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Bangladesh J. Sci. Ind. Res. **59(1)**, 17-26, 2024

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

ISSN. 0304-9809

Extrinsic properties of unsaturated polyester resin-based hybrid composite reinforced with waste-fibers versus waste-fibers and talc: A comparative study

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ARTICLE INFO

Received: 04 December 2023

Revised: 24 January 2024

Accepted: 25 January 2024

eISSN 2224-7157/

DOI: https://doi.org/10.3329/bjsir.v59i1.69839

Abstract

This study demonstrates a comparative study on the mechanical, thermal, and morphological properties between waste-fibers/unsaturated polyester (WF/PE) and talc/waste-fibers/unsaturated polyester (T/WF/PE) hybrid composite. Here, reinforcing materials came from discarded coir doormats and jute sacks. The waste fibre was treated with NaOH and then embedded into the polyester matrix using a cold compression moulding technique. On the other hand, talc filler and waste-fibres reinforced polyester resin hybrid composite was developed using the same technique, and a comparative study was performed. WF/PE hybrid composite showed tensile and flexural strength of 36.67 MPa and 38.76 MPa respectively. Talc filler-filled T/WF/PE hybrid composite reported 23.95 MPa of tensile strength and 65.2 MPa of flexural strength. Average Leeb's robust hardness (LRH) was found 495.667 and 524.75 for WF/PE and T/WF/PE respectively. T/WF/PE hybrid composite presented low-temperature thermal degradation compared to WNF/PE hybrid composite. Surface morphology studies showed that coagulation of fibres, voids, and fibre pullout at the inner interface of the composite was a common phenomenon for both composites. WF/PE composite showed higher electrical resistivity to applied voltage compared to T/WF/PE. Water absorption studies showed that talc filler boosted the water adsorption of the T/WF/PE hybrid composite.

Keywords: Discarded doormat; Discarded jute sack; Mechanical properties; Thermal properties; Surface morphology; Water absorption

Introduction

Aiming to have a sustainable environment, scientists are focused on developing materials from biomass sources (e.g., natural fibers), which will help to inhibit the production of traditional plastic materials (Thakur *et al.* 2014; Mulinari *et al.* 2011). According to sustainable environmental policy, biodegradable composites are promising materials fabricated from biomass feedstock (e.g., jute, coir, sisal, pineapple, bamboo, banana, etc.), with a wide range of mechanical properties and thermal properties along with ensured decomposability (Brinchi *et al.* 2013). Hence natural fibres are cheap, renewable, ubiquitously available in nature (Thakur *et al.* 2014; Mulinari *et al.* 2011; Brinchi *et al.* 2013) and widely used for conventional household products like baskets, brushes, doormats, sacks etc. These products are usually discarded after a one-time application.

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These conventional products consume a very small portion of total coir and jute volume all over the world, and the remaining part is out of potential application and considered waste materials. These waste natural fibers could be employed as reinforcing materials in hybrid composite in the substitution of industrial fibers (reference application of sisal, bamboo, coir and jute natural composites in structural upgradation). several reports have been found regarding natural fibers such as jute fibers (Sanjay *et al.* 2018), coir fibers, flax fibers (Shenoy Heckadka *et al.* 2022), sisal fibers (Ferreira *et al.* 2019), and others where they were utilized as reinforcing material in polymer composite (Madhusudhana Reddy *et al.* 2014; Kumar *et al.* 2012) because of their higher mechanical and physical characteristics in relation to high lignin content, microfibrillar angle, and strain value (reference Mechanical performance of coir fiber/polyester composites). Moreover, these waste-fiber processes lack toxicity, no processing temperature, biodegradability, and no CO_2 emission (Saheb and Jog, *et al.* 1999) when they are deployed in a polymeric matrix composite. Unsaturated polyester resin is a popular thermosetting polymeric matrix material widely used in industrial applications due to its stable mechanical and thermal properties (Tsunemi *et al.* 1991; Kim *et al.* 2007). In recent decades, natural fiber-reinforced polymeric hybrid composite has gained popularity and significant attraction due to sustainable environmental concerns (Thakur *et al.* 2014; Mulinari *et al.* 2011). These hybrids composite exposed excellent function in regard to water absorption, thermal and mechanical properties. Moreover, they could provide enhanced modifying material properties based on unique characteristics of the constituents, which have been proved from several previous investigations (Ganesan *et al.* 2021). In this regard, Ganesan *et al.* (2021) studied water absorption behaviors and mechanical properties of jute/coir fibers/ waste eggshell powder (ESP)/montmorillonite nano clay fillers reinforced polyester composite under dry and wet (river and sea water) environmental conditions. Results showed that the introduction of fillers into the composite increased the tensile and flexural properties of the composite, and the composite exhibited better functions under variable environmental conditions rather than non-fillers. Gopinath *et al.* (2018) investigated jute and coconut fibre with polyester resin and epoxy resin. They established that fiber composite with epoxy resin matrix exhibited improved mechanical properties than polyester resin. Sanjay *et al.* (2018) analyzed the hybridization of synthetic fiber with jute kenaf fibre epoxy composite; the result depicted that glass/jute/kenaf hybrid composite exhibited low moisture absorption. Monteiro *et al.* (2008) evaluated the structural and mechanical characteristics of coir fiber and polymer composites. They found the flexural property of composite varies with the mass fraction of coir fiber and moulding pressure of composite fabrication.

