

Article

A *Hericium erinaceus* Erinacine A–Extracellular Polysaccharide Dual-Marker System for Photoaging-Related Extracellular-Matrix Homeostasis: Mechanistic and Translational Evidence

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Abstract: Photoaging is driven by repeated ultraviolet exposure, redox imbalance, matrix metalloproteinase activation and progressive disruption of the dermal collagen network. A standardized *Herichium erinaceus* active system was developed by separately isolating an erinacine A-enriched mycelial fraction and an extracellular-polysaccharide (EPS) fraction from the same fermentation batch, followed by controlled 1:10 dry-basis recombination. The active dispersion contained 0.05% erinacine A and 5.2% EPS and was incorporated at 4.00% into an essence emulsion containing squalane, caprylic/capric triglyceride, glycerol and hydrogenated lecithin. The formulation remained physically stable after centrifugation and three freeze-thaw-type temperature cycles. Published *H. erinaceus* research shows that aqueous extracts can reduce UVA-induced MMP-1 and elastase while increasing type-I procollagen in human dermal fibroblasts, and *H. erinaceus* polysaccharides have been linked to antioxidant enzymes, collagen and MMP/TIMP biology in preclinical skin models. Erinacine A research in non-cutaneous models further identifies Nrf2/HO-1, iNOS, MAPK and NF-kappaB as redox-inflammatory pathways of potential mechanistic relevance. Human studies of fungal beta-glucan/chitin-glucan systems and topical phosphatidylserine provide complementary clinical context for elasticity, roughness and collagen-related endpoints. The integrated evidence supports future formulation-specific evaluation of wrinkles, roughness, elasticity and firmness while preserving clear separation between current physicochemical observations and published biological data.

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1. Introduction

Chronic ultraviolet exposure accelerates visible skin aging through repeated oxidative stress, activation of MAPK/AP-1 and inflammatory signaling, induction of collagen-degrading matrix metalloproteinases, and progressive fragmentation of the dermal extracellular matrix [1-3]. In aged human skin, collagen fragmentation itself feeds back to increase oxidative stress and MMP-1 expression, while reduced fibroblast mechanical tension further suppresses collagen production [4-6]. These observations make redox control, MMP-1/elastase activity and type-I procollagen biologically coherent intermediate endpoints for anti-photoaging research.

Herichium erinaceus provides an unusual formulation opportunity because its mycelia and fermentation medium contain chemically distinct bioactive fractions. Aqueous *H. erinaceus* extracts have been reported to counter UVA-associated changes in

human dermal fibroblasts by reducing MMP-1 and elastase and increasing type-I procollagen [7]. *H. erinaceus* polysaccharides have also been associated with antioxidant-enzyme activity, collagen content and MMP/TIMP biology in preclinical skin-aging research [8,9]. Erinacine A, a mycelial cyathane diterpenoid, has a broader experimental literature linking it to antioxidant and anti-inflammatory signaling, including Nrf2/HO-1, iNOS/p38 MAPK and NF-kappaB pathways [10-12].

The current dual-marker system was designed to retain both a defined erinacine A fraction and an EPS-rich fraction rather than allowing one component to dominate an undefined whole-ferment material. In addition, the topical vehicle contains phospholipid and emollient components that may influence stratum-corneum properties and skin mechanical appearance. The objective of this paper is therefore to position the standardized formulation within the established biology of photoaging and to identify translational endpoints that can be tested directly in human skin.

2. Materials and Methods

Hericium erinaceus DSM 11461 (working designation TIMEFLYS-HE-01) was cultivated in a 70-L liquid fermentation at 26°C for 6.5 days with 0.8 vvm aeration and dissolved oxygen maintained at not less than 25%. The mycelia yielded an ethanol-extractable erinacine A fraction purified on HP-20 resin, while the fermentation supernatant yielded an EPS fraction after 0.45- μ m clarification, 10-kDa ultrafiltration, three membrane volumes of diafiltration and controlled heat treatment.

The erinacine A fraction and EPS fraction were blended at a 1:10 dry-basis mass ratio. The final active dispersion contained 0.05% erinacine A, 5.2% EPS, 2.0% total protein and pH 5.10. It was incorporated at 4.00% into an essence emulsion containing 5.00% squalane, 4.00% caprylic/capric triglyceride, 4.00% glycerol, 4.00% 1,3-propanediol, 0.50% hydrogenated lecithin and associated emulsifying/rheology components. The formulation was challenged by centrifugation at 3000 $\times$ g for 30 min and three -5°C/25°C cycles.

For the translational evidence synthesis, priority was given to human skin-aging biology, *H. erinaceus*-specific fibroblast or skin studies, *H. erinaceus* polysaccharide research, erinacine A mechanistic studies and human topical trials with fungal beta-glucan/chitin-glucan or phospholipid-based anti-aging systems [1-18]. Evidence was interpreted according to experimental context: current formulation data were treated as physicochemical observations, while published cellular, animal and human studies were used to construct mechanistic and clinical context.

