The research on the efficacy and safety of natural active ingredients in pharmaceutical cosmetics

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Abstract: *In recent years, pharmaceutical cosmetics have experienced rapid development in fields such as skincare and anti-aging, particularly due to the multifunctionality and safety of natural active ingredients. These natural components, including plant extracts, marine bioextracts, and animal-derived ingredients, exhibit significant antioxidant, anti-inflammatory, reparative, and anti-aging effects, making them widely used in pharmaceutical cosmetics. However, despite being considered a safe choice, potential safety issues such as allergic reactions and photosensitivity still exist. Therefore, systematically studying the efficacy and safety evaluation of natural active ingredients, especially their applications in pharmaceutical cosmetics, is of great importance for driving industry innovation and ensuring product safety. This paper analyzes common natural active ingredients, explores their efficacy and safety evaluation standards, and proposes strategies to optimize their application.*

Keywords: *Pharmaceutical cosmetics; natural active ingredients; efficacy; safety assessment; plant extracts; marine bioactive components*

Introduction

With the growing consumer demand for health and natural skincare products, the pharmaceutical cosmetics market has shown rapid growth in recent years. Pharmaceutical cosmetics combine pharmacological functions with cosmetic benefits, and natural active ingredients, as their core components, are favored for their good biocompatibility and low toxicity. Natural active substances, including plant extracts, marine bioextracts, and animal-derived ingredients, are widely used in pharmaceutical cosmetics due to their multiple benefits such as antioxidant, anti-inflammatory, reparative, and anti-aging effects. However, despite the widespread recognition of natural ingredients in the market, their potential safety issues cannot be overlooked. This study aims to systematically explore the efficacy and safety issues of common natural active ingredients in pharmaceutical cosmetics and propose effective strategies to enhance their safety, thus promoting the further development of pharmaceutical cosmetics.

1. Development Trends of Pharmaceutical Cosmetics and the Widespread Application of Natural Active Ingredients

1.1 Rapid Growth of the Pharmaceutical Cosmetics Market

In recent years, the pharmaceutical cosmetics market has shown significant growth, becoming one of the most dynamic sectors in the cosmetics industry. This growth is primarily attributed to the increasing consumer demand for health, beauty, and skincare products, particularly for those with pharmacological functions. Pharmaceutical cosmetics are defined as lying between drugs and cosmetics, offering not only skincare benefits but also improving skin issues such as sensitivity, inflammation, and aging. Therefore, they are regarded as "functional" skincare products and are increasingly favored by consumers. Market reports indicate a sustained compound annual growth rate for the global pharmaceutical cosmetics market, especially in the Asia-Pacific region, where consumer acceptance and reliance on these products have significantly increased. Pharmaceutical cosmetics have gradually expanded into multiple areas, including anti-aging, whitening, reparative, and anti-sensitivity, enhanced by innovative natural active ingredients.[1]

1.2 Core Role of Natural Active Ingredients in Pharmaceutical Cosmetics

The core competitiveness of pharmaceutical cosmetics lies in the safety and efficacy of their ingredients, with natural active ingredients increasingly becoming a central component in this field. Compared to synthetic chemical components, natural active ingredients are valued highly by developers of pharmaceutical cosmetics due to their good biocompatibility, lower toxicity, and rich biological activity. The application of plant extracts, marine bioactive components, and animal-derived ingredients in pharmaceutical cosmetics continues to expand, covering various benefits such as antioxidant, anti-inflammatory, antibacterial, whitening, and moisturizing effects. For example, components like tea polyphenols and Centella Asiatica extract are used in pharmaceutical cosmetics for their antioxidant and reparative properties, while hyaluronic acid and collagen play crucial roles in moisturizing and anti-aging products. Natural active ingredients not only meet consumer demands for "green" and "additive-free" products but also significantly enhance product functionality and safety through modern extraction and purification technologies. Thus, the innovation and development of natural active ingredients have become a key aspect of pharmaceutical cosmetics.