Furthermore, several researchers studied the reinforcement effect of filler, and the results showed composites exhibited less void and better mechanical, thermal, and physical properties. In these consequences, Ibrahim *et al.* (2011) reported that oil palm ash (OPA)-polyester composite disclosed maximum tensile strength and flexural strength of 21 MPa and 78.17 MPa, respectively. The thermal stability of composites increased as the OPA filler content was increased. Maximum mass loss of composite containing 30% OPA occurred at 476.23ºC, and the thermal degradation of the composite was retarded above 500ºC due to the increase in ash content. Jaafar and Hussein, (2017) found that the thermal conductivity of talc-epoxy composites increased with the rise of talc content.

Various studies have been performed regarding coir and jute mat-reinforced PE hybrid composite. No study is yet to be performed fabrication of WF/PE and T/WNF/PE hybrid composite from discarded doormats and sacks to date. Moreover, no comparative study has been performed between WF/PE and T/WF/PE hybrid composite as per the literature review. In this study, WF/PE and T/WF/PE hybrid composite are compared according to their water adsorption, mechanical and thermal properties.

Materials and methods

The waste jute mat was collected from a used jute sack, which was discharged after using rice storage. Coconut coir was collected from the discarded doormat. Analytical grade unsaturated polyester resin (PE) (Shiv Corporation, India) was used as a polymer matrix. Methyl ethyl ketone peroxide (MEKP) (Scharlau, Spain) was used as an accelerator. Reagent sodium hydroxide (Scharlau, Spain) was used to treat waste coir fiber and jute mat. Technical grade talc (Shiv Corporation, India) was used as a filling agent. All chemicals were used without purification. Deionized water was used for washing and alkali treatment of fibers.

ST-I. Mechanical properties of PE

Mechanical properties	Value
Tensile strength	53.67 Mpa
Flexural strength	81.20 Mpa
Leeb rebound hardness	769

Preparation of alkali-treated coir fiber and jute mat

At first, waste-fibre materials were washed several times with distilled water to remove dust and dirt (Fig. 1). Then, those were dried in the sunlight for a week. For better adhesion among fibers, both materials were treated with 10% NaOH solution for 24 hrs at room temperature, followed by Ganesan *et al.* (2021).

hybrid composite, 40% weight mass of coir and jute mat having the same ratio was mixed with 52% and 8% PE and talc, respectively. MEKP was added to the PE, and the mixture was homogenized using a homogenizer. Mould with dimensions 300×200×3 mm^3 was coated with wax, and then the jute mat and coir were placed in the mould by sandwiching the coir between two jute mats to make the jute

