Jurnal Pharmascience, Volume 13, Issue 1, March 2026, page: 23-40
ISSN-Print 2355 – 5386
ISSN-Online 2460-9560
https://dx.doi.org/10.20527/jps.v13i1.22558
Review Article

Effectiveness Probiotics as Anti-Aging for Facial Skin: A Systematic Review

Efektivitas Probiotik sebagai Anti Penuaan Dini untuk Kulit Wajah: Tinjauan Sistematis

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ABSTRACT

Premature skin aging is increasingly prevalent among individuals in their mid-20s to 30s, influenced by genetic, lifestyle, and environmental factors. Probiotics have emerged as a promising natural intervention to address this issue. This systematic review aimed to evaluate the effectiveness of oral and topical probiotics in preventing and managing signs of premature skin aging. A systematic search of PubMed and Scopus was conducted for Randomized Controlled Trials (RCTs) published between 2020 and 2025, using PICO-based inclusion and exclusion criteria. Methodological quality was assessed with the JBI checklist. Of 202 articles screened, eight RCTs were included. Results showed that oral probiotics improved skin quality by enhancing collagen production (24%), hydration (18%), and antioxidant activity, while topical probiotics reduced wrinkles (22%) and increased skin density (15%). In conclusion, oral and topical probiotics represent effective dual strategies for combating premature skin aging, though further studies are needed to optimize strain-specific formulations.

Keywords: Lactic-Acid Bacteria, Gut–Skin Modulation, Probiotics, Rejuvenation, Skin Microbiota

ABSTRAK

Penuaan kulit dini semakin sering terjadi pada individu berusia 20-an akhir hingga 30-an, yang dipengaruhi oleh faktor genetik, gaya hidup, dan lingkungan. Probiotik muncul sebagai intervensi alami yang menjanjikan untuk mengatasi masalah ini. Tinjauan sistematis ini bertujuan untuk mengevaluasi efektivitas probiotik oral dan topikal dalam mencegah serta mengelola tanda-tanda penuaan kulit dini. Pencarian sistematis dilakukan

pada basis data PubMed dan Scopus untuk Randomized Controlled Trials (RCT) yang diterbitkan antara tahun 2020 hingga 2025, dengan menggunakan kriteria inklusi dan eksklusi berbasis PICO. Kualitas metodologis dinilai menggunakan daftar periksa JBI. Dari 202 artikel yang disaring, delapan RCT memenuhi kriteria untuk dianalisis. Hasil penelitian menunjukkan bahwa probiotik oral meningkatkan kualitas kulit dengan meningkatkan produksi kolagen (24%), hidrasi (18%), dan aktivitas antioksidan, sementara probiotik topikal mengurangi kerutan (22%) dan meningkatkan densitas kulit (15%). Sebagai kesimpulan, probiotik oral dan topikal merepresentasikan strategi ganda yang efektif untuk melawan penuaan kulit dini, meskipun penelitian lebih lanjut diperlukan untuk mengoptimalkan formulasi spesifik berdasarkan strain.

Kata Kunci: Anti-Penuaan, Bakteri Asam Laktat, Mikrobioma Kulit, Peremajaan Wajah, Probiotik Fermentasi

I. INTRODUCTION

The aging process is divided into intrinsic factors (cellular aging and decreased collagen production), as well as extrinsic influences, (UV exposure, pollution, and an unhealthy lifestyle) (Bay & Topal, 2022; Chambers & Vukmanovic-Stejic, 2020); (He et al., 2024; Taghupia et al., 2024). which elevate oxidative stress and accelerate visible aging (Greener, 2025; Hussein et al., 2024).

Globally, 22% will be over 60 years old by 2050, including 426 million people aged 80 and above (Navaneetham & Arunachalam, 2022; World Health Organization, 2024). Global life expectancy averaged 72.5 years (2015-2020), with disparities between developed (>84 years) and developing (≈50 years) nations (Cambois et al., 2023). Climate impacts skin aging: tropical regions face year-round UV-induced photoaging (hyperpigmentation, wrinkles) (Cadet et al., 2020) while in four-season countries, lifestyle factors such as stress, obesity can triggers of skin aging (Bhurosy & Jeewon, 2014; Darlenski et al., 2022; M. Liu & Feng, 2023).

