Journal of Medicinal Plants Studies
www.PlantsJournal.com

ISSN (E): 2320-3862
ISSN (P): 2394-0530
Impact Factor (RJIF): 5.94
www.plantsjournal.com
JMPS 2025; 13(5): 16-22

Received: 14-07-2025
Accepted: 18-08-2025

Muskan Kumari
Rapture Biotech International Pvt. Ltd., Noida, Uttar Pradesh, India

Vinod Kumar Gupta
Rapture Biotech International Pvt. Ltd., Noida, Uttar Pradesh, India

Kiran Yadav
Miko Biotech, Noida, Uttar Pradesh, India

Aniket Mishra
Miko Biotech, Noida, Uttar Pradesh, India

Corresponding Author:
Aniket Mishra
Miko Biotech, Noida, Uttar Pradesh, India

Niacinamide in dermatology: A multifunctional agent for anti-ageing and skin barrier support

Muskan Kumari, Vinod Kumar Gupta, Kiran Yadav and Aniket Mishra

DOI: https://www.doi.org/10.22271/plants.2025.v13.i5a.1930

Abstract
Skin ageing is a complex biological process characterized by structural and functional deterioration of cutaneous tissues, manifesting as wrinkles, fine lines, age spots, and loss of elasticity. This comprehensive review examines the role of niacinamide (vitamin B3) in addressing multiple aspects of skin ageing through analysis of current literature from 1995-2024. Niacinamide demonstrates multifaceted anti-ageing effects including enhanced collagen synthesis, improved barrier function, reduced hyperpigmentation, and protection against oxidative stress. Clinical studies consistently show significant improvements in ageing signs with 2-5% niacinamide concentrations applied topically. The evidence supports niacinamide as an effective, well-tolerated ingredient for comprehensive anti-ageing skincare with excellent safety profile and compatibility with other therapeutic agents.

Keywords: Niacinamide, anti-ageing, vitamin B3, barrier function, hyperpigmentation, photoageing

Introduction
One of the most obvious indicators of human aging is skin aging, which affects appearance, skin function, and general quality of life [1]. The global anti-ageing skincare market, valued at over $58 billion annually, reflects the significant demand for effective anti-ageing solutions.
Ageing occurs through intrinsic processes driven by genetic factors and cellular senescence, and extrinsic factors primarily caused by ultraviolet radiation and environmental damage [2]. These processes result in characteristic changes, including wrinkles, fine lines, uneven pigmentation, reduced elasticity, and compromised barrier function. Niacinamide, the amide form of niacin (vitamin B3), has emerged as a scientifically validated anti-ageing ingredient with proven efficacy across multiple ageing parameters [3]. In contrast to many substances that only target one route, niacinamide has pleiotropic actions that address many signs of skin aging at once. [4]. Its appeal stems from proven clinical efficacy, excellent safety profile, broad applicability across skin types, and compatibility with other anti-ageing agents. The water-soluble nature, chemical stability, and lack of photosensitising properties make niacinamide ideal for diverse formulation applications.

Mechanisms of Skin Ageing
Structural Changes in Ageing Skin
Ageing skin undergoes progressive structural alterations affecting all layers [5]. The epidermis shows decreased thickness, reduced keratinocyte proliferation, and compromised barrier function due to altered lipid composition and reduced natural moisturising factors. The dermal-epidermal junction flattens, reducing mechanical stability and nutrient exchange. Most dramatically, the dermis experiences significant collagen loss at approximately 1% per year after age 30, with decreased synthesis and increased degradation by matrix metalloproteinases (MMPs) [6]. Elastin fibers undergo degradation and abnormal accumulation, particularly in photoaged skin, while hyaluronic acid content decreases substantially, reducing dermal volume and hydration.

Molecular Mechanisms of Ageing
Skin ageing involves multiple interconnected molecular pathways [7]. Genomic instability accumulates from UV radiation and oxidative stress, leading to mutations and cellular dysfunction. Advanced glycation end products (AGEs) form through non-enzymatic protein glycation, cross-linking collagen and elastin fibres and reducing skin flexibility [8]. Chronic low-grade inflammation (inflammageing) characterized by elevated pro-inflammatory

cytokines, promotes tissue degradation and impairs repair mechanisms [9]. Cellular senescence results in the accumulation of non-dividing cells that secrete inflammatory factors, creating a tissue microenvironment that accelerates ageing processes [10].

Hormonal and Environmental Factors

Hormonal changes, particularly estrogen decline during menopause, significantly accelerate skin ageing by reducing collagen synthesis and compromising barrier function. Environmental factors, especially UV radiation, generate reactive oxygen species that overwhelm antioxidant defences, causing cumulative cellular damage to DNA, proteins, and lipids [11]. Pollution, tobacco use, and lifestyle choices additionally exacerbate oxidative stress and hasten the ageing process. These external factors can surpass the natural ageing mechanisms, responsible for as much as 90% of the visible signs of ageing in areas exposed to sunlight.

