

**PHYTOCOSMETICS IN SKIN MICROBIOME MODULATION: EVIDENCE,
BIOACTIVE STRATEGIES AND CHALLENGES FOR SKIN HOMEOSTASIS**

*FITOCOSMÉTICOS NA MODULAÇÃO DO MICROBIOMA CUTÂNEO:
EVIDÊNCIAS, ESTRATÉGIAS BIOATIVAS E DESAFIOS PARA A HOMEOSTASE
DA PELE*

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HOMEOSTASIS DE LA PIEL*

*PHYTOCOSMETIQUES DANS LA MODULATION DU MICROBIOME CUTANE :
PREUVES, STRATEGIES BIOACTIVES ET DEFIS POUR L'HOMEOSTASIE DE LA
PEAU*

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Abstract: The skin microbiome is an integral component of the cutaneous biological barrier and contributes to colonization resistance, immune education and epidermal microenvironment homeostasis. Growing recognition of this ecosystem has stimulated the development of microbiome-friendly cosmetics and interest in plant-derived ingredients capable of modulating resident microorganisms without indiscriminate community suppression. This critical narrative review examines evidence on phytocosmetics and plant bioactive compounds for skin microbiome modulation, focusing on homeostasis, barrier function, inflammation, formulation and translation. Current literature indicates that polyphenols, botanical extracts and fermentation-derived products may exert selective antimicrobial or prebiotic-like effects in experimental models. Specific evidence includes *Ribes nigrum* extracts that favor *Staphylococcus epidermidis* while limiting opportunistic microorganisms in vitro, as well as exploratory clinical studies in which botanical extracts were associated with shifts in facial microbial composition. However, there is no universal “healthy microbiome,” and changes in microbial abundance or diversity do not automatically translate into clinical benefit. Efficacy depends on ingredient composition, concentration, vehicle, pH, preservatives, anatomical site, baseline microbiome and the selected endpoint. Microbiome-oriented phytocosmetics are therefore promising but still emerging. Their consolidation requires phytochemical standardization, formulation controls, robust microbiological and metagenomic methods, demonstration of barrier function and safety, and clinical trials linking microbial changes to clinically meaningful skin benefits.

Keywords: skin microbiome; phytocosmetics; plant bioactives; microbiome-friendly; skin homeostasis; dermocosmetics.

Resumo: O microbioma cutâneo integra a barreira biológica da pele e participa da resistência à colonização, da educação imunológica e da manutenção do microambiente epidérmico. A crescente valorização desse ecossistema impulsionou o desenvolvimento de cosméticos “microbiome-friendly” e o interesse por ingredientes vegetais capazes de atuar sobre microrganismos residentes sem promover supressão indiscriminada da comunidade. Esta revisão bibliográfica narrativa de caráter crítico analisa as evidências sobre fitocosméticos e compostos bioativos vegetais na modulação do microbioma cutâneo, com ênfase em

homeostase, barreira, inflamação, formulação e translação. A literatura sustenta que polifenóis, extratos botânicos e produtos de fermentação podem apresentar atividade antimicrobiana seletiva ou comportamento prebiótico em modelos experimentais. Evidências específicas incluem extratos de *Ribes nigrum* capazes de favorecer *Staphylococcus epidermidis* e limitar microrganismos oportunistas em sistemas *in vitro*, além de estudos clínicos exploratórios com extratos vegetais associados a alterações na composição microbiana facial. Entretanto, não existe um “microbioma saudável” universal, e alterações de abundância ou diversidade não equivalem automaticamente a benefício clínico. A eficácia depende da composição do ingrediente, concentração, veículo, pH, conservantes, sítio anatômico, microbioma basal e desfecho avaliado. Conclui-se que os fitocosméticos direcionados ao microbioma constituem uma estratégia promissora, porém ainda emergente. Sua consolidação requer padronização fitoquímica, controles de formulação, métodos microbiológicos e metagenômicos robustos, demonstração de função da barreira e segurança, além de ensaios clínicos que relacionem alterações microbianas a benefícios cutâneos clinicamente relevantes.

Palavras-chave: microbioma cutâneo; fitocosméticos; bioativos vegetais; microbiome-friendly; homeostase cutânea; dermocosméticos.

