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A Study of Nacl Alkali Treated Muntingia calabura fibre Reinforced Composites

D. Mohana Krishnudu[1], P. Venkateshwar Reddy[2,*], R. V. Saikumar Reddy[1], A. C. Umamaheshwer Rao[2]

Abstract

Natural fibre reinforced composites are more commonly used in various applications due to their biodegradability, low cost, available in nature and less harmful to the environment than synthetic fibres. In the present study, NaCl alkali treated MuntingiaCalaburafibres(MCF) reinforced composites are developed using hand layup technique and evaluated the mechanical properties of the composites. The increase of the NaCl content (up to 20 percent) and the fibre weight is maintained constant for all the specimen, flexural and compression strength are enhanced and the tensile and impact strengths are reduced for the NaCl treated 20 percent MuntingiaCalaburafibre reinforced composites. Interfacial bonding between the alkali treated fibre and the matrix were observed through Scanning electron Microscope(SEM),functional compounds present in the composites were studied using FT-IR analysis, and degradation behaviour of the composite were studied using thermo-gravimetric analysis(TGA). Fibre pull outs are observed with the SEM analysis which indicates that good interfacial bonding between the fibre and matrix. The amount of residue that can be remained in the composite is approximately negligible which indicates that the composites are bio-degradable. Various functional compounds were observed through FT-IR analysis. As per the obtained results these fibre reinforced composites, it is considered as suitable for light weight structural, door panels, and automobile applications.

Keywords: Muntingia calabura fibre; SEM; TGA; FT-IR; composites

INTRODUCTION

In recent times, synthetic fibers are being substituted by natural fibers due to the non-biodegradable property of the synthetic fibers, which are a threat to the environment and cause the non-renewable resources to deplete [1]. Moreover, natural fibers have low density, less cost, acceptable electrical and mechanical properties, are renewable and produced from environmentally friendly sources. It was observed in a research that the processing of natural fibers consumed much less energy when compared to that of synthetic fibers [2].

The exhausting use of fuels and their resources led to an awareness and the inevitable need for renewable resources. The discovery of ever-increasing amounts of renewable plant resources for products might make this century known as the "cellulosic century" [3]. The main disadvantage of natural fibres in respective composites is the poor compatibility between fibre and matrix and their relatively high moisture absorption [4]. Therefore, natural fibre modifications are considered that lead to a change in the fibre surface properties to improve their adhesion with different matrices [5].

***Author for Correspondence**
P. Venkateshwar Reddy

[1]Assistant Professor, Department of Mechanical Engineering, G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India
[2] Assistant Professor, Department of Mechanical Engineering, Vardhaman College of Engineering, Shamshabad, Hyderabad, India

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In order to enhance the performance of natural fibres, researchers created a variety of chemical and physical techniques. It was found that these techniques, as opposed to corona and plasma treatment, showed a preference for chemical modification, which included acetylation, benzoylation, acrylonitrile grafting, malleated coupling, permanganate, peroxide, and isocyanate treatment [6].

Numerous benefits are offered by fibre composites, including high strength, low weight, chemical and water resistance, high durability, electrical resistance, and resistance to corrosion and fire. Furthermore, as per the criteria, fibre composites' performance and characteristics may be tailored, making them economically viable for the majority of applications.[7] The automotive and aerospace industries, as well as structural and construction applications, have made substantial use of composite fibre components, including glass fibre, carbon fibre, and aramid [8]. Hence, The high specific strength and stiffness of composite material make it as a unique kind of material for household application to aerospace application. Importance has been given to the composite materials in research and development of material science for the benefit of mankind [9]. To improve its mechanical, tribological, or thermal property etc., hybridization of composite is highly required. It does not only improve the property but it also help to reduce the cost of the composite. The present piece of research attempts to study the natural fibre composite materials and to overcome the problem associated with natural fibre with the help of hybridization techniques [10]. Governments and society at large are putting pressure on a number of industries, including aerospace, automotive, construction, and energy, to produce more ecologically friendly goods and lessen their reliance on fossil fuels [11]. In this case, using natural fibres is a desirable way for businesses to address environmental and socioeconomic issues. Additionally, using natural fibres will assist achieve the sustainable development goals by generating jobs in rural and underdeveloped areas. Because natural fibre composites have benefits over synthetic composites, they are used in many industries, including building, automotive, aerospace, electrical products, and the medicinal sector [12]. Hawary et al.,[20] studied the overview of the natural fibre reinforced composites are also suitable for the marine field applications because of their ecofriendly nature, bio nature, pollution free and it leads to sustainable development in the environment. Miniappan et al.[21]. evolved the mechanical and wear properties of filler filled sisal reinforced composites.they concluded that filler filled reinforced composites have better properties than pure sisal composites.

