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Skin Aging Biomarkers and the Anti-Aging Potential of Botanical Extracts

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Introduction

Skin aging is a complex, multifactorial biological process influenced by intrinsic (chronological) and extrinsic (environmental) factors. Characterized by the thinning of the epidermis, loss of elasticity, wrinkle formation, uneven pigmentation, and reduced barrier function, skin aging not only affects aesthetic appearance but also the functional integrity of the skin. In recent years, the investigation into molecular biomarkers of skin aging has deepened our understanding of the aging process. These biomarkers include telomere shortening, mitochondrial dysfunction, increased Matrix Metalloproteinase (MMP) activity, oxidative stress markers, and inflammatory cytokines, among others. As science uncovers these hallmarks of aging, it simultaneously opens doors for the development of targeted anti-aging therapies. One area of growing interest is the use of botanical extracts-natural compounds derived from plants-known for their antioxidant, anti-inflammatory, and anti-glycation properties. These extracts, including flavonoids, polyphenols, alkaloids, and terpenoids, show promising efficacy in modulating aging biomarkers, supporting dermal repair, and protecting against environmental aggressors like UV radiation and pollution [1-3].

Intrinsic aging is a genetically driven, time-dependent process leading to a gradual decline in skin functions. It manifests as dryness, fine wrinkles, and reduced collagen synthesis. Extrinsic aging, also called photoaging, results from environmental exposure-most notably UV radiation, but also includes pollution, smoking, and poor nutrition. It leads to deep wrinkles, uneven pigmentation, rough texture, and loss of dermal elasticity. Telomeres are repetitive nucleotide sequences at the ends of chromosomes. With each cell division, telomeres shorten, eventually triggering cellular senescence. Telomerase activity is low in skin cells, making telomere shortening a crucial aging marker.

Description

Senescent cells show increased β-galactosidase activity. Accumulation of such cells in the skin contributes to tissue degradation and inflammatory signaling. UV exposure stimulates MMP-1, MMP-3, and MMP-9, which degrade collagen and elastin, key structural proteins in the dermis. Elevated levels of malondialdehyde (MDA), 8-hydroxy-2'-deoxyguanosine (8-OHdG), and lipofuscin indicate oxidative damage to lipids, DNA, and proteins. Aged skin exhibits elevated expression of IL-1β, IL-6, TNF-α, and COX-2, creating a chronic low-grade inflammatory state known as “inflammaging.” Glycation of skin proteins like collagen results in cross-linking and rigidity, reducing elasticity and accelerating dermal atrophy. Botanical extracts are derived from various parts of plants-leaves, roots, seeds, flowers, and bark-and contain bioactive constituents.

Contains triterpenoids such as asiaticoside and madecassoside. Stimulates fibroblast proliferation, collagen synthesis, and angiogenesis, crucial for wound healing and skin rejuvenation. Studies show significant improvement in skin firmness and hydration in aged populations using Centella-enriched creams. Rich in rosmarinic acid and carnosic acid with anti-inflammatory and antioxidant effects. Shown to reduce lipid peroxidation in UV-damaged skin. In vitro, rosemary extract improved mitochondrial function in dermal fibroblasts, suggesting its role in energizing aged skin. Abundant in oleic acid, tocopherols, and polyphenols. Enhances skin barrier function, prevents trans-epidermal water loss, and supports collagen structure preservation. Popular in East Asian anti-aging regimens. Silymarin, the active compound, has shown efficacy in reducing UV-induced oxidative DNA damage and lipid peroxidation. Potential as a supportive botanical for hyperpigmentation and melasma. Nanostructured lipid carriers (NLCs) and solid lipid nanoparticles (SLNs) enhance the penetration and prolong the release of botanical actives. Hydrogel matrices help stabilize volatile compounds like essential oils and polyphenols [4,5].

Conclusion

The use of botanical extracts in anti-aging skincare represents a convergence of traditional plant medicine and modern molecular science. These natural compounds offer a rich source of bioactives capable of targeting multiple biomarkers of aging, including oxidative stress, inflammation, collagen degradation, and cellular senescence. From green tea catechins to turmeric polyphenols, these agents not only protect the skin from environmental insults but also enhance its regenerative capacity, leading to improved texture, elasticity, and luminosity. Their favorable safety profile and potential for personalized, sustainable, and microbiome-conscious formulations make them a compelling alternative-or complement-to synthetic anti-aging compounds. As research deepens, the integration of botanical extracts with cutting-edge delivery technologies and omics-based skincare strategies will pave the way for a new era of natural, science-backed dermocosmetics, where aging is addressed not just cosmetically, but biologically and holistically.

Acknowledgment

None.

Conflict of Interest

None.

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