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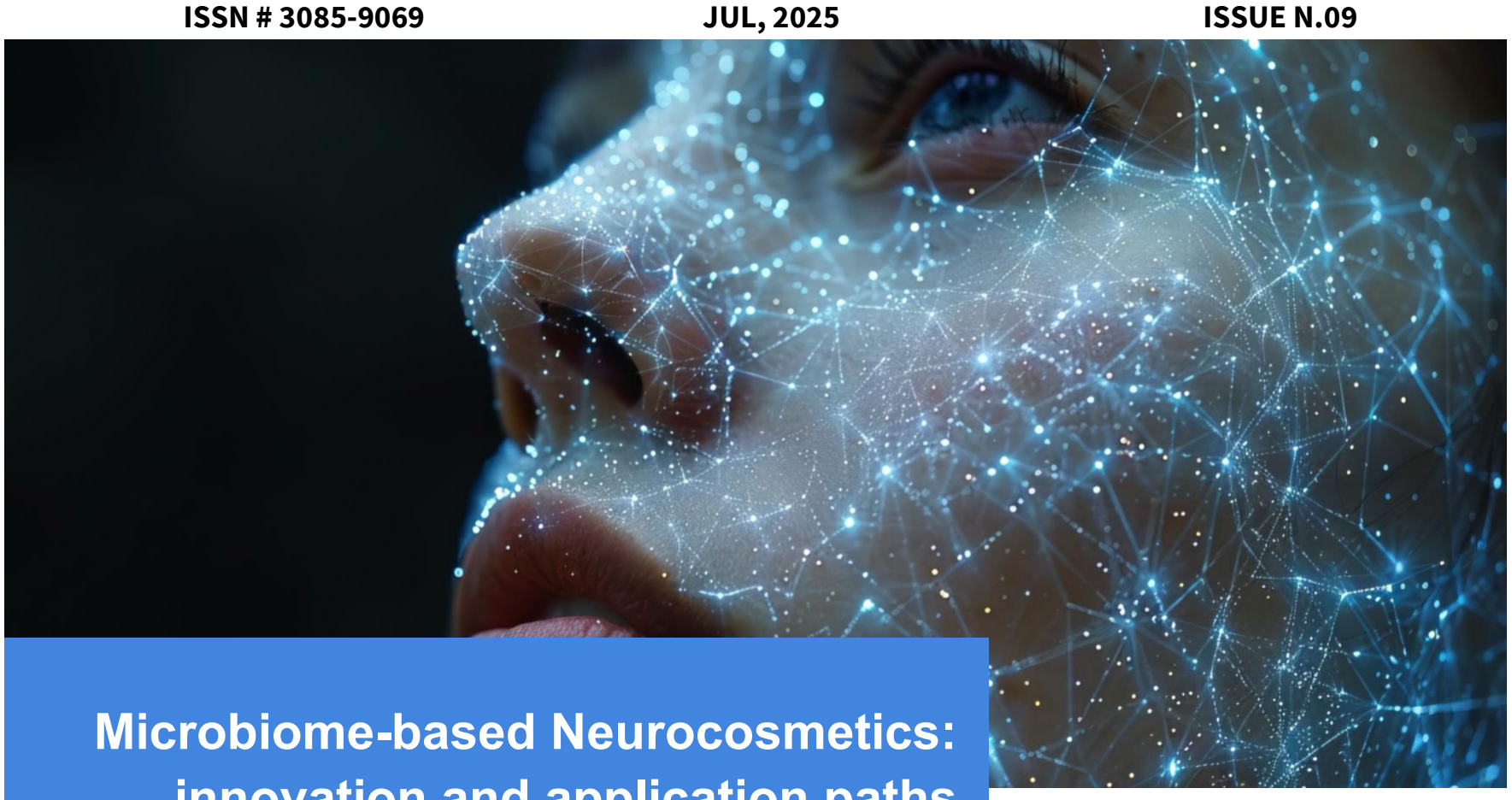

Microbiome-based Neurocosmetics: innovation and application paths

Editor-in-Chief: Dr. Deivis O. Guimarães
Gon1 Biotech frontiersofbioscience@gon1.com.br
Av .N.S Navegantes, 955/719 Vitoria/ES

