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LOW CHEMICAL PULPING OF BIOTREATED JUTE FIBRE FOR MAKING HANDMADE PAPER

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Abstract :

Paper making process for long has mainly used wood from tree stem but environment advocates have proposed the use of non-wood fibres in paper making as a way to preserve natural forests. Moreover, the demand for paper is increasing. So, scientist all over the world have been involved in intensive research for the alternative sources of pulp and jute was found to be a good alternative. Alkaline pulping followed by beating is most suitable for making handmade paper for jute. Pulping using minimum chemicals and beating time result in reduction in chemical consumption as well as energy cost, which is the need of the hour. Specific enzymes like cellulase, xylanase, pectinase, laccase, lipases etc contributes to reduce the amounts of chemicals and energy required for making paper. Objective of the present study is the utilisation of biocatalysts to produce pulp with lower chemical and energy consumption using jute fibre and production of paper with improved optical and physical property. Two commercial enzyme, Texbio-M (cellulase and hemicellulase based enzyme) and Texzyme-J (Xylanase based enzyme) were applied on jute fibre by exhaustion method. Then pulping of control and enzyme treated fibre was carried out following hot soda, cold soda and alkaline sulphite anthraquinone methanol (ASAM) process. Beating of the pulp was done using laboratory valley beater and paper was made by semi-automatic hand-sheet forming machine. The yield of the pulp, physical as well as optical properties of the paper was evaluated following standard procedures. Enzyme treatment of jute fibre before pulping results in improvement of yield by 10%, fold-endurance by 100% and tensile & tear index by 15% using only 50% chemical compared to that produced by control sample. It is concluded that better yield of the pulp and improvement of quality of paper can be obtained using combination of enzyme treatment and chemical pulping using lower dose of chemical and at lower temperature.

1. INTRODUCTION

The pulp and paper industry is one of India's oldest and core industrial sector (1). The demand and use of pulp and paper have marked the levels of civilisation and development of many societies. The pulp in society used in education, information storage, advertising, communication, in protection , transportation and securities of goods in transit, protection of human health and sanitation in form of tissues and sanitary paper products. Both wood and non wood resources are currently exploited for manufacturing of pulp, paper, and soft boards, which consists of similar chemical constituents although in dissimilar magnitudes (2). India has about 2795 handmade paper units which are mainly based on cotton rags, hosiery cuttings, tailor cuttings and small quantities of waste papers. The increasing demand of handmade paper has left a big gap between the projected demand of 28000 tons in 2010 and the present production of 15000 tons (3). This gap can be reduced by introducing alternative lignocellulosic raw materials like jute (4-5).

The pulp and paper sector is among one of the energy intensive and highly polluting industrial sector of the Indian economy and is therefore of particular interest in the context of both local and global environmental concerns (6). Demand of paper is expected to rise in furure with increasing literacy and growth of the manufacturing sector in India. Intervention of biotechnological processes to increase productivity by adoption of innovative, efficient and cleaner process is desirable to address the economic, environmental and social development issues (7-8). Pulp and paper industry converts renewable fibrous raw materials (wood/ forest base, agro residue based or waste paper based) into pulp, paper and paper board. The major production steps for converting raw material to pulp and subsequently to paper can be divided into five processes ; raw material preparation, pulping, bleaching, chemical recovery and paper making.

Raw materials, energy, chemicals, labour and water are the major inputs for the production of paper. Raw material and energy constitute about 50-60% of the total cost of production while chemical cost component varies from 10-15%. Biotechnology offers scope to reduce energy and chemical consumption during pulping, bleaching as well as reduces pollution load to the environment without investing heavily on technology.

