LYCOPENE EXTRACTION FROM TOMATO WASTE USING SUSTAINABLE SOLVENTS

BRYAN LEONARDO M. ESPINO*, CECILIA SEPE, VANESSA SPADAVECCHIA, CHIARA SAMORÍ, PAOLA GALLETI

Erasmus Mundus Joint Master Degrees (EMJMD) in MSc. Chemical Innovation and Regulation (ChIR) and XVII International Postgraduate Summer School on Green Chemistry (GCSS 2025)
Dipartimento di Chimica “Giacomo Ciamician”, Ravenna Campus, University of Bologna, Via Sant’ Alberto 163, 48123 Ravenna, Italy.
*Contact Email: leonardo.espino@hotmaill.com

BACKGROUND:

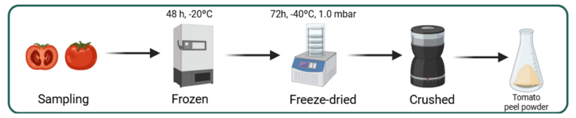
The global production of fresh tomatoes exceeds 180 million tonnes annually, with around 40 million tonnes dedicated to processing [1]. Italy is the top producer of processing tomatoes, accounting for approximately 13.7% of the market share, which equates to about 5.48 million tonnes [2]. The current disposal method of tomato processing waste results in significant byproducts, predominantly composed of skins, seeds, and pulp residues. Lycopene, responsible for the deep-red color of ripe tomato fruits and products, offers potent antioxidant properties and various health benefits, including cancer prevention and cardiovascular protection [3],[4]. Conventional lycopene extraction methods often rely on organic solvents, which pose environmental and health risks due to their toxicity and volatility.[5] Sustainable solvents, such as Deep Eutectic Solvents (DES) and other green solvents, have emerged as promising alternatives, providing comparable extraction efficiencies while being environmentally benign and derived from renewable resources. [6]

OBJECTIVE:

The primary objective is to optimize the Lycopene extraction process from tomato waste with sustainable solvents compared to conventional solvent extraction techniques. A solvent screening assessed the recovery efficacy, purity of lycopene, lycopene stability at direct light exposure, and different thermal conditions.

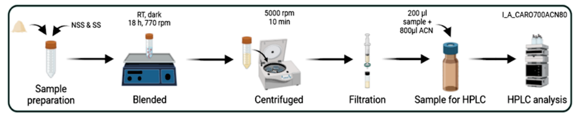
METHODOLOGY

- TOMATO WASTE PREPARATION

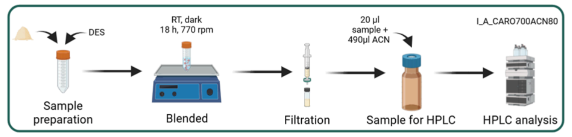


- LYCOPENE EXTRACTION

-Traditional and Alternative Solvents

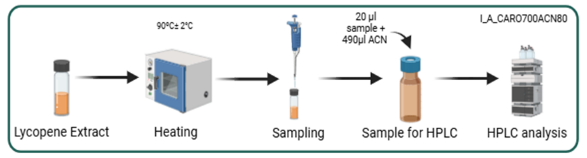


-Deep Eutectic Solvents (DES)

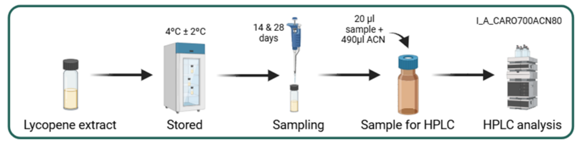


- STABILITY TEST

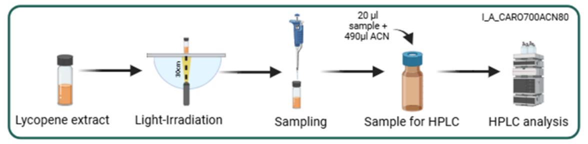
-Thermal Stability Test (90°C ± 2°C)