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Dr. Deivis O. Guimarães

The skin is a highly complex sensory organ that interacts with the nervous system, the immune system, and the resident microbiome. In this context, neurocosmetics emerge as a new generation of formulations that act on cutaneous receptors, promoting both aesthetic and sensory effects. With the advancement of biotechnology, live microbial strains have been successfully studied and applied in dermocosmetics, showing properties such as inflammation modulation, hydration enhancement, and reinforcement of the skin barrier. This article reviews the main scientific advances in the use of live probiotics in neurocosmetics, explores stabilization and delivery technologies, discusses current regulatory challenges, and proposes future perspectives such as microbiome-based personalization and 3D printed skin bioengineering. The convergence of neuroscience, microbiology, and nanotechnology points to a new era of effective, personalized, and scientifically grounded aesthetic treatments.

Keywords: neurocosmetics, probiotics, biotechnology, personalized cosmetics, encapsulation, 3D printing, skin microbiome.

Introduction

Human skin is far more than just a protective layer. Beyond functioning as a physical barrier against external agents it plays active sensory immune and even neurocommunicative roles. Over the past decade research has shown that the epidermis interacts directly with the nervous system participating in emotional regulation and sensory perception. In this context neurocosmetics emerge as products designed to act upon cutaneous receptors promoting not only aesthetic benefit but also sensations associated with physical and emotional wellbeing.

At the same time understanding of the role of the skin microbiome in health continues to grow. The resident microbiota not only protects against pathogens but also regulates pH participates in lipid synthesis and modulates inflammatory responses. These discoveries regarding the influence of microorganisms on skin function have spurred the development of dermocosmetics that use probiotics postbiotics and prebiotics with deeper and more integrated modes of action.

This article aims to gather the most recent scientific advances concerning the use of live microorganisms in neurocosmetics highlighting physiological foundations technological progress for stabilizing these actives regulatory challenges and future perspectives enabled by precision biotechnology in skincare products.

Connections between neuroscience and cosmetics: The skin-brain axis

The epidermis houses a sophisticated network of sensory receptors capable of detecting physical and chemical stimuli and translating them into neurophysiological signals. Receptors such as TRPV1 voltage-gated sodium channels and transient receptor potential channels do more than react to the environment they also interact with local immune cells and vascular structures allowing topical products to evoke perceptible responses that go beyond direct surface effects.

Compounds such as niacinamide acetyl-hexapeptide 8 and palmitoyl pentapeptides interact with neurocutaneous pathways producing effects such as superficial muscle relaxation prolonged hydration and reduced cutaneous stress. These effects are mediated by molecules like beta-endorphin serotonin and substance P which play central roles in both cutaneous homeostasis and emotional modulation (Vinderola, 2024).

Functional Microorganisms and Their Cosmetic Applications

Microorganism / Strain	Primary Metabolite	Proven Cosmetic Effect	Author(s)
***Micrococcus luteus* Q24**	Live colonization	Hydration clearing reduction of wrinkles	Voss 2025
Lactobacillus plantarum	Lactic acid bacteriocins	Anti inflammation barrier repair	Mukarram 2025
Bifidobacterium breve	SCFA fatty acids	Cellular cohesion immune protection	Shirkhan 2024
Streptococcus thermophilus	Ceramides hyaluronic acid	Increased hydration firmness of the skin	Guéniche 2010

Table 1 presents selected microbial strair with documented cosmetic effects. Eac strain produces specific metabolites tha contribute to skin health, such as hydratio inflammation control, and barrie repair. *Micrococcus luteus* Q2 and *Streptococcus thermophilus* improv hydration and firmness, while *Lactobacillu plantarum* and *Bifidobacterium breve*offe anti-inflammatory and immunoprotectiv benefits. These findings support th growing use of live microorganisms i advanced dermocosmetic formulations.

Clinical studies show that regular use of neuropeptide containing products improves not only the appearance of the skin but also the user's subjective experience with increased feelings of comfort vitality and balance. Thus neurocosmetics inaugurate an approach that integrates aesthetics sensorium and neuroscience offering a new concept in personal care.

The Role of the Microbiome in Skin Modulation

The surface of human skin is colonized by vast arrays of microorganisms that are essential for skin health. This microbial community includes bacteria fungi viruses and mites all coexisting in harmony with host cells. Bacteria of the genera Lactobacillus Bifidobacterium Streptococcus and Micrococcus have been studied extensively and associated with benefits such as reducing inflammation enhancing hydration and strengthening the skin barrier.

