OPEN LETTER

REVISED From plant genetic resources to cosmetic active ingredients: when science meets regulation and market rules

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Abstract

The use of plants as a source of cosmetic ingredients has a long history, but has become increasingly important over the last three decades as consumers become more aware of the provenance of cosmetic products and their impact on the environment. Modern cosmetic ingredients must not only be safe, effective and sustainable, but must also comply with a complex framework of regulations, only some of which are internationally standardized. Consumers are also presented with an overlapping and poorly defined set of certification schemes offering claims of sustainability and environmental benefits. In this brief review article, we look at the regulations governing plant-based ingredients in the cosmetics industry, and how these intersect with modern biotechnological approaches for the development of ingredients with proven efficacy and sustainability. We showcase the example of *InnCoCells*, the first Horizon project dedicated to the development of cosmetic ingredients based on sustainable plant-based resources.

Plain language summary

Many of our cosmetic ingredients are sourced from plants, which provide a natural reservoir of bioactive compounds that improve skin health. However, the development of plant-based ingredients in hindered by conflicting international regulations and certification schemes that cover access to genetic resources, permitted substances, and evidence of safety, efficacy and environmental sustainability. An important aspect is the role of biotechnology in cosmetics because biotechnology can make it easier to produce cosmetic ingredients in a sustainable manner from precious plant-based resources. The InnCoCells project, the first Horizon project completely dedicated to the development of natural cosmetic ingredients with proven scientific efficacy, is helping to raise

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Any reports and responses or comments on the article can be found at the end of the article.

awareness about these issues.

Keywords
Cosmetics, sustainability, efficacy, plant-based resources, regulatory framework, biotechnology

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REVISED **Amendments from Version 1**

The article has been revised to include, in the introduction, information about its overall objective (as well as key references) and by adding major sections covering (1) how Regulation (EU) No 511/2014 handles diverse ABS legislation in EU member states, (2) justification for the use of China and the EU as distinct and representative archetypes of regulatory systems governing cosmetic ingredients, (3) a direct comparison of the regulatory frameworks in China and the EU, (4) an expansion of the description of cosmetics regulation in Asia to cover additional important markets – specifically India, Japan, South Korea and ASEAN (including appropriate references to legislative instruments), and (5) a series of recommendations reflecting the authors' opinion on steps that should be taken to harmonize global cosmetics regulations to meet essential safety, quality, ethical and sustainability criteria. The article has also been edited to ensure the new sections are integrated and maintain the narrative flow. Seven new references have been added. Finally, the sections covering the InnCoCells have been updated to recount the final achievements of the project, which formally ended on 30 September 2025.

Any further responses from the reviewers can be found at the end of the article

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Introduction

The global cosmetics market was valued at US$424.72 billion in 2024 and is predicted to reach US$760.61 billion by 2034, representing a compound annual growth rate of 6% (Precedence Research, 2024). Current trends in cosmetics are mainly related to increasing consumer demands for validated efficacy, environmental sustainability, and the removal of synthetic chemicals and their potential for harm. Consumers see a strong link between health and beauty, so they desire safe, effective and personalized products that promote healthy aging. This has created a demand for natural cosmetic products, and manufacturers such as L'Oréal, Procter & Gamble, Patanjali Ayurved, and Estee Lauder are continuously engaged in the production of new herbal and natural ingredients to satisfy this growing market. Plant extracts and plant-derived ingredients will therefore continue to be important raw materials for the future of the cosmetics industry, and will come under increasing regulatory scrutiny (Ferreira *et al.*, 2022; Vieira *et al.*, 2024). This article considers the regulation of plant-based ingredients, including those produced using biotechnology-based processes, and showcases the EU-funded *InnCoCells* project as a foundation for the development of sustainable plant-based ingredients with scientifically validated efficacy.

Plants as a source of cosmetic ingredients

The prominent role of plant-based ingredients in today's cosmetic products is not a modern paradigm. Indeed, plants have been used as a source of cosmetic ingredients since antiquity (McMullen & Dell'Acqua, 2023). However, the extensive use of plant extracts in beauty products expanded in the early 1990s, reflecting a rapid shift away from the use of raw animal-based products due to risks associated with bovine spongiform encephalopathy and related diseases (Brown, 1997). This has coincided with a more gradual trend towards greater sustainability and the replacement of synthetic, oil-derived chemical ingredients such as preservatives with natural alternatives.