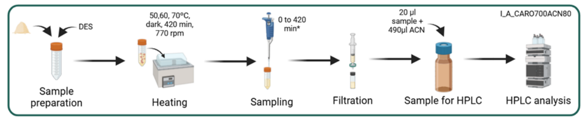
-Thermal Stability Test (4°C ± 2°C)



-Light-Irradiation Stability Test (30cm)



- LYCOPENE EXTRACTION OPTIMIZATION



Complementary tests were carried out such as the characterization of tomato peels, solvent polarity, tomato peels pre-treatment with Pulsed Electric Fields (PEF) and Lycopene extraction technique using glass beads.

RESULTS AND DISCUSSION

The lycopene extraction from tomato peel waste was carried out using traditional, alternative solvents and lipophilic DES. The total lycopene content was determined using 2-MeTHF as the best solvent with higher lycopene power extraction resulting in a lycopene yield of 0.11 mg/g, which is regarded as the 100% benchmark. The maximum extraction efficiencies of 112%, 96%, 89%, and 84% were achieved using solvents prepared with Menthol: Thymol at different molar ratios (2:1, 1:2, 3:1, 1:3), without exposure to direct light, and with constant stirring for 18 hours at room temperature. Additionally, optimizing the Lycopene extraction process included a temperature of 90°C, no direct exposure to light, constant stirring for 2 hours, and a biomass ratio of 1:10 (m/v).

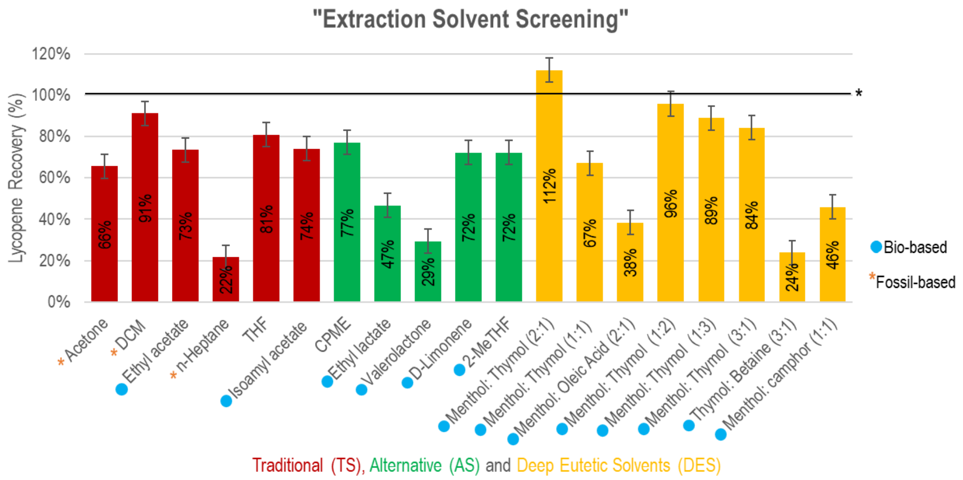


Fig 1. *Extraction Solvent Screening using Traditional, Alternative, and Deep Eutectic Solvents.*
**A 100% Lycopene yield was obtained through solid-liquid extraction using 2-MeTHF until the solution residue became colorless.*

