Enhancing TiO_2 Heterogeneous Photocatalysis for Air Cleaning: Alkaline Modification of Sisal Fiber Supports

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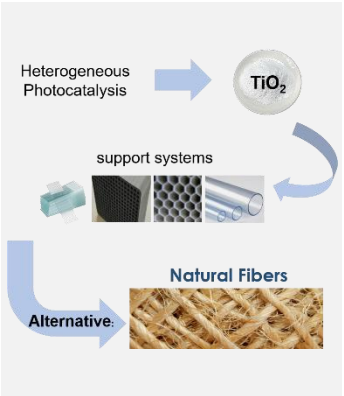

Heterogeneous photocatalysis is an advanced oxidative process with a significant application in the gas phase. However, the support material for the photocatalyst is essential for efficiency and deactivation. This work aimed to study sisal fiber to support, characterize and evaluate the photocatalytic activity of the composite. Thermogravimetric analysis showed the thermal stability of the fiber for work temperature. Infrared Spectroscopy confirmed characteristics bands from cellulose, hemicellulose and lignin even for treated fibers. Lignocelulosic composition analysis demonstrated that the initial NaOH wash did not significantly alter fiber composition. However, photocatalytic activity was lower than expected (24,31%), so NaOH in different conditions washes were studied. Scanning Electron Microscope images indicated that sisal washed with 15 % m/v NaOH by 15 min provides a better TiO_2 impregnation with a less cracked and more uniform layer and photocatalitic activity was increased to 30.07%

Introduction

Advanced Oxidative Processes (AOP) have been used to promote the degradation of contaminants in the indoor air by generating highly oxidizing specifications [1,2]. In this case, the AOP more commonly used is heterogeneous photocatalysis (HP), based on irradiation from a photocatalyst, commonly inorganic semiconductors. One of the most studied photocatalysts is TiO_2 due to its low cost, low toxicity and good physicochemical stability [1].

The main rule for using TiO_2 in the gas phase is to support it on a matrix. The supports commonly used are glass [2], ceramic and coal monoliths [1], and plastics [3,4]. However, these materials have disadvantages, such as low absorption and adherence and/or photodegradation of the support. Searching for better supports continues to be a challenge, especially those that guarantee good adhesion of the photocatalyst and non-self-degradation (or minimal degradation) of the support during the photocatalytic process. Then, this work aims to study sisal fiber as a mesh as an alternative stable support for TiO_2 and to evaluate the photocatalytic activity of the material against isopropanol (C_3H_8O) as a composite target model.

Material and Methods

The original commercial fibers cloth were characterized by Thermogravimetric Analysis (TGA), Attenuated Total Reflection Fourier Transform Infrared Spectroscopy (ATR-FTIR), Lignocellulosic composition and Scanning Electron Microscopy (SEM). The initial studies used fibers washing with deionized H_2O (Sisal-H_2O), 0.1 mol L^{-1} NaOH solution, then deionized H_2O and 0.1 mol L^{-1} acetic acid solution (Sisal-NaOH) dried at 40ºC. TiO_2 was synthesized by the sol-gel method, and the fibers were impregnated by the total coating method by immersion and dried at 40ºC. For improvement in photocatalytic activity, new washing tests using different concentrations of NaOH (2, 5, 10 and 15% w/v) and washing times (5, 15 and 30 min) were tested for better adsorption of TiO_2 and SEM images tests were also done.

In the photocatalytic tests, UVA radiation was used, and the conversion of C_3H_8O into acetone or mineralization was followed by gas chromatography coupled to the flame ionization detector. The liquid C_3H_8O was carried by synthetic air at 100 mL/min, obtaining 300 ppmv of alcohol into the flat continuous flow reactor containing the studied fiber.

Results and Discussion

TGA results (Figure 1) showed loss of water and volatile compounds for all fibers up to 130º and between 210-390ºC loss of hemicellulose, cellulose and lignin. The maximum degradation temperatures of each fiber were: 335ºC (pure Sisal), 346ºC (Sisal-H_2O), and 348ºC (Sisal-NaOH).