This work involves the fabrication and mechanical property evaluation of epoxy composites reinforced with Muntingiacalabura fibre that have been NaCl-alkali treatment. SEM analysis was used to examine the interfacial adhesion between the fibre and matrix. Thermogravimetric analysis was used to examine the degradation behaviour of Muntingiacalabura composites that were treated with alkali. FT-IR spectroscopy is used to evaluate the functional chemicals found in the alkali-treated Muntingiacalabura composites.

MATERIALS AND METHODS

Hand layup technique used to fabricate laminates of the mamtingia fibre reinforced epoxy composites. In this mamtingia fibres are retrieved from the mamtingia plant stem and used. The raw fibre contains hemicelluloses, lignin and cellulose. With these fibre and matrix bonding is reduced and automatically strength of the composite declined. To overcome the above mentioned, the fibres are treated with either alkali or hydroxide materials. In the present work, the NaCl pallets are used. 5%-20% of NaCl pallets are mixed in 1 litre of water and impregnated. Tthe fibres are maintained constant weight(15%) about 2-3 hours to remove the lignin, cellulose and hemicelluloses contents from the fibres and Matrix consists of epoxy and hardener are taken 10:1 ratio, epoxy LY 5052 and hardener HY 5052 and this matrix is used in high end applications. The different weight percentage of mamtingia fibre and matrix are taken, size of the mould is $175 \times 175 \times 3$ mm^3 and fabricated mamtingia fibre reinforced composite laminates using hand layup technique. As per ASTM standard, the samples are cut from the mamtingia composite laminates to know the strengths of the composite laminate. For tensile strength ASTM D3039 ($150 \times 12.7 \times 3$ mm^3), for flexural strength ASTM-07($150 \times 15 \times 3$

mm^3), for impact strength ASTM638 ($62.5 \times 12.7 \times 3$ mm^3) and for compression strength ($10 \times 10 \times 10$ mm^3) are used. The bonding between the mamtingia fibre and epoxy LY5052 are studied using scanning electron microscope(SEM), the degradation behavior of the composite are studied using thermo gravimetric analysis (TGA), the compounds present in the composite laminate are studied using infrared spectroscopy (IR).

RESULTS AND DISCUSSION

Tensile Strength

Tensile tests were conducted according to ASTM D638 standards. Test specimens from each NaCl-treated fiber percentage group were subjected to tensile loading at a constant rate until failure. The tensile strength (measured in MPa) was recorded for each specimen. The tensile strength of the composite shows an interesting pattern in the data. Tensile strength increased substantially as the percentage of NaCl-treated fibers increased from 5% to 15%, with the highest tensile strength observed at 15% NaCl-treated fibers as shown in Figure1. However, when the percentage was further increased to 20%, there was a notable decrease in tensile strength, though it remained higher than the composite with 5% NaCl-treated fibers. This behavior suggests that the incorporation of NaCl-treated fibers can significantly enhance the tensile strength of the polymer composite, with an optimal percentage around 15%. The improvement in characteristics is probably a result of heightened polymer-fiber interactions. The increase in tensile strength of MuntingiaCalaburaFibre (MCF) treated with NaCl may be explained by numerous mechanisms, such as the creation of bonds between the epoxy matrix and the fiber, better distribution of the filler material, and increased capacity of the epoxy matrix to wet the MCF. This treatment enhances the alignment and distribution of MCF within the polymer. In addition, the use of NaCl enhances the capacity of a substance to be wetted and improves the region where the matrix and interphase meet, resulting in enhanced tensile capabilities. The treatment improves the surface interactions between the resin and fiber by augmenting surface roughness, leading to enhanced mechanical characteristics. Nevertheless, as the NaCl concentration reached 20 wt%, a decline in tensile strength was seen, presumably caused by the diminished cohesive strength of the fiber at higher NaCl concentrations. Also, the decrease at 20% NaCl-treated fibers may be due to potential fiber agglomeration or a saturation point in terms of fiber-matrix adhesion.