Facial aging involves cellular/molecular changes affecting skin, bone, fat, and muscle (Chin et al., 2023). These lead to extracellular matrix degradation, impaired skin regeneration, and clinical manifestations like thinning, wrinkles, and dryness (Bagdare & Vinchurkar, 2024; Wyles et al., 2024). Primary indicators include reduced elasticity, prominent wrinkles, and uneven pigmentation.

Various anti-aging approaches now combine scientific and natural treatments (Jahan et al., 2024). Probiotics have gained prominence for maintaining microbiota balance (Basnet et al., 2024; Costa Alves et al., 2024; Dobriyal et al., 2024; H. Lee et al., 2024). Acting through the gut-skin axis

to reduce inflammation and boost antioxidants. Their ability to enhance collagen, combat oxidative stress, and improve hydration positions them as sustainable anti-aging solutions (Gao et al., 2023; Taufiqurrahman et al., 2024).

Clinical studies confirm probiotics anti-aging effects, *Micrococcus luteus Q24* serum boosted hydration by 101% and reduced wrinkles in 25 days (McLoughlin et al., 2024). Probiotics combat photoaging via antioxidant and collagen-boosting mechanisms (Teng et al., 2022). *Lactiplantibacillus plantarum LB244R* improved skin density and elasticity in postmenopausal women (Falholt Elvebakken et al., 2023). Despite promising results, well-structured Randomized Controlled Trials (RCTs) are needed to provide conclusive evidence on probiotics long-term benefits. Purpose of this systematic review was to synthesize and critically evaluate current Randomized Controlled Trials (RCTs) on oral and topical probiotics for premature skin aging, in order to determine their effectiveness and highlight research gaps. Well-structured RCTs are still needed to provide conclusive evidence on the long-term benefits of probiotics in skin aging management.

II. METHOD

A. Literature Screening

This systematic review evaluated probiotics' effectiveness as facial skin anti-aging treatment following PRISMA guidelines (Page et al., 2021). English literature (2020-2025) was searched in PubMed, Scopus, and Google Scholar using keywords including "probiotic," "aging," "anti-aging," "facial skin," "microbiome," "randomized controlled trial," "clinical trial," "facial aging," "skin aging," "gut microbiota," "oral probiotic," "topical probiotic" combined with Boolean operators. AND, OR, NOT for more specific results. Studies were filtered based on facial skin health focus and independently analyzed for relevant skin condition parameters.

B. Data Collection and PICO-Based Extraction

Studies were included if they: (1) were published in English between 2020–2025, (2) were randomized controlled trials (RCTs) or double-blind studies, (3) investigated the effects of oral or topical probiotics on facial skin aging, and (4) reported measurable outcomes such as wrinkle reduction, skin hydration, elasticity, or collagen levels. Exclusion criteria were: (1) studies not involving probiotics, (2) research focused on non-facial skin or systemic diseases unrelated to aging, (3) reviews, case reports, or

observational studies, and (4) articles without accessible full text.

C. Data Collection and PICO-Based Extraction

Following PRISMA protocol (Page et al., 2021), studies were systematically analyzed and extracted using PICO framework (Calderon Martinez et al., 2024). Population (P) included adults with aging skin signs. Intervention (I) comprised oral probiotics, topical formulations, or combinations. Comparison/Control (C) used placebo or standard non-probiotic treatments in RCTs and double-blind studies. Outcomes (O) measured wrinkle reduction, skin hydration, collagen levels, and elasticity. Results were discussed among authors and synthesized to assess probiotic strain effectiveness on skin improvement parameters.

D. Risk of Bias Assesment

Study quality was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal List for RCTs (Barker et al., 2023), to minimize bias risk. The assessment evaluated 13 keys criteria including: randomization methods, allocation concealment, baseline group similarities, blinding of participants and assessors, treatment consistency, follow-up completeness, analysis integrity, outcome measurement reliability, statistical analysis appropriateness, and trial design adequacy.

E. Selected Study

Database searches identified 202 articles (PubMed: 14, Scopus: 68, Google Scholar: 120). After excluding 5 non-English articles and 5 duplicates, 192 remained. Further screening eliminated 174 articles lacking RCT design, irrelevant focus, or limited to in vitro/in vivo studies. Full-text review of 13 articles led to 5 more exclusions, leaving 8 for final risk-of-bias assessment. (Figure 1).

