Bamboo Cellulose Biopolymeric Films with Potential Applications in Agriculture

Medrano-Elizalde, Ricardo; Hernández-Pedraza, Andrea; Heredia-Lino, Ana; Degetau-Sentiés, Emilio & Gutiérrez, C. A.

Departamento de Ingeniería Química, Industrial y de Alimentos (DIQIA). Universidad Iberoamericana Campus Ciudad de México, Prol. Paseo de la Reforma 880, Lomas de Santa Fe. C.P. 01219. México.

Abstract

Several studies have focused on manufacturing controlled-release fertilizers (CRF) using organic residues. Hydrogels can be used as CRFs with water absorption capability. However, technological advancements, production infrastructure, and market availability of these CRFs are limited in Mexico, leading to high-prices for producers. A promising solution is to produce CRF from organic waste, generating an innovative product for the agricultural sector. In this study, a biopolymeric film functionalized as a hydrogel was developed, it contains urea and it is biodegradability.

Background

The food industry faces substantial challenges in maintaining competitiveness and promoting sustainable management practices. Agriculture generates significant amounts of organic waste, and its management is a challenge due to its negative impacts to the environment.

In recent years, new approaches are focussed to valorize these residues to generate energy and to obtain by-products. Specifically, bamboo is utilized in Mexico for several activities including housing construction, furniture making, and crafts. However, the bamboo waste generated by these activities is not used and ends up in the landfill. These residues can be used to extract value-products such as biopolymers. Biopolymers can be used as nutrient encapsulation materials, generating controlled release fertilizers, and thus promoting sustainable agricultural practices. This approach aligns with some objectives of the 2030 agenda.

Objetive

The aim of this study is to obtain a biopolymeric film from bamboo residues with biodegradable character and water absorption capacity for use in the agricultural sector.

Results

The cellulose extraction process from bamboo waste yielded 26.52% ± 3% cellulose content. The resulting cellulose fibers are shown in the SEM micrograph (Fig. 1, a). The biopolymeric films obtained by copolymerization are translucent and the morphology can be seen in the SEM micrograph (Fig. 1, b c). The FT-IR analysis can be seen in Figure 2, where the functional groups corresponding to cellulose are identified: 3332 (O-H), 2897 (C-H tension), 1429 (C-H) of methylene and 1028 (C-O) of aldose ring. (Fig. 3, a).

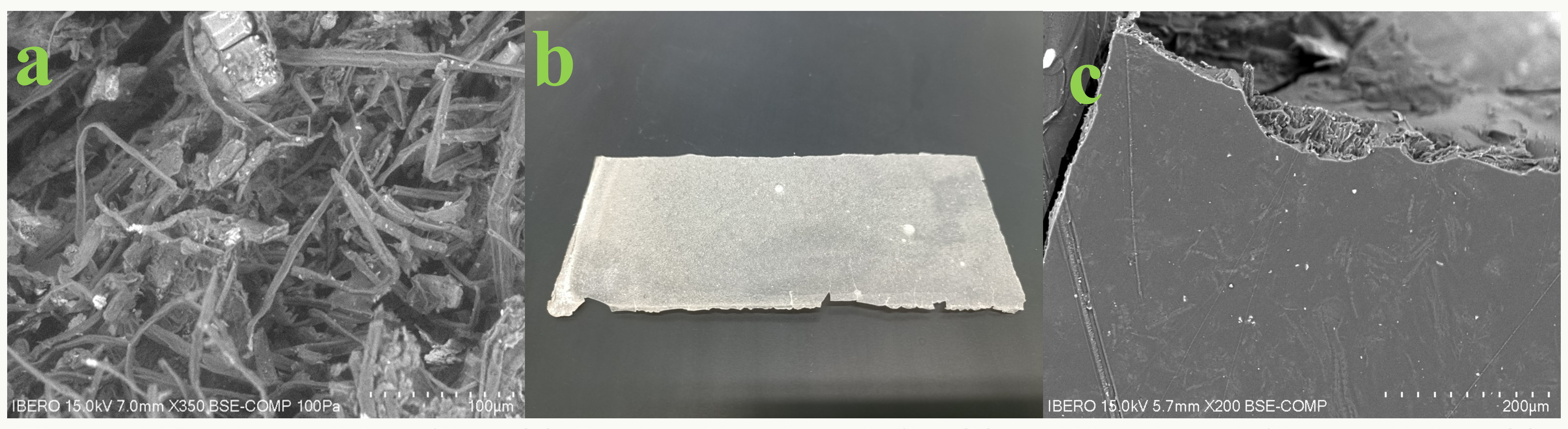
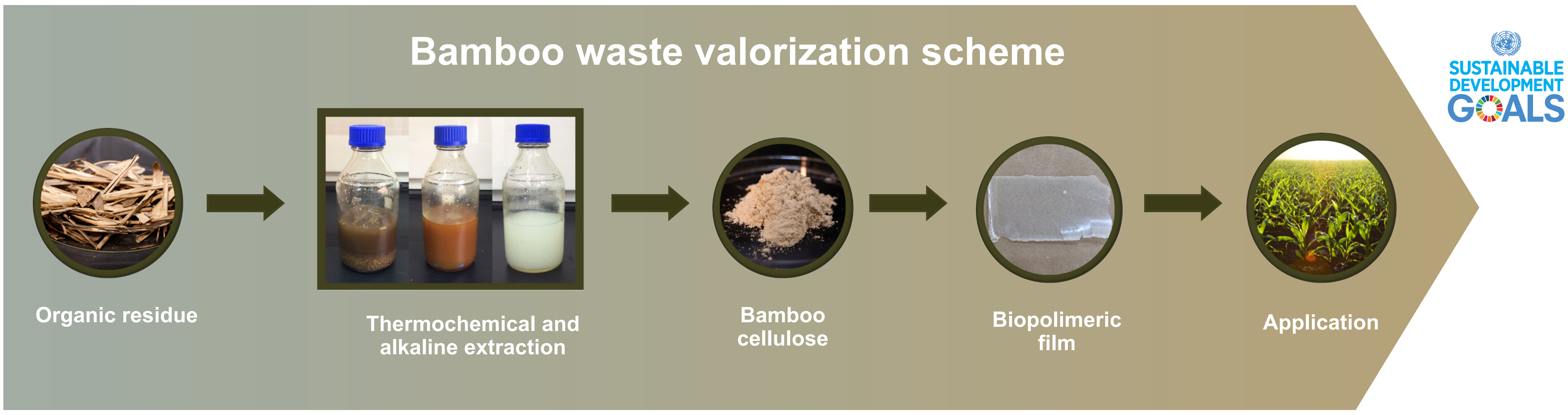


