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Integral Evaluation of the Cellulose of *Tibouchina lepidota (Bonpl.) Baill.* for the Valorisation of Residues in Sustainable Forestry Management

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INTRODUCTION & AIM

Cellulose is an essential component in multiple industrial sectors, standing out for its versatility and ability to improve the physical and chemical properties of various products. In a context where environmental sustainability and resource efficiency are global imperatives, cellulose presents itself as a renewable and sustainable resource, fundamental for circular economy initiatives and the reduction of carbon footprint. The exploration of alternative sources of cellulose, such as pruning residues generated by the forestry industry, is a promising line of research that can offer sustainable solutions and diversify the industry's resource base.

Tibouchina lepidota (Bonpl.) Baill., a species native to the tropical regions of the Americas, emerges as a notable candidate for cellulose extraction. Despite its abundance and rapid growth, this species has been largely ignored in scientific research. Utilizing pruning residues from *Tibouchina lepidota* could not only diversify cellulose sources but also significantly contribute to more sustainable and balanced forest resource management. This species, commonly overlooked in traditional forestry schemes, has the potential to offer viable and sustainable alternatives to conventional tree species such as eucalyptus and pine.

This study focuses on the extraction and characterization of cellulose from *Tibouchina lepidota* pruning residues, evaluating its quality and yield through analytical techniques and comparing them with traditional sources. Demonstrating the viability of this species as a sustainable source of cellulose, promoting a more holistic and sustainable approach to natural resource management. The valorization of forest residues, such as those generated by pruning *Tibouchina lepidota* without being a timber species, and how these sources align with global sustainable development goals and satisfy the growing demand for renewable and ecological materials.

METHOD

- **Botanical Identification and Sample Pretreatment**

The samples were collected in the 9 de Octubre parish of Morona canton, in the province of Morona Santiago in Ecuador. The botanical identification was carried out at the institutional herbarium of the Escuela Superior Politécnica de Chimborazo. After botanical identification, the samples were dried in an oven at 65°C until reaching a constant weight, then ground and sieved to obtain a uniform granulometry, preparing them for cellulose extraction.

- **Cellulose Extraction**

A 10% NaOH solution was used, in which the plant material was immersed. This mixture was heated to facilitate the separation of lignin and other non-cellulosic components present in the biomass.After heating, the sample was allowed to cool and was subjected to washes until reaching a neutral pH. Subsequently, the sample was dried at 65°C. The process continued with a treatment of 4% sulfuric acid, keeping the mixture boiling to remove additional residues and further purify the cellulose. After reaching a neutral pH through successive washes, a treatment with a 3.5% sodium chlorite solution was performed to bleach the fiber. Finally, the sample was subjected to treatments with 20% NaOH and 0.5% sodium chlorite solutions, followed by washes and a final drying at 65°C to obtain pure cellulose.

- **Characterization and Statistical Analysis**

The extracted cellulose was characterized using Fourier transform infrared spectroscopy (FTIR), comparing the stretches with cotton cellulose samples, and optical microscopy, evaluating its molecular structure and morphology. The solubility of cellulose in NaOH solutions was determined to identify its typology. The amount of cellulose extracted was quantified following the TAPPI T 205 standard, and a statistical analysis was performed using R software to evaluate the efficiency of the extraction process.

Figure 1. Graphic summary cellulose extraction scheme

RESULTS & DISCUSSION

- **Cellulose Extraction Yield**

The amount of cellulose extracted from *Tibouchina lepidota* was evaluated, considering the influence of particle size on extraction yield. Ten extraction replicates were performed for each particle size. The sample with a particle size of 250 μm presented an average weight of 4.73 g with a standard deviation of 0.105 g, while the sample with a particle size of 125 μm had an average of 3.624 g with a standard deviation of 0.074 g. The coefficient of variation in each sample is less than 2.25%. The Shapiro-Wilk normality test and Fisher's homogeneity of variances test confirmed the suitability of the data for parametric analysis. The Student's t-test showed significant differences in cellulose extraction yield attributable to particle size, with a higher percentage of cellulose extracted in 125 μm particles (92.76%) compared to 250 μm particles (90.54%).

- **FTIR Characterization**

FTIR characterization revealed significant peaks indicating the purity of extracted cellulose. In the 250 μm samples, peaks were observed at 3336.25 cm-1 and 2919.7 cm-1, indicating the presence of hydroxyl groups and alkyl structures. Other important peaks included 1646.91 cm-1 and 1365.35 cm-1, suggesting C-C bond stretching in cellulose. The 125 μm sample showed similar peaks, confirming the typical cellulose structure and the effectiveness of the extraction process. The consistency in the stretching peaks of C-H, O-H, C-O, and C-O-C bonds indicates the purity of the extracted cellulose and its alignment with typical cellulose structures found in natural sources such as cotton and wood, as related in the present work.