Niacinamide: Biochemical Properties and Mechanisms

Chemical Structure and Properties

Nicotinic acid's amide form, niacinamide ($C_6H_6N_2O$), has a molecular weight of 122.12 g/mol. Its small size and amphiphilic properties facilitate penetration through the stratum corneum. The compound demonstrates excellent stability across pH 5.0-7.0, high water solubility (>500 mg/mL), and resistance to oxidation and photo degradation. These properties make niacinamide suitable for various formulation conditions while maintaining efficacy. Topical application studies show efficient penetration into all skin layers, with the highest concentrations achieved in the epidermis and sustained dermal levels for 8-12 hours.

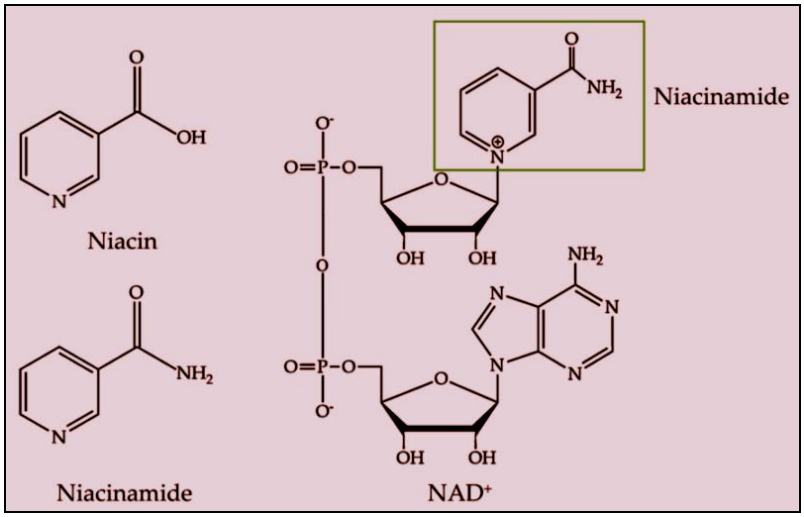

Fig 1: The vitamin B3 complex's niacin and niacinamide molecular structures and their molecular constitutive function in NAD+ production

Cellular Uptake and NAD+ Metabolism

Niacinamide enters cells through nucleoside transporters and is rapidly converted to nicotinamide adenine dinucleotide (NAD+) via the salvage pathway [12]. This conversion involves nicotinamide phosphoribosyl transferase (NAMPT) and nicotinamide mononucleotide adenylyl transferase (NMNAT) enzymes [13]. NAD+ serves as a coenzyme in over 500 enzymatic reactions essential for cellular metabolism, DNA repair, and gene regulation. Age-related NAD+ decline contributes to cellular dysfunction, making niacinamide supplementation particularly relevant for ageing skin [14]. NAD+ supports sirtuin activity, poly (ADP-ribose) polymerase (PARP) function, and various metabolic processes crucial for cellular health and longevity.

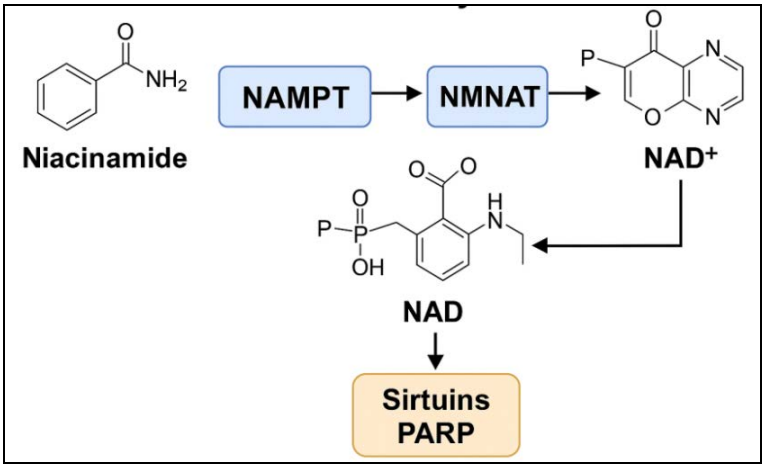

Fig 2: Conversion of Niacinamide to NAD+ via Salvage Pathway.

Anti-Ageing Mechanisms

Niacinamide combats skin aging by employing various mechanisms. It stimulates collagen synthesis by enhancing fibroblast proliferation and increasing procollagen gene expression while inhibiting matrix metalloproteinases that degrade existing collagen. The compound improves barrier function by stimulating ceramide synthesis and enhancing production of structural proteins including filaggrin and

involucrin [15]. Niacinamide exhibits anti-inflammatory effects by inhibiting NF-κB activation and reducing pro-inflammatory cytokine production. It enhances DNA repair capacity through PARP activation and supports cellular antioxidant defenses by maintaining NAD+ levels required for antioxidant enzyme function.

