



## Effect of dye and temperature on the physico-mechanical properties of jute/PP and jute/LLDPE based composites



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### ABSTRACT

Jute fabrics and unidirectional jute fiber reinforced polypropylene (PP) and linear low density polyethylene (LLDPE) based composites were prepared successfully by compression molding technique. The unidirectional jute fiber was treated with Reactive Orange HB® and Deep Blue LW® dye to investigate physico-mechanical properties. The Reactive Orange HB® treated composites showed relatively better mechanical properties than the Deep Blue LW® treated composites. The jute fiber-based composites showed higher mechanical properties than that of jute-based fabrics. The polypropylene-based composites showed better mechanical properties than that of LLDPE. The variations of mechanical properties were also observed. The highest mechanical properties were at -18 °C and lowest at 50 °C. Water absorbent, SEM and FT-IR analysis of the composite was also carried out.

### 1. Introduction

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite, and cultured marble sinks and countertops.

Tightly integrating sensing, actuation, and computation into composites could enable a new generation of truly smart material systems that can change their appearance and shape autonomously. Applications for such materials include airfoils that change their aerodynamic profile, vehicles with camouflage abilities, bridges that detect and repair damage, or robotic skins and prosthetics with a realistic sense of touch [1].

From the few past decades, we have been concerned about the green environment and thus our major investigations have been focused on to make pollution free environment. It is considered that non-degradable

materials are solely responsible for environmental pollution [2]. Presently, different non-degradable composite materials are widely used instead of metals. Non-degradable materials are subjected to be replaced by degradable one in order to make pollution free environment. Thus, natural fiber composites are chosen up to make biodegradable materials [3, 4, 5]. Natural fibers contribute to the easy degradation of the composites. Moreover, these fibers involve less environmental impact on their production compared with both glass fibers and polymers, because they require lower energy and produce fewer emissions [6]. The performance of natural fiber reinforced composites can be comparable to that of the synthetic fiber-based composites, but with lower specific weight and price. The advantages of natural fiber composites are their good dimensional stability and durability against wood-based composites [7, 8, 9, 10, 11]. Natural fiber composite has a good demand in the world for environmental and ecological concerns [12]. Among all the natural fibers, jute appears to be a promising material because it is relatively inexpensive and commercially available in tropical countries [13, 14, 15]. It has low density, higher strength, and modulus than plastic and is a good substitute for conventional fibers in many situations. Widely used natural fibers are cotton, jute, sisal, corn, coir, hemp, banana, pineapple, etc. and these fibers are biodegradable and also environmental friendly [16, 17, 18].

Jute products are comparatively well with other fibers in terms of

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energy use, greenhouse gas (GHG) emission, eutrophication, and acidification. One hectare of jute plants absorbs tons of CO<sub>2</sub> from the atmosphere and add the 11 tons of O<sub>2</sub> during their lifespan 120 days. Additionally decomposed leaves and roots of jute plants enhance the fertility of the soil and reduce fertilizer costs. The manufacture of 1 Kg of the fabric of jute shopping bags saves 80 MJ of energy in comparison to 1 Kg of polyhydroxy alkanoid [19]. Jute Hessian cloth consumes a lesser amount of energy and emits negligible amounts of GHG compared with thermoplastic polymers.

In this research work the jute fabrics reinforced PP and LLDPE based composites were fabricated and physicochemical properties were studied. Two types of dyes were also added to improve the physicochemical properties.

## 2. Experimental

### 2.1. Materials

Jute fabric and jute fiber (bleached commercial grade, Tossa Jute) were collected from a local market near Savar, Dhaka, Bangladesh. Polypropylene and linear low-density polyethylene were purchased from MITSUIPET Company, and Polyolefin Company Ltd. Singapore respectively. Two dyes were used in this research work. They are Reactive Orange HB® and Deep Blue LW®. Those dyes were collected from Kyung In-Synthetic Corporation (KISCO), Frankfurt, Germany.

### 2.2. Composite fabrication

For the preparation of jute/PP based composites initially, granules of polypropylene (PP) were made into thin sheets (thickness about 0.33–0.35 mm). The operating temperature, pressure and time were 200 °C, 3 tons and 5 minutes respectively inside two steel plates, wrapping the PP with silicon papers using heat press (Carver, INC, USA Model 3856). The plates were then cooled (using ice for 1 minute in a separate press under 3 tons pressure).

The resulting PP sheet was cut into the desired size and the jute fabric was also cut in similar size for composite fabrication. Composites were prepared by sandwiching jute fabrics between sheets of PP. The sandwich was then placed between two steel plates and heated at 200 °C for 5 min at a pressure of 3 tons and cooled like PP sheet. The fiber weight fraction of the composites was calculated to be about 10%, 20%, 30%. The highest percentages of jute fiber were 30% [20]. For the fabrication of jute fabrics reinforced LLDPE based composites the methodology was the same, but the operating temperature was 180 °C.

In the preparation of unidirectional jute fiber/PP and jute fiber/LLDPE based composites, the fiber alignment was made unidirectional inside the matrix (PP/LLDPE) sheets. All the other operating conditions and operating procedures were the same as the jute fabrics/PP and jute fabrics/LLDPE based composites respectively.

For the fabrication of dye treated Jute based composite, the jute fiber was soaked in the aqueous dye solution for 5 minutes. Before soaking in dye solution the jute fiber was dried in an oven for 2 h at 100 °C. After soaking 5 minutes, jute fiber was dried again at 100 °C for 2h. Then the composites were prepared using a similar methodology described in the previous section.

### 2.3. Mechanical properties of the composites

For the measurement of mechanical properties of the composite samples were cut to the required dimension using a band saw. The dimension of the test specimen was (ASTM-D638-01): 60 mm × 15 mm × 2 mm for the measurement of tensile properties. Tensile properties of the composites were evaluated by using the Hounsfield series S testing machine (UK) with a cross-head speed of 1 mm/s and gauge length was 20 mm. The impact strength of the composites was measured using Impact tester (model: HT-8041B IZOD, Serial no.: 7406), Pendulum type,

Germany and test specimens were prepared according to ASTM-D256 method.

### 2.4. Scanning electron microscopic analysis

The fracture sides of the composites were examined by Philips scanning electron microscope (JEOL JSM-6490LA) at an accelerating voltage of 10 kV. Fiber-matrix interaction of the composites was also analyzed from the image of the scanning electron microscopy.

