Resveratrol-Loaded Hyperfine Nanocapsules: Enhanced Skin Penetration and Efficacy for Advanced Cosmetics

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Introduction

Resveratrol is a natural polyphenol derived from various plants and is well known for its antioxidant activity in skin health. From a dermatological perspective, resveratrol exhibits antioxidant and anti-wrinkle effects on the skin. However, its practical application is limited by poor solubility and high sensitivity to light and heat, which reduce skin penetration and sustained bioactivity, resulting in low bioavailability. Therefore, advanced delivery systems that enhance the stability and skin penetration of resveratrol are required for skin-targeted applications.

Experimental preparation

Resveratrol loaded Hyperfine nanocapsules (RVT@HNCs) were fabricated using a solvent evaporation method. The physicochemical properties of RVT@HNCs were characterized using Dynamic Light Scattering (DLS) to measure their size and polydispersity index (PDI). The morphology of RVT@HNCs was observed by Transmission Electron Microscopy (TEM). To evaluate the antioxidant and whitening potential of RVT@HNCs, in situ reagent-based assays, including DPPH radical scavenging and tyrosinase inhibition tests, were performed. In vitro cellular assays evaluating anti-wrinkle- and elasticity-related endpoints were conducted to assess the biological efficacy of RVT@HNCs. Skin penetration efficiency was also examined via chemical membranes assay and Franz diffusion cell experiments.

Results

❖ Physicochemical properties of Resveratrol-loaded Hyperfine Nanocapsules (RVT@HNCs)

Samples	Size (nm)	PDI	Zeta potential
RVT@HNCs	40.0 ± 5.4	0.201 ± 0.12	-2.73 ± 1.19

Table 1. Dynamic Light Scattering (DLS) data of RVT@HNCs: Particle size, Polydispersity index (PDI), and Zeta potential

- DLS analysis confirmed that RVT@HNCs exhibited a uniform nanoscale size, with an average diameter of 40 ± 5.4 nm and a polydispersity index (PDI) of 0.201 ± 0.12.
- Long-term stability studies conducted at 25°C and 40°C for three months demonstrated that RVT@HNCs maintained their physicochemical properties without degradation or aggregation.

❖ Skin permeation test of RVT@HNCs

Time (h)	RVT solutions	RVT@HNCs
3	0%	0%
6	1.56%	11.54%
9	4.98%	38.53%
12	7.99%	61.86%
24	13.63%	92.90%

Table 2. Skin permeation results of RVT@HNCs and RVT solution analyzed using a chemical membrane assay over 0 – 24 h period

- Skin penetration studies using a chemical membrane-based permeation assay revealed that RVT@HNCs exhibited approximately an 800% enhancement in penetration efficiency compared to Resveratrol solutions.

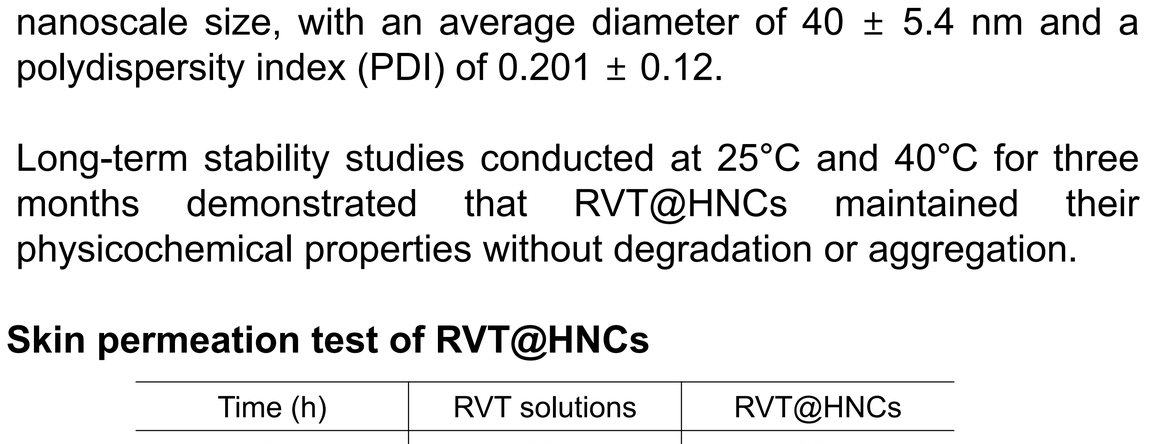

Figure 1. Skin permeation results after 24 h using Franz cell experiments with the model drug Nile Red: (a) RVT solutions and (b) RVT@HNCs.

