Sustainable, microplastic-free encapsulation of lipophilic fragrances using sodium alginate for cosmetic formulations

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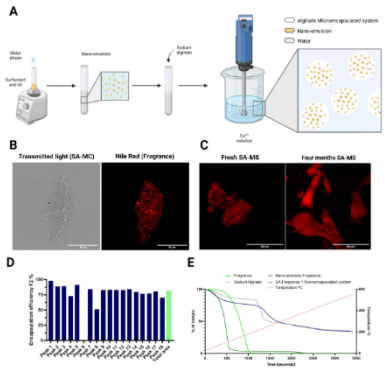
Microencapsulation of volatile lipophilic compounds such as fragrances is essential in the cosmetic industry to control their prolonged release and delay their evaporation. However, conventional systems often rely on non-biodegradable microplastics, which involve environmental risks to aquatic ecosystems. Developing sustainable, biodegradable alternatives that maintain efficacy is therefore crucial for the industry.

The strategy consists of a nano-emulsion within a gelated alginate matrix. O/W nano-emulsions were prepared via phase inversion composition (PIC) method using polysorbate 80, then microencapsulated through internal gelation with $CaCl_2$ and subsequent dispersion (Figure 1.A). Characterisation included DLS for size distribution, GC-MS for encapsulation efficiency, TGA for release profiles, Microscopy for morphology, Oil distillation for fragrance loading, and a 30-day organoleptic study with 21 trained panellists to evaluate fragrance intensity.

The optimised formulation produced long-term stable monodisperse nano-emulsions (around 160 nm). Confocal microscopy confirmed the retention of fragrance within the alginate microsystems (Figure 1.B). The system exhibited excellent stability in a carrier matrix for four months without phase separation (Figure 1.C). The encapsulation efficiency average-compounds is of 81% (up to 97% for individual compounds) (Figure 1.D). TGA (Figure 1.E) and Organoleptic studies showed prolonged release profiles and significantly higher perceived intensity compared to free fragrances.

This work demonstrates a viable biodegradable alternative to microplastic-based encapsulation systems for cosmetic applications. The strategy based on O/W emulsion encapsulated within the sodium alginate matrix achieves high encapsulation efficiency of the fragrances, prolonged diffusion-controlled release, and long-term stability, addressing environmental concerns being a useful alternative to non-biodegradable encapsulation systems.

Keywords:
O/W nano-emulsions, Microencapsulation system, Biodegradable polymer, Sodium Alginate, Fragrance encapsulation, Phase Inversion Composition



Design and characterization of SA-Fragrance Microencapsulated System. A) System designed B) CSFM images of system loaded with Nile Red. Channels at Brightfield and at 365 nm C) CSFM images of fresh and 4 months in a "conditioner matrix" D) Encapsulation Efficiency (%) E) TGA curves.

References:

A.Tarrats-Duran, S. Borrós, J. R. Magaña, and C. Fornaguera, *Colloids Surf. B Biointerfaces* , vol. 259, Mar. 2026,

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