REVIEW / SCIENTIFIC PERSPECTIVE

Beyond Beauty from Within: Multifunctional Nutricosmetics, the Gut-Skin Axis, and the Microbiome as the Next Innovation Platform

From single-outcome beauty supplements to systems-oriented strategies for skin resilience, barrier function, healthy ageing and microbiome-directed nutrition

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Highlights

- Nutricosmetics are shifting from isolated cosmetic endpoints toward systems-oriented support for skin resilience and healthy ageing.
- Microbiome-directed innovation is scientifically promising, but efficacy cannot be extrapolated across probiotic strains or postbiotic preparations.
- Multifunctionality should be defined by mechanistic coherence and clinically relevant dosing, not by the number of ingredients in a formula.
- The strongest future products will integrate formulation technology, human clinical evidence and jurisdiction-specific claim substantiation.

Abstract

Nutricosmetics developed around the proposition that nutritional status and systemic physiology can influence the appearance and functional integrity of skin, hair and nails. The first commercial generation of the category largely translated this premise into single-outcome products focused on hydration, wrinkles, hair quality or nail strength. The emerging generation is broader. Skin is increasingly treated as a systems-biology endpoint influenced by extracellular-matrix turnover, barrier lipids, oxidative and carbonyl stress, immune tone, metabolic health, endocrine status, sleep, psychological stress and the intestinal microbiome. This narrative review examines the scientific and product-development implications of that transition, with particular attention to multifunctional formulation and microbiome innovation. Human data support selected oral interventions with collagen peptides, hyaluronan, plant ceramides, carotenoid-rich preparations and specific probiotic or postbiotic preparations, but the maturity and independence of the evidence vary substantially. Microbiome research is especially promising because it connects intestinal ecology, microbial metabolites, epithelial integrity and systemic immune signalling with cutaneous homeostasis; however, effects are strain-, preparation-, dose-, population- and endpoint-specific. Recent trials also demonstrate that not all microbiome-directed interventions outperform placebo, an important corrective to category-level marketing claims. The central argument of this review is that the next generation of credible nutricosmetics will be defined not by ingredient count but by biological coherence, dose integrity, clinically meaningful endpoints, formulation stability and defensible claims. Multifunctionality is scientifically valuable when it links complementary mechanisms around a defined physiological hypothesis; without that discipline, it risks becoming underdosed ingredient stacking. The category's long-term growth will therefore depend on the convergence of dermatology, nutritional science, microbiology, food technology, clinical trial methodology and regulatory substantiation.

Keywords: *Nutricosmetics; beauty from within; gut-skin axis; microbiome; probiotics; postbiotics; collagen peptides; ceramides; hyaluronic acid; skin ageing; healthy ageing; personalised nutrition.*

1. Introduction: nutricosmetics are entering a second generation

The founding idea of nutricosmetics is biologically plausible: the skin is a metabolically active, immunologically sophisticated and environmentally exposed organ whose structure and appearance partly reflect systemic physiology. Nutritional adequacy influences connective-tissue synthesis, antioxidant defence, epidermal differentiation and immune function, while ageing alters extracellular-matrix turnover, mitochondrial function, barrier lipids and inflammatory signalling. Contemporary skin-ageing biology therefore extends well beyond a simplistic narrative of declining collagen (Russell-Goldman & Murphy, 2020).

Commercial development, however, has historically been narrower than the physiology. The first generation of 'beauty-from-within' products was built around recognisable ingredient-outcome pairs: collagen for wrinkles, hyaluronic acid for hydration, biotin for hair and nails, and antioxidants for photoageing. That architecture was commercially intuitive, but it tended to treat skin, hair and nails as isolated cosmetic outputs rather than phenotypes embedded in a broader network of nutrition, metabolism, immunity, endocrine biology and microbial ecology.

The emerging category is different. Multifunctional products increasingly combine skin-directed actives with ingredients positioned around healthy ageing, gastrointestinal function, stress biology, musculoskeletal support or metabolic resilience. At the same time, the gut-skin axis has moved from an attractive hypothesis to a serious research platform supported by mechanistic studies, observational work and a growing, although still heterogeneous, body of human intervention data (O'Neill et al., 2016; Salem et al., 2018; Sinha et al., 2021; Gao et al., 2023). The

critical question is no longer whether the category will become more complex, but whether that complexity will be scientifically organised.

