

## UTILIZING *SALVINIA MOLESTA* FOR CELLULOSE PRODUCTION: AN ECO-FRIENDLY STRATEGY

A. R. Abeyweera<sup>1\*</sup> and A. M. P. B. Samarasekara<sup>2</sup>

<sup>1, 2</sup> Department of Materials Science and Engineering, University of Moratuwa, Sri Lanka

[abeyashani16@gmail.com](mailto:abeyashani16@gmail.com)<sup>1\*</sup>; [bandu@uom.lk](mailto:bandu@uom.lk)<sup>2</sup>

**ABSTRACT:** *Salvinia molesta* is a very aggressive aquatic weed that poses a significant threat to water bodies worldwide. It invades quickly and disrupts ecosystems leading to serious environmental and economic problems. Traditional ways to control this invasive plant such as biological, physical or chemical methods have often proven ineffective. These methods can also be costly and labour-intensive. Recent research indicates that cellulose may offer viable alternatives. The research aimed at extracting high-purity cellulose from *Salvinia molesta* through a comprehensive pretreatment procedure. This procedure involves an initial Soxhlet extraction followed by an alkaline treatment and a bleaching process with the primary goal of isolating cellulose from the plant's biomass. The extracted cellulose was characterized using Fourier Transform Infrared Spectroscopy (FTIR) to confirm its chemical composition and Scanning Electron Microscopy (SEM) to assess its morphology. The FTIR analysis verified the successful isolation of cellulose while SEM imaging revealed well-preserved structural integrity, indicating high-quality cellulose extraction. These findings demonstrate that high-quality cellulose can be extracted from *Salvinia molesta*. This research presents an innovative and sustainable method for managing *Salvinia molesta* by converting it into cellulose, a biodegradable polymer widely used in the production of biodegradable composites suitable for diverse industrial applications such as packaging, bio-medical and textiles. This study significantly contributes to ecological restoration initiatives through the advancement of biodegradable materials, thereby fostering economic benefits.

*Keywords:* cellulose, FTIR, *Salvinia molesta*, SEM, sustainable material

### 1. INTRODUCTION

In recent decades, the environmental impacts of invasive plant species have received growing attention due to their harmful effects on biodiversity, water quality, and ecosystem stability. These impacts present both environmental challenges and potential opportunities. One particularly destructive aquatic invasive species is *Salvinia molesta*, which thrives in tropical and subtropical regions worldwide, which thrives in tropical and subtropical regions worldwide (Oliver, 1993). This fast-growing plant forms dense mats on water surfaces inhibiting light penetration, depleting oxygen levels and disrupting aquatic ecosystems. As a result, it reduces biodiversity, affects water quality and disrupts vital activities such as transportation, hydropower production, and fishing. Despite these environmental challenges, the plant also presents potential opportunities for resource utilization (Kariyawasam et al. 2021). Efforts to control *Salvinia molesta* through biological, chemical, and physical methods have proven costly and often ineffective, sometimes resulting in unintended side effects, such as nutrient leaching and greenhouse gas emissions from biomass disposal.

As a lignocellulosic fern, *Salvinia molesta* consists mainly of cellulose, hemicellulose, and lignin, along with essential nutrients like phosphorus, potassium, and calcium (Moozhiyil and Pallauf n.d.). Among these components, cellulose is one of the most abundant biopolymers; it is renewable, biodegradable, and integral to plant biomass. However, traditional cellulose sources, including wood, rice husk, bamboo, and cotton raise environmental concerns related to deforestation and high resource demands. Previous studies indicate that these sources were used to extract cellulose using methods such as chemical, enzymatic, ionic liquid and mechanical techniques (Giri and Adhikari 2013). Due to its high cellulose content and rapid growth rate, *Salvinia molesta* is a promising, sustainable lignocellulosic resource that does not compete with land use. Extracting cellulose from invasive plants like *Salvinia molesta* offers a dual benefit: it mitigates the ecological impact of invasive species while providing a sustainable alternative to traditional cellulose sources.

This study investigates an eco-friendly approach for extracting high-purity cellulose from *Salvinia molesta*, evaluating its potential as an alternative cellulose source. The complex structure of *Salvinia molesta* is effectively broken down through alkaline and delignification processes to isolate cellulose, establishing it as a viable and sustainable raw material. This research aims to address both the management of invasive species, and the environmental consequences associated with *Salvinia molesta*, transforming it into a valuable resource for conventional cellulose production. Potential applications of this research encompass fields such as biomedical engineering, renewable energy, and various other domains.

## 2. METHODOLOGY

### 2.1 De-waxing

*Salvinia* was thoroughly washed with both tap water and distilled water to remove soil, sand and debris. It was then dried for 3 to 5 days. After drying, *Salvinia* was crushed into a fine powder using a grinder. A weighed amount of 30 grams of this powder was placed in a porous thimble. Next, a mixture of 300 ml of toluene and 150 ml of ethanol (in a 2:1 ratio) was prepared, and the crushed *salvinia* powder was extracted using the Soxhlet method for 6 hours (Sofla et al. 2016). After being dewaxed, the powder was neutralized by washing it in ethanol. Then, the dewaxed powder was dried for two hours at 60°C in an oven.