Figure 1. *Bamboo cellulose fibers (a), Bamboo biopolymeric film (b) and biopolymeric film morphology (c).*

The elemental composition of the biopolymeric film comprised 50.68 ± 1.57% carbon, 37.13 ± 1.16% oxygen, 11.94 ± 1.58% nitrogen, and 0.07 ± 0.04% sulfur. The nitrogen content is due to the inclusion of urea into the biopolymeric film (Fig. 2). The water absorption capacity of the film can be observed in the decreasing gap between the film and the surface (clamping cell), where the distance shortened over time from 250 µm less than 50 µm. (Fig. 3, b).



Methodology

- Cellulose was extracted from bamboo leaves trough the sequential application of thermochemical and alkaline peroxide treatments. An infrared spectroscopy analysis (FT-IR) was conducted to compare the cellulose extracted from bamboo waste with commercial cellulose (Avicel).
- The biopolymeric film was synthesized via a copolymerization reaction with bamboo cellulose, methacrylic acid, and urea, and potassium persulphate as initiator at 68°C.
- Fiber surface and biopolymeric film morphologies were evaluated through scanning electronic microscopy (SEM). Moreover, energy dispersive X-ray spectroscopy analysis (EDS) was conducted to find out the nitrogen content within the films, coupled with mapping to visualize the distribution of carbon, oxygen, nitrogen, and sulfur into the film.
- The water absorption capacity of the film was determined by measuring the gap with a clamping cell in surpass 3 equipment (Anton Paar) with KCl solution at 0.1 M. Finally, the biodegradation test was conducted in petri dishes containing topsoil and distilled water to observe the matrix deterioration.