Formulation composition

Table 1. Composition and Functions of the Dual-Marker Active Essence Emulsion

Component	Mass %	Function
Dual-marker active material	4.00	Core active dispersion
Squalane	5.00	Emollient oil
Caprylic/capric triglyceride	4.00	Light emollient oil
Glycerol	4.00	Humectant
1,3-Propanediol	4.00	Humectant solvent
Hydrogenated lecithin	0.50	Lamellar-structure aid
Glyceryl stearate citrate	1.00	Emulsifier
Cetearyl alcohol	0.80	Structuring agent
Polyacrylate Crosspolymer-6	0.20	Rheology modifier
Phenoxyethanol/ethylhexylglycerin	0.80	Microbial control
Citric acid/sodium citrate buffer	0.15	pH adjustment
Purified water	75.55	Continuous phase

Mechanistic framework linking the *Hericium* dual-marker system to photoaging biology

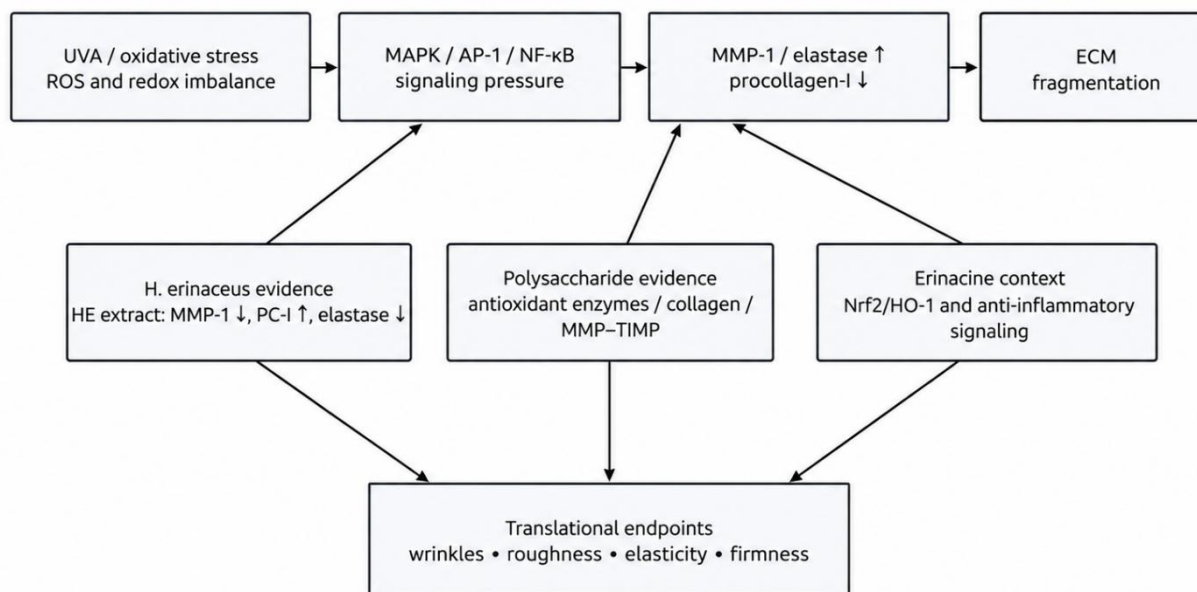


Figure 1. Mechanistic framework linking the dual-marker system to photoaging-related extracellular-matrix biology.

3. Results

The dual-fraction production process recovered 84.1% of EPS mass from the fermentation supernatant and 81.9% of erinacine A from the mycelial ethanol extract. After controlled recombination and homogenization, the resulting active material met dual-marker specifications and was compatible with the essence emulsion. The finished product showed no visible phase separation, irreversible precipitation or extensive crystallization following the defined stress tests; pH shifted only from 5.20 to 5.24. These results support the physical integrity required for consistent topical dosing.

The strongest *H. erinaceus*-specific photoaging evidence comes from UVA-exposed human dermal fibroblasts. Choi and colleagues reported that aqueous *H. erinaceus* extract increased type-I procollagen while decreasing MMP-1 production and elastase activity, with corresponding recovery of mRNA expression patterns after UVA exposure [7]. In aged-rat skin, *H. erinaceus* polysaccharides altered antioxidant-enzyme activity, collagen content and MMP-1/TIMP-1-related measures [8]. Structural studies of *H. erinaceus* polysaccharides further confirm substantial radical-scavenging capacity in vitro [9]. Together, these findings align with the central oxidative-stress-matrix-remodeling axis of human photoaging [1-6].

Erinacine A contributes a second mechanistic layer. Reviews published through 2026 describe anti-inflammatory and antioxidant properties across experimental systems [10]. In injury and neuroinflammation models, erinacine A has been linked to suppression of iNOS/p38 MAPK or NF-kappaB-associated inflammatory signaling [11,12]. These models are not skin models; their value here is to identify testable redox-inflammatory pathways that can be examined in keratinocytes, fibroblasts or reconstructed skin exposed to the standardized topical system.