2. Scope and methodology of this narrative review

This article is a critical narrative review rather than a systematic review or meta-analysis. It integrates peer-reviewed human intervention studies, systematic reviews, mechanistic reviews, consensus statements and official regulatory sources relevant to oral skin health, microbiome-directed interventions and multifunctional product development. Priority was given to randomized controlled trials, recent meta-analyses, internationally recognised consensus definitions and primary regulatory materials. Searches and source verification were updated through August 2026.

Because the commercial term 'nutricosmetic' does not correspond to a single harmonised regulatory or biomedical category, the literature was organised by biological platform rather than by product label. Evidence was interpreted according to intervention specificity, study design, population, endpoint selection, dose, formulation identity, sample size and conflict-of-interest context. The purpose is therefore not to assign a universal efficacy verdict to broad ingredient classes, but to distinguish mature evidence from promising, preliminary or commercially overextended claims.

3. Multifunctionality should mean biological architecture, not ingredient accumulation

The term 'multifunctional' can describe two very different formulation philosophies. The first is additive: a product contains collagen, vitamins, minerals, botanicals, hyaluronic acid, probiotics and antioxidants because each ingredient is associated with a desirable consumer benefit. The second is hypothesis-driven: each component addresses a distinct but complementary mechanism within a defined physiological model. Only the second approach represents meaningful scientific multifunctionality.

This distinction has practical consequences. A formula containing many actives may become impossible to dose appropriately within a gummy, capsule or small-volume shot. It may also create analytical, stability, sensory and regulatory problems that are invisible at the concept stage. More importantly, a long ingredient list can make the clinical hypothesis unfalsifiable: if the product improves one endpoint, it becomes unclear which component or interaction was responsible; if it fails, underdosing and antagonistic interactions are difficult to exclude.

A more defensible architecture might combine a dermal structural component, an epidermal barrier component, a microbiome-directed component and a targeted antioxidant or micronutrient system, provided that each is present at a dose compatible with the evidence. The objective is not maximal breadth. It is mechanistic complementarity without loss of dose integrity.

4. From cosmetic ageing to healthy ageing

Visible skin ageing overlaps biologically with several hallmarks of systemic ageing. Chronic low-grade inflammation, impaired redox control, accumulation of damaged macromolecules, extracellular-matrix remodelling and altered tissue regeneration all affect the skin while also participating in broader age-related physiology. This makes the boundary between 'beauty' and 'healthy ageing' increasingly artificial.

Collagen peptides illustrate both the opportunity and the evidentiary challenge. Multiple randomized trials and meta-analyses report improvements in hydration, elasticity and wrinkle-related outcomes, yet the literature is heterogeneous in peptide source, molecular profile, dose, duration, comparator and endpoint methodology (Pu et al., 2023; Žmitek et al., 2024). A 2025 systematic review and meta-analysis of 23 randomized trials found overall benefits but reported that positive effects were attenuated when analyses were restricted by study quality and funding source, raising an important question about the robustness and independence of the evidence base (Myung & Park, 2025).

The appropriate conclusion is not that collagen is ineffective, nor that every collagen supplement works. It is that category-level efficacy claims are less informative than product-specific evidence. For future nutricosmetics,

ingredient identity, peptide characterisation, dose and trial quality should be treated as part of the active technology rather than as secondary details.

5. The gut-skin axis: a plausible systems framework, not a marketing shortcut

The gut-skin axis describes bidirectional communication among intestinal microbial communities, gastrointestinal barrier biology, immune signalling, microbial metabolites and cutaneous physiology. The concept is supported by the capacity of the intestinal microbiome to influence systemic immune tone and metabolite exposure, and by associations between intestinal dysbiosis and several inflammatory skin conditions (O'Neill et al., 2016; Salem et al., 2018; Sinha et al., 2021).

Microbial metabolites provide one plausible mechanistic bridge. Short-chain fatty acids, tryptophan-derived indoles, modified bile acids and other products of microbial metabolism can influence epithelial integrity, immune-cell differentiation and inflammatory pathways. Nevertheless, the common commercial equation 'better microbiome equals better skin' is scientifically inadequate. There is no single universally optimal microbiome, and community composition varies with diet, geography, age, medication, host genetics and analytical method.