Recent clinical research has demonstrated that topical application of specific strains can significantly improve dermatological conditions like rosacea acne and atopic dermatitis. Notably Micrococcus luteus Q24 delivered topically showed consistent improvements in hydration oil reduction skin discoloration and texture within just twenty eight days of use (Voss, 2025). Similarly Lactobacillus plantarum exhibited anti inflammatory and barrier repair action in atopic dermatitis models promoting restoration of skin integrity and reduction of transepidermal water loss (Mukarram, 2025).

Technological strategies for topical use of live microorganisms

Using live probiotics in cosmetic formulations requires advanced solutions to preserve viability until application. Microorganisms are vulnerable to oxidation heat and solvents which limits their inclusion in traditional creams and lotions. To overcome this barrier researchers have used encapsulation techniques that protect bacterial cells and enable controlled release on the skin surface.

Systems such as nanoliposomes niosomes polymeric microcapsules and bioadhesive hydrogels effectively preserve viability of strains for extended periods. These systems also allow targeted delivery into specific epidermal layers increasing efficacy and reducing microbial imbalance risk (Jain, 2023).

Furthermore AI based technologies are already employed to map individual skin microbiomes and propose personalized probiotic combinations based on skin type clinical history and environmental exposome.

Regulatory and safety challenges

Despite promising potential regulatory frameworks for cosmetics containing live microorganisms still face significant gaps. Many countries including Brazil United States and the European Union lack specific guidelines for formulation registration and commercialization of probiotic cosmetics. The absence of clear criteria limits scientific validation and regulatory approval of such products.

It is recommended that selected strains b thoroughly genetically characterized be fre of antibiotic resistance genes and produce n harmful toxins or undesirable metabolite Additionally stability of the final product mus be demonstrated in terms of microbia viability and absence of contaminatio (Truglio, 2024).

FAO and WHO probiotic guidelines ma provide foundational recommendations bu translation of these guidelines into cosmetic standards has yet to occur given the uniqu nature of the cosmetic sector distinct fror food or pharmaceuticals.

Microbial Personalization an Cutaneous Neuroengineering

The future of live neurocosmetics lies i personalization. Developing formulatior tailored to each individual's microbiom opens the possibility of truly bespok skincare products. Genomic sequencin metabolomics and artificial intelligenc already enable profiling of an individual microbial residents and proposing probiotic to restore ecological balance.

Research into 3D bioprinting of skin tissu with embedded microbial communities underway and may revolutionize treatmer of wounds chronic ulcers and prematur aging. Cutaneous neuroengineering aims t design molecules that interact selectivel with sensory receptors in the skin deliverin both sensory and aesthetic effec simultaneously.

This convergence of microbiolog neuroscience and biotechnology points to new paradigm in health and beauty wher skincare is not just about appearance but als systemic balance and personalize intervention.

Conclusion

Live neurocosmetics represent a bold and promising frontier in the field of applied biotechnology, where aesthetics, health, and neuroscience come together. Their purpose goes far beyond superficial beautification, aiming to interact with the deeper biological layers of the skin. This includes modulation of sensory pathways, reinforcement of immunological responses, and communication with the skin's microbial community. The use of live microorganisms in topical formulations adds a new level of sophistication, allowing not only physical restoration but also sensory and emotional balance through neurocutaneous mechanisms.

Although significant challenges remain, such as maintaining microbial stability, navigating unclear regulatory environments, and validating clinical outcomes, scientific advances have shown that these barriers are being addressed with growing precision. Innovations in encapsulation methods, strain-specific functional characterization, and tools for microbiome-based personalization are paving the way for a new philosophy in skin care. The capacity to deliver viable microorganisms in stable and functional formats is helping redefine the borders between cosmetics, dermatology, and health-supportive biotechnology.

As research continues to reveal how skin receptors, microbial metabolites, and neurochemical pathways influence overall physiology, the role of neurocosmetics is expected to expand. These formulations may not only improve physical appearance, but also support emotional well-being, help reduce stress-related skin conditions, and possibly serve as complementary tools for managing chronic inflammatory disorders that manifest in the skin. The use of precision formulations based on individual microbiome profiles and specific cutaneous needs opens the possibility of deeply personalized solutions.