### 2.2 Alkali treatment

The dewaxed powder was treated with 2 (wt%) and 5 (wt%) potassium hydroxide for 2 hours at 90 centigrade while being continuously agitated in a magnetic stirrer (Chen et al. 2011). The process was repeated twice for each concentration (wt%). The ratio of the dewaxed sample to the alkaline treatment solution was 1:20 (g/ml). The sample underwent many rinses in distilled water to attain pH neutrality following each treatment. In this step, hemicellulose and a portion of lignin of the fiber, targeting non-cellulosic polysaccharides were removed.

### 2.3 Bleaching process

Following the alkaline treatment, the dried sample was bleached using 50 (wt%) hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) as described by Sun et al. (2000). The sample-to-solvent ratio in use was 1:20 (g/ml). The procedure was carried out twice in a magnetic stirrer at 90°C for two hours while swirling continuously. During each step of the bleach treatment, the sample was neutralized by washing it with distilled water. The sample was then dried in an oven at 60°C for two hours. Once dried, the cellulose was stored in an airtight bottle for storage. This step also removed residual lignin, resulting in cellulose with improved purity and whiteness of the cellulose.

## 2.4 Characterization

### 2.4.1 Fourier transform infrared spectroscopy (FTIR)

The FTIR spectra of *Salvinia molesta* was recorded under ambient conditions using a Bruker ALPHA spectrometer (Bruker Corporation, Billerica, MA) following chemical treatment. For sample preparation, the material was finely ground and mixed with KBr at a 1:100 (w/w) ratio and pressed into clear pellets. The spectra were obtained from a total of 24 scans at a resolution of 4 cm<sup>-1</sup> covering the range of 4000-600 cm<sup>-1</sup> in transmittance mode.

### 2.4.2 Scanning Electron Microscopy (SEM)

The structural alterations, morphological structure, and surface properties of the materials were examined by scanning electron microscopy analysis (EVO 18, Carl Zeiss AG, Germany). An accelerating voltage of 15 kV was used to evaluate samples that had been coated with gold sputter.

### 3. RESULTS AND DISCUSSION

#### 3.1 Analysis of Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR spectral analysis of cellulose extracted from *Salvinia molesta* as shown in Fig.1 revealed significant peaks corresponding to various chemical functionalities. A notable peak observed between 3500 and 3000  $\text{cm}^{-1}$  was associated with the sharp free O-H stretching vibration, attributed to aliphatic alcohols and absorbed water present in hemicellulose, cellulose, and other extractive components. Concurrently, absorptions in the 3000 to 2800  $\text{cm}^{-1}$  range were attributed to C-H stretching vibrations while C-O stretching vibrations of the C- O- C ether group appeared between 1270 and 1050  $\text{cm}^{-1}$ . The intensity of the peak at 1060  $\text{cm}^{-1}$ , corresponding to the C-O stretch and alcohol structure, increased gradually from raw *Salvinia molesta* to bleached samples after chemical treatments. This increase indicates enhanced cellulose content (Hussain et al. 2016).