1.3 Consumer Demand for Natural Ingredients Driving Industry Innovation

As consumer demand for natural and healthy products continues to rise, the application of natural active ingredients in pharmaceutical cosmetics has driven innovation throughout the industry. Consumers now seek more than simple skincare benefits; they prioritize ingredient safety and sustainability. Natural ingredients, characterized by their "gentle" and "non-irritating" properties, are gradually replacing some traditional synthetic components, particularly in addressing issues such as skin sensitivity and allergic reactions. Furthermore, with the growing health consciousness among consumers, natural ingredients are viewed as having higher added value for skincare, prompting companies to innovate in product development. For instance, pharmaceutical cosmetic products based on plant extracts have been refined and stabilized using modern biotechnology and nanotechnology, thereby improving the stability and efficacy release of natural active ingredients. As consumers pay more attention to "green technology" and sustainable development concepts, the future development of pharmaceutical cosmetics will increasingly focus on the efficient development and safe use of natural ingredients, driving the industry toward innovation-driven growth.[2]

2. Types and Efficacy of Natural Active Ingredients in Pharmaceutical Cosmetics

2.1 Diversity and Efficacy of Plant Extracts

Plant extracts are among the most common natural active ingredients in pharmaceutical cosmetics, widely applied due to their diversity and broad biological activity. These ingredients exhibit various effects, including antioxidant, anti-inflammatory, moisturizing, and whitening properties, by extracting specific active compounds such as polyphenols, flavonoids, and terpenes from various plants. For example, polyphenolic compounds like tea polyphenols and resveratrol possess powerful antioxidant properties, effectively scavenging free radicals and reducing oxidative stress damage to skin cells, thereby delaying the aging process. Tea polyphenols also demonstrate significant anti-inflammatory and antibacterial characteristics, helping to alleviate skin inflammation and inhibit bacterial growth, thus maintaining skin health. Centella Asiatica extract is widely used in pharmaceutical cosmetics for its remarkable reparative abilities, promoting collagen synthesis, accelerating skin healing, and reducing scar formation, particularly suitable for postoperative care and sensitive skin repair. Aloe vera extract is extensively utilized in products for sensitive skin due to its soothing, moisturizing, and anti-inflammatory properties, effectively alleviating skin irritation, redness, and dryness.[3]

Moreover, the diversity of plant extracts is reflected in the efficacy variations brought about by plants growing in different regions and climates. For instance, alpine plants typically exhibit stronger antioxidant and reparative functions due to their harsh growing environments, while tropical plants are rich in moisturizing and nutritional components. These differences allow plant extracts to be further applied in pharmaceutical cosmetics according to varying skin needs and regional characteristics. Additionally, with technological advancements, more plant active ingredients, such as plant stem cell extracts, are being discovered and applied, offering further innovation and research directions in the pharmaceutical cosmetics field.

2.2 Uniqueness of Marine Bioactive Ingredients

Marine bioactive ingredients have received increasing attention in pharmaceutical cosmetics in recent years. Due to the unique conditions of their living environment, marine organisms have evolved distinctive active substances that offer antioxidant, moisturizing, and reparative benefits. Algal extracts represent the most widely used category of marine bioactive ingredients, rich in polysaccharides, amino acids, and trace elements, providing excellent moisturizing and anti-inflammatory effects that can repair damaged skin and enhance skin barrier function. Additionally, microalgae such as spirulina contain high levels of protein, polyunsaturated fatty acids, and vitamins, enhancing the skin's antioxidant capacity and slowing the aging process, even helping to reduce UV-induced photodamage. Compounds like carotenoids and chlorophyll found in microalgae also exhibit positive effects in skin anti-inflammation and antibacterial actions, particularly in the treatment of acne and skin barrier repair.

Fish collagen from marine organisms holds an important position in anti-aging and reparative products due to its superior biocompatibility and good absorption. Fish collagen promotes collagen synthesis in the skin, enhancing elasticity and reducing fine lines and wrinkles. Compared to collagen derived from terrestrial animals, fish collagen has a smaller molecular weight and higher absorption efficiency, making it widely used in high-end skincare products. Fish collagen not only significantly enhances skin hydration but also repairs UV damage, improving skin elasticity and radiance.[4]

Furthermore, other marine bioactive ingredients, such as sea urchin extract and marine peptides, are gradually demonstrating potential in the skincare field, showcasing antioxidant, anti-aging, and cell regeneration effects. Pearl powder, as a marine-derived active ingredient, not only whitens the skin but also promotes skin metabolism and repair due to its rich calcium and trace element content. Overall, the uniqueness of marine bioactive ingredients is characterized by their structural complexity and functional diversity, particularly exhibiting immense potential in deep repair, anti-aging, and cell regeneration. As technology advances, the application scope of marine bioactive ingredients in pharmaceutical cosmetics is expected to expand further, driving industry innovation and enhancing product efficacy.

