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Enhancing the Performance of Lignocellulosic Textile Fabrics by Chemical Treatment and Filler Modification

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ABSTRACT

To improve the durability of lignocellulosic jute textiles, the raw woven fabric (plain weave) was treated with alkali and aloe vera solution. A coating of unsaturated polyester resin was employed to protect the jute textiles from outdoor environmental degradation. The initiator for the resin was methyl ethyl ketone peroxide (MEKP). To further improve the performance of the polyester-coated jute textiles, 10% $Ca(OH)_2$ fillers were mixed with the resin. Hence, the developed jute textile samples were – J0 (raw jute textile), J1 (alkali and aloe vera treated and polyester resin-coated jute textile), and J2 [$Ca(OH)_2$ filler-modified textiles of J1]. The physico-mechanical characteristics of all the jute textile samples were examined and evaluated via tensile, moisture, and water uptake performances. It was revealed that tensile breaking strength increased by 56% and 129% for J1 and J2 textiles, respectively, compared to the J0. The filler content samples (J2) also demonstrated an enhanced moisture resistance performance compared to J0. Further characterization was performed using FTIR (Fourier Transform Infrared) spectroscopy, TGA (Thermogravimetric Analysis), and SEM (Scanning Electron Microscopy) analysis. The aging test demonstrated improved properties for the modified jute textile samples in acidic and salt solutions, but weight loss occurred in alkaline solutions.

摘要:

为了提高木质纤维素黄麻纺织品的耐久性，用碱和芦荟溶液处理了平纹织物. 采用不饱和聚酯树脂涂层保护黄麻纺织品免受室外环境退化. 树脂的引发剂是过氧化甲乙酮（MEKP）. 为了进一步提高聚酯涂层黄麻纺织品的性能，将10%的Ca（OH）2填料与树脂混合. 因此，开发的黄麻纺织品样品是-J0（生黄麻纺织品）、J1（碱和芦荟处理的聚酯树脂涂层黄麻纺织品）和J2[Ca（OH）2填料改性的J1纺织品]. 通过拉伸、吸湿和吸水性能对所有黄麻纺织品样品的物理力学特性进行了检查和评估. 据透露，与J0相比，J1和J2纺织品的拉伸断裂强度分别提高了56%和129%. 与J0相比，填料含量样品（J2）也显示出增强的防潮性能. 使用FTIR（傅里叶变换红外）光谱、TGA（热重分析）和SEM（扫描电子显微镜）分析进行了进一步的表征. 老化试验表明，改性黄麻纺织品样品在酸性和盐溶液中的性能有所改善，但在碱性溶液中出现了重量损失

KEYWORDS
Jute fibers; natural fibers; polyester resins; aloe vera; fillers; natural textiles

关键词
黄麻纤维; 天然纤维; 聚酯树脂; 芦荟; 填料; 天然纺织品

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Introduction

The natural lignocellulosic plant fiber "jute" has been employed in many sectors, such as clothing and garments, ropes, sacks, geotextiles, and composite materials (Akter, Sadekin, and Islam 2020; Akter et al. 2020; Jahan, Hossain, and Khan 2022; Shahinur et al. 2022). Jute fibers are more sustainable than synthetic fibers in terms of environmental impacts. The main ingredients in jute fibers are cellulose, comprising 59–71.5%, while other ingredients are hemicellulose (13.6–20.4%), lignin (11.8–13%), pectin (0.2–0.4%), waxes (0.5%) in their chemical structure. Their physical properties, such as density, length, diameter, and moisture content, are 1.3–1.49 g/cm^3, 1.5–120 mm, 20–200 μm, and 12.5–13.7%, respectively. The mechanical properties of the fibers are 8–78 GPa of tensile modulus, 320–800 MPa of tensile strength, 1–1.8% of elongation and approximately 30 of specific modulus (Dittenber and GangaRao 2012). They are nontoxic, available, low-cost, high-yielding, carbon-negative plants. The jute plant absorbs CO_2 and emits O_2 to the environment during its growth periods (Khan et al. 2015). The major producing countries are Bangladesh, India, and China (Jute Production by Country 2024). In Bangladesh, jute fiber is called the "golden fiber" due to the high foreign currency earnings from exporting it. It is of two classes, such as white and tossa jute.

Numerous attempts have been reported to enhance the performance and durability of jute textile fabrics (Khan et al. 2015; Sachin Chakravarthy, GuhaRay, and Kar 2021; Srishti, Sinhamahapatra, and Kumar 2023). Saha et al. (2016) utilized polyester resin (5–25%) in jute textiles of different structures (plain, twill, zigzag, and diamond weave), where 25% resin-manipulated jute textiles exhibited the optimum performance. The work proclaimed that at the optimum stage, the moisture content and water uptake diminished to about 50% and 60%, respectively, while the tensile strength was increased by approximately 19%. Other stiffness-related performances, such as bending length, bending rigidity, and modulus, were also enhanced by approximately 7%, 56% and 11%, respectively, for the case of 25% resin-manipulated jute textiles. Upon analyzing the degradation behavior under the soil environment, a significant improvement of tensile properties was revealed for the polyester-treated jute textiles (only 9% tensile strength degraded) compared to the virgin jute (34% tensile strength degraded). In the case of different weave structures, the plain weave demonstrated better tensile performances than other structures after the polyester treatment (Saha et al. 2016). Akter et al. (2018) studied two combinations of bitumen emulsion/polyester resin (20/10 and 10/20%) coated jute textiles. The 10/20% combination of bitumen emulsion/polyester demonstrated the optimum outputs, such as tensile strength boosting up approximately 61% and 45% in the direction of warp and weft, respectively. In the case of soil degradation, the virgin jute completely degraded after 90 days, while the polymer-treated jute retained 14–36% of its mass values. A significant improvement in moisture resistance was highlighted in the polymer-coated jute, i.e., moisture regain and moisture content dropped by approximately 30–32%, while the maximum water uptake diminished by approximately 44% (Akter et al. 2018). In a later study, Akter et al. (2020) applied gamma (γ) irradiation (dose range between 2.5 and 10 kGy) to these polymer-coated jute textiles, revealing remarkable moisture resistance performances. At the 5 kGy γ-dose, the highest enhancement of tensile strength (approximately 16–28%) was exhibited. Recently, Akter et al. (2025) pre-treated the jute textiles with HEMA (2-hydroxyethyl methacrylate), then coated them with polymer and irradiated, demonstrated better performances of tensile properties and moisture resistance behavior than the raw jute textiles. In addition, γ-irradiated textiles showcased good resistance to soil degradation and microbial invasion.