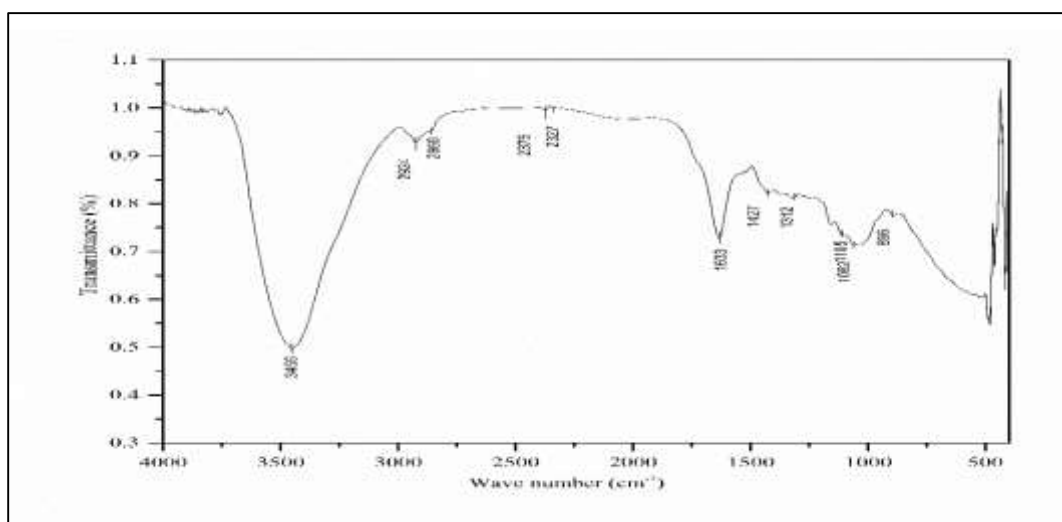


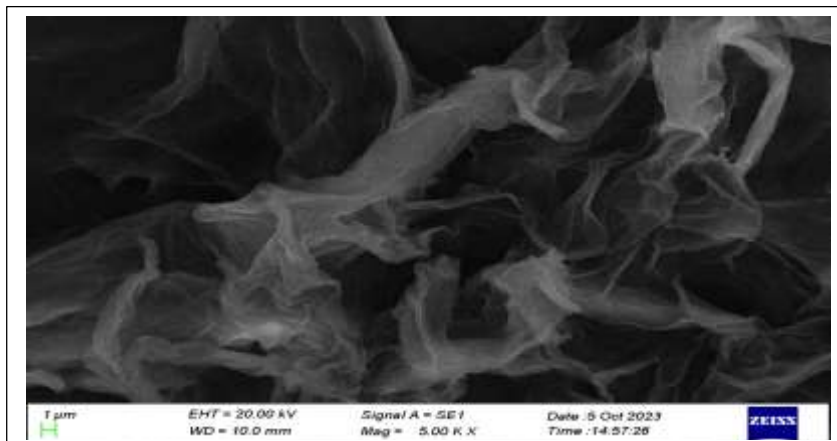
Fig. 1. FTIR spectrum of extracted cellulose sample

Moreover, spectral patterns in the range from 3000 to 2850  $\text{cm}^{-1}$  attributed to C-H stretching of alkenes and aromatics, were observed. The appearance of a peak around 2000  $\text{cm}^{-1}$  suggested the presence of triple bond groups, including weak H-C bending. Ester's presence was indicated by significant C-O band absorption peaks between 1300 and 1000  $\text{cm}^{-1}$ . A consistent peak at around 1630  $\text{cm}^{-1}$ , attributed to O-H bending from absorbed water, was observed across all extraction stages (Asrofi et al. 2018). Additionally, peaks at 1370  $\text{cm}^{-1}$  and 1420  $\text{cm}^{-1}$  were attributed to C-H bending and  $\text{CH}_2$  bending of the pyranose ring, respectively. Notable vibrations at 1030  $\text{cm}^{-1}$  highlighted C-O-C pyranose ring vibrations in bleached samples after chemical treatments.(Ratnakumar et al. 2020). Furthermore, the characteristic peak around 890  $\text{cm}^{-1}$ , indicative of the  $\beta$ -glycosidic linkage between glucose units in cellulose, was observed in bleached samples. These spectral findings offer valuable insights into the chemical composition and structural changes that occur during the cellulose extraction process from *Salvinia molesta*.

#### 3.2 Analysis of Scanning Electron Microscopy

The SEM image of extracted cellulose from the *Salvinia molesta* sample shown in Fig. 2 is magnified at 5.00 KX. It reveals a clear network of thin, crisscrossing fibrils indicating the successful separation of cellulose microfibrils. The fibrous structure exhibits a smooth surface texture and a generally uniform distribution, suggesting the effective removal of lignin, hemicellulose, and other non-cellulosic components during the bleaching treatment. There are no obvious leftover materials or large agglomerates, indicating the successful elimination of contaminants. Instead, the presence of thin, continuous fibers with minimal surface roughness indicates a high degree of cellulose purity. Further, evidence of the structural integrity of the cellulose fibers can be seen in the folds or

undulations on the fiber surfaces which is important for applications requiring strong mechanical strength and stability.



**Fig. 2.** Scanning Electron Microscopy (SEM) of extracted cellulose of *Salvinia molesta* sample

Previous research (Sun et al. 2000; Li et al. 2007) has shown that chemical treatments such as bleaching and alkaline processes effectively separate cellulose by eliminating lignin and hemicellulose. These findings align with the current results. In addition to having a smooth surface and no particle matter, the well-preserved shape of the fibers is in line with what is expected of high-purity cellulose made from plant materials using similar pretreatment techniques. *Salvinia molesta* has the potential to yield high-quality cellulose suitable for a variety of applications, and the SEM image provides overall confirmation that the pretreatment methods employed were effective in achieving this.

#### 4. CONCLUSIONS

In conclusion, this study successfully demonstrates the extraction of high-purity cellulose from *Salvinia molesta* using a systematic chemical process. FTIR and SEM analyses confirm the progressive removal of lignin, hemicellulose, and wax, underscoring the material's structural integrity and purity. The findings emphasize *Salvinia molesta's* potential as a sustainable, low-cost feedstock for applications in bio composites, biodegradable packaging, and pharmaceutical carriers. Future research could focus on optimizing extraction methods, assessing scalability, and exploring functional modifications to tailor these cellulose fibers for specific industrial applications. This work opens pathways for managing invasive species while advancing sustainable materials science.

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