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Oral Presentations #6

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Keywords: *Nutrient recovery, Waste valorization, Purple phototrophic bacteria, Photobiorefinery, Circular bioeconomy*

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According to the latest 2025 agri-food sector report from CaixaBank Research, Spain's agri-food sector continues to expand due to increasing production, exports, and food demand. However, this growth also increases the generation of biogenic residues such as livestock manure and nutrient-rich agro-industrial effluents. Conventional management strategies often lead to greenhouse gas emissions, nutrient losses, and inefficient resource recovery. In this context, integrated biorefineries emerge as sustainable platforms to transform these residues into bioenergy, fertilizers, microbial protein, and other high-value bioproducts through the integration of thermochemical, biological, and electrochemical technologies.

Within the BIVALIA-CM framework, our research line develops purple phototrophic bacteria (PPB)-based photobiorefineries for the valorization of pig slurry as a model agro-industrial residue. PPB are highly versatile microorganisms capable of growing under photoheterotrophic, photohydrogenotrophic, and photoelectrotrophic conditions, enabling simultaneous nutrient recovery, CO_2 fixation, and production of value-added biomolecules.

Figure 1. Conceptual scheme of the BIVALIA-CM purple photobiorefinery platform for pig slurry valorization

First, we demonstrated the feasibility of coupling steam explosion pretreatment, gas-permeable membrane ammonia recovery, anaerobic digestion, and PPB cultivation within a single integrated photobiorefinery. Thermal hydrolysis enhanced organic matter solubilization by up to 57%, while more than 99% of ammoniacal nitrogen was recovered in less than 3 h. Anaerobic digestion increased methane production up to 3.5-fold, and recovered ammonium was successfully reused as nutrient source for PPB cultures growing under photohydrogenotrophic conditions, where CO_2 from biogas was converted into microbial protein-rich biomass [1].

Second, we explored sequential PPB–microalgae photobiorefineries inspired by raceway systems for comprehensive carbon and nutrient recovery from pig slurry. PPB assimilated organic matter and ammonium into bioactive biomass, while subsequent microalgae cultivation enabled tertiary treatment and additional CO_2 assimilation. The integrated system achieved up to 85% COD removal and 86% NH_4^+ recovery, demonstrating the potential of phototrophic consortia for sustainable pig-waste treatment and nutrient circularity [2].

Finally, PPB-based photo-electro-biorefineries using polarized cathodes demonstrated that PPB can directly uptake extracellular electrons supplied by an electrode to drive CO_2 fixation. This extracellular electron flux can modulate cellular redox metabolism, redirecting intracellular electron sinks toward biomass formation, carotenoid accumulation, and coenzyme Q10 biosynthesis, thereby opening new opportunities for renewable electricity-driven production of food-grade biomolecules within circular agri-food systems.

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