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abstract

Biotechnological innovation is profoundly transforming the cosmetic landscape, opening the way to the creation of next-generation active ingredients that combine scientific efficacy with sustainable production methods. In this context, the present work introduces a novel active ingredient specifically designed for the delicate eye contour care, obtained via precision fermentation of upcycled *Vitis vinifera* leaf extracts, a valuable by-product of the winemaking chain. This innovative process allows the valorization of agricultural residues while reducing environmental impact, fully aligning with the principles of circular economy. The resulting ingredient is particularly rich in bioavailable polyphenolic compounds, whose structure and functionality are optimized through a controlled bioprocess designed to enhance molecular efficacy and skin compatibility. Functional studies (in vitro and ex vivo) demonstrate a comprehensive 360° action on the periorbital area, with measurable reduction in dark circles, puffiness, and fine lines. The ingredient acts on inflammation, oxidative stress, and microcirculation, restoring skin brightness and firmness. The results support its use in advanced cosmetic formulations, combining proven performance with a circular and sustainable development model.

Introduction

The cosmetic industry is currently experiencing a profound transformation, driven by the demand for high-performance, scientifically validated, and environmentally sustainable ingredients. Within this evolving landscape, biotechnology has rapidly emerged as a key innovation driver, offering advanced tools to design and produce active ingredients through controlled and reproducible, and highly scalable processes. Among the different biotechnological approaches, biofermentation represents a particularly sustainable and efficient approach for obtaining high-value cosmetic actives. By leveraging agro-industrial by-products as fermentation substrates, it aligns with circular economy principles, reducing environmental impact while adding functional value. Furthermore, recent advances in microbial engineering and precision fermentation allow for the production of targeted bioactive molecules with specific cosmetic benefits. These include improved antioxidant protection to counteract oxidative stress, regulation of pigmentation pathways to address hyperpigmentation, and stimulation of cellular mechanisms involved in skin renewal and anti-aging effects. The versatility and reproducibility of such processes ensure consistent efficacy and safety, meeting the rigorous standards of modern cosmetic science. As a result, biotechnologically derived actives are positioned as essential, next-generation tools for formulating evidence-based cosmetics that combine proven performance with sustainability.

Biotechnological approach and ingredient development

Controlled microbial fermentation is becoming an important and modern method for creating cosmetic active ingredients. By leveraging selected strains under optimized conditions, this approach ensures the production of high-quality bioactive compounds with enhanced skin bioavailability. Unlike traditional fermentation, which relies on naturally occurring microbes, precision fermentation uses specific, well-characterized microorganisms to drive targeted biochemical transformations – offering both consistency and efficacy. Building on this methodology, ROELMI HPC has developed an advanced cosmetic active through the fermentation of upcycled *Vitis vinifera* leaf extracts. This ingredient results from a tailored bioprocess involving a proprietary *Lactobacillus plantarum* strain, selected for its ability to generate a complex of beneficial metabolites such as polyphenols, polysaccharides, and peptides. These components work in synergy to address multiple signs of skin fatigue around the eye contour.

Particularly suited for this delicate facial area, the ingredient targets visible concerns such as puffiness, dark circles, fine lines—common effects of both intrinsic aging and environmental stressors. Its efficacy has been demonstrated through a combination of laboratory studies and clinical evaluation, confirming its potential as a multifunctional solution for comprehensive eye contour care.

Mechanism of action

The biotech ingredient works through a broad and effective mechanism of action, demonstrating a multi-targeted activity profile. It helps control melanin production, leading to a more even and radiant skin tone. It exhibits significant anti-glycation activity, reducing the buildup of advanced glycation endproducts (AGEs) linked to skin aging. Its antioxidant properties were demonstrated by a decrease in reactive oxygen species (ROS) following UV-induced oxidative stress in skin cells. Moreover, it improves microcirculation by stimulating the formation of new capillaries, giving the skin a fresher and healthier look.

In-vitro efficacy dossier

In vitro studies have clearly demonstrated the various mechanisms of action of the ingredient. Thanks to its synergistic effect, it works on multiple levels at the same time, making it particularly effective and versatile in cosmetic applications for eye contouring.

