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Hybrid bleaching of jute yarn using hydrogen peroxide and peracetic acid

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An alternative eco-friendly method of bleaching of jute fibre and yarn has been developed using peracetic acid as bleaching agent and it is found that the treatment produces satisfactory whiteness with minimum loss in tensile properties. Comparative study on bleaching of jute using these two bleaching agents (hydrogen peroxide and peracetic acid) clearly demonstrates that hydrogen peroxide bleaching produces 5-8 grades higher whiteness in HUNTER Scale but peracetic acid bleached fibre and yarn show better retention of tensile strength after bleaching. Partial bleaching of jute has also been carried out using 25%, 50% and 75% (normal dose) of both bleaching agents separately and their whiteness indexes as well as tensile strength are evaluated. In both the bleaching processes, whiteness increases with increase in concentration of bleaching agents and tensile strength retention decreases. It is also clear that for any particular percentage of bleaching agent, whiteness index is more in peroxide bleached sample, while tensile strength is more in case of peracetic acid bleached samples. Hence, hybrid bleaching has been carried out using both the bleaching agents (peracetic acid and hydrogen peroxide) by two-step bleaching process so that the synergistic effect can produce higher whiteness with high retention of tenacity. Moreover, the sequence of bleaching, i.e. peracetic acid followed by hydrogen peroxide or vice versa has also been studied in detail. It has been found that the hybrid bleaching of jute using peracetic acid followed by hydrogen peroxide produces better whiteness with high retention of tensile strength. The hybrid bleaching of jute using 75% peracetic acid followed by 25% hydrogen peroxide produces the best result.

Keywords: Hybrid bleaching, Hydrogen peroxide, Jute fibre, Peracetic acid, Tensile properties, Whiteness index

1 Introduction

Natural fibres are characterized for their renewability, biodegradability, comfortable moisture retention capacity, affinity to different classes of dyestuffs and wide variability to cater different needs with respect to use, season, temperature, etc. Jute, the ligno-cellulosic and annually renewable fibre, stands next to cotton in regard to production, and different steps are being adopted to improve its quality parameters, like fineness and strength, so that the fibre can find its uses in higher proportion in making diversified and value-added products. The conventional use of jute in packaging sector is still consuming the major part of this fibre in terms of total production and its use in diversified areas like home textiles, lifestyle products upholsteries, and to some extent, in apparel sector is increasing day by day. Now different types of fashion bags, ornaments, outer garments, curtains, soft luggage and fashion accessories has entered in to market worldwide, which demand for better quality as well as performance[1-5]. Hence, production of finer yarns and fabrics, and their eco-friendly chemical processing has become important[6].

Bleaching is the most important unit operation in chemical processing of the fibre, which makes it white, and absorbent, and a lot of work has been carried out to bleach jute fibre using different bleaching agents[7-10]. In order to reduce the requirement of different resources like water and heat as well as to make the process user friendly, study has been done to bleach jute fibre at ambient temperature[11-16]. Till date, hot hydrogen peroxide bleaching is the most popular and being practiced in industry, which produces maximum whiteness with substantial damage to its tensile strength and pliability. The hydrogen peroxide bleaching is carried out at high alkaline condition and elevated temperature using sodium silicate as stabilizer. Jute fibre is very sensitive to alkali at high temperature and results in weight loss due to removal of a part of hemi-cellulose, producing loss of strength. The deposition of silicate on the surface of the fibre produces harsh feel. So, the study has been done to bleach jute fibre with peracetic acid at neutral or mild alkaline condition without using sodium silicate[17]. The analysis of the bleached fibre reveals that

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the bleaching causes minimum loss in tenacity but the feel is found good. However, it should produce a little more whiteness index for producing light and bright shade. Hence, for achieving good optical properties with higher retention of tensile strength, it was realised that a combined treatment of jute with hydrogen peroxide and peracetic acid may be fruitful where lower dose of individual bleaching agents for lower duration may be used in sequential manner by two-step bleaching process.

Hence, a comparative study of bleaching has been done using hydrogen peroxide and per acetic acid by conventional process. Partial bleaching of jute has also been carried out by using different percentages of bleaching agents individually and their effect on whiteness index and retention of tensile strength studied. Then hybrid bleaching of jute yarn has been done using different proportions of both the bleaching agents (peracetic acid and hydrogen peroxide) using two-step bleaching process for obtaining good whiteness with high retention of tenacity. The sequence of hybrid bleaching, i.e. hydrogen peroxide followed by per acetic acid or vice versa has been studied in detail to arrive at a suitable bleaching protocol.

