Olive Leaves and Citrus Peels: Harnessing Waste for Eco-Friendly Cosmetic Applications

Antonio Silletta [1], Nicola d'Avanzo [2,3] , Antonia Mancuso [2,3], Rosario Mare [1], Samantha Maurotti [2] , Ortensia Ilaria Parisi [4,5] , Maria Chiara Cristiano [1] and Donatella Paolino [2,3]

[1] Department of Medical and Surgical Sciences and [2] Department of Experimental and Clinical Medicine, "Magna Graecia" University of Catanzaro, Campus Universitario "S. Venuta"—Building of BioSciences, Viale S. Venuta, 88100 Catanzaro, Italy; [3] Research Center "ProHealth Translational Hub", Department of Experimental and Clinical Medicine, "Magna Graecia" University of Catanzaro, Campus Universitario "S. Venuta"—Building of BioSciences, Viale S. Venuta, 88100 Catanzaro, Italy; [4] Macrofarm s.r.l. and [5] Department of Pharmacy, Health and Nutritional Sciences, University of Calabria, 87036 Rende, CS, Italy.

antonio.silletta@unicz.it; paolino@unicz.it

The valorization of food-waste byproducts, such as clementine peels and olive leaves, for cosmetic applications is an emerging area of interest. These materials, often discarded, hold potential as sustainable sources of bioactive compounds that can enhance cosmetic formulations. This study aims to evaluate the suitability of clementine peel extract (CPE) and olive leaf extract (OLE) as ingredients in face creams in combination with another waste material that is bergamot wastewater. The extracts was obtained by means supercritical CO2 extraction method and subsequently characterized in terms of antioxidant activity, in vitro cytocompatibility profiles, and overall impact on cream stability and sensory attributes. The incorporation of these extracts into face cream did not affect the stability and the microrheological properties as assessed by Turbiscan Lab® analysis and diffusion wave spectroscopy. Moreover, dynamic rheological analyses revealed that the creams with extracts maintained pseudoplastic behavior, with slight reductions in viscosity at higher extract concentrations. In vivo tolerability tests, carried out on human healthy volunteers, confirmed that the creams did not adversely affect skin barrier function or induce irritation, since transepidermal water loss and skin's erythematous index did not undergo significant changes compared to the negative control. Concerning primary and secondary skin feelings evaluations, enrolled volunteers expressed positive feedback after the application of the proposed cosmetic formulations, highlighting their suitable spreadability and pleasant fragrance. This study highlights the potential of clementine peel and olive leaf extracts as beneficial ingredients in cosmetic formulations. The use of these byproducts supports a circular economy approach, offering an environmentally friendly alternative in cosmetic product development.

CHEMICAL CHARACTERIZATION AND IN VITRO CYTOTOXICITY OF THE EXTRACT

Graphical Abstract

UV-Vis Spectrophotometer

Sample	TPC (mg/mL GAE)	TFC (mg/mL)	Antioxidant Activity (%I)
Olive leaves extract	0.0903 ± 0.0035	0.2164 ± 0.762	23.23 ± 1.47
Clementine peels extract	0.330 ± 0.017	0.8844 ± 0.0796	25.86 ± 3.07

Liquid Chromatography (HPLC)

Sample	Rutin (ppm)	Naringin (ppm)	Hesperidin (ppm)	Oleuropein (ppm)
Olive leaves extract	n.a.	n.a.	n.a.	7.44 ± 0.52
Clementine peels extract	25.97 ± 1.10	28.16 ± 2.13	679.88 ± 59.29	n.a.

Table 1. Chemical characterization of extracts obtained from clementine peels and olive leaves using UV-Vis spectrophotometry, in terms of total phenolic and flavonoid content, and their subsequent antioxidant activity. Liquid Chromatography (HPLC) detected the presence of various compounds such as rutin, naringin, hesperidin, and oleuropein.

