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Comparative Experimental Study on Mechanical Properties of Chemically Treated and Untreated Sisal Fiber Reinforced Poly Lactic Acid (PLA) Matrix Composites

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Abstract

A chemically untreated and treated sisal fibre reinforced with Poly Lactic Acid Matrix green composites were tested for mechanical properties in this research. Different volumetric fractions like, 20, 25, 30, and 35% of untreated and treated sisal fiber are chosen to prepare the composite specimens by coalesce with Poly Lactic Acid (PLA). The ASTM standards were followed in the preparation of the composite specimens used in the various mechanical testing. The mechanical characteristics of the composites were determined using standard testing procedures. The PLA matrix with treated sisal fibre reinforced composites had higher ultimate tensile strength, tensile modulus, flexural strength, flexural modulus, and Izod impact strength than the pure PLA and untreated-PLA composites, according to the experimental results. Conversely, tensile elongation exhibited by the treated sisal-PLA and untreated PLA composite was decreased largely when compared to pure PLA composite correspondingly.

Keywords: Mechanical properties, chemical treatment, sisal fiber-PLA composites, comparative experimental study.

1. Introduction

Many people are becoming interested in using natural fibres as reinforcing components in together plastic and thermoset matrices. These advantages include the capacity to easily renew the fibres and the fact that they degrade naturally. [1] Fibers like sisal, coir, jute, ramie, and kenaf can be utilised as alternate for glass or another regular reinforcement composites [2]. Polymer composites made from natural fibres like hemp and jute have gained worldwide attention because of their extraordinary mechanical properties and their ability to withstand high temperatures. [2]. One of them, sisal fibre, is receiving increasing attention as a reinforcing material. These fibres can be utilised to make green composites from petroleum-based plastics or renewable polymers [3]. Polylactic acid nanocomposites and biodegradable composites have been extensively studied over the last two decades by numerous researchers. [4]. Natural fiber-reinforced PLA biocomposites have become a hot topic in recent years among material scientists. Reinforcement in the PLA matrix is most typically provided by jute, sisal, bamboo, pineapple leaf, etc. [5]. The thermophysical characteristics of composites are affected by the concentration of NaOH. Temperature-physical characteristics of sisal fibre composites treated with 10% NaOH were superior to those treated with 2% NaOH [6]. At 21 % volume of fibre composites with 1% MAPP absorption exhibit the best mechanical characteristics [7]. There has been a great deal of success in alkalizing and acetylating natural fibres, which will most certainly increase the performance of natural fibre composites [8]. An epoxy resin-based bio composite including peanuts shell powder was studied for its material properties [9]. Peanut shell powder was shown to greatly improve the mechanical characteristics of epoxy resin/sisal fibre composites. Jute fiber-reinforced, egg shell-powdered epoxy resin bio composite materials were tested for mechanical properties [10]. The mechanical characteristics of epoxy resin/jute fibre composites were dramatically improved when egg shell powder was added to the mixture. Sisal fibre reinforced camellia sinensis particle occupied with epoxy resin bio composites were tested for impact and hardness[11].The mechanical characteristics of epoxy resin/sisal fibre composites are greatly improved when camellia sinensis particles are added[12]. The water absorption capabilities of treated and untreated hybrid biocomposites were investigated in experiments [13]. The tensile characteristics of hybrid polymer composites were studied practically[14]. The flexural performance of epoxy matrix composites containing chemically modified and unmodified sisal fiber/camellia sinensis particles was evaluated [15]. Polymer Nanocomposites have been tested for the effects of layered double hydroxide. Mechanical properties of jute-reinforced epoxy resin biocomposites incorporating cocoa shell particles were examined experimentally, and found to be satisfactory[16]. Poly Lactic Acid matrix, untreated cellulose-Poly Lactic Acid, and NaOH-treated sisal fiber-Poly Lactic Acid composites were tested for different fibre fractions in PLA matrix..

