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Sustainable Commercialization of Duckweed Production in Malaysia

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Duckweed is a sustainable biomass resource capable of high-value protein production, carbon sequestration, nutrient recovery, and water purification. This study evaluated the feasibility of commercial-scale duckweed production in Malaysia through pilot-scale cultivation, sequential nutrient optimization, drying process development, and life cycle assessment (LCA). A two-stage sequential media strategy was employed to optimize biomass growth and nutrient accumulation independently. Pilot-scale cultivation successfully reproduced laboratory-scale performance, demonstrating scalability while maintaining species-specific characteristics. *Lemna minor* achieved the highest relative growth rate (0.227 day^{-1}) with 36.8% protein (dry weight), whereas *Spirodela polyrhiza* accumulated 50.2% protein under sustained low-nitrogen conditions. *Wolffia globosa* exhibited unique metabolic traits, producing both high carbohydrate (50.7%) and protein (44.0%) contents under prolonged high-nitrogen cultivation. Drying conditions ($40\text{--}55^{\circ}\text{C}$) significantly affected nutrient retention, pigment stability, powder properties, and downstream processing suitability, enabling biomass quality to be tailored for specific applications. LCA identified electricity use ($80.4 \text{ kg CO}_2\text{-eq kg}^{-1}$ dry biomass) and water production ($39.8 \text{ kg CO}_2\text{-eq kg}^{-1}$) as the major environmental hotspots. Nevertheless, cultivation of *L. minor* and *S. polyrhiza* achieved net carbon removal of $33.6 \text{ kg CO}_2\text{-eq kg}^{-1}$ dry biomass through biogenic carbon sequestration. Furthermore, integrating photovoltaic electricity transformed *W. globosa* cultivation into a net carbon sink, sequestering $81.0 \text{ kg CO}_2\text{-eq kg}^{-1}$ dry biomass. These findings demonstrate that optimized cultivation and processing strategies can support application-specific duckweed production while enhancing environmental and economic sustainability in tropical regions.

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References

None

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