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# CURRENT TRENDS IN COSMETICS USING PLANT STEM CELLS

**Nakul Chandan Suryawanshi*[1], Atharv Pundalik Sonawane[1], Mrs. Kalyani Uttam Chande[2]**

[1]Students, Dr. D.Y. Patil College of Pharmacy, Akurdi, Pune-411044.

[2]Assistant Professor, Dr. D.Y. Patil College of Pharmacy, Akurdi, Pune-411044.

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***Corresponding Author**

**Nakul Chandan Suryawanshi**
Students, Dr. D.Y. Patil College of Pharmacy, Akurdi, Pune-411044.

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## ABSTRACT

Plant stem cells have emerged as a promising area in cosmetic science due to their regenerative potential, antioxidant activity, and sustainable production methods. The growing demand for natural and eco-friendly cosmetic ingredients has accelerated research into plant-derived bioactive compounds and their applications in anti-aging and skin protection products. This review discusses the fundamentals of plant stem cells, extraction techniques, bioactive compounds, mechanisms of action, cosmetic applications, commercial trends, safety concerns, regulatory issues, and future innovations in the field.

**KEYWORDS:** Plant stem cells; Cosmetics; Cosmeceuticals; Bioreactor technology; In vitro culture; Anti-aging; Antioxidants; Skin regeneration; Phytochemicals; Plant cell culture; Bioactive compounds; Sustainable skincare; Dermal repair; Secondary metabolites; Cosmetic biotechnology.

## INTRODUCTION

The global cosmeceutical market paradigms are changing to “botanical biotechnology”. Consumers are looking for products with pharmacological effects and ecological integrity. Plant stem cells (PSCs) and their extracts have found themselves at the crossroads of these demands. Unlike mammalian stem cells, which present ethical and stability challenges, PSCs represent a totipotent source of bioactive molecules that can be sustainably harvested without harming the environment. This review summarises the state-of-the-art PSC technologies, from the cultivation of meristematic cells to their delivery using sophisticated nanocarriers.

**Global Cosmetic Industry Plant Stem Cell Techniques**

More and more pharmaceutical and cosmetics companies are utilizing bioreactors to produce innovative new products with great attributes. One way they do this is by using in vitro cell culture to carry out micropropagation (or microreproduction) of plant stem cells for cosmetics. This begins with choosing what part of the plant you want to use (leave, fruit or root). Then, once a part of the plant has been cut, you transfer the extracted stem cells onto an agar plate to encourage the formation of callus tissue. The stem cells will grow in a liquid medium. Large-scale cell culture uses specialized bioreactors because they provide controlled culture conditions. Once the stem cells are developed, high pressure is applied to the developed stem cells, breaking down the cell membrane and releasing the contents of the cell into the substrate. Unhwa Corporation holds a patent for an anti-aging/antioxidant composition that contains the active ingredients derived from the stem cell line of Ginseng cambium. The antioxidant activities of the ginseng leaves will protect your skin against the production of reactive oxygen species, which is the leading cause of skin aging, when exposed to UV rays. Zhang YC et al. measured the antioxidant properties of the ginseng leaf extracts from various aged ginseng plants by conducting three different in vitro radical scavenging assays, including the scavenging capacity against 2,2-diphenyl-1-picrylhydrazyl.[1,2]

In 2016, an Italian team (e.g., Tito et al.) created active ingredients for cosmetic formulations from somatic embryos of the species Citrus limon; Lotus japonicus; and Rosa gardenia. The patent that protects this invention primarily addresses the effects of aqueous, ethanol, and sugar/peptide extracts from the somatic embryos of Lotus japonicus on the gene expression of GDF11; SIRT1; and SIRT6. Testing concentrations of these various extracts were performed in groups as follows: aqueous and ethanolic (0.05% to 0.0004%); mixture of peptides and sugars (0.01% to 0.00008%). The combination of lotus somatic embryo extracts activated GDF11 at a greater rate than the mixture of sugars/peptides alone creating a more intense stimulation of both anti-aging and rejuvenation activities in skin cells.[15] In 2017, Berry et al. developed a cosmetic product using a dedifferentiated stem cell culture from Camellia sinensis var.assamica to protect skin against drying out and/or photodamage from UV radiation. The effectiveness of this invention was assessed using dermal fibroblasts from adult humans. Tea extracts produced by the inventors appeared to be anti-inflammatory, protect skin from drying out; and otherwise assist in maintaining healthy complexion.[1,2,3]

