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Towards a Zero-Waste Duckweed Biorefinery: Pulse Electric Field and High-Pressure Assisted Fractionation for Enhanced Recovery of Functional Ingredients

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Duckweed is a sustainable aquatic biomass with potential for biorefinery applications owing to its rapid growth and rich proteins, starch composition, and bioactive compounds. However, conventional processing methods often fail to efficiently fractionate its components, limiting biomass valorization. This study investigated aqueous fractionation assisted by pulsed electric field (PEF) and high-pressure processing (HPP) as non-thermal pretreatments to enhance the recovery of functional duckweed ingredients. PEF was applied at 12 and 24 kV (9 μ s; 5 or 10 treatment cycles) or HPP at 200, 400, and 600 MPa for 5 min, followed by centrifugation and fractionation into (i) an aqueous extract rich in phenolic compounds, minerals, and soluble proteins and (ii) a solid fraction enriched in starch, dietary fiber, and residual proteins. Protein solubilization increased with HPP pressure (27.91–28.44%) and PEF electric field strength (26.10–27.80%), while additional PEF cycles had minimal effects. Starch enrichment in the pellet increased with higher treatment intensity (4.50–5.32%), whereas phenolic recovery was enhanced by PEF, reaching 13.8 μ mol/g at 24 kV-10 cycles, and by HPP, with the highest recovery at 200 MPa (18.52 μ mol/g). Functional characterization showed superior foaming capacity in aqueous extracts, reaching 236% after HPP (400 MPa) and 345% after PEF (12 kV-10 cycles), while pellet fractions exhibited greater water-holding and fat-binding capacities. Thermal analysis and FTIR indicated structural modifications and molecular rearrangement without significant chemical degradation. Overall, HPP- and PEF-assisted aqueous fractionation represents a promising approach for duckweed valorization and the sustainable production of multifunctional food and biobased ingredients.

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References

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