Resumen: El microbioma cutáneo integra la barrera biológica de la piel y participa en la resistencia a la colonización, en la educación inmunológica y en el mantenimiento del microambiente epidérmico. La creciente valorización de este ecosistema impulsó el desarrollo de cosméticos “microbiome-friendly” y el interés por ingredientes vegetales capaces de actuar sobre los microorganismos residentes sin promover la supresión indiscriminada de la comunidad. Esta revisión bibliográfica narrativa de carácter crítico analiza las evidencias sobre fitocosméticos y compuestos bioactivos vegetales en la modulación del microbioma cutáneo, con énfasis en homeostasis, barrera, inflamación, formulación y translación. La literatura sostiene que polifenoles, extractos botánicos y productos de fermentación pueden presentar actividad antimicrobiana selectiva o comportamiento prebiótico en modelos experimentales. Entre las evidencias específicas se incluyen extractos de *Ribes nigrum* capaces de favorecer a *Staphylococcus epidermidis* y limitar microorganismos oportunistas en sistemas *in vitro*, además de estudios clínicos exploratorios con extractos vegetales asociados a alteraciones en la composición microbiana facial. Sin embargo, no existe un “microbioma saludable” universal, y las alteraciones de abundancia o diversidad no equivalen automáticamente a un beneficio clínico. La eficacia depende de la composición del ingrediente, la concentración, el vehículo, el pH, los conservantes, el sitio anatómico, el microbioma basal y el desenlace evaluado. Se concluye que los fitocosméticos dirigidos al microbioma constituyen una estrategia prometedora, aunque todavía emergente. Su consolidación requiere estandarización fitoquímica, controles de formulación, métodos microbiológicos y metagenómicos robustos, demostración de la función de barrera y de la seguridad, además de ensayos clínicos que relacionen las alteraciones microbianas con beneficios cutâneos clinicamente relevantes.

Palabras clave: microbioma cutâneo; fitocosméticos; bioativos vegetales; microbiome-friendly; homeostasis cutânea; dermocosméticos.

Résumé: Le microbiome cutané fait partie de la barrière biologique de la peau et participe à la résistance à la colonisation, à l'éducation immunitaire et au maintien du microenvironnement épidermique. La valorisation croissante de cet écosystème a stimulé le développement de cosmétiques « microbiome-friendly » et l'intérêt pour des ingrédients d'origine végétale capables d'agir sur les micro-organismes résidents sans provoquer une suppression indiscriminée de la communauté. Cette revue bibliographique narrative à caractère critique analyse les preuves relatives aux phytocosmétiques et aux composés bioactifs végétaux dans la modulation du microbiome cutané, en mettant l'accent sur l'homéostasie, la barrière, l'inflammation, la formulation et la translation. La littérature soutient que les polyphénols, les extraits botaniques et les produits de fermentation peuvent présenter une activité antimicrobienne sélective ou un comportement prébiotique dans des modèles expérimentaux. Parmi les preuves spécifiques figurent des extraits de *Ribes nigrum* capables de favoriser *Staphylococcus epidermidis* et de limiter les micro-organismes opportunistes dans des systèmes *in vitro*, ainsi que des études cliniques exploratoires portant sur des extraits végétaux associés à des modifications de la composition microbienne du visage. Cependant, il n'existe pas de « microbiome sain » universel, et les variations d'abondance ou de diversité ne se traduisent pas automatiquement par un bénéfice clinique. L'efficacité dépend de la composition de l'ingrédient, de sa concentration, du véhicule, du pH, des conservateurs, du site anatomique, du microbiome de base et du critère évalué. Il en ressort que les phytocosmétiques ciblant le microbiome constituent une stratégie prometteuse, mais encore émergente. Leur consolidation exige une standardisation phytochimique, des contrôles de formulation, des méthodes microbiologiques et métagénomiques robustes,

la démonstration de la fonction de barrière et de l'innocuité, ainsi que des essais cliniques reliant les modifications microbiennes à des bénéfices cutanés cliniquement pertinents.

Mots-clés: microbiome cutané ; phytocosmétiques ; bioactifs végétaux ; microbiome-friendly ; homéostasie cutanée ; dermocosmétiques.

1 Introduction

The skin is an interface organ in which physical, chemical, immunological and microbial components operate in an integrated manner. The stratum corneum limits water loss and the entry of external agents, while keratinocytes, immune cells and resident microorganisms take part in a network of signals that influences defense, inflammation and repair. The skin microbiome is therefore not a passive layer of microorganisms: its composition and functional activity take part in barrier physiology and vary according to anatomical site, humidity, lipid content, age, environment and individual habits (BYRD; BELKAID; SEGRE, 2018; HAN; KIM, 2024).

