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Chemical treatments of coir pith: Morphology, chemical composition, thermal and water retention behavior

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ABSTRACT

Coir pith is one of the most abundant agro waste found in the southern coastal regions of India, where the economy and livehood of people are largely dependent on the coconut industry. Many technologies have been developed successfully for the alternate use of coir pith. However the application of coir pith as fillers in polymer composite is limited. The major drawback of coir pith as filler in polymer is its low adhesion with the matrix and high water sorption and retention behavior. The present work is a part of research work carried out in our laboratory to modify the morphology and chemical properties of pith to make it better filler in the processing of polymer composites. Coir pith was subjected to mercerization followed by different types of chemical treatment. The products were analyzed in detail using FTIR, XRD, optical microscope, AFM and SEM. The chemical treatment resulted in increased density, thermal stability and reduced water retention behavior.

1. Introduction

Coir pith is generated in the separation process of the fiber from the coconut husk and is generally dumped as an agro waste. For every ton of fiber extracted, the pith is produced to the extend of 2 tons. It is estimated that at present there is an accumulated stock of 10×10^6 metric tons of coir pith in the southern states of India and about 7.5×10^5 tons of coir pith is produced annually in India. They are generally dumped as hillocks or disposed of by burning. Because of its low degradation in the environment, the hillocks of coir pith collected or dumped pause serious health hazards and loss of fertile lands. Because of the high lignin content left it takes decades to decompose; it only begins to break down when it is 10 years old. The pentosan/lignin ratio of pith is 1:0.30 and the minimum required for moderately fast decomposition in the soil is 1:0.50. Burning of agro-wastes results, increased green house gases. The tannins and phenols from coir pith leach out into the soil and water bodies causing pollution. Because of its fluffy nature, its transport is not economical. Therefore alternate ways to dispose of coir pith is of critical importance. Cost effective technologies that address the development of value added products from coir pith therefore become relevant for countries producing coir pith. Proper use of coir pith can lead to biodegradable and eco-friendly product. Coir pith is widely used for removal of reactive dyes from waste water [1], growth substrate for production of mushrooms [2], soilless medium [3] etc. However, the application of coir pith as filler in polymer composites industry is not reported yet. Coir pith contains cellulose, a feature that has invited much attention due to the possible use of such resources as a reinforcing component in high composite materials.

One factor that has prevented a more extended utilization of the agro-wastes in composite industry is the lack of compatibility of these fillers in most polymeric matrices. The hydrophilic nature of natural fillers adversely affects adhesion to hydrophobic matrix and as a result, causes poor mechanical properties. The structural composition of coir pith (cellulose, hemicelluloses, lignin, pectin and waxy substances) allow moisture absorption from the environment which leads to poor bonding with the matrix materials. Additionally, the chemical structures of lignocellulosic materials and polymer are different and couplings between these two phases become a huge challenge.

Chemical treatment of lignocellulosic material improves their surface topography, surface chemical groups and results in structural modification [4,5]. These treatments are usually based on the use of reagent functional groups that are capable of reacting with the lignocelluloses structures and changing their composition. These changes may have positive influence on interfacial interaction in the case of polymer composites [6,7]. In case of these natural filler reinforced composites, chemical treatment of lignocelluloses stimulate the hydroxyl groups that can efficiently interlock with matrix. The main advantage of removing the shell impurities of natural fibers is to improve fiber–matrix adhesion which improves mechanical interlocking and bonding reaction contact between the hydroxyl groups of fibers to chemicals like dyes and resins. Many chemical treatment methods for

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lignocellulosic materials are adopted and are well known. In a recent review on international research into natural fiber/polymer composites, Kabir et al. [8] has summarized a number of works on the effect of chemical treatment on the morphology and other properties of fibers and composites. One of the most common techniques adopted for chemical treatment of lignocelluloses are alkaline treatment. The treatment with sodium hydroxide results in the removal of non-cellulosic components such as hemicelluloses, lignin, and wax [9–11]. Chemical treatments of natural fibers with a combination of sodium hydroxide and bleaching chemicals such as H_2O_2 [11], DCP [12,13], NaOCl [14,15] is well known. The treatments resulted in surface modification of lignocelluloses and in certain cases the thermal stability also. The treatment with peroxides was also reported to decrease the moisture absorption tendency of lignocelluloses [16,17]. The effect of different acid treatment on natural fillers is reported by many researchers [18–20]. The treatment with acrylic acid [21,22] and acetic acid [23,24] results in the functionalization of lignocelluloses. Roy et al. [6] reported that alkaline treatment of jute fibers improves mechanical properties such as tensile strength and elongation at break. It also reduces the diameter and hydrophilicity of fiber. The alkaline treatment of coir fibers was find to improve fiber–matrix adhesion and improved tensile strength by 53% as compared to untreated coir fiber composites Rosa et al. [11]. The effect of chemical treatment of fibers on coir/sisal/natural rubber hybrid composites was investigated in detail by Haseena et al. [25]. The resulting composites possessed high abrasion resistance, tear strength and hardness compare to raw coir/sisal fiber filled hybrid composites. Kostic et al. [26] worked on chemically modified sisal fiber composites and found improved fiber fineness and composite flexibility with treatment. Cordeiro et al. [27] reported that chemical treatment can help in achieving overall performance and properties of agro fibers when compared to wood fibers. Recently our own research group has successfully extracted cellulose microfibrils from *Hibiscus Sabdariffa* [28]. Delignification of coir pith for various applications has been reported earlier [29,30]. However no extensive work is carried on the effect of chemical treatments on coir pith especially from the point of composite industry.