2.3 Application of Animal-Derived Natural Ingredients

Animal-derived natural active ingredients also play an important role in pharmaceutical cosmetics, particularly in moisturizing, reparative, and anti-aging areas. Collagen, a common animal-derived ingredient, mainly sourced from fish and pigskin, is similar in structure to human skin collagen and offers good biocompatibility. In skincare products, collagen is often used to enhance the skin's moisture retention, promote skin regeneration, and reduce wrinkles and sagging. Collagen also exhibits excellent elasticity recovery, helping the skin regain firmness and radiance, especially in repairing damage from UV exposure and environmental pollution. The application of modern technologies allows collagen to penetrate deeper into the skin more effectively in the form of small peptides, thereby delivering more significant anti-aging effects.

Honey and its derivatives (such as beeswax and propolis) are widely used in pharmaceutical cosmetics due to their natural antibacterial and antioxidant properties, particularly effective in anti-inflammatory, soothing, and moisturizing products. The various vitamins and amino acids in honey nourish the skin, improving dryness and flakiness, while its natural moisturizing ability helps lock in moisture and prevent water loss due to external environmental factors. Propolis, known for its potent antibacterial properties, is particularly effective in treating skin inflammation and acne by effectively eliminating pathogens and promoting rapid healing of the skin.

Additionally, lanolin (sheep fat) serves as a natural moisturizer that forms a protective barrier on the skin's surface, helping to lock in moisture and enhance the skin's softness and elasticity. The lipophilic nature of lanolin allows it to penetrate the skin, providing deep hydration and strengthening the skin barrier function, making it especially suitable for moisturizing needs in dry climates. It also possesses anti-inflammatory and soothing effects, making it appropriate for daily care of dry and sensitive skin as well as addressing seasonal dryness.

Although the use of animal-derived ingredients is restricted in certain markets, particularly in areas emphasizing ethics and environmental protection, plant-based alternatives are gaining preference. Nonetheless, the exceptional efficacy of animal-derived ingredients ensures their continued importance in pharmaceutical cosmetics. Particularly in high-end reparative skincare products, animal-derived ingredients such as collagen, propolis, and lanolin provide reparative, moisturizing, and anti-aging effects that are difficult to achieve with other components. With technological advancements and optimized

extraction techniques, the future use of animal-derived ingredients is expected to continue in a more sustainable and environmentally friendly manner, bringing further innovation and efficacy enhancements to pharmaceutical cosmetics.

3. Safety Assessment of Natural Active Ingredients in Pharmaceutical Cosmetics

3.1 Safety Evaluation Standards for Natural Active Ingredients

Natural active ingredients are widely regarded as safer due to their "natural origin." However, their complex chemical structures and biological activities necessitate rigorous safety evaluations. The safety assessment of natural active ingredients in pharmaceutical cosmetics should adhere to relevant standards outlined in cosmetics regulations, primarily including tests for skin irritation, sensitization, phototoxicity, and systemic toxicity. Skin irritation tests assess the immediate irritation potential of ingredients on the skin over a short period, typically utilizing animal testing or in vitro alternatives. With increasing ethical concerns, more in vitro methods, such as 3D skin models, are being adopted to reduce reliance on animal testing. Sensitization tests aim to detect whether specific ingredients can induce allergic reactions, usually evaluated through human closed patch tests or repeated exposure experiments, ensuring the long-term safety of ingredients during repeated use.[5]

Phototoxicity tests are conducted to evaluate potential skin reactions of certain natural ingredients under light exposure, particularly for plant extracts like citrus essential oils and St. John's wort, which may cause photosensitive reactions leading to adverse effects such as erythema and pigmentation. Therefore, testing for phototoxicity risk under ultraviolet exposure is essential. Systemic toxicity tests assess chronic toxicity, carcinogenicity, or reproductive toxicity through long-term exposure experiments, typically including acute, subacute, and chronic toxicity tests to comprehensively understand the long-term safety of ingredients. Metabolism and absorption studies are also critical for systemic toxicity assessments, clarifying the metabolic pathways and potential accumulation effects of ingredients within the body.