To understand why plants are so popular in human cosmetic products, we should consider that terrestrial plants have been on earth for more than 450 million years (Morris *et al.*, 2018), and have adapted to tolerate oxidative stress brought about by harsh environmental conditions (Sperling *et al.*, 2022), as well as interactions with pathogens, parasites and insect pests (Kapoor *et al.*, 2023). Plants have evolved defense systems (Rieseberg *et al.*, 2023) including metabolic responses that buffer oxidative bursts, hinder pathogens (Ramaroson *et al.*, 2022) and deter infestations with insects (Kortbeek *et al.*, 2019). Today's plants therefore provide a rich source of so-called secondary metabolites, which are not essential for plant growth and development but confer important ecological advantages due to their specific bioactivities. Many such metabolites are currently approved as drugs in the pharmaceutical industry because of their strong and specific pharmacological properties (Miralpeix *et al.*, 2013). The chemical diversity of plants is much higher than any chemical library made by humans and thus the plant kingdom represents an enormous reservoir of bioactive molecules to be discovered – not only for pharmaceutical applications but also for the cosmetics sector. Some of these metabolites are widely distributed, such as phenolics (Kähkönen *et al.*, 1999) and carotenoids (Young & Lowe, 2001), both of which act as antioxidants. Others are only found in certain plant families or species, such as particular alkaloids and terpenoids (Oksman-Caldentey & Inzé, 2004). These molecules are useful to humans because pathophysiological processes in animals and plants are related. For example, inflammation and aging-related effects in humans are associated with oxidative damage (Leonarduzzi *et al.*, 2012), and are inhibited by treatment with antioxidant and anti-inflammatory compounds produced in plants (Im, 2020; Phan *et al.*, 2018). Plant extracts are therefore valued for their anti-aging effects in cosmetic products (Zaid & Al Ramahi, 2019; Zhu *et al.*, 2022). Other valuable plant-derived secondary metabolites confer resistance to pathogens. Although plant pathogens generally do not infect animals (and vice versa), plant metabolites that inhibit the growth of plant pathogens can also inhibit other microbes, making them suitable as natural preservatives, which are highly sought after by the cosmetic industry (Bouarab Chibane *et al.*, 2019).

Although plants are popular materials for cosmetics, it takes more than science and technology to transform plant extracts into valuable cosmetic products. Indeed, the development of cosmetic active ingredients requires compliance with multiple international regulations, and our intention in this article is to describe the major regulatory challenges that a plant extract must successfully overcome to meet the expectations of the cosmetic market.

Use of plant genetic resources

Plants are part of the world's terrestrial biological diversity. Therefore, the use of any plant species must be considered in terms of the international regulations defining access to genetic resources. The Rio Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity, 2023) recognizes the right of countries to control access to their own genetic resources and has been ratified by 196 countries. The Rio Protocol was supplemented by the Nagoya Protocol (2010) on access to genetic resources and the sharing of benefits arising from their use (Secretariat of the Convention on Biological Diversity, 2015). It entered into force on 12th October 2014. The Nagoya Protocol establishes fundamental obligations for contracting countries to take measures surrounding access and benefit sharing (ABS) and compliance with national and supranational regulations.

Access obligations require that any institution, such as a cosmetics company or research laboratory working on the development of plant-based products, takes measures at the national level ensuring that it:

- creates legal certainty, clarity, and transparency
- establishes clear rules and procedures for prior informed consent and mutually agreed terms (PIC/MAT)
- can provide a permit or equivalent to demonstrate that access is granted
- creates conditions to promote and encourage research contributing to the conservation and sustainable use of biodiversity

Benefit-sharing obligations require that the relying party offers an equitable share of the benefits arising from the use of the genetic resources with the contracting party providing the genetic resources through mutual agreement. This includes research and development on the genetic or biochemical composition of genetic resources, in addition to applications and commercialization. Benefit sharing can be monetary, in the form of a deposit and/or royalties, or non-monetary such as sharing research results, or promoting businesses and economies from which the genetic resources originate.

Compliance obligations imply that the party utilizing genetic resources will support compliance with national laws of the party providing genetic resources. In particular, the relying party must take measures to monitor the use of genetic resources once they have left a country by carefully following effective control points at each stage of the value chain (research, development, innovation, marketing, and commercialization). In practical terms, the party wishing to access genetic resources must first consider the country of origin and comply with both its own national regulations but also the regulations in force in the country holding the genetic resources. National regulations are extremely diverse. For example, a company in France wishing to use local genetic resources for research only must request a permit from the Ministry of Ecological Transition, whereas no research permit is necessary in Germany.

The diversity of national regulations leads to a rather fragmented implementation of the Nagoya Protocol. The EU provides an interesting case study because different member states have different national regulations covering access to domestic genetic resources but implementation is governed under Regulation (EU) No. 511/2014. Some member states, such as France and Spain, have fully developed national ABS regulations and require PIC for access as well as MAT for their use. Others, such as Germany, have no ABS regulations for domestic genetic resources, although other laws may be relevant. A third group uses hybrid regulations, an example being Finland, with no PIC/MAT required for most Finnish resources but consent required for the use of Sámi traditional knowledge. Regulation (EU) No. 511/2014 makes no attempt to harmonize these national systems but instead imposes due diligence obligations to ensure the provider country's rules are followed, involving national competent authorities, monitoring at key checkpoints, and penalties for noncompliance. Although intended to promote legal certainty and fairness, the diversity of national regulations within and beyond the EU inevitably increases the administrative burden and causes delays, particularly in collaborative research projects. In sectors such as crop improvement, the coexistence of the Nagoya Protocol with the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) adds complexity because plant genetic resources for food and agriculture can circulate under a separate multilateral system and the two ABS systems are not fully aligned. It is fair to say that ABS regulations, while well intentioned, have been only partially successful, with benefits often skewed towards administrative rather than scientific or community outcomes.