F. Risk of Bias Statement

The risk of bias assessment in 8 studies showed that all included studies had no significant impact on the risk of bias. The primary outcome measures used are valid, reliable, and suitable for further analysis (Table I).

Quality assessment used a scoring system where "Yes" answers scored 1 point (criteria met), "No" answers 0 points (criteria not met), and unclear reporting 0 points (or 0.5 for partial compliance). "N/A" criteria were not scored to ensure relevance. Final scores determined study inclusion, exclusion, or need for additional information.

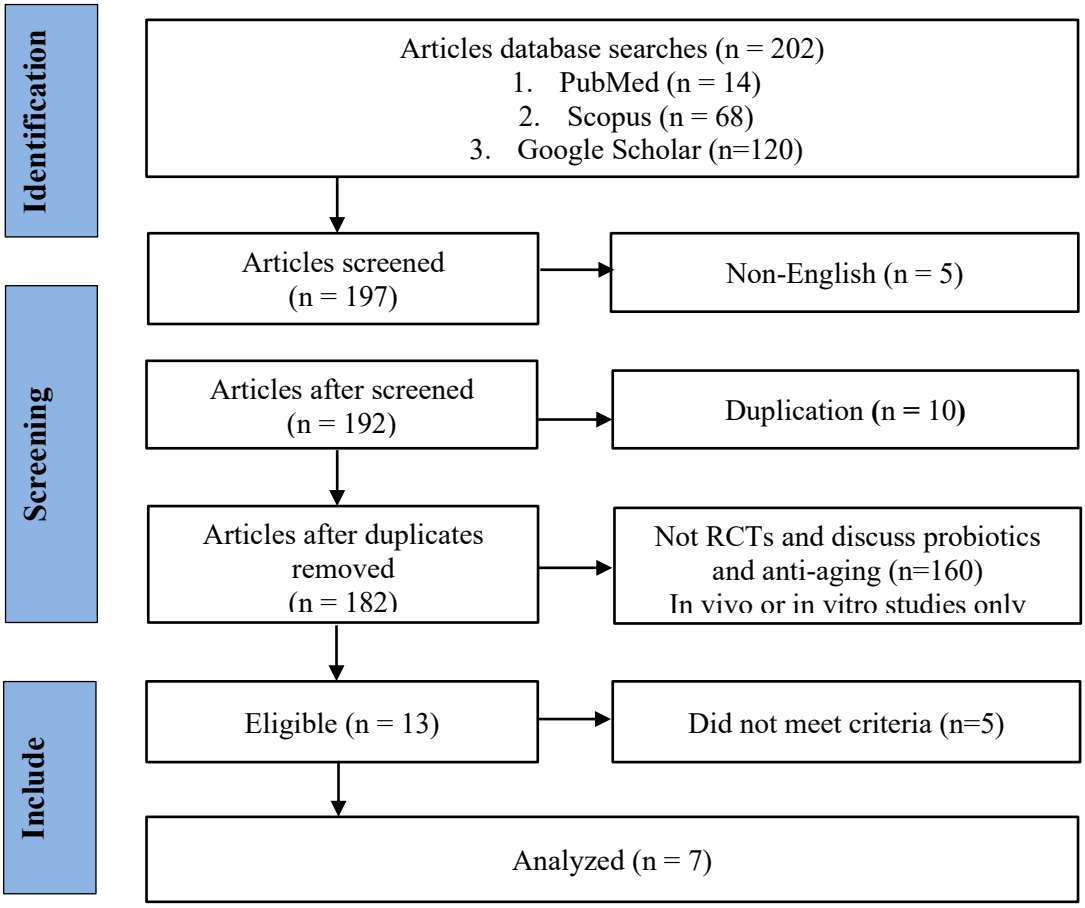

Figure 1. PRISMA flow diagram

Table I. Risk of bias

Indicator Risk of Bias	**Author List**						
	(C. Liu et al., 2022)	(Elveb-akken et al., 2024)	(Fei et al., 2024)	(Huusk-onen et al., 2022)	(Majeed et al., 2023)	(M. Lee et al., 2023)	(S. W. Lee et al., 2022)
Number of Article	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(8)**
True Randomization	+	+	+	+	+	+	+
Allocation Concealment	+	+	+	+	+	+	+
Blinding of Participants	+	+	+	+	+	+	+
Blinding of Outcome Assessors	+	+	+	+	+	+	+
Completeness of Follow-Up	+	+	+	+	+	+	+
Appropriateness of Statistical Analysis	+	+	+	+	+	+	+
Trial Design Adequate	+	+	+	+	+	+	+

(+) = Yes; (-) = Unclear; (X) = N/A

III. RESULTS AND DISCUSSION

This systematic review of 8 studies (7 genus, 8 strains: 4 oral, 4 topical) revealed significant anti-aging effects across 7 skin parameters (Table II).