Recently, Ramasamy et al. (2023) studied various chemical treatments to enhance the performance of lignocellulosic natural fiber *(Cissus quadrangularis)*. They used a 5% concentration of different chemical solutions, namely NaOH, $MgCO_3$, Na_2CO_3, $NaHCO_3$, and $Ca(OH)_2$, and the best performance (tensile and thermal) was exhibited for the case of $MgCO_3$ treated fiber sample. Alkali (NaOH) treatment on the same fibers also reported physico-mechanical improvement for single fiber treatment case (Siva, Mobithis, et al. 2021). They also studied other chemical treatments to improve the performance of lignocellulosic fibers to apply them to composite materials (Ramasamy et al. 2022; Siva, Gopinath, et al. 2021; Siva, Kumar, and Mupparaju 2021). Cai et al. (2016) studied 5, 10, and 15 wt.% NaOH solution to treat abaca fibers for 2 h, exhibiting increased tensile properties and crystallinity after treatment with 5 wt.% solution. Gassan and Bledzki (1999) treated tossa jute yarns with NaOH (25%) solution at 20°C for 20 min, and unlocked the significant improvement of tensile strength (approx. 120%) and modulus (approx. 150%) values. Rawal and Sayeed (2014) reported 4% NaOH treatment with jute fibers and demonstrated that the tensile strength and secant modulus enhanced by 44% and 57%, respectively. In the case of NaOH-treated jute/PP (polypropylene), geotextiles reported a 38% increment in their puncture properties. Other studies on jute textiles were reported by Sachin Chakravarthy, GuhaRay, and Kar (2021) for alkali-activated binder-treated jute, Saha et al. (2012) for trans-esterified jute, Sayeed (2019) for alkali-treated jute/PP, Joshi and Midha (2022) for chitosan-treated jute, Thakur et al. (2021) for bitumen emulsion-treated jute. All the studies exhibited enhancement of the physico-mechanical properties of natural fibers as a function of alkali treatment.

The herbal leaf aloe vera (AV) is traditionally used for different biomedical applications as well as the functionalization of textile materials (Mondal and Saha 2019; Mondal, Saha, and Rahman 2021; Parveen et al. 2024). The AV leaf contains numerous chemical components such as polysaccharides, sugars, phenolic compounds, enzymes, minerals, organic acids, water- and fat-soluble vitamins, and so on (Hamman 2008; Mondal and Saha 2019; Parveen et al. 2024). Moreover, they exhibited tremendous properties for textile applications such as anti-septic, anti-microbial, anti-fungal, anti-bacterial, anti-viral, anti-oxidant, UV-protective, etc. (Hamman 2008; Mondal and Saha 2019; Parveen et al. 2024). In the case of cellulosic textile treatment with AV, improved physico-mechanical, anti-microbial, and UV-resistance properties were revealed by (Mondal and Saha 2019). Recently Dayan et al. (2024) used AV gel extract in jute/cotton/polyester composites, which exhibited decreased water resistance and mechanical performance. However, the thermal insulating properties were increased. Other uses of AV on cellulosic materials are reported by Canche-Escamilla et al. (2019), Saad et al. (2021), and Ghazal and Elshamy (2024).

The objectives of the work were to investigate the effect of chemical treatment and filler modification of woven jute textiles. To do so, first, the jute was treated with alkali and aloe vera (AV), then coated with unsaturated polyester resin. To further boost the performance, $Ca(OH)_2$ fillers were mixed into the polyester polymer. The developed jute textiles were characterized via moisture, water uptake, and tensile testing. Further characterization was performed using FTIR (Fourier Transform Infrared) spectroscopy, TGA (Thermogravimetric Analysis), and SEM (Scanning Electron Microscopy) analysis.

Materials and methods

Materials

Jute woven fabrics (1 × 1 plain weave) were purchased from the local market of Tangail, Bangladesh. Aloe vera (AV) was collected from Tangail. Unsaturated polyester resin, methanol, MEKP, and other chemicals were purchased from the local market of Dhaka, Bangladesh. The specifications of raw (untreated) jute fabric are presented in Table 1, and the properties of unsaturated polyester resin are presented in Table 2.