Approved lists of plant species and extracts for cosmetic products

Many plants produce toxic compounds, so both the plant species and the technological processes used to extract and prepare ingredients must be approved before inclusion in a cosmetic product. Official documents regulating plant authorizations are issued by countries based on risk assessments. The Chinese and EU systems are often used as examples because they represent large segments of global cosmetics sales and R&D, and also embody distinct regulatory archetypes (ingredient-centric in China vs product-centric in the EU).

China has a list of permitted plant extracts found in the Inventory of Existing Cosmetic Ingredients in China (IECIC), the most recent version of which was published in 2021 by the Chinese National Medical Products Administration (NMPA, 2021). Initially, the IECIC list contained 8972 already-used ingredients, including extracts defined by the plant species and often a particular organ, such as roots or flowers. These ingredients were considered approved in China as long as historical maximum concentrations were not exceeded (these maximum values were provided for each listed ingredient). For example, *Scutellaria baicalensis* Georgi extract has three entries in IECIC2021: root powder (no. 03075), root extract (no. 03076), and plant extract (no. 03077), the latter meaning that any part of the plant may be used. Conversely, *Scutellaria*

lateriflora L. is not listed in IECIC2021, even though it is widely used in herbal medicine (Awad *et al.,* 2003). Plant extracts that are not listed in IECIC2021 are considered new cosmetic ingredients (NCIs) and require registration with NMPA before they can be used as ingredients for cosmetics sold in China (NMPA, 2021). Depending on the level of risk represented by an NCI, this registration process will follow either a high-risk or low-risk route. The high-risk track includes a mandatory toxicology report demonstrating product safety, which may sometimes require animal testing at the request of the Chinese authorities. The low-risk track involves the completion of online dossiers. In this case, the NCI is considered to be notified and can be used to manufacture a new cosmetic product in China and/or import it. Only six NCIs were notified in 2021, but this increased to 41 in 2022, 68 in 2023, 101 in 2024, and 11 more as of February 2025, showing that companies producing cosmetic ingredients are becoming more accustomed to China's regulatory guidelines.

No formal NCI registration is required in the EU, so ingredients may be used if not prohibited/restricted and the finished product passes safety assessment. However, colorants, preservatives and UV filters do require pre-authorization. Animal testing for cosmetic ingredients has been banned in the European Union since 11th March 2009 (European Commission, 2009). Therefore, any company wishing to introduce a high-risk NCI would have to choose between the Chinese and European markets. Given these conflicting regulatory issues, we are unaware of any European cosmetic company having filed for the registration of a high-risk NCI in China. The EU places responsibility on industry self-regulation backed by strict safety standards and post-market surveillance, whereas China operates a more centralized, pre-approval model. For companies, this means that an ingredient considered compliant in the EU may face duplicated or lengthier procedures in China, especially due to divergent requirements on toxicological data and the persistence of animal testing. This creates regulatory asymmetry that can delay the global rollout of innovative natural or biotechnology-derived cosmetic ingredients.

Beyond these two major archetypes, there are differences between national regulations that must be taken into account when courting wider global markets. In Asia, for example, we can compare the regulations in India, Japan, South Korea and the Association of Southeast Asian Nations (ASEAN). In India, the Cosmetics Rules (2020) modernized licensing, import registration and labeling under the Drugs and Cosmetics Act (CDSCO, 2020). India has banned the import of animal-tested cosmetics since 2014 (CDSCO, 2020). "Herbal cosmetics" are regulated as cosmetics unless positioned as AYUSH medicines (Ayurveda, yoga/naturopathy, Unani, Siddha and homeopathy) under separate statutes. Policy has also moved to professionalize exports through the AYUSH Export Promotion Council (AYUSHEXCIL) launched in April 2022 (Minister of AYUSH, 2023). For biotechnology-derived and other novel plant ingredients, there is no NCI-like pre-approval. Safety evidence and compliance standards apply at the product level, so India aligns more closely with the EU's product-centric model than China's NCI gatekeeping. Japan and Korea use similar systems based on negative and positive lists (Japan) or negative and restricted lists (Korea) with no separate category for plant-based or botanical ingredients (Ministry of Health and Welfare, 2000; Ministry of Food and Drug Safety, 2019). In practice, this means that new plant-based extracts can be used without ingredient pre-approval if not on the positive list (similar to EU, contains colorants, preservatives and UV filters), is not restricted, and is safe. Animal testing on cosmetics is discouraged but not banned in Japan, and is banned with exceptions (if no alterative tests are validated) in Korea. In both countries, functional cosmetics (quasi-drugs) require separate approval. Finally, the ASEAN Cosmetic Directive harmonizes definitions, product information and safety assessment, labeling, and post market surveillance across the 10 member states, closely tracking the EU model and embedding ISO 22716 GMP (ASEAN, 2012). The ASEAN Cosmetic Directive has measurably reduced technical barriers to trade while maintaining safety expectations.