Clinical Evidence for Anti-Ageing Effects

Collagen Synthesis and Wrinkle Reduction

Clinical studies consistently demonstrate niacinamide's ability to stimulate collagen synthesis and reduce wrinkles. Research has shown that 5% niacinamide applied twice daily for 12 weeks significantly improved fine lines (23% reduction), wrinkles (18% reduction), and skin elasticity (16% improvement) compared to placebo [4]. Molecular studies confirm increased mRNA expression for collagen types I and III, indicating enhanced synthesis at the transcriptional level. Long-term studies extending to 24 weeks show continued improvement with increased dermal thickness and enhanced collagen organisation. The effects are dose-dependent, with concentrations between 2%-5% showing optimal efficacy for anti-ageing applications.

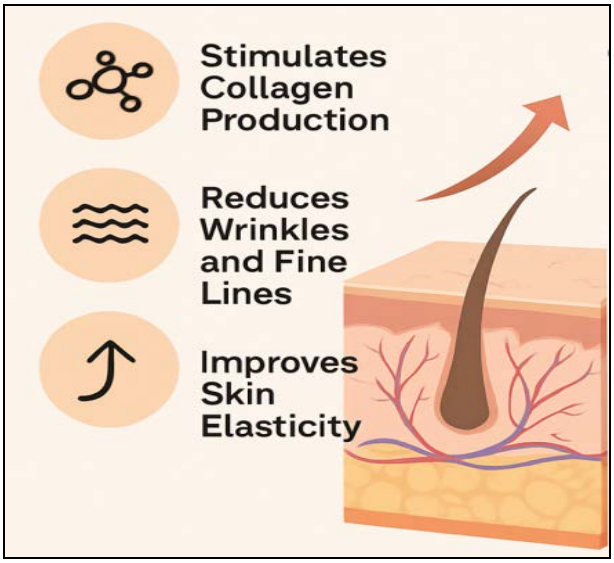

Fig 3: Effect of Niacinamide in Ageing

Barrier Function Enhancement

Niacinamide significantly improves epidermal barrier function through multiple mechanisms. Research has demonstrated that 2-5% niacinamide increases ceramide synthesis by 34-67%, along with enhanced cholesterol and fatty acid synthesis [15]. Clinical studies show a 24% reduction in transepidermal water loss (TEWL) and 35% increase in stratum corneum hydration with 2% niacinamide treatment [16]. The compound stimulates production of barrier proteins including filaggrin, involucrin, and keratin, essential for barrier integrity. These improvements are particularly pronounced in aged skin, where barrier function is naturally compromised, leading to enhanced hydration, reduced irritation, and improved tolerance to other anti-ageing ingredients.

Hyperpigmentation Reduction

Niacinamide effectively addresses age-related hyperpigmentation through inhibition of melanosome transfer from melanocytes to keratinocytes. Research has demonstrated that 2% niacinamide reduces melanosome transfer by 35-68% without affecting melanocyte viability, selectively reducing hyperpigmented areas while maintaining normal skin pigmentation [17]. The mechanism involves protease-activated receptor 2 (PAR-2) pathway inhibition and weak tyrosinase inhibition. Clinical studies show significant improvement in age spots and overall skin tone evenness within 4-8 weeks of regular application [18]. This selective action provides effective depigmentation while preserving the photoprotective benefits of normal melanin distribution.

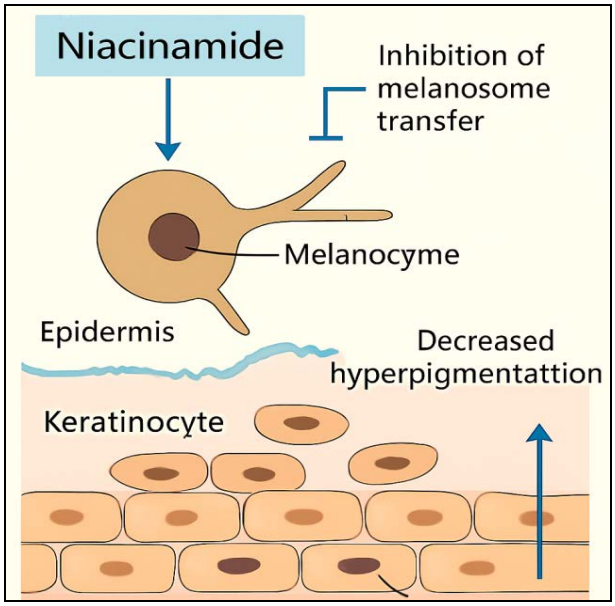

Fig 4: Reduction of Hyperpigmentation by Niacinamide.

Sebaceous Gland Regulation and Pore Appearance

Niacinamide enhances the appearance of pores and controls sebaceous gland activity, two issues that are frequently associated with aging skin. Draelos & Matsubara [19] demonstrated that 2% niacinamide reduces sebum production and improves pore appearance through regulation of sebaceous gland activity and enhanced keratinocyte turnover. The compound promotes cellular renewal leading, to smoother skin texture and refined pore appearance. These effects contribute to overall skin appearance improvement and may help prevent acne formation that can complicate anti-ageing treatments. The sebum-regulating effects are particularly beneficial for individuals with combination or oily skin types seeking anti-ageing benefits.