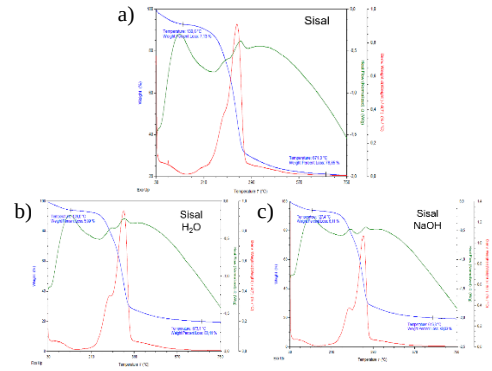

Figure 1. TGA of a) Sisal, b) Sisal-H_2O and c) Sisal-NaOH

FTIR analyses (Figure 2) revealed characteristic bands of cellulose, hemicellulose, and lignin: 3331.07 and 1614.42 cm-1 (OH), 2920.23 and 2872.01 cm-1 (C-H),

1726.29 cm-1 (C=O), 1423.47 cm-1 (-CH_2), 1371.39, 1317.38 and 1244.09 cm-1 (C-O-H, -CH_2 and –COO), and 1028.06 cm-1 (C-O) [6].

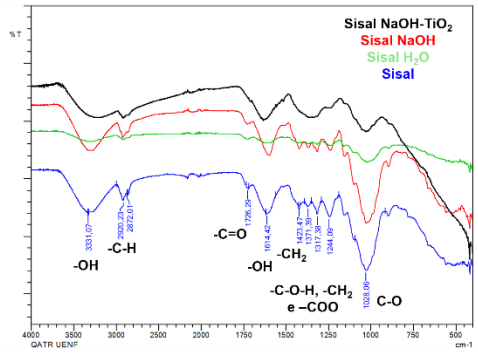

Figure 2. ATR-FTIR of fibers

The Lignocellulosic composition of each fiber was pure sisal: 56.19% cellulose, 16.13% hemicellulose and 13.26% total lignin; Sisal-H_2O: 53.48% cellulose, 16.00% hemicellulose and 13.79% total lignin; Sisal-NaOH: 55.99% cellulose, 16.93% hemicellulose and 13.20% total lignin. The results showed no loss of lignin in the washing processes. SEM images (Figure 3) confirm the presence of titanium in the impregnated fibers, but show cracked layers.

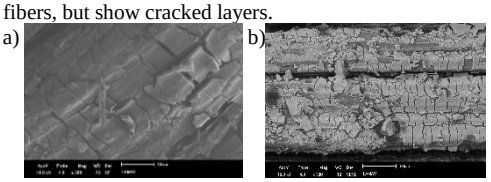

Figure 3. a) Sisal-H_2O-TiO_2 and b) Sisal-NaOH-TiO_2 SEM images with 300 increases

New wash tests were done using different NaOH concentrations and washing times to improve TiO_2 adsorption. SEM images (Figure 4) indicated that sisal washed with 15 % m/v NaOH for 15 min provides a better TiO_2 impregnation with a less cracked and more uniform layer. Photocatalytic tests using this material confirmed an improvement in isopropanol reduction efficiency to 30.07%, with 68.45% selectivity to acetone.

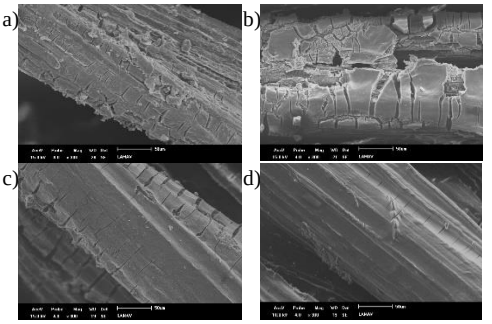

Figure 4. SEM images with 300 increases of different conditions of NaOH washes and TiO_2 impregnation (better results of each NaOH concentration): a) NaOH 2%m/v, 5 min, b) NaOH 5% m/v, 30 min. c) NaOH 10% m/v, 30 min and d) NaOH 15% m/v, 15 min.

Conclusions

Sisal natural fiber presents a good thermal stability for being a photocatalyst support. The photocatalic atividy was lower than expected, but the chemical treatment is an important step to study, seeking to improve this efficiency. The initial washings did not significantly alter the composition of the fiber, but changing the concentrarion and expouse time of NaOH, the TiO_2 impregnation can be modified and it was possible to increase the photocatalytic efficiency of the material.

Acknowledgments

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