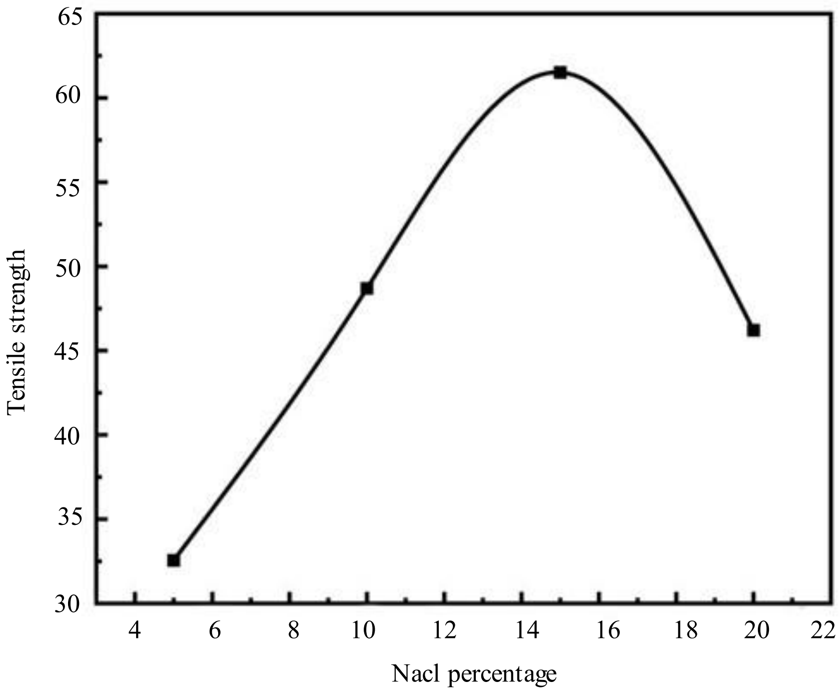

Figure 1. Tensile properties of Muntingia calabura reinforced composites.

Flexural Strength

The polymer matrix was reinforced with NaCl-treated fibers at different percentages of 5%, 10%, 15%, and 20%. The data revealed a strong trend in flexural strength, with the most dramatic increase found when the NaCl-treated percentage went from 5% to 20%. The highest flexural strength occurred at 15% NaCl-treated fibers, as demonstrated in Figure 2. However, raising the concentration to 20% resulted in a modest drop in flexural strength, but it remained substantially greater than at 5% and 10%. These results suggest that adding NaCl-treated fibers efficiently boosts the flexural strength of polymer composites, with 15% being the ideal concentration. The examination of the graph indicated that the composite with 15% NaCl-treated Muntingia Calabura Fiber (MCF) had the greatest flexural modulus, around 135 N/mm^2. The sample with 10% NaCl-treated fibers produced a value of roughly 85 N/mm^2, ranking second in terms of flexural modulus. The NaCl treatment substantially strengthened the MCF, enabling it to efficiently transmit stress from the epoxy matrix, resulting in enhanced flexural strength of the composites. The mechanical characteristics of composites are affected by several aspects, such as the properties of the matrix and fibers, the volume percentage of fibers, the geometry and alignment of fibers, the adhesion between the matrix and fibers, the clustering of fibers, and the breakage of fibers. Given that the alkali-treated samples displayed higher flexural characteristics, it may be deduced that the alkali treatment promoted the elimination of hemicellulose and lignin, hence increasing interfacial adhesion between the MCF and the epoxy matrix. NaCl treatments led to an approximately 55% and 50% increase in the bending modulus for the respective samples, owing to the higher fiber strength arising from the alkali treatments.

Impact Strength

Higher impact strength in composites is indicative of their energy absorption capacity, which is mostly dictated by the strong interfacial bonding between the fiber and matrix [13,14]. The results demonstrate a progressive increase in impact strength as the NaCl-treated fiber percentage goes from 5% to 15%, with the maximum impact strength obtained at 15% NaCl-treated fibers, as represented in Figure 3. However, when the NaCl concentration was raised to 20%, a little drop in impact strength was noted, although it remained near the highest value attained at 15%. These data demonstrate that while the insertion of NaCl-treated fibers significantly improves the impact strength of polymer composites, the effect is minimal, with 15% being the ideal concentration for generating the maximum impact resistance. This research demonstrates the subtle function that NaCl-treated fibers have in boosting composite performance, stressing the significance of adjusting fiber content for certain mechanical qualities

