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Transforming Olive Leaf By-Products into Stable Functional Ingredients: Optimization and Characterization

CARLOS ABELLÁN-DIÉGUEZ[1,2], SILVIA RODRIGO GALLEGO[1,2,*], FRANCISCO JAVIER LEYVA-JIMÉNEZ[3] and M. ELENA ALAÑÓN[1,2]

[1]*Regional Institute for Applied Scientific Research (IRICA), University of Castilla-La Mancha, Avda. Camilo José Cela 10, 13071 Ciudad Real, Spain*
[2]*Department of Analytical Chemistry and Food Science and Technology, University of Castilla-La Mancha, Ronda de Calatrava 7, 13071 Ciudad Real, Spain*
[3]*Department of Analytical Chemistry University of Granada, Science Faculty, Fuentenueva s/n, E 18071 Granada, Spain*

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Abstract

The development of stable functional ingredients from agro-industrial by-products represents a major challenge for the food industry. Olive leaves are an abundant by-product rich in phenolic compounds such as oleuropein (OLE) and hydroxytyrosol (HT), which exhibit antioxidant, anti-inflammatory, and antimicrobial properties (Demirer, 2025). Nevertheless, the industrial use of these compounds remains limited due to their low stability under environmental conditions, especially pH and temperature changes (Duque-Soto et al., 2023), which promote their degradation during gastrointestinal digestion and compromise their bioavailability and technological performance in food systems. Spray drying has emerged as a robust, cost-effective, and industrially scalable technology for the protection and stabilization of bioactive compounds (Pacheco et al., 2018). Therefore, the present study aimed to optimize the spray-drying microencapsulation process of OLE and HT from a commercial olive leaf extract using maltodextrin (MD) and sodium alginate (ALG) as wall materials. Process optimization was carried out through a 22 central composite design (CCD) with 4 central points. The extract to encapsulating agent ratio and inlet temperature were selected as independent variables, while encapsulation efficiency (EE) of OLE and HT was used as response variables. Response surface methodology (RSM) identified the optimal encapsulation conditions as an extract to encapsulating agent ratio of 1:4.3 and an inlet temperature of 128ºC. under these conditions, encapsulation efficiencies of 73% for OLE and 95% for HT were achieved, closely matching the predicted values (72% and 97%, respectively), thereby confirming the robustness and predictive capacity of the model. The optimized formulation was further evaluated in terms of bioaccessibility and characterized by scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), stability analysis, colorimetric evaluation, and powder flowability. The results demonstrated improved bioaccessibility of both phenolic compounds. Moreover, the optimized microcapsules exhibited favourable morphological, thermal, and flowability properties, highlighting their suitability for handling, storage, and incorporation into industrial food matrices. Overall, these findings demonstrate the potential of spray-dried olive leaf phenolic microcapsules as value-added functional ingredients, contributing to the sustainable valorisation of olive industry by-products and supporting the development of industrially applications.

Keywords: Spray drying, microencapsulation, oleuropein, hydroxytyrosol and olive leaf

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