- LYCOPENE EXTRACTION OPTIMIZATION

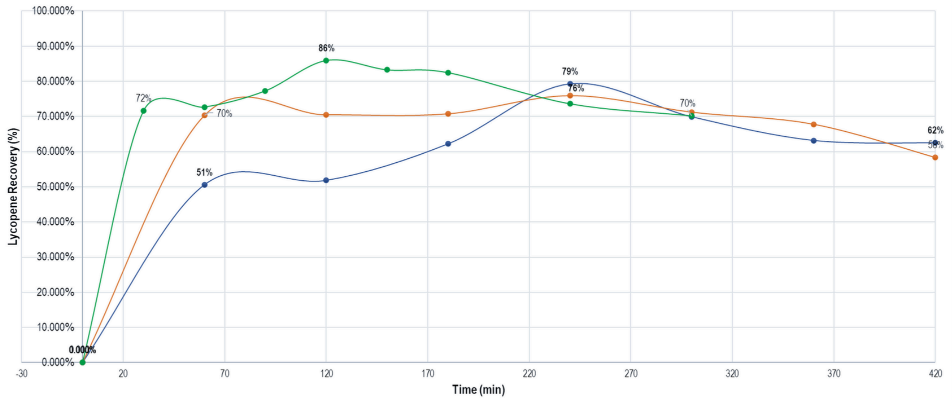


Fig 2. *Lycopene Extraction Optimization with DES M:Thy (3:1) using thermal conditions.*

DES: eutectic mixture of two or three constituent components that are prepared by mixing a hydrogen bond acceptor (HBA) with a hydrogen bond donor (HBD). [7]

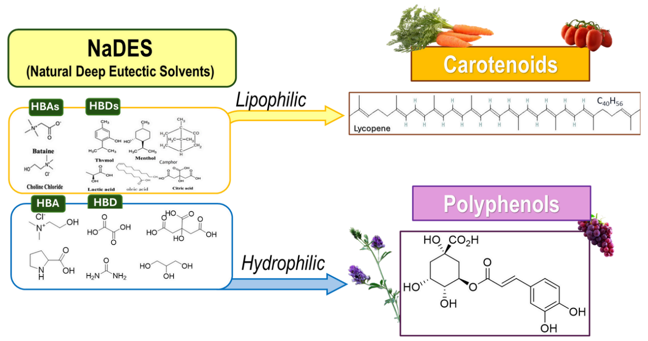


Fig 3. NaDES Classification

NADES are bio-based deep eutectic solvents composed of two or more compounds that are generally plant-based primary metabolites. These metabolites include organic acids, sugars, alcohols, amines, and amino acids. [7]

Fig 4. Lycopene Extract using Deep Eutectic Solvents (DES)

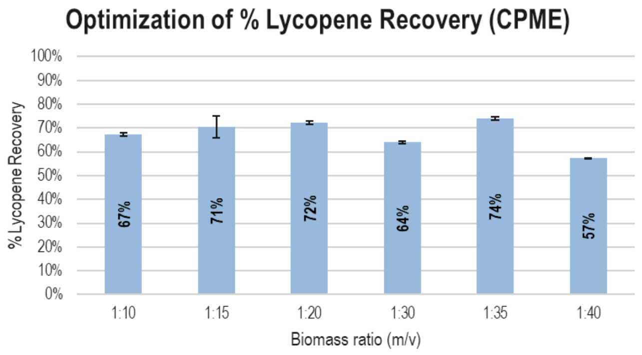


Fig 5. Lycopene Extraction Optimization with CPME using different biomass ratio.

- SOLVENT POLARITY [8]

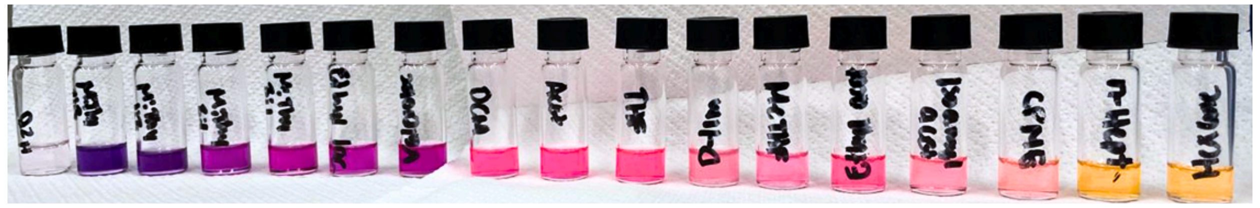


Fig 6. Solvatochromic method using Nile red to evaluate the solvent’s polarity. [8]