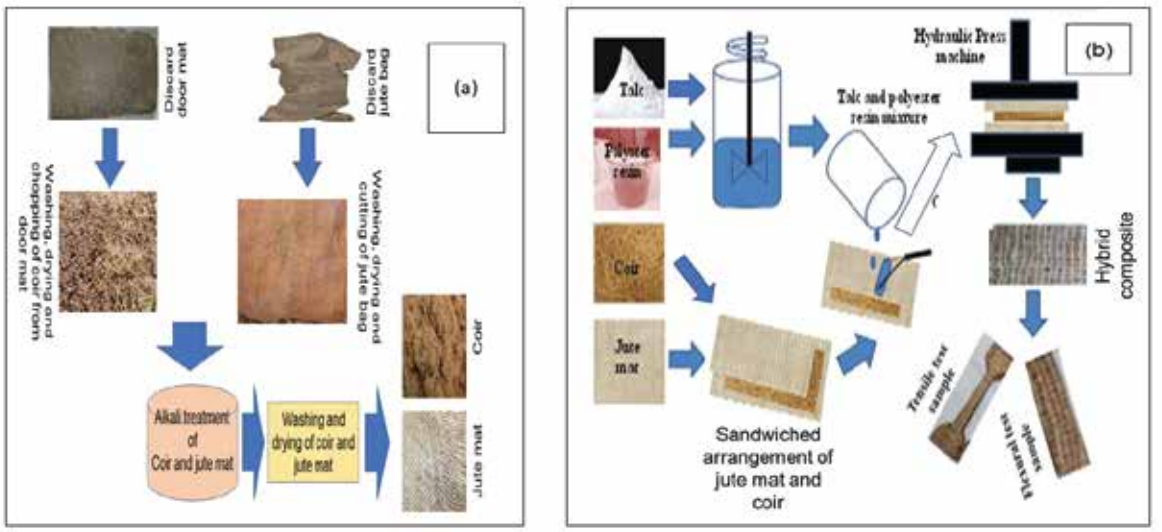

Fig. 1. Preparation of coir and jute mat (a), preparation of hybrid composite (b)

The reaction of alkali with fibre is as follows.

Cell-OH +NaOH→ Cell-O-Na + H_2O + (Surface impurities)

The excess NaOH from the fiber surface was removed by washing it with dilute H_2SO_4 water. The coir fibers were further washed with distilled water several times to remove excess NaOH. Then, the coir was oven-dried at 60ºC for 48 hrs. Preparation of reinforcing fibers is shown in Fig. 1 (a).

Fabrication of hybrid composites

The composite fabrication was done by combining the hand lay-up method with the mould cold compression method (Ganesan *et al.* 2021). Hybrid composite fabrication is present in Fig. 1 (b). The treated coir was chopped and screened by 2mm mesh sieves. The treated jute mat was cut into 22-23 cm length and breadth. Both fibrous materials were dried at 56ºC for 24 hrs in the oven to remove moisture. Moreover, talc was also dried overnight in the oven at 80ºC. For preparing the WF/PE hybrid composite, 40% weight mass of coir and jute mat having a 1:1 ratio was mixed with 60% weight percentage of PE. Furthermore, the T/WF/PE

mat–coir–jute mat sandwiched. The weight of the individual mat was approximately 10 gm (% wt.). Then the mixture was applied on the jute mat-coir-jute mat sandwiched, and another half of the wax-coated mould was placed over the sandwiched structure, and then the mould was closed. This closed mould was transferred into the Weber Hydraulic Press machine, where 10 bar pressure was applied for 6 hrs at room temperature. After removing from the Hydraulic Press machine, the prepared composite was left to cure at room temperature for another 2 hrs before being removed from the mold.

To prepare T/WF/PE hybrid composite, talc was added with PE; then, the mixture was mechanically stirred for 1hr at 200 rpm. After homogenization of the mixture, MEKP was added to the mixture. Sticking of composite in the steel mould was avoided by using the wax coating. Mould with dimensions 300×200×3 mm^3 was coated with wax, and then the jute mat and coir were placed in the mould by sandwiching the coir between two jute mats to make the jute mat-coir-jute mat sandwiched. The weight of the individual mat was approximately 10 gm (wt.%). Matrix mixture was poured

into the arrangement. Wax-coated another half of the mould was placed over the sandwiched structure, and then the mould was closed. This closed mould was transferred into the Weber Hydraulic Press machine, where 10 bar pressure was applied for 6 hrs at room temperature. After removing from the Hydraulic Press machine, the prepared composite was left to cure at room temperature for another 2 hrs. before being removed from the mold.

Characterization of composite

Mechanical properties

Tensile properties

The ASTM D 3039M method was followed to characterize the tensile properties of the composite using the universal testing machine (UTM) (HK10K, Hounsfield, UK) with a load cell of 10 tons. The specimen size of the test sample was 100 x 19 x 4 mm^3. For the measurement, pieces were clamped between the two jaws of the UTM and operated at the cross speed of 10 mm/min. The values were reported by taking the average of at least 10 measurements.

Flexural properties

According to the ASTM D790M method, the flexural properties of the composites were determined using UTM (HK10K, Hounsfield, UK) with a load cell of 10 tons. The required dimension of the test specimen was 130 x 19 x 4 mm^3. The experiment was conducted by placing the test specimen in a support span length of 60 mm, and the test speed of UTM was 2 mm/min. The results were taken as an average of at least 10 measurements.