What is still seen today as an experimental approach is likely to become part of routine skin care practices in the coming years. Future neurocosmetic innovations will likely offer more than surface-level benefits. They will act in harmony with the body, promoting health, resilience, and biological balance through intelligent interaction with the skin's complex ecosystem.

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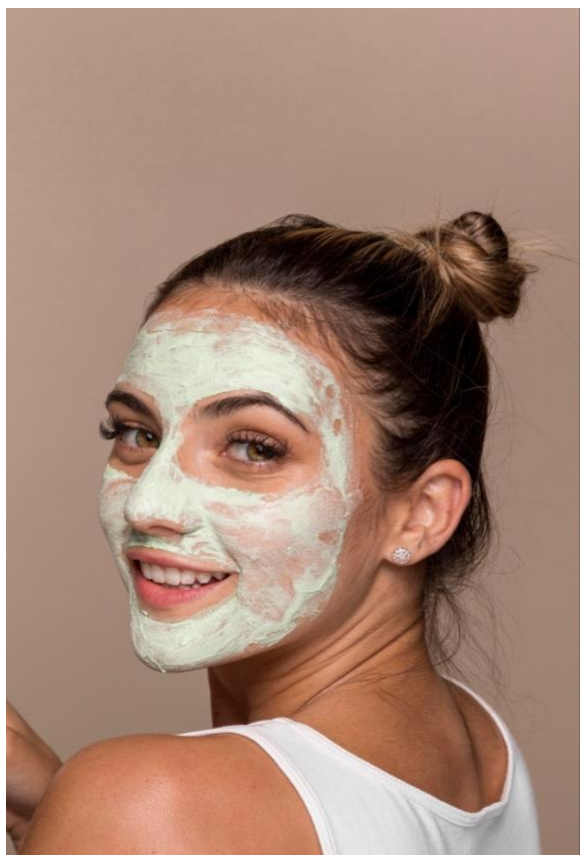

Key Innovations to Watch in the Field of Live Neurocosmetics

To conclude, researchers, formulators, and biotech professionals should remain attentive to the following trends that are reshaping the future of live neurocosmetics and microbiome-based skincare:

Personalized microbiome profiling

Advances in skin microbiota sequencing will enable customized probiotic formulations tailored to individual microbial signatures and skin needs.

Neuroactive postbiotics

Metabolites such as GABA, serotonin, and SCFAs produced by beneficial strains may be used to modulate not only skin inflammation, but also emotional responses through the skin–brain axis.

Smart release formulations

Encapsulation systems that activate based on skin temperature, pH, or UV exposure will allow targeted delivery and controlled release of live strains or their metabolites.

3D printed skin with functional microbiota

Bioprinting of skin tissues embedded with live beneficial microbes may revolutionize regenerative dermatology and clinical testing for cosmetic actives.

Autologous probiotics and microbiome banking

Using a person's own microbial strains preserved and re-applied to restore healthy flora could become the gold standard in personalized dermatological care.

Neurosensory actives targeting cutaneous receptors

Bioengineered compounds designed to activate TRPV1 or Piezo receptors may expand cosmetic effects into the emotional and cognitive domains of user experience.

Eco-intelligent formulations

Emerging interest in biointelligent cosmetics that support not only the skin ecosystem, but also promote environmental regeneration and microbial diversity on a broader scale.

These innovations point to a new paradigm in which live neurocosmetics evolve into systemic health modulators, combining biotechnology, neuroscience, and dermatology with precision and personalization.

Frontiers of BioScience is a weekly digital publication dedicated to showcasing the most relevant Brazilian scientific innovations in biotechnology, clinical research, and precision medicine. With a firm belief in the transformative power of science, this serial publication offers technical content in accessible language for a broad audience of healthcare professionals, researchers, investors, and decision-makers in the life sciences. Its goal is to bridge cutting-edge research and real-world impact, amplifying Latin American voices and giving global visibility to local discoveries. We believe that Brazil, with its unparalleled biodiversity and immense scientific potential, is ready to lead the next revolution in health and biotechnology. This publication is our modest yet determined contribution to that vision.

Contacts:
frontiersofbioscience@gon1.com.br

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