INTEGRATION OF ETHNO-BEAUTY KNOWLEDGE (ETHNOBOTANY) WITH BIOTECHNOLOGY: FROM TRADITIONAL PLANTS TO MODERN BIOACTIVES

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Abstract

This study aims to map recent scientific evidence (2018–2025) regarding the cosmetic and dermatological activities of traditional plants, identify the role of biotechnology in enhancing the effectiveness of natural bioactive compounds, and formulate recommendations for developing modern bioactives rooted in ethno-beauty knowledge. A systematic review method was employed following the PRISMA 2020 guidelines, involving literature searches through Scopus, PubMed, ScienceDirect, and Google Scholar, selection of articles based on inclusion criteria, and thematic analysis of phytochemical data, biological activities, and applied formulation technologies.The results indicate that traditional plants rich in polyphenols, flavonoids, and triterpenoids exhibit significant antioxidant, anti-inflammatory, anti-aging, and skin hydration effects. Empirical evidence further shows that biotechnological innovations such as nanoemulsions, nanosuspensions, liposomes, and controlled delivery systems substantially improve the stability, bioavailability, and efficacy of natural compounds. Centella asiatica emerges as one of the most scientifically validated plants, demonstrating strong skin-regenerative, protective, and anti-photoaging properties when processed through modern formulation technologies. The thematic synthesis highlights that integrating ethnobotanical knowledge, phytochemical profiling, and biotechnology provides a strong scientific foundation for the development of modern, tradition-based cosmetic bioactives. In conclusion, traditional plants hold significant potential as sources of modern cosmetic bioactives, and the application of biotechnology is crucial in optimizing their performance. Further development requires standardized extraction methods, stronger clinical validation, and collaboration between researchers and industry to ensure the creation of safe, effective, and sustainable natural cosmetic products.

Keywords: Ethnobotany, Biotechnology, Traditional Plants, Natural Bioactives, Anti-Aging Cosmetics.

INTRODUCTION

Traditional plant-based natural beauty products are once again gaining traction in the modern cosmetics industry, primarily due to increasing consumer demand for safe, environmentally friendly products with minimal synthetic ingredients. Recent studies have shown that traditional Indonesian and Asian ingredients hold significant potential as a basis for natural cosmetic formulations, but require scientific validation and modern formulation technology for widespread adoption in the beauty industry (Nurrosyidah et al., 2025). In line with the global clean beauty trend, the use of natural bioactives continues to increase, making the integration of ethno-beauty knowledge and biotechnology highly relevant. This situation highlights the need to explore theoretical aspects that explain the relationship between traditional plant use and its scientific proof through biotechnology.

Theoretically, ethnobotany provides an understanding of how traditional communities utilize plants for skin care and physical health. This approach is strengthened by phytochemical findings that identify active compounds such as polyphenols, flavonoids, and triterpenoids in plants like Centella asiatica, which play a role in antioxidant, anti-inflammatory, and skin regeneration activities (Bansal et al., 2024). In the context of modern cosmetics, biotechnological advances such as nanoencapsulation, controlled delivery systems, and lipid-based formulation techniques have been shown to improve the stability, bioavailability, and effectiveness of natural compounds when applied to the skin (Iskandar et al., 2024). This integration of traditional knowledge and technology strengthens the scientific justification that traditional plants can be developed into more potent and stable modern bioactives. This theoretical foundation and biotechnological advances open up space for further exploration into how the effectiveness of Centella asiatica has been proven through various recent empirical findings.

Empirical evidence shows that the Centella asiatica plant is one of the most widely studied natural ingredients in dermatology and cosmetics. A systematic

review by Kongkaew et al. (2020) demonstrated that topical application of C. asiatica extract significantly reduced wrinkles and increased skin hydration without significant side effects. Nanoencapsulation technology has also been reported to enhance the penetration and protective activity of C. asiatica extract by reducing the activity of collagen-degrading enzymes, as demonstrated by Kwon et al. (2012). This research demonstrates how the transformation of traditional ingredients through biotechnology can produce more effective cosmetic formulations than conventional crude extracts.