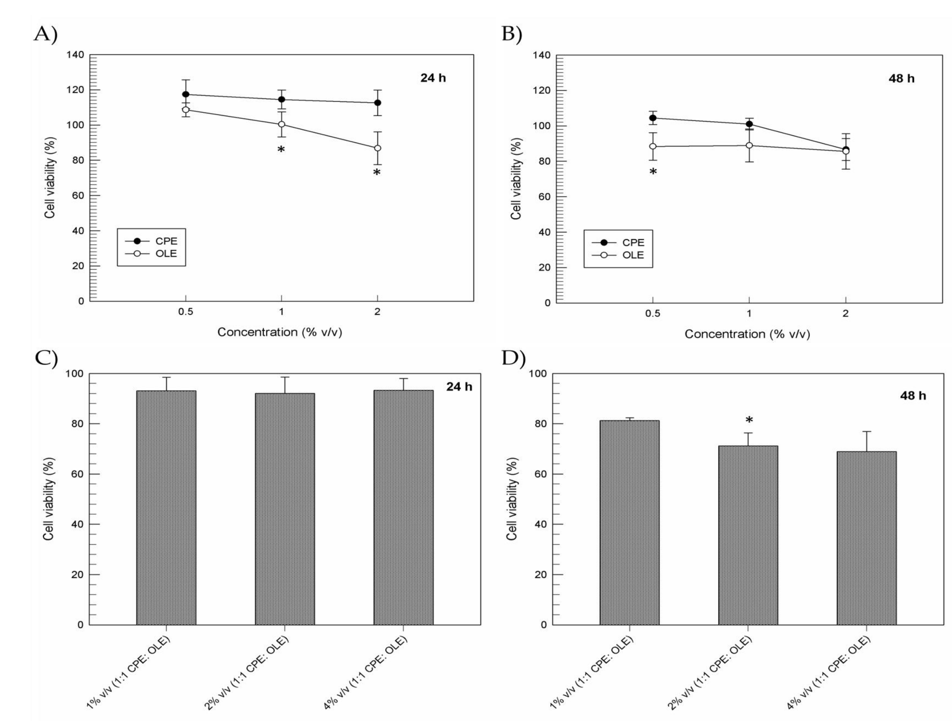

Figure 1. In vitro cytotoxic effects of OLE and CPE on human keratinocytes when used alone (A, B) or in combination (C, D). The results are presented as a function of extract concentration and incubation duration. The cytotoxic impact of ethanol at the same concentrations utilized for the extracts is used to standardize the data. The findings are a mean of three separate tests with standard deviation. * p<0.05.

MICRORHEOLOGICAL AND DYNAMIC RHEOLOGICAL CHARACTERIZATION

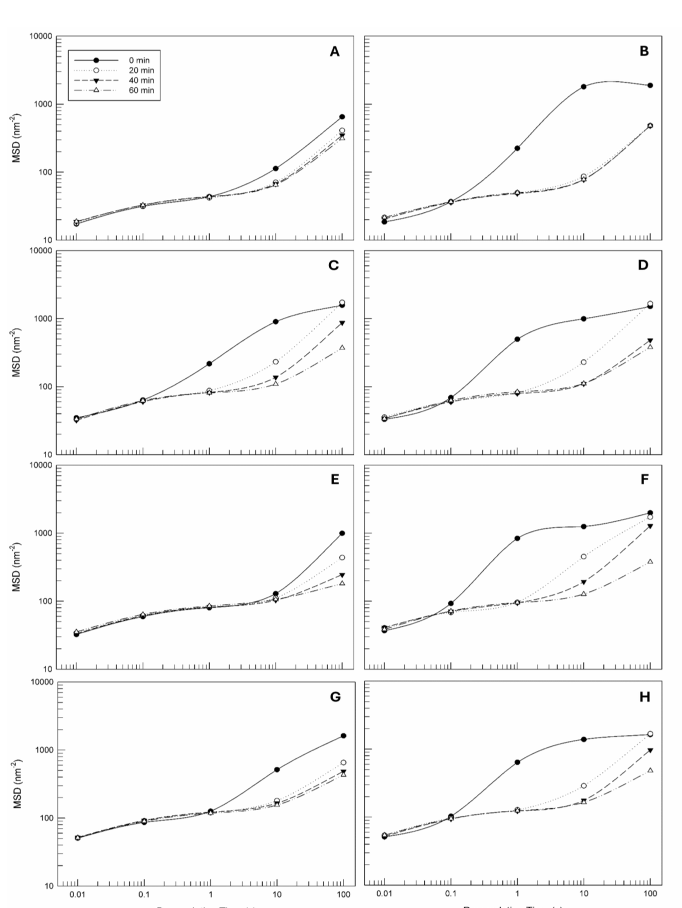

Figure 2. Mean square displacement (MSD) curves for the empty and OLE-CPE formulations as a function of decorrelation time (s). The illustrated results are representative of three independent experiments. The panels are representative of: empty formulations at 25 °C and 40 °C (A) and (B), respectively; 2% OLE-CPE at 25 °C (C) and 40 °C (D); 3% OLE-CPE at 25 °C (E) and 40 °C (F); 4% OLE-CPE at 25 °C (G) and 40 °C (H).