Among the most frequent groups on the skin are species of the genera *Cutibacterium*, *Staphylococcus* and *Corynebacterium*, in addition to fungi, viruses and other microorganisms. Ecological interpretation is more relevant than the mere presence of a taxon, because potentially beneficial or opportunistic microorganisms may behave differently depending on strain, niche, abundance and barrier status. Alterations of the ecosystem are described in acne, atopic dermatitis and other dermatoses, but an association between dysbiosis and disease does not, by itself, demonstrate causal direction (BYRD; BELKAID; SEGRE, 2018; BOXBERGER et al., 2021).

This knowledge has changed the way topical products are conceived. Formulations can alter the microenvironment through pH, surfactants, preservatives, lipids and active ingredients, and the “microbiome-friendly” concept has come to designate strategies intended to preserve or favor microbial relationships compatible with skin function. Recent reviews, however, stress that the clinical evidence is still heterogeneous and that there is no universally standardized criterion for stating that a cosmetic is beneficial to the microbiome (HAN; KIM, 2024; SANTOS et al., 2026; TALÉNS-VISCONTI; DIEZ-SALES; NÁCHER, 2026).

In parallel, plant-derived ingredients remain relevant in cosmetology because of their chemical diversity. Polyphenols, flavonoids, terpenes and other metabolites may exert antioxidant, anti-inflammatory and antimicrobial activities, but contemporary interest goes beyond these classical properties: certain extracts show selective effects on members of the microbiota, opening the possibility of formulating products that act simultaneously on the host and on its microbial ecosystem (DINI; LANERI, 2021).

The expression “smart phytocosmetic”, although useful for communicating a multifunctional approach, should be used with caution. A product does not become “smart” merely because it contains a plant extract or a nanocarrier. Scientifically, it is more appropriate to demonstrate which attribute was optimized: stability, skin retention, release, microbial selectivity or response to a stimulus. Likewise, broad-spectrum antimicrobial activity should not be confused with beneficial modulation of the microbiome.

The recent literature offers more specific examples. *Ribes nigrum* extracts obtained by an enzymatic process showed prebiotic potential in models with members of the skin microbiota, favoring *Staphylococcus epidermidis* and showing an inhibitory effect on opportunistic microorganisms under experimental conditions (PETROV IVANKOVIĆ et al., 2023). In an exploratory clinical study, topical application of *Epilobium fleischeri* extract was associated with changes in facial bacterial composition, including enrichment

of commensal taxa in certain regions. These findings demonstrate plausibility, but do not yet allow generalization to any plant extract or formulation.

Beyond the active ingredient, the vehicle may determine the final effect. pH, preservatives, fragrances, surfactants, emollients and the delivery system influence both phytochemical stability and the microbial environment. Therefore, cosmetic microbiome studies need to compare the active formulation with an appropriate vehicle and to assess whether the observed change stems from the plant ingredient, the cosmetic base or the interaction between the two (SANTOS et al., 2026; TALÉNS-VISCONTI; DIEZ-SALES; NÁCHER, 2026).

Given this scenario, the aim of this review is to critically analyze the evidence on the use of phytocosmetics and plant bioactives in the modulation of the skin microbiome, distinguishing experimental effects from clinical benefits and discussing the requirements for developing formulations aimed at skin homeostasis and regeneration.

2 Methodology

The study was developed as a critical narrative literature review. This classification was adopted because it is compatible with the aim of integrating the foundations of skin microbiology, phytochemistry and cosmetic science without attributing to the work the characteristics of a systematic or integrative review, which would require a formal protocol, a fully reproducible strategy, a structured risk-of-bias assessment and a selection flowchart.

The literature search was directed to PubMed/MEDLINE and literature indexed in international journals, complemented by screening of pertinent references. Terms related to skin microbiome, skin microbiota, microbiome-friendly cosmetics, botanical extracts, plant-derived bioactive compounds, phytocosmetics, polyphenols, prebiotics, probiotics, postbiotics, skin barrier and cosmetic formulations were used. Publications from 2019 to 2026 were prioritized, while earlier studies were retained when fundamental to understanding the skin microbiome or the review methodology.

The analysis was organized into four axes: microbiome functions in homeostasis; the relationship between cosmetics, plant bioactives and the microbiota; the quality of the evidence on modulation; and challenges of formulation, safety and translation. In vitro studies were interpreted as mechanistic or proof-of-concept evidence; ex vivo and in vivo studies, as intermediate levels of validation; and human trials, as evidence closer to translation. Changes in relative abundance, diversity or microbial growth were distinguished from clinical outcomes such as hydration, transepidermal water loss, inflammation and skin lesions.

A conservative approach to terminology was also adopted. “Microbiome modulation” was used only to describe demonstrated changes in microbial composition, growth or function, without presupposing benefit. “Microbiome-friendly” was treated as a formulation concept and not as a universal guarantee of efficacy. The review uses exclusively published data and does not involve primary data generation in humans or animals.