### 2.5. Water uptake of the jute fibers and composites

Water uptake tests of the fiber (about 10 g) were performed in de-ionized water at room temperature (25 °C). Composite samples were placed in static glass beakers containing 500 ml of distilled water. At set time points, samples were taken out and dried for 48 hours at room temperature and then re-weighed. Composites were paced for water uptake up to 30 days. Similar methodologies are reported elsewhere.

### 2.6. FT-IR spectroscopy

Fourier Transform Infrared Spectroscopy was used to identify the functional group of the composite materials. The FTIR attenuated total reflectance (ATR) machine was used to identify the functional group.

## 3. Results and discussion

### 3.1. Water uptake

Water uptake was measured by soaking the samples in distilled water. The Fig. 1 shows the water uptake properties of unidirectional jute fiber and Fig. 2 shows water uptake of the fiber reinforced composites. Jute fibers absorbed 105% of water within 80 min of immersion in distilled water. Jute fibers reinforced PP and LLDPE based composites absorbed 35% and 27% water in 10 days immersion. Unidirectional jute/PP based composites uptake 35% water within the 5 days and then maintained static values up to 10 days. On the other hand unidirectional jute/LLDPE based composites reached in its static values within 4 days.

The reason behind these phenomena is that jute is mainly built up of cellulose, which is a hydrophilic polymer. The elementary unit of jute is anhydro-d-glucose, which contains three hydroxyl (–OH) groups. These hydroxyl groups in the cellulose structure account for the strong hydrophilic nature of jute. As a result jute fiber absorbed such a huge amount of water. On the other hand, the composite material the jute fibers are coated with hydrophobic polymers such as PP and LLDPE. For this reason, the composites absorbed a relatively small amount of water.

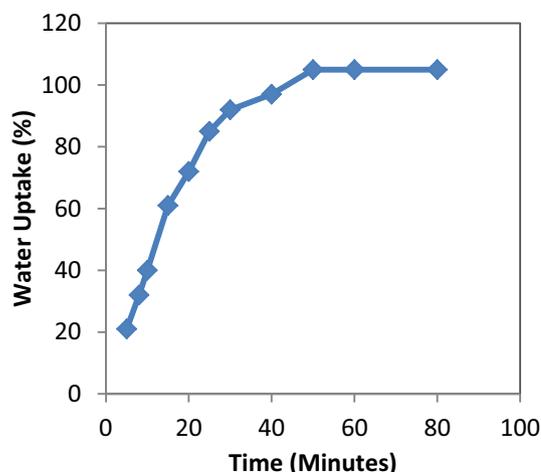


Fig. 1. Water uptake of unidirectional jute fiber.

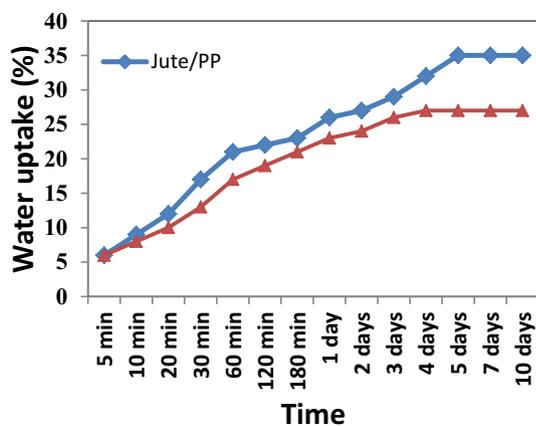


Fig. 2. Water uptake properties of unidirectional jute fiber reinforced composites.

### 3.2. Optimization of jute fiber on PP and LLDPE

Optimization of composite materials is necessary for the fabrication of composite material in an efficient way. To optimize unidirectional jute fiber reinforced polypropylene (Jute/PP) based composite 10%, 20%, and 30% unidirectional fiber was incorporated in the polypropylene matrix. Similarly, 10%, 20% and 30% unidirectional jute fiber were incorporated in linear low-density polyethylene (Jute/LLDPE) based composite. On the other hand to optimized dye treated unidirectional jute fiber reinforced polypropylene (PP) and low-density polyethylene (LDPE) based composite dye solution was used.

Polypropylene has a higher elongation at break and high hydrophobic nature, but jute fiber has higher mechanical property. This research work was carried out to combine these two dissimilar properties in an efficient way using a different percentage of jute fiber. To optimize Jute/PP based composite mechanical properties like tensile strength (TS), tensile modulus (TM) and elongation at break (Eb) were studied. Tensile strength (TS) of unidirectional jute fiber reinforced PP and LLDPE based composite was measured for the 10%, 20% and 30% unidirectional jute fiber. TS value was increased linearly with an increasing percentage of jute fiber. This is because of the tensile strength values of jute fiber is much higher than tensile strength values of PP and LLDPE. The minimum TS value (30 MPa) was obtained for 10% unidirectional jute fiber-containing composites and the highest TS value (39 MPa) was obtained for 30% fiber containing PP based composites. In a similar way for the LLDPE based composites, the TS value was increased from 26 to 33 MPa. The effects of unidirectional jute fiber in the PP and LLDPE based composites are shown in Fig. 3.

With the jute fiber loading, YM values were also increased in a similar fashion. The Lowest YM value (825 MPa) was obtained for 10% jute fiber and highest value (1118 MPa) was obtained for 30% fiber and PP based

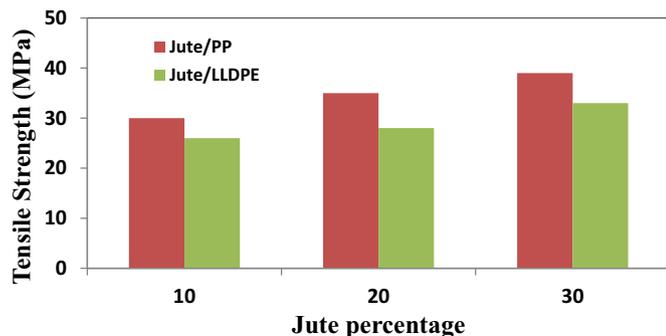


Fig. 3. Tensile Strength of unidirectional jute fiber based composites.

composites. Similarly, the lowest (520 MPa) and highest (872 MPa) YM value was obtained for 10% and 30% fiber containing LLDPE based composites. All the YM related values of PP and LLDPE based composites are shown in Fig. 4.