- Skin penetration studies using a Franz cell permeation assay revealed that RVT@HNCs exhibited approximately an 800% enhancement in penetration efficiency compared to Resveratrol solutions.

❖ In situ and In vitro Efficacy Evaluation Test of RVT@HNCs

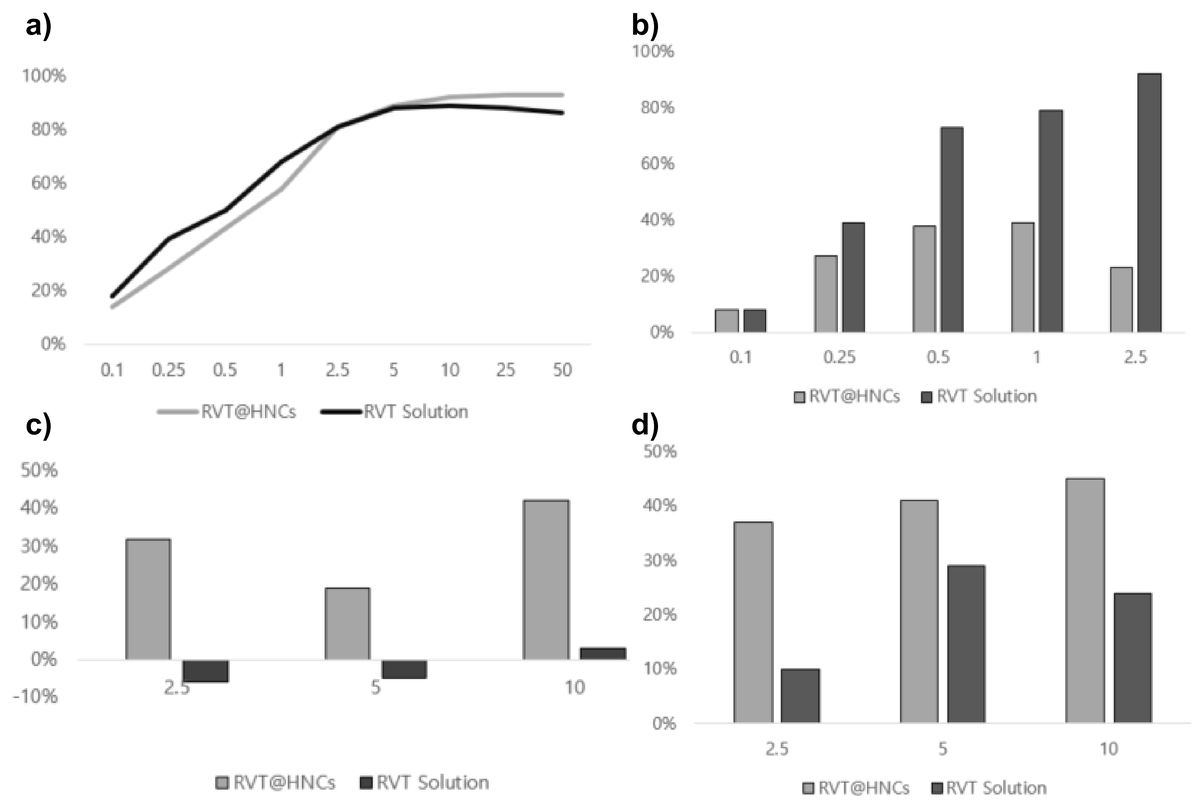

Figure 2. Efficacy study results: (a) DPPH assay and (b) tyrosinase inhibition assay for chemical experiments; (c) elasticity (qRT-PCR, ELN) and (d) wrinkle reduction (qRT-PCR, COL1A1) for cellular experiments, comparing RVT@HNCs and RVT solution.

- In situ DPPH radical scavenging and tyrosinase inhibition assays showed that RVT@HNCs exhibited cell-free antioxidant and anti-tyrosinase activities comparable to free resveratrol.
- In contrast, in vitro cellular assays demonstrated significantly enhanced biological efficacy, with anti-wrinkle and elasticity-related effects increased by 50% and 30%, respectively, relative to free resveratrol.

CONCLUSION

- Using the hydrotropy method, RVT@HNCs were successfully fabricated.
- Skin permeation studies using Franz cells and chemical membrane assays demonstrated superior skin penetration of RVT@HNCs compared to the control group (RVT solutions)
- In efficacy studies, RVT@HNCs showed similar effects to the control group in reagent-based assays but exhibited significantly enhanced efficacy in cellular experiments.

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