Safety Profile and Tolerability

Adverse Effects and Contraindications

Niacinamide demonstrates an excellent safety profile with minimal adverse effects reported in clinical studies [20]. The most commonly reported side effects are mild and transient, including slight skin irritation during initial use and temporary redness in sensitive individuals. These effects typically resolve within days to weeks as the skin adapts. Rare cases of contact dermatitis have been reported, primarily in individuals with pre-existing sensitivity. The compound has very few contraindications, with hypersensitivity to niacin or niacinamide being the primary concern. Patch testing is recommended for individuals with very sensitive skin, though reactions are uncommon.

Compatibility and Drug Interactions

Niacinamide shows excellent compatibility with most skincare ingredients, allowing incorporation into comprehensive anti-ageing regimens [21]. It is compatible with retinoids, alpha and beta hydroxy acids, vitamin C, peptides, and hyaluronic acid without concern for negative interactions. This compatibility is particularly valuable as it allows

combination with other proven anti-ageing ingredients for enhanced efficacy. Niacinamide does not promote photosensitivity, therefore it may be used during the day without raising any worries about sun sensitivity, unlike certain anti-aging substances. The compound is also safe during pregnancy and breastfeeding, making it suitable for use across diverse populations.

Formulation Considerations and Optimal Use

Concentration and Delivery

Lower concentrations (1-2%) provide modest benefits primarily for barrier function, while higher concentrations (>10%) may increase irritation risk without proportional efficacy gains. Various delivery systems enhance niacinamide's penetration and efficacy, including liposomal formulations for improved skin penetration, microencapsulation for stability and controlled release, and nanotechnology applications for enhanced delivery to deeper skin layers. The compound demonstrates good stability in cream, lotion, serum, and gel formulations, with an optimal pH range of 5.0-7.0 for maximum stability and efficacy.

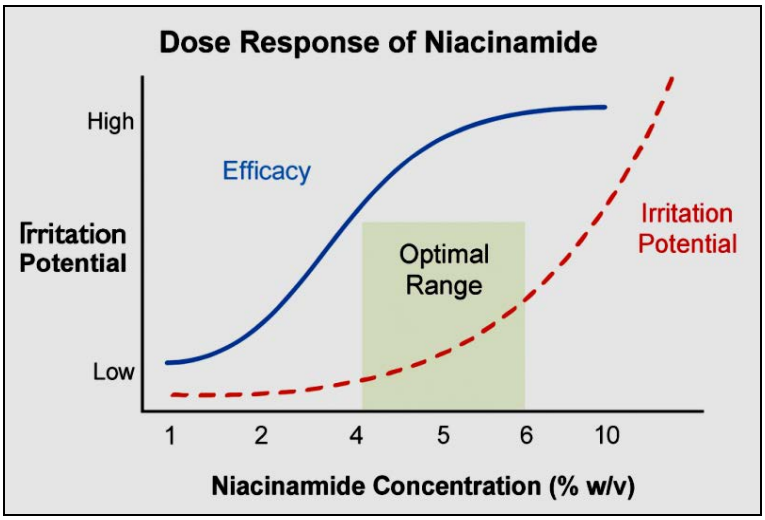

Fig 5: Dose-response curve with optimum range highlighted, illustrating niacinamide concentration (1-10%) vs effectiveness and irritation potential.

Treatment Protocols and Timeline

Effective niacinamide anti-ageing protocols typically involve twice-daily application for a minimum 8-12 weeks to achieve visible results. Initial improvements in barrier function and hydration may be observed within 2-4 weeks, while significant improvements in fine lines, pigmentation, and texture typically require 8-12 weeks of consistent use. Continued use maintains and enhances benefits, with some studies showing progressive improvement through 24 weeks. The compound is suitable for long-term use with maintained efficacy and no evidence of tolerance development. Treatment protocols can be individualised based on skin type, ageing concerns, and tolerance to optimise outcomes.