A. Collagen Production

Streptococcus thermophilus TCI633 enhanced collagen synthesis and dermal integrity (C. Liu et al., 2022). Probiotics act through positive regulation, as SCFA metabolites penetrate the dermis and stimulate fibroblasts, activating TGF-β signaling and upregulating COL1A1/COL3A1 gene expression (Kanmani & Kim, 2022; Y. Liu et al., 2021; Hong et al., 2022). This cascade strengthens collagen fiber density and integrity, effectively counteracting age-related structural degradation.

B. Elasticity

Topical *Lactiplantibacillus plantarum* LB244R® and *Lacticaseibacillus rhamnosus* IDCC 3201 improved skin elasticity (Elvebakken et al., 2024; M. Lee et al., 2023). Probiotics protect skin firmness by inhibiting MMP-1 and MMP-9, thereby reducing collagen/elastin breakdown (Huuskonen et al., 2023). Additionally, they promote hyaluronic acid synthesis via microbiota-mediated signaling (Al-Smadi et al., 2023; Galla et al., 2025), supporting dermal hydration and elasticity.

C. Wrinkle Reduction

Wrinkle reduction was consistently reported with *Streptococcus thermophilus* TCI633, *Bifidobacterium animalis* subsp. *lactis* Bl-04, and *Lacticaseibacillus rhamnosus* IDCC 3201 (C. Liu et al., 2022; Huuskonen et al., 2022; M. Lee et al., 2023). Mechanistically, probiotics neutralize free radicals by upregulating antioxidant enzymes (SOD, catalase, glutathione peroxidase) (Feng & Wang, 2020; C. Liu et al., 2022) and suppress pro-inflammatory cytokines such as IL-6 and TNF-α (Mazziotta et al., 2023; Thoda & Touraki, 2023), reducing oxidative stress and extracellular matrix degradation.

D. Hydration & Barrier Function

Oral *Bacillus coagulans* MTCC 5856 (LactoSporin) and *Streptococcus thermophilus* TCI633 improved hydration (C. Liu et al., 2022; Majeed et al., 2023). Topical *Lactiplantibacillus plantarum* LB244R®, *Lactobacillus plantarum* GT-17F, and *Lacticaseibacillus rhamnosus* IDCC 3201 also enhanced skin moisture (Fei et al., 2024; M. Lee et al., 2023). Mechanistically, probiotics upregulate aquaporin and filaggrin (Kim et al., 2021; Dou et al., 2023), improve stratum corneum lipids, and reduce TEWL (Cui et al., 2023). SCFAs such as butyrate strengthen tight junctions, improving barrier resilience

(Srivastav et al., 2019; Trompette et al., 2022).

E. Skin Brightness & Inflammation

Streptococcus thermophilus TCI633 improved skin brightness, while topical *Lactiplantibacillus plantarum* LB244R® enhanced complexion radiance (C. Liu et al., 2022; Elvebakken et al., 2024). Topical *Lactobacillus plantarum* GT-17F reduced erythema (Fei et al., 2024), while *Lactobacillus plantarum* JBMI F5 (BB-1000) improved skin transparency (S. W. Lee et al., 2022). Probiotics regulate skin tone by inhibiting NF-κB signaling and modulating melanogenesis, thereby reducing hyperpigmentation and age spots (Cristofori et al., 2021; Kober & Bowe, 2015; Park et al., 2024; Tsai et al., 2021; Wu et al., 2023).