Methods

Jute geotextile preparation

Figure 1 represents the process flow chart of the treatment of jute textiles. The untreated or raw jute fabrics (J0) were cut into small pieces (24 inch × 16 inch). First, the jute fabric was treated with a 5 wt.% NaOH solution for 1 h. The 5 wt.% alkali solution was selected based on the literature (Cai et al. 2016; Rawal and Sayeed 2014). Then, it was dried at 80°C for 2 h.

Table 1. Specifications of raw jute fabric.

Parameters	Values
Weave structure	1×1 plain weave
GSM	600
Thickness (mm)	0.89
EPI (Ends per inch)	13
PPI (Picks per inch)	12
Warp count	10
Weft count	10

Table 2. Properties of unsaturated polyester resin (Das, Paul, et al. 2021).

Properties	Values
Appearance	Opaque
Viscosity at 30°C	4–5
Water absorption (%) (7 day)	0.35
Heat distortion temperature (°C)	67.3
Elongation at break (%)	3.2
Bending strength (kgf/mm^2)	8.4
Bending modulus (kgf/mm^2)	536.1
Tensile strength (kgf/mm^2)	3
Impact strength (kgf-cm/cm)	3.9

Table 3. Sample formulation.

Symbol	Formulations
J0	Raw jute or untreated jute
J1	Alkali and AV-treated jute/polyester
J2	Alkali and AV-treated jute/polyester + $Ca(OH)_2$

The process of aloe vera (AV) gel extraction from the leaf is presented in Figure 2. First, a stainless-steel spoon was used to peel out the gel from the AV leaf, and then a blender machine was used to make the gel solution. Distilled water was mixed to prepare a 20 wt.% AV gel solution for the treatment of jute fabrics.

For the case of AV treatment, the alkali-treated jute samples were treated with this AV gel solution and impregnated in the solution for 1 h. Afterwards, the treated fabrics were removed from the solution and dried (80°C for 2 h) to prepare for the following process.

At this stage, the alkali and AV-treated jute samples were treated with polyester resin (50 wt.%) solution and cured according to the work of Akter et al. (2018). This sample is denoted as "J1" and presented in Figure 3(a). For the preparation of J2 samples (Figure 3b), the alkali and AV-treated jute samples were then treated with 10 wt.% $Ca(OH)_2$ mixed polyester resin solution, and following the same curing procedure Akter et al. (2018). Prior to the treatment, 10 wt.% $Ca(OH)_2$ was mixed with 50 wt.% polyester resin solution and stirred thoroughly. Table 3 shows the sample formulation.

Characterization

Tensile testing. The tensile breaking force of the specimens was measured according to the ISO 13,934/2 Fabric traction Grab Method. The test sample was cut 152.4 mm × 101.6 mm in both warp and weft directions. The machine worked at a constant rate of extension (CRE) of 50 mm/min, until it reached a breakpoint. The pretension was 0 N.

Moisture testing. The moisture regain (MR) and moisture content (MC) of the jute textile fabrics were calculated according to the procedures described in Akter et al. (2018, 2020) and using the following equations:

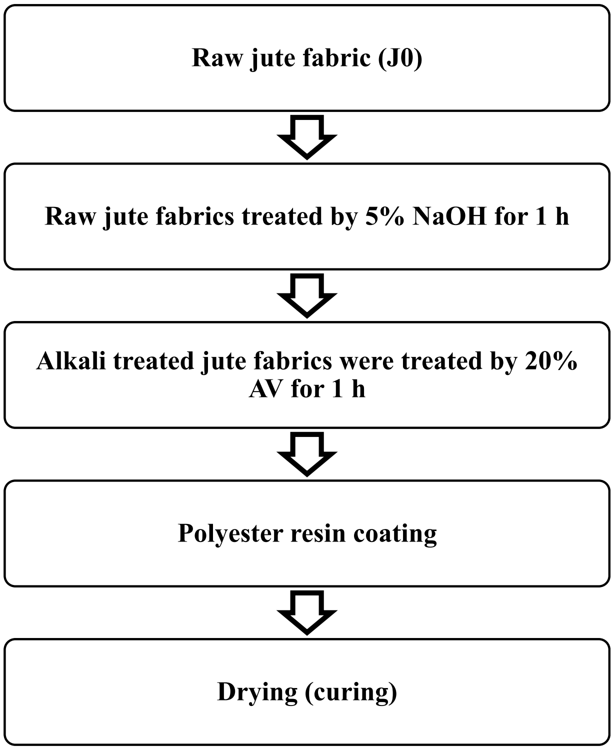


Figure 1. Process flow chart of the treatment of jute textiles.

