UTILIZATION OF BIOSURFACTANT IN THE PRE-TREATMENT OF COCONUT FIBERS FOR CLEANING SPILLED OIL IN THE MARINE ENVIRONMENT

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ABSTRACT

Technological alternatives have been developed for cleaning marine areas affected by oil spills. Among these alternatives, adsorbents stand out for being quicker, easier, and more efficient in interacting with oil. These adsorbents can be made from plant fibers, which are renewable and highly effective in adsorbing pollutants. These materials can modify their chemical, physical, and morphological characteristics through pre-treatments, enhancing target contaminants' sorption. In this context, this research aims to investigate the efficiency of pre-treatments on coconut fibers to make them more capable of separating oil from affected marine environments through sorption tests with hydrodynamic simulations. Conventional treatments (acid, thermal, mercerization/acetylation, and alkaline) and an unconventional treatment using biosurfactant as a solvent were applied to the coconut fibers. The fibers were characterized using SEM and FTIR to understand the alterations, in addition to sorption tests. The results showed that the coconut fibers modified their characteristics after the applied pre-treatments, increasing adsorption. Additionally, the fibers with conventional pre-treatments did not show significant statistical differences in adsorption; however, the fibers treated with the biosurfactant achieved better sorption results compared to the others treated coconut fibers.

Keywords: Surfactin. Crude oil. Sorption. Biofibers. Bioadsorbents.

1 INTRODUCTION

The compounds from oil spills in marine waters are highly contaminating and have become one of the main pollutants in water bodies. They threaten flora, fauna, human health, and the economy[1]. Among the techniques used in an oil spill are adsorbent materials, aiming to remove the oil from marine waters and prevent it from reaching more sensitive environments[2]. Various materials can be used as adsorbents. However, using plant fibers has the main advantages of low cost, low abrasiveness, non-toxicity, low density, and ecological and social aspects due to better recyclability and biodegradability[3]. Therefore, they are viable and promising biomaterials.

Among plant fibers, coconut fibers (*Cocos nucifera L.*) stand out due to their availability as solid waste in Brazil. The country's coconut production was approximately 2.5 billion fruits in 2021[4]. This practice generates a large amount of solid waste from residues, such as coconut fibers, often sent to landfills or incinerated[5,6]. Residual plant fibers are lignocellulosic and have many pores in their physical structure and high wear resistance, making them excellent sorbents[7]. Their chemical composition contains lignin, cellulose, and hemicellulose with predominantly hydrophilic characteristics[1].

To increase the oil wettability, porosity, and chemical and physical characteristics of these biomaterials, aiming to improve sorption, pretreatments are performed[8]. The most studied treatments for biofibers in the literature are chemical (with acids and bases)[2,3,7] and physicochemical (thermal)[9,10]. On the other hand, little has been explored about organic solvents, especially biosurfactants, which are microbial-origin compounds capable of reducing surface or interfacial tension and are biologically degradable[11].

Given this, this study aims to investigate the efficiency of conventional pretreatments, such as chemical and physical treatments, and innovative treatments, such as the use of biosurfactants on coconut fibers, to enhance their ability to separate more oil from the affected marine environment. This will be assessed through sorption tests with hydrodynamic simulations on a laboratory scale.

2 MATERIAL & METHODS

Conventional Pretreatments: Coconut fibers were treated with acid (10% H_2SO_4), base (10% NaOH), heating in distilled water at 80 ºC, and mercerization with NaOH (5%). After stirring, they were filtered, washed, and dried at 100 ºC. For acetylation, the fibers were immersed in acetic anhydride and glacial acetic acid at 80 ºC for 3 hours, followed by filtration, washing, and drying.

Biosurfactant Pretreatment: Surfactin from *Bacillus subtilis* UFPEDA 86, diluted in distilled water (2%), was mixed with the fibers, followed by stirring, washing, filtering, and drying at 100 ºC.

Characterization of the Fibers: Morphology was evaluated by SEM and FTIR to confirm chemical changes.

