Second Dissemination Workshop

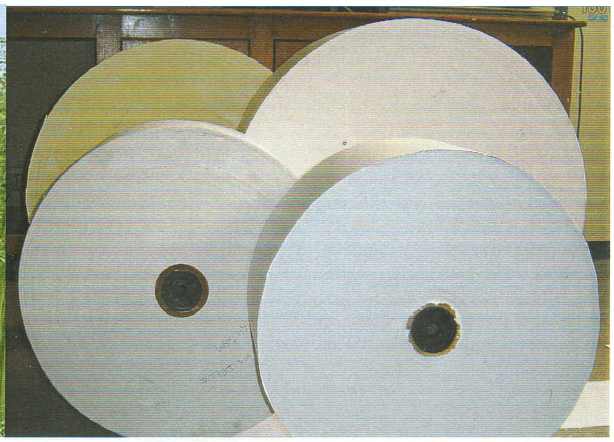
on

Biotechnological Application of Enzymes for Making Paper Pulp From Green Jute/Kenaf (The Whole Plant)

at

Hyderabad, AP, INDIA

18-19th Nov. 2004



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CENTRAL PULP & PAPER RESEARCH INSTITUTE
CPPRI

Central Pulp & Paper Research Institute
Saharanpur, INDIA.

2ND DISSEMINATION WORKSHOP ON

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE / KENAF

HELD ON

18 & 19 NOVEMBER 2004

AT HYDERABAD, A.P., INDIA

SPONSORED BY

GOVT. OF INDIA, UNIDO, CFC & IJSG

ORGANISED BY

CENTRAL PULP & PAPER RESEARCH INSTITUTE

SAHARANPUR - 247001, INDIA

CONTENTS PAGE

अशोक झा
ASHOK JHA

सचिव
भारत सरकार
वाणिज्य एवं उद्योग मंत्रालय
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MESSAGE

I am very happy to learn that Central Pulp & Paper Research Institute is organizing the Second International Dissemination Workshop on Findings of Project on "Biotechnological Application of Enzymes for making Paper Pulp from Green jute/Kenaf" at Hyderabad on 18th and 19th November,2004.

The substitution of conventional raw material for pulp & paper by jute/kenaf is both timely & beneficial in view of dwindling forest resources. The efforts put in by CTP, France; A&FI, The Netherlands; IBFC, PR China; BJRI, Bangladesh and CPPRI, India under the guidance of experts from UNIDO, Vienna, IJSG, Dhaka and CFC, The Netherlands are commendable. This second international dissemination workshop of this nature in India would certainly provide a useful platform for the participants from India & abroad which include investors, technocrats, industrialists and scientists to exchange their views on the latest know-how and measures to reduce consumption of chemicals & energy through the application of eco-friendly industrial processes thereby lowering production cost and ensuring the environmentally sustainable process for commercial production of pulp & paper from Jute/Kenaf.

I wish this workshop a success and congratulate CPPRI, IJSG, UNIDO & CFC for holding this workshop in India.

(ASHOK JHA)

सत्यमेव जयते

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वाणिज्य एवं उद्योग मंत्रालय
(औद्योगिक नीति और संवर्धन विभाग)
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Ministry of Commerce & Industry
(Deptt. of Industrial Policy and Promotion)
Udyog Bhawan, New Delhi-110011

FOREWARD

Pulp and paper industry is one of the core industries, and growth of this industry has a direct impact on the socio-economic development of the country. The sustainability of Indian paper industry is very important and depends mainly on three primary factors – namely; (i) sustained availability of cellulose raw materials;(ii) how the industry will address environmental issues; & (iii) ability of the industry to keep pace with the modernization. The continuous and sustained availability of cellulose raw material is the single most important factor, which will determine healthy growth of the Indian paper industry. In the last 30 years, due to depleting forest based resources and change in the national forest policy, availability of good quality cellulose raw materials have been one of the major challenges before the Indian paper industry, and thereby a constant shift in the raw material usage pattern has been observed. Today, the forest based cellulose raw materials; agro-residues and the recycled fibres equally share the total paper production in the country.

Keeping in view, the importance of cellulose raw materials, a number of R&D schemes were initiated under the Cess funded research programmes. During my first interaction at the **First Dissemination International Workshop** held at Dhaka (Bangladesh), I was convinced that Jute/Kenaf (the whole plant) is going to be an important cellulose raw material for the Indian paper industry, however there is a need for consorted efforts for commercial exploitation of these annual plants, so that there is a benefit for the poor farmers as well as to the paper production. The joint research work carried out by five Institutions namely; **CTP (France), ATO-DLO (The Netherlands), IBFC(PR China), BCIC(Bangladesh) & CPPRI(India)** is commendable one, and there is a need for full exploitation of the R&D results.

Keeping in view of the importance of these fibers in the Indian context, I made a special request to UNIDO/IJSG/CFC authorities to have the similar type of dissemination international workshop in India with joint financial support from Cess funds & UNIDO. I am glad that this proposal has now matured and resulted into **Second International Dissemination Workshop** of the findings of project No.FC/RAS/00/153 on **"Biotechnological Application Of Enzymes For Making Paper Pulp From Green Jute/Kenaf(The Whole Plant)".**

I am sure that deliberations during the next two days of **Second International Dissemination Workshop** of the findings of the above-cited UNIDO/IJSG/CFC sponsored project, will lead to many ideas and cover all the issues, which should help us in commercial exploitation of this important fiber resources in the Indian subcontinent.

I wish this Second International Dissemination Workshop a grand success.

S. JAGADEESAN

SECOND DISSEMINATION WORKSHOP ON APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE / KENAF

18 - 19 NOVEMBER 2004

HOTEL VICEROY, TANK BUND ROAD, HYDERABAD.

DATE :- 18.11.04

	TECHNICAL SESSION – I **11.45 A.M. to 1.30 P.M.** **PULPING & BLEACHING OF JUTE / KENAF**	
	Session Chairman:	**Dr. George Tzotzos**
(i)	Prospects for Paper Pulp from Jute / Kenaf	Dr. A.G. Kulkarni, Director, CPPRI, India
(ii)	Assessment of Chemical Pulping Process for Green Jute / Kenaf Pulping	Dr. S.V. Subrahmanyam, CPPRI, India
(iii)	Pilot & Commercial Scale Trials on Green Jute / Kenaf Pulping	Sh. V.K. Mohindru, CPPRI, India
(iv)	Bleaching of Chemical Pulps from Green Jute	Mr.Bernard Brochier, Fiber Resource Division, Centre Technique du Paper, Grenoble, France
	LUNCH - 1.30 TO 2.30 P.M.	
	2.30 to 3.30 P.M.	
(v)	Effect of variety cum fertilizer cum storage of Harvest of Mesta crop to increase pulp production for paper making	Sh.A.Kanaka Raju, Agriculture Research Station, India
(vi)	Enzymatic Prebleaching of Whole Jute Kraft Pulp	Dr. R.K. Jain, CPPRI, India
	TEA - 3.30 to 4.00 P.M.	
	TECHNICAL SESSION – II **4.00 to 5.00 P.M.** **HIGH YIELD PULPING & ENVIRONMENTAL ISSUES**	
	Session Chairman:	**Mr. T. Nand Kumar**
(i)	Mechanical Pulp from Green Jute	Dr. Ed de Jong, Department of Fiber & Paper Technology, ATO, Wageningen, The Netherlands.
(ii)	Black Liquor Management in Jute Pulping	Dr. R.M. Mathur, CPPRI, India
(iii)	Effluent Management in a Kenaf based pulp Mill	Dr. S. Panwar, CPPRI, India

DATE :- 19.11.04

	TECHNICAL SESSION – III **10.00 to 11.00 A.M.** **TECHNO ECONOMIC ASPECTS OF MAKING PULP / PAPER FROM JUTE / KENAF**	
	Session Chairman	Sh. S. Jagadeesan, IAS, Jt. Secretary, to the Govt. of India.
(i)	Economics of Jute Based Pulp Mill – A Case Study	Dr. S.L. Keshwani, Chemprojects & Consultants Ltd., India
(ii)	Techno economic studies on production of pulp & paper from jute	Mr. Yoshitaka Hamazaki, Japan
(iii)	Summing up of Project Activities	Mr. G. Mohiuddin, IJSG, Bangladesh
	INTERACTIVE SESSION **11.00 A.M. to 1.00 P.M.**	
	Panel Members, Interaction Meet	Mr. George Tzotzos Mr. Gatachew Gebre Medin Mr. T. Nand Kumar Mr. G. Mohiuddin Dr. A. G. Kulkarni
	LUNCH - 1.00 TO 2.00 P.M.	

Prospects For Paper Pulp From Jute/Kenaf

Dr. A.G. Kulkarni,
Director, CPPRI

About The Author

Dr. A.G. Kulkarni, Director Central Pulp & Paper Research Institute (CPPRI) Saharanpur, Uttar Pradesh, India has been with the CPPRI since its inception. He holds a Master degree in Chemistry & Doctorate in Black Liquor and Lignin Chemistry.

Dr. Kulkarni has pioneered the research work on Desilication of black liquor with eventual development of mill scale plant, installed at Hindustan Newsprint Ltd., Kerala and High Rate Bio methanation of black liquor rich effluent and a mill scale unit is successfully operating at Satia Paper Mills is another achievement of Dr. Kulkarni. His contribution in the area of physico chemical & thermal properties of agro - residue non-wood black liquors has now made it possible to process this liquor in chemical recovery boilers. He has published more than 300 scientific papers in Indian and International journals. He is widely traveled in Europe, S. E. Asia, and Australia and has been on several foreign missions as UNDP/UNIDO Consultant.

His areas of specialization include pulping and bleaching, black liquor-its chemistry & processing, environment and energy management. Dr. Kulkarni holds several patents-important ones being on desilication of black liquor, thermal treatment of black liquors and Direct Alkali Recovery System etc. He is a member of several National and International Scientific & Technical organizations and also on board of Directors of Paper Mills & Research organizations.

Prospects For Paper Pulp From Jute/Kenaf

A.G.Kulkarni

Director

Central Pulp & Paper Research Institute, P.O.Box 174, Paper Mill Road,

Saharanpur - 247 001, U.P., India

Indian paper industry is more than a 100-year-old industry, and has steadily grown over the years. It is a bulk consumer of fiber resources. The Industry uses diverse cellulose raw materials from forest-based resources, agriculture residues and waste paper. Forest products include bamboo and mixed hardwoods. However, the relative share of wood fibre in the paper making fibre furnish has been declining due to the rapid growth in the use of agricultural residues and recycled fibre in paper production.

Agricultural residues are emerging as a potential alternative fibrous material resource for the pulp and paper industry in India. The use of agricultural residues has grown since the early 1970's, partly due to the dwindling bamboo resources, and partly due to the Government's industrial policy encouraging investments in agro-based paper production to meet the demand for paper. The main agricultural residues used by the paper industry include bagasse and cereal straws. Even if the theoretical availability of bagasse and straw is high, there are limitations in their use due to seasonal availability, transportation costs for long distances and relatively inferior quality of the paper products as compared to bamboo and wood.

Indian paper industry is also showing growth rate of 6-7% per year. About 35% of paper is made from hardwood/bamboo, 30% from agro residues like straw and bagasse and 35% by waste paper. The present paper and newsprint production is around 5.8 million MT and demand is likely to increase to 8.53million Mt in the year 2010. The shortage of raw material required to fulfill the required growth rate of medium and high quality paper cannot be met with forest resources and the pulp from agro residues is of inferior quality. Hence, there is a need to look for alternative fibrous raw materials so the demand for quality products can be fulfilled. In the recent years whole jute/kenaf, which have got strength properties similar to hardwood have emerged as potential fiber sources. The whole jute price is competitive in comparison with bagasse and yields pulp comparable to hardwood (Figure 1).

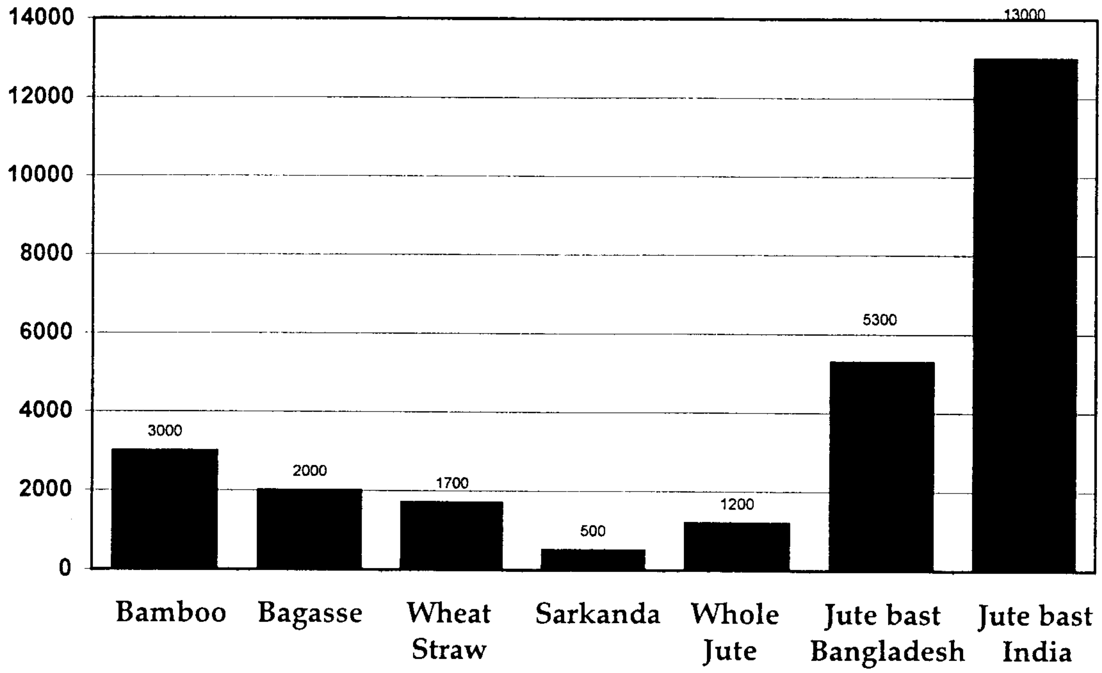
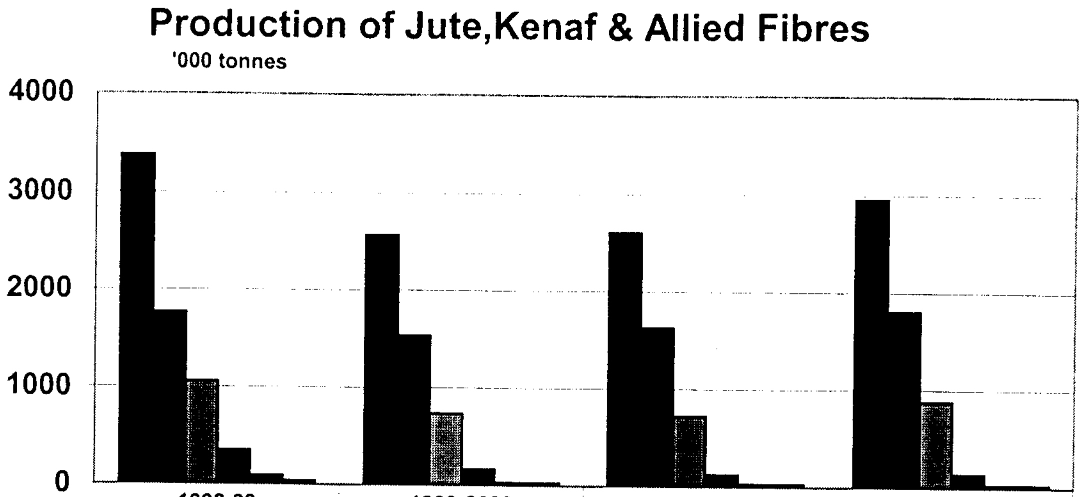


Figure 1. Cost of nonwood fibrous raw material

There is also a drive for diversification of these annual plants from conventional textile uses. India is the world's largest producer of jute and allied fibers (1.941 million Metric tons) that accounts for about two third of the world's production (3.092 million Metric tons) (Figure 2). The area under jute cultivation is 0.817 million hectares and Mesta cultivation is 0.184 million hectares. A sustained demand for jute/kenaf by a bulk consumer like paper industry would promote the interest of the jute/kenaf growers in the agriculture sector.



	1998-99	1999-2000	2000-2001	2001-2002
World total	3378	2565	2605	2951
India	1761	1530	1620	1800
Bangladesh	1052	732	720	876
China	347	164	126	136
Thailand	88	30	30	30
Myanmar	35	27	28	28

Figure 2. Production of Jute in the international arena.

One of the major difficulties for use of whole jute/kenaf/mesta as raw material with its 95-kg/m^3 chip bulk density tend to reduce the throughput in the digester. The bulkiness also has negative impact on the transportation cost and the storage area requirement would be substantially high. The solution for managing the bulky raw material is to set up the mother pulp mill in the vicinity of the jute/kenaf cultivation.

The whole jute has both short derived from core wood and long fibers derived from the bast (Figure 3) in the desired proportions. The chemical pulps thus made from whole jute do not require addition of neither reinforcing long fiber nor short fiber pulps to improve formation in the paper. The application of enzymes in fiberline operations has shown promising results, which has positive impact by reducing the pulping and bleaching chemical requirement.

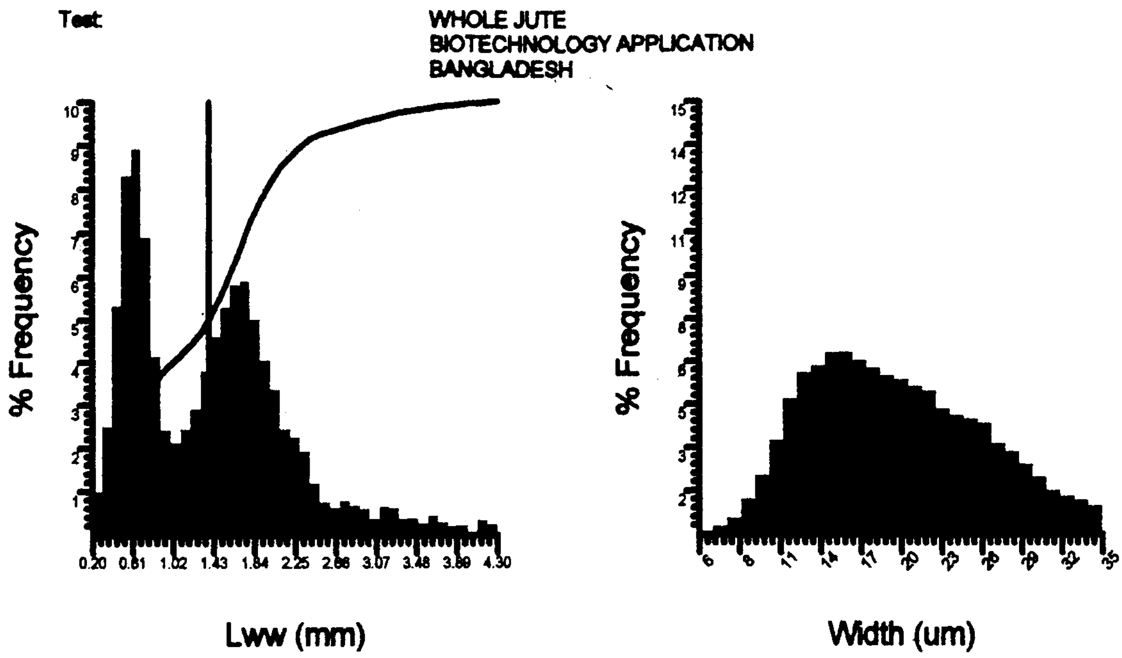


Figure 3. Fiber length and width distribution in whole jute chemical pulp.

Japan has good demand for jute/kenaf pulp. According to Non Wood Paper Promotion Association of Japan, the import of Non Wood Pulp, including Pulp of Reed, Kenaf and Bamboo is estimated approximately 5,000 Mt/year, which is 0.02% of Japanese Paper and Paperboard Production of approximately 31.5 million tons and such Pulps are mainly mixed for Wall Paper, Paper Cups, Wrapping for Foods as well as for Table Napkins at 2 - 5 % in weight. Paper industry plays a vital role in socio-economic development of a country.

The mechanical pulp from kenaf whole plant is particularly suitable for newsprint, which has been successfully tried by American Manufacturing Association with the co-operation from United States Department of Agriculture. The whole kenaf TMP is found to be readily bleachable with alkaline hydrogen peroxide and the bleaching significantly enhanced strength characteristics of the TMP pulp. CPPRI also demonstrated the suitability mesta to make newsprint. The pilot scale APMP trials at CTP, France indicate its suitability for making good quality newsprint having ISO brightness above 60%.

The demand growth scenario for India is highly encouraging and in the next 15-20 years, in all the paper grades including, newsprint, writing printing paper, tissue and packaging grades, growth rate of 5-6% is envisaged. The increase in demand for copiers and home computers has catalyzed the growth of quality papers and this trend will continue in future.

Presently 10,639 tonnes newsprint and 1,81,979 tonnes wood free, board & other grades of paper is exported. There is potential for export to neighboring countries as well as niche market in the Middle East and same Western countries. The potential export market for newsprint, wood free printing/ writing papers and coated duplex board is Bangladesh, Pakistan, Sri Lanka, Myanmar and Nepal table shows the import in these selected markets.

The potential for growth of paper industry and dearth for good renewable fibrous raw material points to the new sources of cellulose fibers and the prospects for paper pulp from green jute/kenaf are very bright.

Assessment Of Chemical Pulping Processes For Green Jute

Dr. S.V. Subrahmanyam
Scientist E - I
CPPRI, Saharanpur

About The Author

Dr. Subrahmanyam has a Masters degree in Botany with specialization in Wood Science and obtained his Doctoral degree in Botany from Sardar Patel University, Gujarat.

He joined Hindustan Paper Corporation in 1981 in their R & D group in the Kerala unit and worked in the area of biotechnological application in Pulp & Paper industry and evaluation of various fibrous raw materials for their suitability in Paper industry.

In 1990, he joined Central Pulp & Paper Research Institute, Saharanpur as a Scientist. He has worked in the areas of refining of wood and non-wood fibers. He has obtained training in the area of fiber morphology and quality control from PAPRO, New Zealand. He is currently working in area of Pulping & Bleaching.

Assessment Of Chemical Pulping Processes For Green Jute

S.V.Subrahmanyam*, P.S.Lal*, R.D.Godiyal*, S.Tripathi*, A.K.Sharma* & A.G.Kulkarni**

* Scientist, ** Director

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ABSTRACT

Jute is fast growing renewable annual plant alternative to wood based fiber for making paper pulp. The pulpable fibrous stalks of whole jute contain 60 to 65 % core woody part and 30 to 35% peripheral/surface bast part. The fibers from core are short and similar to hardwood fibers and the fibers from bast are long and slender. The right composition of short and long fibers naturally in whole Jute makes it choice raw material to produce the quality paper with desired properties.

INTRODUCTION:

India is the world's largest producer of jute and allied fibers (1.941 million Metric tons), which accounts for about two third of the world's production (3.092 million Metric tons). The area under jute cultivation is 0.817 million hectares and mesta cultivation is 0.184 million hectares in the year 2001-2002 in India (Source: Ministry of Agriculture, Govt. of India). Jute plants are classified into two broad groups i.e. *Corchorus capsularis* (White jute) and *Corchorus olitorius* (Tossa jute). Mesta / Kenaf yielding fibers of commerce are similar to jute, constitute a third group. All these four varieties can be considered as one, although it is known that there are marginal variations in their pulping characteristics.

The Jute advisory board of India's preliminary estimates indicates 8.7% increase in the raw jute crop in the year 2002-2003 and the board has resolved to apprise the Union Ministry of Textiles about the concerns of the jute industry regarding the apprehended decline in mill's consumption and purchase of raw jute in current season which could have far reaching consequences, particularly on jute growers in India. - This statement in the INDIAN JUTE - the quarterly newsletter of the Jute manufacturers Development council indicate the gravity of problem due to lack of alternative and sustained raw jute consumers like paper industry. A consistent consumer of jute and allied fibers on a sustained basis will give a boost for increased production by the farmers.

Commercial aspects of Jute and Allied fibers:

Jute and allied fibers are used after retting the bark for manufacture of sacks, carpet backing cloth, yarn and other handicraft items. The handicraft items include carpets, soft luggage, decorative fabrics, curtains, blankets, shopping bags and jute composites. The other potential sustained bulk consumer could be pulp and paper industry, provided the right kind of cleaner technology, which can produce specialty and ecograde pulp, is identified for the jute and allied fibers.

Paper market:

Traditionally wood is used for producing paper grade pulp. Other fiber sources like nonwood raw materials are converted to paper grade pulp, mostly in China and Indian subcontinent due to shortage of forest based fiber.

New development in printing technology has revolutionized the industry worldwide. The scenario has changed rapidly from letterpress to offset and to laser printing and every day newer innovations are being carried out in this area in order to meet the requirement of modem society. This has resulted in great demand for superior quality i.e. high strength and high brightness papers like fax papers, computer stationary, copier paper, higher GSM bond papers etc. Their demand is rising faster than the cultural grades of paper. There is a sizeable consumption of high quality paper in the industrialized countries. The papermakers abroad find it a more profitable proposition to produce and market this type of paper more, so in the recent years, paper units registering low return on investment. Strict pollution laws forcing the industry to spend a sizeable amount of money on pollution abatement program or using other process which may be expensive but less polluting.

Jute and Kenaf are annual plants, widely cultivated in the Eastern and Central part of India. The main users of these raw materials are the gunny bag Industries using only bast portion discarding the jute sticks as waste. The bast fiber also being used Jute textiles industry, but to a limited level. The papermaking properties of jute are well established for a long time and work on this has been time-to-time published in different journals and periodicals. Use of biotechnological for papermaking can make this process more economical and environment friendly. A project for "Biotechnological application of enzymes for making paper pulp from jute and Kenaf " was sponsored by UNIDO with association of IJO, Bangladesh. The objective of this program is to promote jute utilization in papermaking by eco-friendly processes.

Jute and Kenaf are annual plants, widely cultivated in the Eastern and Central part of India. The main users of these raw materials are the gunny bag Industries using only bast portion discarding the jute sticks as waste. The bast fiber also being used Jute textiles industry, but to a limited level.

EXPERIMENTAL:

Raw material preparation: Green jute sample in the form of stalks was received from IJO- Bangladesh. It was kept in polythene bag to attain the uniform moisture content and moisture was analyzed before starting the pulping experiment.

Proximate chemical analysis of green jute: Proximate chemical analysis of green jute before and after enzyme treatment was carried out as per standard procedures.

Pulping experiments: Pulping experiments were carried out using different cooking chemical dosage of kraft, soda and soda AQ process in order to optimize cooking chemical demand for getting bleachable grade pulps of kappa no. around 20-25. Experiments were performed in a series digester consisting of six bombs of 2.5 liter capacity, rotating in an electrically heated polyethylene glycol bath. At the end of the cooking time, the bombs were removed and quenched in the water tank to cool down and the cooked mass from each bomb was taken for washing. Washing was carried out with hot water till the cooked mass was free from spent liquor. After thorough washing, the unscreened pulp yield was determined and the pulp was screened in laboratory 'Serla' screen by using 0.25 mm. slot width mesh. Kappa number of the screened pulp was determined as per the Tappi standard procedure T-236-OS-76. The constant cooking conditions are given below:

Cooking conditions:

Raw material taken in each bomb	:	200 gm. (B.D)
Bath ratio (raw material to liquor ratio)	:	1:4
Sulphidity of cooking liquor	:	19 %
Cooking temperature	:	165 °C
Cooking time	:	90 min.