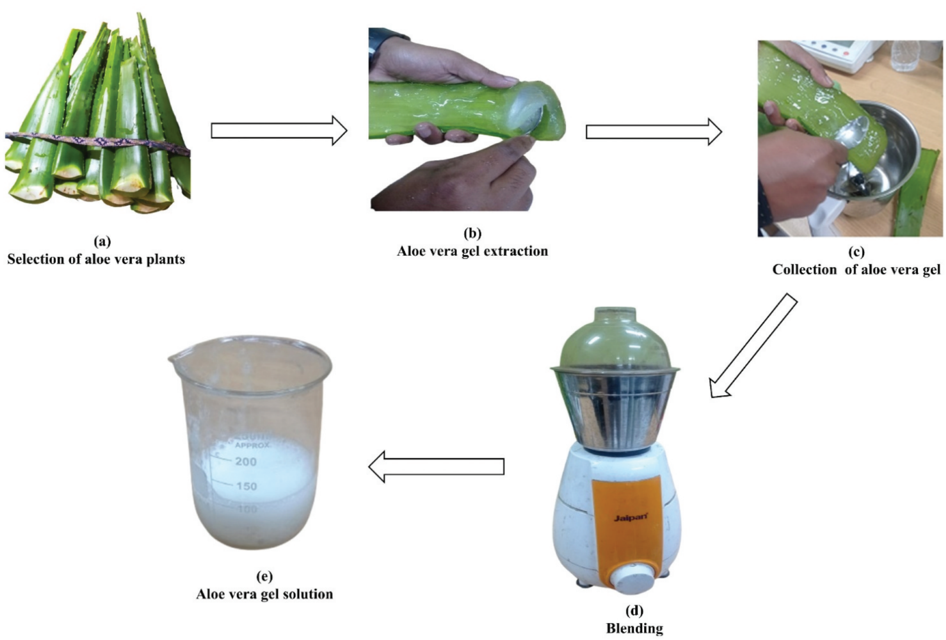
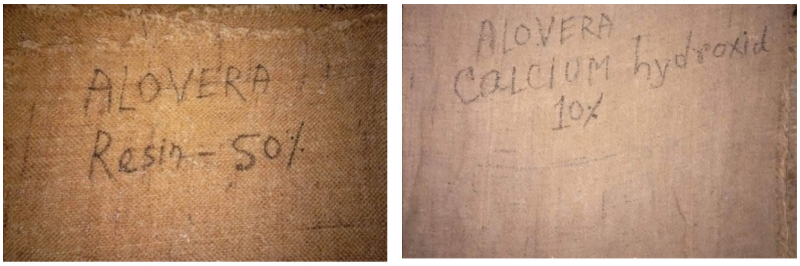


Figure 2. Extraction process of aloe vera gel.



(a) (b)

Figure 3. (a) AV-treated jute/polyester (J1), and (b) filler-modified jute/polyester (J2).

$$MR = W/D \times 100\% \quad (1)$$

$$MC = W/(W + D)x100\% \quad (2)$$

Where,
W = weight of water (A-D),
A = Weight of the sample before drying,
D = Moisture free weight after drying.

Water absorption. Water uptake of the jute fabric samples was performed per the compliance of British Standard 3449 (Hu 2008), and following the procedures in Akter et al. (2018, 2020). The following equation was used to calculate the water uptake (%):

$$\text{Water absorption}(\%) = \frac{\textit{Mass of water absorbed}}{\textit{Original mass}} \times 100 \quad (3)$$

FTIR spectroscopy. Fourier Transform Infrared (FTIR) analyses were conducted to characterize the treated and untreated jute and jute/polyester fabrics. Spectral data were obtained using a Thermo-Scientific™ Nicolet™ iS50 FTIR spectrometer (Thermo Fisher Scientific, USA), covering a wavenumber range of 500 to 4000 cm^{-1}.

TGA. The weight loss of the jute fabric samples *vs*. temperature was conducted in a TGA machine (Model: TGA 4000, Perkin Elmer). The temperature range was 50°C to 800°C, with a ramp rate of 10℃/min.

SEM. The surface morphology of the jute fabric samples was analyzed using a Scanning Electron Microscope (FE/SEM) (HITACHI SU/1510 in Japan).

Chemical aging. For the chemical aging test, three chemical solutions, 5 wt.% of alkali (NaOH), acid (HCl), and salt (NaCl), were used. The jute fabric samples (2 inch × 2 inch) were immersed in these solutions, and their weight gain or loss was observed after certain intervals of up to 288 h.

Results and discussion

Tensile properties

Figure 4 represents the tensile properties of raw (J0) and treated jute (J1 and J2) samples. The tensile breaking strength and elongation at break of the J0 textiles were 191 N and 2.5%, respectively. After the chemical treatment, the strength of the samples became 298 N for J1 and 437 N for J2, while the

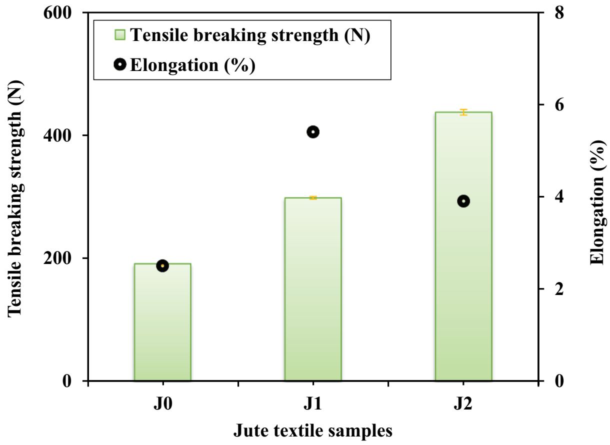


Figure 4. Tensile breaking strength and elongation of the jute textile samples.

elongation at break was found to be 5.4% and 3.9% for J1 and J2 fabrics, respectively. Hence, it revealed that the tensile breaking strength increased 56% after the chemical treatment, *i.e.*, for J1 (alkali, aloe vera, and polyester resin) and 129% after the chemical treatment and filler addition, *i.e.*, for J2.

