Bio-softening of Coir Yarn for Ecofriendly Wet Processing

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Abstract

Conventional chemical bleaching of coir generates a considerable amount of effluent which is discharged into the local water bodies thereby affecting the water quality there. The possibility of bio-bleaching and bio-softening of coir yarn in order to reduce the requirement of softening and bleaching chemicals in wet processing of coir was studied. Treatment of coir yarn for 72 hrs using *Trametes versicolor* (NCIM 993) and Coirret, a bacterial consortium was carried out. The bio-treatment could impart an appreciable degree of softness to the yarn which was confirmed by the Flexural Rigidity Test. An improvement in softness of the yarn to the extent of 38% using bacterial treatment and 46% using fungal treatment was achieved. A noticeable change was observed in surface morphology of the fibre through SEM analysis. The lignin content of the fungal treated yarn was also reduced to some extent. An increase of 10% in Brightness Index of the fungi treated yarn was observed and a reduction in the requirement of bleaching chemicals could also be achieved. The physico-chemical parameters of the residual bleach liquor were also studied and a considerable decrease in BOD, COD and phenol content was observed.

Keywords: Coir yarn, Micro-organism, Eco-friendly, Coirret, Wet processing

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Flexural Rigidity Assessment of Coir Yarn

Flexural Rigidity of the untreated, bacterial treated and fungal treated yarn was tested using the Flexural Rigidity Tester (developed by CCRI). Flexural rigidity test indirectly measures the degree of softness by evaluating the flexural rigidity of the fibre, when subjected to deformation. 25 samples each of raw, control and treated fibre were tied around a PVC pipe of 2 inch diameter to attain the shape of a ring. After 24 hours, the rings were tested using the Flexural Rigidity Tester with and without load (1g) and the ring diameter and deformation of ring on loading was noted. The average radius of the ring and deformation on loading were calculated. The Flexural Rigidity was calculated using the following formula:

$$\text{Flexural Rigidity} = 0.0047\ mg.\ (2\ \Pi\ r)^2 \cos\varnothing / \tan\varnothing\ (gcm^2)$$

where, mg = weight of load applied in grams

r = radius of the ring in cm

d = deformation of lower end of ring in cm

$\varnothing = 493d/2\ \Pi\ r$

Scanning Electron Microscopic Study of Coir Yarn

The surface morphology of the treated, untreated and control coir yarn were observed using Scanning Electron Microscope (SEM) JEOL JSM 6380LV.

Estimation of Lignin in Fibre Samples by Acid Hydrolysis Method

One gram of coir yarn/fibre was accurately weighed and cut into small pieces. Weighed coir yarn was packed in a whatman 1 filter paper and refluxed with ethanol-benzene mixture (1:2) in a Soxhlet extraction apparatus for 4 hours. After cooling, the fibre was filtered, washed with ethanol and dried in hot air oven. The dried sample was refluxed with 200ml boiling water for 4 hours in a round bottom flask attached to a Liebig condenser. It was then cooled, filtered and air-dried. The dried sample thus obtained was transferred to a 100ml beaker and carefully macerated into a fine paste with the addition of 5ml 72% H_2SO_4. Another 20ml 72% H_2SO_4 was then added to make the final volume 25ml. This mixture was kept at room temperature for 2 hours. The sulfuric acid treated sample was diluted with 580ml distilled water in a 1000ml round bottom flask. Diluted sample was again refluxed for 4 hours. After refluxing, the mixture was cooled and filtered through a sintered G-4 crucible and washed thoroughly to remove all the residual acid. The sintered G-4 crucible with the residues was dried at 105°C in a hot air oven for 5-8 hours for complete moisture removal till a constant weight was obtained. The residue obtained after this treatment is lignin and the lignin content of coir fibre was calculated as follows

$$\text{Lignin content} = \frac{\text{Weight of lignin (in grams)} \times 100}{\text{Weight of sample taken}}$$

(Stephen Y.Lin & Carlton W.Dence(Eds.), 1992)

Evaluation of Brightness Index

Brightness index (TAPPI 452 / ISO 2470) of the raw, control and treated samples were measured using Premier Colorscan Spectrophotometer in the visible wave length (360-700nm) range.