F. Antioxidant Effects

Streptococcus thermophilus TCI633 demonstrated significant antioxidant activity (C. Liu et al., 2022). Probiotics enhance the body's antioxidant defense through the activation of nuclear factor erythroid 2–related factor 2 (Nrf2), a transcription factor protein that regulates antioxidant response element (ARE)-driven genes. Nrf2 activation upregulates antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase, thereby reducing reactive oxygen species (ROS) and protecting DNA, proteins, and lipids from oxidative damage (Averina et al., 2021; Petrariu et al., 2023; Wang et al., 2017). Probiotics indirectly stimulate Nrf2 pathways by modulating gut microbiota, which release metabolites such as short-chain fatty acids that trigger host antioxidant signaling. Although oral probiotics rarely become permanent members of the gut microbiome, they exert transient colonization and functional modulation of gut ecosystems, thereby strengthening systemic antioxidant capacity and slowing molecular-level skin aging.

Key findings include oral *Streptococcus thermophilus TCI633* (C. Liu et al., 2022) while topical *Lactiplantibacillus plantarum LB244R*® improved dermal density (Elvebakken et al., 2024). Elasticity improved with Heat-killed *Fructobacillus fructosus OS-1010* (Nishikawa & Idogaki, 2024), topical *Lactiplantibacillus plantarum LB244R*® and *Lacticaseibacillus rhamnosus IDCC 3201* (Elvebakken et al., 2024; M. Lee et al., 2023).

Wrinkle are reported reduced in all studies specially in *Streptococcus thermophilus TCI633* (C. Liu et al., 2022) *Bifidobacterium animalis subsp. lactis Bl-04* and *Lacticaseibacillus rhamnosus IDCC*

3201 (Huuskonen et al., 2022; M. Lee et al., 2023).

Hydration and barrier function improved with *Bacillus coagulans MTCC 5856* (LactoSporin) and *Streptococcus thermophilus TCI633* (C. Liu et al., 2022; Majeed et al., 2023). Skin moisture and protection, was reported using topical probiotic *Lactiplantibacillus plantarum LB244R®*, *Lactobacillus plantarum GT-17F and Lacticaseibacillus rhamnosus IDCC 3201* (Fei et al., 2024; M. Lee et al., 2023).

Skin brightness and inflammation reduction were also reported using *Streptococcus thermophilus TCI633* (C. Liu et al., 2022) and complexity radiance by using topical probiotic *Lactiplantibacillus plantarum LB244R®* (Elvebakken et al., 2024), decrease in erythema area using *Lactobacillus plantarum GT-17F* for 8 weeks (Fei et al., 2024) and skin transparency using oral topical *Lactobacillus plantarum JBMI F5 (BB-1000)* (S. W. Lee et al., 2022). Skin antioxidant activity, highly significant increases in *Streptococcus thermophilus TCI633* (C. Liu et al., 2022).

This systematic review assessed probiotics anti-aging effects using high-quality RCTs with low risk of bias (Table I). Emerging research demonstrates probiotics exert clinically meaningful anti-aging effects through multiple biological pathways: gut-skin axis modulation, immune regulation, antioxidant enhancement, and epidermal barrier support, confirming benefits extend beyond superficial cosmetic improvements.

Probiotics enhance collagen production by upregulating COL1A1/COL3A1 genes and activating TGF-β signaling (Kanmani & Kim, 2022). his process is driven by probiotic metabolites like SCFAs (Y. Liu et al., 2021) that reach the dermis to stimulate fibroblasts (Hong et al., 2022). By improving collagen fiber density and integrity, probiotics effectively counteract age-related skin structural degradation.

Skin elasticity depends on collagen/elastin balance. Probiotics inhibit MMP-1 and MMP-9 (Huuskonen et al., 2023), reducing collagen/elastin degradation, while boosting hyaluronic acid (HA) via microbiota-mediated epidermal signaling (Al-Smadi et al., 2023; Galla et al., 2025). maintaining firmness and delaying sagging.

For wrinkles, probiotics neutralize free radicals by upregulating antioxidant enzymes (SOD, catalase, glutathione peroxidase) (Feng & Wang, 2020; C. Liu et al., 2022), and suppress pro-inflammatory cytokines (IL-6, TNF-α) (Mazziotta et al., 2023; Thoda & Touraki, 2023), reducing oxidative stress and matrix degradation.

This improves skin texture and diminishes wrinkles.