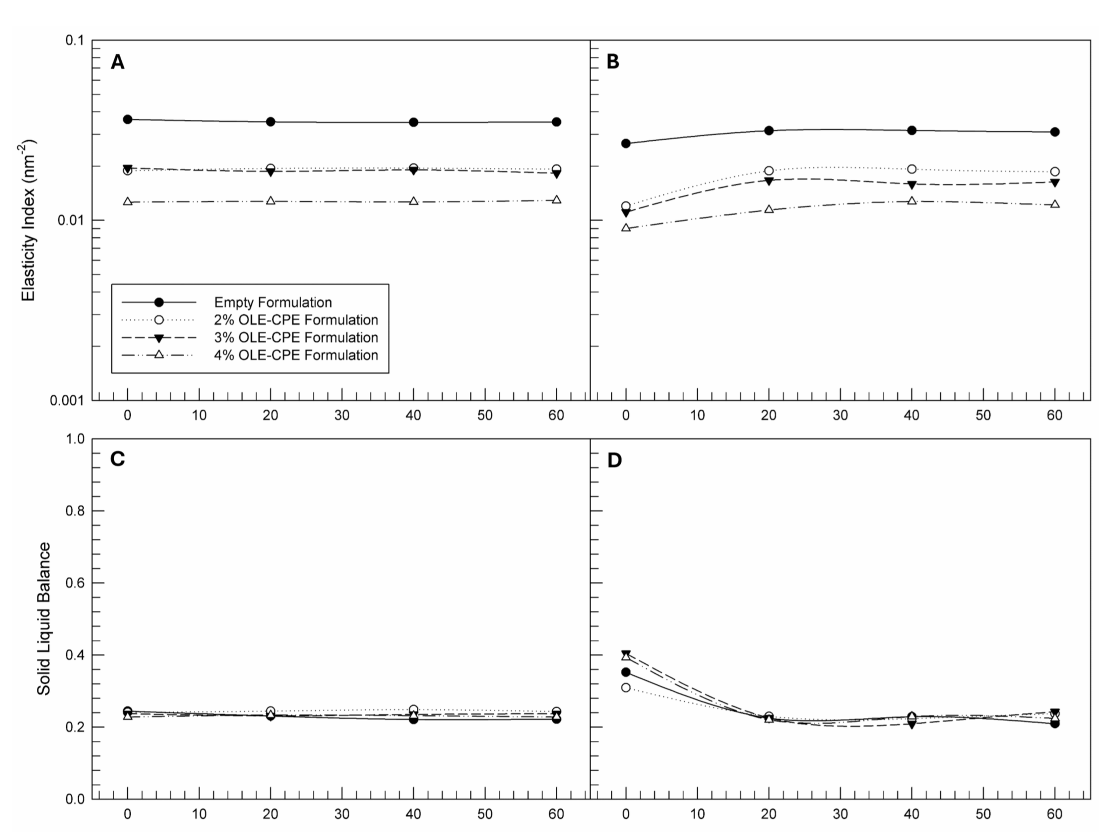

Figure 3. Elasticity Index and Solid Liquid Balance curves for formulations analyzed at various temperatures as a function of time. The panels shown are representative of three independent experiments and refer to: Elasticity profiles at 25°C (A) and 40°C (B). Solid Liquid Balance profiles at 25°C (C) and 40°C (D).