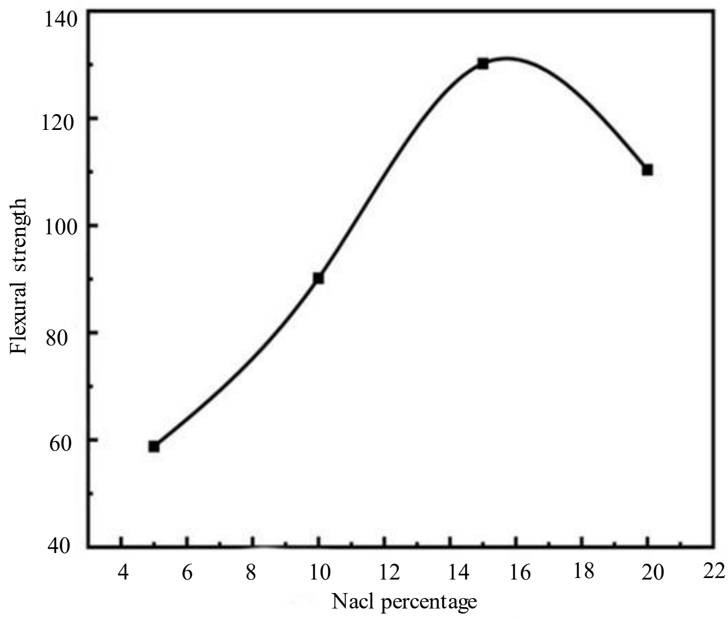

Figure 2. Flexural properties of Muntingia calabura reinforced composites.

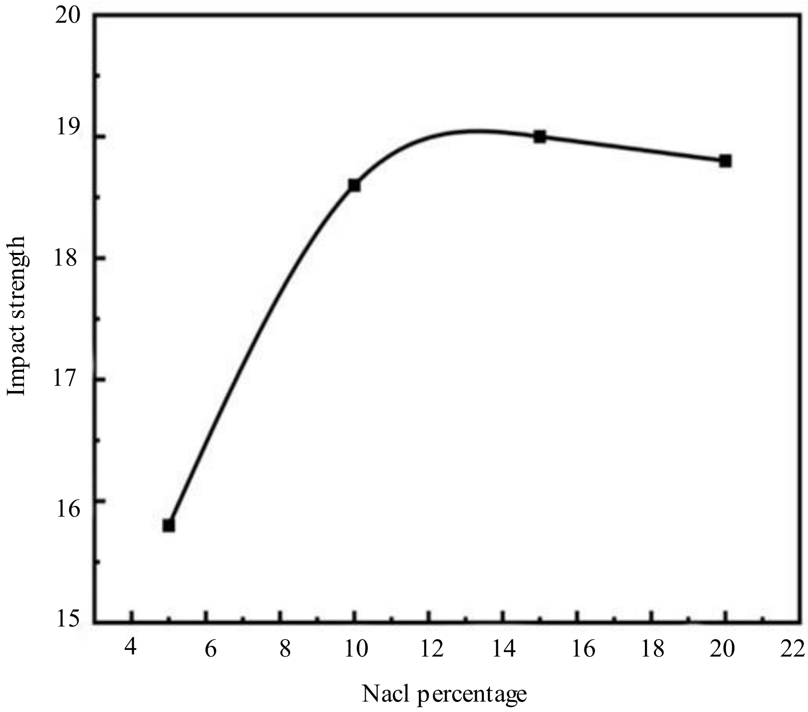

Figure 3. Impact strength of Muntingia calabura reinforced composites.

SEM Analysis

Alkali treatment greatly changes the surface topology of natural lignocellulosic fibers, such as Muntingia calabura. The SEM pictures demonstrate that untreated fibers display uneven and rough surfaces, which are representative of their natural shape. However, with the application of alkali treatment, particularly at greater concentrations, there is a notable smoothing of the fiber surfaces. This treatment eliminates hemicellulose, which surrounds the cellulose microfibrils, leading to a more uniform and refined surface structure. The reduction in surface roughness is directly proportional to the percentage of alkali applied. In composite applications, this modification is essential because the smoother surface increases the interfacial adhesion between the fibres and the matrix, improving the mechanical properties of the composite. The increased contact surface area owing to decreased surface roughness facilitates improved stress transmission between the matrix and the fibers, hence boosting the overall performance of the composite material. This morphological modification, obtained by alkali treatment, highlights its relevance in enhancing the mechanical characteristics of fiber-reinforced composites, particularly in situations where strong fiber-matrix bonding is required. Figure 4(a) illustrate the fibers treated with 5% NaCl which resulted in smooth hemicellulose fibers where as figure 4(b) illustrate the fibers treated with 15% NaCl attributing to rough fibers resulting in strong bonding with the matrix materials.