Human evidence from related topical systems provides a clinically relevant endpoint map. Topical phosphatidylserine has been shown in human skin to prevent UV-associated reduction of type-I procollagen and induction of MMP-1 [13]. Fungal chitin-glucan formulations increased skin firmness and hydration and reduced roughness in a randomized double-blind study [14]. A 12-week randomized placebo-controlled study of a topical/oral chitin-beta-glucan antioxidant complex reported improvements in several photoaging-related biophysical variables [15], while a pleuran beta-glucan cream improved moisture, elasticity, radiance and total antioxidant capacity over 30 days [16]. More general randomized topical studies demonstrate that wrinkle topography, elasticity and firmness can respond measurably within 4-8 weeks when a biologically active skin-care system is compared with control [17,18].

Representative human evidence

Table 2. Summary of Published Studies on Photoaging-Related Skin Outcomes and Relevant Biological Endpoints

Study	Design / population	Key endpoints
Choi et al. [7]	UVA-exposed human dermal fibroblasts	MMP-1 ↓; elastase ↓; type-I procollagen ↑
Cho et al. [13]	Topical phosphatidylserine; human skin in vivo	UV-induced procollagen loss attenuated; MMP-1 ↓
Gautier et al. [14]	Randomized double-blind fungal chitin-glucan trial	Firmness ↑; hydration ↑; roughness ↓
Morganti et al. [15]	70 subjects; randomized placebo-controlled, 12 weeks	Photoaging-related biophysical variables improved
Schiano et al. [16]	20 subjects; pleuran beta-glucan, 30 days	Elasticity, moisture, radiance and antioxidant capacity improved
Spada et al. [17]	30 women; double-blind randomized split-face, 28 days	Wrinkle dimensions ↓; elasticity ↑; hydration ↑
Tucker-Samaras et al. [18]	Double-blind split-face retinol moisturizer, 8 weeks	Lines/wrinkles, elasticity, firmness and photodamage improved

4. Discussion

The evidence converges on a biologically coherent photoaging pathway: UV exposure increases oxidative stress and AP-1-associated matrix degradation, dermal collagen becomes fragmented, and altered fibroblast mechanics perpetuate higher MMP-1 activity and lower collagen synthesis [1-6]. H. erinaceus extract data directly intersect this pathway at MMP-1, elastase and type-I procollagen [7]. The EPS fraction may contribute antioxidant and matrix-supportive effects suggested by polysaccharide studies [8,9], while the erinacine A fraction offers a distinct redox-inflammatory mechanistic hypothesis that can be tested in skin-specific models [10-12].

The formulation architecture may also affect translation. Squalane and caprylic/capric triglyceride improve sensory spread and emolliency, glycerol and 1,3-propanediol support hydration, and hydrogenated lecithin supplies a phospholipid component. Human phosphatidylserine research demonstrates that selected phospholipids can interact with procollagen and MMP-1 biology in vivo [13], although phosphatidylserine and hydrogenated lecithin are chemically distinct. The practical implication is that whole-formula testing is preferable to assigning all visible outcomes to a single active marker.

A second consideration is endpoint hierarchy. Mechanistic studies justify measuring oxidative stress, MMP-1 and procollagen in preclinical skin models, whereas human cosmetic studies are best anchored in validated visible and biomechanical outcomes: wrinkle surface/depth, roughness, Cutometer elasticity, firmness and standardized

photography [14-18]. Hydration and TEWL should be retained as secondary outcomes because barrier quality can alter surface texture and optical appearance and may therefore influence perceived anti-aging performance.

Within the TIMEFLYS topical-care program, the most informative next translational design would combine a vehicle-controlled facial study with a parallel mechanistic substudy. A 8-12 week human study could quantify crow's-feet topography, elasticity and firmness, while an ex vivo or reconstructed-skin arm could examine UV-induced MMP-1, procollagen-I and oxidative-stress markers. This paired design would connect a visible endpoint to a biologically interpretable pathway without conflating the two evidence levels.

Research Scope and Future Directions

The current experimental observations establish standardized active composition and finished-product physical stability. Published *H. erinaceus* and erinacine research supplies mechanistic context, while the human literature identifies feasible anti-aging endpoints. Future work can extend this framework by evaluating the complete formulation against a matched vehicle, testing dose dependence of the dual-marker active, and examining whether changes in wrinkle morphology or elasticity track with biomarker changes in a controlled skin model. Such studies would progressively refine the dose-response and mechanistic profile of the complete composition.

5. Conclusion

The *Herichium erinaceus* dual-marker system integrates a defined erinacine A fraction and an EPS-rich fraction in a physically stable topical essence emulsion. *H. erinaceus*-specific fibroblast research connects the mushroom to UVA-responsive MMP-1, elastase and type-I procollagen biology [7], while polysaccharide studies and erinacine A research broaden the mechanistic context toward antioxidant and inflammatory signaling [8-12]. Human topical studies with fungal beta-glucan and phospholipid-containing systems demonstrate that firmness, elasticity, roughness and collagen-related endpoints are measurable and responsive in clinical settings [13-18]. Together, these findings establish a coherent scientific framework for direct formulation-specific assessment of photoaging-related skin structure and appearance.

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