Probiotics enhance the skin barrier by upregulating filaggrin and aquaporin (Dou et al., 2023; Kim et al., 2021) and improving stratum corneum lipids, and reducing trans-epidermal water loss (TEWL) (Cui et al., 2023). This effect is mediated by SCFAs like butyrate, which strengthens tight junctions (Srivastav et al., 2019; Trompette et al., 2022) resulting in more hydrated, resilient, and healthier-looking skin.

Chronic inflammation contributes to skin aging, but probiotics regulate immunity by inhibiting the NF-κB pathway, reducing pro-inflammatory molecules (Cristofori et al., 2021; Kober & Bowe, 2015). This results in brighter, more even-toned skin with reduced hyperpigmentation. Certain probiotic strains also modulate melanogenesis, improving skin tone and diminishing age spots (Park et al., 2024; Tsai et al., 2021; Wu et al., 2023).

Probiotics enhance the body's antioxidant defense by boosting Nrf2 levels, which regulates antioxidant genes, and reduces reactive oxygen species (ROS) by improving gut microbiota. This helps decrease oxidative damage to DNA, proteins, and lipids in the skin, thereby slowing molecular-level aging.(Averina et al., 2021; Petrariu et al., 2023; Wang et al., 2017).

This study has several limitations that should be acknowledged. First, the search relied on a limited number of databases and restricted access to full-text articles, which may have introduced selection bias and limited the comprehensiveness of the evidence base. Second, most included interventions were short in duration (4–12 weeks), restricting the ability to assess the long-term efficacy and safety of probiotic use in skincare. Additionally, substantial variability was observed in probiotic strains, dosages, formulations, and delivery methods, making direct comparisons across studies challenging and potentially influencing the consistency of reported outcomes. Differences in study design, population characteristics, and outcome measures may also contribute to heterogeneity and limit generalizability.

Future studies should explore probiotics anti-aging mechanisms (collagen/elastin/antioxidant effects) and long-term efficacy/safety for oral and topical use. Research should include diverse populations, combination therapies, product interactions, lifestyle factors, and cost-benefit analyses.

Table II. Outcome study

Authors, year	Population	Intervention	Control	Outcomes	Mechanism of Action
(C. Liu et al., 2022) **(1)**	30 healthy subjects, 35–55 yo. with visible wrinkles, dry skin, and pigmentation;	Oral intake Of *Streptococcus thermophilus (TCI633)* capsules, two tablets daily for 8 weeks	Placebo capsules	Collagen +20.7% Elasticity +11.4% Wrinkles −21.6% Crow's feet −32.8% Moisture +12.8% Texture −14.2% Pores −12% Brightness +3.4% Spots −4.6% SOD +3.1% Catalase +135.2%	↑ Collagen via TGF-β & COL1A1/3A1; Antioxidant (Nrf2–ROS); Barrier support (SCFAs).
(Elvebakken et al., 2024) **(2)**	46 healthy postmenopausal females, 40–65 yo., fitzpatrick skin phototype II and III, sensitive skin, no active skin diseases	Topical application of *Lactiplantibacillus plantarum* LB244R® ointment applied twice daily (morning and evening) for 56 days	Vehicle placebo ointment	Collagen fiber perimeter +15.9% Collagen fiber density +12.7% Dermal density +20.1% Elasticity +16.4% Firmness −11.1% Wrinkle score −4.9% SLEB thickness −13.1% Smoothness +11.4% Hydration +66.7% TEWL −7.2% Radiance +15.9% pH +11.1% Spot score −6.9%	Collagen remodeling; Barrier strengthening; Anti-inflammatory.
(Fei et al., 2024) **(3)**	99 healthy females, 30–60 yo., visible wrinkles (grade 3-5), no skin diseases, no chronic diseases, non-pregnant	Topical application of *Dendrobium officinale* fermented with *Lactobacillus plantarum* GT-17F applied twice daily (morning	Unfermented D. officinale extract and placebo	Wrinkle area −22.9% Wrinkle proportion −24.8% Elasticity +9.3% Hydration +12.6% TEWL −16.4% Erythema area −12.4% Erythema proportion −14.7%	Wrinkle reduction (ROS ↓); Barrier repair; Anti-inflammatory.