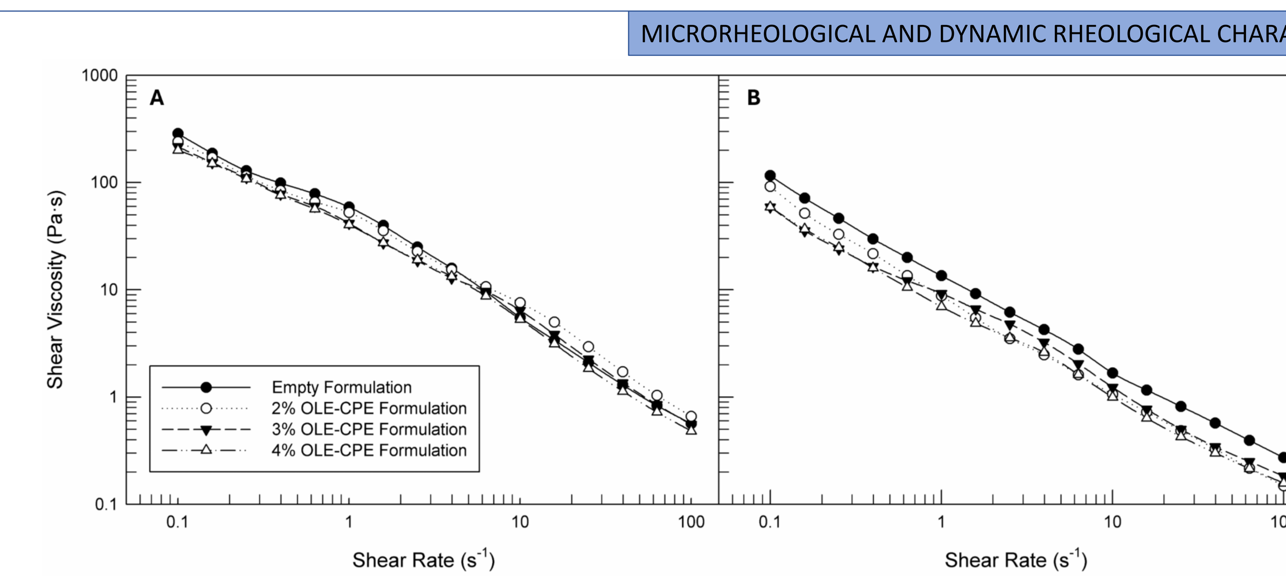

Figure 4. Shear viscosity profiles of the empty and OLE-CPE formulations at 25 °C (A) and 40 °C (B). The results are representative of three independent experiments.

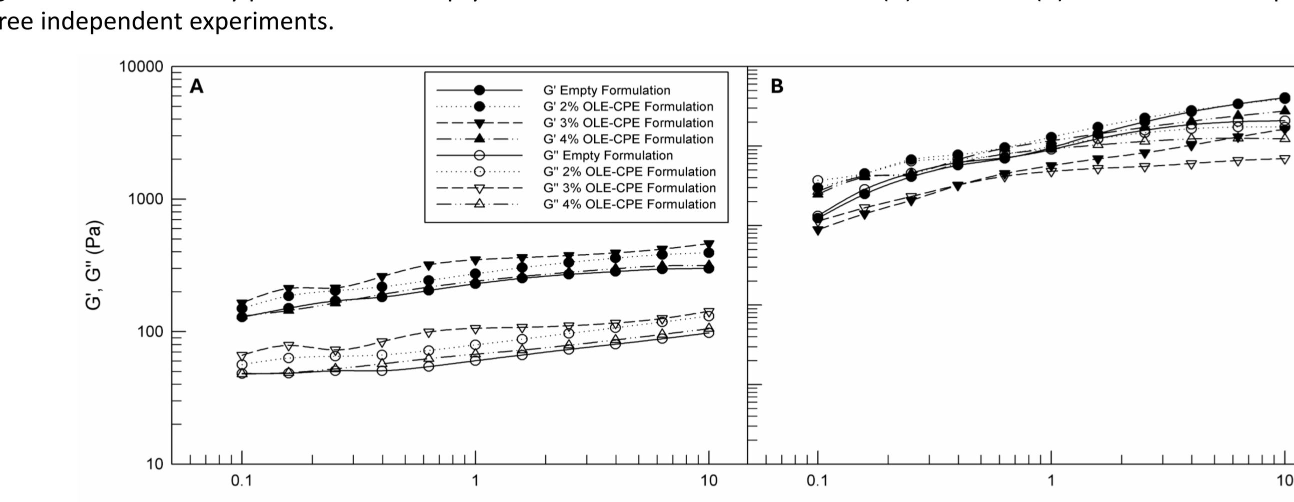

Figure 5. Curves of G' and G" moduli (Pa) for empty and OLE-CPE formulations at 25 °C (A) and 40 °C (B) as a function of frequency (Hz). The displayed results refer to three separate experiments' outcome.