Cooking schedule:

Ambient to 100 °C	:	30 min.
100 °C to 165 °C	:	90 min.
At 165 °C	:	90 min.

RESULTS & DISCUSSION:

Morphology of the Raw Material:

The jute plant is an annual plant and grows to a height of 5-16 feet in height and normally do not have significant branches. Diameter of the stem may reach up to 10 to 20 mm on maturity. The stem portion has two distinct zones viz. bark and core. The bark portion becomes loosely attached to core when the plant is dry. The dry bark is dark brownish and core (wood) is pale yellow or cream colored (fig 1,2,3).

Fig 1. Chips of Whole Jute

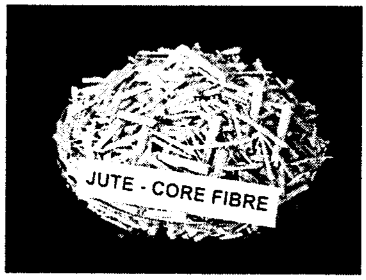

Fig 2. Chips of Jute corewood

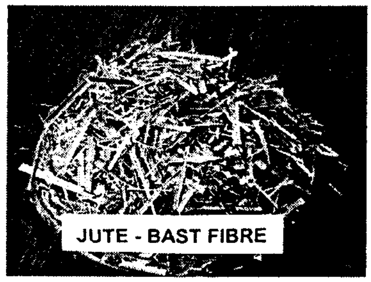

Fig 3. Chips of Jute bast

Physical Properties:

The physical properties of Jute raw material are furnished in table 1. Bast fiber constitutes 36% of the weight in the whole jute, and the balance 64 % is core wood. Bulk density of the whole jute is very low compared to the hardwood and softwood. Bulk density of jute bast fiber is very low compared to core wood. Bulkiness of the raw jute fiber has disadvantages in terms of volumetric loading, throughput etc. Impregnation of chips with liquor also is affected due to high bulkiness, as the chips tend to float.

Table 1: Physical Properties

Sl. No.	Particulars	Whole Jute	Bast Fibre	Core Fibre
1.	Ratio of Bast and Core, %	100	36	64
2.	Bulk Density, kg/m^3	93.4	69.2	110.5

Morphology of Jute Stem:

The cross section of jute is illustrated in figs 4, 5. The outer layers (sheath) are of bast and the fiber from which is used as cordage etc. after retting. The central most core portion is filled with parenchyma tissue, which is termed as pith. The woody tissue located between pith and bast. The fibers from this woody tissue are short and are normally discarded as waste or used as domestic fuel.

The jute fibers have different dimensions based on the tissue source. The fibers from the bast are long with thick fiber walls. Whereas the fibers from core (wood) are short and relatively thin walled. The average length of the whole jute fiber is 1.01 mm and average width is 18.4 μm.

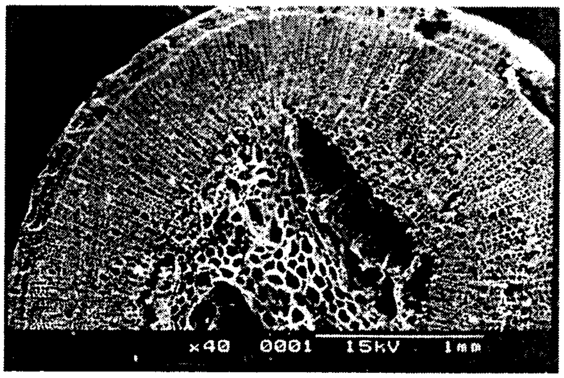

Fig 4. Cross section of Jute stem

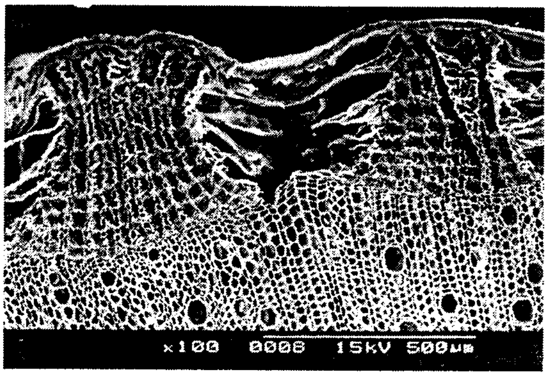

Fig 5. Magnified view of cross section

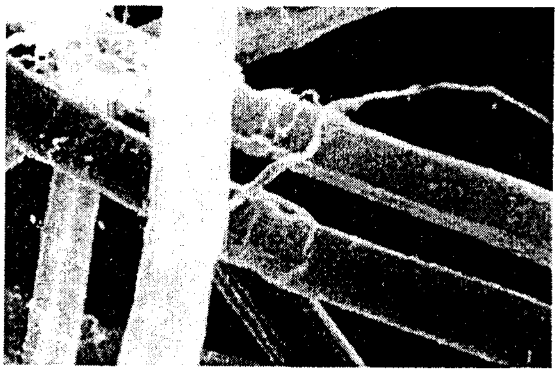
Fig 6. Magnified view of bast fibers

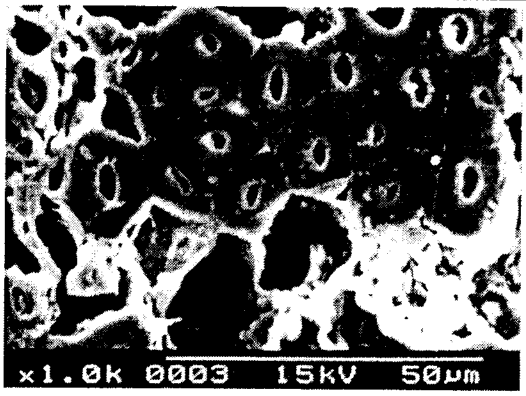

Fig 7. Bast fibers in sectional view

The diagnostic feature of the jute bast fiber is the irregular width of the broad and well defined lumen. Sometimes the lumen closes up and is entirely missing for a short distance. The individual fiber is cylindrical with little variation in diameter. The fiber walls are thick and generally smooth (fig 6, 7), having more or less numerous nodes and cross markings depending upon the mechanical they have received. The fiber ends are slender and pointed. The cross section of the fiber is of polygonal shape with sharply defined angles and a round or oval lumen (fig. 7). The comparative fiber dimensions and properties are recorded in table 2 and fig. 8 - 13 for Whole jute, Central core wood (stick) and bast fibers (skin).

Table 2 Comparative fiber dimensions and properties of Jute fibers*

Sl No.	Dimensions	Unit	Whole Jute	Core Wood	Bast Fiber
1.	Mean Fiber Length (Weight weighted) (L = 0.20 - 5.0mm)	mm	1.389	0.687	1.953
2.	Mean Fiber width (w= 7 - 35)	µm	20.1	21.9	16.4
3.	Fiber curl index (Weight weighted) (L = 0.50 - 5.0mm)	-	0.077	0.033	0.114
4.	Fiber kink index (L = 0.50 - 5.0mm)				
4.a	Kink index	(1/mm)	0.70	0.44	1.05
4.b	Total kink angle	degrees	14.23	5.35	30.90
4.c	Kinks per mm	(1/mm)	0.44	0.25	0.54
5.	Fines (L = 0.01 - 0.20 mm)				
5.a	Arithmetic	%	32.07	33.58	20.87
5.b	Length weighted	5	5.10	6.86	1.56

* For the detailed Fiber Quality Analyzer data, please is pages from 30 to 41.

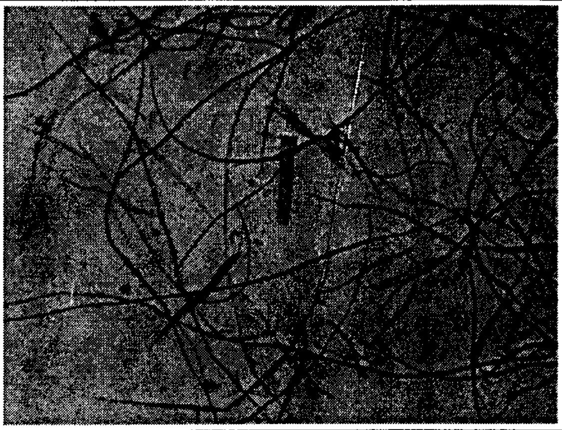

Fig. 8 Whole Jute Pulp

Fig. 9 Mag. View of Whole Jute Pulp

Fig. 10 Jute Core wood Pulp

Fig.11 Mag. View of Jute Core wood Pulp

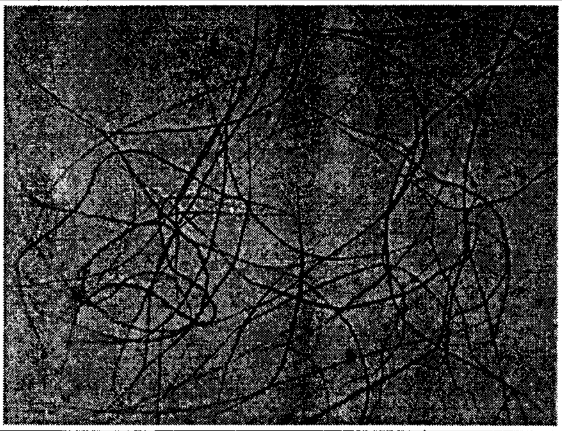

Fig. 12 Jute bast Pulp

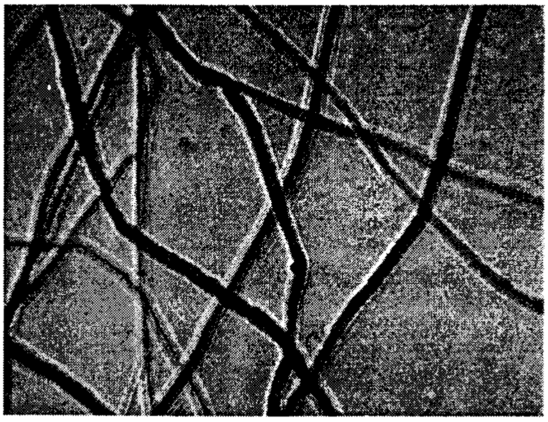

Fig. 13 Mag. View of Jute bast Pulp

Chemical Properties of Raw Material:

Complete proximate analysis of whole jute, bast fiber and core wood was carried out the results are furnished in Table 3. The ash content of the bast is higher since the bast portion carries extraneous silica. The holo-cellulose component in the bark is comparatively higher. Higher α - Cellulose content in the bark indicates that the pulp yield levels will be significantly higher and the pulp strength will also be superior.

Table 3: Chemical Properties of Raw Material

Sl. No.	Particulars	Whole Jute	Bast Fibre	Core Fibre
1	Ash content, %	3.58	4.43	1.89
2.	Cold Water Solubility, %	4.1	4.5	2.4
3.	Hot Water Solubility, %	4.9	8.6	3.0
4.	1/10 N NaOH Solubility, %	26.2	30.1	23.3
5	Alcohol Benzene, %	2.65	3.73	2.75
6	Klasson Lignin, %	21.1	15.3	24.2
7	Acid soluble Lignin, %	1.0	1.1	1.2
8	Holo-cellulose, %	79.5	81.4	75.5
9	α - Cellulose, %	43.5	54.7	36.5
10	β - Cellulose, %	19.9	14.6	25.9
11	χ - Cellulose, %	16.2	12.1	13.1
12	Pentosan, %	15.3	14.6	16.0

Chemical Pulping:

The whole jute raw material was cooked using three different cooking processes to identify a suitable pulping process. In these experiments, the whole jute was cooked using Soda, Soda plus Anthraquinone and Kraft pulping.

Soda and Soda Aq Pulping of Green Jute:

Optimization experiments were initially carried out using Soda as the cooking chemical (Table 4). The alkali requirement found to be very high when used only soda. When the soda pulp was prepared to desired kappa for bleach grade, the residual alkali level was high making it undesirable. Therefore the experiments were extended to additive pulping using Anthraquinone as catalyst. The bleachable grade pulp with around 18 kappa could be produced by adding 0.05% of Anthraquinone to 24% of Soda dose. The pulp thus produced has lower reject level with 50.6% screened yield.

Table 4: Soda and Soda-Aq pulping of Green Jute

Sl,	Particulars	Soda	Soda-AQ	Soda	Soda-AQ	Soda	Soda-AQ
1.	Alkali as NaOH, %	20	20	24	**24**	28	28
2.	Anthraquinone, %	0.00	0.05	0.00	0.05	0.00	0.05
3.	Unscreened yield, %	55.5	50.4	51.9	50.7	47.9	48.9
4.	Screened rejects, %	10.9	0.4	3.5	0.2	0.5	0.4
5.	Kappa number	56.7	25.9	36.7	**18.4**	21.5	14.9
6.	Black liquor properties:						
	• pH	11.0	11.2	11.8	11.9	11.9	12.0
	• RAA, gpl	1.6	2.4	4.2	5.76	7.3	6.7
	• Total solids, % (w/w)	10.5	12.0	12.6	12.8	12.8	13.2

Strength Properties of Jute Unbleached Soda Aq Pulp:

The physical strength properties of jute unbleached kraft pulp and soda Aq were carried out in laboratory PFI mill at 500, 1000, 2000 and 3000 revolutions are given in Table 5. The results indicate that there is substantial improvement in burst index and tensile index in unbleached kraft pulp compared to unbleached soda Aq pulp. However, the unbleached kraft pulp has lower strength properties as compared to unbleached soda Aq pulp.

Table 5 Strength Properties of Jute Unbleached Soda Aq Pulp

PFI (rev)	Freeness ml,CSF	Apparent Density g/ cm³	Burst Index KPam²/g	Tensile Index Nm/g	Tear Index mNm²/g	Fold KM (log)	Porosity Bendtsen (ml/min.)
0	610	0.51	1.10	21.0	8.10	0.85	2850
1000	400	0.64	4.00	54.5	12.50	2.55	440
2000	300	0.66	4.10	57.5	16.00	2.66	270
3000	250	0.71	4.80	69.5	14.10	3.38	120

Optimisation of Kraft Pulping Of Green Jute:

Optimisation experiments for kraft pulping were carried out for green jute and the results are furnished in table 6. The sulphidity of the white liquor was maintained at 19 keeping the Asian countries like India, Bangladesh and China in view. Bleachable grade pulp with a kappa around 20 could be produced by a chemical charge of 16% as Na_2O.

Table 6: Kraft Pulping of green jute

S.L	Particulars	A	B	C
1.	Cooking chemical dose as Na_2O	**16 %**	18%	20%
2.	Sulphidity,%	19	19	19
3	Unscreened yield, %	49.3	48.1	47.2
4	Screened rejects, %	1.8	1.0	0.6
5	Kappa number	**20.7**	17.2	15.7
6	Black liquor properties:			
	a) pH	10.8	11.1	11.6
	b) RAA, gpl	1.4	2.6	4.8
	c) Total solids, % (w/w)	12.9	13.4	18.5

The physical strength properties of green jute unbleached kraft pulp were carried out in laboratory PFI mill at 1000, 2000 and 3000 revolutions are given in Table 7. The result indicate that there substantial improvement in burst index, tensile index and tear index at 2000 PFI revolutions. At 3000 PFI revolutions, there is further improvement in burst and tensile index but slight drop in tear index.

Table 7: Strength Properties of Green Jute Unbleached Kraft Pulp

PFI (rev)	Freeness ml,CSF	Apparent Density g/cm^3	Burst Index KPam^2/g	Tensile Index Nm/g	Tear Index mNm^2/g	Fold KM (log)	Porosity Bendt. (ml/min.)
0	610	0.51	1.10	21.0	8.10	0.85	2850
1000	400	0.64	4.00	54.5	12.50	2.55	440
2000	300	0.66	4.10	57.5	16.00	2.66	270
3000	250	0.71	4.80	69.5	14.10	3.38	120

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Pilot Scale Trials On Green Jute Kraft Pulping

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Pilot Scale Trials On Green Jute Kraft Pulping

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ABSTRACT

The pulping conditions & chemical dose were optimized for green Thosa jute procured from Kolkata region in CPPRI laboratories using kraft pulping process prior to pilot plant trials. The pilot plant trials were conducted in tumbling digester using the optimized laboratory conditions. The pulp yield, reject content, Kappa number & intrinsic viscosity were determined for pulp produced during pilot plant trials and compared with those of lab trials. It was found that results of pilot plant were comparable with lab trials and also reproducible. The pulp evaluation by beating of pulps from pilot plant and preparation of hand sheets using TAPPI method was done. The results indicate that kraft pulp from whole plant so produced is suitable for making writing and printing grade paper.

INTRODUCTION

UNIDO-IJSG and CFC have sponsored the project on "Biotechnological application of enzymes for making paper pulp from jute / Kenaf". The aim of the project was to find a biotechnological route to produce paper pulp from jute / Kenaf. The project involved seven institutes from five countries namely BJRI & BCIC from Bangladesh, IBFC and Yuanjiang Mill from China, CPPRI from India, CTP from France and ATO-DLO from The Netherlands. The objectives are successful. In the review meeting at IJSG head quarters in Dhaka, Bangladesh, CPPRI had discussed the viability of green field pulp mills based on environmental regulations and economics of production technologies. The results on Soda, Soad-Aq and Kraft pulping processes were discussed in the review meeting, and it was decided that the pilot plant trials should be carried out on whole jute using Kraft pulping process.

MATEIALS & METHODS

The 5 tonnes of green Thosa jute (on bone dry basis) obtained from Barrackpore, Kolkata was transported from Kolkata to Saharanpur by trucks (Fig 3 to 7). It was stacked in open to get dried to less than 25% moisture. The chipping was tried by disc chipper, drum chipper & guillotine chipper. The guillotine chipper (Fig 8) was found to be most suitable. The pulping conditions & chemical dose required was optimized in laboratory & Kappa number, pulp yield & shieve content of pulp produced were found out.

As per the pulping parameter optimized in the laboratory, the pilot plant trials were conducted using 11 m^3 tumbling digester with 0.25 rpm having direct steaming system. After cooking was completed, the pulp was blown to blow tank and brown stock washing was done using both rotary drum vacuum washers and also double wire belt washer. The pulp thus produced was evaluated for strength properties & bleaching trials were done in the laboratory. The results of pilot plant were reproducible and gave better properties as compared to laboratory trials.

RESULTS & DISCUSSION

The physical properties of whole jute are given in Table 1 and the raw material and storage space required for different capacity mills is given in Table no.2

Table 1: Physical Properties

Sl. No.	Particulars	Whole Jute	Bast Fibre	Core Fibre
1.	Ratio of Bast and Core, %	-	36	64
2.	Bulk Density, kg/m^3	93.4	69.2	110.5

Table 2. Raw material and storage facilities

Mill Capacity Tons/day	Whole Jute requirement, t	Yard size Sq.Km
50	35,000	0.1
100	71,000	0.2
150	105,000	0.3
300	213,000	0.6
500	355,000	1.07

Laboratory Pulping

The chemical properties of raw material i.e. proximate analysis of whole jute were evaluated as in Table no. 3 which indicates 77.2% holocellulose & 22.97% lignin & suitability for pulping & chemical recovery. During laboratory experimental evaluations Soda, Soda AQ & Kraft pulping processes were studied (Fig. 1). Keeping in view chemical consumption, yield & chemical recovery, it was decided to use Kraft process.

Table 3 Chemical Properties of Raw Material

Sl. No.	Particulars	Whole Jute
1	Ash content, %	2.5
2.	Cold Water Solubility, %	5.7
3.	Hot Water Solubility, %	6.2
4.	1/10 N NaOH Solubility, %	25.8
5	Alcohol Benzene, %	2.8
6	Klason Lignin, %	22.1
7	Acid soluble Lignin, %	0.87
8	Holo-cellulose, %	77.2
9	α - Cellulose, %	42.5
10	β - Cellulose, %	20.0
11	χ - Cellulose, %	12.7
12	Pentosan, %	16.3

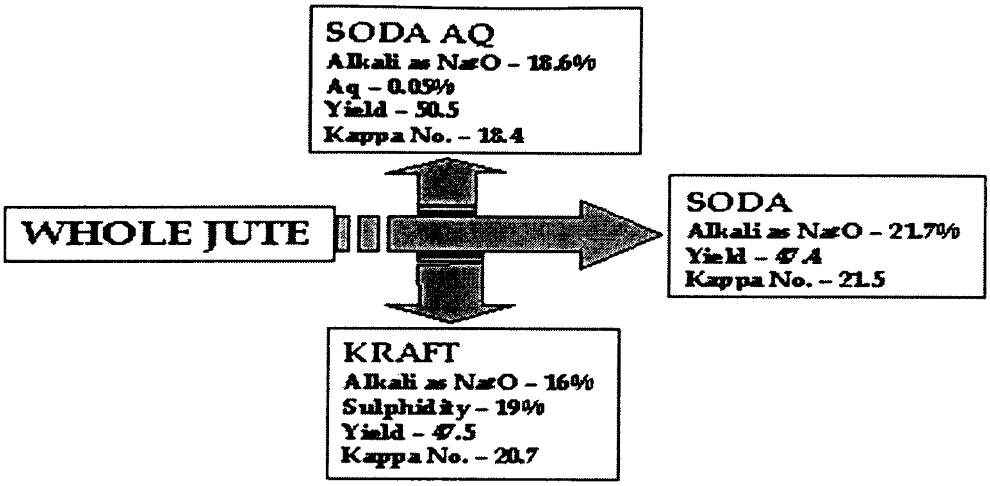


Fig.1 Laboratory pulping of green jute

The results were discussed in First dissemination workshop held at Dhaka Bangladesh also & it was decided that pilot plant trials should be carried out on whole jute using Kraft pulping process.

Optimisation of kraft pulping of jute in laboratory

Optimisation experiments for kraft pulping were carried out for jute and the results are furnished in table 4, 5. The Sulphidity of the white liquor was maintained at 20.6 keeping the Asian countries like India, Bangladesh and China in view. Bleachable grade pulp with a kappa around 20 could be produced by a chemical charge of 17% as Na_2O.

Table 4 Pulping conditions optimized in laboratory

S.No.	**Cooking conditions:**	
1.	Raw material taken in each bomb	200 gm. (B.D)
2.	Bath ratio (raw material to liquor ratio)	1:4
3.	Sulphidity of cooking liquor	20.6 %
4.	Cooking temperature	165 °C
5.	Cooking time	90 min.
6.	**Cooking schedule:**	
7.	Ambient to 100 °C	30 min.
8.	100 °C to 165 °C	90 min.
9.	At 165 °C	90 min.

Table 5 Laboratory optimisation of kraft pulping of jute:

S.L	Particulars	A	B	C
1.	Cooking chemical dose as Na_2O	15	16	17
2.	Sulphidity,%	20.6	20.6	20.6
3	Unscreened yield, %	49.3	47.7	47.2
4	Screened rejects, %	1.3	0.8	0.2
5	Kappa number	26.0	23.0	20.0
6	Black liquor analysis:			
	d) pH	11.0	11.3	11.8
	e) RAA, gpl	2.9	3.5	5.3
	f) Total solids, % (w/w)	10.1	11.1	11.3

The laboratory optimisation trials indicate that the chemical requirement is 17% as Na_2O with which we could produce a pulp with about 20 kappa. The reject content is also low. Based on these laboratory results, we have carried out the pilot plant trials using the kraft pulping process.

Pilot plant kraft pulping of jute

The pilot plant kraft pulping trials were conducted using 17.5% alkali dose, which is 0.5% higher than the requirement worked out in the laboratory. The cooking conditions applied for the two cooks in the pilot plant are as follows (Table 6) and the resultant quality of the pulp is furnished in Table 7 and 8. The visuals of pilot trials were also documented (Fig. 9-14).

Table 6 Pulping conditions adopted in Kraft pulping trials in Pilot Plant.

S.No.	Cooking conditions:	Unit	I Trial	II Trial
1.	OD Raw material taken in the digester	kg	678.2	626.9
2.	Bath ratio	-	1:4	1:4
3.	Sulphidity of cooking liquor	%	20.0	20.0
4.	Cooking temperature	^{o}C	165	165
5.	Cooking time	min	90	90

	Cooking schedule:			
6.	Ambient to 100 °C	min	30	30
7.	Degas pressure	Kg/cm^2	At 2.0	2.0
8.	100 °C to 165 °C	min	90	90
9.	At 165 °C	min	90	90
10.	Blow pressure	Kg/cm^2	5.0	5.0

Table 7 Kraft Pulping of jute in pilot plant on 1st and 12th December, 2003

S.L	Particulars	Unit	I Trial	II Trial
1.	Cooking chemical dose as Na_2O	%	**17.5**	**17.5**
2.	Sulphidity	%	20	20
3	Unscreened yield	%	47.3	47.0
4	Screened rejects	%	0.8	0.5
5	Kappa number	-	**19.8**	**19.9**
6	Unbleached pulp brightness	% ISO	**30.5**	**31.5**
7	Unbleached pulp viscosity	Cm^3/g	**849**	**810**

Table 8. Physical strength properties of unbleached pulp of pilot plant trial pulp

	PFI (rev)	Freeness ml, CSF	Apparent Density g/ cm3	Burst Index $KPam^2/g$	Tensile Index Nm/g	Tear Index mNm^2/g	Fold Kohler Molin(log)	Porosity Bendtsen (ml/min.)
Unbleached pulp	0	320	0.68	3.50	61.0	5.60	1.90	166
	500	250	0.71	4.50	74.0	5.10	2.24	58.3

The flow sheet of pilot plant pulping followed in CPPRI is given in Fig. 2

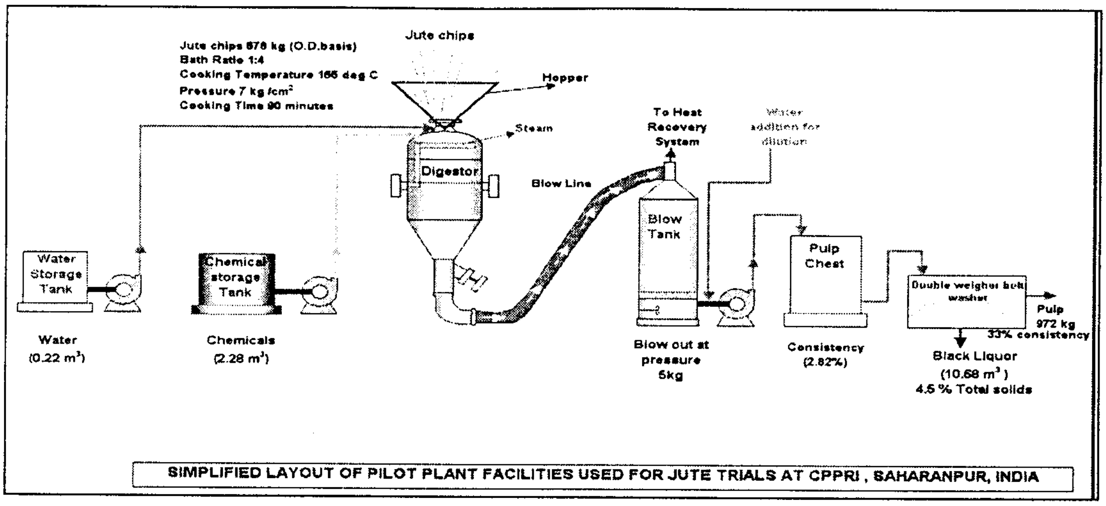


Fig. 2 Flow sheet of pilot plant at CPPRI

The visuals of pilot plant are documented in Fig. 9-14

Fig.3 Harvesting of green jute from the fields in Barrackpore, Kolkata, India

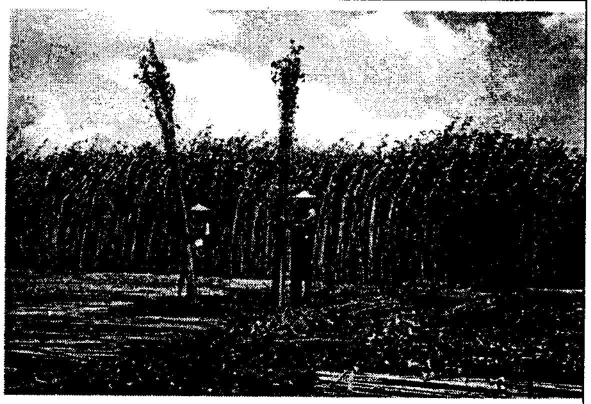


Fig. 4 Harvesting of green jute from the fields in Barrackpore, Kolkata

Fig. 5 Bundling of green jute in the fields in Barrackpore, Kolkata.