Authors, year	Population	Intervention	Control	Outcomes	Mechanism of Action
		and evening) for 28 days			

Authors, year	Population	Intervention	Control	Outcomes	Mechanism of Action
(Huuskonen et al., 2022) **(4)**	148 Healthy females, 33–60 yo., dry skin (cheek hydration <48 AU), visible facial wrinkles, no acute or chronic skin disease, non-pregnant 148	Oral intake of Bifidobacterium animalis subsp. lactis Bl-04 capsules 1.75×10^9 CFUs per day (oral capsule) for 12 weeks	Placebo capsules	Wrinkle depth +2.3% Wrinkle area −0.1% Wrinkle volume +2.2% Cheek hydration +0.8%	Mild hydration via microbiota modulation.
(Majeed et al., 2023) **(5)**	56 healthy females, 35–65 yo., visible facial fine lines and wrinkles, no active skin disease or allergy, non-pregnant	Topical application of LactoSporin (2% LactoSporin cream applied twice daily morning and night) for 10 weeks	Placebo cream	Crow's feet wrinkles −22.2% Nasolabial folds −13.7%; Frown lines −18.9% Fine lines −15.7% Texture −14.2% Firmness/Elasticity +12.1% Hydration +25.1%	Antioxidant peptides; Collagen support; Barrier repair.
(M. Lee et al., 2023) **(6)**	24 female participants (45.46 ± 9.78 yo.) for TEWL measurement for 5 days and 21 female participants (50.33 ± 5.7	Topical application of Cera-Glow cream containing Lacticaseibacillus rhamnosus IDCC 3201 for 5 days (TEWL	Untreated control skin	Wrinkle depth +2.3% Wrinkle volume +2.2% Hydration +34.2% TEWL improvement +74.9 Skin barrier recovery +39.1%	Hydration ↑ (aquaporin); Barrier recovery (SCFAs).

Authors, year	Population	Intervention	Control	Outcomes	Mechanism of Action
	4 years) for a skin hydration evaluation for 4 weeks	study) and 4 weeks (hydration study) applied twice daily in morning and evening			
(Nishikawa & Idogaki, 2024)	60 healthy males and females, 30–59 yo. concerned with dry and rough skin, no chronic diseases, non-pregnant	Oral intake of heat-killed *Fructobacillus fructosus* OS-1010 tablets 1.75 × 10^9 CFUs per day (oral capsule) for 8 weeks	Placebo tablets		-
(S. W. Lee et al., 2022) **(7)**	102 healthy males and females, 35–59 yo. with dry skin and clear wrinkles, wrinkle score grade ≥3 (KFDA standard), no acute skin diseases	Oral intake of BB-1000 (fermented blackberry by Lactobacillus plantarum JBMI F5) at 800 mg/day for 12 weeks	Placebo capsules	Wrinkle area −26.8% Pore area −22.1% Elasticity +11.5% Moisture +12.7% Gloss +36.5% Translucency +16.7%	Antioxidant activity; Barrier support; Skin tone regulation.

(+) = increase; (-) = decrease; CFUs: Colony-Forming Units; SLEB: Subepidermal Low Echogenic Band; SOD: Superoxide Dismutase; TEWL: Trans-epidermal Water Loss

IV.CONCLUSION

Probiotics show significant potential as active ingredients in anti-aging skincare, with oral supplementation improving skin hydration and elasticity, while topical applications demonstrate greater effects on wrinkle reduction, skin density, and brightness. These outcomes highlight their clinical relevance in addressing key aspects of skin aging through complementary mechanisms. Pharmacists play a central role in translating these benefits into safe and effective products by ensuring probiotic stability, optimizing delivery systems, and integrating compatible formulations. Looking forward, further clinical trials with standardized protocols are needed to validate long-term efficacy, elucidate underlying mechanisms, and explore personalized approaches to probiotic-based skincare. Collectively, the evidence positions probiotics as promising agents in advancing both cosmetic and therapeutic strategies for skin health.

CONFLICT OF INTEREST

All authors declare that there is no conflict of interest in this research.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to all those who have supported and contributed to this research. Special thanks to everyone who provided valuable assistance and encouragement during the research.

AUTHORS' CONTRIBUTIONS

AN and RW were involved in concepting and planning the research, AN and PS performed the data acquisition/collection, AN, RW and PS calculated the experimental data and performed the analysis, AN drafted the manuscript and designed the figures. All authors took parts in giving critical revision of the manuscript.

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