STABILITY STUDIES

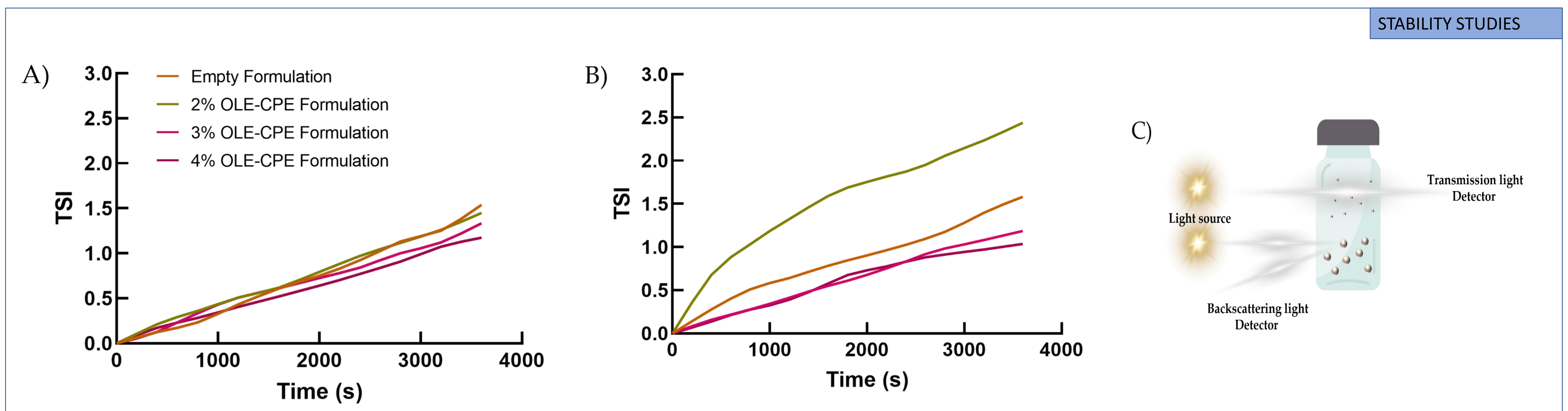

Figure 6. Turbiscan analyses of cosmetic emulsions. The kinetic destabilization profiles are reported as a function of time (0–60 min) and temperature (25 °C and 40 °C for Panel (A,B), respectively). The results obtained are indicative of three analyses that were performed on three distinct batches of every formulation. Panel C is representative of the operating principles of the technique.

Shear Viscosity (Pa·s) at Different Shear Rate (s−1)

Formulation	$0.1\ s^{-1}$	$1\ s^{-1}$	$10\ s^{-1}$	$100\ s^{-1}$
T = 25.00 ± 0.01 °C				
Empty Formulation	285.40 ± 9.21	58.96 ± 6.54	5.51 ± 0.86	0.56 ± 0.02
2% OLE-CPE Formulation	240.10 ± 6.28 *	52.51 ± 4.36	7.56 ± 1.04	0.66 ± 0.04 *
3% OLE-CPE Formulation	215.20 ± 5.98 **	41.58 ± 3.05 *	6.41 ± 1.58	0.55 ± 0.00
4% OLE-CPE Formulation	199.90 ± 7.02 **	40.40 ± 4.35 *	5.29 ± 0.99	0.48 ± 0.07
T = 40.00 ± 0.01 °C				
Empty Formulation	115.60 ± 11.21	13.50 ± 2.45	1.67 ± 0.58	0.27 ± 0.05
2% OLE-CPE Formulation	91.55 ± 8.24 *	8.76 ± 1.98	1.06 ± 0.78	0.15 ± 0.02 *
3% OLE-CPE Formulation	58.99 ± 8.25 *	9.23 ± 1.14	1.23 ± 0.45	0.18 ± 0.02 *
4% OLE-CPE Formulation	59.05 ± 6.25 *	6.92 ± 1.87 *	0.99 ± 0.05	0.16 ± 0.00 *

Table 2. Shear rate-dependent viscosity (Pa·s) of empty and OLE-CPE formulations. Values are reported as the average of three independent experiments ± standard deviation. * $p < 0.05$ and ** $p < 0.001$ with respect to empty formulation at the same shear rate values and temperature.

