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GUST Sustainability Policy Brief

When Peak Science meets Sustainability: Why Microalgae Should Shape the Future of Sustainable Cosmetics?

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About the author:

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Highlights:

- *The cosmetics industry faces increasing pressure to reduce environmental impacts while maintaining innovation and product performance.*
- *Conventional cosmetic ingredients often depend on resource-intensive processes, synthetic chemicals, and non-renewable inputs.*
- *Despite strong scientific progress on microalgae, adoption remains constrained by regulatory uncertainty, high costs, and limited industry awareness.*
- *Policy action is needed to support microalgae adoption through clear regulations, financial incentives, and multi-stakeholder collaboration aligned with the SDGs.*

Keywords:

Microalgae, Cosmetics, Product development and innovation, Scientometric networks, Intellectual structure, Keyword co-occurrence, Collaboration networks

SDGs:
3,9,12,13,17

1. Introduction: Sustainability at a Turning Point in Cosmetics

The global cosmetics industry is experiencing a major shift (Sasounian et al. 2024). Consumers, regulators, and investors are increasingly demanding products that are not only effective but also environmentally responsible (Statista 2024). Sustainability is no longer a niche concern—it has become a core business and policy priority.

However, the industry still relies heavily on conventional ingredients that can contribute to deforestation, biodiversity loss, excessive water use, and chemical pollution. As a result, identifying alternative raw materials that are renewable, efficient, and environmentally friendly is essential (Martínez-Ruiz et al. 2022; Morocho-Jácome et al. 2020).

One promising solution lies in microalgae—microscopic photosynthetic organisms found in freshwater and marine environments. Over the past two decades, scientific research has increasingly highlighted the potential of microalgae in cosmetic applications, supported by scientometric analyses of global research trends (Kinawy et al. 2024). The findings offer valuable insights for policymakers, industry leaders, and sustainability advocates.

2. Why Microalgae Matter for Sustainable Development

Microalgae are increasingly recognized as a promising resource for advancing sustainable development due to their unique biological and environmental characteristics. Unlike conventional raw materials, microalgae are renewable and fast-growing, with the ability to be cultivated continuously throughout the year under controlled conditions. Another critical advantage of microalgae lies in their capacity for carbon capture, contributing to climate change mitigation efforts and positioning them as a viable component of low-carbon production systems. This high productivity makes them a reliable and scalable resource for industrial applications (Kinawy et al. 2024).

In addition, microalgae cultivation requires significantly fewer natural resources compared to traditional agricultural inputs. They can grow on non-arable land and utilize saline or wastewater, thereby avoiding competition with food crops and reducing pressure on freshwater resources (Kinawy et al. 2024). This characteristic is particularly important in regions facing land and water scarcity.

From a commercial perspective, microalgae are rich in bioactive compounds, including antioxidants, pigments, fatty acids, and vitamins. These compounds are highly valuable in the cosmetics industry, where they are used in products such as anti-aging creams, sunscreens, and skin treatments. Their multifunctional properties enable the development of innovative, high-value, and environmentally sustainable cosmetic products. This growing application is strongly supported by the increasing volume of global research on microalgae-based cosmetic ingredients (Kinawy et al. 2024).

Collectively, these characteristics align closely with the UN Sustainable Development Goals (SDGs). Particularly, SDGs 9 (Industry, Innovation and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Climate Action).

3. The Policy Gap: From Research to Real-World Impact

Despite significant scientific advancements in microalgae research, their large-scale adoption in the cosmetics industry remains limited. This gap between research and commercialization can be attributed to several interrelated policy and market barriers (Kinawy et al. 2024).

One of the primary challenges is the lack of targeted policy incentives that encourage the substitution of conventional ingredients with sustainable alternatives. Without financial or regulatory support, firms have limited motivation to transition toward microalgae-based inputs, particularly when existing supply chains are already well established.

Regulatory uncertainty also presents a major obstacle due to a lack of clear and standardized guidelines governing the approval, safety assessment, and labeling of microalgae-derived ingredients. This ambiguity increases compliance costs and delays market entry, discouraging innovation and investment.

