Evaluation of the Effects of an Ulvan–Squalane Nanoemulsion on Skin Photoaging Damage

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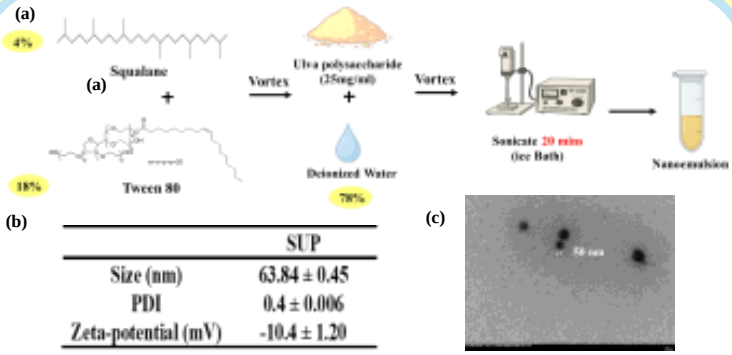
Abstract

The incidence of UVB-induced skin damage has increased globally due to ozone depletion, industrialization, and artificial UV sources. Current treatments are often costly and may cause side effects. In this study, ulvan was combined with squalane to prepare a nanoemulsion gel for skin protection. DLS and TEM confirmed that the nanoemulsion exhibited good particle size distribution. Treatment with nanoemulsion to HaCaT cells improved wound healing and UVB-induced ROS production and cell death. Adding 0.5% Carbopol® 940 gel provided a suitable texture for skin application. Franz diffusion assays confirmed the skin permeation of both ulvan and squalane. Mice treated with the nanoemulsion gel alleviated UVB-induced thickening of skin layers, and improved redness, scaling, and wrinkling. These findings suggest that the ulvan-squalane nanoemulsion gel is a promising topical agent for alleviating UVB-induced skin damage.

Results



(b)

	SUP
Size (nm)	63.84 ± 0.45
PDI	0.4 ± 0.006
Zeta-potential (mV)	-10.4 ± 1.20

(c)

Figure 1. Preparation and characterization of ulvan–squalane nanoemulsion. (a) Schematic illustration of the preparation process, (b) Dynamic light scattering (DLS) analysis: particle size, polydispersity index (PDI), and zeta potential and (c) Transmission electron microscopy (TEM) image.

Ex vivo

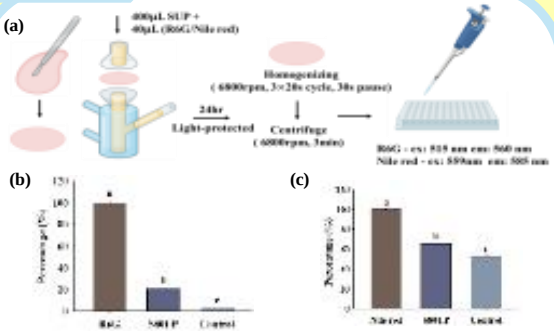
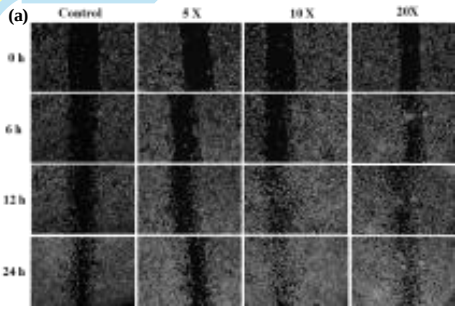


Figure 2. *Ex vivo* skin permeation assay of ulvan–squalane nanoemulsion (a) schematic diagram of the experimental procedure. (b) Permeation result using Rhodamine B (hydrophilic fluorescent dye) and (c) Nile Red (lipophilic fluorescent dye). Each value is mean ± standard deviation (n = 3). Different letters indicate significantly different values ($p < 0.05$).