Clinical study

A comprehensive clinical study was designed and carried out on a panel of 120 volunteers, carefully categorized according to their predominant under-eye concerns: which included dark pigmented circles (characterized by a dark brown hue), vascular dark circles resulting from impaired microcirculation, and visible under-eye bags associated with puffiness and fluid retention. The objective of the study was to rigorously evaluate the efficacy of the novel biotechnological ingredient over time. Assessments were performed after 28 and 56 days of continuous treatment, combining instrumental analyses with expert clinical evaluations to obtain both objective and perceptible results.

- **Dark Circles Color Intensity:** the intensity of pigmentation in dark circles was another critical factor evaluated. This was measured using the ITA (Individual Typology Angle), an established indicator of skin color and brightness. The biotech ingredient demonstrated a reduction in the pigmentation intensity of dark brown circles up to 17% after 56 days (**Figure 1**)

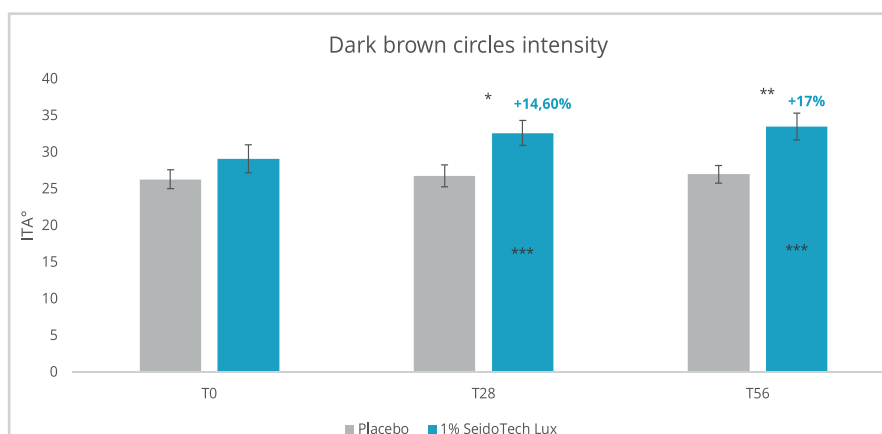


Fig.1 Dark Brown circles intensity assessed on 40 subjects with dark brown circles, aged between 18 and 65 years old. * $p < 0,05$ ** $p < 0,01$ *** $p < 0,001$

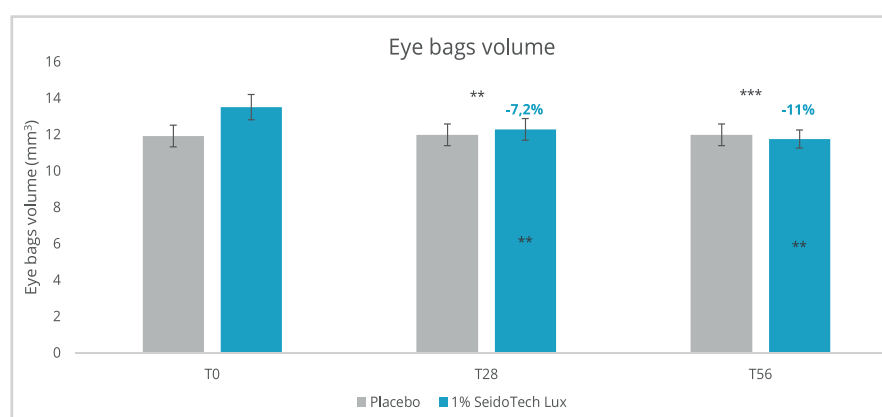


Fig.2 Eye bags volume on 40 subjects with eye bags, aged between 18 and 65 years old. * $p < 0,05$ ** $p < 0,01$ *** $p < 0,001$