In the previous study, Saha et al. (2016) demonstrated approximately 3.5–18.8% improvement in tensile strength after the polyester resin treatment on jute textiles, while a significant improvement was reported in the case of the treatment of bitumen emulsion/polyester resin mixture, as probed by Akter et al. (2018). In the warp and weft directions, the tensile strength of jute fabrics improved by 4.9% and 5.3%, respectively, after treatment with a mixture of 20/10% bitumen emulsion/polyester resin. At the same time, the improvement was significant (i.e., 61.4% and 44.7%, respectively) after treating with a 10/20% mixture of bitumen emulsion/polyester resin. In the case of alkali-treated jute yarns, Gassan and Bledzki (1999) found approx. 120% and 150% improvement in tensile strength and modulus.

The treatment of alkali and aloe vera (AV) may reduce some of the -OH groups of the jute fibers. Polyester is a viscous thermoset polymer that coats the jute fibers, establishes a strong fiber-polyester interfacial adhesion, as well as blocks the voids inside the cellulose polymer structure of the jute fibers (Akter et al. 2018; Saha et al. 2016). Adding fillers in the polyester resin may strengthen the interfacial adhesion and stress concentration phenomena. All these factors may be responsible for the higher tensile performance of jute textile fabrics after the treatment of AV, polyester resin, and filler modification (Das, Ashek-E-Khoda, et al. 2021).

Moisture properties

Figure 5 manifests the moisture content (MC) and moisture regain (MR) of jute textile samples (J0, J1, and J2). The MC and MR of raw jute fabric (J0) were 10.5% and 11.73%, respectively. These values were 8.5% and 8.8% for J1, while J2 samples presented 6.5% and 8.5%, respectively. So, it is seen that the MC and MR decreased after the AV-treated jute/polyester (J1) and filler modification (J2). The highest values of the moisture properties were revealed for filler-modified jute samples, i.e., for J2 textile fabric.

Basically, jute is a plant-based lignocellulosic fiber composed of cellulose, hemicellulose, and lignin as chemical ingredients. Hence, they are hydrophilic due to the presence of enormous polar -OH groups in the chemical structure of jute fiber (Khan et al. 2015; Rahman et al. 2024). These significant number of -OH groups facilitated H-bonding with water molecules while in contact with any moist, wet, or aquatic environment. After that, the jute fibers swell and gain weight (Akter et al. 2018; Rahman et al. 2024; Saha et al. 2016). The treatment of chemicals and polyester resin coating to jute fibers reduces the -OH groups, thus bringing down their hydrophilic behavior. The existing voids in

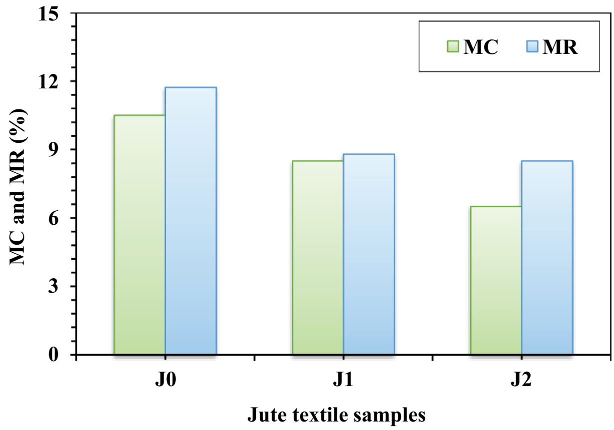


Figure 5. Moisture content (MC) and moisture regain (MR) of the jute textile samples.

the fibers are also blocked by resins (Akter et al. 2018; Saha et al. 2016). As a result, the resin manipulation acted as a barrier against moisture and induced somewhat hydrophobic properties in the treated jute textiles. The introduction of $Ca(OH)_2$ fillers in the resin polymer may boost the hydrophobic properties of jute fibers due to the enhancement of fiber-resin interfacial adhesion, blocking the -OH groups and filling the voids in the treated textile fabrics rather than the raw ones (Das, Ashek-E-Khoda, et al. 2021; Dinesh et al. 2020; Gupta 2020; Saha et al. 2016).

Water absorption

Figure 6 represents the water uptake *vs*. soaking period (h) curves for J0, J1, and J2 samples up to 288 h. It is viewed from Figure 6 that the water uptake was significantly higher for raw jute (J0) fabrics than the chemical-treated jute fabrics (J1 and J2). The J0 fabrics uptake water rapidly at the beginning; after reaching saturation or peak, the water uptake slightly decreases and maintains a steady trend, which may be due to the degradation or leaching of fibers and their chemical constituents present in jute fibers (Rahman et al. 2024). In the case of polyester-coated jute (J1) and filler-modified jute (J2), the water uptake was significantly reduced than that of their raw ones (J0). The chemical treatment and

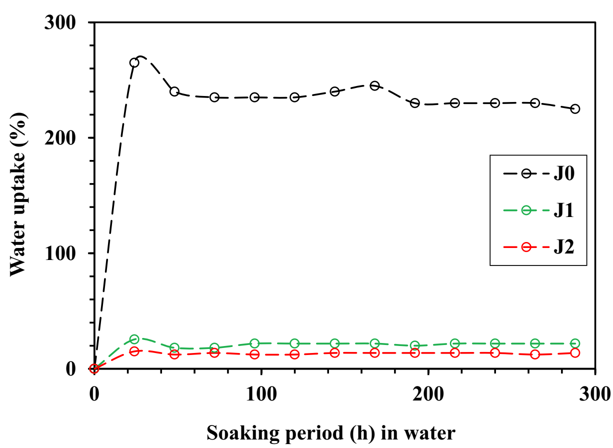


Figure 6. Water uptake (%) of untreated (J0) and treated (J1, J2) jute fabric samples.

coating in jute fabrics and adding fillers restricted the water molecules from penetrating freely inside the fibers, decreasing the water uptake. This was explained in the previous section.