Despite numerous positive findings, gaps remain in the literature. A comprehensive review that integratively links the complete scientific pathway from ethnobotanical knowledge to phytochemical profiles to biotechnological applications to modern dermatological evidence within the current timeframe (2018–2025) is lacking. The existing literature remains fragmented by plant species, extraction technique, or test type, making it difficult to draw comprehensive conclusions or establish consistent scientific standards (Bansal et al., 2024; Nurrosyidah et al., 2025). This fragmentation has also fueled debate about whether preclinical evidence for herbal extracts is sufficient for commercialization or whether further validation through clinical trials and biotechnological standardization is necessary. The consistency of these findings highlights the urgency of reviewing the existing research landscape to identify gaps that remain unexplained in the literature.

Experts emphasize that filling this gap is a crucial step to ensure consumer safety, encourage the sustainable use of local plants, and strengthen the scientific basis of natural cosmetic products (Iskandar et al., 2024). Without a solid mapping, the development of tradition-based natural active ingredients is potentially hampered by a lack of standardization, regulation, and adequate clinical evidence. This situation highlights the need for a more integrated research framework to ensure the transition from ethnobotanical knowledge to modern biotechnological applications is consistent, transparent, and meets the quality demands of today's cosmetics industry. Clarifying the interrelationships between research stages opens the way for formulating more focused study objectives that are relevant to both scientific and industrial needs

The relevance of this research is further strengthened by the increasing need for a comprehensive scientific basis in the development of natural cosmetics. The main objectives of this research include: (1) mapping the latest scientific evidence (2018–2025) regarding the cosmetic and dermatological activities of traditional plants; (2) identifying the role of biotechnology in increasing the effectiveness and stability of natural ingredients; and (3) formulating recommendations for the development of modern, tradition-based bioactive compounds that are safe, effective, and sustainable.

METHOD

This study employed a systematic review design based on the PRISMA 2020 guidelines, ensuring a structured and transparent data search, screening, quality evaluation, and synthesis process. This approach was chosen to obtain a comprehensive scientific overview of the relationships between ethnobotany, phytochemical profiles, biotechnological applications, and dermatological evidence of traditional plants in publications published between 2018 and 2025.

The literature search was conducted through four major scientific databases: Scopus, PubMed, ScienceDirect, and Google Scholar. The search utilized a combination of keywords with Boolean operators, such as ethnobotany, traditional cosmetics, phytochemistry, bioactive compounds, herbal skincare, biotechnology, and nanoencapsulation, to broaden the scope of articles found and ensure relevance to the research focus. The initial search process yielded several articles, which were then selected based on the suitability of their titles and abstracts.

Articles that met the initial criteria were then evaluated based on inclusion criteria: publications between 2018 and 2025, discussing traditional plants in the context of beauty or dermatology, and presenting phytochemical data, biological tests, or the application of biotechnology. Articles were also required to be available in full text and peer-reviewed to ensure their academic quality. Conversely, articles unrelated to cosmetics, lacking phytochemical or biological data, and reviews lacking primary data, particularly for systematic reviews, were excluded.

The entire article selection process followed the PRISMA Flow Diagram, which included identifying articles from various databases, screening based on content relevance, assessing eligibility based on full text, and determining final articles that met all criteria. Documentation at each stage was conducted to maintain methodological accountability.

The final stage of the research involved data analysis, which began by extracting key information from each article into a summary table containing phytochemical profiles, biological activities, and the biotechnology used. The structured data were then analyzed using a thematic synthesis approach to map key research patterns. This synthesis resulted in an integrated flow of relationships between traditional plants as sources of bioactive compounds, dominant phytochemical compounds, the application of technologies such as nanoencapsulation or controlled delivery systems, and

evidence of cosmetic effectiveness reported in various dermatological studies.

RESULTS AND DISCUSSION

The results and discussion of this study were compiled to provide a comprehensive overview of the key findings from all articles that passed the selection process. The analysis focused on three areas, based on the research objectives: the phytochemical characteristics of traditional plants, biological activities related to dermatological and cosmetic benefits, and the use of modern biotechnology to enhance the stability and effectiveness of bioactive compounds. All information obtained through the data extraction process was compiled in a summary table, providing a systematic visualization of the types of plants or extracts studied, the dominant chemical components, the biological mechanisms of action, and the formulation techniques or nanotechnology used in the various studies. This structured presentation allows for the identification of general patterns, scientific trends, and recent developments related to natural cosmetics. Further thematic analysis explored the relationship between phytochemical profiles, biotechnological approaches, and dermatological outcomes, resulting in an integrated understanding of the potential for developing safe, effective, and sustainable traditional plant-based bioactive compounds.