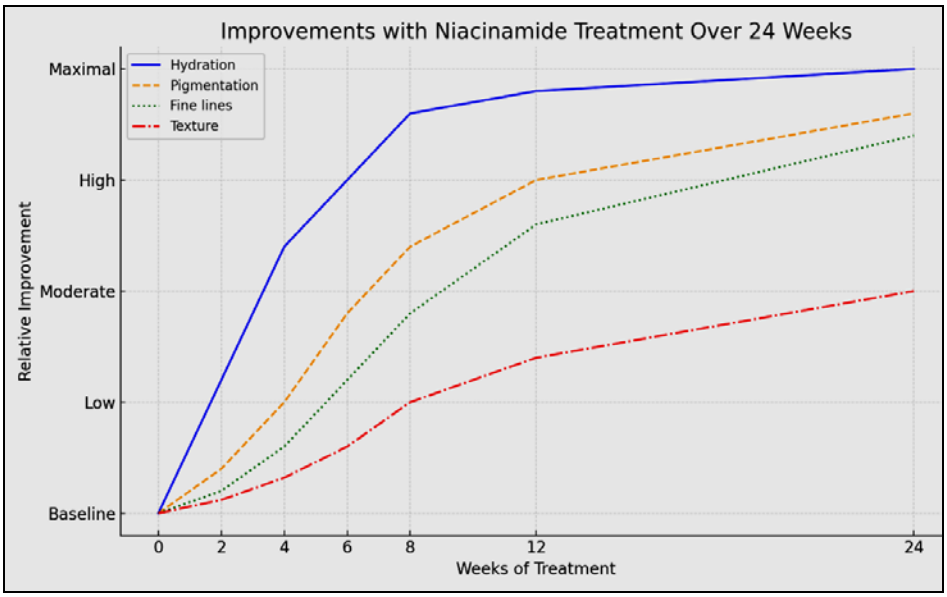

Fig 6: Treatment timeline chart showing expected improvements in different skin parameters (hydration, pigmentation, fine lines, texture) over 24 weeks of niacinamide treatment.

Comparative Analysis with Other Anti-Ageing Ingredients

Niacinamide vs. Retinoids

Retinoids remain the gold standard for anti-ageing treatments, but niacinamide offers several advantages [22]. Niacinamide demonstrates significantly better tolerability with minimal irritation potential compared to retinoids' common side effects of irritation, dryness, and peeling. Unlike retinoids,

niacinamide does not increase photosensitivity and can be used during pregnancy and breastfeeding. The two ingredients can be used synergistically, with niacinamide helping to reduce retinoid-associated irritation while providing complementary anti-ageing benefits. While retinoids may provide more dramatic results for severe ageing, niacinamide offers consistent, gentle improvement suitable for sensitive skin and long-term use.

Niacinamide vs. Vitamin C and Other Antioxidants

Niacinamide and vitamin C both provide antioxidant benefits, but through different mechanisms. Niacinamide demonstrates superior stability compared to most vitamin C forms, which are prone to oxidation and degradation. While vitamin C acts as a direct antioxidant, niacinamide supports cellular antioxidant systems and provides additional benefits, including barrier enhancement and anti-inflammatory effects. The two can be used together for comprehensive antioxidant protection, though some formulation considerations may apply. Niacinamide's anti-inflammatory properties and barrier benefits complement the direct antioxidant effects of vitamin C, alpha-lipoic acid, and other antioxidants.

Table 1: Comparative Analysis with Other Anti-Ageing Ingredients

Aspect	Niacinamide	Retinoids	Vitamin C & Other Antioxidants
Anti-Ageing Effectiveness	Gentle, consistent improvement; suitable for long-term use and sensitive skin	Gold standard; more dramatic results for severe ageing	Effective antioxidant; supports collagen, brightening
Tolerability	High; minimal irritation	Common side effects: irritation, dryness, peeling	Can cause irritation in sensitive skin (especially vitamin C in acidic forms)
Photosensitivity	Does not increase photosensitivity	Increases photosensitivity	Vitamin C can help protect against UV, but unstable under sunlight
Use During Pregnancy/Breastfeeding	Safe	Not recommended	Vitamin C is generally safe; others vary
Mechanism of Action	Supports cellular antioxidant systems; enhances barrier; anti-inflammatory	Promotes cell turnover, collagen production	Direct antioxidant (Vitamin C), neutralises free radicals
Stability	Very stable in formulations	Moderate stability	Vitamin C it is unstable and prone to oxidation
Synergistic Use	Can be combined with retinoids to reduce irritation and enhance benefits	Works well with niacinamide to improve tolerability	Can be used with niacinamide for broader antioxidant protection
Additional Benefits	Improves skin barrier, reduces inflammation, brightens skin tone	Treats acne, reduces fine lines, boosts collagen	Brightens skin, reduces pigmentation, and provides antioxidant defense

Current Research and Future Directions

Recent Breakthroughs (2022-2024)

Recent research has significantly advanced the understanding of niacinamide's anti-ageing mechanisms and applications. A landmark 2024 study demonstrated the senomorphic activity of niacinamide combined with hyaluronic acid, showing improvements in fine lines, wrinkles, luminosity, smoothness, homogeneity, and plumpness in a clinical trial with forty-four women over two months of treatment [23]. This research represents the first demonstration of niacinamide's ability to modulate cellular senescence pathways, a key mechanism of ageing. A comprehensive 2024 review highlighted niacinamide's pivotal role in NAD+ synthesis and its contribution to redox reactions and energy production in cutaneous cells, emphasising its influence on DNA repair and cellular stress responses. Simultaneously, research in 2024 demonstrated that systems-based approaches targeting multiple points in the NAD+ salvage pathway can significantly increase NAD+ concentrations in human participants, providing new insights into optimizing niacinamide's cellular effects.