New trends in green cosmetics

The trend in consumer demand for more sustainable, eco-friendly cosmetic products mirrors the general growth in the market for natural ingredients. From a technological perspective, this demand translates into the application of green chemistry principles during ingredient manufacturing (Anastas & Eghbali, 2010). However, as appealing as it may be to the public, the term "green" is extremely vague. The lack of a common definition makes it difficult to distinguish genuinely sustainable products from "greenwashing". To overcome this issue, various certification systems have emerged to verify product qualities throughout the manufacturing chain, including the supply of genetic resources used as raw materials, ingredients, production processes, transportation and storage, packaging, and waste management. Other standards involve life cycle assessment methods that consider aspects such as eco-responsibility through the measurement of energy and water use and/or carbon emissions (Rocca *et al.,* 2023). For example, the COSMOS standard was created by five certification agencies in Europe: Bundesverband der Industrie- und Handelsunternehmen (BDIH, 2023), Cosmebio (Cosmebio, 2023), Ecocert (Ecocert, 2023), Istituto Certificazione Etica e Ambientale (ICEA, 2023) and the Soil Association (Soil Association, 2023). Many additional certification standards have been developed over the last decade such as the Union for Ethical Biotrade (UEBT), NATRUE, Rainforest Alliance, Responsible Sourcing Palm Oil (RSPO), and Responsible Mica Initiative (RMI).

Biotechnology plays an increasingly prevalent role in the manufacture of plant-based ingredients so it is also important for the public to understand how this aligns with the certification programs. Concerning the use of genetically modified organisms (GMOs), the COSMOS standard provides a clear technical guide (COSMOS, 2021). Genetically modified plants are not authorized, but ingredients produced using GMO-derived enzymes can be approved if they comply with the following conditions:

- The enzymes from GMOs are purified before use
- The GMOs are used in closed tanks

- The GMOs are deactivated after the process
- A risk assessment linked to the impact of the release of GMOs into the environment is carried out
- A risk plan to deal with accidental release of GMOs into the environment is established
- A negative PCR or other method must be provided to prove that no DNA from the GMO is present in the final material

Given the expanding role of GMO-derived enzymes in the food and pharmaceutical industries (Trono, 2019), it is likely that cosmetic ingredients produced using such enzymes could soon reach the market. In addition, fermentation media must comply with COSMOS standard criteria stating that each ingredient in the medium must be of mineral, vegetable, microbial, animal, or marine origin and, where applicable, must be guaranteed of non-GMO origin.

The IECIC2021 list already contains cosmetic ingredients that are produced by fermentation using GMO microbes, including resveratrol, kojic acid, and hyaluronic acid (Gomes *et al.*, 2020). These were introduced to the Chinese market before 2020 and are therefore approved as "historic ingredients" both in terms of the chemical entities themselves and the biotechnological processes used to produce them. The IECIC2021 list also contains many other pure compounds of natural plant origin that could be produced by GMO microbes in the future, including ferulic acid (no. 11020), carvacrol (no. 07021), gallic acid (no. 01212), phytic acid (no. 03146) and coumarin (no. 06985). Because these products will be introduced to the Chinese market after 2020, they will require a low-risk approval route. The use of optimized biotechnological processes to manufacture such products could help to reduce the carbon footprint of the cosmetic industry and free up agricultural lands for crops, which would be in keeping with green chemistry principles (Yi & Ng, 2023).

InnCoCells – innovative high-value cosmetic products from plants and plant cells

The issues outlined above concerning the role of biotechnology in the development of sustainable, plant-derived cosmetic ingredients led to the conception of *InnCoCells*, a Horizon 2020 project focusing on innovations in bioprospecting, production systems, purification methods and functional bioassays relevant to today's cosmetics market. To our knowledge, *InnCoCells* is thus far the only EU-funded project focusing solely on cosmetic ingredients, and more projects covering this topic should be funded in different countries to advance its key objectives. The *InnCoCells* consortium comprised 17 partners from 11 countries representing European academic and industrial leaders, and was coordinated by VTT Technical Research Centre of Finland Ltd (Figure 1). The project was launched in May 2021 with a budget of €7.9 million and ran until the end of September 2025. The main objective was to bring at least 10 novel, scientifically validated and well-characterized ingredients to the pre-commercial stage. The production systems

