



Abstract

# Hydrophobic and Hydrophilic Deep Eutectic Solvents to Extract Carotenoids from Orange Peels and Obtain Green Extracts <sup>†</sup>

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**Abstract:** Nowadays the food industry is focusing on the reutilization of fruit by-products rich in bioactive compounds such as carotenoids. These valuable ingredients could be extracted to formulate functional food products. Deep Eutectic Solvents (DES) are a new generation of solvents that comply with the requirements for green extractions and can successfully replace other organic solvents. The aim of the present study was to select the most promising DES for carotenoid extraction from orange peel (OP) and obtain green extracts with biological activity. In order to reduce time and energy, the software COSMOtherm was used for the screening of 68 DES to provide the optimal solvent for carotenoid extraction. The results from the software were validated experimentally with the most suitable and unsuitable solvents. OP was obtained from orange fruits (*Citrus sinensis*, Navel cultivar). Three hydrophobic DES were prepared Menthol:Camphor (Me:Cam), Menthol:Eucalyptol (Me:Eu), Lauric Acid:Octanoic acid (C12:C8) and two hydrophilic Proline:Malic acid (Pro:MA) and Choline chloride:Urea (ChCl:U). Extractions were performed with 1 g of milled OP using different DES (1:10 *w/v*) for 30 min with 50 W of ultrasound power at 45 °C. The obtained extracts were characterized by total carotenoid content (TC), determined spectrophotometrically; the biological activity was evaluated in vitro by an antiproliferative assay in tumor cells (HeLa) using MTS reactive. The extracts obtained with hydrophobic DES showed the highest values of total carotenoids, and no significative difference ( $p > 0.05$ ) was found between Me:Cam ( $163.5 \pm 1.1$  mg/100 g<sub>fw</sub>), Me:EU ( $168.7 \pm 1.6$  mg/100 g<sub>fw</sub>) and C12:C8 ( $153.1 \pm 7.1$  mg/100 g<sub>fw</sub>). The in vitro assay showed an antiproliferative effect of Me:Cam extract on tumor HeLa cells with 26.7% of cell viability. The whole formulation (DES and bioactive compound) could be included in final products without any additional purifying steps and can enhance the bioactivity of food products.

**Keywords:** carotenoids; deep eutectic solvents; orange by-products; COSMOtherm; biological activity



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