Adsorption Test: Treated fibers were tested on a shaker table with saline water and crude oil mixture for 5 minutes. After sorption, the samples were dried and weighed to determine the sorption capacity of the fibers using the equation:

$$S = \frac{Sf - S0}{S0} \quad (1)$$

where S is the adsorption capacity (g of sorbate/g of sorbent), S0 is the initial mass of the fiber, and Sf is the final mass after adsorption.

3 RESULTS & DISCUSSION

Fiber characterization: FTIR analysis revealed the functional groups present on the surface of each fiber, which interact with crude oil. After thermal and biosurfactant treatments, there was a reduction in hydroxyl groups, indicating weaker hydrogen bonds and lower crystallinity, while the intensity of the band indicative of absorbed water increased (Figure 1). Furthermore, aliphatic chains were identified, especially in fibers treated with biosurfactant, where characteristic lipopeptides were also observed. Mercerization/acetylation treatment resulted in the appearance of a band indicative of acetate groups linked to cellulose.

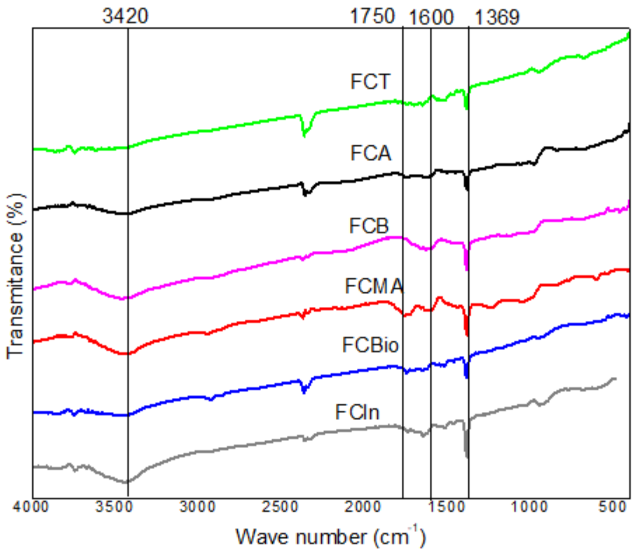

Figure 1 FTIR of coconut fibers with thermal treatment (FCT), acid treatment (FCA), basic treatment (FCB), mercerization/acetylation (FCMA), biosurfactant (FCBio), and untreated (FCIn).

SEM analysis showed significant irregularity on the surface of *in natura* coconut fibers, with pores increasing the surface area, favoring adsorption (Figure 2). After pretreatments, there was an improvement in fiber morphology, with unobstructed pores and increased roughness, facilitating interaction with petroleum.

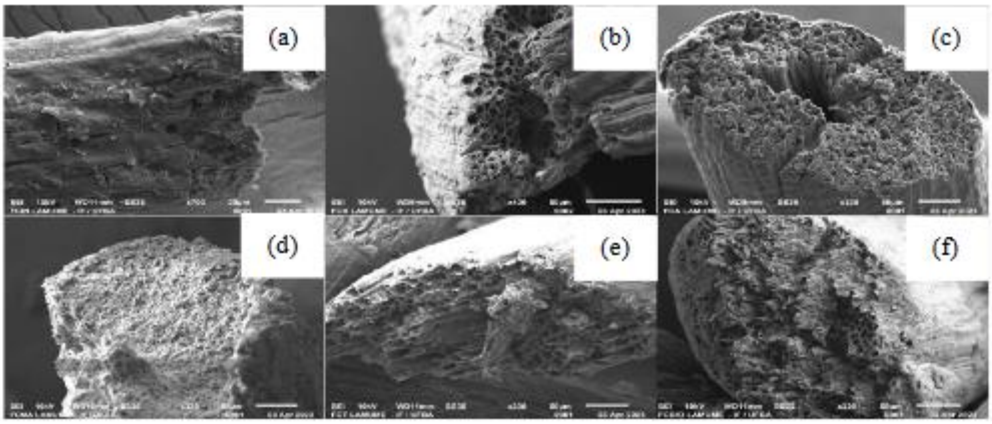

Figure 2 SEM images of FCIn (a), FCB (b), FCA (c), FCMA (d), FCT (e), and FCBio (f).