FTIR spectroscopy

Figure 7 shows the confirmation of the function group of the samples. The raw jute (J0) spectrum displays characteristic bands at 3340 cm^{-1}, corresponding to O-H stretching vibrations indicative of hydrogen-bonded hydroxyl groups in cellulose and lignin. The peak at 2906 cm^{-1} is attributed to C-H stretching vibrations, while the band at 1717 cm^{-1} corresponds to C=O stretching vibrations, primarily from carboxyl or ester groups in hemicellulose (Ahmed et al. 2014; Akter et al. 2020, 2025; Soni, Mahmoud, and Mahmoud 2015). Additional notable peaks include 1429 cm^{-1} for C-H bending, 1270 cm^{-1} for C-O-C stretching, and 1020 cm^{-1} for C-O stretching vibrations, with a minor peak at 913 cm^{-1} related to out-of-plane C-H bending (Akter et al. 2020, 2025; Morshed, Alam, and Daniels 2010; Shahinur et al. 2022).

Upon AV treatment, the spectrum for J1 reveals a reduction in the intensity of the O-H stretching band at 3340 cm^{-1}, suggesting a decrease in hydroxyl group content due to interactions with the AV treatment (Parveen et al. 2024). The C=O stretching peak at 1717 cm^{-1} becomes more pronounced, indicating the presence of ester groups (Ahmed et al. 2014; Soni, Mahmoud, and Mahmoud 2015). The C-H stretching vibrations at 2906 cm^{-1} show modified intensity, reflecting chemical changes due to the treatment.

For the J2 sample, additional modifications are observed compared to J1. Notably, the presence of $Ca(OH)_2$ induces changes in the spectra, particularly in the regions associated with O-H and C=O stretching vibrations. These changes suggest new interactions or chemical bonds formed between the hydroxyl groups of $Ca(OH)_2$ and the polyester resin. Although specific peaks for $Ca(OH)_2$ are not distinctly visible, the more defined peaks at 1020 cm^{-1} and 913 cm^{-1} indicate enhanced interactions within the sample (da Silva et al. 2016; Morshed, Alam, and Daniels 2010).

These spectral differences highlight the structural and chemical modifications resulting from AV treatment and the incorporation of $Ca(OH)_2$, which are critical for understanding the improved properties and performance of the hybrid composites.

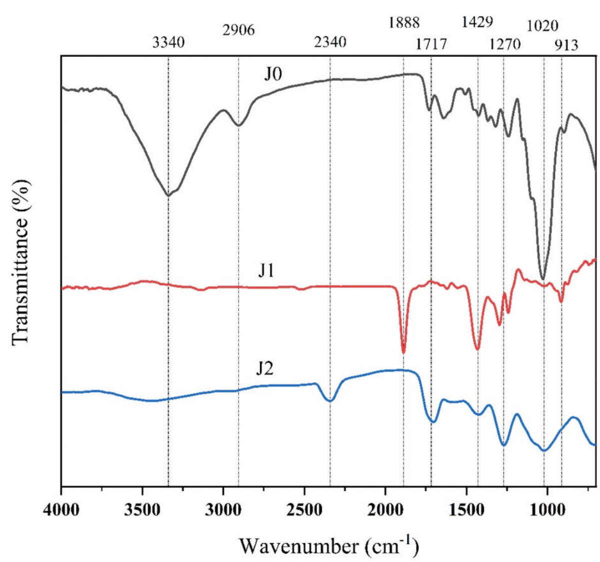


Figure 7. FTIR spectra of J0, J1, and J2 fabric samples.

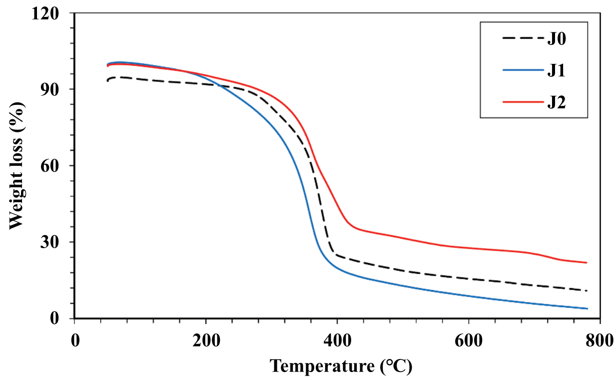


Figure 8. TGA curves of J0, J1 and J2 textile samples.

TGA

Figure 8 shows that at 100°C, a slight weight loss (6.1%) occurred for raw jute textile (J0) while the treated jute textiles exhibited thermal stability at 100°C temperatures, i.e., a tiny weight loss occurred. Usually, the weight loss for natural fibers and polymeric materials takes place in three stages under TGA analysis. The first stage of weight loss occurred between 100°C and 200°C, where the weight loss was observed at approximately 8.1%, 5.8%, and 4.6% for J0, J1, and J2 textiles, respectively, at 200°C temperatures. This is mainly due to the evaporation of moisture, volatile substances, or impurities present in the jute textiles (Akter et al. 2020, 2025; Das, Ashek-E-Khoda, et al. 2021; Gupta et al. 2018; Karuppuchamy, Ramya, and Siva 2024).