Fig 6. Transportation of green jute for weighment in Barrackpore, Kolkata.

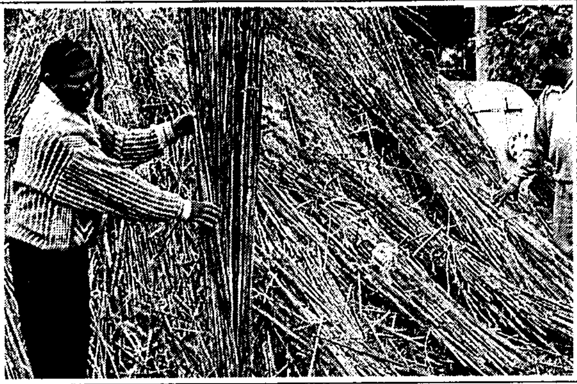


Fig. 7 Transported and stacked jute at CPPRI, Saharanpur

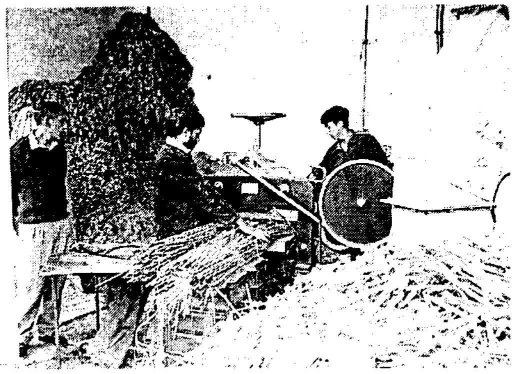


Fig. 8 Chipping of green jute at CPPRI, Saharanpur

Fig. 9 Pulley lifting of weighed jute chips to Pulping Digester

Fig 10. Pulping Digester filled with jute chips

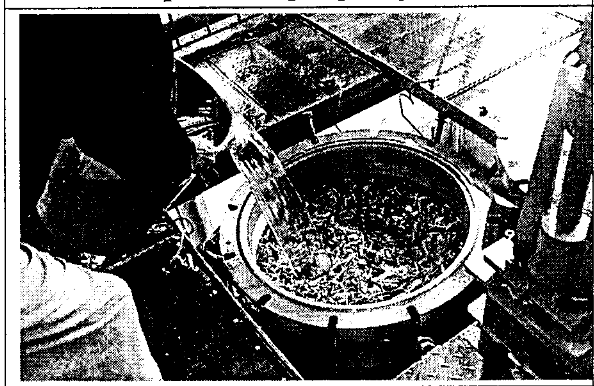
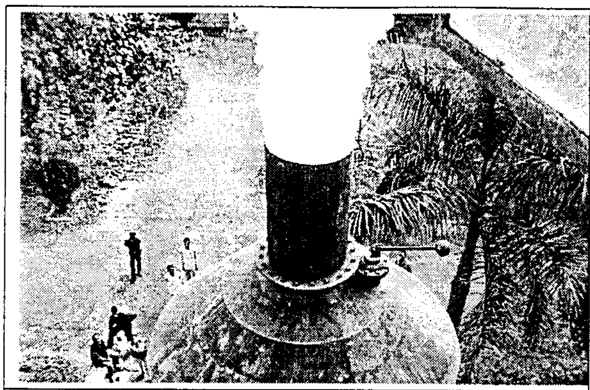


Fig. 11 Addition of make-up water for maintaining bath ratio

Fig. 12 Addition of cooking liquor



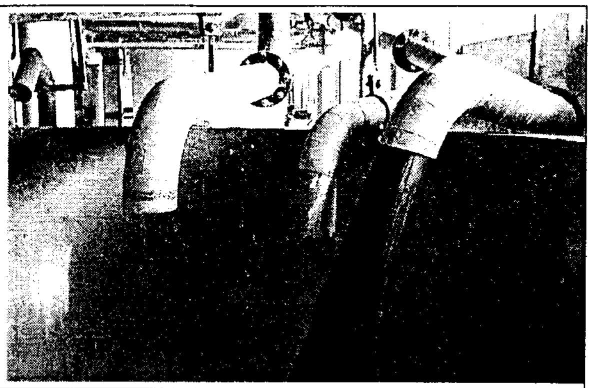


Fig. 13 Blowing of Kraft pulp at 5 kg pressure	Fig. 14 Pumping of Blown Kraft unbleached Pulp to Chest

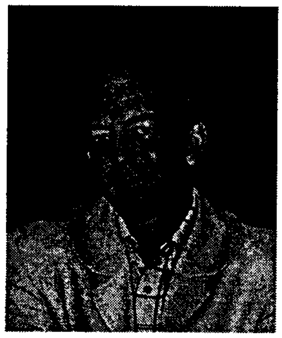
CONCLUSION

1. The raw material is very bulky with high moisture content and low bulk density, so it is better to set up a mother pulp mill in the vicinity of area where raw material is available to avoid uneconomic transportation cost.

2. The guillotine cutter is most suitable for chipping whole jute as the drum chipper separates bast from core in woolen form. Chipping takes place best when the raw material is in semi dry condition.

3. Good quality pulp can be produced from whole jute for producing writing printing grade papers.

Bleaching Of Green Jute Chemical Pulps Based On Biotechnological Treatments



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Bleaching Of Green Jute Chemical Pulps Based On Biotechnological Treatments

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BACKGROUND

Jute is an annual plant, widely cropped in South East of Asia. The main traditional uses of jute and allied fibres are sacking and carpet backing cloth. Bangladesh and India are important producers of jute for such applications. All the jute-based products are facing severe competition due to the emergence of synthetic fibres. In order to survive and to stabilise the jute/kenaf industry, it is necessary to identify and develop new applications and the corresponding markets. One such alternative is to increase the utilisation of jute for the manufacture of pulp and papers.

Annual world production of jute, kenaf and allied fibres is around 3 million tons, of which 2.86 million tons are produced in Bangladesh, China, India and Thailand. In addition to the fibre production, 1.6 million tons of leaves and 8 million tons of sticks are also available for valorisation. The demand for paper and board has drastically increased in Bangladesh, China, India and Thailand with a per capita consumption in 1996 of 3 kg, 29 kg, 5 kg and 32.5 kg respectively /1/. There is an urgent need to develop new fibre sources for pulp and paper manufacture. The production of pulp and paper is based on the use of bamboo, bagasse and some wood. Jute is a potential raw material for supplementing the pulp mills. Biopulping and biobleaching are environmentally friendly technologies, which have to be considered for the green jute utilisation as fibre resource for pulp and paper in Bangladesh. For that, a project supported by UNIDO was launched involving IJSG (International Jute Study Group) Bangladesh, BCIC (Bangladesh Chemical Industry Corporation) Bangladesh, Agrotechnology & Food Industry (A&FI, The Netherland), Centre Technique du

Papier (CTP, France), Central Pulp & Paper Research Institute (CPPRI, India) and Institute of Bast Fibre Crops (IBFC, China).

Chemical pulping of jute was widely studied since the 1990's. More recently, soda, soda-AQ /2-3/ or alkaline sulfite pulping /4-5/ processes are considered for the whole jute plant. The addition of anthraquinone, anthrone and 1,4-dihydro-9,10-dihydroxy anthracene (DDA) in the soda or kraft liquor was investigated /2/. The whole jute plant pulping with these additives in the soda process produced higher pulp yields and lower kappa numbers than the soda and kraft processes. This suggests a more selective delignification. Except for the tear index, all the pulp strengths were higher. DDA is the most effective of the quinone additives. Hexamethylene tetramine (HTMA) was also efficient for improving the pulp yield, the physical pulp properties, due to some preservation of carbohydrates. The soda-HTMA process seems to be suitable for manufacturing good quality pulp for printing-writing papers. Although the alkaline sulfite process required longer cooking time than kraft pulping, it provided a simpler, more economic method for jute fibres with low lignin, pentosans and ash contents, giving higher strengths and pulp yield without producing odoriferous sulfides /4/. Better delignification associated with higher pulp strengths are also obtained with the AQ – alkaline sulfite process /5/ if the alkali charge was higher than 3.8%. The pulp bleachability was improved and especially, lower chlorine charge is needed.

Mohiuddin *et al.* /6/ studied biopulping of whole jute plant with different white-rot strains soda process. The application of white-rot fungus on the whole jute chips has a positive effect on the decrease in kappa number and on the physical pulp properties, without negative effect on the pulp yield. Tear index increased by 17 to 31% and tensile index by 5 to 30% depending on the fungus (*C.subvermispora, P. chrysosporium or F. lignosus*). Some xylanases were tested on jute soda-AQ pulps in a DED and DEDP bleaching sequence /7/. This enzymatic stage reduces the kappa number and increased the pulp viscosity and brightness.

A brightness of 85.6% ISO and 81.3% ISO for the XDEDP and XDED bleaching sequences respectively was reached. For the control, the corresponding brightness were 81.4 and 78.9% ISO. The chlorine dioxide charge is reduced by 11%. Bleached pulps presented higher brightness, viscosity and pulp strengths (2378 m versus 1770 m, 9.4 mNm^2/g versus 8.0 mNm^2/g for control pulp).

OBJECTIVES

Based on results obtained in preliminary studies from diverse institutes and enzymes suppliers a commercial Xylanase was tested in pre-treatment of conventional and ECF bleaching sequences. The study was conducted focusing on an easy mill application.

The objectives of this study were :

- To compare conventional and ECF bleaching sequences with an oxygen delignification, a xylanase pre-treatment and successively oxygen and xylanase treatments. These tests were applied on soda anthraquinone pulps with and without fungal pre-treatment of the whole jute chips
- To evaluate the enzyme efficiency of 3 commercial xylanase and one elaborated by IJSG.

In a second part were compared pretreatments with a commercial Xylanase (Pulzyme HC, NOVO), a Laccase developed by INRA (F)(*Pycnoporus Cinnabarinus*) and successively Xylanase and Laccase. These pretreatments were compared on Conventionnal, ECF and TCF bleaching sequences.

EXECUTIVE SUMMARY

In chemical pulping Soda – AQ and kraft processes were applied on the whole jute plant with and without fungal pre-treatment. Conventional (CEH) and Elementary Chlorine Free (DED) bleaching sequences were applied on Soda-AQ pulps. The incidence of an oxygen delignification, a xylanase pre-treatment and an oxygen delignification followed by a xylanase treatment were evaluated. The brightness target of 80 % ISO was reached and an important reduction of chemical consumption was observed in all cases. The pulp qualities and environmental impact were compared.

In complement of this study in the perspective of environmental friendly bleaching sequences pre-treatment with Xylanase, Laccase and Xylanase-Laccase were applied on TCF bleaching sequences.

RESULTS AND DISCUSSION

Chemical pulping

The objective of this part was to compare two pulps from whole jute issued from soda anthraquinone and kraft processes (Table 1)

1 : A reference pulp

2 : A pulp from whole jute pretreated with *Ceriporiopsis subvermispora* .

Laboratory scale pulping trials were carried out after harvesting.

The Soda-AQ pulps, were produced and bleached with conventional and ECF bleaching sequences.

An oxygen delignification stage was also performed in order to test a possible upscaling of the process.

Finally, a xylanase pretreatment was tested on the unbleached pulps to improve the delignification and save bleaching chemicals.

For normal chips, kraft process produced a pulp with better delignification and lower polysaccharide degradation. For fungus pretreated chips, the difference of both processes in delignification was smaller but kraft process better protected cellulose. This fungal pretreatment of chips allowed to better delignify whole jute chips with limited cellulose degradation.

For practical reasons the Soda-AQ pulps were considered for the bleaching trials.

Table n°1 Soda Anthraquinone cooking

	Normal Chips	***C. subvermispora* pretreated chips**
Cooking Temperature, °C	170	170
Time, min.	90	90
Na_2O Charge, %	17	17
Anthraquinone, %	0.05	0.05
Yield, %	48	48
Kappa number	19.5	16.2
Viscosity, mPa.s	12.6	11.9
Polymerization degree	1050	1020

The kraft pulps were devoted to the comparison of commercial and developed enzymes.

Kraft cooking

	Normal Chips	**C. subvermispora pretreated chips**
Cooking Temperature, °C	170	170
Time, min.	120	120
Na2O Charge, %	17	17
Sulfidity, %	22	22
Kappa number	17.8	16.5
Viscosity, mPa.s	23.8	15.7
Polymerization degree	1480	1200

Comparison of conventional and ECF bleaching sequences on unbleached pulps and after an oxygen delignification

With regard to a potential industrialization, the bleaching study was in a first step conducted on the two Soda-AQ pulps using the conventional (CEH) and ECF (DED) bleaching sequences without and with a complementary oxygen delignification stage.

Reference Soda-AQ

C.Subvermispora pretreated Jute Soda-AQ

Table n°2 summarizes the total chlorine charges applied during the different bleaching sequences and presents the obtained final brightness.

Table n°2

	Reference pulp	Biotreated pulp
CEH	6.0	5.1
O CEH	3.0	3.1
DED	7.2	6.4
O DED	4.5	4.8

Chlorine charge % applied

	Reference pulp	Biotreated pulp
CEH	80	83.3
O CEH	84.8	86.8
DED	83.6	85.2
O DED	87.1	87.4

Final brightness %ISO

An oxygen delignification led to 50% and 40% chlorine charge reduction on the CEH bleaching sequence respectively for reference pulp and biotreated pulp. In spite of this reduction, the final brightness increase from 80.0 to 84.8%ISO and 83.3 to 86.8 %ISO respectively.

The fungal pretreatment of the jute led to 15% chlorine reduction charge, only if oxygen stage was not used, because of its efficiency during cooking.

The oxygen stage seemed to minimize this effect leading to almost the same chlorine charge. However the brightness was improved by 2 units (85.2 to 87.4 %ISO for DED and 83.3 to 86.8 %ISO for CEH). Fungal pretreatment helped to remove lignin during cooking and oxygen delignification

Regarding the DED sequence, the final brightness was higher than for the CEH sequence, but the equivalent chlorine charge was higher, due to a supplementary consumption in the D2 stage compared to the hypochlorite stage.

The same comments could be done about the effect of the biopretreatment of the chips and on the use of oxygen on the chlorine charge, however these effects were less marked than for the CEH sequence (11% chlorine reduction charge by the bio pretreatment and 38% reduction by the oxygen stage).

The brightness gain due to the oxygen stage was also comparable with the CEH trials and the final brightness achieved at 87.1 %ISO and 87.4 %ISO respectively for reference pulp and biotreated pulp. These brightness levels were far from the target (+7 units) revealing that a reduction of the chlorine or chlorine dioxide charge could be envisaged for industrial application.

The bleaching yields were comparable between reference and biotreated jute pulps (Table3).

Table n°3 Bleaching yields %

	Pulp 01	**Pulp 02**
CEH	94.5	94.7
O CEH	92.2	92.0
DED	96.8	95.3
O DED	90.7	91.7

There was no significant difference between pulp 01 and pulp 02. The oxygen stage seemed to reduce significantly the bleaching yield and consequently the total yield. The oxygen stage oxidized hemicelluloses and lignin left in the pulp leading to soluble compounds and also part of the cellulose underlined by the viscosity drop, about 100 units of polymerization degree (Table 4). The CEH sequence was more detrimental to cellulose than DED.

Table n°4

	Pulp 01	Pulp 02
CEH	680	630
O CEH	570	520
DED	1020	960
O DED	910	900

Pulp polymerization degree

DED sequence was less aggressive than CEH whereas OCEH was more interesting than ODED for pulp production

Xylanase pretreatment

During a previous work, an enzymatic pretreatment was associated to an alkaline extraction for reducing chlorine charge. It was interesting to compare the effect of a X (Enzyme), X E (enzyme followed by an extraction stage) and E (alkaline extraction stage) to determine exactly the efficiency of enzymes.

The effect of these pretreatments showed a drop of Kappa number (Table 5) and consequently a reduction of the chlorine charge to apply (Table 6)

Table n°5

	Reference pulp		Biotreated pulp	
X	2.3	Total 5.9	1.3	Total 3.6
E	3.6		1.9	
XE	7.4		3.9	

Kappa number drop along bleaching sequences

The xylanase stage induced a lower kappa number drop than extraction stage (2.3 versus 3.6), but the XE stage was more efficient than the total of the two stages (7.4 versus 5.9). That meant that the xylanase reacted on the xylan lignin linkages leading to more soluble compounds removed by alkaline extraction. The pretreatment applied on the pulp issued from the chips pretreated with *C.Subvermispora* had lower results, but the pretreatment led to the same Kappa number (12.1, 12.3 respectively for the untreated chips and the pretreated).The pulp issued from the pretreated chips had initially a lower kappa number, and the enzymes reacted selectively on only the residual xylans linked to lignin inducing some breakage of the bonds. The effect of the biotreatment of the chips seemed not to be cumulative with the xylanase stage in the bleaching sequence

Table n°6 Chlorine charge % applied

	Reference pulp	Biotreated pulp
Reference CEH	4.9	4.1
X CEH	4.3	3.7
E CEH	4.0	3.6
XE CEH	3.0	3.1

A Xylanase stage led to 12 and 10% chlorine charge savings respectively for reference and biotreated jute pulp.

An alkaline extraction led to 18 and 12% chlorine charge reduction respectively.

The combination of the two stages (XE pretreatment) led to 39 and 25% chlorine charge reduction respectively.

The XE sequence demonstrated the efficiency of xylanase treatment of pulps to reduce chlorine charge beside the brightness was increased by 2.5 units (table n°7). The combination of fungal pretreatment of chips and biobleaching (XE) allowed to better delignification without pulp yield loss and bleaching chemical saving to reach higher brightness levels. With biotreated jute pulp, it was possible to envisage a XE CEH sequence with lower chlorine charge to reach 80%ISO brightness and to limit the H stage.

The bleaching yields were comparable, however 1 point in bleaching yield was noticed in case of pretreated chips comparing CEH and XE CEH but it will not affect the fully bleached pulp yield.

Table n°7 Brightness, %ISO

	Reference pulp	Biotreated pulp
Reference CEH	80	83.3
X CEH	80.6	83.2
E CEH	81.0	84.1
XE CEH	82.5	85.5

A slight drop in viscosity was noticed for the XE CEH sequence compare to the reference (Table 8).

Table n°8 Viscosity results

	Reference pulp	Biotreated pulp
Reference CEH	680	630
X CEH	630	620
E CEH	590	580
XE CEH	620	580

It could be noticed that this drop was mainly due to alkaline extraction and not to the xylanase stage, revealing the attack of sodium hydroxide to cellulose

Due to all these results, the most interesting biobleaching sequence was a sequence including a XE stage.

Comparison of conventional and ECF bleaching sequences after an enzymatic XE stages.

The subject of this part was to compare the efficiency of the conventional and the ECF bleaching sequence on pulps pretreated by XE as previously studied.

The XE pretreatment was perform on the 2 Soda - AQ pulps as described previously. The pretreatment was also applied after the oxygen stage.

The following bleaching sequences were studied :

XE CEH
XE DED
O XE CEH
O XE DED

The XE pretreatment induced a drop in Kappa number, 19.5 to 12.1 for the reference pulp and 16.2 to 12.3 for the pulp with fungal pretreatment. The kappa number after XE pretreatment was equivalent, underlining that the benefit of the chips pretreatment was reduced on the unbleached pulp. This meant that the xylanase only react on xylans linked to the lignin. An oxygen pretreatment already reduced the effect of biopretreatment of the chips leading to kappa number 8.2 and 9.0 respectively. A XE pretreatment on the pulp after oxygen did not generate differences on both pulps. The final kappa number after XE reached at 6.3 and 6.7 respectively. (Table 9)

Table n°9

	Initial	**X**	**XE**	**O**	**OXE**
Reference pulp	19.5	17.2	12.1	8.2	6.3
Biotreated pulp	16.2	14.9	12.3	9.0	6.7

Kappa number of whole jute Soda-AQ pulps

Nevertheless, these decreases in kappa number consequently reduced the chemical charges to apply for the rest of the bleaching sequences. To illustrate this, the chlorine charges applied (as Cl_2 reacted for all the bleaching sequences) are calculated and brightness levels were compared (Table 10).

Table n° 10

	CEH	**DED**	**XECEH**	**XEDED**	**OCEH**	**ODED**	**OXECEH**	**OXEDED**
Reference pulp	6.0	7.2	4.1	5.5	3.0	4.5	2.3	4.1
Biotreated pulp	5.0	6.4	4.0	5.6	3.1	4.8	2.4	4.3

% of Cl_2 charge

	CEH	DED	XECEH	XEDED	OCEH	ODED	OXECEH	OXEDED
Reference pulp	80.0	83.6	82.5	83.9	84.8	87.1	84.8	86.1
Biotreated pulp	83.3	85.2	85.5	85.1	86.8	87.4	87.4	87

Brightness %ISO

The XE pretreatment induced 32% chemical saving in case of conventional CEH sequence and 24% saving in case of ECF bleaching.

An oxygen stage reduced 50% and 38% the chemical consumption respectively for the conventional and the ECF bleaching sequence.

The combination of oxygen followed by an enzyme treatment led to 62% and 43% reduction charge respectively for the conventional and the ECF bleaching sequences.

The enzyme treatment after the oxygen stage reduced by 23% and 9% respectively for conventional and ECF bleaching. The xylanase stage had some efficiency after this complementary oxygen delignification stage.

Concerning the brightness results the chemical charges could be reduced some more for a brightness target of 80% ISO.

In all cases, the achieved final brightness was higher than the target and we could appreciate a benefit of XE, Oxygen and OXE sequence. In the same way, the pulp issued from the *C. subvermispora* chips achieved in every cases at 2 or 3% higher brightness than the pulp without chip pretreatment. The similarity of the kappa number of the two pulps after the pretreatment and the final higher brightness for biotreated jute pulp underline a modification of the lignin by the fungal pretreatment, making it easier to remove by the bleaching chemicals.

Effluent analysis

COD, BOD and AOX analysis were carried out on the total effluent of each bleaching sequence. (Table 11)

It was observed an increase in COD and BOD with biobleaching sequence. This was correlated with the bleaching yields. However the XE pretreatment with higher bleaching yields generate more COD than the oxygen treatment. Nevertheless these COD and BOD levels were quite low and acceptable.

In all cases, the ECF bleaching sequences generated less COD and BOD.

The pulp issued from the pretreated chips generated also less COD and BOD comparatively to the reference pulp.

Table n°11

	COD Kg/t	BOD Kg/t	COD/BOD	Bleaching Yields	AOX Kg/t
CEH Reference pulp	53.20	8.80	6,00	94,50	4.13
CEH Biotreated pulp	45.77	8.61	5,30	94,70	3.09
DED Reference pulp	36.94	6.48	5,70	96,80	0.41
DED Biotreated pulp	23.22	6.29	3,70	95,30	0.24
OCEH Reference pulp	59.94	9.08	6,60	92,20	1.13
OCEH Biotreated pulp	54.27	10.58	5,10	92,00	1.16
ODED Reference pulp	51.57	9.21	5,60	90,70	0.09
ODED Biotreated pulp	43.27	8.65	5,00	91,70	0.09
XECEH Reference pulp	66.49	12.45	5,30	94,40	2.06
XECEH Biotreated pulp	72.73	12.87	5,60	93,70	1.88
XEDED Reference pulp	67.21	11.13	6,00	93,10	0.10
XEDED Biotreated pulp	62.06	11.06	5,60	94,40	0.13
OXECEH Reference pulp	77.68	12.76	6,00	91,00	1.46
OXECEH Biotreated pulp	69.52	13.05	5,30	89,00	1.73
OXEDED Reference pulp	71.70	13.73	5,20	92,50	0.09
OXEDED Biotreated pulp	62.20	14.35	4,30	93,10	0.07

In term of biodegradability, these effluents were comparable with mill effluents. Some ratio COD/BOD lower than 6 indicated an easier biodegradability, in spite of higher COD values.

Globally, the ECF pulps had a lower ratio compared to conventional bleaching and pulp with chip biopretreatment was also in a good position compared to reference pulp.

The AOX content was considerably decreased, due to the chemical reduction charges and especially in the bleaching sequences with oxygen. The XE pretreatment looked less efficient than the oxygen stage.

Regarding the AOX content, the ECF bleaching sequence was preferable.

Mechanical properties

The studied pulps were refined at 40°SR in a PFI mill based on preliminary refining curves

The bleaching sequences selected were all those including a CEH part, and only the DED and the OXEDED for the ECF bleaching.

No significant differences were underlined for all the tested pulps.

The mechanical properties were quite good and these pulps were suitable for printing and writing paper grades.

All the pulps issued from biopretreated chips had a slightly lower mechanical properties and especially the tear index, due to some degradation of the fibre structure during the growth of fungus.

The ECF pulps had comparable mechanical properties but the tear index was higher than for pulps bleached with CEH containing sequences. It seemed to be correlated with the viscosity.

The use of a xylanase pretreatment did not have an influence on the mechanical properties in spite of the chemical charge reduction.

Comparison of pretreatments with Xylanase, Laccase and Xylanase - Laccase

1 Bleaching trials

Based on the results obtained previously, the comparison of Xylanase enzyme was to be studied with an other type such as Laccase.

Xylanase, Laccase and Xylanase followed by Laccase pretreatments were carried out on a Soda - Anthraquinone pulp of Kappa number 18.3 and 1480 degree of polymerization.

The Xylanase pretreatments were carried at 50°C, 120 minutes, 5% consistency, 1 unit / g of od pulp at pH 7.

The Laccase pretreatments were carried out at 50°C, 240 minutes, 5% consistency, 25 unit /g of od pulp at pH 5 under 1.5 bar Oxygen pressure and with 3% HBT mediator.

The comparison of the pretreatments followed by an alkaline extraction are illustrated in table n°12

Table n°12

	Kappa number	Degree of polymerization
Initial pulp	18.3	1480
After X	16.4	
After XE	13.1	1610
After L	15.3	
After LE	13.4	1510
After XL	13.6	
After XLE	10.8	1520

Kappa number and degree of polymerisation after pretreatment

The Xylanase and the Laccase reacted differently, the laccase was more reactive in the enzyme action when the xylanase seemed more focused on the modification of the linquages of the lignin and hemicelluloses, the alkaline extraction leading to a slightly better result.

The association of the 2 stages successively X and L led to cumulative results.

The improvement of the viscosity was much more the result of the elimination of short carbohydrate chains.

Conventional CEH bleaching sequences were applied on these pretreatments.

The chlorine amounts were based on a 0.25 kappa factor.

See table n°13 the Chlorine consumption results and the brightness and viscosity results.