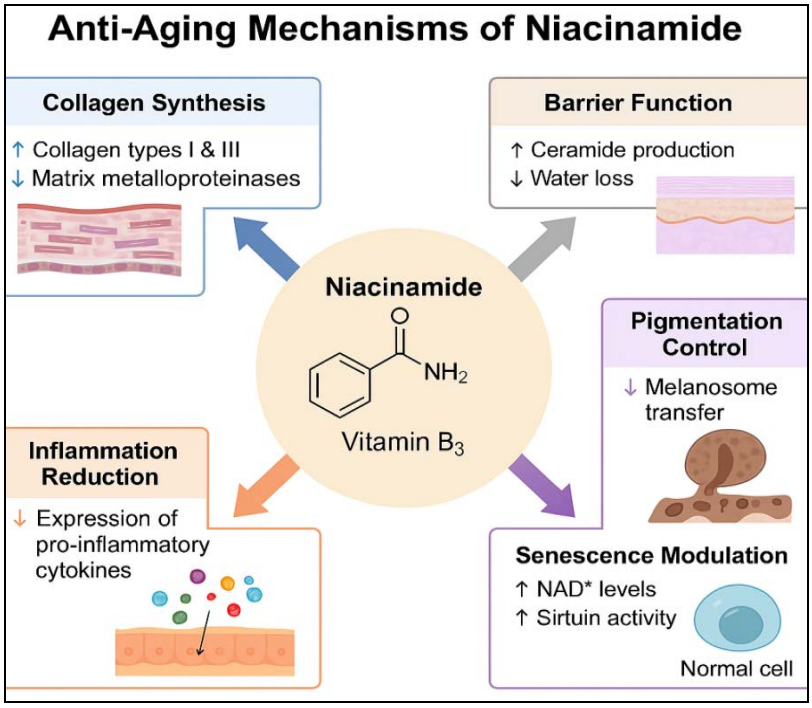

Fig 7: Comprehensive mechanism diagram showing niacinamide's multiple anti-ageing pathways: collagen synthesis, barrier function, pigmentation control, inflammation reduction, and senescence modulation.

NAD+ Biology and Advanced Mechanisms (2023-2024)

The understanding of NAD+ biology in ageing has rapidly evolved, with implications for niacinamide applications. Research in 2023 demonstrated that NAD+ precursors, including niacinamide derivatives, can mitigate ageing-related disorders such as oxidative stress, DNA damage, neurodegeneration, and inflammatory responses [24]. Clinical studies in 2024 showed that oral administration of NAD+ precursors significantly increased blood NAD+ levels in human subjects, with dose-dependent effects, suggesting potential for combined topical and systemic approaches [25].

Novel Delivery Systems and Combination Therapies

Recent advancements in niacinamide delivery focus on enhancing penetration and maximizing anti-aging efficacy. Microneedle-like particles (MLPs) have proven effective: in porcine skin models, they significantly increased niacinamide permeability—achieving up to a 284% increase with 60-second application—demonstrating their potential as efficient, large-area skin enhancers [26]. Hybrid nanogels, formulated using carrageenan and polyvinylpyrrolidone enriched with jojoba oil, deliver niacinamide using transethosome-mediated controlled release. These systems improved skin permeation and provided photoprotective benefits in keratinocyte models, suggesting promise for integration into sunscreen or after-sun care [27]. Additionally, dissolving microneedle-based micro-channeling systems (DMCS) paired with niacinamide/adenosine serums demonstrated superior outcomes in human trials—boosting skin elasticity by nearly 9.6% at four weeks compared to a decline seen with serum-only application [28]. In combination therapies, cross-linked hyaluronic acid dermal fillers containing niacinamide (HAR-1 and HAR-3) enhanced hydrogel resilience and cohesivity while significantly stimulating collagen synthesis in dermal fibroblasts—outperforming standard fillers—highlighting niacinamide's added functional benefits in injectable formulations [29].

Economic and Clinical Applications

Cost-Effectiveness and Market Considerations

Niacinamide is recognized for its favorable cost-benefit profile in anti-ageing dermatology, offering multi-targeted benefits—such as improved skin barrier function, reduction of hyperpigmentation, and enhanced elasticity—at a fraction of the cost of many other active agents [30]. Its affordability, coupled with a broad safety margin, supports sustained long-term use, potentially reducing the need for multiple specialized treatments. From a market perspective, the increasing dermatological endorsement of niacinamide, combined with rising consumer awareness, has fueled demand across mass-market, cosmeceutical, and premium skincare sectors [31]. Continuous innovation in delivery systems and combination formulations further strengthens its commercial appeal, enabling integration into diverse product formats ranging from affordable drugstore lines to high-end, technologically advanced skincare.