The 2nd stage of weight loss was performed between the temperature range 230°C to 400°C, where the 50% weight loss of the jute textile samples occurred at approximately 370°C, 350°C, and 390°C for the case of J0, J1, and J2 specimens, respectively. At 400°C temperatures, the weight loss was revealed by 75.2%, 80.2%, and 55.4% for J0, J1, and J2 samples, respectively. Here, the weight loss of jute materials is related to the decomposition of hemicelluloses, pectin, as well as the cleavage of glycosidic linkages of cellulose structures (Akter et al. 2025; Das, Ashek-E-Khoda, et al. 2021; Gupta et al. 2018; Nabinejad et al. 2015).

The 3rd stage of weight loss displayed after 400°C to 700°C, and at 700°C, the materials lost approximately 87.0%, 94.2%, and 74.7% of their weight, respectively. In this stage, the weight loss may be due to the decomposition of α-cellulose and lignin in jute fibers, as well as the polyester polymer (Akter et al. 2025; Das, Ashek-E-Khoda, et al. 2021; Gupta et al. 2018; Nabinejad et al. 2015). It can be noted that the decomposition of lignin slowly started with the increase of temperatures due to the highly complex chemical structure (aromatic branches), and at high temperatures, it decomposed (Akter et al. 2025; Das, Ashek-E-Khoda, et al. 2021; Gupta et al. 2018; Nabinejad et al. 2015). Here, the addition of fillers in J2 improved the overall thermal stability of the materials. However, the AV-treated jute textiles (J1) exhibited slightly better stability up to 200°C, then experienced lower thermal stability than the raw jute ones (J0). The improvement of thermal stability of jute fiber/polymeric materials as a function of filler addition has also been reported by (Nabinejad et al. 2015) and (Das, Ashek-E-Khoda, et al. 2021).

SEM

Figure 9 represents the SEM images of the surfaces of raw jute fabrics (a, b), aloe vera treated jute/polyester (c, d), and $Ca(OH)_2$ filler modified jute/polyester (e, f) in different magnifications (×250 and × 500). For the case of raw jute fabrics (untreated) in Figure 9(a,b) the fiber surface is clean without having any polymer or treated ingredients, and the multi-cellular traits of jute fibers are also

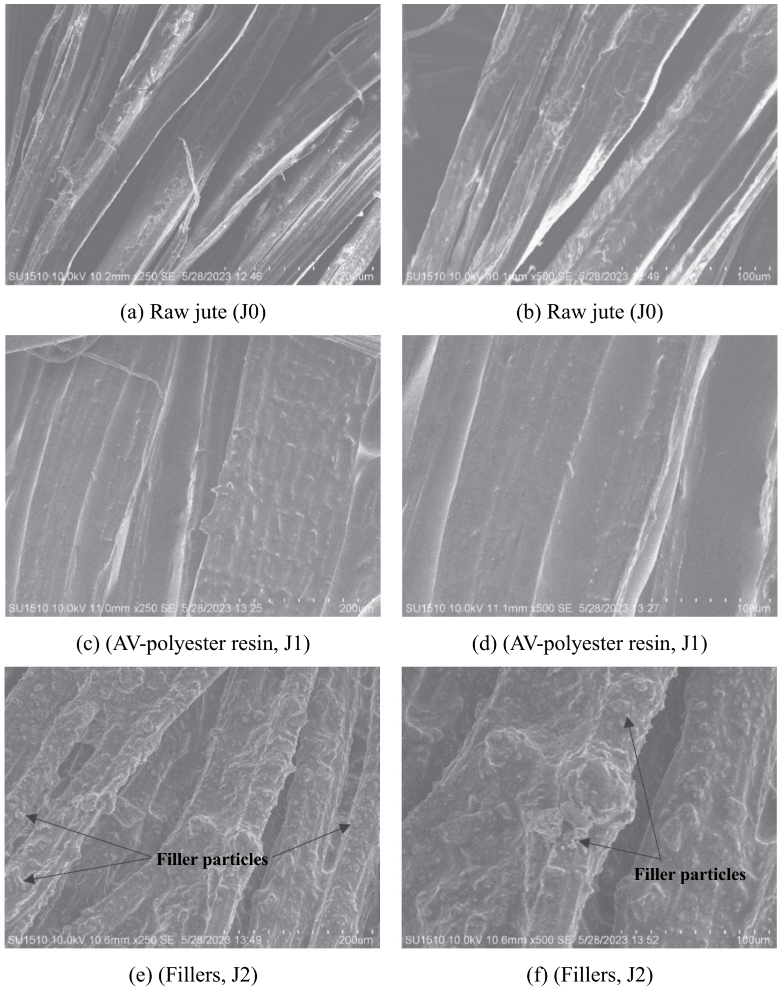


Figure 9. SEM images of surfaces of J0 (a, b), J1 (c, d), and J2 (e, f) fabric samples.

observed (Akter et al. 2018, 2020). In contrast, a rough surface with the existence of polyester polymer and filler particles is visible in the case of treated or surface-modified jute fabric samples (J1 and J2) (Akter et al. 2025), as illustrated in Figure 9(c–f).

In the modified jute surfaces, the hairiness of the jute has been removed, and a compact and dense appearance has been identified (Akter et al. 2018, 2020, 2025). In Figure 9(e,f) the filler particles are vividly observed, which resulted in an extremely rougher surface with the polyester polymer (Jahan et al. 2024). Hence, the treated and filler-modified jute fabrics manifested an alteration of the surface morphology due to the fiber-polymer interfacial adhesion as well as filler addition in them, as illustrated via SEM analysis.