Leeb's rebound hardness

The Leeb robust hardness test of the composites was carried out with an H1000 portable hardness tester (HARTIP-1000, QUALITEST, Canada) according to ASTM A956-06. The hardness of both sample surfaces was assessed at ten separate points.

Thermal properties of composite

Thermo-gravimetric analysis

Thermo-gravimetric analysis (TGA) was carried out using a thermo-gravimetric analyzer (EXSTAR 6000 TG/DTA 6300, SEIKO). The samples were placed in an aluminium sample holder, and the mass loss was detected as a function of temperature with a resolution of 0.1 mg. Analysis was carried out in an inert atmosphere of nitrogen (purity >99.5%) at a flow rate of 50 ml/min and with a temperature range of 30ºC to 600ºC at different heating rates of 5, 10, 20, 30, and 40ºC/min respectively. Any unwanted oxidative decomposition was prevented by purging the furnace with nitrogen gas for 30 minutes.

Thermal conductivity

The thermal conductivity of the composite was done according to the ASTM E1530 method using a thermal Conduct meter (Model: Huber, Polystat CC1). Fourier's Law evaluated the thermal conductivity of the composite for one-dimensional heat conduction at steady-state conditions.

Morphological characterization of composite

Interfacial properties such as fiber-matrix interaction, talc–matrix interaction, void spaces, talc agglomeration, fracture behavior, and fiber pull out of the sample after tensile tests were studied using a scanning electron microscope (Model: EVO-18, Carl Zeiss, Germany). The fractured and cross-section portions of the sample were cut and placed aluminium coated over the surface uniformly for examination. The accelerating voltage used in this work is 5 KV.

Water absorption

The rate of water absorption was conducted by applying the below-mentioned equation at different time intervals under room temperature.

$$wt.\ \% = \frac{wt - wi}{wi} X\ 100 \quad (1)$$

Where wt. is the sample weight at time t hr and wi is the initial sample weight.

Electrical resistivity

It can be calculated by using an LCR meter and following the equation below. The samples were fixed between two electrodes.

$$p = RA/t \quad (2)$$

Where, A - area of cross-section of the sample, R - resistance, t - thickness of the sample.

Results and discussion

Mechanical properties

Tensile strength (TS)

Fig. 2(a), shows the tensile strength of the hybrid composites. The mean tensile strength was detected at 36.6 MPa with a

range of 30.02 to 40.62 for WF/PE hybrid composites, while T/WF/PE showed between 21.67 and 25.44 with an average tensile strength of 23.95 MPa with a range. Talc reinforcement decreased 34.66% tensile strength of T/WF/PE hybrid composites compared to WF/PE. Coagulation of talc (Yu *et al.* 2012) and random orientation of coir fibre in the matrix might be the probable reasons for

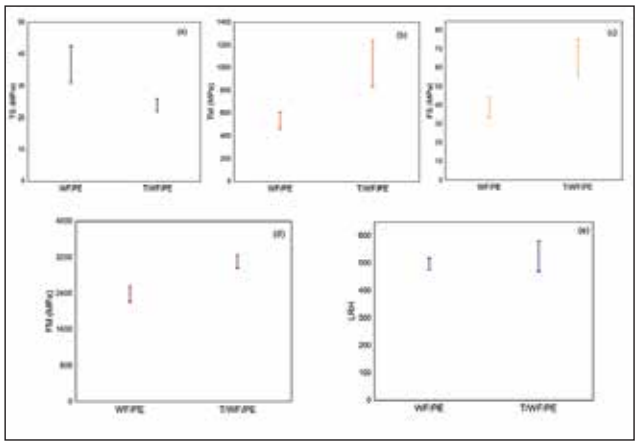

Fig. 2. Mechanical properties

decreasing tensile strength. Studies have demonstrated the addition of fillers lowers the TS of the composite by resisting the formation of strong hydrogen bonding between fiber and matrix (Gbadeyan *et al.* 2020). The tensile strength of PE was reported approximately 19.7 MPa by Rodrigues *et al.* (2011). Tabatabai *et al.* (2018) investigated the tensile strength of PE was about 11 MPa. Therefore, the incorporation of hybrid fibres and filler increased the tensile strength of the developed composites of this study. Acharya *et al.* (2008) presented that 50-60% of the volume fraction of jute fiber with 15% fly ash reinforced polymer composite gives an optimum value of stress to failure 40 MPa, which is approximately two times higher than the tensile strength of T/WF/PE hybrid composites. Ganesan *et al.* (2021) demonstrated that jute fabric and coir mat-based hybrid composite filled with ESP and MMT-NC fillers in a polyester resin matrix showed a maximum tensile strength of 24.57 MPa. The reported value is quite similar to this study. Singh *et al.* (2021) claimed that coir and jute fibres reinforced epoxy resin hybrid composite showed a maximum tensile strength of 16.6 MPa. The demonstrated value is twofold less than the TS of the WF/PE hybrid composite. Hence, hybrid composite WF/PE processes a higher percentage of TS compared to T/WF/PE.

