Photoluminescent Antioxidant Oligomers with Potent UV-Absorbing Properties

Jian Yang[1], Robert van Lith[1], Guillermo A. Ameer[1,2,3*]
[1]Biomedical Engineering Department, Northwestern University, Evanston 60208
[2]Department of Surgery, Feinberg School of Medicine, Northwestern University, Chicago 60611
[3]Simpson-Querrey Institute, Northwestern University, Chicago 60611

Statement of Purpose: UVA radiation can penetrate through the dermis into subcutaneous tissues and induce various biological responses, ranging from erythema to photoaging. To prevent this process, sunscreens are often used. However, some sunscreens may have adverse effects such as contact sensitivity, increased risk of vitamin D deficiency, toxicity, as well as aesthetically unpleasing results for metal oxide-based lotions. Further, safety remains a concern for small molecules. We have synthesized and characterized a novel chromophore oligomer from citric acid and panthenol (provitamin B_5) that has high absorption in the UVA and UVB range and can be easily formulated into a sunscreen that can result in aesthetically pleasing skin protection.

Methods: Equimolar amounts of panthenol (PAN) and citric acid (CA) were mixed and reacted for 2 hours at 120 °C under vacuum (<100 mBar). Photoluminescent properties of panthenol citrate oligomer (PanCit) were investigated on a PC1 photon counting spectrofluorometer (ISS, Champaign, IL). Ultraviolet absorption spectra were recorded using an Agilent Cary 100 UV/Vis spectrophotometer (Agilent, Santa Clara, CA). Chemical characterization was performed by an Ag500 NMR spectrometer (Bruker, Billerica, MA) and Autoflex III Smartbeam Matrix-assisted laser desorption ionization (MALDI) mass spectrometry (Bruker, Billerica, MA). Human umbilical vein endothelial cells (HUVEC) (Lonza, Walkersville, MD), adult human epidermal keratinocytes (HEKa) (Gibco, Carlsbad, CA) and human dermal fibroblast (HDF) (Lonza, Walkersville, MD) were cultured to evaluate cell viability in vitro. The hydrophilic radical cation (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) was used to test the free radical scavenging capacity of PanCit.

Results: A photoluminescent oligomer was successfully synthesized with excitation at 350 nm and emission at 440 nm (Figure 1a). A novel chromophore was formed as identified by NMR and MALDI (Figure 1c). The oligomer is water and ethanol soluble and exhibited UV absorption in the range from 280 nm to 400 nm. The absorption spectrum was significantly improved when compared to avobenzone's, the most efficient chemical UV-blocker on the market. No cytotoxicity was observed for the three cell types at lower doses of PanCit (< 1 mg/ml) (Figure 2a). PanCit showed significant radical quenching over time, confirming its antioxidant properties.

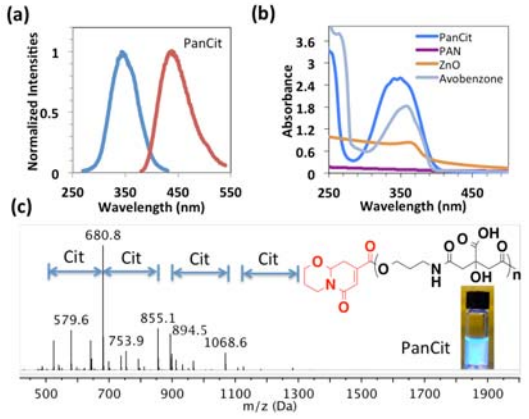

Figure 1. (a) Normalized excitation and emission intensities of panthenol citrate (PanCit) in H_2O of 10 mg/ml. (b) UV/Vis spectra of PanCit oligomer in water at 25°C with the same concentration of 10 mg/ml, panthenol (PAN), ZnO and avobenzone as references. (c) MALDI-MS spectra of PanCit oligomer in α-CHCA over the region from m/z 500 to 2000.

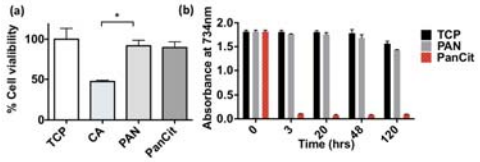

Figure 2. (a) Quantitative analysis of the viability of cells cultured with panCit oligomers (1.0 mg/ml), 5.2 mM citric acid, and 4.88 mM panthenol, $p < 0.0001$, $N = 6$, Mean ± S.D. (b) ABTS radical scavenging capacity of PanCit relative to panthenol.

Conclusions:
Panthenol citrate oligomers show promising photoluminescent, ultraviolet absorption and antioxidant properties that are useful for the preparation of next-generation formulations for skin protection from sun damage.