Furthermore, the high initial capital requirements associated with microalgae cultivation and processing technologies pose a significant barrier, especially for small and medium-sized enterprises (SMEs) (Kinawy et al. 2024). These costs include infrastructure, technology development, and scaling production processes, all of which require substantial upfront investment.

Finally, there is limited awareness within the cosmetics industry regarding the functional and environmental benefits of microalgae. This is particularly evident among SMEs, which may lack access to the latest research or the capacity to explore new sustainable inputs, despite the growing body of scientific knowledge in this area (Kinawy et al. 2024).

Without coordinated and supportive policy frameworks, these barriers are likely to persist, preventing the full realization of the environmental and economic benefits identified in the research.

4. Policy Recommendations

To bridge the gap between research and practical implementation, a set of integrated policy actions is required, with clear alignment to the SDGs.

First, strengthening public–private partnerships is essential to accelerate innovation and commercialization. Governments can play a catalytic role by facilitating collaboration between universities, research institutions, and cosmetic companies. Joint funding initiatives, shared research infrastructure, and pilot projects can reduce risks associated with innovation while promoting knowledge transfer. This approach directly supports SDG 17, which emphasizes multi-stakeholder partnerships as a driver of sustainable development. Expanding these collaborations internationally can further enhance knowledge exchange and technological diffusion.

Second, integrating microalgae into national sustainability strategies can create a more enabling policy environment. By recognizing microalgae as a strategic bio-based resource, governments can promote investment in sustainable industrialization and innovation ecosystems, in line with SDG 9. At the same time, positioning microalgae within circular economy frameworks supports SDG 12 by encouraging resource efficiency and reducing environmental impact across production systems.

Third, establishing clear and transparent regulatory frameworks is critical to ensuring both industry confidence and consumer protection. Governments should develop standardized guidelines for cultivation, processing, toxicity testing, and labeling of microalgae-based ingredients. Such regulatory clarity would reduce uncertainty, facilitate market entry, and ensure that products meet safety and quality standards. This recommendation aligns with SDG 3 by safeguarding public health while supporting the responsible development of new products.

In addition, providing targeted financial incentives can encourage firms to adopt sustainable alternatives. Instruments such as subsidies, tax credits, or green innovation grants can offset the high initial costs associated with microalgae technologies. By lowering financial barriers, these measures can accelerate the transition toward environmentally friendly inputs, contributing to SDG 12. Moreover, reducing reliance on carbon-intensive ingredients supports SDG 13 by advancing climate action objectives.

Finally, raising awareness among both industry stakeholders and consumers is essential for driving demand and adoption. Educational campaigns, industry workshops, and sustainability labeling initiatives can help communicate the environmental and functional benefits of microalgae-based cosmetics. Increased awareness can influence purchasing behavior and encourage companies to integrate sustainable practices into their operations, further reinforcing SDG 12.

4. Conclusion

For cosmetic manufacturers, microalgae represent more than a sustainability solution; they constitute a strategic opportunity to enhance competitiveness through innovation and differentiation with both functional and environmental benefits. This enables firms to develop products that align with increasing consumer demand for transparency, efficacy, and sustainability, while simultaneously strengthening brand positioning in a competitive market.

From a policy perspective, supporting the integration of microalgae into cosmetic supply chains can yield significant environmental, economic, and strategic benefits. The adoption of microalgae-based inputs can reduce the environmental impacts associated with conventional ingredients, contributing to more resource-efficient production systems and advancing SDG 12 (Responsible Consumption and Production) as well as SDG 13 (Climate Action). At the same time, fostering the development of microalgae technologies can stimulate green innovation, support the growth of bio-based industries, and generate skilled employment opportunities, in line with SDG 9 (Industry, Innovation and Infrastructure).

At a broader level, strategic investment in microalgae can enhance national competitiveness by positioning countries within high-value, knowledge-intensive sectors of the bioeconomy. This is particularly relevant in the context of the global transition toward sustainable industrial models, where innovation-driven and environmentally responsible production systems are becoming key determinants of long-term economic resilience.

Collectively, these linkages illustrate how advances in microalgae research can be translated into tangible policy outcomes, reinforcing the role of science-based innovation in achieving sustainable development objectives.

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