Handmade paper industry occupies a very important position in India and employs a large number of rural artisans. The beauty of the handmade paper industry is that they can utilise a variety of raw materials depending on the availability and can produce a wide range of products. The cooking of lignocellulosic fibres like jute is an important step in paper making which requires a lot of chemicals and energy & produce effluents (9). Pretreatments of the fibres with suitable enzymatic formulation can produce modified fibre which may be utilised for pulping using low chemical concentration or alternative mild chemicals at a lower temperature making the process user as well as environment friendly. In this work jute fibre has been treated with cellulose and xylanase enzymes and subsequently pulping of these treated fibres has been done following three different pulping methods using different parameters of pulping.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Jute fibre: Jute fibre of low quality was cut into 2-4 cm pieces and used for biotreatment and pulping.

2.1.2 Chemicals: The following chemicals of analytical grade were used in the experiment : Sodium hydroxide, Sodium carbonate, sodium sulphite, anthraquinone and methanol.

2.1.3 Enzymes: Two commercial enzyme, Texbio-M (Cellulase and hemicallulase based enzyme) and Texzyme –J (Xylanase based enzyme) were procured from M/s Tex Biosciences (P) Ltd, Chennai and used for the study.

2.2 Methods

2.2.1 Enzyme treatment : Jute fibre was treated with a mixture of enzyme , Texbio M (2 ml/L) and Texzyme J (2 ml/L) using material to liquor ratio 1:10 at a temperature of 50- 550C for two hours. The pH was maintained at 8-9 by using sodium carbonate buffer. After the treatment, the samples were boiled for 30 min and washed thoroughly.

2.2.2 Hot soda pulping: Controlled and enzymes treated fibres were boiled for three hours in open vessel using different caustic concentrations (2%, 4%, 8%) using liquor ration of 1:10. After the digestion, the pulps were washed thoroughly with running water.

2.2.2 Cold soda pulping : Control jute fibres was soaked in a 10% NaOH solution and enzyme treated fibres were soaked in a 4%,7% & 10% NaOH solution at 1:10 material to liquor ratio for 24 hrs. The material was washed free of alkali with running water.

2.2.4 ASAM Pulping: Control jute fibres were subjected to ASAM pulping using sodium hydroxide (3%), sodium sulphite (12.9%), anthraquinone (0.01%) at 1:10 material to liquor ratio having 15% methanol at 1600C for 3 hours. Enzyme treated fibres were digested in a rotary digester using sodium hydroxide (1.2%), sodium sulphite (5.0%), anthraquinone (0.01%) at 1:10 material to liquor ratio having 5% methanol at 95, 115 and 1600C for 3 hours.

2.2.5 Beating: Enzyme treated fibres, hot soda pulps and cold soda pulps were subjected to beating in laboratory scale valley type beater for different durations to produce pulp of 400SR freeness.

2.2.6 Paper sheet formation: Paper sheets of 60 GSM were produced by using semi automatic paper sheet making machine.

2.2.7 Evaluation: All the paper sheets were kept in the standard testing atmosphere and following tests were carried out.

2.2.7.1 Optical properties: The Whiteness Index in HUNTER scale, Yellowness Index in the ASTM D1925 scale and Brightness Index in TAPPI 452 scale of handmade paper produced by hot soda process and cold soda process was determined by Spectrascan-5100 computerised colour matching system using relevant software.

2.2.7.2 Physical properties: Tensile properties were evaluated by Tappi Test Method – T404 om-85, Bursting Index was determined by Tappi Test Method – T403 om-85, Tearing strength by Tappi Test Method – T414 om-88 and Folding endurance (Schopper type) was determined by Tappi Test Method – T423 om-89 (10)

3. RESULTS AND DISCUSSION

Control and enzyme treated jute fibres were subjected to hot soda pulping. Yield of the pulp was determined following standard procedure. Following hot soda samples were prepared:

- Sample A : Hot soda pulping of jute fibre was done by using 8% sodium hydroxide by open digestion process.
- Sample B : Enzyme treated sample
- Sample C : Enzyme treatment & hot soda pulping using 2% sodium hydroxide
- Sample D : Enzyme treatment & hot soda pulping using 4% sodium hydroxide
- Sample E: Enzyme treatment & hot soda pulping using 8% sodium hydroxide

All the samples were evaluated for optical and physical properties and the results have been tabulated in table-1 and table-2.