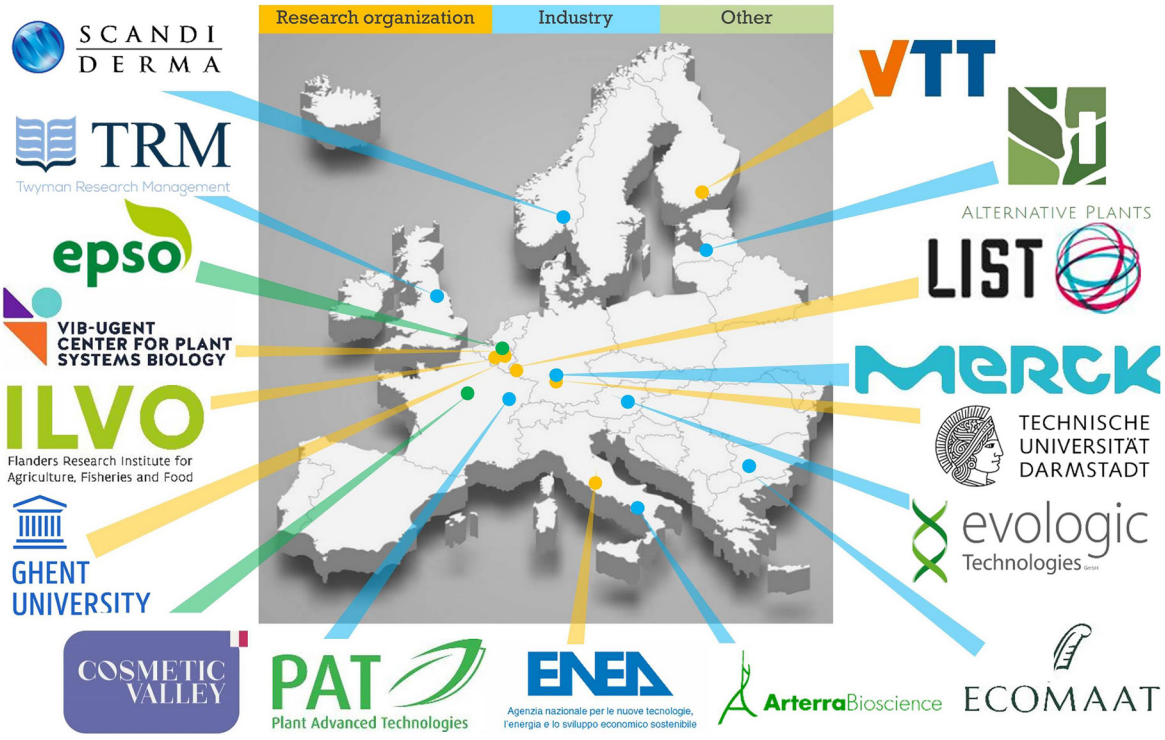

Figure 1. The *InnCoCells* consortium.

considered by the project were plant cell suspension cultures, hairy roots, aeroponic systems and greenhouse/field cultivation (Figure 2). The project also developed highly innovative methods for the preparation of extracts, detailed metabolic analysis, and the testing of bioactivities to provide scientific evidence of efficacy.

The work was divided into five scientific work packages (Figure 3). The bioprospecting phase of the project (**WP1**) resulted in the identification of ~100 underutilized plant species, by-products or waste fractions from the agrifood industry for further investigation. Based on earlier studies by the partners, preliminary tests and information from the literature, we were able to define 25–30 plant species as the most promising resources. Importantly, all the plant species and extracts were included in the IECIC list and their utilization did not violate international regulations defining access to genetic resources, including the Nagoya protocol as described above. This early work therefore ensured that any ingredients delivered by the project would meet current regulatory standards, making them suitable for commercialization.

We developed tailored cultivation processes in all the *InnCoCells* production platforms to optimize biomass production and the accumulation of specific bioactive metabolites in **WP2**. This provided a panel of candidates (product and process combinations) that were tested for scalability in **WP3**. Accordingly, we scaled four cell culture and hairy root lines up to 300 L and two to 1000 L (defined as pilot scale). For the aeroponic cultivation system, three plant species were scaled up to 100 m^2 surfaces (also defined as pilot scale). We developed novel downstream processes based on the pre-treatment of plant biomass using methods such as pulsed electric fields to achieve high yields of extracts with the desired biomolecular composition in **WP4**. The reproducibility of the upstream and downstream processes and the stability of the resulting extracts are important parameters that we focused on towards the end of the project.

More than 100 hydrophilic and lipophilic extracts were tested in **WP5** using a range of advanced bioactivity assays, including tests for cytotoxicity, as well as anti-inflammatory, anti-aging, antioxidant and antimicrobial activities, all of which are important in the cosmetics industry, especially in skincare products. The 25 best-performing ingredients were tested in four different ex vivo assays based on skin biopsy samples. The composition of extracts with the most promising bioactivities has been assessed in detail by advanced targeted and untargeted metabolomics.

As more ingredients came through the pipeline, we focused on regulatory compliance, life cycle assessment and the evaluation of product/process sustainability in **WP6**. This requires extensive documentation and the assessment of techno-economic viability. Regulatory compliance was initially evaluated for a small number of our most advanced ingredients, and we then focused