In vitro



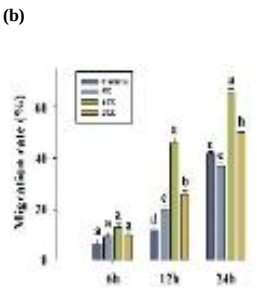


Figure 3. Effects of ulvan–squalane nanoemulsion on wound healing in HaCaT cells (a) Microscopic images at 6, 12, and 24 hours after wound establishment and (b) quantification of cell migration rate. Each value is mean ± standard deviation (n = 3).Different letters indicate significantly different values ($p < 0.05$)

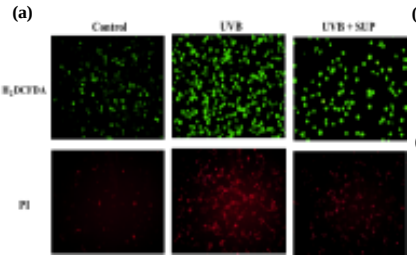


Figure 4 . Effects of ulvan–squalane nanoemulsion on UVB-induced damage in HaCaT cells. (a) Representative fluorescence microscopy images of PI staining and ROS accumulation, quantification of (b) ROS fluorescence intensity and (c) PI-stained dead cell fluorescence intensity. Each value is mean ± standard deviation (n = 3). Different letters indicate significantly different values ($p < 0.05$).

In vivo

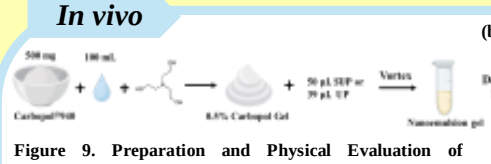
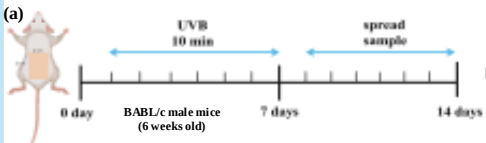


Figure 9. Preparation and Physical Evaluation of Nanoemulsion Gel (a) Preparation process of Carbopol gel.



Groups	UVB	Treatment
NA	-	-
UV	+	-
CA	+	Carbopol®940
UP	+	Carbopol®940 + Ulvan aqueous solution
SUP	+	Carbopol®940 + Nanoemulsion

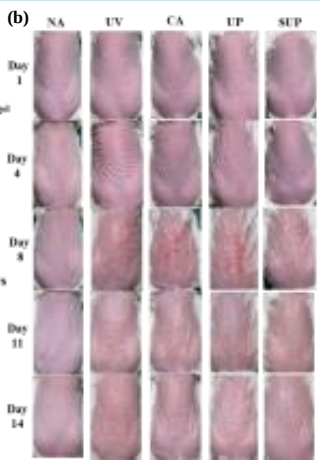


Figure 5. Establishment of UVB-induced skin photodamage model in mice. (a) Experimental flowchart and treatment to mice in each group, and (b) Representative photographs of mouse skin appearance. Each value is mean ± standard deviation (n = 6). Different letters indicate significantly different values ($p < 0.05$).

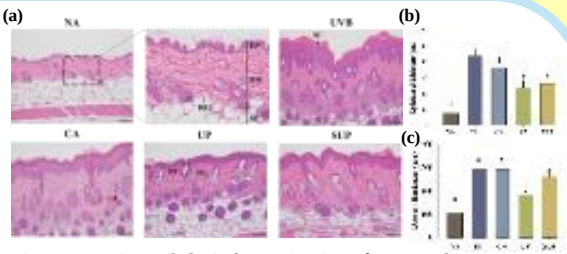


Figure 6. Histopathological examination of mouse skin using H&E staining. (a) Representative tissue section images, (b) epidermal and (c) dermal thickness analysis. DEJ, dermal–epidermal junction; DM, dermis; EP, epidermis; HF, hair follicle; IFC, inflammation cells; SC, stratum corneum; SbC, sunburn cells; ST, **subcutaneous tissue. SG, sebaceous glands.** Each value is mean ± standard deviation (n = 6). Different letters indicate significantly different values ($p < 0.05$).

Conclusion

The ulvan–squalane nanoemulsion effectively reduced UVB-induced photodamage, showing potential as a stable, biocompatible, and low-irritation treatment for photoaging.

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