Through these stringent safety evaluations, natural active ingredients in pharmaceutical cosmetics can be ensured not to harm consumer health when used under appropriate doses and conditions, thus safeguarding their application in daily skincare products. It is noteworthy that with the application of nanotechnology, the bioavailability of some natural active ingredients has improved, which introduces new safety challenges. Consequently, future safety assessments should integrate more advanced technologies and innovative methods to maintain a balance between efficacy and safety in pharmaceutical cosmetics.

3.2 Potential Safety Risks of Natural Active Ingredients

Despite their good biocompatibility, natural active ingredients are not completely harmless. Some natural ingredients may pose potential safety risks, especially when used in high concentrations or over extended periods. Allergic reactions represent one of the most common safety issues associated with natural ingredients. Certain plant extracts, such as lavender and tea tree oil, can provoke allergic reactions in sensitive skin due to their complex chemical compositions, resulting in symptoms like redness and itching. The terpenes in tea tree oil are believed to be one of the primary allergens, particularly posing risks for sensitive individuals. Another major potential risk is phototoxicity; some phototoxic plant extracts, such as citrus essential oils and St. John's wort extract, may induce skin phototoxic reactions after exposure to ultraviolet light, leading to erythema, burns, or even pigmentation. The intensity of phototoxic reactions is influenced not only by the ingredients themselves but also by the duration and intensity of light exposure.

Additionally, certain natural ingredients may be subject to microbial contamination or heavy metal residues due to variations in sourcing and processing methods. In particular, unprocessed and non-purified ingredients may contain harmful impurities, such as arsenic, lead, and mercury, which can be absorbed through the skin and accumulate in the body, potentially leading to chronic toxicity and other health issues. While these risks are relatively low at normal usage levels, heightened caution is necessary for sensitive populations or specific usage scenarios. To ensure consumer safety, scientific testing methods and strict quality control measures must be implemented to eliminate these potential risks, particularly during the large-scale production and promotion of pharmaceutical cosmetics.

3.3 Strategies for Enhancing the Safety of Natural Ingredients

To enhance the safety of natural active ingredients, the development and production of pharmaceutical cosmetics must implement a series of effective strategies. Firstly, through molecular modification and ingredient purification, secondary metabolites that may cause adverse reactions can be removed from natural ingredients, thereby reducing their sensitization and phototoxicity. For example, specific compounds in some plant extracts can be chemically modified or removed to enhance safety, such as certain components of lavender oil being eliminated to lower irritability.[6]

Secondly, optimizing formulation design represents another effective strategy; by combining different ingredients thoughtfully, potential side effects from individual components can be minimized. For instance, anti-inflammatory and soothing ingredients like aloe vera extract can be used alongside potentially irritating components to reduce skin irritation and enhance the safety of the formulation.

Thirdly, appropriate concentration control and usage guidelines are crucial for ensuring the safety of natural ingredients. Some ingredients may cause adverse reactions at high concentrations; thus, it is essential to maintain active ingredient concentrations within safe ranges that comply with relevant regulations. Moreover, special concentration adjustments may be necessary for sensitive skin populations to prevent excessive irritation.

Finally, stringent production and quality control are equally important. By employing modern extraction and purification technologies, contamination and residual impurities can be avoided, ensuring the purity and stability of ingredients. For example, utilizing high-performance liquid chromatography (HPLC) technology to detect and remove harmful substances from raw materials can significantly mitigate safety risks associated with natural ingredients. The comprehensive application of these strategies can greatly reduce the safety risks of natural components, ensuring the safety and efficacy of pharmaceutical cosmetics during use, while providing consumers with healthier and more environmentally friendly skincare options. Through ongoing innovation and strengthened regulation, natural active ingredients in pharmaceutical cosmetics will continue to deliver their unique benefits while ensuring safety to meet market demands.

Conclusion

This study analyzes the types, efficacy, and potential safety issues of natural active ingredients in cosmetic products. The research findings indicate that natural ingredients exhibit significant effects in areas such as antioxidant activity, anti-inflammatory properties, repair, and anti-aging, particularly highlighted in the application of plant extracts, marine biological active components, and animal-derived ingredients. However, safety concerns related to these ingredients, such as allergic reactions and photosensitivity, still require adequate attention. Therefore, future research should further improve the safety assessment system for natural ingredients, employing methods such as molecular modification and formulation optimization to mitigate risks. Additionally, as consumer demand for natural skincare products continues to grow, the cosmetic industry must find the optimal balance between efficacy and safety to enhance product innovation and market competitiveness.

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