Valorization of Food Waste-Derived Brown Juice as a Biostimulant Supplement for *Spirulina* Cultivation: A Trade-Off Between Protein Enrichment and Biomass Productivity

S. Reyhan Yavuz
Institute of Applied Plant Biology, Faculty of Agricultural and Food Science and Environmental Management, University of Debrecen, Hungary

Nevien Elhawat
Institute of Applied Plant Biology, Faculty of Agricultural and Food Science and Environmental Management, University of Debrecen, Hungary

Tarek Alshaal
Institute of Applied Plant Biology, Faculty of Agricultural and Food Science and Environmental Management, University of Debrecen, Hungary

Éva Domokos-Szabolcsy
Institute of Applied Plant Biology, Faculty of Agricultural and Food Science and Environmental Management, University of Debrecen, Hungary

Nóra Bákonyi,
Institute of Applied Plant Biology, Faculty of Agricultural and Food Science and Environmental Management, University of Debrecen, Hungary

Abstract

Global food waste necessitates innovative valorization strategies. This study evaluated by-products from leaf protein concentrate, i.e., brown juice (BJ) from green pea (G), triticale (T), and their mixture (GT), fermented with lactic acid (LA) or lactic acid bacteria (LB), as a *Spirulina* supplement. BJ was added at 1–5% (v/v) to monitor growth, biomass, and crude protein over 11 days. BJ significantly increased protein content, peaking at 75.44% in GT-LA 1% versus 62.24% in control (+21.21%). However, biomass yield declined sharply (up to 61%), offsetting compositional gains. Consequently, total protein yield per liter decreased across all treatments (net losses: −0.12 to −0.65 g/L). The best balance was observed in T-LA at 2.5%, achieving the highest Culture Efficiency Index (0.37) and competitive growth kinetics (μ=0.21 day^{-1}). These findings reveal a physiological trade-off that BJ induces stress-driven protein accumulation, likely mediated by phenolic compounds, while suppressing cell proliferation. Although suboptimal for mass protein production, BJ offers a viable route for upcycling food-processing residues into functionally enriched Spirulina for specialized feed applications, provided that low LA-fermented concentrations are used. This study underscores the critical importance of dose optimization and matrix selection in food waste biorefinery strategies.

Index Terms

Brown Juice Valorization, Food Waste Minimization, Circular Bioeconomy, Sustainable Food Production