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Optimization of Liposomal Nanoencapsulation of Winemaking By-Product Extracts for Sustainable Topical Applications

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Abstract

The wine industry generates large amounts of by-products, including grape pomace and stems, which represent both an environmental challenge and a valuable source of bioactive compounds. These residues are particularly rich in phenolic compounds with antioxidant and potential skin-protective properties, making them promising candidates for cosmetic and topical applications within a circular economy framework. In this work, sustainable extraction methodologies were applied to obtain phenolic-rich extracts from grape pomace and grape stems whereby Accelerated Solvent Extraction (ASE). To improve extract stability, protect phenolic compounds from degradation and enhance their topical delivery, the extracts were nanoencapsulated into liposomal systems. Based on previous screening studies, different liposomal formulations were selected for optimization according to the type of extract. Initially, grape pomace extracts were incorporated at 15mg/mL into formulations containing 180 mg/mL soy lecithin, 1 mL water and 5 mL Transcutol® P. For grape stem extracts, formulations contained 20 mg/mL extract, 180 mg/mL soy lecithin, 0.750 mL water, 0.125 mL propylene glycol and 0.125 mL glycerol. Liposomes were produced by sonication process and the nanoencapsulation process was optimised using response surface methodology (RSM). A 23 centralised experimental design with 4 central points was used to optimize the process. Extract concentration, soy lecithin concentration and sonication amplitude were evaluated as independent variables. Particle size, encapsulation efficiency and polydispersity index were selected as response variables to assess nanosystem quality and stability. The results suggested the feasibility of obtaining stable nanosized liposomal systems suitable for topical applications, demonstrating that liposomal encapsulation may enhance the protection of bioactive compounds against degradation, improve their dispersion and penetration in topical formulations and increase their potential effectiveness on the skin. Therefore, this approach represents a promising strategy for the sustainable revalorization of wine making by-products into high-value bioactive ingredients for topical application.

Keywords: winemaking by-products, phenolic compounds, nanoencapsulation, upcycling, topical applications