Transforming Food Waste into Sustainable Soil Improvers for Enhanced Soil Health and Food System Resilience- A Living Lab approach

V. Proskynitopoulou[1,2], A. Vourros[2], P. Dimopoulos Toursidis[2], S. Lorentzou[2], K.D. Panopoulos[2]

[1]Department of Chemistry, University of Aristotle University of Thessaloniki, Greece

[2]ARTEMIS Laboratory, Chemical Processes, Centre for Research and Technology Hellas, Thessaloniki, 57001, Greece

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Presenting author email: verapros@certh.gr

Food waste encompasses various materials, including food-processing residues (FPR), by-products resulting from food industry processes, such as olive oil pomace, slaughterhouse waste, and wastewater from dairy production. According to the Food Waste Hierarchy, FPR can be reused in the food industry before being classified as food waste. However, once removed from human consumption, it is considered waste, despite being rich in key nutrients such as Nitrogen (N), Phosphorus (P), and carbon (C), valuable for improving soil fertility.

Various valorization pathways exist with objectives ranging from feed and energy production to the creation of Soil Improvers (SI). Soil improvers refer to materials added to the soil primarily aimed at maintaining or improving its physical, chemical, and/or biological properties, excluding liming materials (Regulation (EU) 2019/1009).

All stakeholders in the value chain play a role in improving management practices to generate less waste and enhance FPR transformation processes for economically accessible, environmentally friendly, and socially acceptable soil improvers. The essential objective of the current study is to provide ecosystem solutions by collaborating with diverse stakeholders across the food waste chain from farm to fork (F2F), including farmers, food industries, waste management companies, fertilizer producers, research bodies, training institutions, local and regional authorities, citizens, and civil society.

Engaging all actors in the food waste system from the outset and at all stages leads to co-creating context-based sustainable and accessible solutions, increasing acceptance, and contributing to the transformation into sustainable food systems from F2F. Simultaneously, the developed solutions and products aim to support the application of EU regulations for food waste reduction and the implementation of a circular bio-economy throughout Europe, paving the way for more resilient food systems in the future.

The adoption of a Living-Lab (LL) approach is studied to optimize existing practices and technologies for the exploitation of FPR, the production of soil improvers and their application, developing socially innovative management processes. Research conducted through the context-based and science-driven LL accelerates the development of smart, sustainable, resilient, and inclusive food systems, aligning with the goals of a desirable fit-for-all, circular, and zero-waste societies. This approach allows stakeholders to co-create research and improve co-ownership of results that are key to increasing the reuse of FPR and wastewater from the food industry to improve soil fertility and enhance nutrient use efficiency. This main objective is supported by six clear, realistic, and measurable specific objectives (SOs).

In the current work, through a circular, systemic, and multi-actor approach at the regional level and within the context of a Living Lab, technologies for the processing of byproducts of the anaerobic digestion of FPRs will be investigated. Anaerobic digestion plants transform organic materials, such as olive oil pomace, slaughterhouse waste, and wastewater from dairy production, into biogas and digestate. While biogas is a valuable renewable energy source, the digestate, on the other hand, contains concentrated nutrients, including nitrogen, phosphorus, and potassium. Recognizing the potential environmental and economic benefits, there is a growing interest in developing technologies for nutrient recovery from digestate. These recovered nutrients can be repurposed as valuable fertilizers, offering a closed-loop solution that not only mitigates the environmental impact of waste disposal but also contributes to the circular economy in agriculture.

The technologies that this study is investigating are solid-liquid separation and nutrient recovery via electrodialysis, which has emerged as a cutting-edge method with the potential to revolutionize nutrient management in various sectors, particularly in agriculture. It is an electrochemical process that utilizes ion-selective membranes to selectively transport ions, separating them based on their charge. From reducing environmental pollution to enhancing fertilizer production and promoting circular economy principles, the integration of electrodialysis into nutrient management practices holds promise for a more sustainable and resilient agricultural future.

This study aims to develop applicable recycling technical pathways to transform FPR into soil improvers through anaerobic digestion and selective electrodialysis processing, engaging all relevant stakeholders in the food chain and closing specific loops, including nutrients, organic matter, and water.