**Extraction and Cultivation Techniques**

Pharmaceutical and cosmetic companies make use of bioreactors today to produce new products via high quality standards. One of the most important techniques is in vitro cell culture, which is used for expanding plant stem cells for cosmetic purposes. The procedure usually starts with the selection of a specific plant part, such as leaves, fruits or roots. These parts are processed and the stem cells obtained are placed on agar plates to induce the formation of the callus. The cells continue to grow and multiply when put in liquid culture. For large-scale production, specialised bioreactors are used to maintain stable and controlled growth conditions. When the stem cells reach a certain degree of growth, that they are subjected to high pressure to disrupt their membranes, releasing their bioactive compounds into the surrounding medium.

Plant stem cells have also been used to produce biomimetic lipids. For example, OLEA VITAE from Vytrus Biotech is derived from wild olive tree stem cells. The phytolipid fraction in this product mimics the role of natural cellular lipids and has anti-wrinkle, firming and rejuvenating effects by increasing mitochondrial activity and the production of important skin structural proteins. The increased focus on plant stem cells in cosmetics is part of a wider move towards using biotechnology to create more effective, sustainable and novel skincare products. Applying these advanced technologies is a promising way for the future of cosmetic formulations to improve the appearance of the skin and the overall health of the skin Technological advancements have established new bioreactor systems with controlled in vitro plant cell cultures for the production of bioactive compounds. Traditional cultivation methods rely on the environment (climate, pesticides, and seasons) but the bioreactor provides constant standardized amounts of bioactive compounds with no contaminates produced. Modern-day suspension cultures produce large amounts of secondary metabolites (flavonoids, phenolics, and antioxidant compounds) with much greater purity and consistency than traditional cultivation techniques.[4,5]

**1) Bioreactor technology provides a number of opportunities for improvement**

- Increased production scale
- More effective use of resources
- Consistent quality (batch-to-batch)
- Lower environmental impact

Recent research has shown that the fermentation of plant cells by the bioreactor system can yield larger quantities of anti-aging phytochemicals such as resveratrol, anthocyanins, and polyphenols.

**Regenerative epidermal stem cells and the idea of callus regeneration in plants**

Skin aging is caused by a complex process, which occurs at all levels of the epidermis and dermis, such as the denaturing of proteins and decreased activity of regenerative stem cells. The location of stem cells within the epidermis can be subdivided into progenitor stem cells that reside in the basal layer and interfollicular stem cells. In conjunction with the ultimate shortening of telomeres (which decrease the stem cell's ability to exist and provide new cells to the epidermis), a decline in the functioning of epidermal stem cells has been documented as such; telomere shortening occurs over time with each subsequent cell division, and it will lead to the cellular senescence of stem cells within the epidermis. The question posed thus becomes, "Do plant phytohormones exhibit antioxidant and regenerative properties to facilitate the prevention of human skin aging?".[10,11]

Callus formation from differentiation cells of older adult plants was described for the first time in the year 1902 by the Austrian Botanist, Gottlieb Haberlandt (1902). He reportedly theorized that an individual plant cell can regenerate an entire plant; it was done, in fact in 1958, by cloning a carrot from in vitro grown carrot cells (1958) and since that time, a vast amount of literature has been published on the subject detailing the ability to regenerate entire plant.[9]

