Available Online: 4 November 2026 DOI: 10.54254/3029-0821/2026.38576

Application research of resveratrol in functional cosmetics

Peihan Jiang

Jinling High School Hexi Campus, Nanjing, China

56234776@qq.com

Abstract. With the iteration of the cosmetics industry toward functionality and natural orientation, plant-derived active ingredients have become an important direction in the current research and development of functional skincare products. Resveratrol is a natural polyphenolic compound with antioxidant activity. It can inhibit melanin synthesis, scavenge free radicals, protect the skin against photoaging, and promote collagen repair, and therefore possesses significant application value in the two major tracks of skin whitening and anti-aging. Compared with mainstream functional ingredients such as retinol, alpha-hydroxy acids, and high-concentration niacinamide, resveratrol is less irritating to the skin and has no restrictions on day or night use; however, it also suffers from defects such as instability to light and heat, susceptibility to oxidation, and a low transdermal absorption rate. Taking the skincare application of resveratrol as the core, this paper briefly analyzes its physicochemical properties and its mechanisms of whitening and anti-aging, and also points out the problems existing in current research, including the absence of dosage standards, incomplete safety evaluation, and insufficient human bioavailability. It is suggested that more comparative clinical studies should be carried out in the future for verification, and that technological innovation should be pursued to correct its absorption defects, so as to provide a useful reference for the development of resveratrol in natural multi-functional cosmetic products.

Keywords: resveratrol, plant polyphenols, skin whitening, anti-aging, functional cosmetics

1. Introduction

According to market survey statistics, skincare products with compound efficacy, such as whitening and brightening combined with anti-aging and repair, are more popular among consumers than basic moisturizing products. Although traditional chemically synthesized ingredients have well-defined efficacy, they generally suffer from problems such as strong skin irritation and poor tolerance during long-term use, making it difficult to meet the long-term skincare needs of people with sensitive or fragile skin. Against this background, plant-derived active ingredients that are safe, mild, and multi-functional have gradually become a hotspot in the innovative research and development of functional cosmetics.

Resveratrol is a typical natural plant polyphenol active ingredient. It combines multiple skincare effects, including antioxidant activity, melanin inhibition, anti-photoaging, and promotion of collagen regeneration [1], and can therefore meet multiple skincare needs with a single ingredient. At present, considerable research has been conducted on the pharmacological activity and skincare mechanisms of resveratrol, but problems still

Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

remain, such as the lack of dosage standards, incomplete safety evaluation, and insufficient knowledge of its bioavailability in humans.

On this basis, this paper integrates recent research findings in the field of resveratrol skincare and presents a systematic discussion covering its natural sources, physicochemical properties, mechanisms of action, research deficiencies, and optimization strategies, with a view to providing a useful reference for the in-depth development of resveratrol in natural multi-functional cosmetics.

2. Natural sources and physicochemical properties of resveratrol

2.1. Natural sources

Resveratrol is a defensive secondary metabolite produced by plants under adversity stress. When plants are subjected to external stimuli such as ultraviolet radiation, mechanical injury, or pathogen invasion, they can synthesize this substance on their own; it therefore belongs to the category of natural phytoalexins [2]. Its natural distribution is wide: it has so far been detected in at least 72 plant species, and common sources include Polygonum cuspidatum (Japanese knotweed), grapes, mulberries, peanuts, and blueberries.

2.2. Physicochemical properties

The chemical name of resveratrol is 3,4',5-trihydroxystilbene, and its molecular formula is $C_{14}H_{12}O_3$. At room temperature it is a white to pale yellow solid powder with no peculiar smell. Its water solubility and oil solubility are both poor, while it is readily soluble in organic solvents such as methanol and ethanol, and these characteristics directly affect its compatibility with cosmetic formulations. For formulators, this means that resveratrol usually needs to be pre-dissolved in a suitable solvent or incorporated through carrier systems before being blended into the final product, and the choice of solvent and process can in turn influence the stability and skin feel of the finished formulation.

In the natural environment, resveratrol mainly exists in the trans configuration, but this trans configuration is unstable to light and heat; under light exposure or heating treatment, it can be partially converted into cis-resveratrol. Traditional studies held that the photo-thermal isomerization of resveratrol reduces its antioxidant activity and is a core defect restricting its skincare application. However, existing experiments have confirmed that, compared with freshly prepared resveratrol solutions, the cis-trans mixed products formed after light and heat treatment show an increase in the inhibition rate of tyrosinase monophenolase and diphenolase activity from 0 to 30.74% and 19.42% respectively, together with a 300% increase in free radical scavenging capacity [3]. Therefore, cosmetics containing resveratrol do not need to be stored away from light. This conclusion provides a new theoretical basis for its product application, and it is also of practical significance for the storage, transportation, and shelf-life management of resveratrol cosmetics, as it greatly relaxes the requirements for packaging and storage conditions.