Table n°13

	Total %Cl_2 applied	Total %Cl_2 consumed	Cl_2 Reduction charge %	Brightness %ISO	DP
CEHH	7.6	4.9		80.9	790
XE CEH	5.3	3.6	27	80.2	900
LE CEH	5.3	3.7	25	80.0	880
XLE CEH	4.7	2.9	41	81.9	930

Effect of the Enzyme treatment on the chlorine charge

The chlorine charge was applied based on 0.25*Kappa factor.

The 80%ISO brightness target was obtained with respectively 27, 25 and 41% reduction charge for XE, LE and XLE pretreatment. This chemical charge reduction had a positive effect on the final viscosity.

ECF and TCF bleaching sequences were also tested on the XLE pretreated pulp in comparison with the conventional one.

The brightness and the viscosity results are given respectively in figure n°1 and n°2

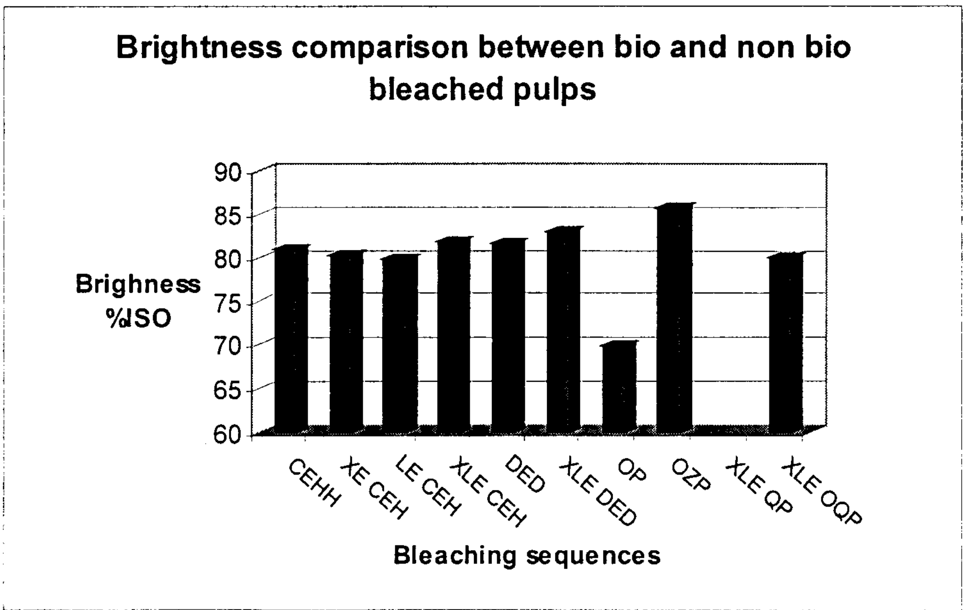

Figure n°1

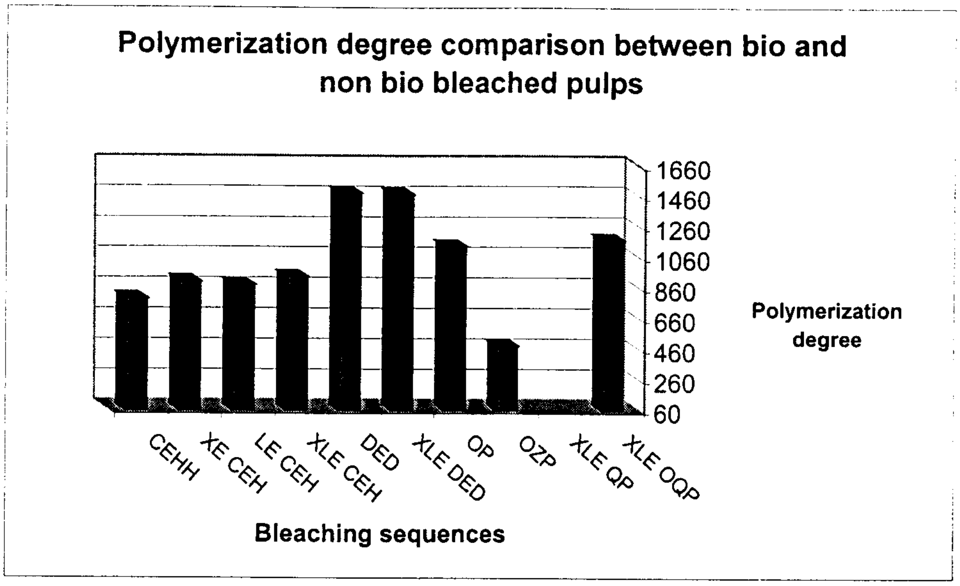

Figure n°2

As seen previously, the Enzyme pretreatment led to save 25 to 40% Chlorine charge in case of CEH bleaching sequence. Concerning the ECF bleaching sequence, the reduction of ClO2 observed was 26% in term consumed ClO_2.

A TCF bleaching sequence using oxygen and hydrogen peroxide (OP) was not efficient even with high hydrogen peroxide charge(8%) achieving at 70%ISO brightness when the brightness target was reached after the XLE pretreatment with 2% hydrogen peroxide consumed.

The introduction of an Ozone stage led to interesting brightness results with low ozone charge (less then 1%) and low hydrogen peroxide charge (2%). However in this case, the final viscosity was very affected. It was not possible to apply this sequence on a pretreated pulp but we can expect to reach the brightness target with less ozone and less hydrogen peroxide leading to higher viscosity.

The other bleaching sequences obtained higher viscosity due to a reduction of chemical charge. The use of Chlorine dioxide in the ECF bleaching sequences improved considerably the viscosity

2 Environmental aspect

On an environmental point of view, COD were measured on the effluents, see table n°14

In term of COD the best sequence was the ECF one. An Enzyme pretreatment led to an increase in the COD(10%). The L containing sequences led to a very important increase in the COD but these values seemed to be artificially increased due to the presence of the mediator.

In term of AOX generated by these sequences, The comparison of the conventional, ECF and TCF led respectively to : 2.48 kg/t, 1.02 kg/t and 0. The AOX were not measured on the effluents of the enzymes pretreated pulps but considering the reduction of the chemical charge, the AOX content would proportionally be reduced.

Table n°14

Stage	COD kg/T	Total COD kg/T	COD kg/T	Total COD kg/T
Xylanase			18.51	
Extraction			12.56	
Chlorine			9.84	
Extraction			10.54	
Hypochlorite			2.84	**54.29**
Xylanase Laccase			115.81	
Extraction			8.46	
Chlorine	18.6		9.24	
Extraction	20.3		10.54	
Hypochlorite	10	**48.9**	1.56	**145.61**
Xylanase Laccase			115.81	
Extraction			8.46	
Chlorine Dioxide	18.9		10.72	
Extraction	6.3		4.32	
Chlorine Dioxide	5.9	**31.1**	1.63	**140.94**
Xylanase Laccase			115.81	
Extraction			8.46	
Oxygen	35.6		20.15	
Quelation	7		7.24	
Hyrogen peroxide	22	**64.6**	16.64	**168.3**

CONCLUSIONS

For conventional bleaching of Soda-AQ pulps, a DED bleaching sequence led to better brightness, bleaching yield and viscosity than CEH sequence.

An oxygen delignification stage prior to the bleaching sequence would be an alternative to reduce the chemical consumption : a decrease of 50% in chlorine in case of CEH and 38% in case of DED was observed. The brightness with less chlorine or chlorine dioxide was increased by 3 to 4 points in brightness.

A Xylanase stage followed by an alkaline extraction induced a reduction of the bleaching chemical consumption of 32% in case of conventional bleaching and 24% in case of ECF bleaching.

The OXE pretreatment led to 62% and 43% reduction respectively for conventional and ECF bleached pulps.

The pulp produced with the chips pretreated with *Ceriporiopsis subvermispora* was bleached to higher final brightness with lower chemical charges.

A pretreatment of the unbleached pulp (O, XE, OXE) decreased the effect of the fungal treatment whatever it is, leading to equivalent kappa number before using chlorine compounds.

With regard to the brightness target of 80% ISO, the chemical charges could be reduced in every cases, except for the CEH bleaching sequence, which had to be carried out as such.

On an environmental point of view, the COD and BOD charges in the effluents increased when applying a pretreatment before the bleaching sequence (O ,XE and OXE)

However these values remained in an acceptable level, and the biodegradability was slightly improved.

It was important to underline that the ECF bleaching sequence generated less COD and BOD charges as well as the pulp issued from the pretreated chips.

The XE bleaching pretreatment led to slightly better bleaching yields.

The AOX content was considerably decreased in case of conventional bleaching (4.1 and 3.1 kg/t to 1.1- 1.2 kg/t with O stage, 2.1 - 1.9 kg/t with XE stage and 1.5 - 1.7 kg/t with OXE stage).

The mechanical properties were similar for all the pulps after bleaching leading to rather acceptable pulp qualities. A slightly better tear index for the ECF pulps.

The oxygen stage seemed to be the most interesting first bleaching stage but at mill scale it will need more investment and more maintenance.

The enzyme stage had to be followed with an alkaline extraction for a better efficiency in delignification.

The Xylanase pretreatment demonstrated its efficiency but other enzymes were to be considered such as Laccase leading to comparable results.

The effect of Xylanase and Laccase were additional.

Nevertheless on a practical point of view the Laccase treatment was more complicated to carry out when the use of Xylanase did not need neither specific additional chemicals nor special equipments.

On an environmental point of view, TCF bleaching sequences could be considered.

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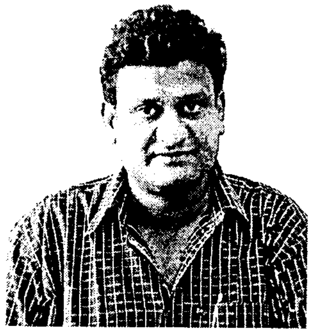
Enzymatic Prebleaching Of Whole Jute Kraft Pulp



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Enzymatic Prebleaching Of Whole Jute Kraft Pulp

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INTRODUCTION

Jute, kenaf, and other allied fibers (JAF) are the second most important natural fibers next to cotton. JAF are cash crops of great socio-economic importance in countries like, Bangladesh, China, India, Nepal, and Thailand.

With increasing deterioration of world environments caused mainly by the extensive exploration and utilization of nature resources and the continuous expansion of synthetic market, naturally renewable materials are gradually attracting more and more attentions from both developed and developing countries. Among many naturally renewable materials, jute, kenaf and allied fibers (JAF) are becoming increasingly important because of their chemical, mechanical, and environmental characteristics.

Paper industry is highly dependent on good quality of cellulosic raw material. The paper industry in India is 100 year old industry and always had a short term planning for raw materials. The industry started with bamboo as a raw material and subsequently shifted to tropical hard wood. In early 70's industry switched over to agro residues such as straws & bagasse. The paper industry is expected to grow at a rate of around 7% and by the year 2010 the demand is expected to be around 8.3 million tonnes in order to augment this capacity. The industry has to look for alternative good quality cellulose raw material.

Jute has gained the importance as an alternate cellulosic fibrous raw material for paper and paper products way back in 1960 and some mills continued to use jute till 1994 as long as prices were competitive. Jute can be excellent raw material for making different grades of pulp and paper. It can be used as substitute for imported soft wood pulp, and as reinforcing fibre in the indigenous furnish. Pulp & Paper made from whole jute exhibit acceptable strength properties which are better than that made from eucalyptus, bagasse, rice straw and wheat straw.

Through the extensive research work carried out by CPPRI and similar research organizations in other countries, there are various technological options available today. The multi-institutional project under the supervision of IJSG is making an effort to reduce the cost of pulp production through biotechnological routes such as bio-pulping and bio-bleaching.

The Global concern regarding imposition of the discharge norms for AOX has forced the paper industry to look for the alternate technologies for pulping and bleaching to have the reduced AOX levels in the discharged effluents. The biobleaching process employing certain class of xylanase enzymes has shown promise an alternate option to reduce the use of chlorine based chemicals during bleaching and thus could help the industry to comply with the regulatory requirements.

The present paper highlights the efforts made at Central Pulp and Paper Research Institute in the area of enzymatic prebleacing of whole jute kraft pulp employing the xylanase enzymes as bleach booster, developed and produced from an identified microbial strain under IJSG project and its comparison with commercially available xylanase enzyme.

2.0 MATERIALS AND METHODS

2.1 Sources of xylanase enzymes

Two Xylanse enzymes preparations were used in the present investigations. These are:

Enzyme A `Xylanase enzyme developed and produced from an identified microbial strain and received from IJSG.

Enzyme B Globally available commercial enzyme preparation procured from an enzyme manufacturing company.

2.1 Pulp Samples

Screened jute kraft pulp manufactured at CPPRI under optimized pulping conditions and produced from whole jute.

2.2 Enzyme Assay technique

Both the enzymes were tested for filter paper activity for cellulase contamination by the method of Mandals & Weber and xylanase activity was measured by the method of Bailey et. al (5).

2.3 Xylanase pretreatment of pulps

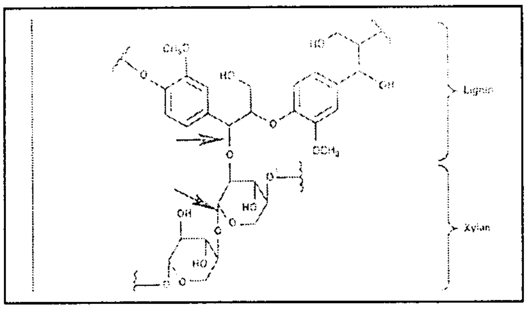
Enzyme pretreatment of jute kraft pulp was carried out under the optimized conditions. The jute pulp (500 gm OD) was mixed with enzyme after sufficient dilution (1:300) with water and mixed properly with Medium Consistency Pulp (10%) by kneading mechanism. Control was run parallel with maintaining all conditions except addition of enzymes. The condition of enzyme pretreatment are shown in table - 1

3.0 Mechanism of Xylanase Treatment (How Xylanase acts on Jute Kraft Pulp?)

One of the predominated hypothesis for the mechanism of xylanase activity in bleaching is that these enzymes catalyze the hydrolysis of re precipitated xylan or removal of the xylan from the lignin carbohydrate (LC) complexes on the surface of the kraft pulp fibers making the lignin fragments in and on the fiber easier to remove in the following bleaching and alkaline extraction stages.

Another hypothesis is that the xylanases by catalyzing the depolymerization of the xylan in the cell walls allow entrapped lignin to diffuse more easily out of the fibers. Figure - 1 shows the possible structure of lignin carbohydrate complexes in unbleached jute kraft pulp and the arrows in the picture shows the possible sites of xylanase hydrolysis.

Figure – 1 Possible structure of lignin-carbohydrate complex in unbleached kraft pulp.



4.0 RESULTS & DISCUSSIONS

4.1 Effect of Xylanse treatment on the yield of bleached jute kraft pulp

While optimizing the doses of enzyme during enzymatic treatment of chemical jute kraft pulp, it was observed that excess doses of xylanase enzymes for a longer period resulted in the decreased pulp yield. This could probably be due to the loss of hemicelluloses by drastic action of the enzyme. However, under optimized doses of enzymes, that is 2 IU/gm pulp and optimized treatment conditions no significant loss in pulp yield could be observed. The yield of the Jute kraft pulps before and after enzyme treatment are shown in Table 1.

4.2 Effect of Enzyme Treatment on Kappa Number

The magnitude of the effect of enzymatic treatment depends on the pulping process and starting kappa number. In general, the higher the initial kappa number, the greater is the effect of xylanase treatment in the bleaching sequence. In the present study, the enzyme treated and the conventionally treated bleach pulp were found to have approximately the same kappa number (3.3-3.5), after the Extraction stage when bleached with CEpH sequence (Table - 2). Based on kappa number, each pulp should have contained about the same amount of residual lignin. However, the enzyme treated jute kraft pulps has a final Brightness of 3-4 points above those of the conventionally treated pulps without enzyme treatment when bleached with various bleach sequences like CEH, CEpH, CoEH, CDEpH (applied Chlorine/ Chlorine & chlorine dioxide - 4.27%).

4.3 Effect of Enzyme treatment on the Physical properties of Jute Kraft Pulp

With the xylanase treatment, the benefit in the bleaching is visible only after the first extraction stage. The bleaching of the jute kraft pulp was carried out by various bleach sequences viz. CEH, CEpH, DCEH, DCEpH (Table - 2,3,4 &5) with an objective to have pulp of higher brightness withut loss in physical strength properties and for environmental benefits. Table - 6 shows the results of pilot plant trial in respect of physical strength properties of the jute kraft bleached pulp before enzyme treatment employing the above said bleach sequences.

Table - 7 shows the results of the physical strength properties of the enzyme treated bleached (C/D EH) Jute kraft pulp using both the xylanase enzyme preparations A and B.

The extensive evaluation of xylanase pretreated pulps indicated that such pulps need equivalent or slightly more energy to refine to the same freeness level.

With regards to the physical strength properties of the xylanase treated pulps no loss in physical streghth properties could be noticed. However, the tear index was improved to a level of 20-25% in the jute kraft bleached pulp when bleached with C/D EH bleach sequences.

4.4 Environmental Effect of Enzyme Treatment.

Effluent properties like AOX and color are likely ot be improved indirectly through the use of xylase treatment which promoted lignin removal and allow lower amount of chlorine containing chemicals during bleaching.

5.0 Important considerations during mill scale trials on enzymatic pre bleaching of jute kraft pulp

Based on the present studies, it has been observed that the key factor influencing the success of mill scale trial on enzymatic prebleaching are:

5.1 Selection of appropriate enzyme

Based on exhaustive studies carried out on enzymatic prebleaching of pulps, it has been observed that efficiency of the xylanase enzymes available commercially and/or developed differ greatly depending upon molecular size, overall structure, the number & identity of amino acids and the structure of the active sites. These characteristics influence the ability of the enzyme to penetrate into the pulp & the nature of the action against the pulp. Thus it would be desirable to evaluate and identify an appropriate xylanase enzyme having optimum efficiency levels under the condition prevalent in the mill in respect:

Temperature, PH & Retention time

5.2 Efficient dispersion of enzyme with pulp

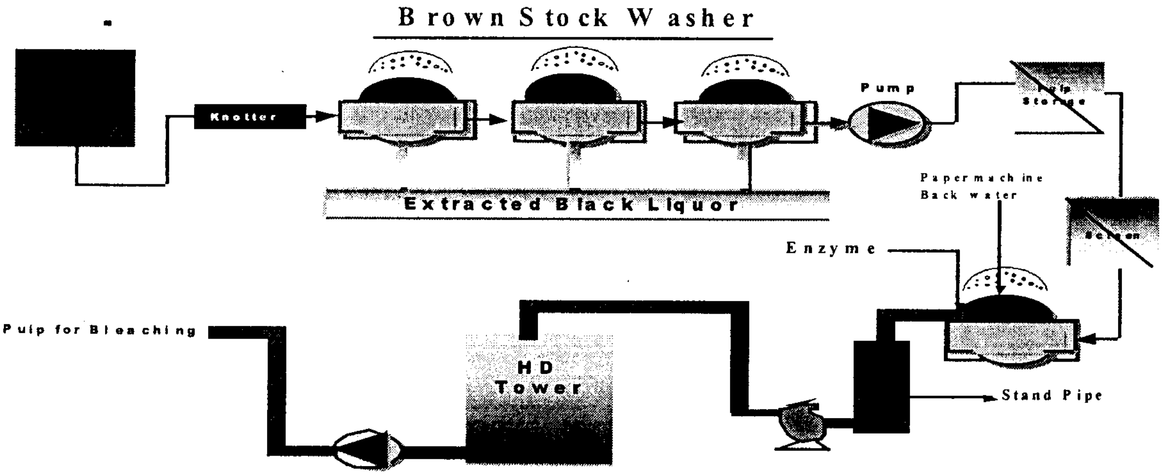
Installation of an MC pump and proper dilution of the enzyme & the pulp to desired consistency with paper machine back water could facilitate the proper mixing & dispersion of enzyme with pulp and desired pH levels. Further, attention is required to be paid to locate the preferred application point for the enzyme dosing.

5.3 Driving force for enzyme usage

It is important to decide the driving force or the usage of xylanase enzyme whether it is higher brightens level of bleached pulp, environmental factor ie reduction in the requirement of chlorine chemicals vis a vis AOX reduction.

Schematic of the proposed plant for enzymatic prebleacing of jute kraft pulp is shown in figure - 2

FIGURE - 2



Proposed Plant for Enzymatic Prebleaching of Pulp trial in identified Pulp and Paper Mill

6. CONCLUSION

i. Xylanse prebleacing of whole jute kraft pulp employing these enzymes could prove to be effective in improving the brightness of pulps to a level of 3-4% ISO without the loss in physical strength properties.

ii. Before introducing enzyme prebleaching technology in any mill it is important to evaluate a particular enzyme preparation for its response towards pulp for various parameters like temp., pH, enzyme activity and cellulose contamination.

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Table -1 Enzyme Pretreatment Conditions

S.No	Particulars	Control	Pulp treated with Enzyme A	Control	Pulp treated with Enzyme - B
1.	pH	6.5	6.5	8.4	8.4
2.	Enzyme dose, % / IU/g OD	-	2.0 IU	-	0.07 %
3.	Treatment time , (hrs)	2.0	2.0	2.0	2.0
4.	Temperature, ° C	50	50	50	50
5.	Consistency of the pulp, %	10	10	10	10
	Unbleached pulp Characteristics after enzyme treatment				
6.	Yield , %	98.9	98.2	98.2	98.1
7.	Kappa Number	19.4	19.3	19.8	19.1

Table - 2 Effect of xylanase Treatment on jute pulp Bleached with CEH Sequence

S.No.	Particulars	pH 6.5		pH 8.4	
		Control	Treated pulp Enzyme A	Control	Treated Pulp Enzyme B
	Chlorination stage (Kappa factor – 0.22)				
1.	Cl_2, % applied	4.27	4.25	4.36	4.2
	Alkali Extraction (Ep) stage				
2.	NaOH, % applied	2.0	2.0	2.0	2.0
3.	Kappa number	3.5	3.3	3.2	3.5
	Hypo stage – H				
4.	Hypo, % applied	1.5	1.5	1.5	1.5
5.	Final brightness of the pulp, % ISO	80.2	83.83	79.4	82.0
6.	Brightness improvement	-	3.6	-	2.6

Table : 3 Effect of xylanase Treatment on jute pulp Bleached With CE(p)H Sequence

S.No.	Particulars	pH 6.5		pH 8.4	
		Control	Enzyme A treated pulp	Control	Enzyme B treated pulp
	Chlorination stage (Kappa factor - 0.22)				
1.	Cl_2, % applied	4.27	4.25	4.36	4.21
	Alkali Extraction (Ep) stage				
2.	NaOH, % applied	2.0	2.0	2.0	2.0
3.	Peroxide, %	0.5	0.5	0.5	0.5
4.	Kappa number	2.7	2.5	2.7	2.2
	Hypo stage - H				
5.	Hypo, % applied	1.5	1.5	1.5	1.5
6.	Final brightness of the pulp, % ISO	82.1	82.1	78.2	81.5
7.	Brightness improvement	-	-	-	3.3

Table : 4 Effect of xylanase Treatment on jute pulp Bleached with C50/D50EH

Sl.	Particulars	pH 6.5		pH 8.4	
		Control	Enzyme A treated pulp	Control	Enzyme B treated pulp
	Chlorination stage (Kappa factor - 0.22)				
1	Total chlorine, % as available Cl_2	4.27	4.25	4.36	4.21
2	Cl_2, % applied	2.14	2.13	2.18	2.10
3	Dioxide % as chlorine	2.14	2.13	2.18	2.10
	Alkali Extraction (Ep) stage				
4	NaOH, % applied	2.0	2.0	2.0	2.0
5	Kappa number	5.6	5.1	5.03	4.5
	Hypo stage - H				
6	Hypo, % applied	1.5	1.5	1.5	1.5
7	Final brightness of the pulp, % ISO	81.2	83.4	80.4	84.4
8	Brightness improvement	-	2.2	-	4.0

Table : 5 Effect of xylanase Treatment on jute pulp Bleached With C50/D50E(p)H

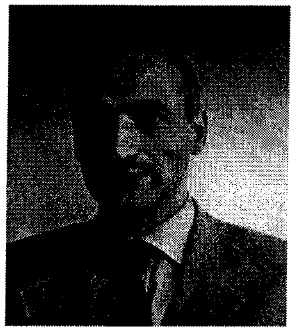
S.No.	Particulars	pH 6.5		pH 8.4	
		Control	Enzyme A treated pulp	Control	EnzymeB treated pulp
1.	Chlorination stage (Kappa factor - 0.22)				
2.	Total chlorine, % as available Cl_2	4.27	4.25	4.36	4.21
3.	Cl_2, % as available chlorine	2.14	2.13	2.18	2.10
4.	Dioxide % as chlorine	2.14	2.13	2.18	2.10
	Alkali Extraction (p) stage				
5.	NaOH, % applied	2.0	2.0	2.0	2.0
6.	Peroxide, %	0.5	0.5	0.5	0.5
7.	Kappa number	4.4	3.4	4.2	3.7
	Hypo stage - H				
8.	Hypo, % applied	1.5	1.5	1.5	1.5
9.	Final brightness of pulp, % ISO	82.4	85.5	82.4	86.7
10.	Brightness improvement	--	3.1	-	4.3

Table 6 Physical strength properties of C/DEH, bleached pulp of pilot plant trial (after enzyme treatment)

	PFI (rev)	Freeness ml,CSF	Apparent Density g/ cm^3	Burst Index $KPam^2/g$	Tensile Index Nm/g	Tear Index mNm^2/g	Fold Kohler Molin(log)	Porosity Bendtsen (ml/min.)
C1	0	345	0.70	3.10	51.5	5.00	1.70	149
	1000	235	0.76	4.20	71.0	4.30	1.90	45.8
C2	0	370	0.70	3.30	55.5	6.80	2.11	158
	1000	280	0.75	4.60	72.0	5.70	2.32	51.1
E1	0	360	0.72	3.80	58.	6.10	2.09	129
	1000	230	0.77	4.90	77.0	5.30	2.39	38.4
E3	0	395	0.67	3.10	46.0	6.90	1.71	278
	1000	270	0.68	4.20	61.0	5.60	1.98	102

C1-Control at pH 8.0 ; C2-Control at pH 6.5 ; E1-Enzyme A treated pulp ; E3-Enzyme B treated pulp

High-Yield Pulps From Whole Jute For Utilisation In Wood Containing Papers



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1987 Graduated at Agricultural University Wageningen, the Netherlands.
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1994 Research associate at the University of British Columbia, Vancouver, Canada within the Paprican building on pulping and (bio)bleaching of softwood species.
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He has been involved in biomass research for the last 15 years, and has authored and co-authored more than 40 papers in international journals and is the inventor of 3 patents relating biomass transformation. He has been awarded the Shell studiereisprijs in 1993 and is currently Editor in Chief of the Elsevier Journal Industrial Crops and Products. He is president of the International Lignin Institute (ILI). His main area's of expertise are (bio-)chemical pretreatment of lignocellulose, enzymatic conversion of cellulose and fibre and lignin applications (paper, fibreboards, lignin based adhesives, colourants, UV-stabilizers, bioethanol etc).