The Eb values of all the prepared composites were decreased with the increment of jute percentage. The Eb of polymer matrix materials (PP and LLDPE) is relatively very high. The highest Eb was obtained for 10% fiber-containing composites and the lowest value was obtained for 30% fiber-containing composites. The effects of jute fiber loading on the composites are shown in Fig. 5. Jute fiber loading was optimized to 20% unidirectional jute fiber and 80% PP/LLDPE.

### 3.3. Comparison between jute fabrics and unidirectional jute fiber-based composites

The tensile strength of 20% jute fabrics reinforced PP based composite was 32 MPa and fiber-based composite was 37 MPa. The tensile strength of unidirectional jute fiber reinforced PP composite was 16% higher than jute fabrics reinforced PP based composite. Similarly, the tensile strength of 20% jute fabrics reinforced LLDPE based composite was 25 MPa and fiber reinforced LLDPE based composite was 28 MPa. The tensile strength of unidirectional jute fiber reinforced LLDPE composite was 12% higher than jute fabrics reinforced LLDPE composite. Fig. 6 shows the TS values of fabrics and fiber reinforced PP and LLDPE based composites.

In a similar way, TM of the optimized fabrics based composites showed slightly lower values than the unidirectional fiber based composites. For the PP based composites, the unidirectional jute fiber increased the TM value 40% than the jute fabrics. Likely for LLDPE based composites 33% improvement was observed for fiber based composites. The TM related values are shown in Fig. 7.

The elongation at break of the jute PP based composites decreased 13% when unidirectional jute fiber was used. Similarly, for jute/LLDPE based composites, Eb values were decreased by 14% for the replacement of jute fabrics with unidirectional jute fibers. The decreased trend of Eb is shown in Fig. 8.

### 3.4. Effects of dyes on the unidirectional jute fiber-based composites

Tensile strength of unidirectional jute/PP based composite of no dye, deep blue LW dye, and reactive orange HB dye was 34.10 MPa, 34.5 MPa, and 37 MPa respectively. The tensile strength of non-dyed unidirectional jute fiber reinforced LLDPE based composite was 30 MPa while the tensile strength of deep blue LW dyed unidirectional jute fiber reinforced PP based composite was 34 MPa and tensile strength of reactive orange HB dyed PP based composite was 38 MPa.

In case of deep blue LW dyed fiber, the increase of tensile strength was almost 1.5% and 13.5% respectively for PP and LLDPE based composites than the no-dye based composites. Similarly for reactive orange HB dyed fiber reinforced PP and LLDPE based composites the increase of tensile strength was 9% and 27% respectively than the no-dye based composites.

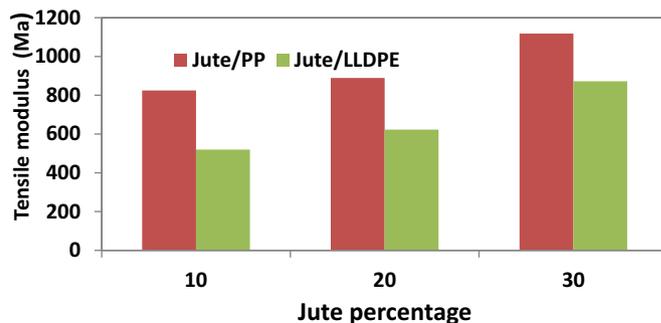


Fig. 4. Tensile modulus of unidirectional jute fiber based composites.

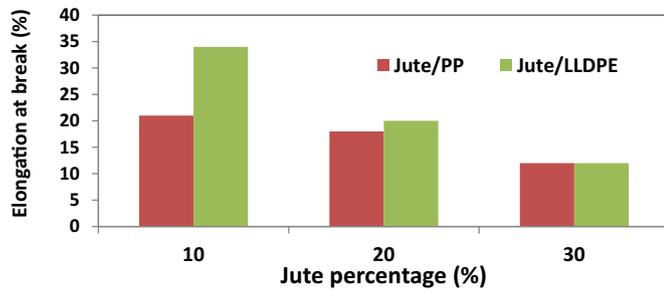


Fig. 5. Elongation at break of unidirectional jute fiber-based composites.

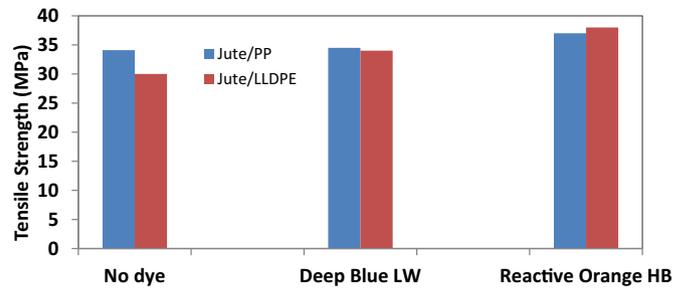


Fig. 9. Effects of dyes on tensile strength.

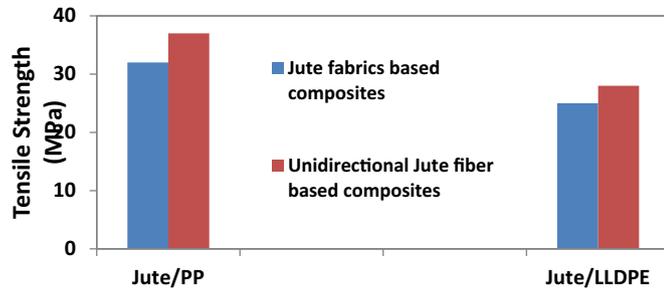


Fig. 6. Tensile strength of jute fabrics and unidirectional jute fiber based composites.

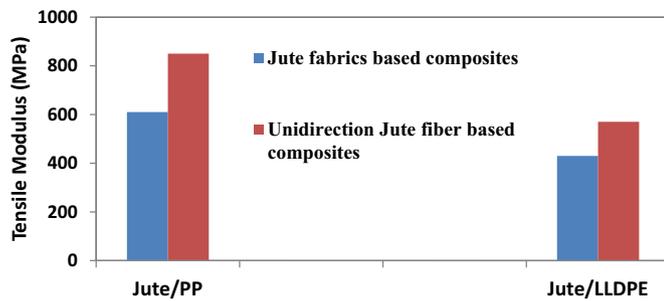


Fig. 7. Tensile modulus of jute fabrics and jute fiber based composites.