Throughout an individual's adult years, the skin continues to renew itself, and the hair follicle cycle of growth and deterioration continues on and on. Stem cells (SCs), which are found within both the epidermis and hair follicle, contribute to the overall maintenance of adult epidermal homeostasis and hair regeneration in addition to assisting with repair of the epidermis after injuries. This article reviews current knowledge regarding adult epidermal SCs, including defining characteristics, recent methods of isolating, genes that are differentially expressed within the multipotent stem cell niche, and signaling pathways involved in forming a stem cell niche, maintaining the stem cells and activating them. Finally, we propose a potential role for the aberrant regulation of these pathways in the development of cancers.[6,7,8]

**Mechanism of Action in Cosmetic**

**1) Anti-Aging & Collagen Stimulation**

The key target for any anti-aging compound is the fibroblast. The fibroblast is responsible for the synthesis of collagen, elastin, and GAGs. Retinoids: Retinoids are considered the most potent compounds. They bind to retinoic acid receptors, activating the transcription of collagen-producing genes. Peptides: Signal peptides, such as Palmitoyl Pentapeptide-4, act as fragments of fragmented collagen. This sends a signal to the skin about damage, resulting in an which increased production of collagen through the feedback mechanisms.[27]

**2) Decreasing Wrinkles**

The decrease in wrinkles is achieved via two mechanisms: enhancing skin density and decreasing muscle contractions.

Fillers: Compounds like HA are not able to effectively fill wrinkles, but large molecules form a film, moisturizing the stratum corneum, while small molecules penetrate the epidermis, thus enhancing elasticity (Pavicic et al., 2011).

Neurotransmitter-affecting peptides: Peptide Acetyl Hexapeptide-8 (Argireline) mimics Botulinum neurotoxin activity. It disrupts the SNARE complex and slightly reduces the release of neurotransmitters and that stimulate muscle contractions.[27,28]

**3) Anti-Inflammatory Effects**

Low-grade chronic inflammation, referred to as inflammaging and contributes to the acceleration of dermal breakdown.

Polyphenols: Polyphenols such as EGCG from green tea act to suppress the NF-κB signaling pathway, which acts as the main activation switch for inflammation in skin cells.

Panthenol (Pro-vitamin B5): Acts as a humectant as well as an anti-inflammatory compound. It possesses the ability to induce the proliferation of the fibroblasts as well as re-epithelialization.[30,29]

**4) Skin regeneration and repair It entails stimulating the rate of cell turnover and the regeneration of skin barrier (lipid bilayer).**

Alpha hydroxy acids (AHAs).

Such compounds as glycolic acid lower calcium ion concentrations within the epidermis and cause the disintegration of desmosomes This facilitates cell sloughing and the production of new cells from the basal layer.

Ceramides: It contains lipids necessary for the proper structure of the skin barrier.

Ceramides help to fill gaps in the barrierand reducing TEWL.[31,32]

**Current Applications in Cosmetics**

Animals have a pool of stem cells known as mother cells that are capable of ongoing differentiation into any kind of specialised cells for different tissues throughout the body, including cardiac muscle, skin and liver tissue. Plants are however able to be more flexible about establishing new niches for stem cells than animals. The beauty industry faces a great challenge in supplying products that function, are 'on-trend', innovative and safe while having a longer shelf-life. With the existence of human or animal derived sources of supply being objectionable, all new product development and research for cosmetics is therefore directed towards the utilisation of biotechnology and plant-cell culture technology to overcome the industrial, end-user and regulatory constraints of shelf-life.[33] The supply of plant species of interest to the cosmetic industry has been limited due to slow growing, seasonal harvests, variability in amounts of active ingredient present in the same type of plant and between different species, as well as the presence of metabolites that may be toxic to consumers.[33] Plant cell culture techniques have been successfully utilized the address the manufacturing challenges of cosmetic products, enabling the production of higher concentrations of active ingredients by the application of external stimulating factors such as UV radiation, jasmonic acid or toxic materials.[35] This technology encompasses a variety of intricate tasks that will promote the growth of plant cells, tissue or organs under sterile growing conditions.

