Integrated Processes for the Valorization of Brewery Spent Grains: Hydrothermal Carbonization Aqueous Phase as Supplement for *Chlorella* sp. Growth

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Abstract

Beer production generates large amounts of by-products, with brewery spent grains (BSGs) accounting for approximately 85% of total brewing waste and about 36.4 million tons produced annually worldwide [1]. Their valorization is constrained by high moisture (>70%) and lignin (~30%) content, resulting in landfill disposal or low-value application as livestock feed, thereby limiting the recovery of their cellulose, proteins, and minerals. Hydrothermal carbonization (HTC) is a thermochemical method suitable for wet lignocellulosic biomasses such as BSGs, as it avoids energy-intensive pre-drying steps [2]. Under subcritical water conditions (180–250 °C), HTC yields hydrochar, a functionalized carbon-rich material, and minor organic and gaseous phases, that may serve as precursors for fuels or chemicals after upgrading. An aqueous phase (AP) is also generated as HTC by-product and, despite requiring proper management, represents a suitable substrate for microalgal cultivation due to its soluble carbon and nitrogen content [3]. In particular, Tarhan et al. reported the efficient growth of *Chlorella minutissima* on diluted HTC-derived AP from organic waste, enabling nutrient removal and biomass production [4]. Building on this concept, this study investigates the energetic and nutritional valorization of AP produced via HTC of BSGs at 220 °C for 4 h. AP contains soluble organic compounds (COD ~3.0 g L^{-1}) as well as potential microalgal inhibitors, including phenols (~1.3 mg L^{-1}) and formic acid (~3.7 mg L^{-1}). Its suitability as growth supplement was initially evaluated by cultivating seven microalgal strains (*Scenedesmus*, *Desmodesmus*, and *Chlorella* spp.) in $BG11_0$ medium with different dilutions of AP (1:5, 1:10, and 1:20 v/v) under continuous light. Among the tested strains, *Chlorella* sp. achieved the highest dry weight (0.17 g L^{-1}) at the most concentrated AP content (1:5 v/v), indicating the highest tolerance to organic load. This behavior was further confirmed in subsequent experiments conducted in 100 mL tubes with air and CO_2 supply. High AP concentrations (1:3 and 1:6 v/v) caused growth inhibition, whereas excessive dilution (1:10 and 1:20 v/v) led to nutrient imbalance. Based on these results, intermediate AP dilutions were selected for fed-batch cultivation of *Chlorella* sp. to optimize the balance between nutrient availability and inhibitory effects. This thermochemical–biological approach enables nutrient recovery and the conversion of soluble organic matter into value-added biomass, as a step toward enhanced HTC valorization and reduced waste generation.

References

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