Tensile modulus (TM)

The TM of the WF/PE and T/WF/PE hybrid composite is shown in Fig. 2(b), where T/WF/PE shows more than two folds of TM compared to the WF/PE hybrid composite. The range of TM for WF/PE was detected between 451 and 592 MPa (mean: 535 MPa), while TM was found with a range of 911 to 1272 MPa (average 1037 MPa) for T/WF/PE hybrid composite. The incorporation of filler that restrains the motion of the matrix phase in the proximity of each particle consequently contributes to the enhancement in modulus and stiffness (Siddika *et al.* 2013). The filler was stiffer than the matrix, and it deformed less under load. That caused an overall reduction in matrix strain, especially in the vicinity of the filler in the filler-matrix interface (Whaling *et al.* 2006).

Flexural strength (FS)

As shown in Fig. 2(c), the optimum mean FS of WF/PE and T/WF/PE is 38.76 MPa (32.63-42.32 MPa) and 65.2 MPa (58.97-76.46 MPa) respectively. The result shows that the FS of the hybrid composite increased with the incorporation of talc filler. Filler accelerates the mechanical strength of the composite by filling interfacial spaces, which helps to provide proper adhesion between the matrix and fibers and control the elasticity of the composite (Mortazavi *et al.* 2012). Singh *et al.* (2021) reported that jute/coir/epoxy resin hybrids composite exhibits FS 14.83 MPa, which is approximately one-third FS of WF/PE. Hybrid fillers/hybrid fibers reinforce hybrid composite exhibited FS 46.97 MPa reported by Ganesan *et al.* (2021). The reported value of the hybrid composite is much lower than FS of T/WF/PE. Higher resistance to bending rapture of talc compared to montmorillonite nano clay and eggshell powder fillers might be the probable reason for lower FS in hybrid fillers/hybrid fibers reinforcing hybrid composite.

Flexural modulus (FM)

Fig. 2(d), depicts the improved mechanical property of T/WF/PE caused by the addition of talc filler in the matrix-enhanced FM value of the same sample. T/WF/PE shows 30.47% higher FM than WF/PE as talc could control matrix mobility under applied load, which might be the probable reason for showing a higher value of FM for composite T/WF/PE. T/WF/PE shows mean FM at 3104, and WF/PE presents an average FM 2379 MPa (2257-2573 MPa) (Fig. 2d). ESP/MMT-NC hybrid fillers in jute/coir hybrid composites showed about 1750 MPa FM, which was much lower than the studied values (Ganesan *et al.* 2021).

Leeb's rebound hardness (LRH)

The LRH of WF/PE and T/WF/PE hybrid composites are shown in Fig. 2(e), with values ranging from 476 to 520 and 475 to 601, respectively. T/WF/PE exhibited a higher value of LRH than WF/PE. This is because the internal voids between the matrix and fibers, which induce fracture initiation under load, may be reduced by the incorporation of talc filler. Additionally, optimal filler distribution, aligned fiber orientation, and appropriate interfacial bonding all contribute to composites' hardness.

Thermal properties

Thermogravimetric analysis

TGA is used to investigate the degradation temperature of composite, weight loss due to temperature, and amount of residual material after applying the height temperature (Veerasimman *et al.* 2022). Cellulose, polymer and talc usually undergo degradation at the corresponding temperature through three stages of degradation. Firstly, moisture removal starts between room temperature and 150ºC. Secondly, the degradation of cellulosic materials like hemicellulose, lignocellulose and lignin occurs between 200ºC and 500ºC. Thirdly, degradation happens due to de-polymerization of the matrix (Arifuzzaman Khan *et al.* 2012). The thermal degradation of fiber composites is characteristic of fiber–matrix interaction and strength of fibre, thermal characteristics of the fiber, and matrix. As shown in Fig. 3(a), WF/PE showed 10% and 60% weight loss at 280.30ºC and 392.28ºC, respectively, with a major degradation ranging between 300ºC and 450ºC. However, the degradation temperature of T/WF/PE was found to be about 276.75ºC and 388.71ºC, respectively, for the same weight loss, with major degradation ranging from 250ºC to 450ºC. This may cause the addition of talc in the composite to decrease the thermal stability of the composite by reducing available matrix and agglomeration. Moreover, this agglomeration imparts additional degradation from shearing and greater water retention in the available voids from the atmosphere, resulting in the degradation of the T/WF/PE hybrid composite at lower temperatures (Snowdon *et al.* 2019). At 580ºC, approximately 10.82% and 19.52% residues were found for WF/PE and T/WF/PE composites. Degradation of talc usually occurs above 800ºC; this might be the probable reason for obtaining a higher percentage of char residues for T/WF/PE than WF/PE. Therefore, filler reinforcement faster the initial degradation and delays the final degradation temperature of the composites.