TABLE – 1: Effect of hot soda pulping on optical properties of paper

Sample code	Loss in weight (%)		Yield (%)	Whiteness Index	Yellowness Index	Brightness Index
	Enzymolysis	Pulping				
A	-	19.5	80.5	60.41	35.05	30.93
B	7.6	-	92.4	63.04	30.16	34.86
C	7.6	4.0	88.4	59.60	33.07	30.58
D	7.6	5.0	87.4	59.59	32.68	30.78
E	7.6	10.1	82.3	61.38	34.42	32.17

TABLE – 2: Effect of hot soda pulping on physical properties of paper

Sample code	Freeness (^{0}SR)	GSM	Fold endurance	Tensile Index (Nm/g)	Burst Index (KPam^2/g)	Tear Index (mNm^2/g)
A	38	60	190	59.94	3.53	10.67
B	40	57	5	25.24	1.17	5.26
C	37	60	73	56.67	3.55	10.10
D	37	64	310	67.43	4.59	14.04
E	39	57	136	56.53	3.66	9.84

Analysis of the results reveal that yield of the pulp is about 80% in case of hot soda pulp using 8% caustic concentration. Enzymolysis results in about 8% loss in weight of jute fibre. Yield of the pulp produced by sequential treatment of enzyme and hot soda pulping is high i.e., 88%, this may be due to the use of low alkali concentration during digestion process. It is clear from the table-2 the paper produced by hot soda process results in good physical properties but only enzyme treated fibres shows poor tensile and folding properties. Pulping of enzyme treated fibre results in improvement of strength and folding properties of paper using only 4% sodium hydroxide concentration during pulping. Further increase in alkali concentration shows no improvement.

Following cold soda samples were prepared:

- Sample A : Jute fibres were subjected to cold soda pulping using 10% sodium hydroxide at ambient temperature.
- Sample B : Enzyme treated sample
- Sample C : Enzyme treated fibres were subjected to cold soda pulping using 4% sodium hydroxide at ambient temperature.
- Sample D : Enzyme treated fibres were subjected to cold soda pulping using 7% sodium hydroxide at ambient temperature.
- Sample E : Enzyme treated fibres were subjected to cold soda pulping using 10% sodium hydroxide at ambient temperature.

The cold soda pulp and the papers produced from them were evaluated for yield, optical and physical properties. The results have been tabulated in table-3 and table-4.

TABLE -3: Effect of cold soda pulping on optical properties of paper

Sample code	Loss in weight (%)		Yield (%)	Whiteness Index	Yellowness Index	Brightness Index
	Enzymolysis	Pulping				
A	-	3.6	96.4	50.45	49.64	20.18
B	7.6	-	92.4	63.04	30.16	34.86
C	7.6	2.6	89.8	54.33	37.54	25.02
D	7.6	4.2	88.2	59.61	35.21	30.20
E	7.6	4.8	87.6	60.29	34.10	32.02

TABLE -4: Effect of cold soda pulping on physical properties of paper

Sample code	Freeness (^{0}SR)	GSM	Fold endurance	Tensile Index (Nm/g)	Burst Index (KPam^2/g)	Tear Index (mNm^2/g)
A	41	63	30	28.23	2.33	6.97
B	40	57	5	25.24	1.17	5.26
C	43	56	134	52.55	3.48	7.86
D	41	60	248	59.58	4.38	10.33
E	45	59	192	57.20	3.64	10.50

The yield of the cold soda pulp is found to be very high but the paper produced from this pulp shows poor optical and physical properties. Cold soda pulping of enzyme treated fibres shows very encouraging performance as the yield is about 88-90% and the paper shows very good physical properties. Enzyme treatment followed by cold soda pulping using 7% (owf) sodium hydroxide produces paper with high brightness and physical properties are comparable to that produced by hot soda pulping which are clear from table-3 and table-4.