TGA Analysis

In this research, it is focused on the effect of NaCl-treated fiber percentage, specifically at 15%, on the thermal stability of a polymer composite and is shown in figure 5. Up to 900°C, thermogravimetric analysis, or TGA, was used to evaluate the thermal stability. The TGA graph revealed a progressive weight loss at each temperature point. up to 200°C, a slight reduction of 10% in weight was observed, indicating the initial decomposition of the composite. As the temperature was elevated to 400°C, the weight loss continued, albeit at a reduced rate, with 40% of the initial weight remaining. The most intriguing result was found at 800°C, where only 10% of the initial weight was retained. This indicates that the polymer composite with 15% NaCl-treated fibers displayed improved thermal stability, highlighting the potential benefits of NaCl treatment in enhancing the high-temperature performance of polymer composites.

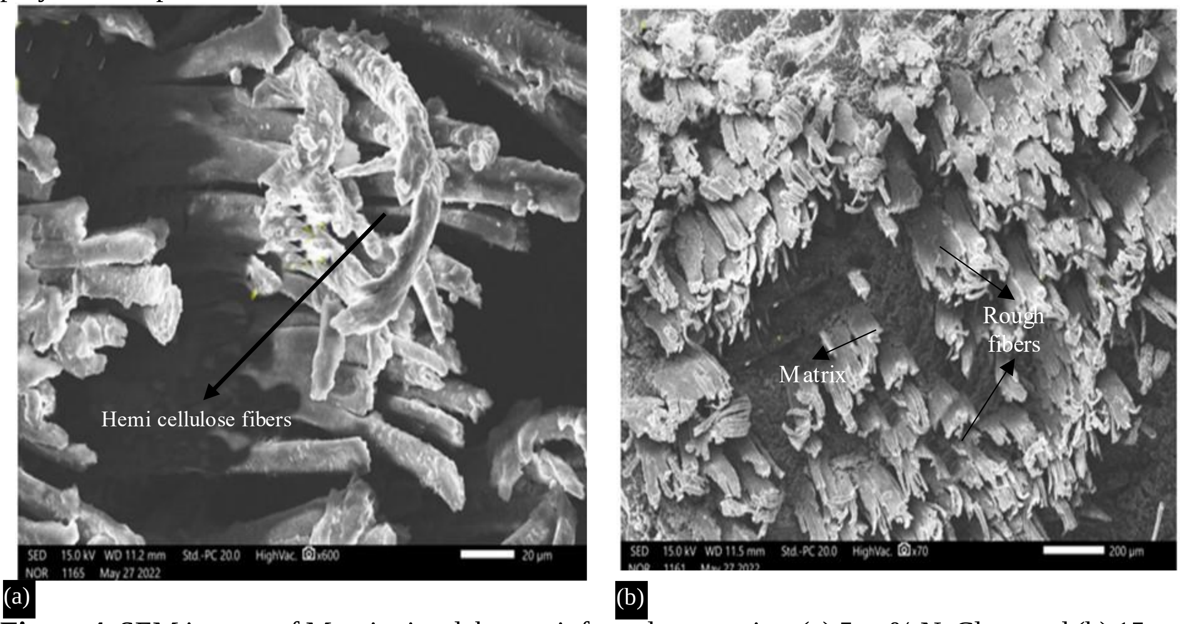

Figure 4. SEM images of Muntingiacalabura reinforced composites (a) 5 wt% NaCl treated (b) 15 wt% NaCl treated.

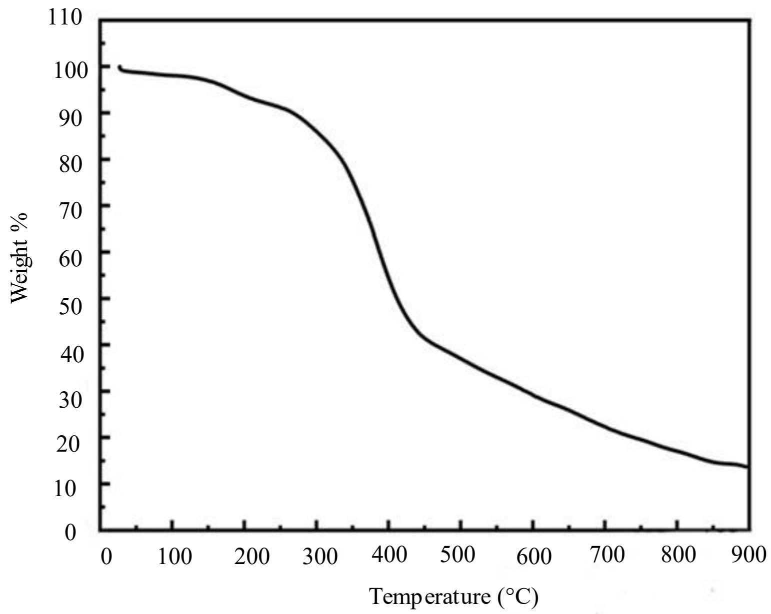

Figure 5. Thermo-Gravimetric analysis of NaCl treated Muntingiacalabura reinforced composites.

