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Exploitation of *Spirogyra* sp. as an Alternative Raw Material for Sustainable Paper Production

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Abstract

The global paper industry relies predominantly on wood-based cellulose, resulting in substantial environmental burdens associated with deforestation, chemical-intensive pulping, and the discharge of polluted effluents. This study evaluates *Spirogyra* sp., a rapidly growing filamentous green alga, as a lignin-free alternative raw material for sustainable paper production within a green chemistry framework. The objectives were to culture and optimize the growth of *Spirogyra* sp., minimize the use of toxic chemicals in processing, produce algal paper sheets, and evaluate their physicochemical and mechanical properties. *Spirogyra* sp. cultures were optimized using three growth media, CHU 10, BBM, and 3N BBM over a 6-day period (initial inoculum ~10 mg). Growth in 3N BBM produced the highest biomass increase (10.2±0.1 mg to 12.7±1.2 mg), whereas CHU 10 supported minimal growth, declining to 3.1±1.0 mg by day 6. ANOVA indicated significant differences among treatments (p<0.05). Further optimization using a 100 mg inoculum (n=16) showed maximal biomass accumulation at 72-96 h (137.9±4.9 mg), defining the optimal harvest window. Scaling cultures to 500 mL was successful, with dissolved oxygen identified as a limiting factor. Pigment removal using hot saturated salicylic acid solution and fibre softening with dilute fabric softener solution enabled lignin-free paper sheet formation using a deckle and mould process. The resulting sheets exhibited a grammage of 182.4±1.6 g/m^2, thickness of 0.32±0.01 mm, moisture content of 11.48±0.47%, density of 0.563 g/cm^3, and bulk of 1.776 cm^3/g. Long filament lengths (up to 5 cm) contributed to high grammage, although tensile strength remained low (0.4416 N; 29.44 N/m). Blending *Spirogyra* sp. fibres with softwood pulp improved mechanical properties, demonstrating the potential of algal biomass as a supplementary resource for sustainable paper manufacturing.

Keywords: *Spirogyra sp., Algal cellulose, Sustainable paper production, Alternative fibre, Environmental impact*