Chemical aging

The chemical aging of J0, J1, and J2 in alkaline, acidic, and salt water solutions are presented in Figures 10, 11 , and 12, respectively. Similar to water uptake, the raw jute experiences the highest uptake of chemical solutions than the treated or modified jute samples (J1 and J2). Because in the touch of moisture environments, jute fabrics usually absorb it and swell, gaining weight. After reaching saturation, they

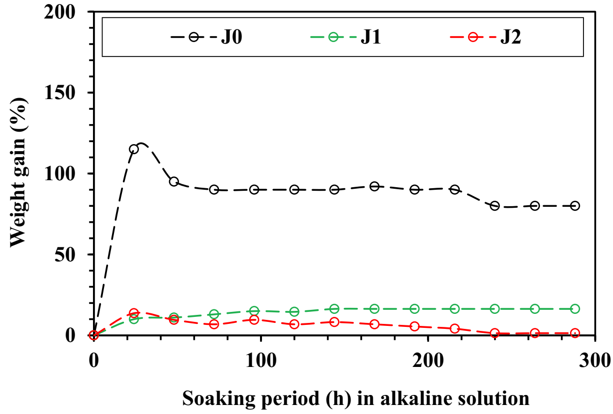


Figure 10. Weight change (%) of jute textile samples in alkaline solution.

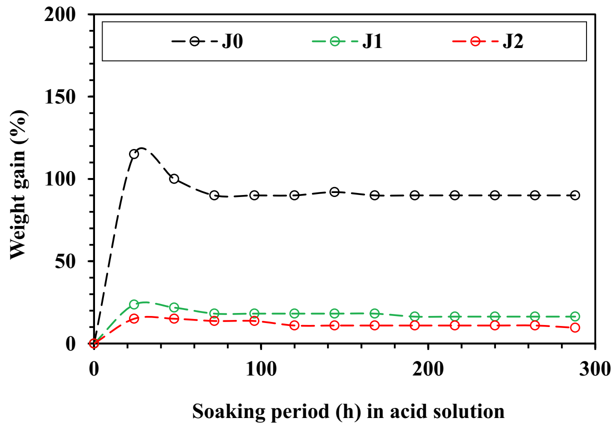


Figure 11. Weight change (%) of jute textile samples in acidic solution.

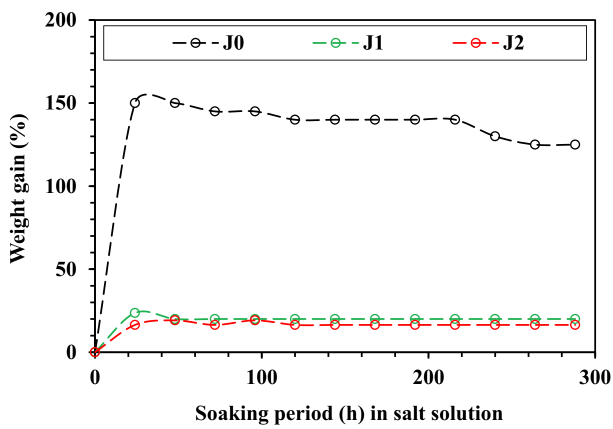


Figure 12. Weight change (%) of jute textile samples in a saltwater solution.

desorb moisture, or fibers, and polymer ingredients degrade and leach out (Rahman et al. 2024). Consequently, a decreasing trend was observed after the saturation peak. A comparatively higher degradation was reported for alkaline solution aging.

Conclusions

In this study, 100% jute woven textile fabrics (1 × 1 plain weave) were chemically treated, coated with polyester resin, and then modified with $Ca(OH)_2$ fillers. The significant findings of this study are highlighted below:

- The tensile breaking strength improved by 56% and 129% for J1 and J2 jute textiles, respectively, than the untreated jute textiles (J0).
- The MC and MR enhanced by 19% and 25% for J1, respectively, while the values were 38% and 28%, respectively, for J2 jute textiles, compared to the raw jute (J0) textile. On the other hand, a significant reduction of water absorption was revealed for J1 and J2 compared to J0.
- TGA reveals the improvement of thermal stability after filler addition; however, J1 had inferior results compared to J0.
- The results of FTIR and SEM analyses support the above findings.
- The treated jute textile samples exhibited significantly greater resistance to chemical aging than raw jute; however, weight loss occurred during alkali aging.

The developed jute textile fabrics are expected to be used for short-term geotextile applications in cultivation and vegetation farming.

Highlights

- An attempt has been made to enhance the performance of jute textile fabrics by chemical treatment and filler modification.
- The tensile and moisture properties of the treated jute textiles improved.
- The durability of the treated jute textiles also exhibited significant resistance against chemical solution aging environments.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Author contributions

M.M. Khan: Conceptualization, experimental works, methodology, data curation, writing, review, and editing. **M. Rokonuzzaman**: Supervision and review the final document. **A. Sayeed**: Experimental works, methodology, visualization, and review. **T. Islam**: FTIR testing and writing, review, and editing. **D. Paul**: Investigation and review the final document. **A.T.M.G. Moula**: Investigation and review the final document. **M.S. Jahan**: Writing and reviewing the final document. **S.C. Das**: Conceptualization, supervision, methodology, validation, writing, review, and editing. All authors have read and agreed to the published version of the manuscript.

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