3 Results and discussion

The first point that emerges from the literature is that the skin microbiome should be analyzed as a context-dependent ecosystem. Microbial composition varies among sebaceous, moist and dry regions and among individuals, so that a single taxonomic

profile cannot be adopted as a universal standard of health. Byrd, Belkaid and Segre (2018) consolidated this view by describing the strong influence of the microenvironment and of host-microorganism interactions. More recent reviews maintain this perspective and warn of the difficulty of turning isolated taxonomic changes into robust clinical biomarkers (HAN; KIM, 2024; SANTOS et al., 2026).

Barrier function and the microbiome are interdependent. Changes in pH, lipids, hydration and stratum corneum integrity modify ecological niches, while resident microorganisms take part in colonization resistance and communication with the immune system. Consequently, a cosmetic product can alter the microbiome indirectly simply by modifying the physicochemical environment of the skin. This fact is decisive for interpreting studies of active ingredients: the microbial change cannot be attributed to the phytocompound without appropriate vehicle control.

The notion of dysbiosis also requires precision. In inflammatory dermatoses, changes in community structure are frequent, but reduced diversity is not a universal outcome and greater diversity is not necessarily beneficial at every site. Boxberger et al. (2021) highlight methodological challenges of sampling, low biomass, contamination and interpretation. Thus, cosmetic studies need to report anatomical site, collection method, analytical platform, negative controls, bioinformatic processing and the associated clinical outcome.

In the cosmetic field, recent evidence favors the use of the expression “microbiome-friendly” as a verifiable hypothesis rather than a presumed property. Han and Kim (2024) describe the potential of prebiotics, probiotics and postbiotics, while Santos et al. (2026) and Taléns-Visconti, Diez-Sales and Náchter (2026) show that conventional and microbiome-targeted formulations can influence the ecosystem in different ways. At the same time, these reviews point to heterogeneity of designs, small samples and the absence of standardized criteria for claims.

Plant ingredients add a further layer of complexity. The activity of an extract depends on species, plant part, cultivar, growing conditions, solvent, extraction method and chemical standardization. Dini and Laneri (2021) demonstrate the breadth of natural ingredients used in cosmetics, but the presence of polyphenols or terpenes is not sufficient to predict selectivity toward the microbiota. To claim modulation, it is necessary to measure the microbial effect directly.

One of the most useful experimental examples is the *Ribes nigrum* extract. Petrov Ivanković et al. (2023) optimized a polyphenol-rich enzymatic extraction and evaluated its effect on members of the skin microbiota. The extract showed prebiotic potential for *Staphylococcus epidermidis* and a moderate effect on *Cutibacterium acnes*, in addition to favorable performance when incorporated into a hydrogel in compatibility tests. The study is relevant because it connects ingredient characterization, microbial response and formulation, but it remains predominantly in vitro and does not demonstrate global remodeling of the human microbiome.

This type of result illustrates why “antimicrobial” and “microbiome-modulating” are not synonyms. An essential oil that reduces bacterial growth in a diffusion assay may display antimicrobial activity, but this test does not demonstrate preservation of commensals, maintenance of diversity or barrier benefit. To support an ecological claim, comparators with relevant species or strains, concentrations compatible with topical use and, ideally, community or metagenomic models are required.

Clinical studies with botanicals are beginning to provide translational evidence. A four-week randomized controlled trial with *Epilobium fleischeri* extract identified changes in facial microbiota composition and enrichment of certain commensal

microorganisms in the active group. Although promising, the study involved a small sample and demonstrates compositional modulation, not a rule applicable to plant extracts in general. This type of evidence should be valued without extrapolation.

The integration of prebiotics, probiotics and postbiotics broadens formulation possibilities. Prebiotics are substrates intended to be selectively utilized by host microorganisms; probiotics involve live microorganisms when the definition is applied strictly; and postbiotics are preparations of inanimate microorganisms and/or their components with demonstrated benefit to the host. In cosmetics, incorporating viable cells is technologically challenging because the microbiological preservation of the product and the viability of the microorganism may be conflicting goals. Reviews from 2026 therefore highlight the growth of strategies based on prebiotics and postbiotics (SANTOS et al., 2026; TALÉNS-VISCONTI; DIEZ-SALES; NÁCHER, 2026).

The complete formulation needs to be considered as the experimental unit. Preservatives are indispensable for the microbiological safety of many products, but their concentration and spectrum may influence resident microorganisms. Surfactants can alter lipids and pH; fragrances and solvents can modify tolerability; and emollients alter hydration and substrate availability. Thus, a final product may produce a different response from that observed with the isolated active ingredient.

