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Synergistic Nutrient Formulations and Thermal Drying Strategies for Enhanced Duckweed Nutrition

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Duckweeds are gaining attention as sustainable nutrient-rich biomass due to their exceptional capacity to accumulate proteins and carbohydrates. However, maximizing biomass production alone does not guarantee the preservation of nutritional quality after harvest. This study investigated both cultivation and post-harvest processing conditions for three duckweed species (*Lemna minor*, *Spirodela polyrhiza*, and *Wolffia globosa*) using a two-phase approach. During cultivation, single and sequential nutrient media with different nitrogen-to-phosphorus (N:P) ratios were evaluated over 12–28 days. Distinct species-specific responses were observed. *L. minor* achieved the highest relative growth rate (0.138 day^{-1}) and protein content (50.2% dry weight) under a sequential shift from a high to low N:P ratio (18:1 to 6:1). *S. polyrhiza* produced the highest protein concentration overall (51.7% dry weight) and performed best under prolonged cultivation at a low N:P ratio (6:1). In contrast, *W. globosa* exhibited slower growth (0.071 day^{-1}) but accumulated the greatest lipid content (6.2%) and carbohydrate content (52.4% dry weight) during extended cultivation at a high N:P ratio (18:1). Drying temperature significantly affected biochemical composition. Lower temperatures (40–50°C) better preserved protein integrity, maintaining protein yields of approximately $300\text{--}340 \text{ mg g}^{-1}$ while minimizing lipid oxidation. Higher temperatures (50–60°C) promoted degradation of non-carbohydrate components, increasing apparent carbohydrate concentrations ($>400 \text{ mg g}^{-1}$) and enhancing anthocyanin extractability from approximately 12 to over 43 mg g^{-1} . These results demonstrate that species-specific nutrient management combined with low-temperature drying (40–50°C) is essential for preserving duckweed biomass quality and supporting large-scale, sustainable production systems.

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