Clinical Implementation Guidelines

Niacinamide is particularly beneficial for patients unable to tolerate retinoids, alpha-hydroxy acids, or other potentially irritating actives. For sensitive individuals, treatment initiation with lower concentrations (≈2%) is recommended, gradually increasing to the commonly used 5% concentration as tolerated to maximize benefits while minimizing irritation risk [30]. Niacinamide is broadly suitable for clinical use across all skin types, including sensitive skin, and is considered safe during pregnancy and breastfeeding due to its excellent tolerability profile [31].

Limitations and Future Considerations

Current Limitations

Although effective, niacinamide alone may not address advanced ageing signs such as deep wrinkles or extensive photoageing, which often require procedural interventions. Visible results typically develop over 8-12 weeks and vary between individuals, which may not meet expectations for rapid improvement. Its mechanisms, while diverse, do not target all pathways of skin ageing, making combination therapies advisable for optimal outcomes [32] [33].

Quality and Regulatory Considerations

Niacinamide product quality depends on raw material purity, formulation stability, and manufacturing standards, all of which influence efficacy and safety. Adhering to good manufacturing practices ensures consistency and minimises contamination risks. Regulatory classifications differ across regions, influencing permissible claims and marketing. Standardising testing methods could enhance product comparability and clinical reliability [33] [34].

Conclusion

This comprehensive review demonstrates that niacinamide represents a highly effective, well-tolerated, and versatile ingredient for addressing multiple aspects of skin ageing, with significant recent advances expanding its therapeutic potential. The extensive clinical evidence supports its use as both a standalone treatment and a component of comprehensive anti-ageing regimens. Key strengths include multi-mechanism action addressing collagen synthesis, barrier function, hyperpigmentation, and oxidative stress; excellent clinical efficacy demonstrated across numerous controlled studies; superior safety profile with minimal adverse effects suitable for all skin types; and broad compatibility with other anti-ageing ingredients enabling synergistic combinations.

Advanced delivery systems and combination therapies continue to enhance efficacy, with clinical evidence supporting superior outcomes from multi-ingredient formulations.

The evidence strongly supports niacinamide as a first-line treatment for individuals seeking effective, gentle anti-ageing solutions. Its cost-effectiveness, stability, and proven efficacy make it accessible to diverse populations seeking evidence-based anti-ageing care. Future research should focus on optimizing senomorphic applications, exploring advanced NAD+ enhancement strategies, developing personalised treatment protocols based on genetic profiles, and investigating synergistic combinations with emerging longevity technologies.