A more rigorous formulation question is therefore: which microbial function, organism, preparation or metabolite is expected to influence which skin endpoint in which population? This shifts development away from generic microbiome language and toward intervention-specific causal hypotheses.

6. Probiotics: strain specificity is fundamental

Probiotics are defined by a health benefit delivered by live microorganisms administered in adequate amounts, and their effects are strain-specific. Evidence from one strain cannot be automatically transferred to another strain of the same species, still less to an entire genus. This principle is frequently diluted in consumer communication but is indispensable in product development.

A frequently cited randomized double-blind placebo-controlled trial evaluated Lactobacillus plantarum HY7714 (now classified within Lactiplantibacillus) in 110 women with dry skin and wrinkles. The intervention was associated with improvements in hydration, transepidermal water loss, wrinkle depth and elasticity over 12 weeks (Lee et al., 2015). Later mechanistic work supported the possibility that this strain could influence gut and immune parameters relevant to skin physiology.

More recent human studies have widened the field. Nishikawa et al. (2025) evaluated Bifidobacterium breve M-16V in women and integrated facial imaging with gut and skin microbiome analyses. The results suggested protection against deterioration in selected facial parameters, including brown-spot measures, but they do not justify extrapolating an anti-ageing claim to Bifidobacterium as a genus. A 2026 clinical review similarly concluded that microbiome-targeted interventions are promising while emphasising strain specificity, formulation stability and the limited number of adequately powered randomized trials (Yiğit et al., 2026).

7. Postbiotics: a formulation technology as well as a biological platform

Postbiotics are particularly attractive to nutricosmetic developers because they address a central technological limitation of probiotics: viability. The International Scientific Association for Probiotics and Prebiotics defines a postbiotic as a preparation of inanimate microorganisms and/or their components that confers a health benefit on the host (Salminen et al., 2021). The definition is deliberately preparation-specific and requires demonstrated benefit in the target host.

This matters for food technology. Live microorganisms can be sensitive to heat, oxygen, water activity and storage time, complicating their use in gummies, powders, ready-to-drink beverages and multi-active matrices. Inanimate microbial preparations can offer greater process robustness and shelf-life stability, although inactivation method, matrix and compositional characterisation remain part of the product identity (Salminen et al., 2021).

Human skin data are emerging. Yoshitake et al. (2022) reported improvements in selected skin-function parameters after daily intake of heat-killed Lactiplantibacillus plantarum L-137, with subgroup effects related to age and baseline dryness. Sawashita et al. (2025) reported improvements in selected elasticity parameters with a heat-treated Latilactobacillus sakei KABP-065 preparation in healthy middle-aged women. Conversely, a 2026 randomized trial of heat-killed Lactobacillus acidophilus IDCC 3302 did not demonstrate superiority over placebo for its prespecified primary wrinkle endpoints, although exploratory differences were observed for some secondary parameters (Kim et al., 2026).

That negative result is scientifically valuable. It shows why 'postbiotic' cannot function as a category-level efficacy claim. Biological activity must be demonstrated for the specific preparation, produced by the same relevant process, at a defined dose and for a defined outcome.

8. The future may be microbiome-directed rather than merely probiotic

Microbiome innovation is likely to expand beyond the addition of live or inactivated microorganisms. Prebiotics can alter microbial substrate availability; synbiotics can combine microorganisms and selectively utilised substrates; postbiotics decouple microbial bioactivity from viability; and metabolomic approaches can focus directly on microbial functions rather than taxonomic abundance.

The most consequential development may ultimately be responder stratification. Baseline microbial ecology could help explain why identical nutritional interventions produce different outcomes among consumers. If reproducible responder signatures can be identified, microbiome-directed nutricosmetics may move from generic 'balance' claims toward precision nutrition. That transition, however, requires prospective validation. A microbiome test has limited value if the resulting profile does not improve the prediction of response or change a clinically useful recommendation.

9. Barrier biology may become as important as dermal collagen

The stratum corneum is a highly organised permeability barrier in which corneocytes are embedded within a lipid matrix rich in ceramides, cholesterol and free fatty acids. Barrier competence influences transepidermal water loss, hydration and resilience to environmental stress. For this reason, the future of nutricosmetics is likely to pay greater attention to epidermal lipids rather than treating collagen as the sole structural target.