Adsorption test: Gravimetric analysis of the adsorption tests showed that, despite pretreatments, the fibers still interacted with water, as indicated by the mass reduction after lyophilization. The sorption results for conventionally treated fibers and biosurfactant-treated fibers, along with the statistical Tukey test (95% confidence), are shown in Figure 3. The Tukey test indicated no significant differences in sorption between conventional treatments (acid, base, thermal, mercerized/acetylated) for coconut fibers. However, fibers treated with biosurfactant showed a more significant result, likely due to chemical and physical alterations. Surfactin, a bioemulsifier, demonstrated a 95% recovery rate for crude oil[12]. FTIR analysis confirmed the interaction with polar and non-polar groups, enhancing sorption results.

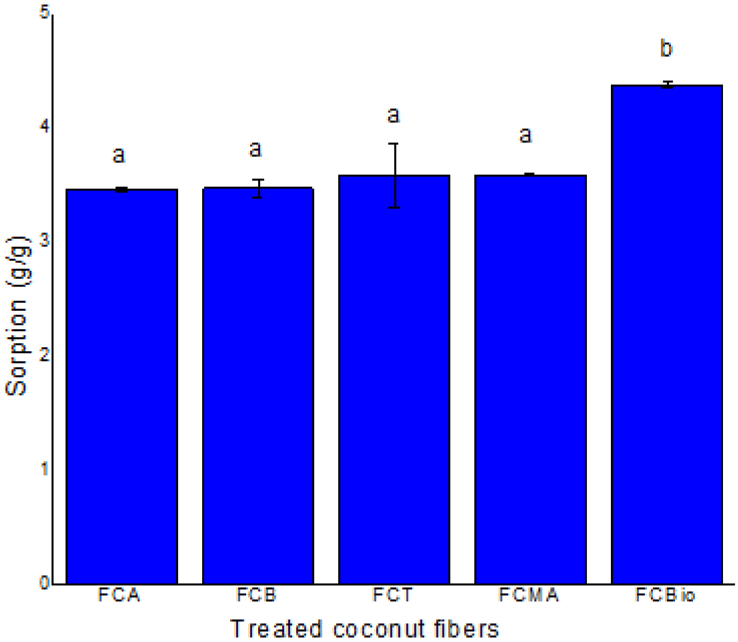

Figure 3 Comparison of the adsorption test between pre-treatments on the studied coconut fibers and Tukey test study at 95% confidence.

Further characterization of the fibers is needed to understand better these results, including surface area and pore size, elemental analysis to determine aromaticity and polarity, and contact angle measurements. Literature indicates that non-conventional pretreatments improve sorption capacity by altering chemical, physical, and morphological structures[2,3,7,11]. In this study, untreated coconut fibers had a sorption result of 2.91±0.24 g/g, which was lower than that of pretreated fibers.

4 CONCLUSION

Coconut fibers subjected to biosurfactant treatment showed higher sorption capacity than conventionally treated coconut fibers. Conventional treatments (acid, alkaline, mercerization followed by acetylation, and thermal) have similar sorption without significant differences according to the Tukey Test at 95% confidence. The characterizations of the fibers showed favorable changes for sorption after pretreatments. Therefore, the results found in this study reveal the potential of biosurfactant, a biological solvent, in the pretreatment of coconut fibers to be used as bioadsorbents for oil.

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ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the Human Resources Program of the National Agency of Petroleum, Natural Gas, and Biofuels (PRH/ANP – PRH36/UFBA), supported by resources from the investment of qualified oil companies under the R&D clause of ANP Resolution No. 50/2015. This work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Funding Code 001.