High-Yield Pulps From Whole Jute For Utilisation In Wood Containing Papers

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R.G.M. Op den Kamp, Dr. H.C.P.M. van der Valk and Dr. E. de Jong

SUMMARY

AIMS

The objectives of the tasks of Agrotechnology & Food Innovation (formerly ATO) in the project are:

- to determine at laboratory level the best conditions for producing high-yield pulps from whole jute for utilisation in wood containing papers,
- to test the potential of using recommended enzyme recipes in both extruder and refiner processes in terms of pulp quality, chemicals and energy consumption, brightness and production cost,
- to evaluate the potential of a micro-biological pre-treatment of green jute with selected strains of fungi,
- to establish process conditions for pilot confirmatory trials

RESULTS

Refiner versus extruder-pulping

During the first year of the project two methods of pulping sun-dried jute (refining and extruding) have been investigated. Obviously, processing jute pulp with a refiner was more efficient than using extruder technology. This is expressed in the mutual differences in the total power consumption. For the applied material, both root and bark fibres, the milling performance in the refiner is better than in the extruder. This also gives better mechanical and structural performances of the jute pulp and paper. However, extruder-pulping resulted in improved bleaching efficiency compared with refiner-pulping due to the continuous and more homogeneous mixing of the bleaching agent (ATO Progress Report 1). During the second and third year it appeared that alkaline peroxide mechanical pulping (APMP) is the method of choice to produce high brightness, high strength mechanical pulps suitable for newsprint production.

Enzymatic treatments

In the second year the attention was focused on enzymatic and microbiological treatments of the extruded and refined pulps. Extruded/refined pulp (XRP), treated with the recommended laccase recipe, showed an increased brightness of 2 to 3 points, corresponding with up to 1% less hydrogen peroxide addition. Strength properties were not impaired.

With the suggested xylanase recipe the brightness of green jute paper, made from Alkaline Peroxide Extruded Pulp (APXP), was also increased by 1 ISO%, replacing 1 to 2 % of hydrogen peroxide in post bleaching. However, the treatment causes significant losses of fines. This decreases the beating degree but impairs strength properties. This problem has to be solved by e.g. treating the jute in a more coarse stage.

It has been shown that enzymes may be of help in improving the brightness when making paper from green jute chips (ATO Progress Report 2).

Microbiological pre-treatments of APMP

In a further study simulated Alkaline Peroxide Mechanical Pulps (APMP) were produced in a PFI mill and pre-treated with the fungus *Fomus lignosus*. Initially, no statistically significant differences between treated and untreated pulp were found.

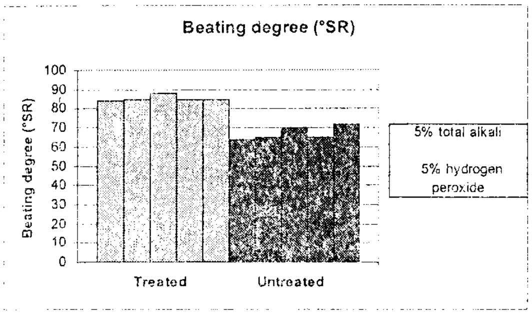
Because of the great number of different processing steps that are needed to produce a sheet of paper of jute, the variability is high. The steps include size reduction, pre-treatment, washing, bleaching, beating and making of the paper. Particularly the size reduction is an important step in this procedure. If particles are too large in size, the fungal pre-treatment and the bleaching can be hampered. Besides, long bast fibres tend to form flocs that create extra variation in the ratio of core and bast fibre. It is expected that this last point is not a problem if the process is eventually carried out at industrial scale.

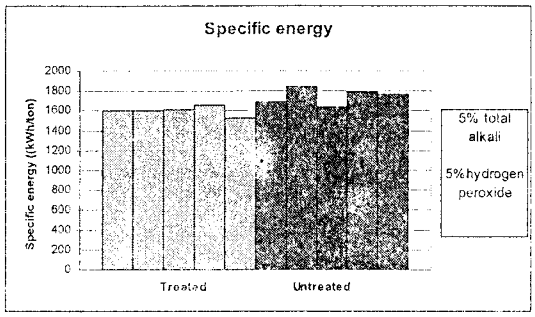
For the small-scale experiments a more homogeneous size distribution and a further reduction to smaller pieces would be beneficial. This was done in extra studies. After the size reduction, a pre-refining step was added to the procedure. This step resulted in a more homogeneous material and an easier running of the PFI-mill. In this test a clear difference between treated and untreated pulps evolved. The APMP-process consumes about 25% less energy and results in better paper properties than the RMP process, whereas the fungal treatment saves at least an extra 5% on top of this. This may increase even further to 20% with optimised beating times.

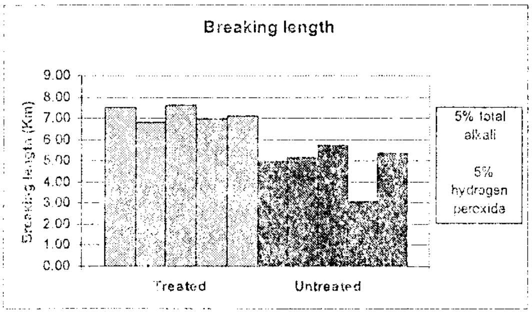
In both types of simulated APMP studies there were no differences in the brightness of the treated and untreated pulps. Probably, the small brightening effect of *F. lignosus* is overshadowed by the brightening effect of the peroxide treatment. The average brightness after pre-refining was 63.2 ISO %, which is 2.7 % higher than in the first APMP test. Apparently, the extra size reduction in the pre-refining in combination with a higher consistency during bleaching was beneficial.

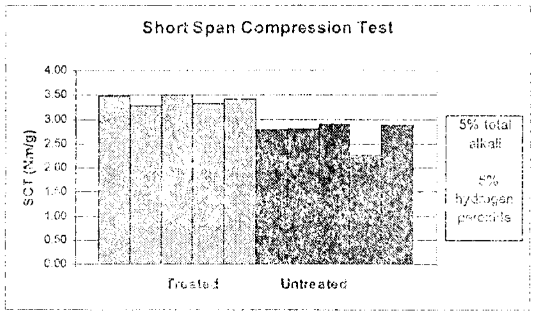
In the last APMP test, the fungal treatment raised the weight loss from 16 to 21 %. The extra 5% weight loss is low compared with the extra weight loss that fungal treatment caused in the RMP experiments. This means that the main part (60%) of the losses caused by the fungal treatment in RMP process occurs in an APMP process anyway.

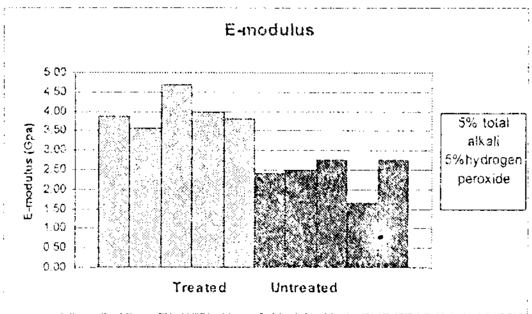
Appendix 9: Graphic presentations of the test results of the second experiment of APMP simulated PFI-mill

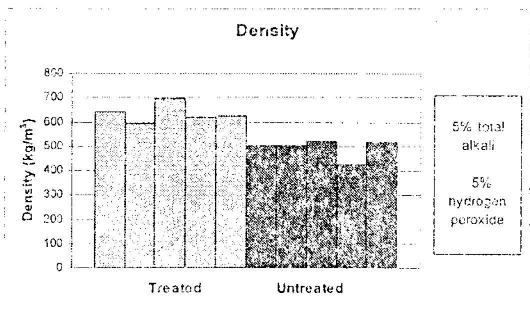


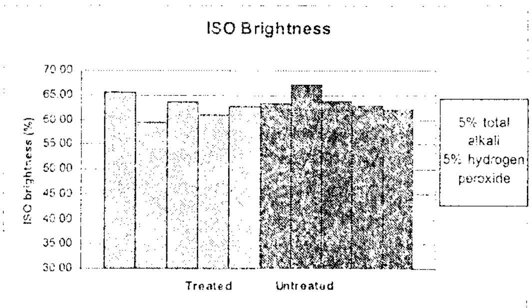












Contrary to RMP pulps the strength properties and brightness were raised by the alkali peroxide process to a level that makes it possible to use this pulp for the production of newsprint. The brightness was increased from below 40 ISO % to well above 60 ISO %.

After the laboratory scale experiments with the PFI mill, APMP tests were carried out on a larger scale with a 12" pressurised refiner system. In these tests an average yield after bleaching, refining and washing of 79% was obtained, which is comparable with the described laboratory experiments and about 6% lower than for e.g. an aspen CTMP pulp. The produced pulps had brightnesses of around 63% and the breaking length was around 4 km (Table 1). This brightness exceeds the brightness of the initial extruder-pulp significantly. It makes the pulps suitable for use in newsprint. The specific energy needed to produce these pulps was around 500 kWh/ton, which is only 25% of the production of a TMP pulp for newsprint from wood.

The first attempt to test the fungal pre-treatment in a pilot scale trial resulted in substantial problems with inhomogeneous fungal growth in the incubation vessels. Black liquor analyses as planned for these trials could therefore not be executed. The research on large-scale fungal treatments needs more attention than originally expected. However, such solid state studies were not part of the project and within the allocated budget (ATO Progress Report 3).

Table 1: Handsheet properties of APMP pulps made on a 12"inch refiner

	Run 1 1st stage	Run 1 2nd stage	Run 1 2nd stage	Run 1 2nd stage	Run 2 1st stage	Run 2 2nd stage	Run 2 2nd stage	Run 2 2nd stage
Drainability (° SR)	18	29	60	48	20	46	52	47
Grammage (g/m2)	76.8	76.4	75.4	78.8	83.9	80.9	79.7	82.4
Density (kg/m3)	320	361	428	387	337	404	427	424
Strength properties								
Breaking length (km)	2.05	2.87	3.69	3.18	2.22	3.64	3.99	3.85
Tensile index (Nm/g)	20.1	28.2	36.1	31.2	21.8	35.7	39.1	37.7
T.E.A.-index (Nm/g)	128	262	322	290	145	360	408	380
E-modulus (Gpa)	0.9	1.5	2.1	1.7	1.3	2.0	2.2	2.1
Strain (%)	1.0	1.4	1.4	1.4	1.0	1.5	1.6	1.5
Tearing resistance	4.7	5.5	3.8	4.4	6.0	6.0	5.4	5.6
SCT (Nm/g)	1.7	2.0	2.5	2.2	1.9	2.3	2.5	2.5
Optical properties								
ISO brightness (%)	62.5	63.7	64.1	64.3	61.4	62.6	63.1	63.3
Yellowness (%)	25.1	23.5	22.7	22.7	26.0	24.8	24.8	24.8
Opacity (%)	92.9	94.3	94.5	95.3	94.7	95.7	95.0	95.3
Scattering coefficient (m2/kg)	45.5	51.3	52.9	54.9	46.7	53.9	52.5	52.4
Absorption (m2/kg)	1.6	1.7	1.8	1.8	1.7	1.9	1.7	1.7

CONCLUSIONS

- Refiner-pulping of jute is superior to extruder-pulping regarding energy consumption and mechanical and structural performance of pulp and paper.
- Alkaline Peroxide Mechanical Pulping (APMP) process results in better paper quality and has a lower energy demand than the RMP process.
- APMP pulp from green jute can be produced with only 25% of the energy needed to produce a TMP pulp for newsprint from wood.
- Enzymatic pre-treatment, as performed with the pre-described procedures, slightly improves the brightness of RMP jute paper.
- The strength properties of RMP derived jute paper are too low to make newsprint.
- APMP pulps from green jute are suitable for the production of newsprint
- When producing RMP at lab-scale, a pre-treatment with *F. lignosus* results in lower specific energy and a 1 to 2 ISO % higher brightness.
- When producing APMP at lab-scale, a pre-treatment with *F. lignosus* results in a further decrease of specific energy, but not in a higher brightness.
- Further size reduction by means of a pre-refining step results in better reproducible fungal pre-treatment experiments and probably a more efficient bleaching step
- The main part of the losses caused by the fungal treatment in an APMP process occurs anyway in an alkaline bleaching step.
- The yield of the APMP from green jute after fungal pre-treatment, bleaching and washing is about 79%, being 5% lower than APMP that is not treated with fungi.
- Scaling-up of the fungal treatments faces specific solid-state fermentation obstacles that need to be investigated in more detail before industrial implementation is feasible.

EXPERIMENTAL PROCEDURES

Extruding, refining and bleaching

Raw materials

The Project Leader provided sun-dried jute sticks from the whole stem, harvest Bangladesh 2000. The sticks had an average length of 50 cm. To reduce length, they were processed by a standard woodchipper first. Next, the material was chopped to a length of 6.25 mm by means of a guillotine chopper.

Pre-treatment

The fibres were impregnated with 0.1 M sodium hydroxide with a 1:10 dry fibre: water ratio corresponding to 4% dissolved NaOH on dry matter fibre. The chelating agent DTPA was added at 0.1% on dry fibre weight. The impregnation was done overnight (16 hours) at room temperature.

Before extruder pulping, the liquid was allowed to drain after the impregnation through a perforated screen for 30 minutes. After draining the impregnated fibres were preheated with saturated steam at atmospheric pressure. Before refiner pulping experiments, an additional press stage was necessary to remove unwanted liquid components from the drained pulp.

Extruding

The pulps were extruded in one pass at four to five stages, the bleaching chemicals were injected and mixed with the pulp at the end of the pass. A more detailed description of the used procedures extruding the fibres is given below.

The impregnated, preheated fibre was introduced manually into a modified Clextral BC45 extruder. The pulp mass output was recorded every 30 seconds together with the motor power, thus giving an almost continuously reading of the specific energy consumption of the pulp. Steam was injected into the extruder to supply additional heat to the pulp. At the end of the extruder the bleaching chemicals were injected. Due to the applied screw configuration the chemicals were more or less thoroughly mixed with the pulp.

For all trials the extruder was virtually divided in three successive sections. The first section consists of the inlet of the extruder, transport screws and a reverse screw element (RSE) to defibrate and cut the fibres. In this stage a press action was applied to remove unwanted liquid components from the drained pulp. Upstream of the RSE an outlet for the excess water is placed. The second section consists of a steam inlet, transport screws, an RSE and a filter. The filter is placed upstream from the RSE to remove excess water. The third section consists of transport screws, an inlet for the bleaching chemicals and an RSE or kneading elements to mix the chemicals with the pulp. At the end of the third section self-wiping screws transport the pulp to the outlet of the extruder. The screw configurations were -25H10, -15H8 and -15H12 respectively.

The codes used for the RSE elements are the pitch [mm] of the element, the orientation of the slots (helicoidal) and the slot width [mm]. The kneading element consists of 20 successive rings that are placed off centre on the screw axe. A positive flight as indicated by kneading is created by placing the rings on the axe at different angles. The positive flight significantly reduces the strain between the extruder barrel and the kneading elements.

Refining and bleaching

After the first refining stage all pulps were bleached batch-wise in one step. In all processes the same bleaching chemical composition was used. The chemicals for the bleaching are given below. Before bleaching the pulp was washed twice to remove unwanted liquid components.

Bleaching liquor for the bleaching step

Chemical	% on dry fibre
$MgSO_4$	0.1
DTPA	0.05
NaOH	1.4
Silicate	1.0
H_2O_2	2.1

For the regulation of the temperature during the bleaching the following set-up is used:

Bleaching in a closed vessel heated by direct contact with steam

The pulp is put in an open stainless steel vessel, closed with a wooden lid. From the bottom of the vessel, saturated steam is introduced, heating up the pulp in direct contact. Mixing is done both manually and by the motion created by the steam. The temperature of the pulp is about 70 °C. The temperature differences in the pulp are small. The bleaching is stopped with cold water after 1.5 hrs, reducing the reaction rate. The water is drained using a sieve.

Post-treatment

After bleaching the pulps were washed 3 times until pH 8 by adding water up to a consistency of about 5 %. The chemicals were allowed to migrate out of the pulp for some time and the water is drained. Finally the pulps were centrifuged to a dry matter content of about 30% and stored in a freezer.

Determination of the mechanical and optical properties

Hand sheets were formed using a standard sheet former and pressed twice at 4 bar for 5 minutes. The sheets were conditioned and tested at 23 °C with 50% RH. Mechanical and optical measurements were done using ISO standards. For several pulps the properties depending on beating degree were determined.

Enzymatic pre-treatment before hydrogen peroxide post-bleaching of Alkaline Peroxide Extruder Pulp (APXP)

Pulping

Green jute was treated in an extruder with bleaching chemicals as described in the quarter report 2002-1 (run 4 Table 2). The amount of energy used to prepare this still very course APXP pulp was about 180 kWh/ton. After the extrusion step the pulp was held for 1.5 hour in a warm water bath to complete the bleaching step.

Enzymatic treatment

Enzymatic treatment was carried out between the DTPA pre-treatment and the hydrogen peroxide bleaching. Green Jute APXP pulp was diluted to 1.7% and disintegrated in a phosphate buffer of 25 mM and pH 7.0. Pulp was heated with electric cooking plates, under constantly stirring, till 50°C. As soon as this temperature was reached, the enzymes were added. The temperature and stirring speed were kept constant. Xylanase (Pulpzyme HC) was used in concentrations of 1, 5, 25 and 50 units/g and laccase (Novozyme 51003) was used at 100 units/g.

After enzymatic treatment the pulp was drained and pressed to a consistency of about 50% before bleaching chemicals were added.

Post bleaching with Hydrogen Peroxide

The APXP pulp was pre-treated with 0.6% DTPA during 1 hour at a temperature of 70 °C. After this pre-treatment the pulp was drained and pressed to a consistency of about 40%

Peroxide bleaching was performed in plastic bags during 90 minutes at a temperature of 70 °C and a consistency of 20%. The addition of 0.2% $MgSO_4.7H_2O$ and 7% Sodium silicate of 39° Bé (S.G. 1.37 kg/l) was the same in each bleaching experiment. The peroxide concentration was varied between 1 and 4% and the total alkali concentration was varied between 0.5 and 2%.

Sodium silicate and magnesium sulphate concentrations were high to be sure that maximum brightness is achieved under the chosen hydrogen peroxide and alkali conditions, optimisation of these chemicals has to be done in the industrial situation.

The enzymatic treated pulps were bleached at a total alkaline and hydrogen peroxide concentrations of 1%. After bleaching the pH of the bleach liquor was measured and a qualitative test on hydrogen peroxide was carried out. The pulp was acidified to a pH of 5 to 5.5.

Hand sheet properties : After bleaching the pulp was disintegrated and hand sheets of 160 g/m2 were made on a Rapid-Köthe sheet former. The production, conditioning, brightness measurements and strength property measurements of these hand sheets were carried out according to ISO standards.

Microbiological pre-treatment before simulated refiner alkaline peroxide mechanical pulp (APMP) of green jute

Pre-treatment : Green jute was chopped in smaller pieces and subsequently treated with *F. lignosus* as described before, brightened with a hydrogen peroxide bleaching and beaten in a PFI mill. After beating the pulp was analysed and hand sheets were made for evaluation.

The size reduction and microbiological treatment was carried out as described in the RMP simulation experiment with an incubation time of 13 days.

In the second set of experiments the shortening and the microbiological pre-treatment were as described before, but a coarse refining step in a 12" refiner was added to the procedure to create more uniform dimensions of the shortened jute and a more homogeneous mixture of jute bast and core fibre. In this refining step 100 kWh/ton was used.

Brightening

After the fungal pre-treatment the jute was soaked in water at a dry matter content of 5%. Soaking was done during 10 minutes with stirring by hand every 5 minutes. The surplus of water was drained off. The jute was then treated with 0.6% DTPA during 1 hour at 60 °C and 5% consistency. After the DTPA and washing treatment the yield was determined.

The green jute was then bleached with 5% hydrogen peroxide and 5% total alkali in combination with 0.2% Magnesium sulphate and 7% sodium silicate. This bleaching was carried out at 70 °C at 14% consistency during 90 minutes. After bleaching the pulp was diluted to 5% consistency and the pH was corrected to 5-5.5.

To be sure that bleaching would not be hampered, the DTPA and sodium silicate amounts were high. In trials on a more practical scale these amounts can be reduced to a lower and more economic level.

Beating

After the bleaching step the green jute was beaten in a PFI mill

Four samples of the treated and washed jute were beaten in a PFI mill at 10% consistency during 500 revolutions with a gap of 2 mm and 500 revolutions with a gap of 1 mm. After these two stages the jute was beaten with a gap of 0 mm and the standard pressure of 3.33 N/mm bar length (66.6 N/cm^2) during respectively 6000, 9000, 10500, 12000 and 15000 revolutions. In this way a beating curve of the pulp was made. The beating procedure is a lab scale simulation of the refiner mechanical pulping process (RMP). The energy needed in the stage with a zero gap was measured. The beating degree was limited to about 70 °SR because higher beating degrees would have no practical meaning. After disintegration during 10.000 revolutions in a standard disintegrator, the beating degree (°SR) of the beaten pulp was measured.

Evaluation of hand sheets : After disintegration hand sheets were made with a Rapid-Köthen sheet former. The hand sheets were tested for grammage, thickness, bulk or density, breaking length, strain, short span compression strength (SCT) and brightness at 50% relative humidity (RH) and 23 °C. Beating, hand sheets making and testing were all performed according to the ISO-standards.

Production of APMP pulps on a 12"inch refiner

Material and methods : The material used was from the first received batch of green jute. The jute was chipped in a wood chipper and subsequently cut in a cutting mill (Pallmann) equipped with a sieve of 15 x 15 mm. These particles are further reduced in size by a pressing step as described below. In the laboratory experiments this further reduction in size was found beneficial for the bleaching step.

Pre-treatment :

The jute was soaked in hot water of 70 °C for half an hour. After soaking the surplus of water was drained. This soaking treatment was repeated once and subsequently the jute was soaked with water of 70 °C and 0.6 % of DTPA on dry matter for one night (about 16 hours) in an isolated vessel and drained again. After draining the jute was pressed in the Multiple screw device (MSD) of the refiner to a dry matter content of about 50 %. The jute was further reduced in size by this pressing action. This will also happen when production is on an industrial scale, in that case chips are always fed to a refiner with this kind of equipment.

Bleaching and first stage refining

The chemicals were added and mixed before refining. On dry mass 0.2% of $MgSO_4.7H_2O$, 7% of Sodium silicate solution of 38 Bé (s.g.(1.37) , 5% total alkali and 5% of H_2O_2 was added. The chemicals were added after solution in warm water and mixed by hand and in a ribbon mixer for one minute. The consistency was 20%.

The jute was then added to the pre-heated storage bin of the refiner and steamed at atmospheric pressure for 10 minutes. Refining was carried out with refiner plates of type D2A505 NH and at a plate gap of 0.2 mm. The refining temperature was 128 and 131 °C and the average residence time at this temperature was 14 minutes. After refining the pulp was held in an isolated vessel for another hour at 70°C.

Washing

The bleached and refined pulp was washed three times with cold water at a consistency of about 7% in the above-mentioned vessel. After diluting to this consistency with cold water, the pulp was stirred by hand and after a residence time of 15 minutes the diluted pulp was drained. This procedure was repeated three times. The pulp was then squeezed to a consistency of about 15%.

Atmospheric refining

A second stage of refining of the pulp was applied under atmospheric conditions. The applied plate distance was 0.15, 0.1 and 0.75 mm. The refining temperature varied between 37 and 55 °C and the consistency was between 2.5 and 3%.

Making of hand sheets

60 grams of pulp was disintegrated during 10,000 revolutions. For latency release the pulp was first disintegrated in hot water during 5000 revolutions. After 45 minutes of residence time another 5000 revolutions of disintegration were carried out. Hand sheets were made of the first and second stage pulps.

Black Liquor Management In Jute Pulping

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Black Liquor Management In Jute Pulping

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BACKGROUND

Spent liquor obtained after pulping of the raw material is a complex colloidal system. Spent liquor is comprised of dissolved and colloidal organic residues and inorganic components[1]. The organic residues mainly contain lignin and carbohydrate degradation products and main inorganic components are sodium hydroxide, sodium carbonate and organically bound sodium. Wide variations in chemical composition of spent liquors are observed and the ultimate composition would depend on the type of fibrous raw material processed, conditions applied during cooking (chemical charge, cooking temperature, time etc.) and the type of pulping process employed. Evaluation of chemical composition of spent liquor is a primary step both for understanding the characteristics of black liquor as well as from the viewpoint of design of equipment for the chemical recovery operation. Important analysis are total solids, residual active alkali (RAA), total alkali, elemental composition(C,H,N,O,Na) and ratio of organic to inorganic matter, Rheological and thermal properties[2]. Each of these tests has its own significance and estimation of each of this component will throw light on the quality of spent liquor. Treatment options for black liquor are very much dependent on quality of black liquor.

2. EXPERIMENTAL

2.1. Pulping of Jute for Generation of Black Liquor

The chemical composition of spent liquor is invariably influenced by the type of raw material processed, conditions employed during pulping and quality of resultant pulps desired. Different raw materials require different cooking conditions like chemical concentration, cooking temperature etc.

In order to obtain a representative black liquor quality as envisaged under the mill conditions, jute Kraft black liquor was generated under the specified pulping conditions after taking in to consideration the washing of the pulp. Black liquors were generated by employing the Kraft and soda AQ processes. Pulping conditions employed were as under.

Table –1 Pulping Conditions Employed During Kraft & Soda AQ Pulping

S.No	Particulars	Value	
		Kraft	Soda AQ
1.	Raw material	Whole jute	Whole Jute
2.	Chemical charges on raw material basis, % as Na_2O	16.0	16.0
3.	Sulphidity on raw material basis, %	20	nil
4.	AQ on raw material basis, %	nil	0.05
5.	Bath Ratio	1:4	1:4
6.	Time at top temperature, minutes	90	90
7.	Top temperature, °C	165	165

2.2 Physico-Chemical Characterization of Black Liquor

Physico-Chemical characterization of black liquor was carried out with respect to following parameters.

pH at 25°C

Total Solids, %

Suspended Solids, g/l

Residual active alkali, g/l as NaOH

Total Alkali, g/l as NaOH

Inorganic, % w/w as NaOH (Sulphated ash)

Organics, % w/w (by difference)

Lignin, % w/w

The above parameters were analysed using standard testing method as published by TAPPI, SCAN, and CPPRI.

2.3 Elemental Analysis

Elemental analysis was carried using Flame Emission Spectrophotometer and Atomic Absorption Spectrophotometer.

2.4 Thermal Properties

Theermal property like Calorific value and Swelling Volume ratio are the important properties of black liquor which determines its burning behavior in the recovery furnace. Calorific value was determined by bomb calorimeter while SVR was determined by using CPPRI standard testing manual method.

2.5 Rheological Properties

Viscosity of black liquor is an important parameter for its processing in evaporator. Viscosity was determined by using HAAKE Rotaitional viscometer.

3.0 RESULTS & DISCUSSION

3.1 Physico-Chemical Characterization of Black Liquor

Results obtained are depicted in table 2 & 3.

Table 2 Physico Chemical Properties of kraft black liquor

Particulars	Value
Physico Chemical Properties:	
pH at 25°C	11.7
Total Solids, %	12.56
Suspended Solids, g/l	0.471
Residual active alkali, g/l as NaOH	1.55
Total Alkali, g/l as NaOH	35.6
Inorganic, % w/w as NaOH (Sulphated ash)	31.18
Organics, % w/w (by difference)	68.82
Lignin, % w/w	37.0

Table 3 Physico Chemical Properties of Soda black liquor

Particulars	Value
Physico Chemical Properties:	
pH at 250C	12.35
Total Solids, % w/w	10.9
Suspended solids, g/l	0.38
Residual active alkali, g/l as Na2O	2.79
Total Alkali, g/l as NaOH	34.4
Inorganics, % w/w as NaOH (Sulphated ash)	33.69
Lignin, % w/w	45.45

The results obtained from physico-chemical analysis are discussed below.

pH: pH values around 12 is quite optimum for recovery point of view. However a little increase in pH value will further improve the stability of black liquor during evaporation.