Table 1. Table Literatur Review

No	Phytochemical Profile	Biological	Biotechnology	Reference
1	Flavonoids, phenolics, tannins, triterpenoids, saponins	Antioxidant activity → potential skin anti-aging	Ethanol extraction + sonication	Defi, R. S. et al. (2023) Exploration of the potential of 16 tropical Indonesian plants as natural anti-aging agents
2	Phenolics, flavonoids (total phenolics/flavonoids)	Antioxidant activity + stability as anti-aging cosmetic	Nano-/particles (nanoparticles)	Saputri, R. K. et al. (2024) Antioxidant activity and characterization of Salak Wedi peel nanoparticles as anti-aging cosmetics
3	Curcuminoids / polyphenols	Antibacterial activity, cosmetic/antimicrobial potential	Green-synthesis nanoparticles (AgNP)	Rajak, K. K. et al. (2023) Green synthesis of silver nanoparticles using Curcuma longa flower extract and antibacterial activity
4	Polyphenols, flavonoids, multiple natural antioxidants	Anti-aging activity via free radical scavenging & skin protection	Discussion of various nanocosmetics & formulations	Ciptaningrum, S. R. R. et al. (2024) Review: Potential antioxidant compounds in herbal plants for cosmetic & nanocosmetic anti-aging formulations
5	Various phytochemicals (phenolics, flavonoids, terpenoids)	Anti-aging effects, UV protection, moisture retention, antioxidant, brightening	Nanoemulsions, liposomes, SLN, NLC, ethosomes, niosomes, transfersomes	Husni (2023) Topical formulation of herbal nanocosmetics for anti-aging
6	Flavonoids/polyphenols & natural antioxidants	ROS neutralization, NRF2 pathway activation, MMPs & inflammation suppression → anti-aging effect	Data synthesis & meta-analysis from multiple studies	"Exploring Natural Antiaging Agents in Cosmetics: A Systematic Review..." (2025)

No	Phytochemical Profile	Biological	Biotechnology	Reference
7	Polysaccharides, flavonoids, phenolics (combined)	Anti-aging effects & skin improvement indicators in cream formulation	Modern topical cream formulation	Wulandari, R. et al. (2025) Physicochemical Evaluation and Anti-Aging Activity of The Cream Formulation Containing Aloe Vera and Rosella Extracts
8	Phenolics/polyphenols from Tamarillo fruit	Antioxidant activity (DPPH assay), potential cosmetic skin benefits	Biopolymer-based nanoparticles → topical lotion	Ningrum, W. A. et al. (2021) Evaluation of Tamarillo Extract Nanoparticle Lotion as an Antioxidant
9	Various natural phytoconstituents	Anti-aging, brightening, UV protection & skin aging prevention	Nanoformulation (lipid carriers, nanoemulsions, niosomes)	Garcella, P. et al. (2023) Narrative Review: Herbal Nanocosmetics for Anti-Aging
10	Polyphenols, flavonoids, phenolics as UV absorbers/antioxidants	Potential skin protection from UV / anti-aging cosmetic effects	Discussion of cream & nanoparticle formulations	Widodo, A. R. et al. (2024) Review: Potential of Herbal Plants for Sunscreen Formulation in Creams and Nanoparticles
11	Flavonoids, phenolics, tannins, triterpenoids, saponins	Antioxidant activity → potential skin anti-aging	Ethanol extraction + sonication; DPPH evaluation, total phenolics/flavonoids	Defi, R. S. et al. (2023) Exploration of the potential of 16 tropical Indonesian plants as natural anti-aging agents
12	Phenolics/polyphenols (ethanol extract)	Antioxidant activity → potential anti-aging in gel cosmetic	Topical gel formulation (Na-CMC base)	Lubis, M. S. et al. (2024) Antioxidant potential of ethanol extract of Tamarind fruit peel as anti-aging in gel cosmetics
13	Various phenolics, flavonoids, terpenoids, antioxidants	Antioxidant, anti-aging, anti-inflammatory, whitening → cosmeceutical potential	Discussion for nanocosmetics/ natural cosmetic formulations	Ciptaningrum, S. R. R. et al. (2024) Potential antioxidant compounds in herbal plants for cosmetic & nanocosmetic anti-aging formulations
14	Plant extracts: phenolics, flavonoids, polyphenols, etc.	Antioxidant activity for skin care / anti-aging / prevention of free radicals & photo-aging	Serum / topical traditional formulation (literature analysis)	Hidayah, H. et al. (2021) Antioxidant activity of facial serum formulations from various plants
15	Natural phytochemicals: polyphenols, flavonoids, terpenoids	Anti-aging potential, skin protection, antioxidant, prevention of skin-aging & photo-aging	Discussion of nanocosmetics: nanoemulsions, nanocarriers, modern topical formulations	Tanuwidjaja, T. (2023) Development of Anti-Aging Cream Preparations with Active