Physico-Chemical Parameters of Bleach Liquor

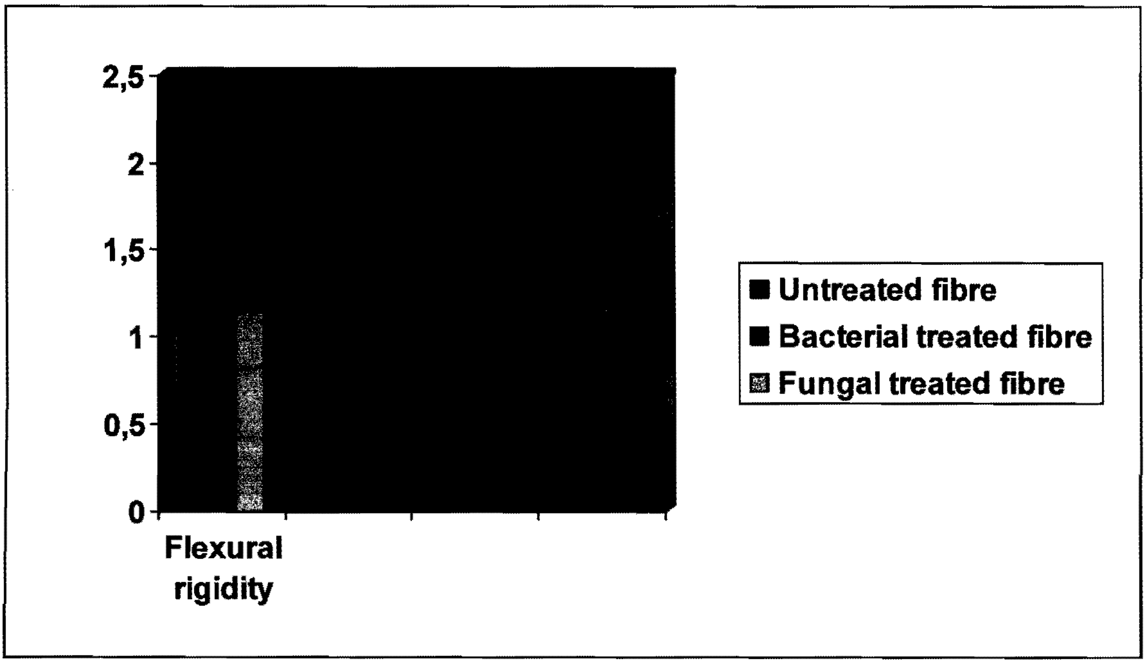
pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Phenol content of the bleach liquor were estimated using standard methods. (Standard Methods for the examination of water and waste water, 1989).

Results and discussion

The observations of the biobleaching study are furnished in Figure 1. It was observed that 72 hour treatment with *Trametes versicolor* considerably improved the brightness of the coir yarn. The treatment with bacterial consortium revealed comparatively less bleaching effect. The coir yarn treatment with the cell free culture fluid of *T. versicolor* also displayed the same degree of brightness to the yarn, which confirms the presence of extra-cellular lignin degrading enzymes in the culture fluid.

Figure 1. Control (left), Fungal (middle) and Bacterial treatment (right) on coir yarn

Figure 2. Flexural rigidity change on biosoftening



The coir yarn obtained after the chemical bleaching was observed to be rougher in texture than the unbleached yarn. The shade of the chemical bleached yarn was taken as the standard for evaluation of the chemical reduction trials.