Oral plant-derived ceramides and glucosylceramides are an emerging approach. In a 2024 randomized double-blind placebo-controlled trial, a wine-lees-derived ceramide/glucosylceramide preparation produced significantly lower TEWL than placebo after 12 weeks, while several secondary outcomes did not differ significantly (Sanjaya et al., 2024). The study was small and industry-sponsored, so replication is needed; nevertheless, it demonstrates the value of using a barrier-specific primary endpoint rather than relying exclusively on global cosmetic assessments.

A coherent multifunctional product could therefore combine dermal matrix support with epidermal lipid support and microbiome-directed modulation. Such a concept is biologically stronger than a generic anti-ageing blend because each component maps to a distinct level of skin physiology.

10. Oral hyaluronan: promising evidence, but synergy should not be assumed

Oral hyaluronan has been investigated for hydration, dryness and wrinkle-related outcomes. A 12-week double-blind placebo-controlled study reported improvement in wrinkles and several skin-condition measures after oral hyaluronan ingestion (Hsu et al., 2021). A 2025 meta-analysis of randomized trials also reported statistically significant improvements in hydration, elasticity and wrinkle depth, while noting heterogeneity and limited sample size across the evidence base (Amin et al., 2025).

The formulation lesson is more important than the ingredient story. If collagen, hyaluronan and vitamin C each have plausible roles, their combination does not automatically produce synergy. Žmitek et al. (2024) found benefits for

collagen-containing interventions but did not establish universal incremental benefit across endpoints from adding hyaluronic acid. Synergy is an empirical result, not a design assumption.

11. Antioxidants are evolving toward photobiology and redox resilience

'Antioxidant' is one of the most overused words in the supplement industry. Reactive oxygen species also function as physiological signalling molecules, so the objective should not be framed as indiscriminate suppression of oxidation. A more defensible concept is support of redox homeostasis and resilience to environmental exposure.

Ultraviolet radiation and pollution can activate oxidative pathways and matrix metalloproteinases that contribute to extracellular-matrix degradation. Dietary carotenoids are of interest because they can accumulate in tissues and modify photobiological responses. A systematic review and meta-analysis found that tomato and lycopene interventions can reduce UV-induced erythema, consistent with a modest nutritional contribution to photoprotection (Zhang et al., 2024). This effect should be positioned as complementary to, never a substitute for, established topical photoprotection.

The direction of innovation is therefore shifting from generic 'anti-oxidant' claims toward defined environmental-stress endpoints, measured under controlled conditions.

12. Micronutrients: essential physiology does not justify indiscriminate megadosing

Vitamins and minerals remain foundational to the hair-skin-nails category because deficiencies can produce dermatological manifestations. Yet an essential nutrient can be indispensable at adequate intake without producing additional cosmetic benefit at pharmacologically excessive doses.

Biotin is the clearest example. Deficiency can be associated with dermatitis, alopecia and brittle nails, but the US National Institutes of Health notes that cosmetic claims for biotin supplementation in otherwise adequate individuals are supported mainly by small studies and case reports (NIH Office of Dietary Supplements, 2022). In Europe, authorised health claims exist for selected nutrients under defined conditions of use, but the legal claim is not equivalent to proof that escalating the dose above adequacy produces progressively greater benefit.

Premium nutricosmetic formulation should therefore distinguish correction of insufficiency from supra-nutritional intervention. Nutritional precision is more defensible than megadose symbolism.

13. Stress, sleep and the emerging gut-brain-skin framework

Psychological stress can influence barrier function, cutaneous immunity, wound healing and inflammatory signalling through central and peripheral neuroendocrine pathways (Hunter et al., 2015; Sun & Rieder, 2021). Sleep quality is also associated with barrier recovery and visible signs of ageing. These relationships create a plausible bridge between nutricosmetics and broader wellness formulations.

The commercial temptation is to add an adaptogen, magnesium or sleep ingredient to a collagen formula and call the result a 'stress-skin' product. Scientifically, that is insufficient. A credible development programme would need to prespecify both systemic and cutaneous endpoints—for example validated sleep or stress scores together with TEWL, hydration, elasticity or inflammatory biomarkers—and demonstrate that the combined intervention changes them in a coherent manner.