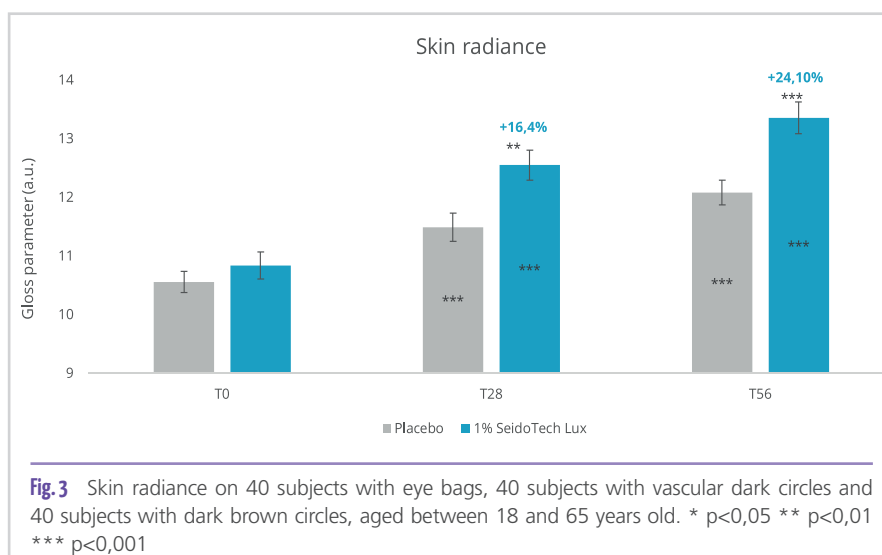
- **Under-Eye Bag Volume:** the reduction of under-eye puffiness was assessed by measuring the volume of eye bags using the PrimosCR 3D imaging system. This advanced technology reconstructs the skin's surface in three dimensions, allowing precise and objective evaluation of volume changes. The biotech ingredient results recorded to a decrease of eye bags volume, respectively by 7.2% at T28 and by 11.0% at T56 (**Figure 2**)
- **Skin Radiance:** one of the key parameters evaluated was skin radiance, measured through the gloss parameter, which quantifies the skin's ability to reflect light. Using a spectrophotometer/colorimeter, this parameter was assessed by measuring the reflected light from the skin after it was illuminated by diffuse light. The biotech ingredient enhances skin brightness by +16.4% at T28 and by +24.1% at T56 (**Figure 3**)

An expert scoring method was employed using internal clinical scales to evaluate the visibility of under-eye concerns such as eye bags, brown dark circles, vascular dark circles, and signs of fatigue around the eye contour. This method provided an objective assessment of improvement after 56 days of treatment with the biotech ingredient.

The results showed the following improvements compared to the placebo group:

- Eye bags visibility: Reduced in 53% of subjects (vs. 20% placebo).
- Vascular dark circles visibility: Reduced in 58% of subjects (vs. 25% placebo).
- Dark brown circles visibility: Reduced in 60% of subjects (vs. 21% placebo).
- Signs of fatigue around the eye contour: Improved in 60% of subjects (vs. 27% placebo).

These results provide robust evidence of the multifunctional efficacy of the biotechnological ingredient, clearly demonstrating its ability to target the key biological mechanisms responsible for visible periocular concerns. By targeting pathways linked to pigmentation, inflammation, oxidative stress, and microcirculation, the ingredient addresses both the aesthetic and physiological dimensions of skin aging in the eye contour area. Clinical and instrumental assessments reveal measurable improvements in the reduction of hyperpigmentation and dark circles, a visible attenuation of under-eye puffiness, and a progressive smoothing of fine lines. In addition, subjects reported enhanced skin radiance and a significant decrease in the visual signs of fatigue, contributing to a more youthful and refreshed appearance. The consistency of these results, confirmed across multiple parameters over an 8-week treatment period, underlines the reliability of the outcomes and validates the ingredient as a clinically proven, multi-target active. Altogether, these findings support its application in next-generation cosmetic formulations designed for comprehensive periocular skin rejuvenation.



Conclusion

This work highlights the strategic relevance of precision fermentation as a driver of innovation in the cosmetic sector. Through the use of selected microbial strains and upcycled plant-based substrates, it is possible to obtain multifunctional active ingredients capable of addressing the complex needs of sensitive areas such as the eye contour. The bioactive complex developed through this approach demonstrates activity on key biological pathways involved in skin fatigue and aging—such as oxidative stress, pigmentation, glycation, and microcirculation—providing visible improvements in tone, radiance, and periocular comfort. Beyond its demonstrated efficacy, the ingredient stands out for its alignment with circular economy principles, thanks to a low-impact production process that minimizes waste and valorizes agricultural by-products. This positions it as a next-generation active, combining scientific rigor, performance, and environmental responsibility. As such, it represents a valuable resource for formulators seeking evidence-based and sustainable solutions, confirming the potential of fermentation-based biotechnology as a foundational tool for the future of advanced cosmetic formulation.

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