3. Mechanisms of the whitening and anti-aging effects of resveratrol

3.1. Whitening mechanism

Resveratrol can inhibit melanin synthesis through the synergistic action of multiple pathways, thereby achieving a mild and long-lasting whitening and brightening effect. It can directly inhibit the catalytic activity of tyrosinase, the key rate-limiting enzyme in melanin synthesis; it can also indirectly suppress tyrosinase activity by influencing its transcription or regulating it post-transcriptionally, and it can even inhibit the

activity of melanin-generating enzymes [1], thereby blocking the melanin biosynthesis pathway at its source and reducing abnormal pigment production in the skin. Tyrosinase is the key enzyme catalyzing the conversion of tyrosine into dopaquinone in the melanogenesis pathway; once its activity is suppressed, the upstream raw materials for melanin production are cut off, and the whitening effect is therefore achieved at the most fundamental enzymatic level. Resveratrol can also activate the cellular antioxidant switch, scavenge excess free radicals within skin cells, and increase the activity of antioxidant enzymes [1, 4], which inhibits skin lipid peroxidation, reduces the abnormal accumulation of lipofuscin, and effectively improves the oxidative sallowness and dullness of the skin.

3.2. Anti-aging mechanism

With respect to the skin photoaging induced by ultraviolet radiation, resveratrol can significantly reduce the DNA damage to HaCaT cells caused by UV irradiation, reduce the expression of matrix metalloproteinases and the release of inflammatory factors, and inhibit the decomposition of collagen [1, 5], thereby delaying the senescence and apoptosis of skin cells. Matrix metalloproteinases are a class of enzymes that degrade collagen and elastin in the extracellular matrix; inhibiting their expression is equivalent to slowing the loss of the structural support of the skin at its source. Meanwhile, resveratrol can up-regulate the expression of transforming growth factor and type I procollagen [1], promote the proliferation of fibroblasts and the synthesis of collagen fibers [5], and increase the thickness of the dermis and epidermis, thereby improving the supporting capacity and elasticity of the skin and alleviating early signs of aging such as dry lines and sagging.

3.3. Synergistic effects between whitening and anti-aging

Unlike single-efficacy skincare ingredients, the core antioxidant activity of resveratrol runs through both the whitening and the anti-aging skincare systems, forming a unique synergistic effect. Its antioxidant action can scavenge free radicals and reduce the degradation of collagen [5], while also directly inhibiting the stimulation of melanin synthesis by inflammatory senescence factors; its inhibition of tyrosinase reduces melanin intermediates, which prevents pigmentation and at the same time reduces the oxidative pressure brought by these intermediates; its regeneration and repair effects on collagen and elastin can improve skin firmness, and its hydration-enhancing effect can improve the gloss and translucency of the skin, ultimately achieving an integrated effect of anti-aging, brightening, and repair [1, 5].

4. Application of resveratrol in cosmetics

Cosmetics containing resveratrol on the market cover multiple product categories, including essences, face creams, face masks, and ampoules. There are mainly two methods of incorporation. The first is to dissolve resveratrol powder directly in an organic solvent such as ethanol and then add it to formulations such as creams and essences; this is the simplest and lowest-cost method, but its disadvantages are susceptibility to oxidative browning, difficulty in adapting to the aqueous phase, and a low transdermal absorption rate. The second is to adopt nano-encapsulation technology to solve the solubility problem, which enables a sustained-release effect and significantly improves the transdermal absorption rate, but its disadvantages are a complex preparation process and high production costs. In addition, some carrier materials have various defects of their own: for example, lipid vesicles prepared with phospholipids, cholesterol, and other lipid membrane materials suffer from the problem that the membrane material is prone to oxidation; the transdermal absorption of cyclodextrin inclusion complexes is lower than that of liposomes; and novel lipid carriers require the addition of large amounts of emulsifiers, posing a risk of significant skin irritation. In terms of product positioning,

resveratrol-containing products are mostly found in mid-to-high-end anti-aging and brightening lines, and they are often used in combination with other antioxidants to build a layered antioxidant system.

5. Deficiencies in current research on resveratrol cosmetics

5.1. Unclear usage concentration

At present, resveratrol has been included in the International Cosmetic Ingredient Standard Catalogue, but the European Union, the United States, and Japan have not yet set explicit limit standards for the concentration of resveratrol used in cosmetics. In China, resveratrol has also been included in the Inventory of Existing Cosmetic Ingredients in China (2021 Edition) issued by the National Medical Products Administration [1]. In 2025, the National Institutes for Food and Drug Control (NIFDC) further released usage information for some ingredients collected in the International Cosmetic Safety Assessment Data Index that lack assessment conclusions or are subject to restrictions on conditions of use, showing that the highest historical usage of resveratrol is 5% in leave-on body products and 4% in leave-on eye products; however, these figures are not mandatory provisions of laws or regulations.