Methodology and Materials

In this experimental study, matrix material of Poly Lactic Acid (PLA) was procured from local market. The sisal fibers that are used as reinforcing materials were purchased from eco green unit, Coimbatore, Tamilnadu, India. The sisal fibres were cut into roughly 2 mm lengths. Sisal fibre was cleaned by hand and then splashed over distilled water and dried out for 48 hours at 120ºC in oven. An empty beaker containing water, sodium hydroxide, and dried sisal fibres was used. Disinfect the fibres with soap solution after the chemical treatment is complete. For six hours at 135ºC, the sisal fibres were individually dried in an oven. It was precisely blended with PLA in volumetric fractions extending from 20 percent to 35 percent based on the weight of the sisal fibres used. Double screw extruder machines were used to process the sisal fiber-PLA mixtures into the various composites. At 160ºC and the same pressure, the extrusion temperature was maintained. At a predetermined rate, the composites were fed through a rod-shaped die. A hot air oven is used to dry the small bits of composites that were cut from the composite rods, which are around 15 to 20 centimetres long. An injection moulding machine is used to create the composite specimens necessary for mechanical testing according to ASTM standards. At a process temperature of 160oC, the well-dried composite rods were moulded into test specimens. There are tensile test specimens of 250 mm length, 25 mm breadth, and 4 mm thickness obtained from the injection moulding machine. Similarly, the test specimens for flexural tests have dimensions of 165 x 13 x 4 mm. 165 mm in length, 13 mm in width and 4 mm thick is the impact test specimen for the Izod impact test. There are three types of mechanical tests that are performed to determine the mechanical properties of composite materials, namely the tensile strength, tensile modulus, and % elongation at break of these materials.

2. Results and Discussions

For example, tensile strength was shown in figure.1 through figure.5, while Izod impact resistance was shown in figure.5 to illustrate the diverse mechanical qualities acquired from mechanical tests. Pure PLA and untreated sisal fiber-Poly Lactic acid composites had a lower ultimate tensile strength than the treated sisal fiber-PLA composite, as illustrated in figure 1. Untreated sisal fiber-PLA composites had low tensile strength because of the poor compatibility among the hydrophilic effect of sisal fibre and the hydrophobic effect of PLA. It was shown that alkali-treated sisal fiber–PLA composite composites had tensile strengths that were 13 percent and 36 percent greater than those of untreated PLA and pure PLA matrix composites. Because sisal fibre was chemically treated with sodium hydroxide in an alkaline media, the compatibility between sisal fibre and PLA was primarily enhanced.

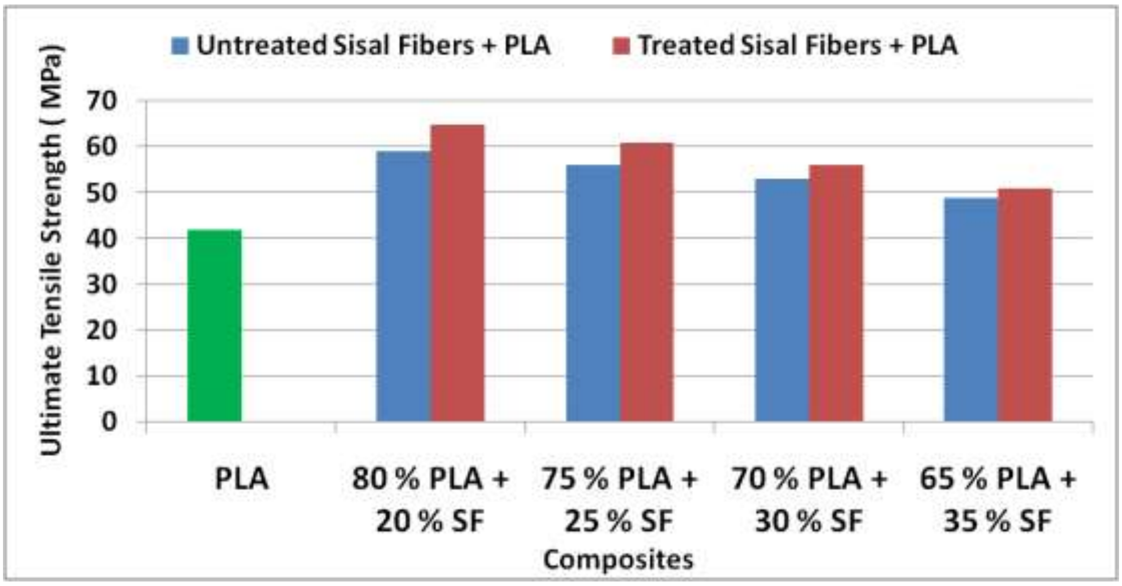

Figure 1. Test results on different composite materials' ultimate tensile strengths based on the presence of different types of fiber-PLA:

Compatibility enhancement between the sisal fiber and PLA composites was enhanced due to effect of sodium hydroxide treatment on sisal fiber, in that way dropping the hydrophilic character of sisal fiber. Interfacial attachment among the sisal fiber and PLA composites also enhanced due to the treatment of sisal fiber with sodium hydroxide. Tensile modulus for pure PLA matrix, PLA matrix with untreated fiber reinforcement and PLA with treated sisal fiber reinforcement were illustrated in figure2 respectively.