2 Materials and Methods

2.1 Materials

Grey jute fibre of TD3 variety in reed form and jute yarn of 176 tex were used in this study. The following chemicals of analytical grade (Merck) were used, viz. hydrogen peroxide (30%), tetra sodium pyro phosphate (TSPP), tri-sodium phosphate, sodium carbonate, acetic acid, sodium silicate and non-ionic surface active agent. The peracetic acid (35%), obtained from M/s Chemtex speciality Ltd., Kolkata, was used for bleaching of jute fibre and yarn.

2.2 Methods

2.2.1 Soft Scouring

Raw jute fibre was treated with sodium carbonate (2% owf) and non-ionic surface active agent (Ultravon JU, 2 g/L) at 50 ºC for 30 min, keeping the material-to-liquor ratio at 1:20. After this treatment, the fabric was washed thoroughly in cold water and dried.

2.2.2 Bleaching

2.2.2.1 Hydrogen Peroxide Bleaching

Bleaching of mild scoured jute fibres and yarn was done in a closed vessel for 90 min at 80-85 ºC, keeping the material-to-liquor ratio at 1:20 with hydrogen peroxide (20ml/L), trisodium phosphate (5 g/L), Ultravon JU (2 mL/L), sodium hydroxide (1 g/L) and sodium silicate (10 g/L). The *p*H of the bath was maintained at 10. After bleaching, the fabrics were washed thoroughly in cold water, neutralised with acetic acid (2 mL/L), washed again in cold water and finally dried. The partial hydrogen peroxide bleaching of jute using 25%, 50% and 75% of bleaching agent was carried out considering 20 mL/L concentration as 100% and other auxiliaries were used in proportionate amounts.

2.2.2.2 Peracetic Acid Bleaching

Bleaching of mild scoured jute fibres and yarn was done in a closed vessel for 120 min at 60-70^{0}C, keeping the material-to-liquor ratio at 1:20 with peracetic acid (20 mL/L.), tetra sodium pyro-phosphate (1-3 g/L), sodium carbonate (1-2 g/L) and sodium silicate (10 g/L). The pH of the bath was maintained at 7.5-8. After bleaching, the fibres are washed thoroughly in cold water and finally dried. The partial peracetic acid bleaching of jute using 25%, 50% and 75% of bleaching agent was carried out considering 20 mL/l concentration as 100% and other auxiliaries were used in proportionate amounts.

2.2.2.3 Hybrid Bleaching of Jute Yarn

Hybrid bleaching of jute yarn has been done using both the bleaching agents (peracetic acid and hydrogen peroxide) in different proportions by two-step bleaching process. The sequence of hybrid bleaching was hydrogen peroxide followed by per acetic acid or vice versa.

(i) Peracetic Acid followed by Hydrogen Peroxide Bleaching

Peracetic acid bleaching of soft scoured jute yarn was done using the method as given in section **2.2.2.2** using 25%, 50% and 75% peracetic acid for one hour. Then, the required bleaching agents and auxiliaries were added for hydrogen peroxide bleaching as per the method given in section **2.2.2.1** using 25%, 50% and 75% bleaching agents. Gradually, the temperature was raised to 80-85^{0}C. The bleaching was carried out for one more hour. The material was taken out followed by washing, souring with mild acetic acid and finally washing.

(ii) Hydrogen Peroxide followed by Peracetic Acid Bleaching

Hydrogen peroxide bleaching of soft scoured jute yarn was done as per the method given in section **2.2.2.1** using 25%, 50% and 75% hydrogen peroxide for one hour. The temperature of the bath was brought

down to 70^0C and *p*H was adjusted to 8 by adding acetic acid. Then the required bleaching agents and auxiliaries were added for per acetic acid bleaching as per the method given in section **2.2.2.2** using 25%, 50% and 75% bleaching agents. The bleaching was carried out for one more hour. The material was taken out followed by washing and finally drying.

2.2.3 Evaluation of Fibre Properties

K/S value, L, a*, b*, whiteness index on the 'HUNTER' scale, yellowness index on the 'ASTM D 1925' scale and brightness index on the 'TAPPI 452' scale of all the jute fibre samples were measured by the Spectrascan-5100 computerized colour matching system.