Using plant cell cultures is an effective means of creating a diverse variety of phytochemicals, many are created for use in food additives, pharmaceuticals and cosmetic ingredients.[34] While the majority of studies thus far have been dedicated specifically to producing pharmaceutical products, recent technological advancements have allowed for greater progress in plant cell culture technology regarding producing both food additive and active cosmetic ingredients.[34] There are a number of technological, economic and regulatory/economic obstacles to producing either differentiated or undifferentiated plant cell cultures at scale; growing either of these (undifferentiated/differentiated) types of plant tissue (cells, tissues or organs) is expected to be the most viable eco-friendly technology for

generating a continuous supply of phytoingredients for pharmaceuticals, food and cosmetics, even from rare, endemic, protected, threatened or endangered species of plants.[34] The continued growth of plant cell culture technology may offer an increasing number of bioactive natural products to meet growing demands in the near future. Most people today are interested in using natural-based products that have a minimal ecological footprint when they are making purchasing decisions (for food or cosmetic products). In recent years, the number of cosmetics that contain active ingredients produced using plant cell cultures has increased substantially. There has been an increasing amount of interest and effort towards innovation and developing innovative products for the use of plant cell culture technology.[34]

**Commercial Products and Market Trends**

Natural and plant-based cosmetic products have been growing significantly on the global stage. Consumers are now looking more towards finding options that are organic, have been produced sustainably, and/or are more eco-friendly.[33,35]

There are many brands promoting the use of plant stem cell technology to create high-quality skincare options. Most of these brands have marketing strategies highlighting the anti-aging properties found within their products; how they provide antioxidant protection; and the regenerative effects of using their products. The demand for plant stem cell skincare products will be especially high in the Anti-Aging segment of cosmetics, particularly for Anti-Aging Serums & Creams. Brands that sell skincare products are using creative marketing techniques and labeling their anti-aging serum and cream products (made with plant stem cells) as "premium" priced products for mature (i.e., older) consumers, as these consumers tend to be very concerned about the aging process and its effects on their skin..[36,37] There is an unspoken competition among brands that are selling these types of skincare products to be perceived as providing consumers with the best possible experience, namely by creating high-performance products that deliver immediate and noticeable results to consumers that are seeking a reliable solution to the effects of aging. All plant stem cell infused anti-aging serums & creams are packed with bioactive compounds that provide powerful antioxidant and vitamin support, both of which are important for maintaining youthful skin.[36,37]

As a result, the demand for Anti-Aging plant stem cell products will continue to increase as people become more aware of the efficacy of these products, as well as the fact that they produce incredible results in consumers who use them as part of their daily skincare regiment.

The plant stem cell skincare product market will be largely dominated by the pricing for the mid-premium segment. Companies positioned in the mid-premium segment of the skincare industry usually invest in sophisticated marketing techniques and brand image in order to promote themselves as luxurious and effective. Plant Stem Cell Skincare Brands use these marketing methods in order to differentiate themselves from competing products, as well as to appeal to the more discerning consumer who is willing to pay a higher price for premium quality skincare. Many consumers purchasing financial products within the mid-price range will spend money on products that will provide an inexpensive cost compared to the high price. Plant Stem Cell Products are considered to be premium due to the advanced formula used in their creation, as well as the claims made about them providing an anti-aging effect. Therefore, consumers looking to purchase high quality skincare will be attracted to these types of products.[33,35,36,37]

**Limitations and Challenges**

Although plant stem cell cosmetics are becoming more popular and profitable worldwide, there are still many issues that need to be solved before they can be completely accepted by consumers. While the antioxidant properties of plant stem cell extracts have been largely proven, many of the claims about their use in cosmetic products are still affected by insufficient clinical research and the misperception about how they work.