5.2. Safety not certified by authoritative institutions

Available data show that resveratrol has no genotoxicity, is low in irritation to the skin and eyes, has not been listed as a prohibited substance, and the catalogue annotation reads "possible risk substances: none". However, some in vitro studies have shown that when the mass concentration of resveratrol is 125-500 μg/mL, the hemolysis rate of red blood cells reaches 17.2%-29%, which has exceeded the 10% hemolysis threshold generally considered safe and indicates clear membrane toxicity; when resveratrol is formulated into a nano-emulsion, the hemolysis rate at the same concentration drops to 3.3%-9.2%, indicating that its toxicity is directly related to its physical form and concentration. When the mass concentration of resveratrol reaches 10.0 μg/mL, cell viability drops to 73%-86%, whereas in the range of 0.5-5.0 μg/mL cell viability remains above 98%, indicating that the safety of resveratrol is clearly dose-dependent. However, the safety thresholds of resveratrol in various forms have not yet been certified or verified by authoritative institutions. This means that, although existing evidence suggests that resveratrol is generally safe at conventional use levels, formulators still lack authoritative threshold data on which to base their dosage decisions.

5.3. Insufficient research on human bioavailability

A large number of cell experiments and animal models have used high concentrations of resveratrol and demonstrated antioxidant, anti-inflammatory, and other activities. However, when taken orally, resveratrol undergoes rapid and extensive metabolism, resulting in extremely low bioavailability in humans [5]; the free concentrations that can be reached in blood and tissues are far below the effective concentrations used in in vitro experiments. In the state of topical application on the skin, the transdermal penetration rate of resveratrol is less than 1%, and the amount entering systemic circulation is even smaller. Most current skin permeation studies focus on testing various delivery systems, but a high encapsulation rate does not equal a high penetration rate. Research on the absolute values of skin penetration is also very limited; the vast majority of delivery studies have not measured the real intracellular concentrations, nor have they correlated them with biological effects. Consequently, the efficacy observed in the laboratory is difficult to reproduce directly in real-use scenarios, and this gap has become one of the main bottlenecks restricting the clinical translation of resveratrol.

6. Optimization and development directions

6.1. Carrying out dose-response research on efficacy concentrations and safety concentrations

At the national regulatory level, the National Medical Products Administration should carry out corresponding human studies to quantify the "minimum effective concentration" and the "maximum safe concentration" of resveratrol cosmetics. At the industry research level, group standards should be promoted to agree in advance on recommended dosage ranges, filling the gap during the "no limit" stage. At the enterprise management level, multiple tests should be conducted throughout the shelf life and a complete safety assessment should be carried out to prevent uncertain influences brought by light and heat effects. Only when the dose-efficacy and dose-safety relationships are clarified can product claims be supported by solid data.

6.2. Carrying out systematic safety evaluation in line with modern toxicological standards

First, a complete set of in vitro alternative toxicological tests should be carried out, including genotoxicity, reconstructed human epidermis skin irritation, in vitro phototoxicity, and in vitro sensitization screening, with non-animal tests given priority. When the in vitro results indicate risks, limited in vivo animal tests should be supplemented to obtain the no-observed-adverse-effect level. Then, on this basis, human patch tests and open-use tests simulating daily use should be conducted, and the skin exposure dose and safety margin should be calculated in combination with transdermal absorption data. At the same time, it is necessary to examine the toxicity of the oxidative degradation products of resveratrol during the shelf life and to evaluate the influence of delivery carriers such as nano-encapsulation on exposure levels. Finally, all test data should be integrated to conduct uncertainty analysis, comprehensively judge the use risks, and form a complete cosmetic safety assessment conclusion.

6.3. Technological deepening to cross the skin barrier

Multi-ingredient scientific compounding technology has the advantages of high cost-effectiveness and strong feasibility for industrialization, and it is currently the mainstream optimization method in the industry. The antioxidant capacity of resveratrol alone is limited; when compounded with vitamin E, it can form a synergistic antioxidant system whose antioxidant and yellow-removing brightening effects are significantly better than those of a single component [6]; compounded with niacinamide, it can effectively alleviate the oxidative damage caused by hydrogen peroxide to HaCaT skin cells, constructing a dual whitening pathway of "inhibiting melanin at the source + blocking it midway" [7]; compounded with glabridin and polydatin, it can synergistically inhibit tyrosinase activity and reduce melanin generation, with the combined efficacy significantly superior to each single ingredient [8].