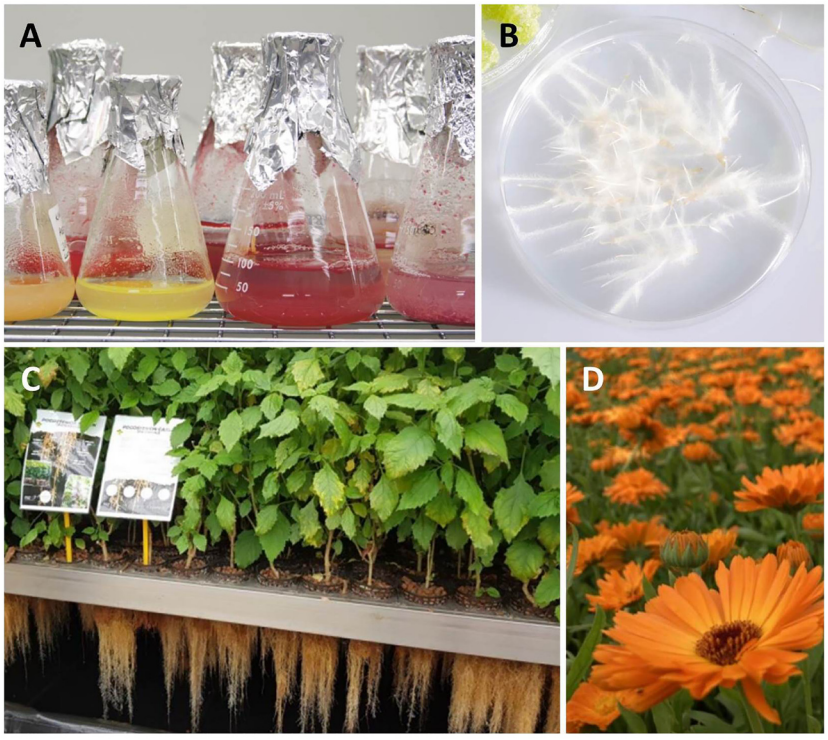

Figure 2. The production systems used in the *InnCoCells* project: (**A**) Plant cell suspension cultures; (**B**) Hairy roots; (**C**) Aeroponic systems; and (**D**) Field cultivation. Image credits: (**A**, **B**) VTT, (**C**) Plant Advanced Technologies, (**D**) EVILVO.

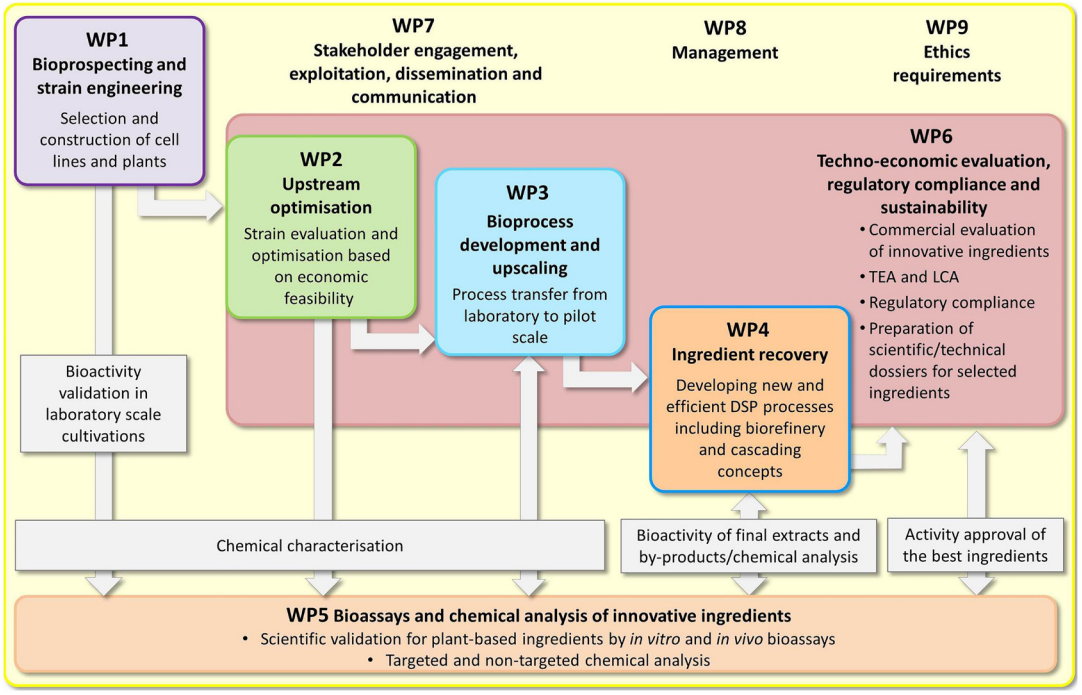

Figure 3. The organization of the *InnCoCells* project.

on the preparation of safety and technical data sheets, scientific dossiers, and the pre-commercial evaluation of efficacy claims. This work was complemented by an extensive panel of dissemination, exploitation and communication activities in **WP7**. These include an informative website, an active social media presence, the publication of research articles, presentations at scientific conferences, and the organization of public webinars and stands at high-profile cosmetic industry exhibitions such as the annual Cosmetic360 event in Paris. Our Stakeholder Group, made up of cosmetic industry representatives, farmers, academic researchers and cosmetic end-user groups, has guided the selection of promising cosmetic ingredients and has helped to raise awareness about the project by attending our meetings and media events, and by publicizing our brochures, podcasts, and promotional videos. In this way, the *InnCoCells* project aims to span the value chain from discovery, through product and process development and testing, up to the pre-commercial stage, where our industrial partners and Stakeholder Group members have the opportunity to take the resulting ingredients to the next stage on the road to the cosmetics market.

Outlook

In conclusion, neither market regulations nor the ban on GMO-derived ingredients constitutes an insurmountable hurdle to the use of biotechnology for the production of cosmetic ingredients. We already have clear requirements from national authorities and non-governmental standards to help us define innovative cosmetic ingredients based on biotechnological processes that meet market expectations in terms of safety, validated efficacy and low environmental impact. However, it is true that global cosmetic regulations are inconsistent, leading to variable quality and safety standards. In our view, what is needed is not a single global regulation, which would be politically and legally unrealistic, but the development of a simple, harmonized regulatory pathway grounded in a few core principles that can be adapted across jurisdictions. Such a pathway could include baseline safety and quality requirements (e.g., mandatory toxicological data, laboratory testing to exclude contaminants, and validated non-animal testing methods), recognition of traditional use, incorporation of sustainability data (e.g., life cycle assessment), ABS compliance, and international convergence supported by organizations such as the WHO and OECD. This approach would simultaneously safeguard consumer health, support innovation in herbal and biotechnology-derived cosmetics, and ensure that biodiversity-rich countries benefit equitably from resource utilization.