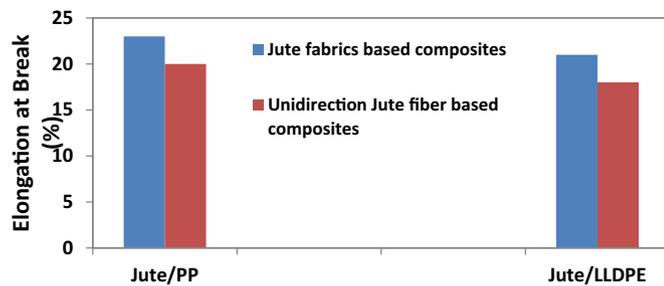


Fig. 8. Elongation at break of jute fabrics and unidirectional jute fiber based composites.

So every time there was increased in tensile strength in dye treated jute fiber reinforced PP and LLDPE based composites. Fig. 9 shows the effects of dyes on jute fiber based composites.

Similar results were observed for the TM of the composites. When deep blue LW was treated with the unidirectional jute fiber the TM value was improved 18% and 8% respectively for PP and LLDPE based composites than the no-dye containing composites. Maintaining the same trend with the addition of reactive orange HB increased the TM values 20% and 105% respectively for PP and LLDPE based composites. The TM

values of composites are illustrated in Fig. 10.

Elongation at break of unidirectional jute fiber reinforced PP based composite was 17.89%. When the fiber is dyed with deep blue LW dye the elongation at break became 15% and when the fiber was dyed with reactive orange HB dyed elongation at break became 10%. So we see there is a decrease in elongation at break for dyed fibers. Elongation at break of 20% unidirectional jute fiber reinforced LLDPE composite was 19.93%. When the fiber is dyed with deep blue LW and reactive orange HB dyed the elongation at break reduced to 17% and 12% correspondingly. The elongation at break of the dye-treated and untreated fiber PP as well as LLDPE based composites is shown in Fig. 11.

We see from the values that the dyed fiber reinforced composites have higher tensile strength than that of non-dyed fiber reinforced composite as dye acts as a filler in jute fibers. Another reason is stress transfer from fiber to the matrix is higher in case of dyed fiber-based composite. So every time there was increased in tensile strength in dyed reinforced jute fiber reinforced PP or LLDPE based composite.

### 3.5. Effect of temperature

The tensile strength of unidirectional jute fiber reinforced PP composites at room temp (27 °C) was 34 MPa. But at 30 °C, the TS was 34.19 MPa and at 50 °C TS was 27 MPa. While at -18 °C TS of PP based composite was 54.5 MPa. So we see from the assigned values that the tensile strength of unidirectional jute fiber reinforced PP composite decreased with increasing temperature and increased with decreasing temperature.

For LLDPE composites the TS at room temperature (27 °C) was 30 MPa. But at 30 °C TS was 29 MPa and at 50 °C TS was 6 MPa. While at -18 °C tensile strength of unidirectional jute fiber reinforced PP composite was 46 MPa. Tensile strength decreases at high temperature because the rotational and vibrational motion of molecules increase with increasing temp, as a result, there is a decrease in tensile strength. On the other hand, rotational and vibrational motion of the molecules decrease with decreasing temperature so there is an increase in tensile strength. The TS related data is shown in Fig. 12.

Young's modulus of unidirectional jute fiber reinforced PP based composites at room temperature (27 °C) was 850 MPa. But Young's modulus of unidirectional jute fiber reinforced.

PP composites at 30 °C was 811 MPa and at 50 °C TM was 650.67 MPa. While at -18 °C tensile modulus of unidirectional jute fiber

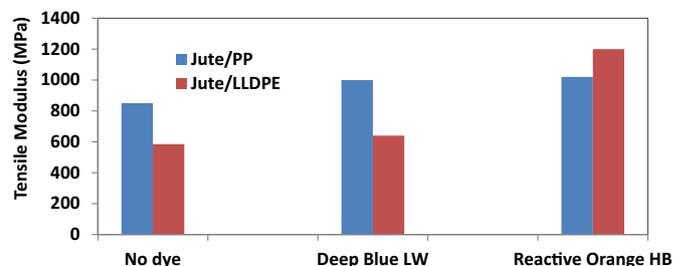


Fig. 10. Effects of dyes on tensile modulus.

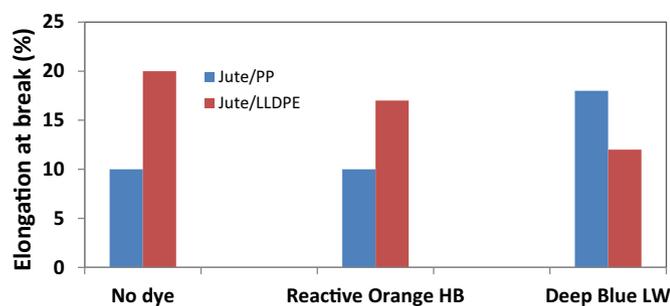


Fig. 11. Effect of dyes on elongation at break.

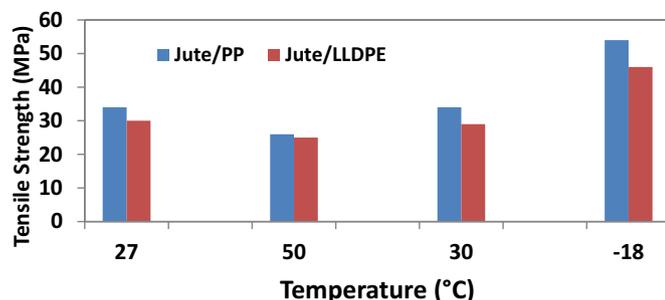


Fig. 12. Effect of temperature on tensile strength.

reinforced PP composite was 1283 MPa. For LLDPE based composite the TM was at room temperature, 30 °C, 50 °C and -18 °C temperature 560 MPa, 512 MPa, 470 MPa, and 778 MPa respectively. So we see from the assigned values that Young's modulus of unidirectional jute fiber reinforced PP composite decreases with increasing temperature and increase with decreasing temperature. The reasons of such change were discussed in the tensile strength section. The effect of temperature of jute fiber reinforced PP and LLDPE based composites is shown in Fig. 13.