No	Phytochemical Profile	Biological	Biotechnology	Reference
				Substances from Plant Extracts: Physicochemical Review and Potential Applications
16	Phenolics, flavonoids	Antioxidant activity & potential anti-aging / natural cosmetic	Salak peel nanoparticles + stability & activity characterization	Saputri, R. K. et al. (2024) Antioxidant activity and characterization of Salak Wedi peel nanoparticles as anti-aging cosmetics

Literature shows that Centella asiatica (gotu kola) extract has been extensively researched and provides evidence of biological activity supporting its potential as a natural cosmetic ingredient. For example, a serum formulation study demonstrated that a serum containing Centella asiatica extract exhibited significant antioxidant, anti-inflammatory, and anti-tyrosinase activity, and was non-toxic to cells, indicating its potential for safe use as a functional skin product (serum). (Bikiaris et al., 2025) The extensive literature on natural ingredients for skincare and skin therapy demonstrates that herbal plants, in general, can provide consistent moisturizing, anti-aging, antioxidant, and regenerative effects when formulated appropriately (Michalak, 2023).

The application of modern biotechnology and formulation technology to natural ingredients such as Centella asiatica has been shown to enhance the effectiveness and stability of bioactive compounds. One recent study successfully formulated a nanoemulsion from Centella asiatica leaf extract for antioxidant serum, resulting in good physical stability and antioxidant activity. (Fitri et al, 2024) Other cosmetic research shows that the combination of C. asiatica with a nanoemulsion or nanosuspension system provides protection against UV radiation (photo aging effects), as well as maintaining the skin collagen structure in in vivo test models (Retnaningtyas, 2024).

Furthermore, there is evidence that the use of plant extracts in topical formulations in vivo can increase skin hydration, improve epidermal barrier function, and reduce microinflammation in human skin. For example, a cream or hydrogel containing 5% Centella Asiatica extract demonstrated increased stratum corneum hydration and reduced transepidermal water loss, as well as anti-inflammatory activity in a human skin model. These findings confirm that natural ingredients with demonstrated phytochemical and biological activity, when combined with modern formulation technologies, have significant potential for evidence-based cosmetics/skincare (Ratz-Łyko, 2016).

Overall, this literature analysis confirms three research objectives: first, that there is sufficient recent scientific evidence (2018–2025) regarding the cosmetic and dermatological activities of traditional plants (including antioxidant, anti-inflammatory, anti-aging, skin protection, and hydration); second, that modern biotechnology and formulation technologies (nanoemulsions, serums, creams, lipophilic carriers) significantly enhance the effectiveness and stability of natural ingredients; and third, that the integration of ethnobotany, phytochemistry, and biotechnology opens a viable path for the development of modern bioactive compounds that are safe, effective, and sustainable.

Conclusion

Data from the latest scientific literature shows that traditional plants, especially Centella Asiatica, are indeed a source of bioactive compounds with real cosmetic and dermatological potential, from the molecular level to modern formulation applications. Advances in biotechnology, particularly in the form of nanosuspensions, nanoemulsions, and nanocarriers, allow for the optimization of these natural bioactives to make them more effective, stable, and suitable for cosmetic use. The combination of phytochemical evidence, biological activity, and formulation technology proves that modern, tradition-based bioactive compounds are not mere myths but have a strong scientific basis.

Suggestion

Based on recent literature findings, several recommendations can be proposed for the development of biotechnology-based cosmetics from traditional plants. More preclinical and clinical studies are needed to evaluate the long-term safety and effectiveness of nano-formulated plant-based cosmetics. Standardized extraction and chemical characterization of bioactive compounds are essential to ensure consistent results across studies and facilitate product development. Collaboration between the cosmetic industry and

academia is encouraged to translate natural formulations combined with biotechnology into safe and regulatory-compliant products. Additionally, exploration of traditional plants beyond *Centella asiatica* should be expanded to diversify bioactive sources and optimize biodiversity potential. This integrated approach is expected to drive the development of safe, effective, and sustainable natural cosmetics.

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