This is a general principle of multifunctional product development: if the product claims to connect systems, the clinical design should measure more than one system.

14. Menopause and female healthy ageing: a natural multifunctional platform

The menopausal transition illustrates why the separation between beauty and health is becoming less useful. Declining oestrogen affects skin collagen, thickness and elasticity while also influencing bone, body composition, sleep and thermoregulation. Reviews of menopausal hormone therapy confirm that hormonal status materially affects

skin structure, although pharmacological hormone therapy is a distinct clinical intervention and must not be conflated with food supplementation (Pivazyan et al., 2023).

For nutricosmetics, the opportunity lies in clustered multifunctionality. A formulation designed for midlife women might rationally connect skin barrier function, connective tissue, protein adequacy and musculoskeletal ageing. By contrast, attempting to address skin, sleep, cognition, mood, metabolism, immunity, joints and weight within a single formula risks dose dilution and regulatory overreach.

The most credible products are likely to choose a small number of physiologically related targets and develop a clinical programme around those targets.

15. Metabolic health, glycation and the appearance of ageing

Metabolic physiology is increasingly relevant to nutricosmetic thinking. Chronic hyperglycaemia and carbonyl stress promote the formation of advanced glycation end products that can modify long-lived proteins such as collagen and elastin, increasing cross-linking and tissue stiffness (Danby, 2010). This provides a mechanistic basis for considering metabolic health as part of long-term skin ageing rather than as a completely separate domain.

The concept should not be overextended. Evidence that a specific 'anti-glycation' supplement produces clinically meaningful cosmetic benefit is much less mature than the biochemical rationale. Nevertheless, the growing use of pharmacological weight-management strategies and the associated focus on body composition, protein adequacy and lean-mass preservation may further blur the boundary between metabolic nutrition and appearance-related outcomes.

Future products in this area should resist opportunistic claims around GLP-1 pharmacotherapy and instead focus on well-defined nutritional needs—adequate protein, micronutrient sufficiency, hydration and maintenance of tissue quality—supported by appropriate endpoints.

16. Delivery format is part of efficacy

Nutricosmetic innovation is increasingly format-driven: gummies, stick packs, powders, shots and functional beverages compete with conventional capsules and tablets. Yet the preferred consumer format may be incompatible with the clinically relevant dose, stability profile or sensory properties of the active system.

Gram-level collagen doses fit naturally in powders and beverages but poorly in small gummies. Live probiotics may lose viability during heat processing or storage. Lipophilic carotenoids require suitable dispersion and absorption conditions. Minerals can create off-tastes or interact with other components. Postbiotics may offer greater manufacturing latitude than live organisms, but inactivation process and matrix remain part of the defined preparation (Salminen et al., 2021).

The correct development sequence is therefore: biological target, active identity, evidence-based dose, stability and bioavailability requirements, then consumer format. Reversing that sequence is a common reason why attractive prototypes become scientifically weak commercial products.

17. Precision nutricosmetics and artificial intelligence

Inter-individual variability is intrinsic to nutrition. Age, sex, menopausal status, baseline diet, medication, UV exposure, metabolic phenotype and microbial ecology can all influence both baseline skin characteristics and response to intervention. This creates a credible long-term pathway toward precision nutricosmetics.

Machine-learning approaches could help identify responder profiles when multi-omic datasets become sufficiently large and well-curated. Potential inputs include microbiome composition, metabolomics, nutrient status, digital skin imaging and longitudinal behavioural data. The central methodological warning is that algorithmic sophistication cannot compensate for weak labels, small samples or poorly controlled interventions. Prediction is only valuable if it is prospectively validated and changes a useful decision.

The near-term opportunity is therefore not personalised marketing for its own sake, but better stratification of clinical trials and clearer identification of subpopulations in whom a particular intervention is most likely to be effective.

18. Clinical trials must evolve with multifunctional products

Traditional nutricosmetic trials often measure hydration, TEWL, elasticity, wrinkle profilometry or facial imaging. These remain valuable, but systems-oriented products require trial designs that reflect the proposed mechanism. Microbiome-directed interventions may justify microbial profiling or metabolomics; stress-skin products may require validated psychometric measures; metabolic-skin concepts may require nutritional or metabolic biomarkers.

