations, offering a reliable and sustainable source of high-quality plant-derived ingredients without depleting natural plant populations (4,5). Current applications are both diverse and sophisticated. Anti-aging products increasingly

feature stem cells derived from edelweiss and rare apple varieties, known for their regenerative properties. Skin-brightening formulations often include extracts from licorice root, bearberry, and *Coffea canephora*, targeting hyperpigmentation and uneven tone. Plant tissue culture also enables the production of soothing and anti-inflammatory agents from botanicals such as chamomile and *Centella asiatica*. Additionally, antioxidant-rich serums benefit from bioactives cultured from *Ginkgo biloba*, green tea, coffee, and other plants known for their protective effects against oxidative stress. (1,6–8). By ensuring consistent quality, reducing environmental impact, and enhancing safety, plant tissue culture biotechnology aligns seamlessly with the expectations of today’s health-conscious and eco-aware consumers. It represents not just a scientific advance, but a strategic response to the evolving priorities of the cosmetic and healthcare industries (9).

Key innovations and future prospects

Looking to the future, a series of groundbreaking innovations is poised to redefine the role of plant tissue culture in skincare and cosmetic science (10). Among the most promising developments is the advancement of next-generation plant stem cells. Thanks to breakthroughs in molecular biology and metabolic engineering, researchers can now cultivate optimized plant cell cultures capable of producing rare and highly potent bioactive compounds with increased precision and yield (11).

At the same time, the integration of 3D bioprinting and *in vitro* skin models in product development and testing. These technologies enable the incorporation of plant-derived actives into bioprinted skin platforms, offering ethical, reproducible, and scientifically robust alternatives to traditional animal testing. This shift not only addresses regulatory and ethical concerns but also improves the accuracy of efficacy and safety assessments (12). Another transformative trend is the rise of precision cosmetics, driven by the convergence of artificial intelligence and plant-based biotechnology. Personalized skincare is becoming increasingly viable, as AI tools analyze individual skin profiles to tailor formulations with specific cultured plant actives, maximizing therapeutic benefits and consumer satisfaction. Sustainable biomanufacturing is also gaining significant traction. Plant tissue culture presents an efficient, scalable alternative to conventional harvesting, reducing reliance on natural ecosystems and promoting environmentally responsible production. This aligns closely with circular economy principles, supporting clean, low-impact, and regenerative practices across the cosmetic value chain (9). Finally, the incorporation of advanced delivery systems, particularly those based on nanotechnology, is elevating the performance of plant-derived formulations. These encapsulation technologies enable controlled release, enhanced skin penetration, and greater stability of bioactive compounds, ultimately improving both



Illuminated Cultivation: Phototrophic Bioreactors in Cosmetic Production.

A fascinating technological curiosity in the field of plant biotechnology applied to cosmetics is the use of phototrophic bioreactors for cultivating plant cells. Unlike traditional bioreactors, these systems are designed with transparent panels or tubes that allow controlled illumination for microorganisms or plant cells that perform photosynthesis. This enables the efficient cultivation of specific plant cultures to produce high-value bioactive compounds such as polyphenols, flavonoids, and carotenoids, without relying on large areas of conventional cultivation.

efficacy and user experience (1,7). Together, these innovations point to a dynamic future where plant tissue culture not only meets but anticipates the evolving needs of the cosmetic industry and its increasingly conscious consumers.

Market and industry outlook

The global market for plant stem cell skincare products is experiencing robust and sustained growth. Industry projections estimate a compound annual growth rate (CAGR) ranging between 8.2% and 11.3%, with market value expected to rise from approximately USD 401.02 million in 2024 to USD 635.54 million by 2030 (13) (Figure 1).

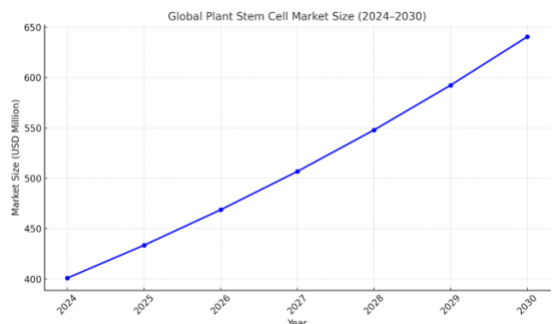


Figure 1. Projected global market size of stem cell skincare products, 2024–2030.