At room temp (27 °C) elongation at break of unidirectional jute fiber reinforced PP based composite was 17.89%. When the temperature was raised to 30 °C the elongation at break increased to 21.21% and at 50 °C, it became 28.1%. But when the temp was maintained at -18 °C elongation at break was reduced to 11.6%. For LLDPE based composite the Eb was at room temperature, 30 °C, 50 °C and -18 °C temperature 19.90%, 23%, 30%, and 15.4% respectively. The reasons were discussed in the tensile strength section. Fig. 14 shows the effects of temperature on the elongation at break.

### 3.6. Impact strength of composites

The impact strength of dyes treated fiber reinforced PP composite showed a better result than impact strength of non-dyed fiber reinforced PP composite. When fiber was dyed with reactive orange HB dye the impact strength increased almost 89% and, when fiber was dyed with

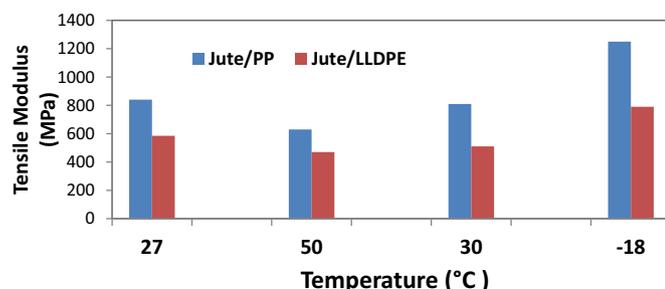


Fig. 13. Effect of temperature on tensile modulus.

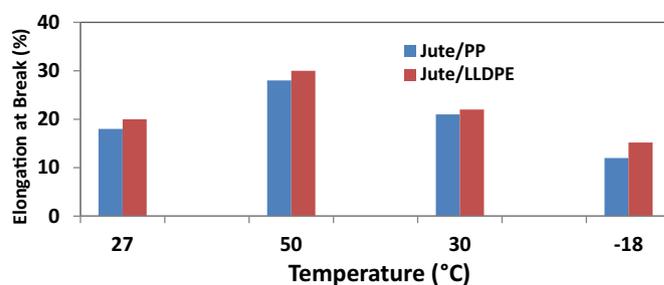


Fig. 14. Effect of temperature on elongation at break.

deep blue LW dye impact strength increased by 44%.

For LLDPE based composite the IS showed better results than that of no-dye fiber reinforced LLDPE based composite. When fiber was dyed with reactive orange HB dye the impact strength increased almost 88% and when the fiber was dyed with deep blue LW dye impact strength increased by 57%. Fig. 15 shows the IS values of the composites.

### 3.7. FT-IR of jute fiber reinforced PP and LLDPE based composites

In the jute fiber reinforced PP based composite the FT-IR analysis for the functional groups is shown in Fig. 16. For the presence of polymeric -OH group very broad peak appeared in the wave number of 3400  $\text{cm}^{-1}$ . This hydroxyl group peak may be for jute fabrics. In the region of 2900  $\text{cm}^{-1}$  another peak was observed and this peak was for C-H vibration of (-CH<sub>3</sub>) group of PP and jute. In the region of 1575  $\text{cm}^{-1}$  another peak was observed and this peak was for the presence of CH<sub>3</sub>, CH and CH<sub>2</sub> group (for sp<sup>3</sup> bending). In the region 1458  $\text{cm}^{-1}$  another peak was observed this was for Methyl asymmetric deformation vibration of PP.

Similarly, the untreated jute fiber reinforced LLDPE based composite the FT-IR analysis for the functional groups is shown in Fig. 17. For the presence of polymeric -OH group, a very broad peak appeared in the wave number of 3400  $\text{cm}^{-1}$ . Narrow two peaks were observed in the region of 2855  $\text{cm}^{-1}$  and 2930  $\text{cm}^{-1}$  those two peaks for the presence of CH group in asymmetric stretching and for symmetric stretching respectively. In the region of 1575  $\text{cm}^{-1}$ , another peak was observed and this peak was for the presence of CH<sub>3</sub>, CH and CH<sub>2</sub> group (for sp<sup>3</sup> bending).

In the reactive orange HB, dyed jute fiber reinforced PP based composite the FT-IR analysis for the functional groups is shown in Fig. 18. For the presence of polymeric -OH group very broad peak was appeared in the wave number of 3400  $\text{cm}^{-1}$ . The hydroxyl group presences in the cellulose structure of jute fabrics. In the region of 2900  $\text{cm}^{-1}$  another peak was observed and this peak was for C-H vibration of (-CH<sub>3</sub>) group of PP and jute. In the region of 1575  $\text{cm}^{-1}$  another peak was observed and this peak was for the presence of CH<sub>3</sub>, CH and CH<sub>2</sub> group (for sp<sup>3</sup> bending). In the region 1458  $\text{cm}^{-1}$  another peak was observed this was for methyl symmetric deformation vibration of PP. Almost the same result was obtained as untreated jute fiber reinforced PP composite.

In the deep blue LW dyed jute fiber reinforced PP based composite, the FT-IR analysis for the functional groups is shown in Fig. 19. In the

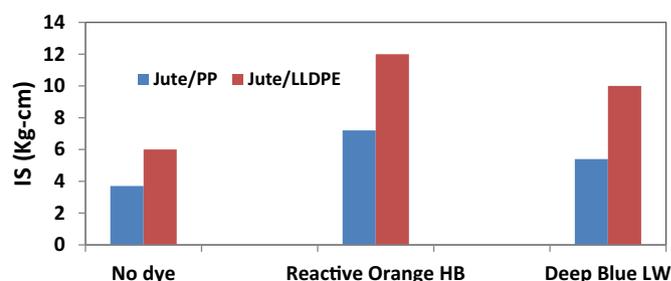


Fig. 15. Effects of dye on impact strength values.