Jute and sisal alkalinized hybrid composite showed a similar percentage of char residue between 480–600ºC reported by Neto *et al.* (2019). reported that charcoal-filled sisal polyester hybrid composite showed higher thermal stability compared to sisal polyester composite and left around 30-40% of weight even after the degradation at 450°C, indicating more thermal stability of composite compared to composites of this study. The thermal stability of Kenaf/sisal hybrid composites containing 20% sisal fibre and 20% Kenaf fibre was reported by Nimanpure *et al.* (2019). Kenaf/sisal hybrid composite showed a weight loss of 10% at 300°C, which is higher than prepared composites of this study. Sumesh *et al.* (2019) showed thermal stability of sisal, banana, and coir fibres hybrid had increased by around 20% due to the incorporation of biosynthesized alumina nanoparticles. Venkatram *et al.* (2016) reported that the 3 wt.% nano clay incorporated sisal polyester hybrid composite showed 79% weight loss at 300°C while hybrid composite without nano-clay showed a major weight loss of 82% at 290°C, indicating lower thermal stability compared to studied composites.

DTG curves for WF/PE and T/WF/PE represent the degradation of fibre matrix and talc by maximal kinetics through different peaks (Fig. 3b). WF/PE showed degradation at 355.3°C and 395.5°C with a degradation rate of 0.682 µg/min and 0.977 µg/min respectively. This thermal degradation might result from the degradation of cellulosic materials like α-cellulose and lignocellulose. Similarly, T/WF/PE showed three degradation peaks at about 80, 351.2 (1.609 µg/min) and 389.8°C (1.066 µg/min). The first peak at 80°C indicates degradation due to moisture loss as fibers show an endothermic peak within the range of 30 to 120ºC. The remaining two peaks show degradation due to cellulosic materials. Thus, it can be concluded from the DTG studies

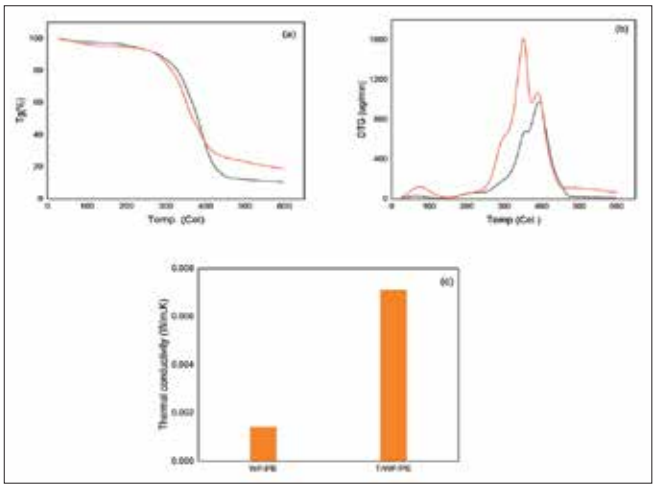

Fig. 3. Thermal properties (black line for WF/PE; red line for T/WF/PE)

that the rate of thermal decomposition of T/WF/PE was higher than WF/PE. Agglomeration of talc in the matrix and less available matrix may cause deboning between matrix and fibres which resulted in degradation of T/WF/PE composite at a lower temperature compared to WF/PE.

Thermal conductivity

Fig. 3(c), shows the effect of filler loading on the thermal conductivity of composites at 80ºC. T/WF/PE showed higher thermal conductivity (0.0071 W/m. K) than WF/PE composites, possibly because talc was more thermally conductive than polymer and fibers. T/WF/PE composite shows five-fold more thermal conductance than WF/PE composite in the present study. Moreover, talc particles create a thermally conductive path in the composites, which initiates faster heat transfer in the composites (Suplicz and Kovacs, 2012). Fiber shows lower thermal conductivity than polymer, which might be the reason for the lower thermal conductivity of the WF/PE composite having no talc. Jaafar and Hussein (2017) reported the study of thermal conductivity and solution absorption for epoxy–talc composites. Composite showed increased thermal conductivity with the increment of the talc percentage.