FTIR Analysis

The FTIR spectrum of the material, as displayed in Figure 6, exhibits multiple conspicuous absorption peaks that were investigated to determine the functional groups present. A large absorption peak detected at around 3400 cm^{-1} suggests the presence of hydroxyl (O-H) groups, which is characteristic of alcohols, phenols, or carboxylic acids. The hydrogen bonding in these compounds greatly broadens the peak [15]. The absorption peak about 2900 cm^{-1} is due to the stretching vibrations of C-H bonds, typical of aliphatic hydrocarbons, showing that the sample comprises saturated alkyl chains, as found in alkanes [16]. A prominent signal about 1700 cm^{-1} corresponds to the C=O stretching vibration, which is a strong diagnostic of carbonyl groups. This peak is typically detected in compounds such as ketones, aldehydes, carboxylic acids, and esters, demonstrating that carbonyl-containing functional groups are integral to the molecular structure of the sample [17]. Additionally, the peak detected at 1600 cm^{-1} may be connected with C=C stretching vibrations, characteristic of alkenes or aromatic rings, indicating the existence of unsaturated carbon bonds or aromatic structures within the sample [18]. The area between 1200 and 1000 cm^{-1} reveals many absorption peaks, possibly owing to C-O stretching vibrations, which are typical of ethers, esters, or alcohols. This shows that the sample contains these sorts of functional groupings [19].

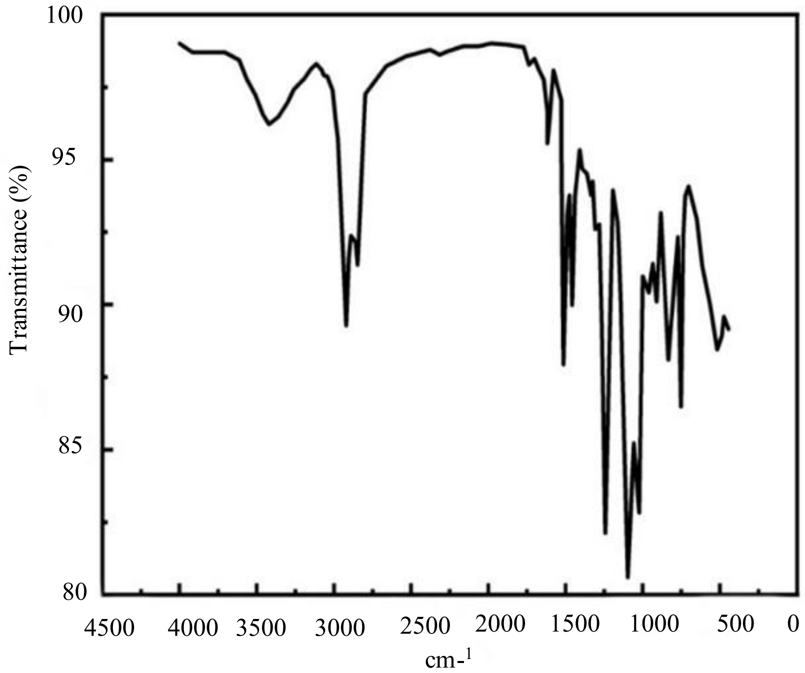

Figure 6. FT-IR analysis of NaCl treated Muntingiacalabura reinforced composites

CONCLUSIONS

The effects of NaCl treated Muntingiacalaburafibre reinforced composites were analysed in this work, with the increase of NaCl concentration from 5 to 15% and the fibre weight maintained constant enhances the mechanical properties and thereafter the strength of the composites gradually decreased due the excess of NaCl concentration, more avoids present in the composites. Pull outs are observed with the SEM analysis which indicates that good interfacial bonding between the fibre and matrix. The amount of residue that can be remained in the composite is approximately negligible which indicates that the composites are bio-degradable. Various functional compounds were observed through FT-IR analysis.

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