(NON POLAR) Hexane < n-Hep < CPME < Iso. Ac < Ethyl ace. < 2-Me-THF < D-Lim < THF < Acetone < DCM < Valero < Ethyl lac. < 3:1 < 2:1 < 1:2 < 1:3 < H2O (POLAR)

CONCLUSION

The DES extraction method has shown a greater efficiency in extracting lycopene compared to traditional and alternative solvents.
DES offers a promising environmentally friendly extraction approach using non-toxic solvents derived from renewable sources, as well as biodegradable petrochemical solvents. Moreover, DES can adjust its properties to achieve high extraction efficiency of poorly water-soluble compounds.

- ANAEROBIC DIGESTION AFTER LYCOPENE EXTRACTION [9]

Volatile Fatty Acids (VFA) production through an anaerobic Digestion using Thermophilic Bacteria at 55°C, after lycopene extraction with DES. (In progress)

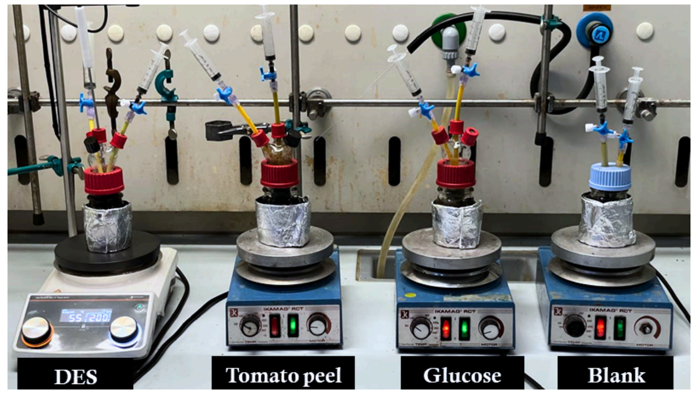


Fig 7. Bioreactor for Volatile Fatty Acids (VFA) production.

LITERATURE CITED

[1] World Processing Tomato Council (WPTC). (2024)Production of Fresh Tomatoes. Retrieved 11 June 2024, from https://www.wptc.to/
[2] World Processing Tomato Council (WPTC). (2022). WPTC crop update as of 25 October 2022. Retrieved 6 June 2024, from https://www.wptc.to/production/
[3] Shi, J., & Maguer, M. L. (2000). Lycopene in tomatoes: chemical and physical properties affected by food processing. Critical Reviews in Biotechnology, 20(4), 293-334.
[4] Rao, A. V., & Agarwal, S. (1999). Role of antioxidant lycopene in cancer and heart disease. Journal of the American College of Nutrition, 18(5), 567-573.
[5] Kumar, A., Prasad, A., & Mishra, D. (2010). Optimization of lycopene extraction from dried tomato peel powder using response surface methodology. Separation Science and Technology, 45(16), 2415-2424.
[6] Dai, Y., van Spronsen, J., Witkamp, G. J., Verpoorte, R., & Choi, Y. H. (2013). Natural deep eutectic solvents as new potential media for green technology. Analytica Chimica Acta, 766, 61-68.
[7]Hikmawanti, N. P. E., Ramadon, D., Jantan, I., & Mun’im, A. (2021). Natural Deep Eutectic Solvents (NADES): Phytochemical Extraction Performance Enhancer for Pharmaceutical and Nutraceutical Product Development. Plants, 10(10), 2091.
[8] ACS Sustainable Chem. Eng. 2021, 9, 46, 15451–15460
[9]Spadavecchia, V. (2023). Thesis about the “Development of an innovative method to produce biomethane through anaerobic digestion of liquids byproduct of biosolids pyrolysis”. University of Bologna, Italy.