Assessment of Softness-Flexural Rigidity Test

Both the bacterial and fungal treatments were found to be capable of imparting softness to the coir fibre. Apart from improved sensory perception in the feel of the fibre, the flexural rigidity test confirmed the softness. FR values obtained were 2.13 gcm^2 for raw fibre, 1.32 gcm^2 for bacterial treated fibre and 1.15 gcm^2 for fungal treated fibre. Almost 38% reduction in flexural rigidity of the yarn was observed after bacterial treatment whereas the fungal treatment showed a reduction of 46% without any loss in strength of the fibre. Reduction in flexural rigidity is directly proportional to the improvement in softness. The result can be interpreted as a bar diagram as shown in figure 2.

Scanning Electron Microscopic Study

Samples of untreated, control, biobleached and chemical bleached coir yarn/fibre were scanned at different magnifications to examine the changes in surface structure on bleaching. Details of SEM studies are furnished in Figures 3, 4 and 5. Fig. 3 portrays the normal and cross-sectional view of the untreated fibre. A thin layer of cuticle can be observed all over the surface of the fibre in the case of untreated and control fibres. This layer was absent in the chemical as well as biotreated fibres.

Another important finding was the appearance of pores on the surface of the treated fibre, which was not observed in the control and untreated fibres. The distribution of pores was higher in chemical bleached fibre, followed by fungal and bacterial bleached fibre. This indicated that bleaching modifies the surface topology of the fibre to some extent.

Variation in Lignin Content

Lignin content (Klason lignin) of the treated and untreated yarn was estimated by Acid Hydrolysis method and the results are furnished in Table 2. There was no significant difference in the lignin content of the untreated and bacterial treated yarn. However, the lignin content of fungal treated yarn was observed to be 32%, which was around 12% lower than that of the lignin content of untreated yarn. The lignin content of chemical bleached yarn was 23% lower than that of the untreated yarn.

Table 2. Lignin content of bio-treated coir yarn

Samples	Lignin content (%)
Untreated yarn	36.270
Bacterial treated yarn	36.268
Fungal treated yarn	32.070
Chemical bleached yarn	28.590

Chemical Reduction Trials

Bio-bleaching was evident in fungal bleached coir yarn as the brightness was significant over the control yarn. The fungal treated yarn (CRT-A) bleached with the same amount of chemicals was found to be brighter than the chemical bleached yarn. Hence the chemical reduction trials were carried out on the fungal treated coir yarn. Three reduction trials were carried out with 2.4%, 4% and 8.8% reduction in the usage of chemicals. The yarn obtained after the combined bleaching trials retained the same brightness as that of chemical bleached yarn. To confirm the visual assessment, the brightness index of the treated yarn was also evaluated (CRT-B, CRT-C and CRT-D).

Evaluation of Brightness Index

The colour/brightness of the yarn was quantified in terms of Brightness Index using Premier scan Spectrophotometer. Brightness index of the untreated yarn was observed to be 10.093. Fungal treatment increased the brightness index by a factor of 0.97 ie 11.063. Brightness of the chemically bleached yarn was 18.507. The chemical reduction trials (CRT) were assessed in terms of brightness index, so as to retain the same degree of brightness. The brightness index of the fungal treated yarn bleached with the same amount of chemicals

Figure 3. Scanning Electron Microscope image of Untreated fibre (Normal view & Cross sectional view)

