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IS IT POSSIBLE TO PRODUCE BACTERIAL CELLULOSE USING PASSION FRUIT PEEL AND USE THIS CELLULOSE AS AN ADSORBENT?

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Abstract

Brazil is one of the main producers of agricultural products, however, the industrial processing of these fruits and vegetables also generates significant amounts of waste that may cause environmental impacts, such as an increase in greenhouse gases emissions and water pollution. In this context, this study investigates the feasibility of producing bacterial cellulose (BC) from passion fruit peel (*Passiflora edulis*), an abundant agro-industrial co-product. The peel underwent acid hydrolysis, which yielded 9.98 g/L of glucose and 19.03 g/L of xylose. These sugars were used as carbon sources for fermentation using a symbiotic culture of bacteria and yeast (SCOBY) derived from kombucha production. The process resulted in the production of 6.064 g of purified BC. The material suggests promising physical and chemical properties, with potential applications in adsorption processes, such as removing heavy metals, industrial dyes, and organic contaminants from wastewater. However, further experiments are needed to fully evaluate its effectiveness in these applications. This research suggests that utilizing agro-industrial waste like passion fruit peel adds value to these by-products, promotes sustainable practices, and supports the circular economy.

Keywords: Bacterial cellulose; Passion fruit peel; Fermentation; Kombucha; Circular economy.

1. Introduction

The agro-industrial sector plays a significant role in the global economy, contributing substantially to the Gross Domestic Product (GDP) of various nations. However, the growth of this sector also presents environmental challenges, particularly in waste management. In Brazil, the world's largest producer of passion fruit, the peel of this fruit is an abundant co-product composed of pectin, cellulose, hemicellulose, and lignin [1].The valorization of this agro-industrial co-product offers a promising opportunity to develop sustainable bioproducts.

Among the various possibilities for utilizing this material, the production of bacterial cellulose (BC) from passion fruit peel hydrolysate stands out. BC is characterized by high crystallinity, biocompatibility, and mechanical strength, making it a material of interest for various industries, including medicine, textiles, and packaging [2].

Recently, BC has garnered significant interest in adsorption processes due to its porous structure and high specific surface area, making it an effective adsorbent for removing pollutants from wastewater, including heavy metals and organic compounds [3]. The exploration of this potential in adsorption aligns directly with current needs for effluent treatment and resource recovery, which are central themes in the development of sustainable technologies and will be explored in future research.

This study investigates the feasibility of using passion fruit peel (PFP) hydrolysate as a substrate for BC production, utilizing the symbiotic culture of bacteria and yeast (SCOBY) from kombucha fermentation. By optimizing the hydrolysis and fermentation processes, we intend to establish parameters that maximize both the quantity and quality of the BC produced, contributing to the advancement of a biorefinery focused on the utilization of agricultural co-products. Additionally, the potential of BC as an adsorbent will be explored in future studies to expand its applications and provide sustainable solutions to environmental challenges, particularly in effluent treatment and water purification.

2. Methodology

2.1 Preparation and characterization of passion fruit peel

The passion fruit peel was obtained from a local juice market in Fortaleza, Brazil. After collection, the peels were washed three times with tap water, cut into smaller pieces, and dried in an oven at 60 °C for 24 hours. After drying, the peels were ground and sieved to obtain flour with particle sizes ranging between 0.177 mm and 0.841 mm (20–80 mesh). The obtained flour was stored at room temperature (25 °C) until used for characterization and subsequent experiments. The passion fruit peel was characterized using validated methodologies to determine the contents of cellulose, hemicellulose, lignin, and ash, as described by Gouveia et al. (2009).

2.2 Hydrolysis of passion fruit peel

The acid hydrolysis of passion fruit peel was carried out using sulfuric acid (H_2SO_4) under optimized conditions to maximize the release of fermentable sugars. The process was conducted using a 10% (w/v) ratio of passion fruit peel (mass/volume) with an H_2SO_4 concentration of 0.71 M, and a thermal treatment time of 21.84 minutes at 121 °C.

2.3 Detoxification of the passion fruit peel hydrolysate

The hydrolysate was subjected to a detoxification process to remove fermentation-inhibitory compounds. Initially, the pH of the hydrolysate was adjusted to 10.0 using calcium hydroxide ($Ca(OH)_2$). After the precipitation of impurities, the pH was readjusted to 6.0 with the addition of sulfuric acid (H_2SO_4). The hydrolysate was then treated with 1% (w/v) activated carbon, agitated at 200 rpm and 35 °C for 1 hour, ensuring the removal of toxic compounds such as organic acids and phenols derived from biomass degradation.