For practitioners and consumers, niacinamide represents a science-backed, accessible, and effective solution for addressing visible signs of skin ageing while supporting overall skin health and cellular longevity. The continued investigation into its mechanisms and applications, particularly in senescence modulation and NAD+ biology, will likely expand its role in comprehensive anti-ageing strategies and position it as a cornerstone ingredient in the evolving field of longevity-focused dermatology.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Liang Y, Su W, Wang F. Skin ageing: a progressive, multi-factorial condition demanding an integrated, multilayer-targeted remedy. Clin Cosmet Investig Dermatol. 2023;16:1215-1229.
2. Fisher GJ, Kang S, Varani J, Bata-Csorgo Z, Wan Y, Datta S, *et al*. Mechanisms of photoageing and chronological skin ageing. Arch Dermatol. 2002;138(11):1462-1470.
3. Gehring W. Nicotinic acid/niacinamide and the skin. J Cosmet Dermatol. 2004;3(2):88-93.
4. Bissett DL, Miyamoto K, Sun P, Li J, Berge CA, Fitzpatrick R. Topical niacinamide reduces yellowing, wrinkling, red blotchiness, and hyperpigmented spots in aging facial skin. Int J Cosmet Sci. 2004;26(5):231-238.
5. Gilchrest BA, Krutmann J. Skin ageing. Berlin: Springer-Verlag; 2006.
6. Quan T, Fisher GJ. Role of age-associated alterations of collagen in skin ageing. Gerontology. 2015;61(5):427-434.
7. López-Otín C, Blasco MA, Partridge L, Serrano M, Kroemer G. The hallmarks of ageing. Cell. 2013;153(6):1194-1217.
8. Gkogkolou P, Böhm M. Advanced glycation end products: key players in skin ageing? Dermatoendocrinol. 2012;4(3):259-270.
9. Franceschi C, Garagnani P, Parini P, Giuliani C, Santoro A. Inflammageing: a new immune-metabolic viewpoint for age-related diseases. Nat Rev Endocrinol. 2018;14(10):576-590.
10. Campisi J, d'Adda di Fagagna F. Cellular senescence: when bad things happen to good cells. Nat Rev Mol Cell Biol. 2007;8(9):729-740.
11. Rinnerthaler M, Bischof J, Streubel MK, Trost A, Richter K. Oxidative stress in ageing human skin. Biomolecules. 2015;5(2):545-589.
12. Young JD, Yao SY, Baldwin JM, Cass CE, Baldwin SA. The human concentrative and equilibrative nucleoside transporter families, SLC28 and SLC29. Mol Aspects Med. 2013;34(2-3):529-547.
13. Revollo JR, Grimm AA, Imai S. The NAD biosynthesis pathway mediated by nicotinamide phosphoribosyltransferase regulates Sir2 activity in mammalian cells. J Biol Chem. 2004;279(49):50754-50763.
14. Verdin E. NAD^+ in ageing, metabolism, and neurodegeneration. Science. 2015;350(6265):1208-1213.
15. Tanno O, Ota Y, Kitamura N, Katsube T, Inoue S. Nicotinamide increases biosynthesis of ceramides as well as other stratum corneum lipids to improve the epidermal permeability barrier. Br J Dermatol. 2000;143(3):524-531.
16. Zhai H, Maibach HI. Skin moisturization mechanisms and topical agents. Skin Pharmacol Physiol. 2004;17(4):143-152.
17. Hakozaki T, Minwalla L, Zhuang J, Chhoa M, Matsubara A, Miyamoto K, *et al*. The effect of niacinamide on reducing cutaneous pigmentation and suppression of melanosome transfer. Br J Dermatol. 2002;147(1):20-31.
18. Kimball AB, Kaczvinsky JR, Li J, Robinson LR, Matts PJ, Berge CA, *et al*. Reduction in the appearance of facial hyperpigmentation after use of moisturizers with topical niacinamide concentrations of 5%: a randomized, double-blind, vehicle-controlled trial. Br J Dermatol. 2010;162(2):435-441.
19. Draelos ZD, Matsubara A. The effect of 2% niacinamide on facial sebum production. J Cosmet Laser Ther. 2006;8(2):96-101.
20. Wohlrab J, Kreft D. Niacinamide—mechanisms of action and its topical use in dermatology. Skin Pharmacol Physiol. 2014;27(6):311-315.
21. Walocko FM, Eber AE, Keri JE, Al-Harbi MA, Nouri K. The role of nicotinamide in acne treatment. Dermatol Ther (Heidelb). 2017;7(4):433-445.
22. Kang S, Chung J, Lee JH, Fisher GJ, Wan YS, Duell EA, *et al*. Topical N-acetyl cysteine and genistein prevent ultraviolet-light-induced signaling that leads to photoaging in human skin in vivo. J Invest Dermatol. 2003;120(5):835-841.
23. Aragonès G, Francisco R, Rierda M, Verdura S, Cordero A, Ribas-Latre A, *et al*. Senomorphic activity of a combination of niacinamide and hyaluronic acid: correlation with clinical improvement of skin aging. Sci Rep. 2024;14:16624.
24. Yoshino J, Mills KF, Yoon MJ, Imai S. Nicotinamide mononucleotide, a key NAD+ intermediate, treats the pathophysiology of diet- and age-induced diabetes in mice. Cell Metab. 2011;14(4):528-536.
25. Covarrubias AJ, Perrone R, Grozio A, Verdin E. NAD+ metabolism and its roles in cellular processes during ageing. Nat Rev Mol Cell Biol. 2021;22(2):119-141.
26. Shin CI, Kim M, Kim YC. Delivery of niacinamide to the skin using microneedle-like particles. Pharmaceutics. 2019;11(7):326.
27. Basto R, Andrade R, Nunes C, Lima SA, Reis S. Topical delivery of niacinamide to skin using hybrid nanogels enhances photoprotection effect. Pharmaceutics. 2021;13(11):1968.
28. Sim J, Gong S, Kang G, Jang M, Yang H, Park J, *et al*. Enhanced micro-channeling system via dissolving microneedle to improve transdermal serum delivery for various clinical skincare treatments. Pharmaceutics. 2022;14(12):2804.
29. Porcello A, Chemali M, Marques C, Scaletta C, Lourenço K, Abdel-Sayed P, *et al*. Dual functionalization of hyaluronan dermal fillers with vitamin B3: efficient combination of bio-stimulation properties with hydrogel system resilience enhancement. Gels. 2024;10(6):361.
30. Bissett DL, Miyamoto K, Sun P, Li J, Berge CA. Topical niacinamide reduces yellowing, wrinkling, red blotchiness, and hyperpigmented spots in aging facial skin. Int J Cosmet Sci. 2004;26(5):231-238.
31. Gehring W. Nicotinic acid/niacinamide and the skin. J Cosmet Dermatol. 2004;3(2):88-93.
32. Bissett DL, Oblong JE, Berge CA. Niacinamide: a B vitamin that improves aging facial skin appearance. Dermatol Surg. 2005;31(7 Pt 2):860-866.
33. Draelos ZD, editor. Cosmetic dermatology: products and procedures. 2nd ed. Hoboken (NJ): John Wiley & Sons; 2021.
34. Dayan N, Kromidas L. Formulating, packaging, and marketing of natural cosmetic products. Hoboken (NJ): John Wiley & Sons; 2011.