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Eco-Friendly Chemical Modification of Agave Americana Fibers for Biocomposite Properties Enhancement

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Chemical treatments are used to remove hydrophilic OH groups and surface particles from the fiber surface for increasing aspect ratio of fibers and subsequently, mechanical properties. In this paper, the effect of two eco-friendly chemical treatments on morphology, chemical structure, and thermal stability of Agave Americana fibers (AAFs) is investigated. The first chemical treatment of AAF is based on citric acid ($C_6H_8O_7$) to substitute OH groups contained in AAF by ester groups, while the second one involves sodium bicarbonate ($NaHCO_3$) to remove the lignin and hemicellulose components with the aim to promote good fiber-matrix adhesion. Attenuated total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR) data shows that both treatments are efficient to remove hemicelluloses and a part of lignin contained in AAF resulting in a rough and clean fiber surface. Thermal stability of AAF has clearly increased by $NaHCO_3$ treatment compared to untreated one, unlike $C_6H_8O_7$, which reduces this property. The study highlights the possibility of substituting conventional polluting chemical treatments with environmentally friendly ones to modify the surface of plant fibers for polymer composites reinforcement.

1. Introduction

Biodegradable biocomposite materials based on biopolymers and biofillers have gained a lot of interest in the last decade due to their ability to be completely decomposed at the end of their life cycle and also to their potential ability to substitute conventional polymers.[1,2] Most of the biofillers used in green composites are derived from renewable sources and are generally cellulose-rich materials. Indeed, natural cellulosic fibers such as hemp, sisal, jute, kenaf, flax, and bamboo, among others, have been extensively used as reinforcement in polymer composite materials regarding their abundance, low density, nonabrasiveness, and high specific mechanical strength and modulus.[3] As well established, the fiber performances used in a given application depends on several factors including mainly, chemical composition, physical properties, fiber–matrix interface, environmental service conditions, loading ratio, and orientation and fibers' aspect ratio.[4] As a matter of fact, numerous research works are available in literature dealing with the preparation methods and properties characterization of various cellulosic fibers-polymer matrices.[5] If this approach is interesting on several counts, as the valorization of natural fibers, the energy saving considerations, the low cost and the preservation of the environment, the hydrophilic nature of cellulosic fibers prevents; however, their good dispersion in the hydrophobic polymeric matrix forming aggregates and subsequently reducing their mechanical performances.[6] To overcome this drawback, one of the most common approaches used, consists of modifying the fiber surface aiming at improving the fiber–matrix interfacial adhesion. In this topic, treatments based on sodium hydroxide, potassium permanganate, or grafting with maleic anhydride or acetyl groups are frequently used.[7] However, the large quantities of solvents generated limit their application on an industrial scale in addition to the problems of toxicity and environmental pollution. Faced with this constraint, some authors have developed eco-friendly chemical treatments. In this regard, Fiore and Calabrese[8] reported the effect of surface modification by sodium bicarbonate of various plant fibers, i.e., sisal, flax, and jute fibers on the flexural properties of epoxy-based composites. The results show the roughness of the treated fiber surface due to the removal of hemicelluloses and part of lignin, thus improving fiber–matrix interfacial adhesion and consequently the flexural properties, unlike epoxy composites filled with jute fibers, which decrease flexural properties. This indicates that the surface modification efficiency depends on the type of fibers used. Further, Chaitanya and Singh[9] applied the same chemical treatment on Aloe Vera fibers and the effect on properties of PLA biocomposites. It was found an optimum time of 72 h to modify the fibers with improved good tensile and flexural properties. Beyond 72 h, a drastic decrease is observed for the tensile and flexural strength. Moreover, no significant effect is observed on the modulus. Another eco-friendly chemical treatment reported by Cui et al.[10,11] consists of modifying microcrystalline cellulose surface by citric acid in order to substitute the hydroxyl groups by ester groups, thus reducing the

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