2.3 Preparation of kombucha inoculum and fermentation

Black tea was used as the base for cultivating the kombucha culture. The tea infusion was prepared by steeping 10 g of black tea leaves in 1 L of boiling water for 10 minutes, followed by adding 100 g of sucrose. The mixture was then sterilized at 121 °C for 15 minutes. After cooling to room temperature (25 °C), the tea was inoculated with a kombucha starter culture of a symbiotic culture of bacteria and yeast (SCOBY). The fermentation process was carried out under static conditions for 3-5 days at 28 °C. The resulting fermented broth, enriched with bacterial cellulose, was then used as a pre-culture for producing bacterial cellulose (BC) using the hydrolysate derived from passion fruit peel.

2.4. Purification of bacterial cellulose

Bacterial cellulose (BC) was purified by washing the pellicles with distilled water, followed by treatment with 0.5% NaOH at 80 °C for 1 hour. Afterward, the BC was rinsed with distilled water until a neutral pH was achieved and stored in distilled water at 4 °C.

2.5 Analytical methods

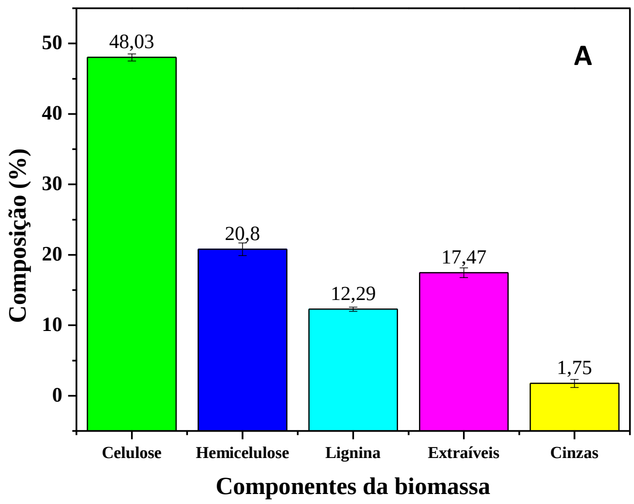
The chemical composition of the passion fruit peel was analyzed to determine cellulose, hemicellulose, lignin, and ash contents using standard methods. The sugar content in the hydrolysate was quantified by High-Performance Liquid Chromatography (HPLC) using a refractive index detector. The detoxified hydrolysate's pH was measured before and after adjustment with $Ca(OH)_2$ and H_2SO_4. The bacterial cellulose (BC) yield was calculated by drying the produced BC at 60 °C until constant weight, and its structure was examined using Scanning Electron Microscopy (SEM) to assess the fibril morphology.

3. Results and Discussion

The results presented in Figure 1A show the composition of passion fruit peel biomass, highlighting the predominance of cellulose (48.03%) compared to other components such as hemicellulose (20.8%) and lignin (12.29%). This high concentration of cellulose and the significant presence of hemicellulose and lignin indicates that passion fruit peel contains a substantial amount of polymers that may be hydrolyzed, resulting in high concentrations of fermentable sugars. These sugars are essential for bacterial growth and bacterial cellulose production, making passion fruit peel a promising raw material for biotechnological processes.

The scanning electron microscopy (SEM) image presented in Figure 1B reveals significant alterations in the structure of the passion fruit peel after acid hydrolysis. The image shows a fibrous structure with clear signs of degradation of the lignocellulosic matrix, confirming the efficiency of the hydrolysis process in breaking down the biomass. This structural modification is important for increasing the accessibility of microorganisms to the substrates during fermentation, facilitating the production of bacterial cellulose.

Figure 1. (A) Percentage composition of passion fruit peel biomass components: cellulose, hemicellulose, lignin, extractives, and ash. (B) SEM image of the passion fruit peel structure after acid hydrolysis, showing morphological changes.



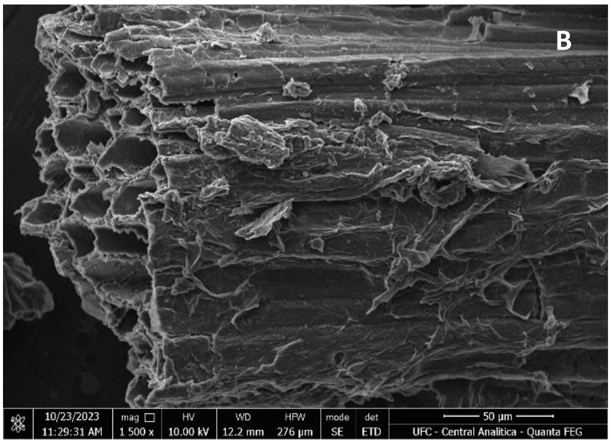
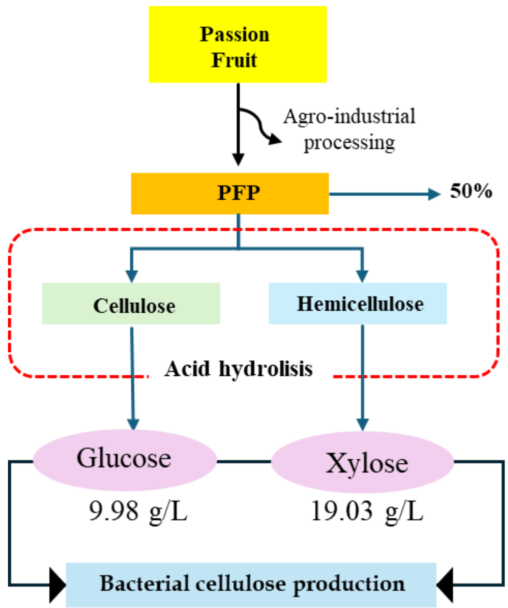