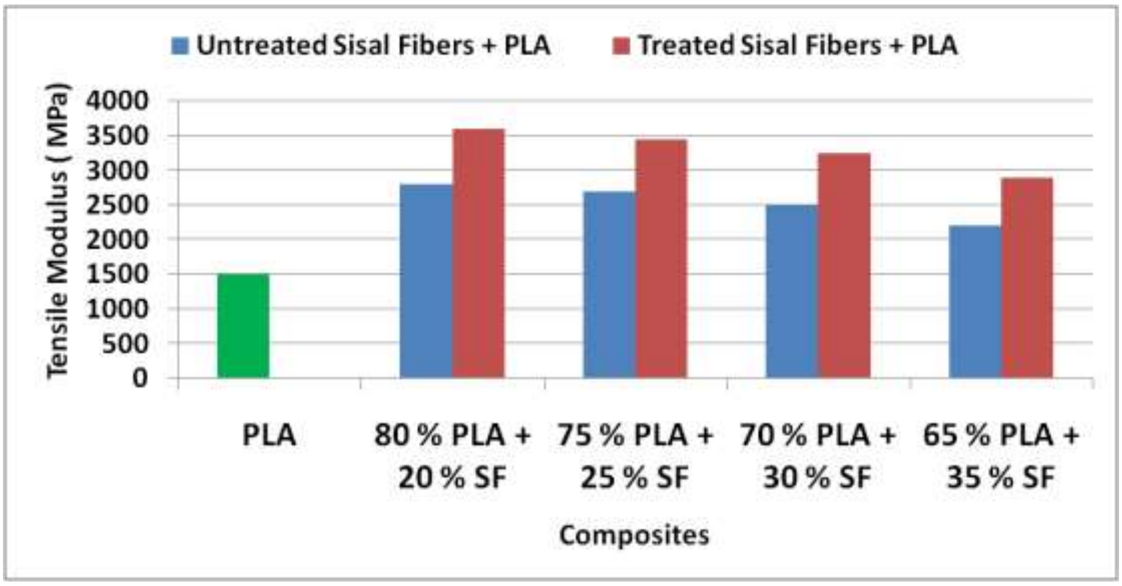

Figure 2 Variation on tensile modulus for pure Poly Lactic acid, untreated and treated fiberPoly Lactic acid composites

Figure 2 shows a tensile modulus comparison between chemically treated sisal fiber Poly Lactic acid composites, pure PLA, and untreated sisal fiber-PLA composite materials.. It has found that the tensile modulus of Poly Lactic acid is unaffected by the addition of 20% to 35% of sisal fibre to the PLA composites, as demonstrated by further studies.

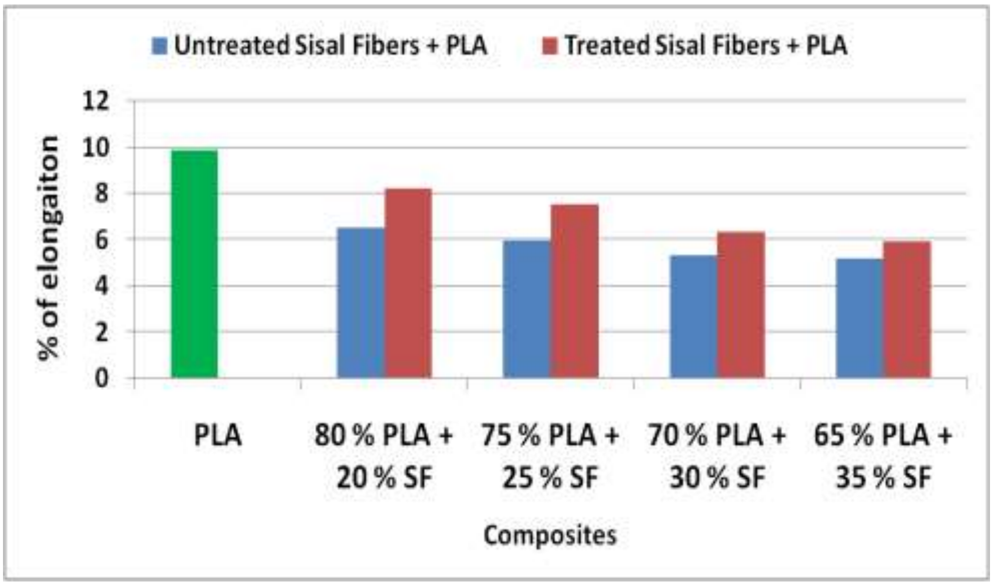

Figure 3Variation in elongation percentage between pure Poly Lactic acid, untreated treated fiber-Poly Lactic Composites composites.