The challenge is multiplicity. Measuring dozens of exploratory variables increases the probability of apparently positive findings by chance. Primary endpoints should therefore be prespecified, statistically powered and clinically interpretable. Secondary and exploratory outcomes should be labelled as such. The 2026 IDCC 3302 trial is instructive because non-significant primary wrinkle endpoints prevent exploratory secondary signals from being presented as confirmatory evidence (Kim et al., 2026).

Future credibility will depend not only on performing trials, but on designing them so that a negative result is scientifically informative. Registration, transparent endpoint hierarchy, adequate comparators and disclosure of funding are therefore part of product quality.

19. Regulation and claims may become the limiting factor in innovation

Nutricosmetics are primarily a commercial and product-development category; they are not a harmonised legal category. In the European Union, ingestible products marketed as foods or food supplements remain subject to food law, including Regulation (EC) No 1924/2006 on nutrition and health claims. Health claims require authorisation within the applicable framework, and evidence generated in a proprietary clinical study does not automatically create a lawful consumer claim (European Parliament & Council, 2006).

Microbiome terminology is especially sensitive. Statements such as 'balances the microbiome', 'repairs the gut-skin axis' or 'reduces systemic inflammation' can carry different scientific and legal implications depending on wording and jurisdiction. The challenge for developers is to align the product's evidence package with the exact communication they intend to use, rather than designing claims after the trial is complete.

In the United States, structure/function claims for dietary supplements are regulated differently from disease claims, but they must still be truthful and non-misleading and require appropriate substantiation (U.S. Food and Drug Administration, 2024). The Federal Trade Commission likewise expects health-product advertising to be supported by competent and reliable scientific evidence and evaluates both express and implied claims (Federal Trade Commission, 2022). The competitive advantage may therefore belong to companies capable of making the strongest defensible claim, not the most dramatic claim.

20. Evidence maturity across major nutricosmetic platforms

Evidence across the category is uneven. Some platforms are supported by multiple randomized trials but remain heterogeneous; others are mechanistically compelling but clinically early. Commercial novelty should therefore never be used as a proxy for evidentiary strength. Table 1 summarises a pragmatic evidence hierarchy for current formulation platforms.

Table 1. Pragmatic evidence maturity across major nutricosmetic platforms

Platform	Evidence maturity	Principal opportunity	Principal limitation
Essential vitamins and minerals	High for normal physiological functions and deficiency correction	Foundational nutritional support; authorised claims may exist under jurisdiction-specific conditions	Benefit above adequacy is often poorly demonstrated; excess dosing may add risk without efficacy
Collagen peptides	Moderate; numerous RCTs and meta-analyses, but heterogeneous	Dermal matrix, elasticity, hydration; potential connective-tissue convergence	Product heterogeneity, sponsorship effects, inconsistent endpoints and independence concerns
Oral hyaluronan	Emerging to moderate	Hydration, dryness and wrinkle-related endpoints	Relatively small evidence base; formulation and molecular-weight differences
Plant ceramides / glucosylceramides	Emerging	Barrier function and TEWL	Small trials; industry sponsorship common; replication needed
Carotenoids / tomato-lycopene preparations	Moderate for selected photobiological endpoints	Nutritional photoprotection and environmental resilience	Effects are modest and cannot replace sunscreen
Probiotics	Promising but strain-specific	Gut-skin signalling, immune modulation and selected skin endpoints	No class effect; viability and stability constraints; limited large RCTs
Postbiotics	Rapidly emerging	Greater process robustness; microbial signalling without viability requirement	Preparation-specific; limited independent confirmatory trials; terminology often misused
Precision microbiome interventions	Experimental	Responder identification and personalised formulation	Predictive validity and clinical utility are not yet established

Note. *Evidence maturity is a critical appraisal for formulation strategy, not a formal GRADE assessment. It reflects the combination of human intervention evidence, replication, heterogeneity and product specificity.*

21. What should define the next generation of successful products?

The next generation of successful nutricosmetics is likely to begin with a biological problem rather than an ingredient trend. It will use complementary mechanisms, maintain clinically relevant doses, account for formulation stability and define the exact population and endpoint it intends to influence. For microbiome interventions, this means strain- or preparation-level identity. For collagen, it means product characterisation and transparent interpretation of funding-sensitive evidence. For micronutrients, it means distinguishing adequacy from pharmacological excess.