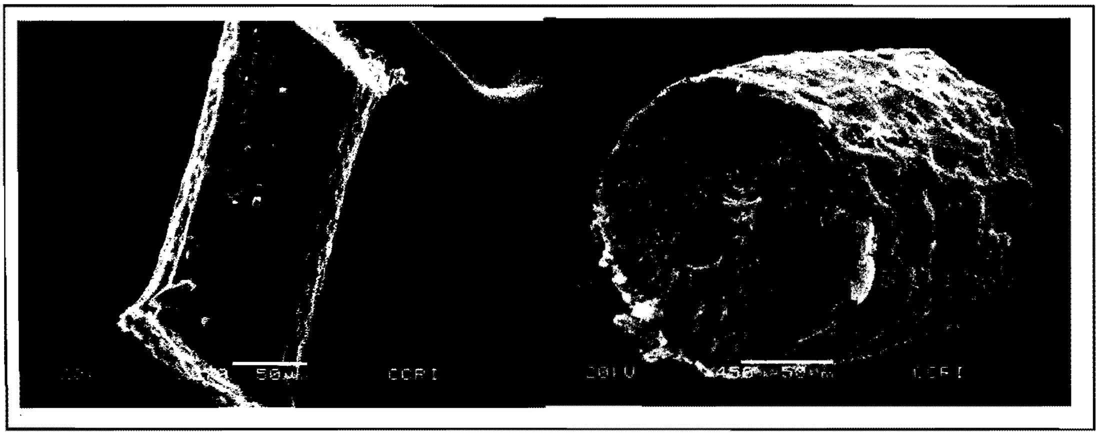


Figure 4. Scanning Electron Microscope image of Control fibre (left) and Chemical bleached fibre (right)

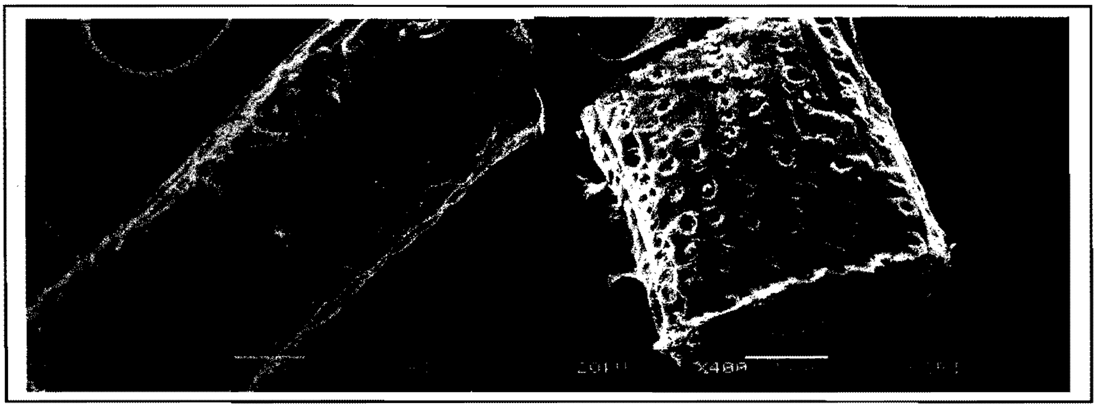


Figure 5. Scanning Electron Microscope image of Bacterial treated fibre (left) and Fungal treated fibre (right)

was 19.978 which was higher than that of the chemical bleached yarn. The coir yarn after combined bleaching was found to have the brightness index close to that of 18.507, the brightness index of chemical bleached yarn. Data on the brightness index of different samples have been furnished in Table 3.

Table 3. Brightness index of treated yarn

Sample	Brightness Index
Untreated yarn	10.093
Control yarn	9.766
Bacterial treated yarn	9.351
Fungal treated yarn	11.063
Chemical bleached yarn	18.507
CRT-A	19.978
CRT-B	19.197
CRT-C	18.128
CRT-D	18.305

Analysis of Bleach Liquor

To evaluate the status of the effluent after biobleaching, different physico-chemical parameters of the residual bleach liquor were studied. pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and phenol content were estimated to analyse the pollution aspects of bleaching. The results obtained are tabulated in Table 4. It was observed that, when compared to chemical bleaching, the biobleach liquor possessed lower BOD, COD and phenol content, thereby confirming that the process leads to reduction in pollution. Combined bleaching or bleaching of fungal treated coir yarn with lesser quantity of chemicals, have considerably reduced the BOD, COD and phenol content of the bleach liquor indicating the advantage of combined bleaching over chemical bleaching.

Although the use of *Trametes versicolor* for paper pulp biobleaching has been well studied there is no literature available on the application of *Trametes versicolor* for biobleaching and biosoftening of coir yarn. In the present study the biobleaching potential of *Trametes versicolor* on coir yarn was evaluated and the observations confirm its potential for biobleaching and biosoftening of coir yarn.