This upward trajectory is fueled by a convergence of market trends and consumer preferences. Foremost among these is the growing demand for clean beauty and plant-based formulations, products that highlight transparency, purity, and minimal environmental impact. Consumers are increasingly seeking skincare solutions that align with personal health values and ecological responsibility (1,9).

In parallel, awareness of sustainable sourcing and ethical production practices continues to expand, reinforcing market momentum. Regulatory bodies and consumers alike are pushing for more accountable, traceable, and environmentally sound alternatives to conventional cosmetic ingredients (9).

Importantly, the market is attracting significant attention from both global cosmeceutical corporations and agile biotech startups. This dual interest underscores a shared recognition of the potential for plant tissue culture to revolutionize skincare, from ensuring consistent ingredient quality to meeting sustainability goals at scale. Together, these forces suggest a strong and resilient outlook for the sector in the coming decade (1,9,13).

Research & regulatory developments

As innovation in plant tissue culture continues to advance, it is imperative that the industry upholds ethical, safe, and sustainable practices. To ensure long-term credibility and responsible growth, three key priorities must guide future developments. First, investment in rigorous clinical research is essential to scientifically validate the safety, efficacy, and therapeutic potential of plant tissue culture-derived extracts. High-quality studies, published in peer-reviewed journals, are critical for building a robust and trustworthy body of evidence that supports product claims and guides informed decision-making by regulators, clinicians, and consumers.

Second, transparency in product labeling must be strengthened. Clear and accurate labeling that distinguishes cultured plant extracts from traditionally sourced materials helps consumers understand the origin, composition, and production methods behind what they’re using. This fosters trust and supports informed choices, while also enabling more consistent regulatory oversight. Third, the development and adoption of comprehensive bioethical guidelines are vital. These guidelines should govern the responsible use of plant resources, particularly when working with rare, endangered, or culturally significant species. Adherence to international standards should emphasize sustainability, fairness, and the respectful integration of biodiversity and indigenous knowledge systems.

Collectively, these efforts will not only support scientific progress but also ensure that innovation

Conclusions

The integration of plant tissue culture biotechnology into cosmetics and healthcare products marks a pivotal advancement at the crossroads of science, sustainability, and consumer care. This innovative platform enables the development of next-generation skincare solutions that are both highly effective and environmentally responsible. By employing controlled cultivation methods, plant tissue culture significantly reduces dependence on wild harvesting, contributing to the preservation of biodiversity and the protection of fragile ecosystems. At the same time, it ensures consistent quality, traceability, and product safety, key factors in meeting regulatory standards and consumer expectations. When guided by rigorous scientific validation and grounded in ethical, sustainable practices, plant tissue culture emerges as a powerful driver of innovation. It not only aligns with the values of modern consumers but also offers a scalable path toward a more resilient and responsible future for the cosmetic and healthcare industries.

References

1. Gardiki V, Pavlou P, Siamidi A, Papageorgiou S, Papadopoulos A, Iakovou K, et al. Plant stem cells in cosmetics. *Plants*. 2025;14(3):433.

2. Zuzarte M, Salgueiro L, Canhoto J. Plant tissue culture: industrial relevance. *Adv Biochem Eng Biotechnol*. 2024;1–15.

3. Abdulhafiz F, Mohammed A, Reduan MFH, Kari ZA, Wei LS, Goh KW. Plant cell culture tech for metabolites. *Arab J Chem*. 2022;15(11):104161.

4. Bapat VA, Kavi Kishor PB, Jalaja N, Jain SM, Penna S. Plant cell cultures as biofactories. *Agronomy*. 2023;13(3):858.

5. Eibl R. Plant cell culture in cosmetics and food. 2018;8661–75.

6. Gabrieli MP, Guidoni M, Aragão VPM, Fronza M. *Coffea canephora* stem

cells in melasma. Arch Dermatol Res. 2024;316(5):158.