IN VIVO EVALUATION

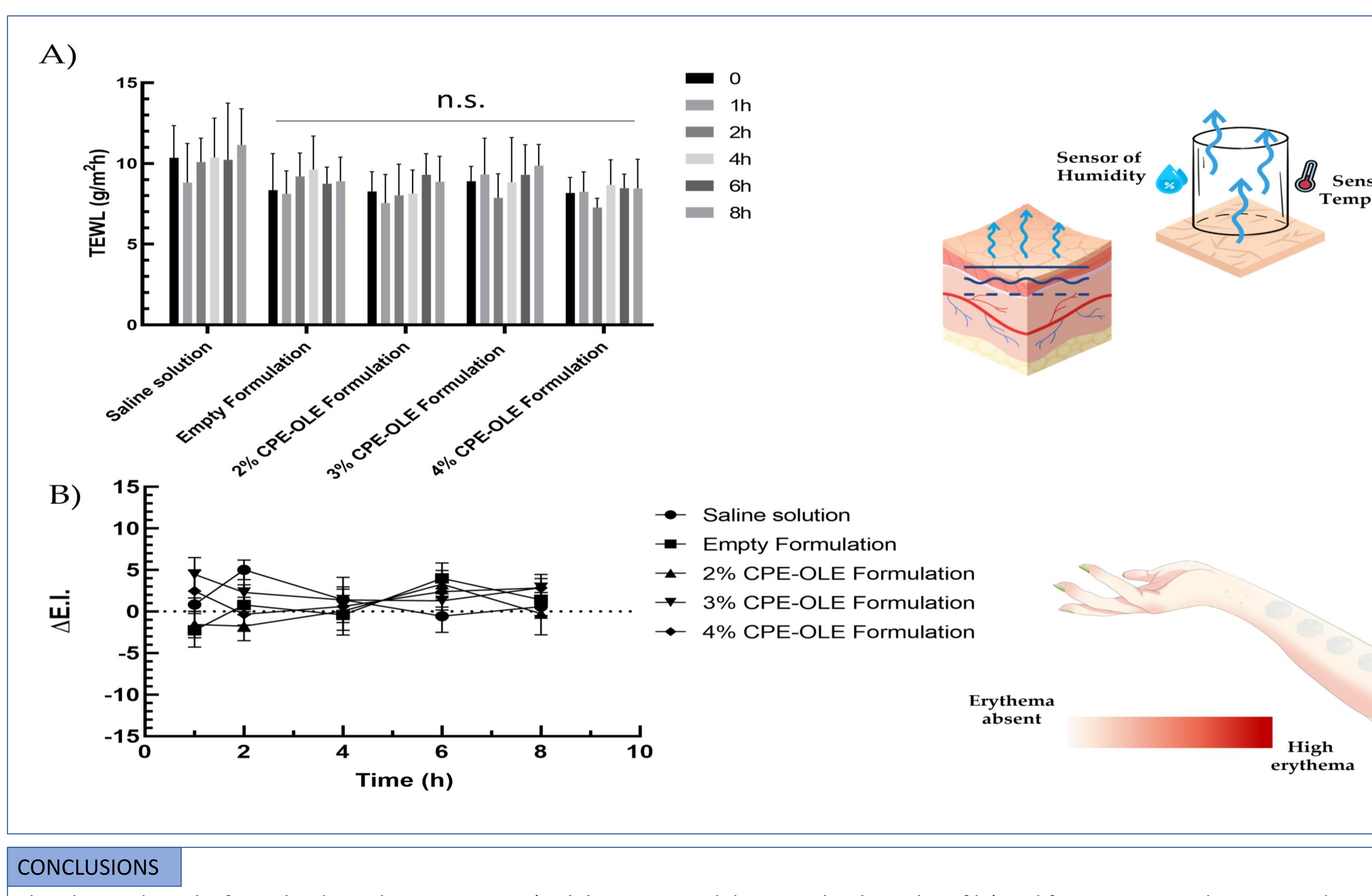

Figure 7. Studies of skin tolerability on healthy human volunteers. The TEWL values following topical application of the empty or formulations containing 2%, 3%, and 4% CPE-OLE formulations are displayed in Panel (A). The variation in erythematous index values following the administration of empty or CPE-OLE-containing formulations is displayed in Panel (B). In both investigations, saline solution (NaCl 0.9% w/v) served as the control. N.s= Non significant.