Total Solids:

From the viewpoint of non-wood black liquor, a solid level of 12.6 in case of kraft cooking is satisfactory for processing of this black liquor in evaporators. Solid level is low (10.9%) in case of soda black liquor. However this is much higher as compared to other non-wood based mill based on bagasse and straws. Further improvement in solid level is possible with modern coking and washing technologies like double belt washer.

Suspended Solids: The Suspended Solid level can be further reduced by installing a melone filter while actually processing the black liquor at mill site.

Residual Active Alkali:

RAA level is on the lower side, however while studying the rheological behaviour of the jute kraft black liquor, the liquor was found to be quite stable. It is still recommended to maintain an active alkali level of at least 3.0-4.0 g/l as Na_2O.

Organic / Inorganic Ratio: The inorganic content of nearly 31 -33 % is quite optimum for chemical recovery point of view.

3.2 Elemental Analysis of Black Liquor

Elemental analysis includes both process and non-process elements. Results obtained are listed in table 4.

Table 4 Process and Non-Process Elements in kraft 7 Soda Black liquor

S.No	Process & Non-Process Elements:	Value	
		Kraft	Soda AQ
1.	Carbon, % w/w as C	34.98	38.14
2.	Hydrogen, % w/w as H	4.25	3.97
3.	Nitrogen, % w/w as N	0.013	nil
4.	Sodium, % w/w as Na	14.3	18.0
5.	Sulphur, % w/w as S	2.40	0.50
6.	Inerts, % w/w as R_2O_3	0.32	0.14
7.	Silica, % w/w as SiO_2	0.80	0.01
8.	Chlorides, % w/w as Cl	0.83	0.87
9.	Potassium, % w/w as K	0.68	0.5
10.	Calcium, % w/w as Ca	0.35	0.39

The higher carbon, negligible nitrogen, lower silica indicate its suitability in various evaporation, recovery boiler and causticization cycles. However, looking in to the values of potassium and chlorides, it is suggested that precaution should be taken to reduce its entry in the chemical recovery system otherwise some problems of deposits will be encountered in recovery furnace.

3.3 Thermal & Rheological Properties

Thermal & Swelling Characteristics:

Thermal properties are important for understanding the behaviour of black liquor in recovery furnace[3]. These properties decide the burning behaiour of black liquor and quantum of steam generation from black liquor. Both Kraft and Soda black liquors were analysed for theral properties. The results are depicted in table 5.

Table 5 Thermal & Swelling Characteristics of Black Liquor

Parameter	Value	
	Kraft	Soda AQ
Swelling Volume Ratio, ml/g	15	29.5
Gross Calrofic Value, Kcals/kg	3299	3438

Results indicate that Soda black liquor shows better thermal properties. However SVR and calorific values are optimum for its processing in chemical recovery plant.

3.4 Rheological Properties

Viscosity of black liquor gives an idea about its procesing in evaporator section. Results of viscosity are given in the following tables.

Table 6 Viscosity of Kraft black Liquor

Viscosity, mPa.S at :						
Temp,	Total Solids Conc., % w/w					
	40	50	55	60	65	70
80 °C	7.1	25	52.5	141	447	1778
90 °C	5.6	20	40	100	282	1000
99 °C	4.46	16	32	71	178	631

Table 7 Viscosity of Soda black Liquor

Viscosity, mPa.S at:						
Temp,	**Total Solids Conc, % w/w**					
	40	50	55	60	65	70
90 °C	4.7	12.6	22	50	174	1072
98 °C	2.8	8.2	17.4	39	110	437
110 °C	2.0	3.5	6.5	31.6	83.2	331

Black liquor can be concentrated to a solids level of 70% without any liquor instability;, this shows that the liquor can be smoothly prcessed in chemical recovery plant. Viscosity values are higher in Kraft black liquor than in case of soda-AQ process.

It is therefore inferred that with steps of raw material cleaning, the jute black liquor obtained either by soda-AQ/kraft process is suitable for its processing in the chemical recovery section.

On comparative basis, the performance of chemical recovery is expected to be better in case of black liquor obtained by Soda-Aq process in comparison to kraft process.

4.0 Comparison of Jute Black Liquor Properties with Wood Black Liquor.

In order to obtain black liquor quality as realistic as under the mill conditions, jute black liquors using Soda-AQ and kraft process were generated under the specified pulping conditions after taking in to consideration the washings of the pulp. The black liquors obtained were studied for their suitability in the chemical recovery section. Table 8 & 9 shows the physico-chemical properties of the jute black liquor in comparison to black liquors from other conventional fibrous raw materials such as wood

Table 8 Physico-chemical properties of jute black liquor vis-à-vis wood black liquor

S.No.	Particulars	Wood[4] kraft black liquor	Jute Soda-AQ black liquor	Jute kraft liquor
	Physico Chemical Properties:			
1.	pH at Room Temperature, ^{o}C			
2.	Total Solids	15.89	10.89	12.56
3.	Suspended Solids, g/l	0.05	0.38	0.471
4.	Residual active alkali, g/l as Na_2O	8.0	2.79	1.55
5.	Total Alkali, g/l as NaOH	51.0	34.4	37.6
6.	Inorganics, % w/w as NaOH (Sulphated ash)	36.0	33.69	31.18
7.	Organics, % w/w (by difference)	64.0	66.31	68.82
8.	Lignin, % w/w	42.0	45.45	37.0
9.	Carbon, % w/w as C	36.8	38.14	34.98
10.	Hydrogen, % w/w as H	3.8	3.97	4.25
11.	Nitrogen, % w/w as N	0.084	nil	0.013
12.	Sodium, % w/w as Na	18.74	18.0	14.3
13.	Sulphur, % W/w as S	1.85	0.50	2.40
14.	Inerts as R_2O_3, % w/w	0.042	0.14	0.32
15.	Silica, % w/w as SiO_2	0.085	0.01	1.27
16.	Chlorides, % w/w as Cl	0.11	0.87	0.83
17.	Potassium, % w/w as K	0.38	0.5	0.68
18.	Calcium, % w/w as Ca	N.D.	0.39	0.35
19.	Swelling Volume Ratio, ml/g	25.0	29.5	15.0
20.	Gross Calorific Value, Cals/g	3160	3438	3299

Table 9 Viscosity of jute black liquor vis-à-vis wood black liquor

Total Solids, % w/w	Viscosity 90 ^{0}C, m.pa.sec.		
	Wood kraft black[5] liquor	Jute Soda-AQ black liquor	Jute kraft liquor
50	19.5	8.2	20
55	48	17.4	40
60	120	39	100
65	380	110	282

Observations on Processing Jute Black Liquor Vis-à-vis Wood Black Liquors (Conventional fibrous raw material):

The black liquor characteristics analyzed for studying its suitability in the recovery section are as follows:

Total Solids: From the viewpoint of processing of non- wood black liquors, solids level of ~11- 12% are quite satisfactory in the rotary tumbling digesters. However, further improvement in solids concentration would help in improving the steam economy in the train of evaporators.

Suspended Solids: The S.S. level can be further improved by installing a melone filter while actually processing the black liquor at mill site.

Residual Active Alkali: RAA level is on the lower side, while studying the rheological behaviour of the jute black liquor, the liquor was found to be quite stable. However, it is recommended to maintain an active alkali level of at least 2.0 g/l as Na_2O.

Organic /Inorganic Ratio: The inorganics content of nearly 31% is quite optimum, however, looking in to the wide variations in the total alkali level and Sulphated ash values, it seems quite prominent that inert material is noticeable in the fresh black liquor itself, which has not been recycled so far.

Process and Non- Process Elements: Compared to the Soda-AQ black liquor, the carbon values are on the lower side and other inerts such as silica and potassium are on the higher side, which indicates that greater caution is required in processing of jute kraft black liquor in comparison to soda-AQ liquor.

Thermal & Swelling Characteristics: Although, in comparison to soda - AQ black liquor, the thermal and swelling characteristics of kraft black liquor are on the inferior side, but still this liquor obtained can be easily processed in the chemical recovery section as efficiently as any other black liquor from the conventional raw materials.

Rheological Properties: Black liquor can be concentrated to a solids level of 70% without observing any liquor instability, but viscosity values are higher than in case of soda-AQ process.

Looking in to the black liquor characteristics, it seems quite feasible that jute black liquor either from a soda or a kraft pulping process is quite a suitable raw material for pulping.

On comparative basis, the performance of chemical recovery is expected to be better in case of black liquor obtained by Soda- AQ process in comparison to kraft process.

Expected Steam Generation:

Based the pulp yield, physico-chemical analysis of the various black liquors, thermal behaviour and results of Gross Calorific Value, the expected steam generation value could be around 5.0-5.25 on per tonne basis with chemical recovery efficiency of over 90%.

5.0 PRELIMINARY OPTIONS FOR BLACK LIQUOR MANAGEMENT - HANDLING OF JUTE BLACK LIQUOR

In absence of a chemical recovery system, mill are discharge valuable chemicals and at the same time the pollutional problems also getting aggravated. Today, with stringent legislations to pollution control, it is necessary for all mills to go either for installation of chemical recovery or treatment of effluents with heavily loaded organic and inorganic pollutants. The pollution load from a jute-based mill is expected to be around as follows.

Table 10 Pollution load from a jute based mill without treatment[6]

Sl. No.	Parameter	Activity 4.1.6 Pollution load, kg/tp
1.	Chemical Oxygen Demand, kg/tp	1700
2.	Biochemical Oxygen Demand, kg/tp	485
3.	Color	1900

Looking in to such high pollutants concentrations limits and comparing them with the laid down standards, it is quite clear that a suitable treatment option is necessary for effective handling and management of black liquors.

However, size of the pulp mill is one of the important criteria in deciding the subsequent handling system for the black liquor in a pulp mill. The two options available before the mill for black liquor management include:

6.0 VARIOUS BLACK LIQUOR MANAGEMENT PROSPECTS IN MILLS OF DIFFERENT SIZES

6.1 For Mill size- 30-50 TPD (Annual productuion 10500-17500 TPD)

A mill of 30-50 TPD size can look for soda, soda AQ pulping process with CEH bleaching sequence. However in this segment of the paper mill, the chemical recovery system is not economically viable. Such size of mill can therefore go for the high rate biomethanation system.

The environmental situation in these mills are better than in mills of $\leq$ 30 tpd capacity, but the pollution parameters such as those measured in terms of COD, SAR (Sodium absorption ratio) are higher than the proposed norms. The capital cost work out to be nearly 33% of the mill of size 150tpd, even in absence of chemical recovery.

The schematic of the mill of size 50 TPD is shown in fig 1. The capital investments required for putting up this size of the mill is as shown in table 11.

6.2 For Mill size- 50-100 TPD (Annual Production 17500- 35000 TPD)

This size of the mill is economically & environmentally compatible, however in this size of the mill, only soda, soda AQ pulping process & CEH bleaching stages can be followed. For this typical size of the mill, the conventional chemical recovery is not economically viable and therefore a fluidized bed type of chemical recovery is recommended.

In this type of chemical recovery system, the chemical in the form of soda ash is recovered. However, there is no cogeneration of electricity. The heat produced through flue gas by burning of the organic is used to concentrate the black liquor of 25% solid to around 42 %, which is then sprayed on the fluidised bed to regenerate the chemicals & produces heat. The investment in this type of the mill is lower than that of a higher sized mill equipped with conventional chemical recovery system, however, this type of recovery system can work on soda pulping process only.

However, since only conventional bleaching sequence can be followed in this of the mill, even the global market demand, which requires ECF or TCF bleaching sequence during brightening of the pulp can not be met in this segment of the mill. The schematic of the mill of size 50-100 TPD is shown in fig 2. The capital investments cost is shown in table 12.

6.3 For Mill size- 100-150 TPD (Annual productuion -35000 - 52500 TPD)

This size of mill has the advantage of adopting different pulping processes. The bleaching sequence incorporating enzymatic prebleaching and oxygen delignification can be followed. However for going towards TCF bleaching sequence, a mill size above 300 TPD is required.

The conventional type of chemical recovery system is recommended for this size of the paper mill with cogeneration facility unlike FBR type of recovery system, where there is no facility for cogeneration. Black liquor properties of Jute black liquor has also shown its suitability for conventional chemical recovery system.

The Schematic of the system is shown in fig 3. The capital investments cost is shown in Table 13.

Fig 1. Overview of pulping and papermaking process in a mill of 30 – 50 TPD

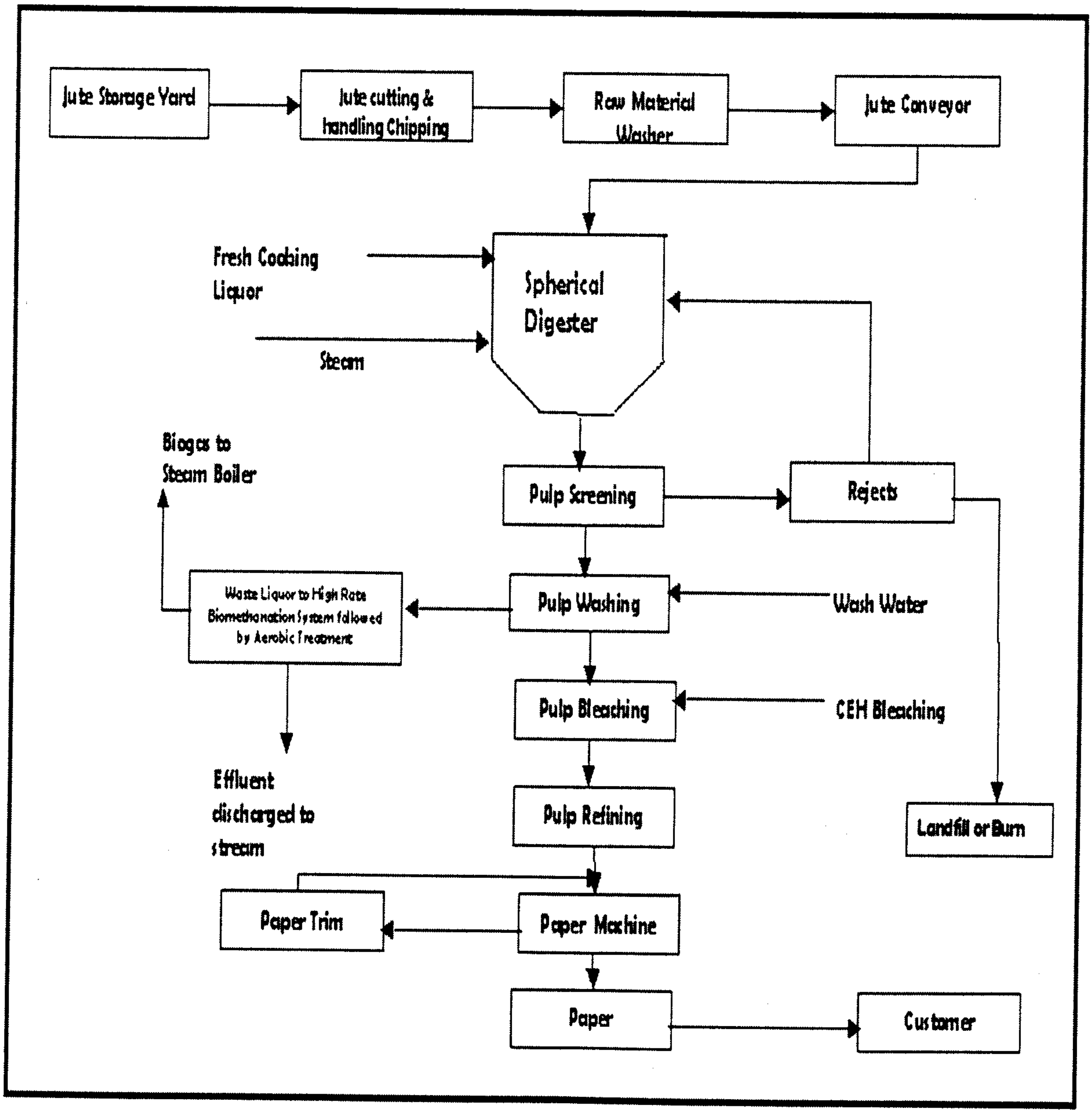

Table 11 Investment costs estimation for 30- 50 tpd with high rate biomethanation facility

Sl. No.	Department	Assumption for Estimate, Million US $	Estimated Investments, Million US $
1.	Main Equipment, ex Works Works • Cost for Fibre Line • Cost for High Rate Biomethanation • Cost for Chemical handling • Cost for steam & Power, Water, Ancillaries • Cost for Stock preparation & Paper making		7.74
2.0	Steel Structure	Approx. 4%	
3.0	Piping Interconnection	Approx. 8%	
4.0	Electric	Approx. 10%	
5.0	Instrumentation & DCS	App.15% of Equip. cost	
	Sub total (2-5)		2.84
6.0	Total Equipment Cost (1-5)		10.58
7.0	Engineering: Project Management.	Approx.10%	
8.0	Spare parts for two years, start up & commissioning	Approx.4.%	
9.0	Packing & ex Works to site	Approx.4%	
10.0	Training	Approx. 2%	
11.0	Erection	Approx. 8%	
12.0	Supervision of erection/ start up, commissioning	Approx. 4%	
13.0	Civil Works	Approx.12%	
14.0	Sub Total 7-13		4.7
15.0	Grand Total		15.28

Fig 2. Overview of pulping and papermaking process in a mill of 50 - 100 TPD

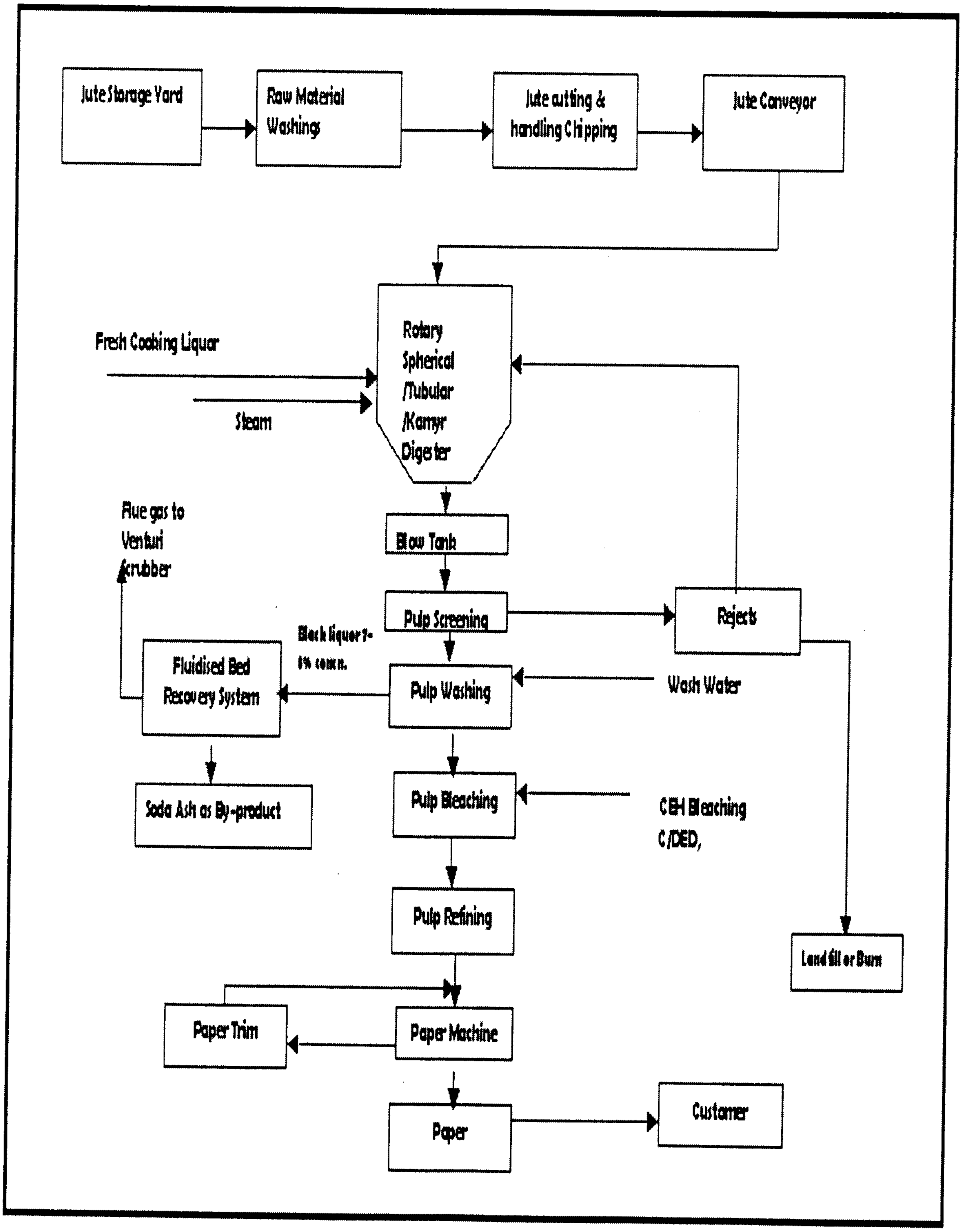

Table 12 Investments costs estimation for 100 tpd with fludized bed type of recovery facility

Sl. No.	Department	Assumption for Estimate MillionUS $	Estimated Investments Million US $
1.	Main Equipment, ex Works • Cost for Fibre Line • Cost for Recovery • Cost for chemical handling • Cost for Steam & Power, Water Ancillaries • Cost for Stock preparation & Papermaking		13.00
2.0	Steel Structure	Approx. 4%	
3.0	Piping Interconnection	Approx. 8%	
4.0	Electric	Approx. 10%	
5.0	Instrumentation & DCS	Aprox.15%of equip. cost	
	Sub total (2-5)		4.81
6.0	Total Equipment Cost (1-5)		17.81
7.0	Engineering: Project Management.	Approx.10%	
8.0	Spare parts for two years, start up & commissioning	Approx.4.%	
9.0	Packing & ex Works to site	Approx.4%	
10.0	Training	Approx. 2%	
11.0	Erection	Approx. 8%	
12.0	Supervision of erection/ start up, commissioning	Approx. 4%	
13.0	Civil Works	Approx.12%	
14.0	Sub Total 7-13		7.59
15.0	Grand Total		25.40

Fig 3. Overview of pulping and papermaking process in a mill of 100- 150 TPD

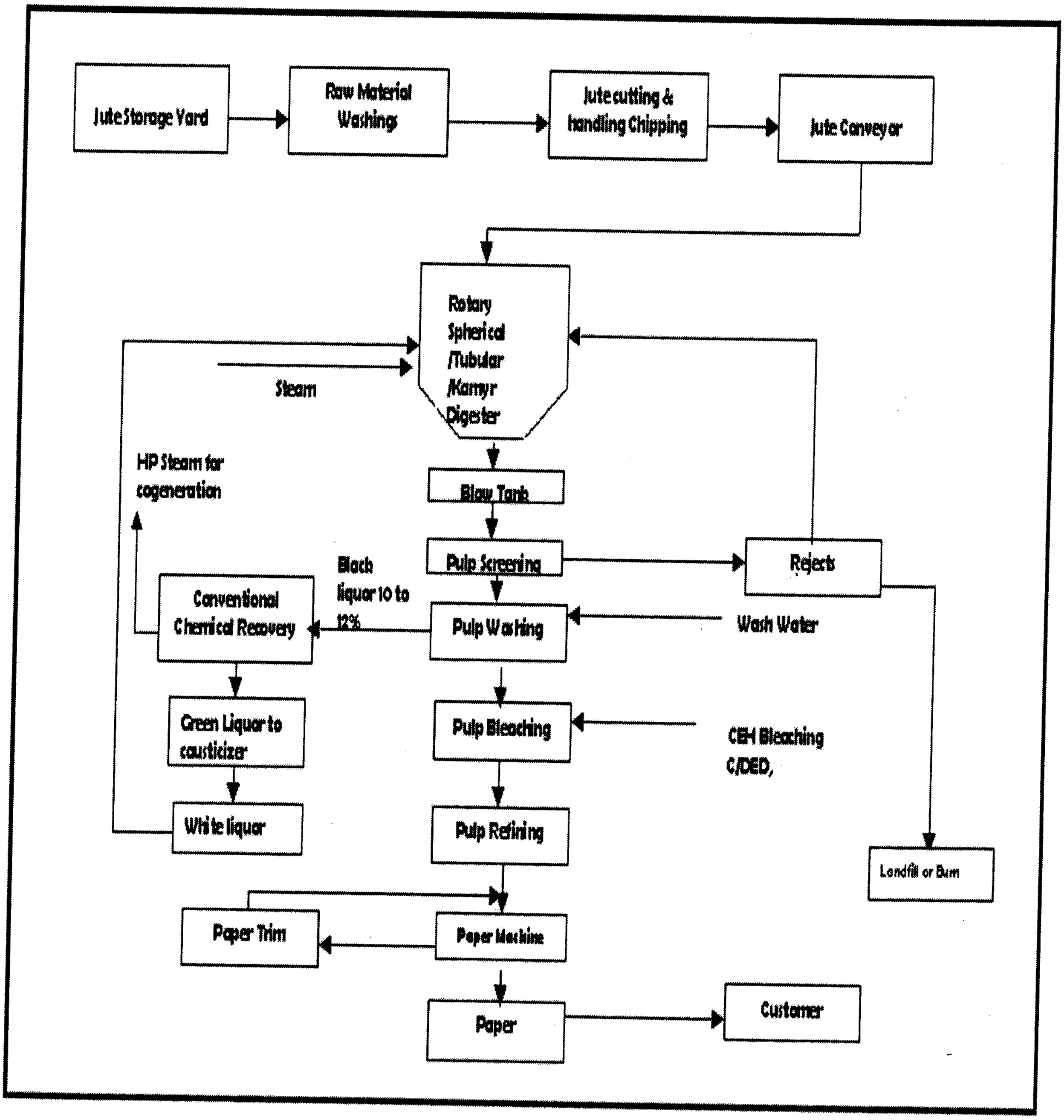

Table 13. Investments costs estimation: for 100 -150 tpd

Sl. No.	Department	Assumption for Estimate, Million US $	Estimated Investments, Million US $
1.	Main Equipment, ex Works Works • Cost for Fiber line • Cost for recovery • Cost for chemical handling • Cost for steam & Power, water Ancillaries • Cost for Stock preparation & Papermaking		16.50
2.0	Steel Structure	Approx. 4%	
3.0	Piping Interconnection	Approx. 8%	
4.0	Electric	Approx. 10%	
5.0	Instrumentation & DCS	App.15% of Equip. cost	
	Sub total (2-5)		6.32
6.0	Total Equipment Cost (1-5)		22.82
7.0	Engineering: Project Management.	Approx.10%	
8.0	Spare parts for two years, start up & commissioning	Approx.4.%	
9.0	Packing & ex Works to site	Approx.4%	
10.0	Training	Approx. 2%	
11.0	Erection	Approx. 8%	
12.0	Supervision of erection/ start up, commissioning	Approx. 4%	
13.0	Civil Works	Approx.12%	
14.0	Sub Total 7-13		10.18
15.0	Grand Total		33.00

7.0 CONCLUSION

i. Jute Kraft and Soda AQ black liquor have shown stability even at low RAA content (2.5 gpl). It is recommended that RAA be maintained ~3-3.5 gpl.

ii. Organic/inorganic ratio, SVR and calorific value of jute black liquor are comparable with wood black liquor. It shows better burning behaviour of jute black liquor as compared to other nonwood black liquors.

iii. Viscosity of Jute black liquor is lower as compared to other nonwood and wood black liquors. This is a pointer towards possibility of high solid evaporation of this this black liquor.

iv. Chloride and potassium content in jute black liquor are higher than wood black liquor, however their concentration is lower than other nonwood black liquor.

v. It is inferred from above studies that black liquor obtained from Soda/ Kraft pulping of jute is suitable for its processing in conventional chemical recovery plant. The performance of chemical recovery is expected to be better in case of Soda AQ black liquor as compared to kraft black liquor.