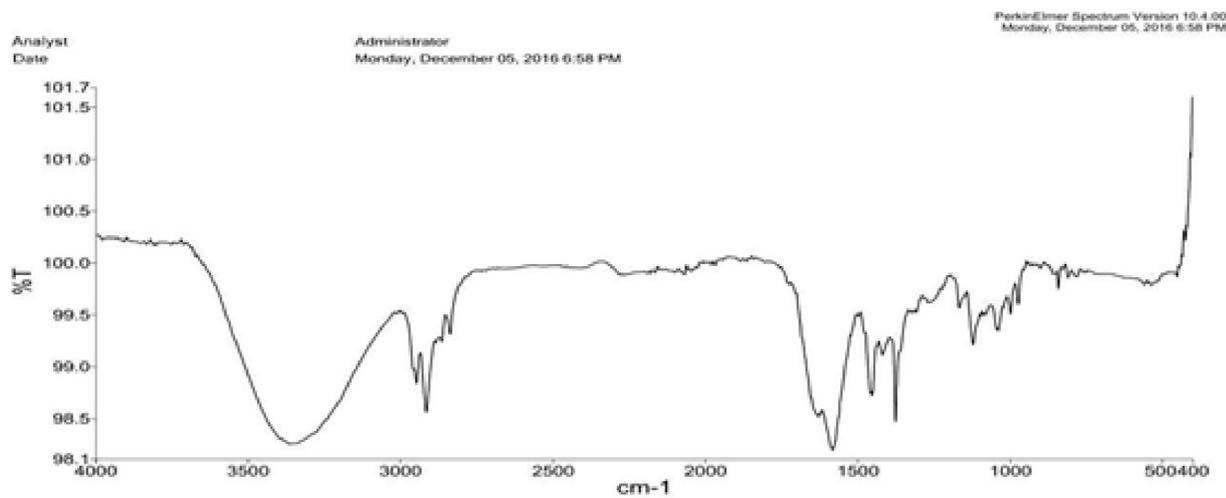


Fig. 16. FT-IR analysis of untreated jute fiber reinforced PP composite.

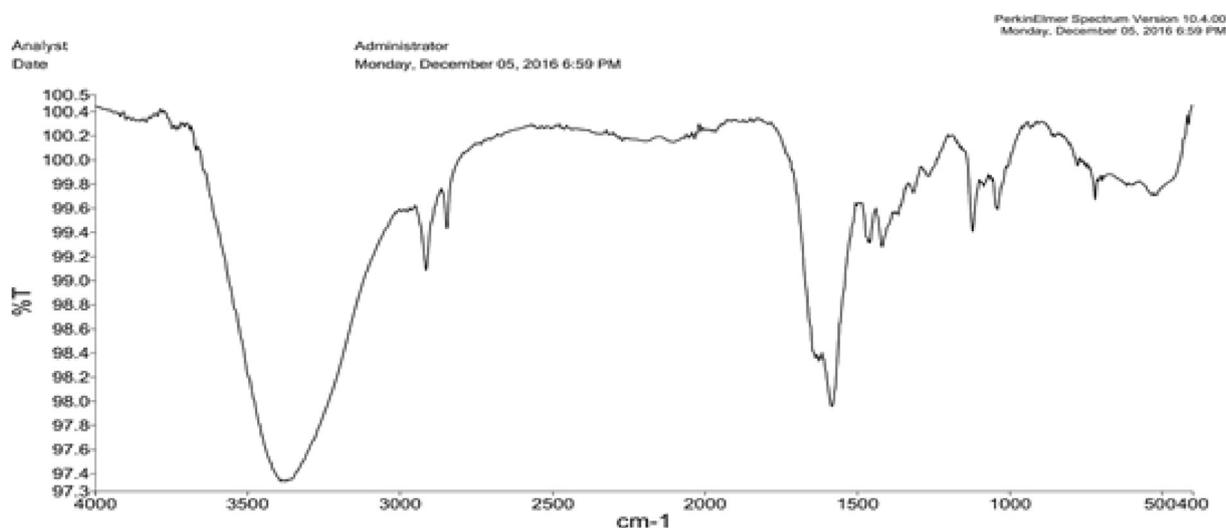


Fig. 17. FT-IR analysis of untreated jute fiber reinforced LDPE composite.

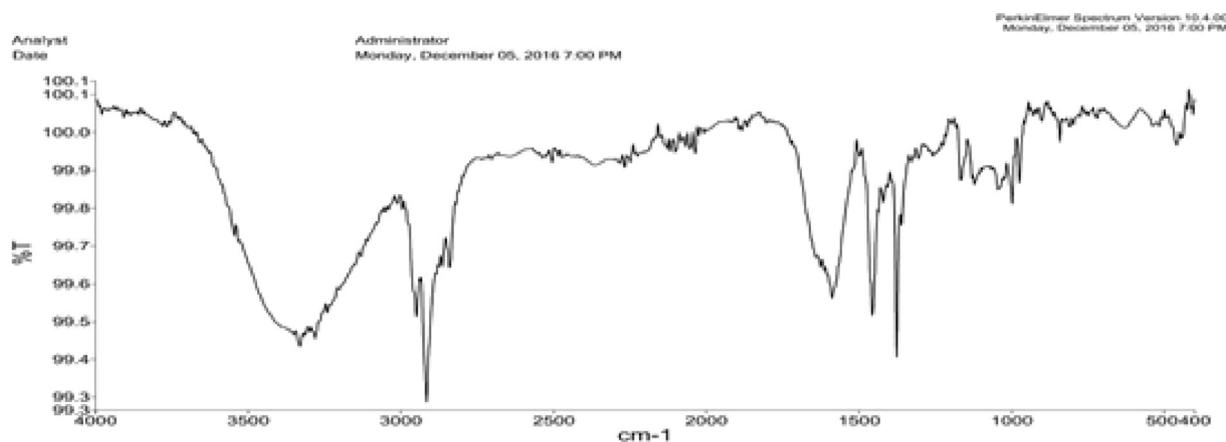


Fig. 18. FT-IR analysis of reactive orange HB dyed jute fiber reinforced PP composite.

range of 2800–3000  $\text{cm}^{-1}$  a peak was found for the presence of the C-H vibration of  $-\text{CH}_3$  group of PP and jute. Another peak was found at 1750  $\text{cm}^{-1}$  for the presence of C=O bond. A peak around 1650  $\text{cm}^{-1}$  showed

the presence of an aromatic ring in the structure. At the range of 1315  $\text{cm}^{-1}$  a peak was found for C-H of jute fiber. At the range of 1215  $\text{cm}^{-1}$  peak was found for  $-\text{OH}$  group.