Surface morphological characterization of composite.

The micrographs of the interface and extensive fibers pull-out from the fractured part of the composite are shown in Fig. 4(a–d). In Fig. 4(a), agglomerated fibers and air gaps (voids) are visible at 30 µm magnification for WF/PE. These bunches of fiber might reduce the mechanical properties of the composite. Moreover, no trace of sticking matrix in the fiber, possibly due to poor adhesion between fiber and matrix, and this poor adhesion results in lower mechanical strength. The coagulated fiber and talc with air gaps (voids) are observed in the composite interface at 20 µm magnification, shown in Fig. 4(b) for T/WF/PE. Random orientation of talc, as well as talc agglomeration, also hamper uniform stress transfer. Fiber pull-out from the fracture portion of the composite indicates the degree of adhesion between fiber and matrix (Saw *et al.* 2014). Fig. 4 (c-d) show extensive fiber pull-out from the tensile fractured surface at 100 µm magnification for both hybrid composite, indicating a lack of adhesion between fiber and matrix.

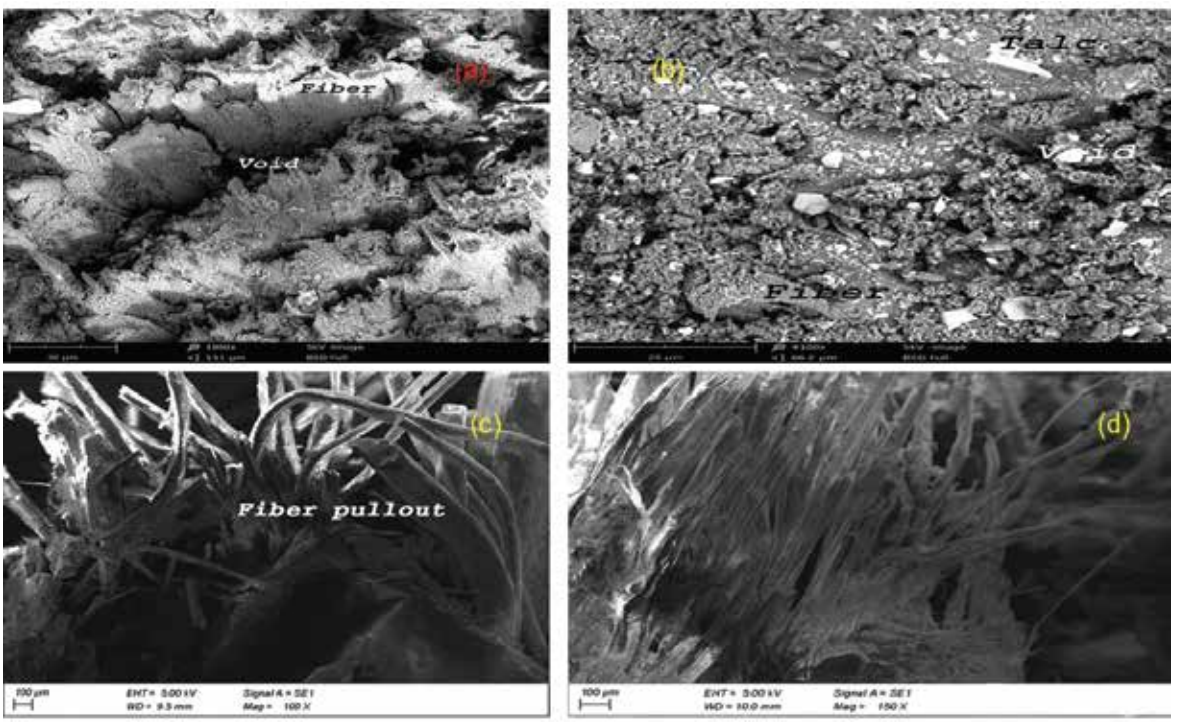

Fig. 4. Cross sectional area of WF/PE (a), cross sectional area of T/WF/PE (b), tensile fibre pulls out of WF/PE (c), and tensile fibre pulls out of T/WF/PE (d)

Water absorption

Fig. 5 shows the water absorption of the hybrid composite. T/WF/PE shows the highest percentage of water absorption over 144 hrs, possibly due to the hydrophilic nature of both talc and fiber (Rozali *et al.* 2017). However, WF/PE composite without talc absorbed a lower percentage of water with a range from 0 to 5.12% in 7 days due to the hydrophobic nature of the polyester resin.