Encapsulation and sustained-release technology is currently the core effective technology for solving the bioavailability problem of resveratrol. It can isolate the active molecules of resveratrol from the external oxygen and acid-base environments, improving the stability of the formulation system and extending the shelf life of products; at the same time, it can achieve targeted sustained-release penetration into the skin, and compared with free resveratrol solutions, its bioavailability can be improved by more than 2 times [9, 10]. In the future, emphasis can be placed on developing new carriers with low cost and low irritation to promote the industrial application of resveratrol active formulations. In addition, the choice of carrier should also take into account the target product form, cost budget, and regulatory compliance, so as to achieve a balance between efficacy and manufacturability.

7. Conclusion

As a natural, highly active polyphenolic raw material, resveratrol possesses excellent whitening and brightening, antioxidant, anti-photoaging, and collagen regeneration repair effects, and it combines the advantages of high safety, wide skin-type adaptability, and strong formulation compatibility, so it has broad application prospects in the field of functional cosmetics. The problems existing in its industrial application, such as low transdermal efficiency and poor stability, can be effectively improved through technical means such as encapsulation modification, transdermal penetration enhancement, scientific compounding, and process optimization. The problems in current research, such as the lack of dosage standards and safety evaluation, can also be further clarified through intensified research. As the cosmetics industry continues to develop toward greenness, functionality, and refinement, resveratrol will achieve wider application in high-end multi-effect repair skincare products. It can be expected that, with the continuous deepening of relevant basic and applied research, the gap between the laboratory performance of resveratrol and its actual user experience will keep narrowing, and collaboration among regulatory authorities, research institutions, and enterprises will be the key to translating the laboratory value of resveratrol into real product value.

References

[1] Shi, J., Jiang, Y. F., & Zhao, C. Y. (2024). Research progress in the efficacy and application of resveratrol on delaying skin aging. *Journal of Light Industry, 39*(3), 119–126.

[2] Zhang, Z. Q., Zhao, J., Li, C. X., Liang, J. Y., & Yang, P. S. (2026). Preparation of resveratrol liposomes and their application in cosmetics. *Shanghai Light Industry*, (3), 86–90.

[3] Shi, X. M., Yan, Z. M., Xie, J. H., Zhou, H. F., He, H. X., & Duan, M. X. (2011). Study on the photo-stability and thermo-stability of resveratrol. *China Surfactant Detergent & Cosmetics, 41*(3), 204–207.

[4] Liao, Y., Zhong, R., Liu, T. Q., Zhan, J. B., Chen, Z. X., & Chen, X. P., et al. (2024). Study on the whitening and barrier repairing effects of oxyresveratrol. *Guangdong Chemical Industry, 51*(21), 63–65.

[5] Li, J. N., Feng, S. Y., Zhang, C., Ge, Z. H., Gao, Z. S., & Zhang, H. J. (2025). Research progress of resveratrol in skin repair application. *China Surfactant Detergent & Cosmetics, 55*(12), 1582–1588.

[6] Wang, N., Gao, E. G., Li, N., Liu, Q. Q., Wang, F., & Ren, H. T., et al. (2022). Study on the synergistic antioxidant effect of resveratrol and vitamin E. *Journal of Henan Agricultural University, 56*(6), 1007–1014.

[7] Xu, C. Y., Zeng, Z. X., Rao, S. Q., Chen, Y., He, M., & Xu, W. J. (2025). Preparation, characterization and antioxidant activity of resveratrol-nicotinamide composite liposomes. *Chinese Journal of Hospital Pharmacy, 45*(18), 2107–2113.

[8] Huang, J., Xie, C., Pan, Z., Li, C. Z., Chen, Q. S., & Gong, S. Z., et al. (2024). Synergistic whitening, antioxidant and anti-inflammatory activities of glabridin-resveratrol-polydatin composition. *Flavour Fragrance Cosmetics*, (3), 99–107.

[9] Song, S. S., Wang, Y. F., Gao, Z. Y., Zhen, H., Jiang, X., & Tian, S. Z., et al. (2025). Preparation, in vitro and in vivo evaluation of resveratrol spanlastics modified with β-cyclodextrin-chitosan. *Chinese Traditional and Herbal Drugs*, (19), 6958–6967.

[10] Wang, X. Y., Li, H. K., Yu, L., Zhao, X. L., Yu, X. Y., & Fu, Y. J. (2020). Preparation of resveratrol lipid carriers and determination of their in vitro antioxidant activity. *Bulletin of Botanical Research, 40*(4), 631–636.