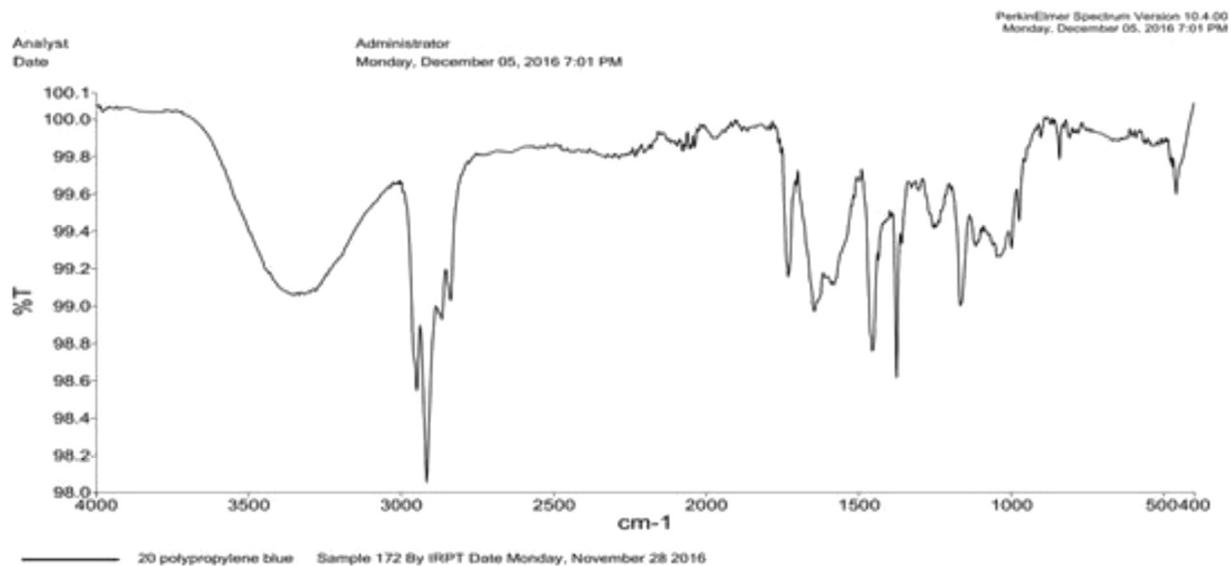


Fig. 19. FT-IR analysis of deep blue LW dyed jute fiber reinforced PP composite.

### 3.8. Scanning electron microscopy

Scanning Electron Microscopy (SEM) was carried out to investigate fiber pull-out and fiber/matrix interaction. Investigation of the fracture surface of the jute composites was performed to study interfacial properties between jute fiber and matrix. SEM images of the fracture surface of (a) 20% unidirectional untreated jute fiber based PP composite (b) 20% reactive orange HB dyed unidirectional jute fiber based PP composite (c) 20% deep blue LW dyed unidirectional jute fiber based PP composite are presented in Figs. 20, 21, and 22 respectively.

The figures clearly indicated that there was a considerable difference in the fiber-matrix interaction between untreated and treated jute fiber-based composite. Fractographic observation suggested the fracture behavior be brittle in nature. Fiber pull-out phenomena were observed for all cases, but for untreated jute fiber PP based composite pull-out was observed as individual fiber, but for treated jute fiber PP based composite there was an agglomeration of fibers into a bundle. In case of untreated jute fiber-based composite, we can see their unidirectional alignment was hampered relative to dyed jute fiber-based composite. This was a significant change of morphology and this was effective for better mechanical bonding between fiber and polymer matrix. From the SEM of the dyed jute fiber based PP composites, it can be clearly said that the fiber matrix adhesion between the jute fiber and the PP composite is higher with respect to the untreated jute fiber based PP composites. This may be the reasons of slightly higher mechanical properties of dyed jute fiber

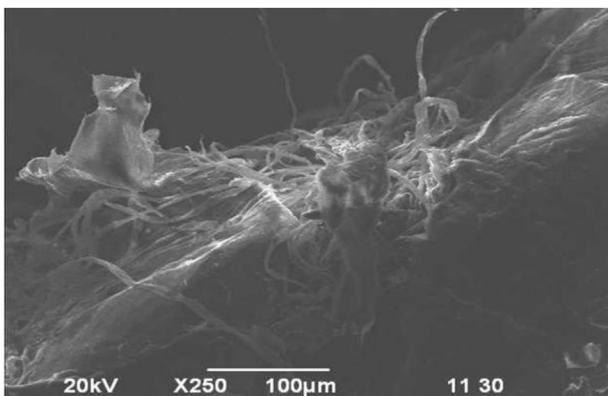


Fig. 20. SEM image of untreated unidirectional jute fiber based PP composite.

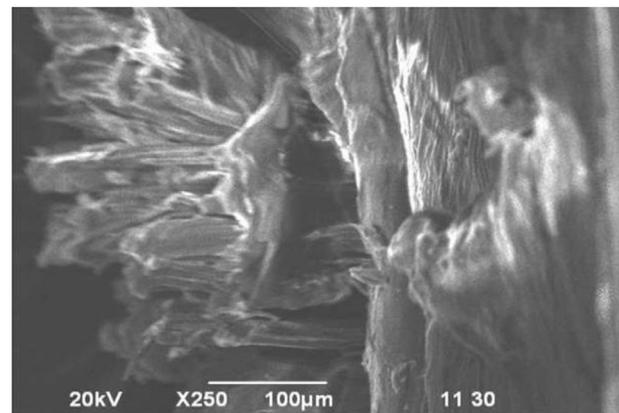


Fig. 21. SEM image of reactive orange HB dyed treated jute fiber based PP composite.

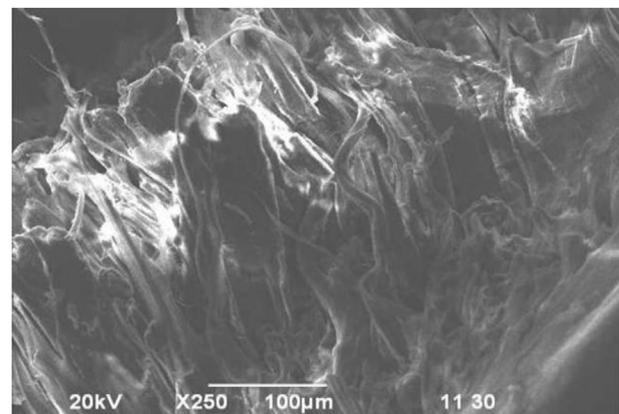


Fig. 22. SEM image of deep blue LW dye treated jute fiber based PP composite.

based PP composites.