For sisal fiber-PLA composites that had been chemically treated or untreated, the percentage of extension at break was depicted in figure 3. Both chemically treated and untreated sisal fibre reinforced-PLA matrix composites exhibit lower elongation at break than pure PLA matrix composites, as shown in the figure 3. As a result of the addition of sisal fibre reinforcement to PLA matrix, sisal fibre composites had a lower elongation percentage. Because of this, the length changes of composite specimens reinforced with both chemically treated and untreated sisal fibres in PLA matrix were reduced. The tensile extension at break of whole composites was virtually unaffected by raising fibre loading from 20% to 35% in volumetric basis with PLA matrix.

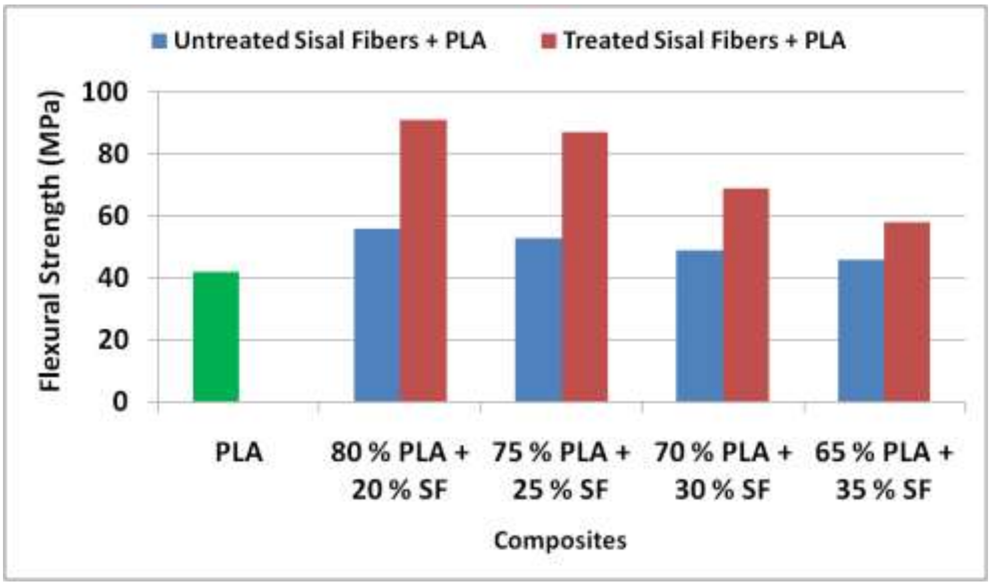

Figure 4Flexural strength variations in PLA, untreated and treated Poly Lactic acid fibres composites

For PLA, sisal fiber-PLA and sisal fiber-PLA composites the flexural modulus and strength are shown in Figures 4 and 5. There were considerable differences between the flexural strength and modulus of the PLA matrix and the sisal fiber-PLA composite, as illustrated in figs. 4 and 5. Because sisal fibre was reinforced with PLA matrix, treated sisal fiber-PLA composites had higher flexural strength and modulus values. The sisal fibres caused the void formations by washing out all of the lignin, cellulose, and hemicelluloses in preparation for PLA molecule amalgamation. Gaping may have occurred as a result of the alkali-treated sisal fibre being washed out. Interfacial familiarity among sisal fibre and Poly Lactic Acid matrix was improved by alkali treatment. The flexural strength and modulus of the sisal fiber Poly Lactic acid composite, both alkali treated and untreated, decreased from 20 to 35 percent, as shown in figures 4&5. As the percentage of sisal fibre increases, the interfacial bonding strength between PLA and sisal fibre may weaken.