Flexural rigidity test indirectly measures the degree of softness by evaluating the flexural rigidity of the fibre, when subjected to deformation. Coir yarn treatments with both the bacterial and fungal cultures were observed to impart a smoother feel to the yarn. Softening of 46% by fungal treatment and 38% by bacterial treatment was achieved. This was remarkably higher than the softening reported in a study on softening of coir fibre using different chemical softeners where the maximum softening (24.65%) was obtained using sodium hydroxide. (Anto, *et al*, 1997b) Since the rigid lignin network between fibre cells restricts its flexible behavior, softening might have occurred as a result of the degradation of surface lignin.

SEM studies of coir yarn could help in understanding the difference in surface structure brought about by bleaching. The appearance of pores on the treated yarn is an indication of the removal of lignin bondage between the cellulose strands. The effect of bleaching was greater in chemical bleaching as also the extent of pore formation. However this may not affect the strength of the fibre/yarn, since the degradation takes place only on the surface of the fibre.

The fact that reduction in lignin content leads to biobleaching and biosoftening the fungal treated yarn is evident since the component responsible for colour and stiffness of coir yarn are one and the same 'lignin'. Chemical bleached yarn retained 28% of its lignin content, which indicates that the action of chemicals is restricted to the surface of the yarn. Similarly, microbial activity was also confined to the fibre surface. The degree of biological delignification can be enhanced by the direct application of lignolytic enzymes secreted by the microorganisms.

Biobleaching using fungi was insufficient to achieve the required brightness of the yarn. A combination of fungal and reduced chemical treatment demonstrated the maximum potential of biobleaching. Apart from the reduction in pollution load this has an additional advantage of being cost effective.

Table 4. Physico-chemical parameters of bleach liquor

TREATMENT	pH	PHENOL Concentration (mg/l)	BOD (mg/l)	COD (mg/l)
Control	7.65	2.656	38.50	1111.04
Bacterial treatment	7.37	7.584	263.54	912.64
Fungal treatment	4.44	10.784	709.46	1289.60
Chemical bleaching	9.35	74.700	1246.62	7022.40
Combined bleaching	9.60	64.700	844.56	4435.20

BOD, COD, phenol content and pH are some of the important physico-chemical parameters of the effluents from the coir industry that are to be monitored continuously. The phenolic constituents present in the residual liquor are toxic in nature and are detrimental to the survival of aquatic organisms. Thus its concentration in the bleach liquor should be as low as possible. The residual bleach liquor after combined bio- chemical treatment of the yarn exhibited decreased levels of phenol, BOD and COD, which is desirable. The BOD of the fungal treatment liquor can be reduced further by applying lignolytic enzymes extracted from culture broth instead of applying the whole cell culture.

In a report on softening of coir yarn conducted at CCRI, caustic soda has been used as the softening agent. Even though caustic soda treatment was found to be quite effective in producing the crimp on the fibre, the colour of the fibre was changed into deep brown. The effluent treatment was another big problem to tackle as the residual alkali needed to be neutralized with huge quantities of inorganic acids making the process hazardous and uneconomical. Therefore, it was rejected by the coir industry. (Sarma, 2001). Thus biosoftening of coir yarn has a better edge over chemical softening in the aspects of pollution control and cost. In biological treatment, the toxic lignin degradation products like phenols are not only removed from the coir but are consumed by the microorganisms, thus reducing the toxicity of the effluent. This in turn reduces the COD, phenol content and other pollution parameters of the effluent.

The present study indicates that the pre-treatment of coir yarn with *T. versicolor* followed by chemical processing could be an economical alternative for bleaching in the coir industry. The wet processing technology, which may be adopted by this combined bio-chemical bleaching, will also lead to the reduction in pollution load released as effluent to the water bodies.

The salient findings of this study pave the way to the development of an eco-friendly process for biobleaching and biosoftening that can be adopted in the wet processing of coir.

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