### 3.9. Scanning electron microscopy (SEM) of LLDPE based composite

Scanning Electron Microscopy (SEM) was carried out to investigate

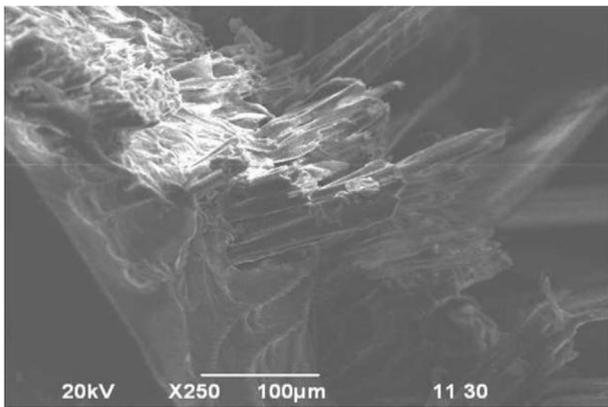


Fig. 23. SEM image of untreated jute fiber based LLDPE composite.

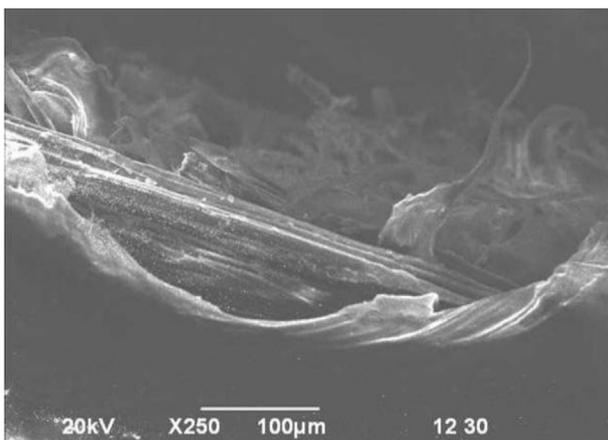


Fig. 24. SEM image of reactive orange HB dyed jute fiber LLDPE based composite.

fiber pull-out and fiber/matrix interaction. Investigation of the fracture surface of the jute composites was performed to study interfacial properties between jute fiber and LLDPE matrix. SEM images of the fracture surface of (a) 20% unidirectional non-dyed jute fiber based LLDPE composite (b) 20% reactive orange HB dyed unidirectional jute fiber based LLDPE composite (c) 20% deep blue LW dyed unidirectional jute fiber based LLDPE composite are presented in Figs. 23, 24, and 25 respectively.

The figures clearly indicate that there was a considerable difference in the fiber-matrix interaction between untreated and treated jute fiber

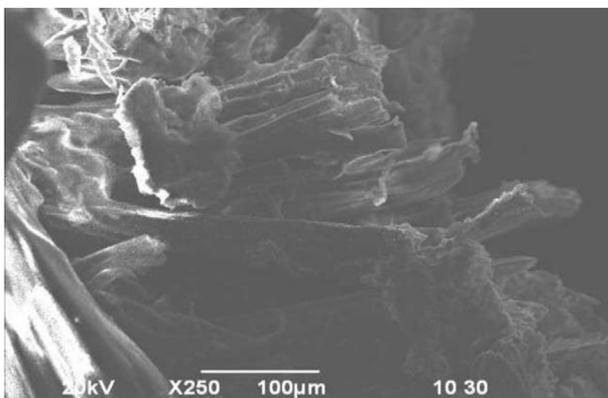


Fig. 25. SEM image of deep blue LW dyed jute fiber LLDPE based composite.

LLDPE based composite as in case of PP based matrix. Fiber pull-out phenomena were observed for all cases, but for untreated jute fiber LLDPE based composite pull-out was observed as individual fiber, but for dyed jute fiber LLDPE based composite there was an agglomeration of fibers into a bundle. The surface of dyed fiber appeared smoother than untreated fiber. From the SEM of the untreated jute fiber based LLDPE composites, it can be clearly said that the fiber matrix adhesion between the jute fibers and the LLDPE composite was lower with respect to the dyed jute fiber based LLDPE composites. This may be the reasons of slightly lower mechanical properties of untreated jute fiber based LLDPE composites.

The mechanical properties of PP are relatively higher than the LLDPE. That was the reason to be higher mechanical properties of PP based composites than the LLDPE based composites as the reinforcing material, jute was fixed. When reinforcing material was increased in percentage the mechanical properties of composites were increased in proportion. The mechanical properties of jute fiber were much higher than the PP and LLDPE. With the addition of dye to the composites, jute increased the mechanical properties of composites. In this research work, two types of dyes were added and mechanical properties were increased. But, the addition of reactive orange HB based dye showed better results than the deep blue LW based dye. The higher mechanical properties were due to the internal structure of the dyes. The addition between the fiber and matrix were good in case of reactive orange HB than the deep blue LW which was observed in the SEM analysis of this research. Though there were slight differences in mechanical properties, there was no chemical bonding between the fiber and matrix or fiber with dye, indicated no extra peak in the FTIR observation. The water absorption properties of the prepared composites were low due to the hydrophobic nature of the matrix materials. And, the matrix material coated the hydrophilic jute fiber.

#### 4. Conclusion

The result of the present research work reveals that

- ❖ Unidirectional jute fiber reinforced composites have better mechanical properties than jute fabrics reinforced composites.
- ❖ Unidirectional jute fiber reinforced PP composites showed better mechanical properties than jute fiber reinforced LLDPE composites.
- ❖ When fiber was dyed with reactive orange HB and deep blue LW dye their mechanical properties increased.
- ❖ For reactive orange HB dye based composites, there was an increase in TS and YM as well as a decrease in Eb. But
- ❖ The mechanical properties of composites decreased with increasing temperature and increased with decreasing temperature.
- ❖ Dyed unidirectional jute fiber-based composite have better adhesion in SEM image.
- ❖ The choice of materials will be easier than the earlier for different use and environment.
- ❖ When slightly higher mechanical properties will be required, different types of dye can be applied to the fabric materials.

#### Declarations

##### Author contribution statement

Md. Niloy Rahaman, Md. Sahadat Hossain, Md. Razzak, Muhammad B. Uddin, A. M. Sarwaruddin Chowdhury, Ruhul A. Khan: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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#### Competing interest statement

The authors declare no conflict of interest.

#### Additional information

No additional information is available for this paper.

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