The aim of the present work was to investigate the effect of different chemical treatments: sodium hydroxide, sodium hypochlorite, dicumyl peroxide, acetic acid, acrylic acid and sulfuric acid on morphology and water retention nature of coir pith. The chemical composition and structure of pith were analyzed in detail. The thermograms of the samples were taken to study the role of chemical treatment on thermal stability.

2. Materials and methods

2.1. Materials

Coir pith was collected from a local coir processing unit (Gudiyathum, Tamilnadu, India). The chemicals used such as sodium hydroxide, sodium hypochlorite, dicumyl peroxide, acrylic acid, acetic acid, acetic anhydride, sulfuric acid were purchased from Sigma–Aldrich. Ferrous ammonium sulfate, potassium dichromate and ferrion indicator were purchased from RFCL Ltd.

2.2. Methods

2.2.1. Chemical treatment

Chemical treatment was carried out in two stages. The pith samples were first subjected to sodium hydroxide treatment followed by five different types of treatment. Alkali Pretreatment of lignocellulosic materials is well known and has been adopted by many researchers in the past [7,17,21,23]. The schematic representation of chemical treatments of coir pith is given in Scheme 1.

2.2.2. Sodium hydroxide treatment (NA)

Coir pith was soaked in NaOH solution (5%) at room temperature for 1 h followed by washing with distilled water. Afterwards, the samples were oven dried at 70 °C for 2 h.

2.2.3. Dicumyl peroxide treatment (DCP)

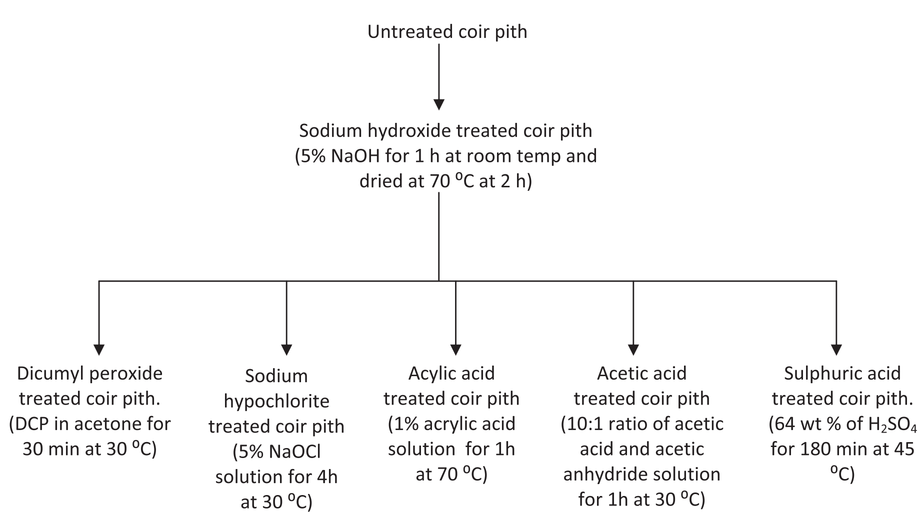
In peroxide treatment, the alkaline-treated coir pith was treated with dicumyl peroxide in acetone solution for about 30 min at 30 °C.

2.2.4. Sodium hypochlorite treatment (NAH)

Sodium hydroxide treated coir pith were bleached by soaking in 5% NaOCl for 4 h at 30 °C and washed with deionized water until free from chemicals.

2.2.5. Acrylic acid treatment (AA)

Sodium hydroxide treated coir pith were treated in 1% of acrylic acid (AA) solution at room temperature for 1 h, then washed with distilled water and dried in an oven for 72 h at 70 °C.



Scheme 1. Various chemical treatment of coir pith.