7. Krasteva G, Georgiev V, Pavlov A. Plant culture in cosmetics and foods. Eng Life Sci. 2021;21(3–4):68–76.

8. Guidoni M, Sousa Júnior AD, Aragão VPM, Toledo E Silva MV, Barth T, Clarindo WR, et al. *Coffea canephora* stem cells: antioxidant and regenerative effects. Braz J Med Biol Res. 2023;56.

9. Bhoir T, Jadhav S, Khatri N. Biotech beauty in cosmetics. Int J Adv Pharm Med Bioallied Sci. 2022;10(2).

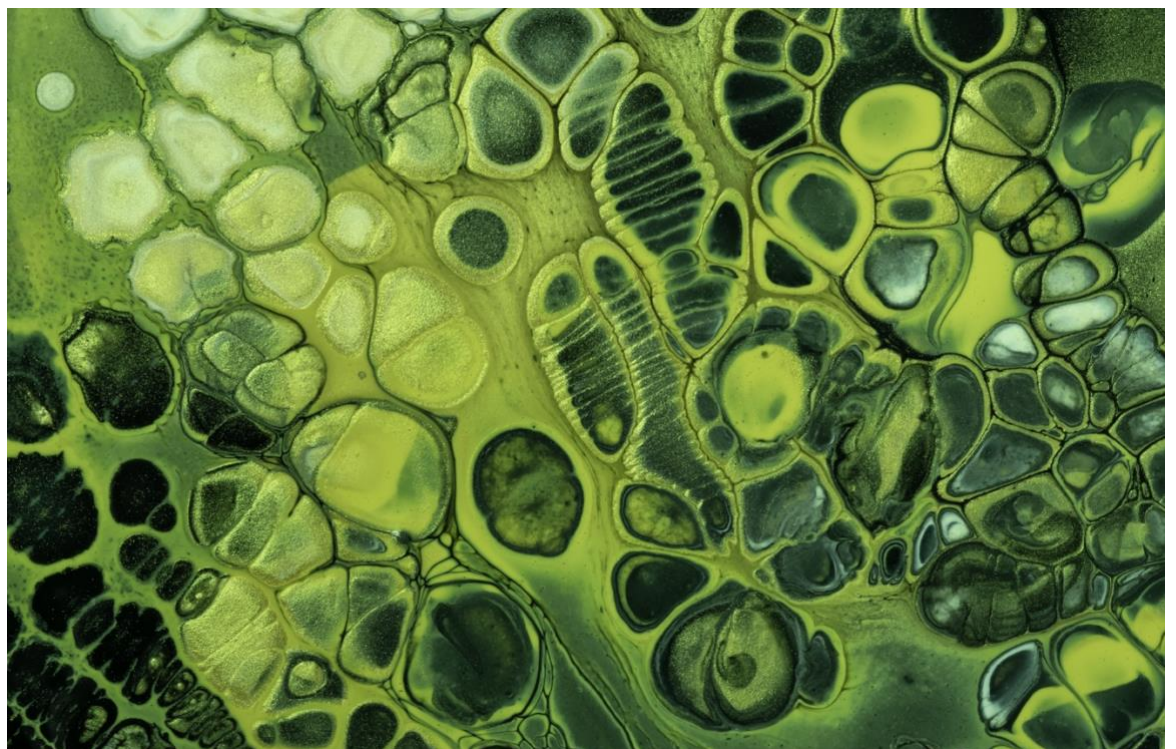
10. Guidoni M, Sousa Júnior AD, Aragão VPM, Pereira TMC, Santos WC, Monteiro FC, et al. Liposomal *Coffea canephora* for tissue repair. Arch Dermatol Res. 2022;315(3):491–503.

11. Hermosaninytyas AA, Chanaj-Kaczmarek J, Kikowska M, Gornowicz-Porowska J, Budzianowska A, Pawlaczyk M. Plant stem cells for skin disorders. Appl Sci. 2024;14(16):7402.

12. Di Stefano AB, Urrata V, Schilders K, Franza M, Di Leo S, Moschella F, et al. 3D bioprinting in skin regeneration. Life. 2025;15(5):787.

13. To UP, Call FW. Plant stem cell market: forecast 2020–2030. 2025;1–8.

14. Al-Sowayan BS, Al-Shareeda AT. Stem cells and youth: promise or fraud. World J Biol Chem. 2021;12(4):52–6.



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