The bundle tenacity of the jute fibre was measured under standard conditions (65±2% relative humidity and 27±2 ºC temperature) using NIRJAFT fibre bundle strength tester (a balance type tester), based on the principle of beam balance (with two unequal arms) following the usual test method [BIS, 1986 (f)].

2.2.4 Evaluation of Yarn Properties

Tensile properties of yarns were evaluated as per IS: 1670-1970. For evaluation of breaking load and extension, the Instron tensile tester was used with 50 cm gauge length and 200 mm/min crosshead speed. The average of 60 test results was taken for each sample.

K/S value, L, a*, b*, whiteness index on the 'HUNTER' scale, yellowness index on the 'ASTM D 1925' scale and brightness index on the 'TAPPI 452' scale of all the yarns were measured by the Spectrascan-5100 computerized colour matching system.

3 Results and Discussion

Jute fibre and yarn has been bleached with both the oxidising bleaching agents (hydrogen peroxide-HP and peracetic acid-PAA). The results of evaluation are given in Table 1. It is clearly observed that the hydrogen peroxide bleaching produces better whiteness in both jute fibre and yarn, but the tensile strength retention is higher in case of peracetic acid bleaching. Hence, peracetic acid bleaching results in satisfactory whiteness with minimum strength loss during bleaching process.

For any bleached yarn or fabric, whiteness as well as brightness properties are very important if they are to be used as bleached product or to be dyed / printed for making value-added product. On the other hand, in all the cases retention of tensile strength is also must to maintain the durability of the final product. Hence, a combined treatment of both the bleaching agent, i.e. hydrogen peroxide and peracetic acid may produce improved whiteness with good retention of strength. So, jute yarn is bleached with different amount of bleaching agents (hydrogen peroxide, peracetic acid) separately to find out the whiteness index achieved in each case and their corresponding tensile properties. Hence, the optical and physical properties of partial bleached jute yarn have been studied and are tabulated in Tables 2 and 3 respectively.

Tables 2 and 3 clearly reveal that the whiteness and brightness indices increase and tenacity decreases with increase in % of bleaching agents for both the bleaching agents. It is also clear that for any particular % of bleaching agent, hydrogen peroxide bleached yarn shows better whiteness and lower tenacity, while retention of tenacity is high in case of peracetic acid

Table 1 — Comparative study for bleaching of jute fibre and yarn using peracetic acid (PAA) and hydrogen peroxide (HP)

Jute	Whiteness index		Yellowness index		Brightness index		Fibre bundle strength, g/tex	Yarn tenacity cN/tex	Yarn extension %
	Fibre	Yarn	Fibre	Yarn	Fibre	Yarn			
Raw	50.45	44.11	40.81	63.77	21.34	14.36	20.96	9.56	1.53
PAA	77.43	74.16	31.16	33.41	52.76	47.67	19.48	7.81	1.23
HP	84.61	77.52	20.14	36.91	66.44	50.14	16.48	5.86	1.25

Table 2 — Optical properties of partial bleached jute yarn using different % of hydrogen peroxide and peracetic acid

Yarn	*K/S*	WI	YI	BI	L	a*	b*
Grey (a)	2.75	48.35	57.08	17.95	60.72	6.68	21.21
Mild scoured (b)	2.98	44.85	52.00	16.22	56.03	7.21	16.73
PAA 25 (c)	1.06	65.01	43.21	34.82	75.93	2.97	20.18
PAA 50 (d)	0.58	75.47	36.20	48.51	84.86	0.16	19.66
PAA 75 (e)	0.47	77.66	33.14	52.20	86.36	-0.36	18.35
HP 25 (f)	0.79	71.64	38.04	43.32	81.77	-0.08	20.32
HP 50 (g)	0.39	79.72	28.33	56.46	87.58	-1.56	16.28
HP 75 (h)	0.31	82.65	25.86	61.61	89.77	-1.93	15.31

WI - Whiteness index, YI- Yellowness index, and BI- Brightness index .