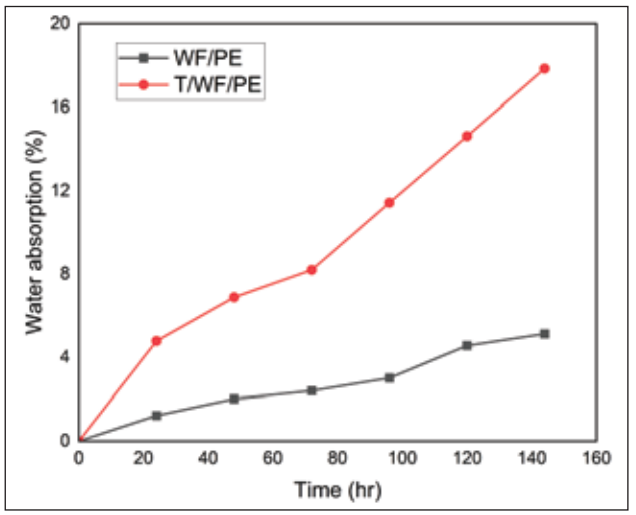

Fig. 5. Water absorption

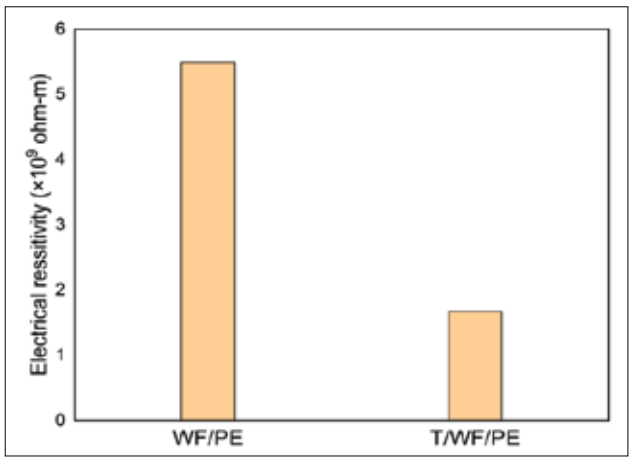

Fig. 6. Electrical resistivity

Surface electrical resistivity

The electrical resistance to leakage current along an insulator's surface is known as a material's surface resistivity. As shown in Fig. 6, the electrical resistivity of the composite declined with the addition of the talc. This is due to talc's sheet-like structure and increased surface area, leading to a wider open channel for free electrons to travel through the polymer matrix.

Conclusion

The present study demonstrates a comparative study of mechanical and thermal properties between waste-fibers/unsaturated polyester resin hybrid composite and talc/waste-fibers/unsaturated polyester resin hybrid composite using discarded coir doormat and jute sack. Reinforcement of talc declined TS of T/WF/PE composite compared to composite without talc WF/PE. However, T/WF/PE showed higher TM, FS, FM and LRH values than WF/PE. T/WF/PE attributed less thermal stability compared to WF/PE, while it demonstrates higher thermal conductivity to WF/PE. SEM images showed agglomeration of talc in the T/WF/PE hybrid composites. Voids and dis-orientation of fibers were seen for both composites, while no visible matrix was seen for both composites. Water absorption studies demonstrate that T/WF/PE is more hydrophilic compared to WF/PE. WF/PE showed better insulating properties compared to T/WF/PE due to high electrical resistivity. Finally, both composites might be a potentially viable environmentally friendly material for false ceilings, internal partitions, furniture, interior parts of vehicles (inner fenders and bumpers), and other low-load applications. For commercial applications, further study is required to find optimum conditions.

Author contribution

Conceptualization, Aynun Nahar; Data curation, Aynun Nahar, Nigar Sultana Pinky, Aninda Nafis Ahmed; Formal analysis, Methodology, Aynun Nahar; Resources, Sajib Aninda Dhar and Md. Abdul Gafur; Supervision, Md. Abdul Gafur, Muhammed Yusuf Miah, Md. Ashraful Alam and Fataha Nur Robel; Visualization, Monika Mahmud, Fataha Nur Robel and Muhammad Shahriar Bashar; Writing – original draft, Aynun Nahar; Writing – review and editing.

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