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Integrated green extraction strategies for the valorization of agro-industrial residues into value-added products

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Oral Presentations #3

Integrated green extraction strategies for the valorization of agro-industrial residues into value-added products

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Keywords: *Brewer's spent grain (BSG); Enzyme-assisted extraction (EAE); Deep eutectic solvents (DES); Protein recovery; Phenolic compounds; Biorefinery*

Agro-industrial by-products are promising feedstocks for integrated biorefineries, although their efficient valorization requires extraction strategies tailored to the physicochemical characteristics of each biomass. Within this framework, the present work focuses on destarched brewer's spent grain (d-BSG), a protein-rich lignocellulosic residue. Due to the strong association of proteins and phenolic compounds with the cell wall structure, efficient and sustainable extraction approaches are required to maximize the recovery of high-value compounds while improving the downstream valorization of the residual biomass.

Enzyme-assisted extraction (EAE) was investigated as the first step towards the development of tailored green extraction strategies for d-BSG valorization. A screening of commercial proteases with different catalytic specificities was performed under mild processing conditions. In parallel, a choline chloride:trehalose deep eutectic solvent (DES) was evaluated as an alternative green extraction medium for protein and phenolic recovery. Extraction performance was assessed through soluble protein recovery (BCA assay), residual protein in the solid fraction (Kjeldahl), total phenolic content (TPC) and antioxidant activity.

Alkaline proteases exhibited the highest extraction performance, achieving approximately 35% soluble protein recovery and 37% TPC recovery. Protein solubilization reached a plateau after approximately 1 h, whereas phenolic extraction continued to increase up to 6 h, indicating different extraction kinetics for both fractions. Kjeldahl analysis of the residual solids revealed a substantial decrease in protein content, from 22.6 g/100 g in the initial d-BSG to 4.3–6.8 g/100 g dry solid after 24 h using the most effective proteases, demonstrating their potential for d-BSG deproteinization. In contrast, the evaluated DES showed limited extraction efficiency, highlighting the recalcitrant nature of the d-BSG matrix and the need for complementary extraction strategies. Based on these results, three commercial proteases were selected for further physicochemical and bioactivity characterization.

The selected enzymatic conditions establish a robust benchmark for the rational evaluation of complementary green extraction strategies. Future work will investigate protein-compatible and disruptive DES formulations, together with process intensification technologies such as microwave-assisted extraction (MAE) and ultrasound-assisted extraction (UAE), either as pretreatments or in combination with DES, to enhance mass transfer and maximize the recovery of proteins, peptides and phenolic compounds from d-BSG.

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