**1) Stem cell-free cosmetics**

Many cosmetics are not made with live stem cells from an active plant source because it is a huge misconception to think that commercial cosmetic products actually have active stem cells that can regenerate the skin on humans. Cosmetic ingredients are typically made from.

- Extracts from plant stem cells
- Lysates
- Conditioned media
- Secondary Metabolites from Plant Cell Culture

Because live stem cells cannot survive in traditional cosmetic formulas due to:

- Inadequate nutrients
- Preservatives in the product
- An unstable environment
- Manufacturing and storage conditions

Therefore, instead of relying on living stem cell properties, phytochemical compounds such as antioxidants, flavonoids, phenolic compounds, phytohormones are primarily responsible for the positive effects produced.

**2) Lack of clinical data**

While some laboratory studies and in vitro studies provide evidence for some protective and antioxidant benefits of plant stem cell extracts, there remains an insufficient number of:

- Large-scale clinical trials on human subjects
- Toxicity studies conducted over time to prove safety
- Standardized methods of testing efficacy to be used for comparison
- Studies in the field of dermatology using the same sample

The majority of studies conducted on plant stem cells have been:

- Conducted on cells in culture
- Conducted using animals
- Sponsored by cosmetic companies
- Based upon an inadequate sample size.

As a result, scientific proof supporting most claims regarding anti-aging and regenerative properties of many products remains to be found.

**3) Insufficient Delivery Into The Skin**

The skin barrier protects against penetration of large bioactive molecules into the deeper layers of the skin. As a result of this barrier, multiple active compounds derived from plant stem cells may not reach their intended targets in-vivo, such as.

- Fibroblasts in the dermis
- Locations containing epidermal stem cells
- Deep tissue sites involved in tissue regeneration

This would limit the in vivo therapeutic effect of these compounds. Scientists are investigating new methods for delivering these compounds efficiently (for example, liposomes, nanoparticles, nanoemulsions, and various encapsulation techniques), but these new methods all result in higher costs of manufacturing/producing and increase the complexity of the formulation.[34,35,36,37]

**4) Confusion Around Regulatory Requirements**

Different regulatory bodies in the various countries have differing laws and requirements relating to the definition of a cosmetic and subsequent marketing standards for that item. Therefore, there is little chance for harmonization in cosmetics across all jurisdictions and countries, creating issues with marketing.

Regulators also impose restrictions on the following items.

- Claims made about treatment
- Use of the term regenerative medicine
- Advertising which discusses stem cells
- Unsubstantiated claims related to anti-aging products

Consumers may be misled by the use of the terms "stem cell therapy" and "cellular regeneration" because they may mistakenly believe that these products provide the same potential medicinal or regenerative benefits as human stem cell therapies (Vogue.com).

Due to the potential for misunderstandings or misuse of terms, regulators are continuing to require increased evidence or data to support.

- Scientifically based supportive evidence
- Clinical testing or data
- Safety testing
- Clear and appropriate labeling.

## CONCLUSION

Plant stem cells represent a promising and innovative area in cosmetic science due to their antioxidant, regenerative, and protective properties. Their application in skincare formulations continues to grow with advances in biotechnology and sustainable production methods.

However, scientific validation, regulatory clarity, and improved formulation strategies are necessary to ensure product efficacy and consumer trust. Future developments may further strengthen the role of plant stem cells in advanced cosmetic and dermatological applications.

Cosmeceutical ingredients with the antioxidant, anti-inflammatory and anti-aging properties have been found in the plant stem cell extracts. They stimulate the activity of fibroblast,

which promotes collagen and elastin synthesis, helping to maintain skin securely and elasticity. These extracts also shield skin cells from oxidative stress and assist in cellular repair and regeneration. They have also improve skin hydration, texture and barrier function and reduce wrinkles and signs of aging. In general, plant stem cell based cosmetics provide a natural and effective method to rejuvenate skin and to maintain healthy skin.[33,34,35,38]

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