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Effluent Management In A Kenaf Based Pulp Mill – A Case Study

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About The Author

Dr .S. Panwar is a senior scientist working in Effluent Treatment Div of CPPRI for the last twenty years. He has Masters Degree in Chemistry and has Doctoral degree in Pulp & Paper Chemistry.
He has a rich and wide experience in the area of pulping & bleaching, environmental management including bioenergy recovery from wastes, performance evaluation and trouble shooting of effluent treatment plants, environmental auditing etc. He has been responsible for commissioning of full-scale biomethanation plant for recovery of bioenergy from black liquor. He has been actively associated with the projects completed on behalf of CPCB like "Development of Standards of AOX for Large and Small Scale Pulp & Paper Mills" & "Standardization of Methods for Determination of AOX in Environmental Samples".

He has undergone an advanced training at Finland and Sweden on microbial aspects and application of biomethanation technology in pulp and paper industry. He has also been actively associated with prestigious projects sponsored by UNDP, MNES, and mill associations like IARPMA, IPMA etc. He has represented CPPRI at various national & International Conferences and Seminars. He has around 30 publications to his credit and has been author/ co-author of a number of R& D reports, training and course manuals.

EFFLUENT MANAGEMENT IN A KENAF BASED PULP MILL - A CASE STUDY

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INTRODUCTION

The search for alternate fibrous raw material for pulp and papermaking has been the area of continual research in most of the Asian countries like China, India, and Bangladesh etc. As a result, bagasse, wheat straw, rice straw, sarkanda etc have been successfully used as raw material for pulp & paper making by these countries. In India around one third of paper production is contributed by small & medium scale agro based pulp & paper mills. Inspite of their utility towards resource conservation these agro based residues have some inherent disadvantages of short fiber length & high silica content which not only adversely affect the product quality but also cause increased environmental problems due to discharge of high magnitude of pollution load as liquid & solid wastes. In recent times bast fibers like jute, kenaf, mesta, hemp have gained the attention of paper makers due to the advantage of long fibers ,high content of alpha cellulose and low lignin and less silica which helps in producing pulp & paper of superior quality (high value or speciality pulp & paper) compared to other agro residues. Studies conduced have demonstrated the suitability of jute/kenaf pulping by conventional soda, kraft as well as TMP, CTMP, CMP process. Due to increased environmental awareness, imposition of stricter environmental discharge norms, it is now mandatory to treat the effluent to the acceptable norms. The present paper highlights the magnitude of pollution loads, options for efficient management in a kenaf based pulp mill.

INDIAN PAPER INDUSTRY -AN OVERVIEW

Indian paper industry is marked by diversification in the scale of operation, use of raw materials as well as technology . The Indian paper industry is generally classified broadly into following categories:

Classification Basis		
Raw material Used	**Scale of Operation**	**End products**
Wood based	Large (Above 100 tpd)	Writing & Printing,Newsprint, Rayon grade pulp
Agro based	Medium (30-100 tpd)	Writing & Printing,Newsprint, Packaging paper etc
Recycled Fiber based	Small (5-30 tpd)	Writing & Printing,Newsprint, Packaging paper etc

An estimated segregation of the total mills on the basis of raw material use is indicated in **Table - 1 .**

Table-1 Segregation of Indian Mills (Basis: Raw material Use)

Raw material	*Number of Mills*	*Scale of Operation*	*% Contribution to installed capacity*
Wood	32	*100-700*	37
Agro Residues	*110*	*30 -100*	33
Recycled Fiber	383	*5- 400*	30

As indicated in the table , each of the category are contributing nearly equal proportion to the total paper production. However less than 10% are using forest based woody raw material. Most of the small & medium agro based mills so far have been based on mainly bagasse, wheat straw and rice straw. Though potential of jute / kenaf has been evaluated for paper making on lab scale successfully, it is yet to find application on mill scale. The only indirect use of jute or related products as raw material is in form of old gunny bags by some small mills. An estimation of production / availability of jute & kenaf in India & other Asian countries is indicated in **Table -2**

Table -2 Production of Jute/Kenaf in Major Asian Countries

	Bangladesh	China	India	Thailand
Jute (x 1000 t)				
Fiber	877	-	1741	-
Stick	1754	-	3482	-
Kenaf (x 1000 t)				
Fiber	-	136	201	30
Stick	-	408	602	88

APPLICATION OF JUTE /KENAF & RELATED PLANTS FOR PAPER MAKING - ROLE OF CPPRI

CPPRI recognized the potential of jute/ kenaf / mesta for pulp & paper making and has demonstrated the same on lab, pilot as well as semi commercial scale. It has demonstrated the suitability of whole jute for making writing & printing grade of paper as well as newsprint grade of pulp . So far only bast fiber (which constitute only 30% of whole jute plant) is being used by gunny bag industry and 70% of the remaining is going as waste .Utilisation of whole jute will mutually help the paper industry in meeting the raw material requirement as well as the cultivators who are facing tough times due to availability of synthetic substitutes to gunny bags .CPPRI has also successfully developed technology to produce newsprint from whole mesta .CPPRI has also the honour to participate in the International Project on "Utilisation of Whole Jute / Kenaf as Raw material for Pulp & Paper" sponsored by International Jute study Group (IJSG).

EFFLUENT TREATMENT OPTIONS

The black liquor generated during pulping contains mainly organic matter & inorganic salts. In large mills the black liquor is generally managed through chemical recovery system where the inorganics are recovered back for reuse in the process .In addition the heat is also recovered from flue gases generated during combustion of organic material. In small mills The uneconomic scale of operation makes adoption of chemical recovery system unviable .

The discharge of black liquor in absence of chemical recovery system is a major source of pollution in these small mills. The presence of recalcitrants like lignin, inorgancis etc makes treatment of the black liquor up to acceptable discharge norms difficult .The various options thus available before the small mills for treatment of black liquor alongwith other waste water are discussed below:

(A) Chemical Treatment

Chemical precipitation involves separation of lignin and other inorganic compounds by reducing the pH of the effluent below 6.5 Optimisation studies indicate maximum precipitation occurs in the range of 3-4. The major advantage of this process are ease of application of the technique & low energy requirement . However the major limitations associated with the process are :

- Cost of chemicals
- Difficulty in separation of precipitated mass due to hydrophilic nature of lignin
- Handling and management of chemically precipitated sludge

(B) Biological Treatment

Biological treatment process are basically of two types i.e. Anaerobic & Aerobic. Both the methods have their inherent advantages as wellas limitations as indicated below:

Particulars	AEROBIC	ANAEROBIC
Bacterial Growth	Fast	Slow
Carbon Balance	50% CO_2 50% Biomass	95% CH_4+CO_2 5%Biomass
Energy Balance	60% Retained as O_2 40% Heat Production	90% Retained as CH_4 5% as Biomass
Energy Input for Aeration	Yes	No
kWh/ tonnes COD Reduction	1100	15

Anaerobic treatment of black liquor:

The major advantage of anaerobic treatment are:

- Less Chemical requirement
- Less or no power requirement
- Less investment and maintenance cost

The limitations of longer retention time ,lower reduction in pollution load etc associated with anaerobic treatment have been overcome in recent times by development of high rate biomethanation reactors which give an added advantage of cogeneration of biogas along with appreciable reduction in BOD & COD.

The advantages of biogas utilization are :

- Biogas is a clean fuel
- It can supplement / replace to some extent the conventional fuel used in boilers which can give substantial savings as wellas payback
- Its utilization helps in controlling global warming

Aerobic Treatment Method

Activated sludge process is the most common & widely used method for treatment of industrial effluents The basic mechanism of the aerobic treatment process (activated sludge process) is as under:

$$\text{Organic Material+Microorganism} \xrightarrow{O_2} \text{Microorganisms}\downarrow + CO_2\uparrow + H_2O\text{+Energy}$$

The major merits of the process are :

- High BOD reduction
- Less space requirement
- Function with high organic load
- Fast start up

The process suffers from a major disadvantage of high consumption of energy and chemicals which may be a liability for small mills.

CASE STUDY -EFFLUENT MANAGEMENT IN A 15 -20 TPD KENAF PULP MILL

Recently CPPRI conducted a prefeasibility study for effluent management in a proposed kenaf based pulp mill of 15-20 tpd capacity . Lab scale pulping & bleaching studies were conducted by CPPRI as per the required parameters.

Characterisation of Effluents

The effluent generated during pretreatment of kenaf using water, combination of water, alkali and methanol as well as the black liquor & bleach effluent generated were characterized for various pollution parameters & suitable chemical / biological treatment options were evaluated to treat the effluent to reduce the pollution load The results of the same are indicated in **Table- 3, 4 , 5& 6**

Table -3 Characteristics of Effluent Generated from Pretreatment of Kenaf

S. No.	Sample Details	Results		
		pH*	TS	COD (Total)
1.	Pretreatment with hot water (100oC for 30 minutes)	5.5	14490	10058
2.	Pretreatment with hot water containing alkali (2%) (100°C for 30 minutes)	7.7	16456	11384
3.	Pretreatment with hot water containing alkali (2%) and methanol (2%) (100°C for 30 minutes)	7.8	18156	12033

** Values in mg/l except pH*

As indicated above maximum removal of TS & COD was achieved using combination of water , alkali & methanol. As such the above combination was used in further studies.

Table -4 Characteristics of Soda -AQ Black Liquor

pH*	11.6
Suspended solids, mg/l	1730
Total Solids, mg/l	58840
Total dissolved solids, mg/l	57320
COD, mg/l	53000
BOD, mg/l	17115
Colour,PCU*	182500

** All values except pH & colour in mg/l*

Table -5 Characterisation of Bleach Effluent

Parameter	CEp stage Bleach effluent	H stage bleach effluent	Combined bleach effluent CEpH
pH*	7.9	5.6	6.9
SS, mg/l	269	310	43
TS, mg/l	2145	8064	2052
TDS, mg/l	1914	7764	1968
COD, mg/l	614	1110	466
BOD, mg/l	141	515	114
AOX, mg/l	23.3	15.8	19.7
Chloride, mg/l	561	3111	955
Colour, PCU*	487	152	166

Table -6 Characterstics & Pollution load of Combined Effluent

Parameters	Value	Pollution Load	
	mg/l	kg/t pulp	kg/day
pH*	10.8	-	-
Total Solids	18170	1272	19079
Total suspended Solids	493	34.50	518
Total Dissolved Solids	17680	1238	18564
COD	18934	1325	19881
Chlorides	471	-	-
Color, PCU*	49750	-	-
Effluent Volume, m3/d	1050	-	-
AOX	17.29	1.27	18.2

* *All values except pH & colour in mg/l*

The various chemical & biological options discussed earlier were evaluated for treatment of black liquor & bleach effluent (individual & combined) to reduce the pollution load .The results of the same are discussed as under :

Potential of Biomethanation in Soda -AQ Kenaf Black Liquor

As indicated in Table -4, the soda AQ black liquor is rich in COD and BOD as such anaerobic treatment of black liquor can be a possible option for reduction in pollution load. In this perspective the biodegradability of the Soda -AQ kenaf black liquor was evaluated by batch bioassay method and was found to be around 48% .On the basis of the bioassay studies the potential of biogas generation was estimated and is indicated in **Table -6**

Table-7 Potential of Biogas Generation from Soda AQ Kenaf Black Liquor

Volume of black liquor, m3/d	300
COD load, t/d	15.9
BOD load, t/d	5.14
Reduction in COD (@ 50%), t/d	7.95
Reduction in BOD (@ 80%), t/d	4.12
Biogas generation, m3/d	4000-4500
Equivalent oil, kg/d	2500-2900

As indicated above the biogas generated will be helpful in replacing 2.5 -2.9 t of fuel oil used per day by the mill in the boiler

Response of Chemical Treatment of Combined Effluent

Various chemicals individually and in combination were used to evaluate their response fo treatment of combined effluent the results of which are indicated in **Table -8**

Table-8 Response of Chemical Treatment - Combined Effluent (Black Liquor-CEp 1:2.5)

Particulars	Experimental Trials			
	1	2	3	4
Initial pH	10.6	10.6	10.6	10.6
Initial COD, mg/l	18934	18934	18934	18934
Initial BOD, mg/l	5570	5570	5570	5570
Initial colour PCU.	49750	49750	49750	49750
Initial AOX, mg/l	17.29	17.29	17.29	17.29
Chemical Dosages				
Alum: COD	0.25:1	0.25:1	0.25:1	0.25:1
Lime: COD	-	0.16:1	0.19:1	-
CaCl2 : COD	-	-	-	0.25:1
PAA, ml	0.8	0.8	0.8	0.8
Final pH	4.0	5.0	5.5	4.0
CODReduction,%	53	60	55	53
BODReduction,%	30	44	50	43
Colour Reduction,%	87.8	90.8	90.4	87.9
AOX Reduction,%	62.4	74.9	66.8	61.5

Potential of Combination of Chemical & Biological treatment

As discussed ,the black liquor laden waste water is difficult to treat biologically due to presence of refractory matter .As such potential of combination of chemical and biological treatment were evaluated to reduce the pollutionload The expected overall reduction in COD,BOD & AOX is indicated in **Table -9**

Table -9 Combination of Chemical & Biological Treat. - Removal Efficiency

Particulars	Chemical Treatment	Biological Treatment (Anaerobic + Aerobic)	Overall reduction %
Initial COD,mg/l	18934	7605	-
Final COD, mg/l	7605	1521	-
Reduction %	60	80	92
Initial BOD,mg/l	5570	3118	-
Final BOD,mg/l	3118	250	-
Reduction,%	44	92	96
Initial AOX,mg/l	17.29	4.34	-
Final AOX, mg/l	4.34	1.59	-
AOX Reduction %	75	63	91

OBSERVATIONS

Based on the results and findings of the studies conducted at CPPRI, the following observations are made with respect to various treatment options evaluated for reduction in pollution load:

- The combination of chemicals (alum +lime) was found to be more effective to reduce the pollution load in combined effluent.
- The reduction in COD, BOD, AOX & Colour through chemical treatment was around 60, 44, 75 and 91% respectively.
- In absence of chemical recovery system biomethanation technology has potential to reduce pollution load of black liquor along with the added advantage of cogeneration of biogas, which can be used as a fuel.
- Reduction in COD & BOD through biomethanation was around 50% & 80% respectively which results in reduction in operating cost of subsequent effluent treatment plant.
- The combination of chemical & biologoical treatment process may be a viable option for treatment of effluent generated in a kenaf based pulp mill.

CONCLUSIONS

Jute/ Kenaf has a good potential for pulp & paper making. With trend of increased demand of specialty grade of paper compared to cultural paper, jute / kenaf can replace to some extent imported kraft pulp and paper for producing improved grades of paper. Economic analysis also indicate that it is possible to produce jute/ kenaf pulp in a techno-economic viable manner by selection of appropriate size of the mill & technology. Study carried out at CPPRI earlier indicate that whole jute/kenaf appear to be more economic for all kind of paper products where as bast fiber alone may be used for vaue added products only. The lab scale experimental studies conducted for a proposed 15-20 tpd kneaf based pulp mill on evaluation of effluent treatment options through biomethanation or chemical addition indicate appreciable reduction in major pollutional parameters in both cases. As biomethanation has the advantage of cogeneration of biogas along with reduction in pollution load it is suggested that a combination of anaerobic & aerobic treatment methods can reduce the pollution load and can improve the quality of the effluent to make it compatible to comply with the environmental regulations.

Commercial Trial Of Whole Jute Plant As Raw Material For Pulp And Paper

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About The Author

Dr. Ghulam Mohiuddin is the Project Leader of UNIDO/IJSG Project entitled "*Biotechnological Application of Enzymes for making Paper Pulp from Green Jute/Kenaf (the whole plant)*" funded by Common Fund for Commodities (CFC), European Commission (EC) and Government of France. He was the Project Leader of International Development Research Centre (IDRC) and Government of France funded IJO Project "*Pilot Scale Demonstration and Production of Enzyme for the Improvement of Low Grade Jute and Cuttings for their Large Scale Utilization*". He was also Project Leader of IDRC, Canada funded project entitled "*Improved Processing Techniques for Low Grade Jute and Cuttings*".

He trained scientists of several countries on the production and application of enzymes in the jute Industry. He was involved with a collaborative research work with University of Laval, Canada in 1990. He is ex-Chief Scientific Officer of Bangladesh Jute Research Institute (BJRI).

He received his M.Sc. in Biochemistry from Dhaka University in 1965 and Ph.D. in Biochemistry from U.K. in 1977. He has ***78 publications*** in reputed national and international scientific journals and also presented papers in various national/international seminars, conferences and workshops.

He visited various research Institutes, Universities, Laboratories of Asia, Europe and North America. Apart from his professional activities, he is also Member of New Work Academy of Science, ex-Vice President of Bangladesh Society of Microbiologist, ex-Vice President & Treasurer of Bangladesh Association of Scientist and Scientific Professions, Reviewer of Journal of Textile Institute, U.K. and Supervisor and Examiner of Dhaka University, Jahangirnagar University and Bangladesh Agricultural University.

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Commercial Trial Of Whole Jute Plant As Raw Material For Pulp And Paper

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ABSTRACT

The forest resources of jute/kenaf producing countries are very limited compared to Europe and North America. Commercial non-wood pulp production has been estimated to be 6.5% of the global pulp production. In many countries wood is not available in sufficient quantities to meet the demand for pulp and paper. Various institutes and pulp and paper mills of Jute/Kenaf producing countries have conducted extensive work. It has been revealed that most conventional pulping techniques are suitable for jute/kenaf pulping.

Using whole jute/kenaf plant, bleachable grade pulp with yield of 48% can be obtained in both the chemical process (Soda-AQ and kraft process). The bark (unretted fibre) and core (wood/stick) fractions can be used to produce pulp with properties comparable to those produced from wood.

Kraft and writing papers can be produced in kraft process using existing chippers (pallmann) and stationery digester. The over all quality of kraft and writing papers are better than those paper produced from wood. In order to make jute paper (jute/kenaf) cost effective, environment friendly biotechnological method and oxygen were also used.

In biopulping process in Soda-AQ Process Kappa No. can be reduced by 15% with the same alkali charge. Desired Kappa No. can also be obtained by reducing

the alkali charge (9%). Bleaching of Jute Pulp was also carried out in conventional CEH and ECF (Elemental Chlorine Free) bleaching sequences. ISO brightness of 80-85% was obtained.

INTRODUCTION

World production of jute and allied bast fibres is around 3 million tons (Table 1) annually. In addition to fibre, jute also produces 8 million tons of stick. Traditional jute products are facing severe competition. In view of the growing demand for pulp & paper and increasing consciousness for forest resources (Table 2), jute can be used as raw material for pulp and paper.

It has been revealed by scientists from various Institutes and pulp and paper mills of Jute/Kenaf producing countries that most conventional pulping techniques, such as Kraft, soda, neutral sulfite, mechanical such as thermo mechanical pulp (TMP), chemico-thermomechanical pulp (CTMP), Chemico-mechanical pulp (CMP), are suitable for jute/kenaf pulping. Whole jute/kenaf plant has been tried as a raw material for pulp and paper in Bangladesh, China, India, Thailand and USA.

The stem of jute/kenaf consists of two fibrous components. The bark (fibrous material) is suitable for quality paper making and is similar to softwood fibres. Core (wood) has strength properties similar to that of hard wood. Although jute fibre is a suitable raw material for pulp and paper, it has not been cost effective. But whole jute plant will be cost effective.

The International Jute Organization (IJO), present International Jute Study Group (IJSG) has been implementing a project to utilize whole jute plant/kenaf since January 2001. Seven Institutes of five countries namely, BJRI and BCIC from Bangladesh, IBFC and Yuanjiang Mill from China, CPPRI from India, CTP from France and ATO from the Netherlands are involved in the project.

BCIC/IJSG (Bangladesh), CPPRI (India) and CTP (France) have optimized the conditions of pulping in laboratory scale using Soda-AQ process. Bleaching of

Jute Pulp was also carried out in all these Institutes. Brightness 80-85%ISO was obtained using conventional CEH and ECF (Elemental Chlorine Free) bleaching sequences. With oxygen bleaching in conventional bleaching sequence chemical requirement can be reduced by 45%. Chemical requirement can also be reduced by 30% with enzyme followed by alkali.

EXPERIMENTAL

Chemical analysis of whole jute, bark (bast fibre), core (stick) and bamboo were carried out.

In order to optimise pulping, the liquor ratio with jute chips, AQ dose in Soda-AQ process, and requirement of alkali percentage, a number of experiments were conducted at Karnaphuli Paper Mills with a group digester (Oy.Santasalo-Sohlbergab, Helsinki, Finland) using 60 gm of jute chips to produce pulp with Kappa No. 20-22. Similar experiments were also carried out with bark and stick separately

Experiments were also carried out to optimise alkali charge and sulfidity in Kraft process using whole jute and bark separately to produce pulp with Kappa No. 20-22.

Large Scale Pulping

Whole jute plants were chipped with a pollmann chipper after adjustment of knife and other necessary parameters. Jute chips were washed and kept in the silo before cooking.

300 MT of green jute plants (75 MT of dried jute plant) were cooked in a stationary digester using 15.5% Na_2O and 20% sulphidity. The capacity of digester is 100 M^3. Chips were cooked for 2 hours at 170^0C. Subsequently the pulp was washed, screened and refined before stock preparation.

Bleaching

Bleaching of the washed, screened and refined pulp was conducted in the conventional bleaching sequence chlorine–alkali–hypochlorite (CEH). After the application of chlorine (0.22 of kappa no. of pulp) the pulp was washed and then alkali was used (2% NaOH). After alkali extraction the pulp was again washed and then hypochlorite (1.5%) was used for final bleaching.

Paper Making

These bleached pulp were used for making paper (70 gsm) in paper machine having the speed of 175-200 M/minutes. The brightness of the paper was 80-83% ISO. Physical properties of paper were tested and compared with the paper of bamboo.

Biobleaching Experiments

In laboratory scale, after optimization of pulping in Soda-AQ and Kraft Processes bleaching experiments were conducted in CEH, DED and OCEH sequences with and without enzyme pretreatment to reach a final brightness of 80% ISO.

Bio-pulping

Initially fresh culture of three strains of ***Ceriporiopsis subvermispora*** (from FPL of USDA Forest Service), four strains of ***Phanerochaete chrysosporium*** (three from FPL of USDA Forest Service, one from DSM, Germany), one strain of ***Fomes lignosus*** (locally isolated strain) and one strain of ST-2 (from Central Pulp and Paper Research Institute, India) were used for biopulping experiment. After several trials only 04 strains were used.

The composition of the inoculum media was 0.3% malt extract, 0.3% yeast extract and 1% glucose. The strain was allowed to grow in stationary condition for 7 days. Normally the strains are inoculated in several conical flasks. The biomass weight of one or two conical flask was taken to determine the required biomass for particular quantity of jute chips.

For biopulping, initially dried whole jute plants (***Corchorus olitorius***) were cut into small pieces (2-3 cm) and conducted as mentioned in our paper submitted to TAPPI Conference [6].

Biopulping trials were also conducted in the Soda-AQ Process with reduced alkali charge and cooking time.

Testing

All pulps were tested according to TAPPI Test Methods: T-236 cm 85 (Kappa number), T-205 sp. 95 (hand sheet preparation), T-403 ohm 97 (burst index), T-414 om 98 (tear index), T-404 cm 92 (tensile index), and T-220 sp. 96 (density).

RESULTS

It was observed that the liquor ratio 1:5 and alkali percentage 17% (as Na_2O) have been found to be most effective for desired Kappa No. in Soda-AQ process.

Similarly 12% alkali (Na_2O) and 0.05% AQ were suitable for bark and 19% alkali (Na_2O) and 0.05% AQ with a liquor ratio 1:5 was found to be suitable for stick in Soda-AQ process.

It was also observed that 17% alkali (Na_2O) with 22% sulfidity would be suitable to produce pulp with required Kappa No. (20-22%) from whole jute in kraft process.

Large-scale trial

First large scale pulping experiments were conducted at KPM. Approximately 14 tons of AD (air-dried) chips were cooked in a stationary digester using 12% Na_20, 18% sulphidity and using same liquor as used in case of Bamboo. Subsequently the kraft pulp was washed, screened and refined before stock preparation. The physical properties of kraft paper compared with that of bamboo were shown to be superior.

After this successful trial, large scale commercial trial was also conducted using 300 MT of green jute plant (75 MT of dried jute plant) using 15.5% Na_2O and 20% sulfidity. Screened pulp was bleached in CEH sequence. The physical properties of paper in the kraft process were compared with that of bamboo and hard wood were shown to be superior.

Biopulping

Results of biotreated and untreated cooked pulp in the Soda-AQ process are shown in **Table 11**. Out of the nine fungal strains 4 strains were selected i.e. ***P. chrysosporium-1, P. chrysosporium-3, C. subvermispora-2*** and ***F. lignosus.***

In biopulping experiment alkali charge was reduced (17% to 15.5% as Na_2O), and desired Kappa number of 20 was achieved with improved physical properties. Yield loss is more or less same as with 17% alkali charge.

Figure I shows Kappa number as a function of alkali charge for control pulp and biotreated pulp using Soda-AQ processes. Kappa number was plotted versus yield. It has been revealed that among the four microbial strains ***C. subvermispora*** and ***F. lignosus*** are the most suitable strain for biopulping in the Soda-AQ processes (**Figure I**).

In biopulping, various authors [1, 2, 3] have reported 4-5% yield loss, and reduction of brightness. But they have also reported an energy reduction around 30-35% and improved physical properties for the biotreated samples compared to control mechanical pulping. However, in the biochemical pulping using all four fungal strains showed improved brightness (Table 11) and other physical properties.

The CEH sequences were conducted in conventional conditions in Soda-AQ pulp. The Cl_2 charge was applied according to the Kappa Number ($Cl_2\% = 0.22$ Kappa Number). In the CEH sequence additional hypochlorite was required (H_2) to achieve the 80% ISO brightness.

Various enzyme concentrations were used prior to CEH, DED and OCEH sequences. The bleaching yield was found to be same in the control and enzyme treated pulp. In chlorination stage of CEH sequence, about 10-12% chlorine were reduced by the application of enzyme. In addition, enhancement of brightness was observed with the application of enzyme. Relative viscosity was also improved. This may be due to the less chlorine charge in the **C-stage.**

It was observed that yield and brightness were slightly higher in Soda-AQ pulp. Chlorine requirement was reduced by about 7% in the D1 stage and about 8% in the D2 by using xylanase. Higher percentage of reduction of chlorine was achieved with higher units of xylanase application. In addition to the reduction of chlorine, brightness was also increased by 1-2 units due to the application of xylanase.

In oxygen bleaching 50% Kappa No. can be reduced which will reduce chlorine consumption by 50%. Application of xylanase before and after the treatment of O_2 can improve the brightness by 1-2 units.

Table 1: World Production of Jute and Kenaf.

Country	Area ha x 000	Jute (1000 MT)		Kenaf (1000 MT)	
		Fibre	Stick	Fibre	Stick
World	-	2661.4	5322.8	430.8	1,292
Bangladesh	464	877	1754	--	--
India	1070	1741	3482	200.5	601.5
China	50	--	--	136	408
Thailand	18	--	--	29.5	88
Nepal	11	16.4	32.4	--	--
Rest of the World	-	27	54.4	64.8	194.5

Source:*FAO, jute, kenaf and allied fibres June, 2002. CCP: JU/HF/ST/2002/1.