Control and enzyme treated jute fibres were subjected to hot soda pulping. Yield of the pulp was determined following standard procedure. Following ASAM samples were prepared:

- Sample A : jute fibres were subjected to ASAM pulping using sodium hydroxide (3%), sodium sulphite (12.9%), anthraquinone (0.01%) at 1:10 material to liquor ratio having 15% methanol at 1600C for 3 hours.
- Sample B : Enzyme treated sample
- Sample C : Enzyme treated fibres were digested in a rotary digester using sodium hydroxide (1.2%), sodium sulphite (5.0%), anthraquinone (0.01%) at 1:10 material to liquor ratio having 5% methanol at 950C for 3 hours
- Sample D : Enzyme treated fibres were digested in a rotary digester using sodium hydroxide (1.2%), sodium sulphite (5.0%), anthraquinone (0.01%) at 1:10 material to liquor ratio having 5% methanol at 1150C for 3 hours
- Sample E : Enzyme treated fibres were digested in a rotary digester using sodium hydroxide (1.2%), sodium sulphite (5.0%), anthraquinone (0.01%) at 1:10 material to liquor ratio having 5% methanol at 1600C for 3 hours

The yield of the pulps produced by ASAM process were evaluated and tabulated in table5. The papers were produced from this pulp and results of evaluation of optical and physical properties are tabulated in table-5 and table-6.

TABLE -5: Effect of ASAM pulping on optical properties of paper

Sample code	Loss in weight (%)		Yield (%)	Whiteness Index	Yellowness Index	Brightness Index
	Enzymolysis	Pulping				
A	-	32.2	67.8	47.52	45.93	18.49
B	7.6	-	92.4	63.04	30.16	34.86
C	7.6	6.0	86.4	34.55	37.54	35.72
D	7.6	8.3	84.1	64.42	32.85	36.31
E	7.6	10.6	81.8	43.85	44.69	15.79

TABLE -6: Effect of ASAM pulping on physical properties of paper

Sample code	Freeness (^{0}SR)	GSM	Fold endurance	Tensile Index (Nm/g)	Burst Index (KPam^2/g)	Tear Index (mNm^2/g)
A	41	60	47	61.17	2.75	7.79
B	40	57	5	25.24	1.17	5.26
C	43	60	2	25.07	1.18	5.33
D	41	60	10	39.24	2.14	7.00
E	45	59	50	55.30	3.47	8.33

From the table it is clear that the high chemical high temperature ASAM pulping shows low yield, around 70% but the paper produced from this pulp shows good physical properties but the optical properties are poor. Low chemical ASAM pulping of enzyme treated fibres shows encouraging results. The yield of the pulp is about 82-86%, low temperature low chemical ASAM pulping produces paper with very good optical properties but their physical properties are inferior. The ASAM pulping of enzyme treated fibre using low chemical high temperature produce paper with very good physical properties and are well comparable with that produced by high temperature high chemical ASAM pulping.

So the total study reveals that (i) better yield of the pulp and improvement of quality of paper can be obtained using combination of enzyme treatment and chemical pulping using lower dose of chemical (ii) better yield of the pulp and improvement of quality of paper can be obtained using combination of enzyme treatment and chemical pulping at lower temperature.

4. CONCLUSIONS

Hot soda pulping of jute using 8% caustic soda produces paper with good optical and physical properties. But biotreatment of jute fibre using cellulose and xylanase enzyme followed by hot soda pulping using 50% chemical produces equivalent quality paper with 8% higher yield.

Conventional cold soda pulping of jute produces paper with poor optical property and physical; properties. Enzyme treatments of jute fibre using cellulose and xylanase followed by cold soda pulping using lower dose of chemical produces paper with improved optical and physical properties which are comparable to that produced by hot soda pulping process.

ASAM pulping of jute fibre using high chemical concentration and temperature produces paper with good physical properties but their yield is as low as only 67%. Pretreatment of jute fibre with cellulose and xylanase enzyme and subsequent pulping using low chemical and high temperature produces paper having quality same as that produced by conventional process but the yield is as high as 82%.

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