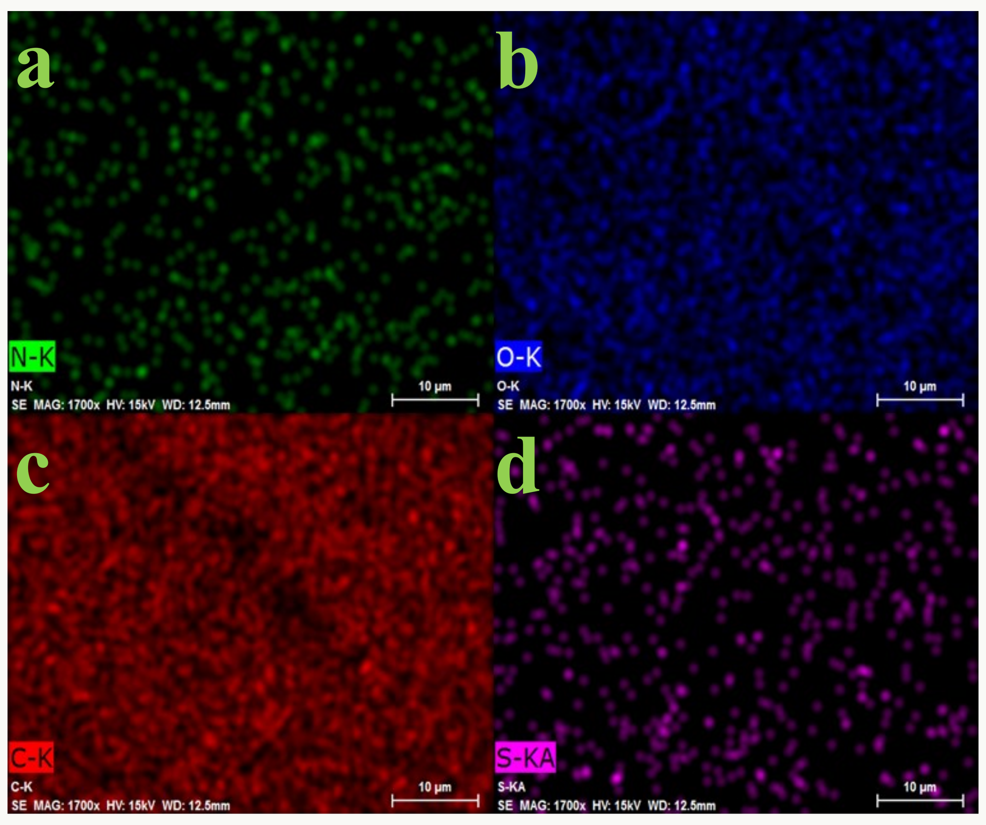


Figure 2. *Element distribution in films by mapping: nitrogen (a), oxygen (b), carbon (c) and sulfur (d).*

Finally, the biopolymeric film shows biodegradability behavior, as evidenced by the discernible alteration of the biopolymeric matrix in a period of only 5 days under simulated soil conditions (Fig. 3, c).

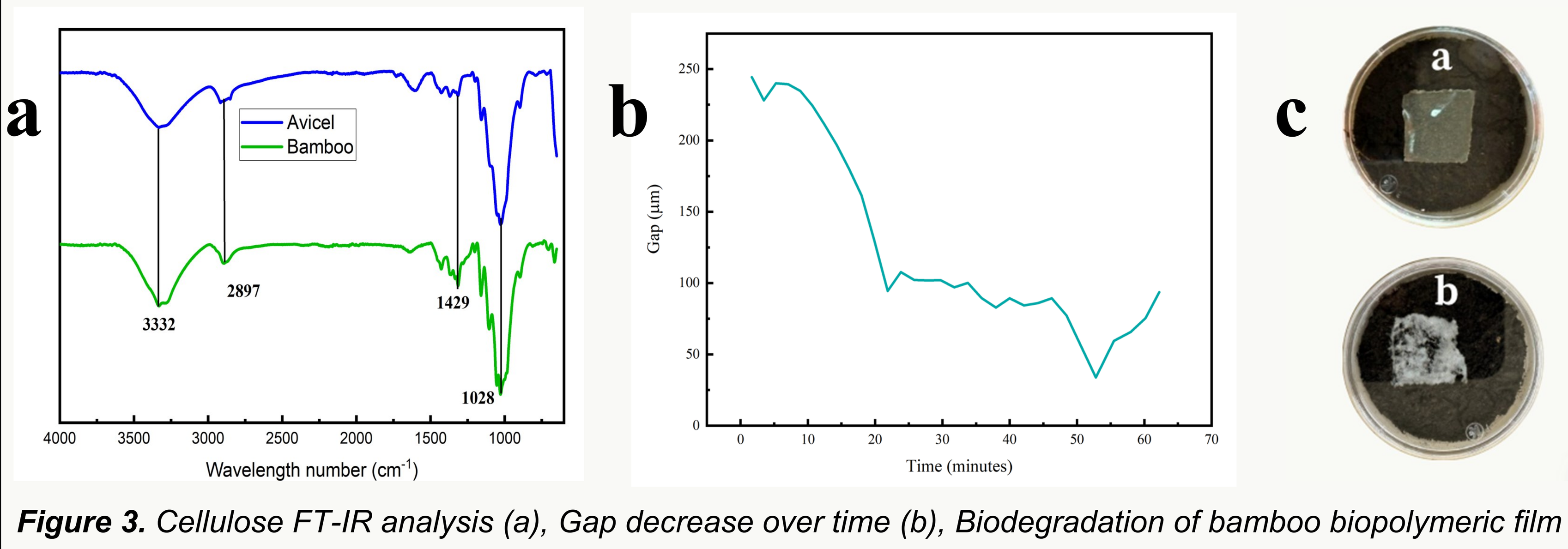


Figure 3. *Cellulose FT-IR analysis (a), Gap decrease over time (b), Biodegradation of bamboo biopolymeric film [initial day(a) and 5 days (b)] (c).*

Conclusions

The biopolymeric film derived from bamboo waste shows a nitrogen content of approximately 12%, and exhibits biodegradability and water absorption properties. Therefore, it is possible to obtain CRFs from organic residues and thus implement circular economy processes in the agricultural sector.

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