A globally harmonized framework would support initiatives such as *InnCoCells*, the first and currently only large EU-funded public project dedicated to the development of sustainable plant-derived cosmetic ingredients with scientifically proven effects. We achieved the major project objective to establish environmentally sustainable pilot-scale production and purification technologies for at least 10 active, fully-characterized, pre-commercial cosmetic ingredients. These were narrowed

down from a much broader panel, which resulted in the screening of more than 100 different plant items (botanical species and parts thereof), the biodiscovery and sustainable exploitation of at least 10 relevant metabolic pathways in various plant species, the development of a multi-step evaluation pipeline for the testing of plant-derived bioactive molecules and extracts yielding at least 50 scientifically verified active ingredients for cosmetic products, and the optimization of production processes and technologies for at least 20 ingredients based on plant cells/hairy roots, aeroponics, and greenhouse/field cultivation. We have also explored more than 10 agrifood by-products and waste fractions in a cascade biorefinery approach to generate value-added extracts, including olive pomace and ginger press cake. The knowledge and intellectual property accumulated by *InnCoCells* will long outlast the project itself and will form the basis of a new generation of plant-based cosmetic ingredients for the well-informed consumers of tomorrow.

Data availability

No data are associated with this article.

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Open Peer Review

Current Peer Review Status: ✔ ✔

Version 2

Reviewer Report 03 October 2025

https://doi.org/10.21956/openreseurope.23080.r59606

✔ **Niharika Sahoo Bhattacharya**
Indian Institute of Technology Kharagpur, Kharagpur, West Bengal, India

The authors have adequately addressed my previous comments. I have no further comments to make.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Drugs and cosmetic regulation, Intellectual Property Laws

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 23 August 2025

https://doi.org/10.21956/openreseurope.21757.r56198

? **Niharika Sahoo Bhattacharya**
Indian Institute of Technology Kharagpur, Kharagpur, West Bengal, India

This Open letter provides an interesting interdisciplinary perspective on biotechnology, plant genetic resources and regulation. The author deserves commendation for the depth of research conducted on the intersection of biodiversity, cosmetic ingredients, and cosmetics regulation.

However, a few areas in the article could benefit from further elaboration.
1.Nagoya protocol to CBD is an important instrument for the sharing of genetic resources and access benefit sharing. However, as the authors pointed out, national legislations are highly diverse when it comes to compliance obligations towards the country providing genetic resources and the national obligations of the receiving country. I feel this section can be elaborated at least with respect to European Union to give a holistic view of diverse national laws or the need of harmonization. Particularly, it will be interesting to learn the role of EU Access and Benefit Sharing (ABS) Regulation (Regulation (EU) No 511/2014) and how it tries to balance the inconsistencies. How successful is ABS mechanism when it comes to exchange of plant genetic resources among different continents?
2. The basis for selecting certain jurisdictions for comparison remains unclear. On what criteria were the specific national regulatory frameworks chosen, and how do these selections reflect broader trends in global cosmetic regulation? While many Asian countries are known for traditional herbal based cosmetics, authors have only reviewed the China and provided information on permitted plant and new plant ingredients for cosmetics and corresponding regulation. It will be interesting to see the position of other Asian countries as well. For example, country like India which has a rich traditional herbal-based cosmetics and many companies are making its global presence by bringing innovative herbal products. How the newer innovations through biotechnology or other processes are addressed in those countries' regulations?
3. The author rightly highlights the shortcomings and inconsistencies in risk assessment practices across jurisdictions. Yet the discussion would have been stronger had it included a comparative analysis of the registration process for new cosmetic ingredients (NCIs) in the EU alongside China. This would help to understand the regulatory imbalance and potential barriers to development.
4.This manuscript provides a comprehensive overview of InnCoCell project, which seems to be an essential endeavor from scientist community towards development of new plant based cosmetic ingredients. Such projects highlight the need of bioprospecting and appropriate regulation for the sustainable development of communities as well as biodiversity preservation. More such projects should be promoted in different Countries to advance these crucial objectives.
5.While it is true that the EU offers well-defined national and central regulatory frameworks, along with clear non-governmental standards, cosmetic regulations globally remain highly inconsistent, with numerous reports highlighting quality and safety concerns. In this context, the authors' perspective on establishing simple regulatory pathway that ensures both quality and safety while supporting sustainable practices and access benefit sharing will be a valuable addition.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)

Partly

Does the article adequately reference differing views and opinions?

Partly

Are all factual statements correct, and are statements and arguments made adequately supported by citations?

Yes

Is the Open Letter written in accessible language? (Please consider whether all subject-

specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Drugs and cosmetic regulation, Intellectual Property Laws

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 01 Sep 2025

Richard Twyman

Response to reviewer #2 We thank the reviewer for recommending additional content for our article, which has improved its scope and level of detail. We provide a point by point response below.