Table 3 — Physical properties of partial bleached jute yarn using different % of hydrogen peroxide and peracetic acid

Yarn	Count, tex	Tenacity, cN/tex	Extension, %	Initial modulus, cN/tex	Total energy, MJ
Grey (a)	176	10.16	1.48	669.87	66.47
Mild scoured (b)	176	9.52	1.93	368.72	71.82
PAA 25 (c)	176	8.32	1.79	300.71	47.34
PAA 50 (d)	176	8.31	1.70	353.05	49.29
PAA 75 (e)	176	7.62	1.65	319.62	42.66
HP 25 (f)	176	7.27	1.53	383.86	42.75
HP 50 (g)	176	7.22	1.54	357.06	40.56
HP 75 (h)	176	6.84	1.55	353.25	40.20

bleached yarn with low whiteness index. The tenacity of the processed yarn is found to be uniform, which is evident from the low CV% (10-15). Hence, it is concluded that a suitable combination of bleaching process using both hydrogen peroxide and peracetic acid may produce sufficient whiteness and brightness, retaining high tensile strength. So, combined bleaching is done using both the bleaching agents. The hybrid bleaching of jute yarn using peracetic acid and hydrogen peroxide has been carried out following both the sequences, i.e. peracetic acid followed by hydrogen peroxide or vice versa. The combined bleached yarns have been evaluated for optical and physical properties and their results are shown in Tables 4 and 5 respectively.

Analysis of two-step hybrid bleaching of jute using both oxidizing bleaching agents (peracetic acid and hydrogen peroxide) shows good whiteness index. The sequential bleaching of jute using peracetic acid followed by hydrogen peroxide bleaching always produces better whiteness and brightness than that produced by bleaching of jute using hydrogen peroxide followed by peracetic acid.

Evaluation of physical properties indicates that tensile strength retention is higher in case of peracetic acid followed by hydrogen peroxide bleaching. So, considering satisfactory whiteness index and higher retention of tensile strength two-steps bleaching using peracetic acid followed by hydrogen peroxide is found to be better than that produced by bleaching of jute using hydrogen peroxide followed by peracetic acid. Hybrid bleaching using 75% peracetic acid followed by 25% hydrogen peroxide bleaching treatment results in best acceptable combination.

4 Conclusion

4.1 Jute fibre and yarn can be bleached with per acetic acid with satisfactory whiteness index (75-80), which is slightly lower than that produced by conventional hydrogen peroxide bleaching (WI 77-84)

Table 4 — Optical properties of hybrid bleached jute yarns

Yarn	Whiteness index	Yellowness index	Brightness index
Grey (A)	46.47	54.49	13.92
Mild scoured (B)	44.11	63.77	14.36
HP 25 + PAA 25 (C)	75.25	33.46	49.05
HP 50 + PAA 25 (D)	79.83	31.79	55.62
HP 75 +PAA 25 (E)	80.53	26.78	58.08
HP 50 + PAA 50 (F)	77.80	30.03	53.36
PAA 25 + HP 25 (G)	76.64	35.15	50.21
PAA 50 + HP 25 (H)	80.31	28.31	57.42
PAA 75 + HP 25 (I)	81.69	28.15	59.55
PAA 50 + HP 50 (J)	80.91	25.08	59.29

Table 5 — Physical properties of hybrid bleached jute yarns

[Count 138 tex]

Yarn	Tenacity cN/tex	Extension %	Initial modulus cN/tex	Total energy MJ
Grey (A)	9.56	1.53	438.61	44.88
Mild scoured (B)	8.91	1.54	486.61	38.86
HP 25 + PAA 25 (C)	8.11	1.74	444.84	50.72
HP 50 + PAA 25 (D)	7.45	1.60	481.81	43.28
HP 75 +PAA 25 (E)	8.04	1.62	465.00	43.62
HP 50 + PAA 50 (F)	7.78	1.65	484.00	46.11
PAA 25 + HP 25 (G)	8.68	1.73	435.61	51.27
PAA 50 + HP 25 (H)	8.45	1.83	414.57	48.24
PAA 75 + HP 25 (I)	8.52	1.62	474.57	53.95
PAA 50 + HP 50 (J)	8.31	1.43	446.22	44.88

4.2 Retention of tensile properties after bleaching is excellent in per acetic acid bleaching (95%), whereas it is only 75-80% in case of conventional hydrogen peroxide bleaching.

4.3 Hybrid bleaching of jute using peracetic acid followed by hydrogen peroxide following two-step single bath processes produces better whiteness and brightness along with higher retention of tensile strength.

4.4 Two- step single bath process of hybrid bleaching of jute using 75% peracetic acid followed by 25% hydrogen peroxide bleaching treatment results in best results with respect to optical and physical properties.

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