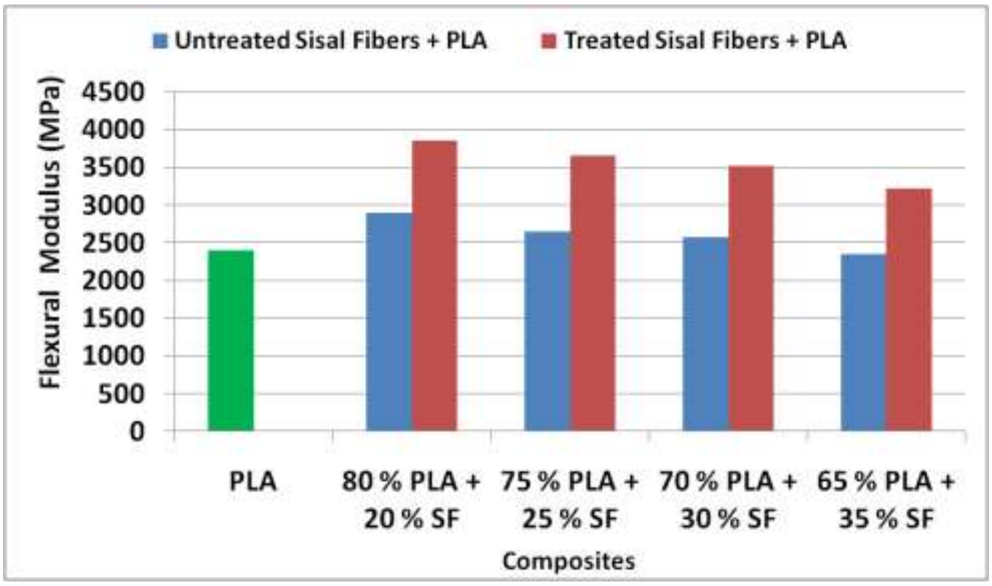

Figure 5Adaptability of flexural modulus in PLA, PLA-treated fibre composites and untreated composites

Figure 6 represents the impact strength examination results for pure Poly Lactic acid, treated and untreated sisal fiber-PLA composites obtained from Izod testing. Another interesting fact to take note that the Izod impact strength values of sisal fiber-Poly Lactic acid composites were lower than those of pure Poly Lactic acid matrix.

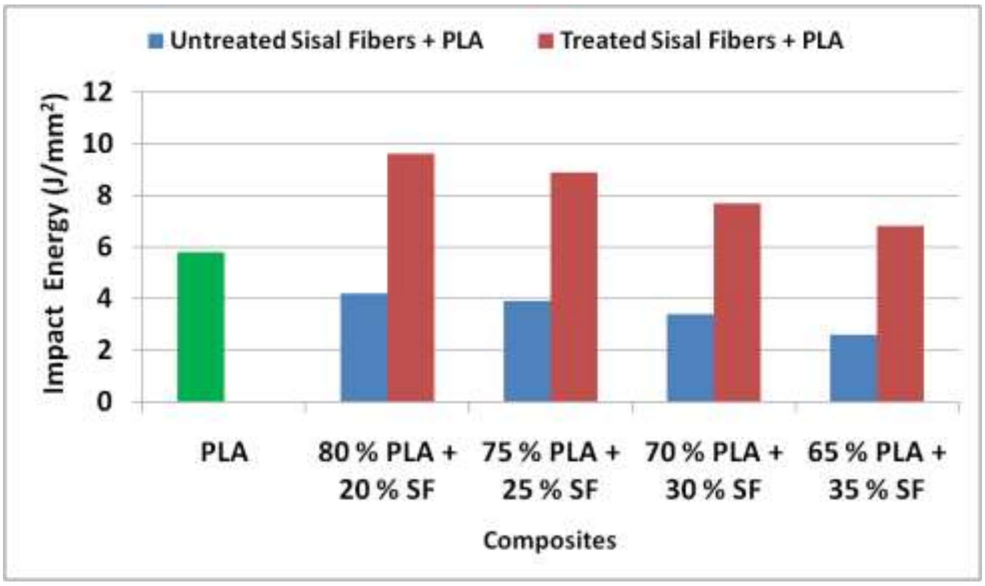

Figure 6Variation on impact energyfor pure Poly Lactic acid, untreated and treated fiber-Poly Lactic acid composites

Alkali treated sisal fiber-PLA composites, on the other hand, had higher Izod impact strength values than pure PLA matrix and untreated sisal fiber Poly Lactic acid composites. Increased compatibility of alkali-treated sisal fibre with PLA matrix may explain the higher values of alkali-treated sisal fiber Poly Lactic acid composites. Fig 6 demonstrates that the composites Izod values dropped as fibre loading increased. Fiber pullout is one of the elements that contribute to failure of fiber-reinforcement during impact. This could explain why the composite's Izod impact strength drops when the amount of fibre is increased.

Conclusions

Chemically preserved sisal fiber-Poly Lactic acid composites outperformed PLA and untreated sisal fiber Poly Lactic acid composites in terms of mechanical characteristics. These composites have stronger tensile, tensile modulus, flexural, flexural modulus, and Izod impact strength compared to those made with a pure PLA matrix and sisal fiber-PLA composites that have not been treated with sodium hydroxide. Apart from other mechanical properties, increasing sisal fibre loading with PLA matrix causes a reduction in flexural and Izod impact strength.

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