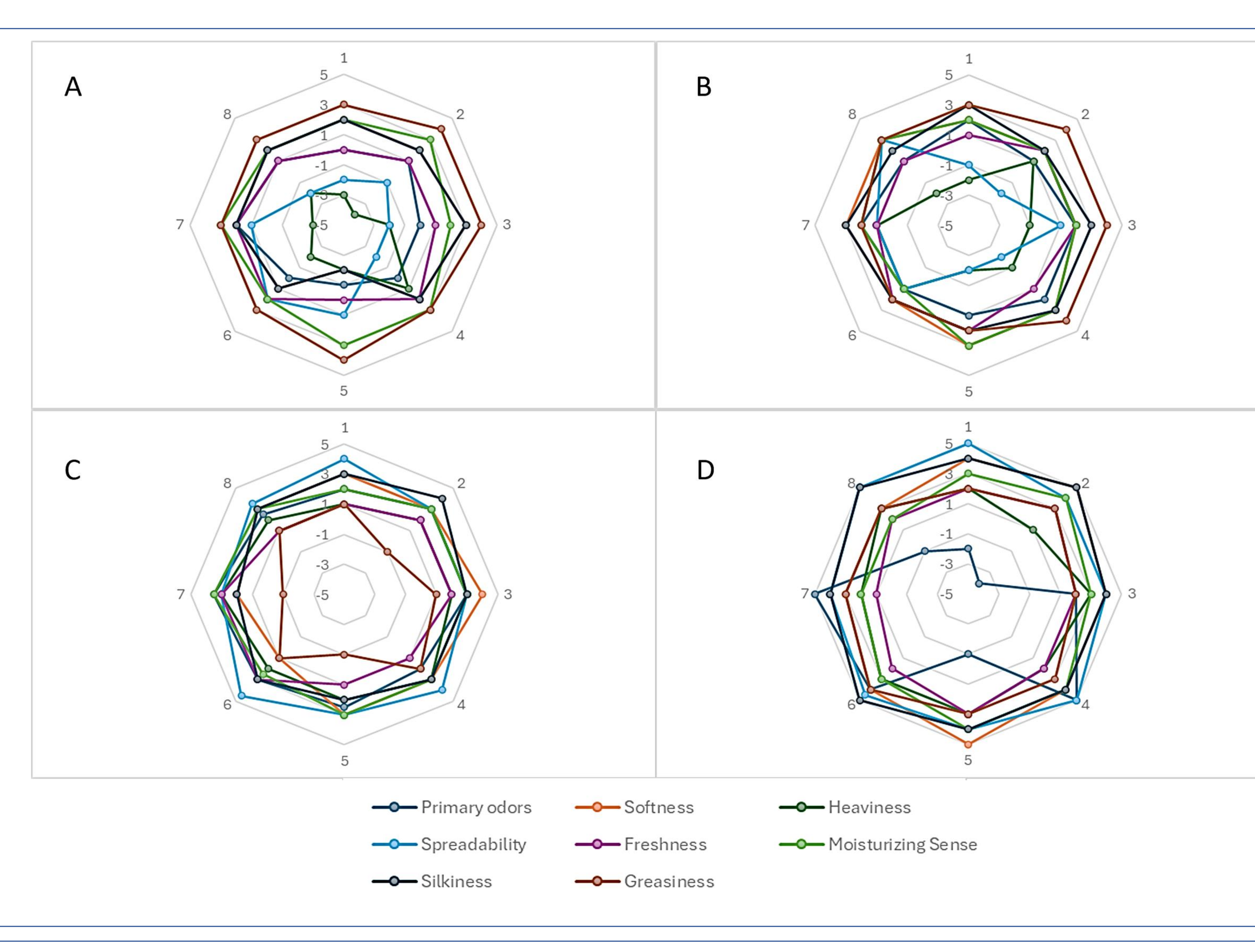

Figure 8. Radar diagrams of skin feelings after the cutaneous application of emulsions. An anonymous questionnaire was used to gauge primary and secondary skin sensations in human volunteers. Panel (A) represent the empty formulations, while (B–D) 2%, 3%, and 4% CPE-OLE formulations.

CONCLUSIONS

The obtained results from the deep characterization (stability, static and dynamic rheological profile) and from in vitro and in vivo studies confirmed the feasible use of the proposed formulations as topical products.. The suggested strategy promotes the recycling of food waste byproducts as ingredients in the beauty industry in order to build a circular economy that can provide material with an additional benefit while minimizing resource depletion and environmental effects.

Reference

1. d'Avanzo, N.; Mancuso, A.; Mare, R.; Silletta, A.; Maurotti, S.; Parisi, O.I.; Cristiano, M.C.; Paolino, D. Olive Leaves and Citrus Peels: From Waste to Potential Resource for Cosmetic Products. Cosmetics 2024, 11, 41.