1. We have added a paragraph to the “use of plant genetic resources section” describing how Regulation (EU) No. 511/2014 applies overarching guidance to the implementation of national ABS regulations in EU member states.
2. In the “approved lists…” section, we have now explained the justification for the selection of Chinese and EU regulatory frameworks, namely that they represent large segments of global cosmetics sales and R&D, and also embody distinct regulatory archetypes (ingredient-centric in China vs product-centric in the EU). In the same section, we have now added a paragraph summarizing the regulatory frameworks in India, Japan, South Korea and ASEAN to provide a broader perspective on how these issues are handled in Asia. We have included, as references, links to documents outlining the primary legislation in these countries.
3. In the same section, we have compared the regulation of cosmetic ingredients in China vs the EU in more detail.
4. We agree that more funding should be available for projects dealing with cosmetic ingredients, and have included a statement at the beginning of the InnCoCells section making this point explicitly.
5. The reviewer raises an excellent point about using this Open Letter as a platform to make recommendations about the establishment of simplified regulatory pathways to harmonize regulatory practice worldwide. We have added such commentary at the beginning of the outlook section and thank the reviewer for this suggestion.

Competing Interests: No competing interests were disclosed.

Reviewer Report 20 August 2025

https://doi.org/10.21956/openreseurope.21757.r56195

Ahmed Zahidi
Mohammed V University, Rabat, Morocco

Title:
From plant genetic resources to cosmetic active ingredients: when science meets regulation and market rules

The manuscript addresses a highly relevant and strategic topic at the intersection of plant-based innovation, regulatory complexity, and sustainable cosmetic development. By focusing on the regulatory and biotechnological dimensions of natural ingredient production, and illustrating them through the Horizon 2020 InnCoCells project, the article provides a clear and timely overview that will interest researchers, industry professionals, and policymakers alike.
The manuscript is scientifically sound and well-structured; however, minor revisions are recommended to improve the precision of certain formulations and to clarify the intended objectives. These improvements will enhance the overall clarity and impact of the article.

General recommendations:

*If the journal's editorial guidelines allow, I recommend including a list of abbreviations to improve clarity and reader accessibility.

Minor corrections
Abstract:
I recommend adding one or two key regulatory references in the abstract.
Please add the term biotechnology in the abstract, especially since it appears in the keywords, to accurately reflect the scientific focus of the article.

Keywords:
I recommend citing the following keywords in this order:
Plant-based ingredients, cosmetics, sustainability, efficacy, regulatory compliance, biotechnology
The selected keywords accurately reflect the main themes of the article; they are precise, consistent with the manuscript's content, and enhance its visibility in both scientific and regulatory databases.

Introduction:
The introduction provides an overview of current trends in the cosmetics market and the growing interest in natural, plant-based products. However, it relies on a single reference (market statistics) and does not cite any regulatory or technical references, even though these are part of the core of the article. Furthermore, the specific objective of the article is not clearly stated.

Use of plant genetic resources:
Please replace:
“The Rio Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity, 2023) recognizes the right of countries to control access to their own genetic resources (Secretariat of the Convention on Biological Diversity, 2023) and has been ratified by 196 countries.”
with
“The Rio Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity, 2023) recognizes the right of countries to control access to their own genetic resources and has been ratified by 196 countries.”

References:
Please ensure that all references are formatted according to the journal’s guidelines, with particular attention to the next references, which may contain formatting or content inconsistencies
Some “Reference Source” entries do not include the date of access, which is generally required for online resources that are subject to updates or changes over time. It is recommended to add the access dates to ensure proper citation standards are met.
Please replace “BDIH” with “Bundesverband der Industrie- und Handelsunternehmen”
Please replace “NMPA” with “National Medical Products Administration”

Please replace
“Trono D: Recombinant enzymes in the food and pharmaceutical industries. Adv Enz Technol. 2019; 13: 349–87.”
with
“Trono D. Recombinant enzymes in the food and pharmaceutical industries. *In* Polaina, J. and MacCabe, A.P. (eds.): Advances in enzyme technology. Amsterdam: Elsevier; 2019: 349–87.”

My conclusion:
This manuscript is scientifically sound and has the potential to influence future research. However, minor corrections are required to ensure its clarity and accuracy

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Yes

Does the article adequately reference differing views and opinions?
Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)

Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Pharmaceutical chemistry, Phytochemicals, Nutrition, Iodine deficiency, Public health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 01 Sep 2025

Richard Twyman

Response to reviewer #1 We thank the reviewer for these helpful comments and suggestions, and provide a point by point response below.

1. The journal's editorial guide does not allow references to be cited in the abstract and does not, as far as we are aware, include keywords that can be selected by the authors. Although the word "biotechnology" is not in the abstract, the word "biotechnological" is already there. Accordingly, we have not modified the abstract. However, we appreciate the reviewer's suggestions and have instead cited new references about the regulation of cosmetics in the introduction, and have added the term "biotechnology-based" there too.
2. In the introduction, we have added two recent references about the regulation of cosmetics and have concluded the introduction with a statement outlining the objective of the article.
3. We have removed the repeated citation from the section on the use of plant genetic resources as suggested.
4. We have updated the references highlighted by the reviewer and are grateful for the additional information provided. Upon submission, we included the data of last access to online resources (as we have for the new references added in this update) and we have asked the journal editors to ensure the access dates are included.

Competing Interests: No competing interests were disclosed.