Delivery systems can be useful when there is a concrete limitation of the bioactive, such as low stability, low solubility or the need for retention in the skin. However, nanoencapsulation should not automatically be presented as an increase in efficacy on the microbiome. It is necessary to demonstrate that the system preserves the active, releases the payload under relevant conditions and improves an outcome relative to the free active and the vehicle. The same logic applies to liposomes, nanoemulsions and lipid carriers.

Another critical point is the relationship between microbial change and skin benefit. An increase in *Staphylococcus epidermidis* or a reduction of a taxon associated with dysbiosis may be biologically plausible, but clinical relevance must be demonstrated by parallel outcomes. Hydration, transepidermal water loss, pH, erythema, inflammatory markers, lesion severity and user perception can help establish whether the microbial change corresponds to functional improvement.

The safety of phytocosmetics also cannot be inferred from natural origin. Extracts may contain sensitizers, photoreactive substances, contaminants or variable concentrations of biologically active constituents. Essential oils, in particular, may cause irritation or sensitization depending on composition and dose. Therefore, safety must include raw-material quality, stability, formulation compatibility and adequate skin evaluation.

Phytochemical standardization is one of the main bottlenecks for reproducibility. Studies that describe only the plant name, without extraction method and chemical markers, hinder comparison between results. For applied research, the ingredient specification should include botanical origin, part used, solvent or production process, chemical profile or marker, concentration in the formulation and storage conditions.

Metagenomics has expanded the capacity to characterize communities, but taxonomic composition does not reveal all of the function. Metatranscriptomics, metabolomics and functional approaches can clarify whether an intervention alters metabolic pathways relevant to the barrier, inflammation or colonization resistance. Even so, greater analytical sophistication does not replace adequate experimental design, controls and clinical relevance.

The 2026 publications reinforce a shift in focus: the goal should not be to indiscriminately maximize microbial diversity, but to preserve or restore relationships

compatible with skin function. Santos et al. (2026) discuss the impact of classes of cosmetic ingredients on the microbiome, while Taléns-Visconti, Diez-Sales and Náchter (2026) emphasize that the results of microbiome-targeted interventions are still preliminary and limited by methodological heterogeneity. This framing is more consistent than classifying any natural product as automatically “microbiome-friendly”.

From a translational standpoint, a rational development chain can be proposed: botanical selection and authentication → phytochemical standardization → demonstration of activity at use-compatible concentrations → assessment of selectivity toward relevant microorganisms → incorporation into a formulation → stability and safety → microbiome analysis with adequate controls → simultaneous assessment of barrier function and clinical outcomes → confirmation in human studies. This sequence reduces the risk of turning a laboratory antimicrobial activity into an unsupported cosmetic claim.

Therefore, the potential of phytocosmetics for microbiome modulation is real, but it depends on the quality of the evidence. The most convincing data are those that connect ingredient composition, microbial response, formulation and skin benefit. Advancing the field requires fewer generalizations about “balance” and “diversity” and greater precision about which microorganism, function, skin site, intervention and outcome were actually modified.

4 Conclusion

The skin microbiome is a functional component of skin homeostasis, but its high variability prevents the definition of a universally ideal microbial profile. This characteristic should guide the development of microbiome-oriented cosmetics: preserving skin ecology does not mean indiscriminately increasing diversity or eliminating microorganisms associated with certain dermatoses.

Plant bioactives show relevant potential because they can combine antioxidant, anti-inflammatory and antimicrobial properties with selective effects on members of the microbiota. Studies with plant extracts, including *Ribes nigrum* and *Epilobium fleischeri*, demonstrate that modulation is biologically plausible. However, much of the evidence is still concentrated in in vitro models, exploratory studies or small clinical samples.

The consolidation of microbiome-targeted phytocosmetics requires that the final product, and not only the isolated active ingredient, be evaluated. pH, preservatives, surfactants, vehicle and delivery systems can modify both the microbiota and barrier function. Therefore, “microbiome-friendly”, selectivity or regeneration claims must be supported by vehicle controls, robust microbiological characterization and clinically relevant skin outcomes.

It is concluded that microbiome modulation by phytocosmetics represents a promising but still emerging frontier of cosmetic science. Responsible translation depends on phytochemical standardization, safety, stability, adequate omics and functional methods and human trials capable of demonstrating that microbial changes translate into measurable benefits for the skin. This approach favors an evidence-based cosmetology in which botanical innovation and microbial ecology are integrated without extrapolating beyond the actual level of scientific knowledge.

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