Figure 2 shows that the acid hydrolysis of passion fruit peel efficiently converts cellulose into glucose (9.98 g/L) and hemicellulose into xylose (19.03 g/L). Glucose is converted by *Komagataeibacter xylinus* into. At the same time, xylose can be metabolized by other microorganisms in the SCOBY, such as *Acetobacter* spp. and *Saccharomyces cerevisiae*, which contribute to cellulose biosynthesis and other fermentation processes.

Figure 2. Conceptual diagram of CB production by passion fruit peel valorization

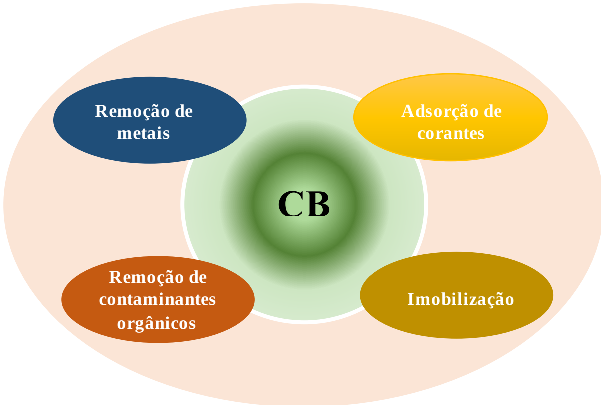


The results show that the bacterial cellulose produced from passion fruit peel had its mass reduced from 18.663 g to 6.064 g after treatment with NaOH. This significant reduction is attributed to the purification process, which removed impurities such as microbial cells, proteins, non-cellulosic polysaccharides (like pectin and hemicellulose), lipids, and lignin residues. Figure 3 shows the aspect of the BC produced from PFP hydrolysate. The removal of these components results in purer bacterial cellulose with enhanced properties, such as high crystallinity and mechanical strength, which are essential for applications in adsorption, packaging, and biomedical materials. Therefore, despite the reduction in mass, the quality of the final product was improved, confirming the viability of using passion fruit peel as a substrate for producing high-purity bacterial cellulose.

Figure 3. BC produced from passion fruit peel hydrolysate before purification

The results confirmed that it is possible to produce bacterial cellulose with a high yield from passion fruit peel (PFP). The efficiency of the fermentation process using PFP hydrolysate as a substrate demonstrates the potential of this material as a sustainable and low-cost source for bacterial cellulose production. The material obtained shows promising characteristics, and future studies could evaluate its potential in various adsorption applications. Due to its unique properties, such as high crystallinity, porous structure, and biocompatibility, bacterial cellulose offers significant advantages in adsorption processes. For instance, its ability to adsorb heavy metals, industrial dyes, and organic contaminants can be exploited in wastewater treatment, helping to mitigate environmental impacts. Additionally, its use in enzyme immobilization can optimize industrial processes by increasing enzyme stability and efficiency. Also presents the valorization of commonly discarded agro-industrial wastes.

Figure 4. Applications of bacterial cellulose (BC) obtained from passion fruit peel



Acknowledgments

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References

[1] J.R. Santos, G.C.C. Viana, R.S. Barbosa, M. de S. Borges, M.K.D. Rambo, D.A. Bertuol, E. Scapin, Effect of different pretreatments of Passiflora edulis peel biomass on the conversion process into bioproducts for biorefineries, Sustain. Chem. Environ. 2 (2023) 100013.

[2] J. Shi, L. Sheng, M. Chen, X. Wu, X. Li, Y.Q. Tan, pH-responsive collagen nanocomposite films reinforced by curcumin-loaded Laponite nanoplatelets for dynamic visualization of shrimp freshness, Food Hydrocoll. 157 (2024) 110447. https://doi.org/10.1016/j.foodhyd.2024.110447.

[3] E. Tsouko, S. Pilafidis, K. Kourmentza, H.I. Gomes, G. Sarris, P. Koralli, A. Papagiannopoulos, S. Pispas, D. Sarris, A sustainable bioprocess to produce bacterial cellulose (BC) using waste streams from wine distilleries and the biodiesel industry: evaluation of BC for adsorption of phenolic compounds, dyes and metals, Biotechnol. Biofuels Bioprod. 17 (2024) 1–17.