Commercial differentiation will increasingly come from the evidence architecture surrounding the formula: analytical specification, mechanistic plausibility, human data, reproducible manufacturing, clinically interpretable endpoints and jurisdiction-specific claims. This is a more demanding development model than traditional beauty supplementation, but it is also more difficult to commoditise.

22. Limitations and research priorities

Several limitations constrain the current evidence base. Many trials are small, short and industry-sponsored. Formulations differ substantially even when they share the same headline ingredient. Cosmetic endpoints can be sensitive to season, humidity, topical skincare routines and baseline phenotype. Microbiome studies add further complexity because sequencing platform, bioinformatic pipeline and taxonomic abundance do not necessarily capture microbial function.

Priorities for the field include larger preregistered randomized trials; replication by independent groups; standardised reporting of active identity and dose; better disclosure of conflicts and funding; harmonised instrumental endpoints; integration of metabolomics with microbial taxonomy; and prospective validation of responder signatures. For multifunctional formulas, factorial or dismantling designs may sometimes be needed to distinguish true combination effects from the activity of a dominant single component.

The category will mature when negative studies are treated as design information rather than marketing failures. That shift is essential if microbiome science and multifunctional nutrition are to become durable scientific platforms rather than transient consumer trends.

23. Conclusion

Nutricosmetics are moving beyond the first generation of beauty-from-within products. The most important change is conceptual: skin is increasingly understood as a systems-level phenotype influenced by nutritional status, barrier biology, extracellular-matrix turnover, immune tone, metabolism, endocrine state, stress, sleep and microbial ecology. This creates a legitimate scientific basis for multifunctional products.

Microbiome innovation may be one of the most consequential components of this transition. Specific probiotics, postbiotics and microbiome-directed strategies can plausibly influence cutaneous physiology through intestinal, immune and metabolic pathways, and selected human trials are encouraging. The evidence nevertheless remains intervention-specific, and recent neutral primary outcomes demonstrate that the category cannot be validated by terminology alone.

Established actives such as collagen peptides, hyaluronan, ceramides and carotenoids will remain important, but they are likely to be incorporated into more coherent physiological frameworks. The principal innovation challenge is therefore to resist confusing complexity with sophistication. A multifunctional product is scientifically stronger only when every major component has a defined purpose, an appropriate dose, a stable formulation and a clinical endpoint capable of testing the hypothesis.

The future of the category may be described less accurately as 'beauty from within' than as health expressed through the skin. If industry adopts the same discipline expected in nutritional science, microbiology, dermatology and clinical research, nutricosmetics can evolve from a narrow cosmetic-supplement niche into a credible interface between nutrition, healthy ageing and systems biology.

24. A development framework for scientifically credible multifunctional nutricosmetics

Table 2 translates the scientific discussion into a practical development sequence suitable for R&D, clinical, regulatory and marketing teams. The sequence is deliberately evidence-first: consumer format and communication are downstream decisions, not the starting point.

Table 2. Evidence-first development sequence

Development step	Technical requirement
1. Define the phenotype	Choose the target population and clinically meaningful skin or healthy-ageing problem before selecting ingredients.
2. Build the biological hypothesis	Map each active to a complementary mechanism; avoid redundant or purely fashionable additions.
3. Protect dose integrity	Use doses compatible with human evidence and the intended delivery format.
4. Specify the active	For probiotics use strain identity; for postbiotics define progenitor, matrix and inactivation process; for peptides define relevant composition.
5. Engineer the format	Validate stability, sensory performance, analytical specification and shelf life in the final matrix.
6. Design the trial around the claim	Prespecify primary endpoints, comparator, duration, statistical hierarchy and target population.
7. Audit regulatory language	Test every intended label, website and advertising statement against jurisdiction-specific claim rules.
8. Publish the whole result	Disclose funding and conflicts, and report neutral as well as positive endpoints to strengthen long-term credibility.

Editorial note on evidence interpretation

This article intentionally retains neutral and negative trial results, identifies study-size and sponsorship limitations where material, and avoids treating broad categories such as “probiotics”, “postbiotics” or “collagen” as uniform interventions. This is necessary to preserve scientific balance and to prevent clinical evidence from being converted into claims broader than the tested preparation, population or endpoint.

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