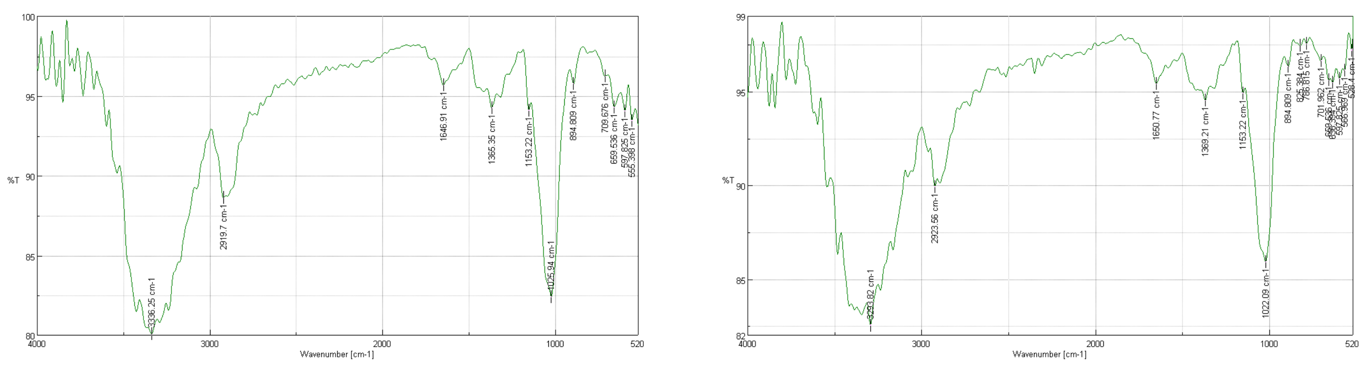

Figure 2. FTIR cellulose

- **Optical Microscopy and Cellulose Typology**

The microscopic observation of cellulose samples revealed a fibrous structure consistent with the characteristic properties of cellulose. The fibers, thin and long, were presented in a random arrangement, with a notably smooth and uniform surface, indicating the absence of surface irregularities and confirming the high quality of the cellulosic fiber. The cellulose typology was determined through solubility tests in 17.5% and 8% sodium hydroxide (NaOH) solutions, revealing that the cellulose from this species is of the beta type, characterized by its ability to dissolve in 17.5% NaOH solutions. This specific crystalline structure allows for the intercalation of NaOH and the disruption of hydrogen bond interactions, facilitating solubility. The identification of beta cellulose in *Tibouchina lepidota* suggests significant potential for industrial use, valued for its mechanical and chemical resistance, thermal stability, and ability to form fibers and films with outstanding physical properties.

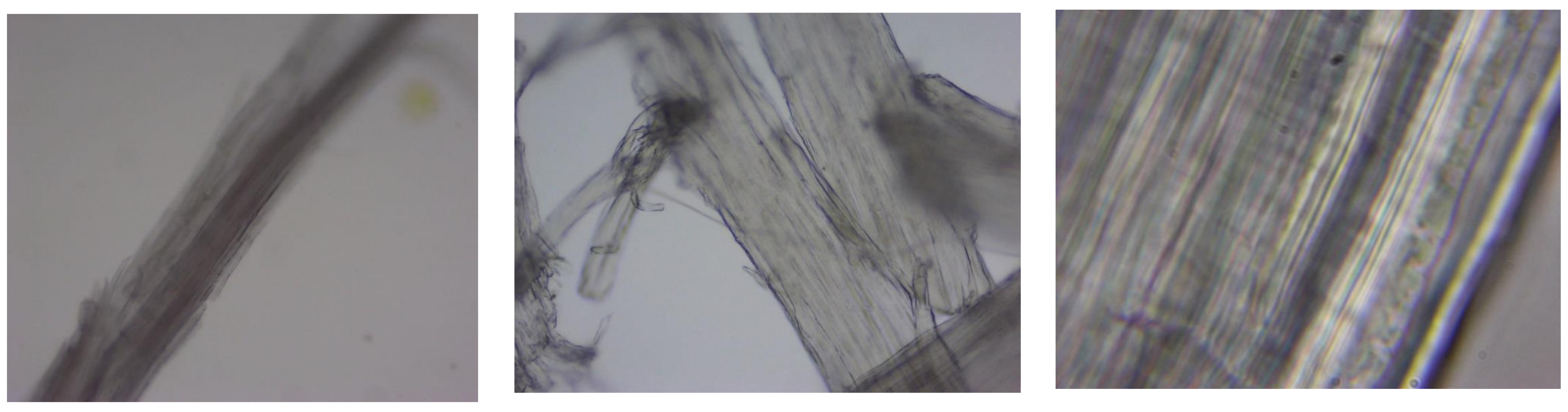

Figure 3. Optical Microscopy cellulose

CONCLUSION

The study demonstrated that the cellulose extracted from Tibouchina lepidota is of high purity, validated by morphological analysis and chemical structure, with an average yield of 92.79% for 125 μm particles and 90.54% for 250 μm particles. The cellulose showed a typical molecular structure and high-quality fibrous morphology, confirming its suitability for industrial applications. This finding suggests that Tibouchina lepidota can be a sustainable source of cellulose, contributing to sustainable forest management by utilizing pruning residues and diversifying cellulose sources, mitigating the environmental impacts associated with monoculture and overexploitation of conventional species.

FUTURE WORK / REFERENCES

Future research could focus on optimizing the extraction process to further improve the yield and purity of the cellulose. Additionally, it would be beneficial to investigate the mechanical and chemical properties of the extracted cellulose in specific industrial applications, such as the manufacture of bioplastics and composite materials.

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