**Calculated from Dempsey James, M. Fibre Crops, 1975. A University of Florida Book.

Table 2: Percentage of forest area and per capita consumption of Jute/Kenaf (P&B) in the world.

Country	Forest Area %	Per capita consumption of (P&B) in kg
Europe	43.000	122
North America:		
Canada	42.000	250
USA	23.000	324
Bangladesh	9.027	3.1
China	13.420	29
India	20.168	5
Thailand	25.281	32

Source: PPI July 2002.

Table 3: Chemical Composition of jute, kenaf and bamboo.

Chemical Composition	Jute			Kenaf			Bamboo
	Whole	Bast	Core	Whole	Bast	Core	
Holocellulose %	77	81.5	74.5	83.7	84.1	78.4	60
Lignin %	20	14	24	14.0	12.5	19.4	26
Ash content %	3.5	4.0	1.8	2.8	2.9	1.8	3.4
Ave. fibre length (mm)	--	2.5	0.8-1.0	1.67	2.31	0.95	2.3

Source: IJSG/CPPRI/Phoenix Paper Mill, Thailand.

Table 4: Optimum conditions for pulping of whole jute, bark and stick in Soda-AQ process.

Material	Na_2O (%)	pH of liquor	Kappa No	S. reject %	Yield %	Burst Index KPa m²/g	Tear Index mNm²/g	Tensile index kN/m	Density Kg/m³	Freeness °SR
Jute Chips	17.0	10.81	22.10	Nil	46.00	2.53	9.60	45.21	520	17
Bark	12	9.45	18.90	Nil	51.00	3.87	18.60	60.32	518	15
Stick	18	10.95	20.80	Nil	41.13	3.65	11.22	60.35	500	19

Rising time - 90 minutes, cooking time - 90 minutes, cooking temperature-170°C, liquor ratio-1:5.

Table 5: Optimum conditions for pulping of whole jute and jute bark in kraft process.

Material	Na_2O (%)	Sulfidity %	PH of liquor	K. No.	S. reject %	Yield %	Freeness °SR	Burst Index KPa m^2/g	Tear Index mNm^2/g	Tensile index kN/m	Density Kg/m^3
W.Jute	17	22	10.55	19.05	Nil	45.66	18	3.81	13.41	67.77	525
J. Bark	15.5	22	10.2	17.88	Nil	52.49	15	2.25	14.00	52.85	521

Rising time - 90 minutes, cooking time - 90 minutes, cooking temperature-170°C, liquor ratio-1:5.

Table 6: Bleachable Grade Pulp of Kappa No. 20 using Soda-AQ and Kraft process optimized at different institutes.

Institution	Alkali % as Na_2O	A.Q %	Sulfidity	Cooking Temperature	Cooking Time (min)	Yield %	M:L	Kappa No.
BCIC	17.0	0.05	Soda-AQ	170°C	90	48	1:5	20.5
	17.0	-	Kraft	170°C	120	48	1:5	20.0
CTP	15.5	0.10	Soda-AQ	170°C	120	48	1:4	18.3
CPPRI	18.6	0.05	Soda-AQ	165°C	90	50	1:4	18.4
	16.0	-	Kraft	165°C	90	47.6	1:4	20.7

Table 7: Cooking conditions of jute plants during commercial trial

Sl.#	Cooking condition	Units	Writing & printing	Kraft (Brown)
1.	OD jute chips taken in each digester	MT	15	15
2.	Material: Liquor	--	1:4	1:4
3.	Active alkali as Na_2O	%	16	12
4.	Sulfidity	%	20	20
5.	Cooking temperature	°C	170	170
6.	Cooking time at 170.0 °C	Minute	120	90
7.	Steaming time	Minute	90	90
8.	Blowing	Kg/cm^2	5-6	5-6

Table 8: Bleaching conditions of pulp from whole jute plant (commercial trial)

Sl.#	Parameters	Units	Chlorination 1 hr at 25.0 °C	Alkali extraction 1 hr at 65.0 °C	Hypo stage H1 1 hr at 40.0 °C	Hypo stage H2 O2 hrs at 40.0 °C
1.	Cl_2 (kappa No.x 0.22)	%	4.6	--	--	--
2.	NaOH	%	--	2.0	--	--
3.	Active Cl_2 from Hypo	%	--	--	1.5	1.0
4.	Consistency	%	2.5	03	03	03
5.	Residual Cl_2	%	0.8	--	0.54	0.30
6.	Residual pH	--	2.2	10.85	8.8	8.9
7.	Relative viscosity	--	6.24	5.32	4.83	4.60
8.	Brightness	% ISO	41.0	43.2	75.2	80.0

Table 9: Comparison of yield and physical properties of unbleached paper from whole jute plant and bamboo

Material	Yield %	Kappa No.	Burst Index KPam²/g	Tear Index MNm²/g	Tensile Index Nm/g
Whole Jute Plant	55	46	2.9	10.08	60.83
Bamboo	45	44	2.2	8.5	42.5

Table 10: Comparison of yield and physical properties of writing and printing paper from whole jute plant and bamboo

Raw material	Freeness °SR	Yield %	Kappa No.	Burst Index KPa m²/g	Tear Index mNm²/g	Tensile index kN/m
Whole jute plant	33	45	21	3.64	13.71	28.51
Bamboo	35	45	22	2.28	10.50	25.03

Table 11: Biopulping Jute Chips in the Soda-AQ Process (15.5% alkali and 0.05% AQ).

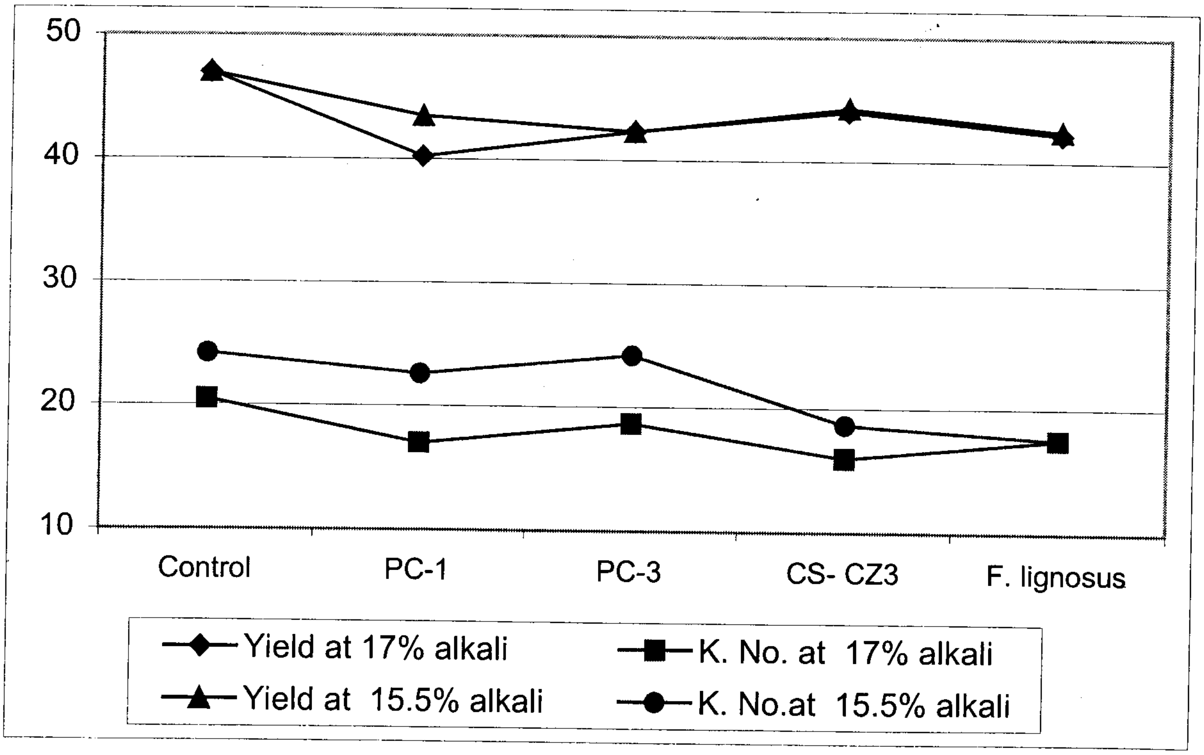
Treatment	Liquor pH	Unscreened yield %	Screen reject %	Kappa no.	Freeness °SR 14/19	Burst Index KPam²/g	Tear Index mNm²/g	Tensile Index Nm/g	Brightness % (Elrepho)
Control (untreated)	12.00	47.00	0.85	24.20	14	2.07	13.41	44.68	22.1
P. *chrysosporium*-1	11.40	43.00	0.58	22.60	19	3.37	14.50	61.00	26.2
P. *chrysosporium*-3	11.80	41.00	0.52	24.24	21	3.26	11.82	45.15	23.2
C. *subvermispora*-2	11.50	44.25	0.00	18.73	20	3.58	14.33	58.76	27.2
F. *lignosus*	11.60	42.00	0.65	17.50	21	2.87	12.20	51.52	28.2

Rising time – 90 minutes, cooking time – 90 minutes, cooking temperature – 170°C, liquor ratio - 1:5.

Table 12: Comparison of Bleaching Yield of Soda-AQ and Kraft Pulp (in laboratory scale).

	Soda-AQ BCIC/IJSG		Kraft Process BCIC/IJSG	
Unbleached Pulp yield %	**48.0**		**47.1**	
Bleaching sequence	**Bleaching Yield**	**Brightness %**	**Bleaching Yield**	**Brightness %**
CEH	94.71	78.12	95.70	76.38
X CEH	95.10	79.28	95.40	77.82
DED	95.12	79.10	95.64	80.56
X DED	94.89	80.51	95.41	81.70
O CEH	94.73	81.36	95.33	82.60
O X CEH	94.34	83.12	94.64	83.43
XOCEH	94.30	81.65	94.30	83.65

Figure I: Yield versus Kappa no. of pulps from control and biotreated chips in Soda-AQ process.



CONCLUSION

Jute/kenaf is an annual crop. It only takes about 120 days for its maturity where as bamboo and other soft wood takes about 5-7 years for their growth.

- Jute and kenaf are good alternate raw material for pulp and paper. Quality of paper from jute/kenaf is similar to that of bamboo and other soft wood.
- In Soda-AQ and Kraft Process bleachable grade pulp with yield of 48% can be obtained (Yield of pulp with bamboo as raw material is around 40-45%) 20 was obtained with 48-50% yield (Kappa number of good quality bleachable grade pulp is around 20-22%).
- With the application of biotechnology in Soda-AQ process, kappa number can be reduced by 15%. Desired kappa number can also be obtained by reducing alkali charge (9%). As a result less chemical will be required in the bleaching process.
- In both the Soda-AQ and Kraft process cooking time can be reduced (from 2 hours to 1 hour in Kraft process, from 90 minutes to 60 minutes in Soda-AQ process). As a result, cooking cycles can be increased which will facilitate to have more throughputs in the existing mill.

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Effect Of Variety Cum Fertilizer Cum Stage Of Harvest Of Mesta Crop To Increase Pulp Production For Papermaking

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Mesta (*Hibiscus sabdariffa* and *Hibiscus cannabinus*), stem contains two distinctive parts, the outer bast and the inner woody core. To be a potential raw material for paper making, any plant must have a satisfactory physical and chemical properties. In terms of chemical properties, mesta compares with other raw materials being use viz., wood, bamboo, etc. among the chemical properties, a material for papermaking should have low lignin content and higher cellulose content.

The material should be porous enough to allow the penetration of liquor during cooking process. in this sense, mesta has a very favourable chemical constitution grown in Srikakulam district (Table-1).

Table1: Properties of mesta grown in Srikakulam area of Andhra Pradesh.

S.No.	Particulars	Whole Plant
1	Alcohol-benzene extractives (%)	3.47
2	Lignin (%)	12.66
3	Holocellulose (%)	78.75
4	Pentosans (%)	16.95
5	Cellulose (%)	65.43
6	Ash (%)	2.82
7	Acid Insolubles (%)	0.81
8	NaOH Solubility (%)	26.63
9	Bulk density (Kg/m^3)	160
10	Fibre length (mm)	1.4
11	Fibre diameter (Microns)	26

(Source: P.C.Puhan, PPRI, Jay Kaypur, Orissa)

The whole palnt grown in Srikakulam has a lignin content of 12.66% as against 20-30% in case of bamboos. Thermo mechanical pulping (TMP) is the process used for production of mechanical pulp from whole mesta plant for manufacture of newsprint and tissue grade paper.

By increasing the biomass production, we can increase the pulp production from whole plant. the experiment was conducted with this objective and studied the effect of variety(AMV-2, AMV-3 and AMV-4) fertilizer level (Control, 25-20-20 and 40-20-20 kgs of NPK/ha) and stage of harvest (110, 130 and 150 days after sowing) for two consecutive years. The results of the experiment furnished in Table- 2.

Table-2: Green biomass production (T/ha) of mesta crop.

Variety/stage of harvest	Activity 4.1.7 Fertilizer levels			
	Control	25-20-20 NPK/ha	40-20-20 NPK/ha	Mean
AMV-2				
110 DAS	7.55	12.92	23.69	14.72
130 DAS	12.92	19.11	39.22	23.68
150 DAS	12.92	25.00	30.05	22.81
Mean	11.13	19.01	31.14	20.40
AMV-3				
110 DAS	7.69	13.83	32.22	17.91
130 DAS	12.33	18.47	34.83	21.88
150 DAS	10.30	22.17	25.63	19.37
Mean	10.11	18.16	30.89	19.72
AMV-4				
110 DAS	8.05	15.92	42.67	22.21
130 DAS	15.17	20.94	44.02	26.71
150 DAS	15.86	28.05	33.88	25.93
Mean	13.03	21.64	40.19	24.95

The results revealed that among the varieties tested, AMV-4 (Kalinga) recorded the highest green biomass production (mean – 24.95 tons/ha) followed by AMV-3 and AMV-2 varieties of mesta. All the varieties recorded highest green biomass production at all fertilizer levels when the crop was harvested at 130 days after sowing compared to 110 and 150 days after sowing. The highest biomass production of 44.02 tonnes/ha recorded with AMV-4 (Kalinga) variety when 40-20-20 Kgs of NPK applied per hectare and harvested at 130 days crop age.

	S.E.m +	C.D. (0.05)
VXH	0.619	1.752
VXF	1.073	NS
HXF	1.073	3.036
VXFXH	1.858	NS
C.V.(%)	14	

There is no significant interaction among varieties x fertilizers x stage of harvest. However, significant interaction was observed between varieties x harvest stages and harvest stages x fertilizer levels.

CONCLUSIONS

1. AMV-4 (Kalinga) is the best variety can be grown for paper pulp making as it is producing maximum green biomass production.

2. Fertilizer level of 40-20-20 Kgs of NPK/ha is to be applied to get higher biomass production of mesta.

3. 130 days crop age is the optimum stage for harvest of crop for paper pulp making and higher biomass production.

Economics Of Jute Based Pulp Mill - A Case Study

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Dr. Keswani has a Doctorate in Pulp and Paper Chemistry from Technical University of Darmstadt (Germany). He is the Managing Director of Chemprojects Consulting Pvt. Ltd. Dr. Keswani has over 40 years of experience in project development, management and implementation in diversified projects primarily with field of Pulp & Paper, feasibility studies, evaluation and impact studies projects etc. He has served as consultant to various national, regional and international organisations.

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ECONOMICS OF JUTE BASED PULP MILL

A CASE STUDY

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INTRODUCTION

- JUTE / KENAF FIBRE BELONG TO HIBISCUS FAMILY
- JUTE/ KENAF IS A RAINY SEASON CROP
- JUTE/KENAF IS A COARSE BAST FIBER AND CONSISTS OF NUMEROUS INDIVIDUAL FILAMENT WHICH FORM A MESHY STRUCTURE.
- JUTE/KENAF IS A STRONG BUT NOT RIGID FIBER. (STABLE OVER A RANGE OF 30 – 80% OF R.H.).
- THE FIBER IS A VERY GOOD INSULATOR OF HEAT AND ELECTRICITY.

cont......

- THE MAJOR COMPONENTS OF THE FIBER ARE LIGNIN, HOLO CELLULOSE, GUMS AND WAXES ETC.
- THE FIBER IS HYGROSCOPIC AND CAN ABSORB MOISTURE BY MANY TIMES OF ITS OWN DRY WEIGHT.
- JUTE/KENAF AGRICULTURE ABSORBS CARBON-DIOXIDE AND THUS REDUCES GREEN HOUSE EFFECT.
- ONE HECTARE OF JUTE / KENAF PLANTS CAN CONSUME ABOUT 15 T OF CO_2 FROM ATMOSPHERE AND RELEASE ABOUT 11T OF OXYGEN IN THE 100 DAYS OF THE JUTE GROWING SEASON.

- THERE IS NO SCOPE OF ACIDIFICATION OF ATMOSPHERE AND DEPLETION OF OZONE DUE TO ACTIVITIES CONCERNING.

MAJOR GROWING AREAS

- JUTE THRIVES BEST IN DAMP HEAT
- WORLD WIDE IT IS GROWN IN
  - BANGLADESH
  - MYANMAR
  - CHINA
  - NEPAL
  - TROPICAL AFRICAN COUNTRIES
  - INDIA

- INDIAN STATES IDEALY SUITABLE FOR CULTIVATION OF JUTE ARE
  - BENGAL
  - BIHAR
  - ASSAM
  - ORISSA
  - UTTAR PRADESH
  - ANDHRA PRADESH
- TOTAL CULTIVATION AREA OF JUTE IN INDIA IS

  ABOUT 9,00,000 HECTARES (68% BENGAL, 15% BIHAR).

- AVERAGE YIELD IS AROUND 1.6 T/HECTARE.
- SOME EXPERIMENTS ON KENAF GROWING ARE BEING CONDUCTED IN AURANGABAD REGION(MAHARASHTRA) REPORTED YIELD 5T – 10 T/ACRE NATH GROUP ACTIVITY INVOLVED AS CROP FOR PAPER FIBRE.
- INDIA CONTRIBUTE ABOUT 2/5 OF TOTAL WORLD JUTE PRODUCTION.

SUITABILITY OF JUTE/KENAF FOR PAPER MAKING

- MOST USEFUL PORTION OF THE JUTE/KENAF PLANT IS THE BAST FIBER. (IT CONTRIBUTE ABOUT 1/3 OF THE WHOLE PLANT).
- AT PRESENT, JUTE/KENAF BAST PORTION IS USED IN PAPER INDUSTRY AS A RAW MATERIAL, BUT IN VERY LITTLE QUANTITY.
- PAPER INDUSTRY IS AN AREA WHERE THERE IS A WIDE SCOPE FOR UTILIZING WHOLE JUTE PLANT. PARTICULARLY FOR NEWSPRINT AND KRAFT PAPER

- STUDIES INDICATE THAT, WHOLE JUTE CONTAINS HIGHER HOLOCELLULOSE (75%) AS COMPARED TO BAGASSE(70%), BAMBOO AND EUCALYPTUS (67%).
- LIGNIN CONTENT IN WHOLE JUTE IS LESS (23%) AS AGAINST BAMBOO (25%) AND EUCALYPTUS (28%).
- LIKE EUCALYPTUS, WHOLE JUTE CONTAINS LESS SILICA (0.2%) COMPARED TO BAGASSE (1.5%) AND BAMBOO (1.8%).
- CHEMICAL PULPING OF WHOLE JUTE CAN BE DONE BY USING ABOUT 17-18% CHEMICAL AS Na2O. (KAPPA NO. 20-21 AND YEILD IS ABOUT 49-50%).

- WHOLE JUTE/KENAF PULP COULD BE BLEACHED TO + 80% BRIGHTNESS BY SIMPLE CE_0HH SEQUENCE (83% ISO, BY USING 3% HYPO CHLORITE IN THE FINAL STAGE OF BLEACHING).
- EFFECT OF H_2O_2 AT EXTRACTION STAGE IS NEGLIGIBLE.
- PHYSICAL STRENGTH PROPERTIES OF THE BLEACHED PULP OF WHOLE JUTE ARE COMPARED WITH BAMBOO, BAGASSE AND EUCALYPTUS AS GIVEN IN FOLLOWING TABLE.

- SEMI-CHEMICAL PULP FROM WHOLE JUTE (BY USING 15% Na OH), SHOWED VERY GOOD STRENGTH PROPERTIES AND CAN BE USED AS A REINFORCING PULP FOR BAGASSE AND OTHER PULPS.

- HIGH YIELD CMP PRODUCED FROM WHOLE JUTE IS OF GOOD STRENGTH PROPERTIES. NEWSPRINT CAN BE PRODUCED FROM THIS PULP WITHOUT BLENDING THE CHEMICAL PULP.

TABLE - 1

PHYSICAL STRENGTH PROPERTIES OF BLEACHED PULP OF WHOLE JUTE, BAGASSE, EUCALYPTUS AND BAMBOO

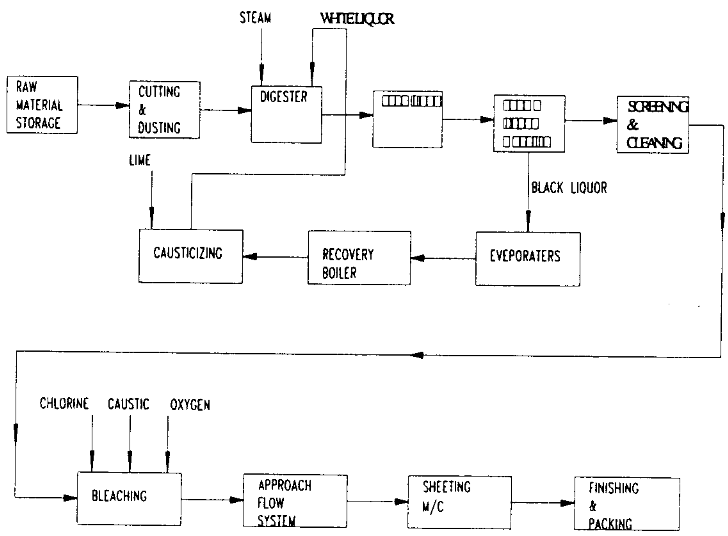
Particulars	PFI (Rev)	Free-ness ml. C.S.F.	Drainage time Sec.	Apparent density g/cm3	BRUST INDEX K pam2/g	Tensil Index Nm/g	Tear Index nMm2/g	Fold Kohler Molin (log)
Whole Jute	500	330	12.09	0.73	5.10	82.5	9.20	2.58
	1500	200	23.90	0.79	6.00	89.0	7.20	2.74
	2000	176	24.10	0.84	5.90	87.0	7.25	2.71
Bagasse	0	525	4.8	0.75	1.90	39.0	5.60	1.28
	250	300	8.0	0.78	3.05	51.0	5.30	1.62
	500	235	11.8	0.81	3.50	51.5	5.25	1.91
Bamboo	0	715	3.3	0.56	0.75	20.0	11.2	0.85
	2000	605	3.5	0.62	2.50	39.5	20.3	1.85
	4000	490	3.9	0.63	3.45	49.5	16.8	2.52
	6000	355	5.0	0.68	4.30	55.5	15.4	3.02
	8000	240	7.0	0.69	4.70	60.5	14.2	3.15
Eucalyptus	0	505	4.05	0.56	1.40	27.5	6.5	0.81
	2000	365	6.30	0.69	3.45	50.0	8.2	1.82
	4000	295	6.68	0.76	4.00	61.5	8.3	2.10
	6000	230	12.95	0.79	3.80	52.5	8.0	2.49

Source: Presentation by Dr. H.K. Gupta, Paperex 1997

CASE STUDY BASIS

- 33000 TPA BLEACHED PULP PRODUCTION
- WHOLE JUTE PLANT
- CHEMICAL CONSUMPTION 16% AS Na_2O
- BLEACH YIELD 46%
- CHEMICAL RECOVERY 92%
- 100% CAPTIVE POWER GENERATION (5 MW)
- CHLORINE CONSUMPTION 6%

TYPICAL FLOW SEQUENCE FOR JUTE / KENAF PULP



TOTAL PROJECT COST		Million US$
1	Land & Site Development	0.10
2	Building & Civil works	2.22
3	Plant & Machinery	14.45
4	Consultancy, Engineering&Project management	0.45
5	Miscellaneous Fixed Assets	3.80
6	Preoperative Expenses	2.10
7		3.34
8	Margin Money	1.10
	Total Project Cost	**27.56**
	Say	**28.00**

MEANS OF FINANCING

1.	Equity 40%	11.20
2.	Loan 60%	16.80
	Total	**28.00**

ANNUAL REQUIREMENT OF RAW MATERIALS, CHEMICALS & UTILITIES AT 100% CAPACITY UTILISATION
PRODUCTION - 33000TPA BLEACHED PULP SHEETS

S.No.	Item	Quantity TPA	Rate US$/T	Amount Mill. US$
A	**Raw materials**			
1	Whole Jute	71000	78.00	5.538
	TOTAL - A			**5.538**
B	**Chemicals**			
1	Caustic	1600.00	334.00	**0.534**
2	Chlorine	1800	167.00	0.300
3	Lime	6600.00	48.00	0.317
4	Alum	0.00	112.00	0.00
5	Rosin	0.00	1200.00	0.00
6	Soap Stone 15% of Paper	0.00	56.00	0.00
7	Other Chemicals @ US$ 6.00/T	0.00	0.00	0.198
	TOTAL - B			**1.349**
C.	**Utilities**			
1	Power, kwh 2% of 700 kwh/T of pulp	500000.00	0.09/KWH	0.045
2	Coal (5Tonne Steam/T of pulp) 4.5T steam / T of coal	36700	49.00	1.798
	TOTAL – C			**1.843**
	TOTAL COST OF PRODUCTION			**8.730**
	US$/TONNE			**264.54**

PROFITABILITY
(AT 100% CAPACITY UTILISATION)

S.No.	Particulars	Mill. US$
1	Estimated cost of Raw Materials, Chemicals & Utilities	8.730
2	Salaries & Wages @ US$27/T	0.891
3	Repairs, Maintenance & Consumables @2.5% of Plant & Machinery & MFA	0.456
4	Factory & Admn. Overheads @ US$3.4/T	0.110
5	Packing Expenses @ US$ 2/T	0.066
6	Selling Expenses @ US$ 2/T	0.066
7	Total cost of production	10.319
8	Net sales realisation @ US$ 500/T	16.500
9	Gross Profit	6.181
10	Interest on Term Loan of @10%	1.680
11	Interest on Working Capital @ 9%	0.133
12	Profit after interest but before Depreciation	4.368
13	Depreciation @ 7% on Project Cost	1.960
14	Profit after Interest & Depreciation	2.408
15	% Return	
a.	On Project Cost	15.60

CONCLUSION

- TECHNICALLY PAPER INDUSTRY CAN USE WHOLE JUTE PLANT PARTICULARLY FOR NEWSPRINT & KRAFT PAPER.
- PHYSICAL STRENGTH PROPERTIES OF BLEACHED PULP OF WHOLE JUTE ARE BETTER THAN BAGASSE , BAMBOO & EUCALYPTUS.
- GENERALLY WRITING & PRINTING PAPER WILL NOT BE PRODUCED BY 100% JUTE PULP.
- PRODUCTION OF WHOLE JUTE PULP DOES NOT REQUIRE ANY MAJOR CHANGE IN EXISTING FIBER LINE.
- PRODUCTION OF WHOLE JUTE PULP IS EECONOMICALLY VIABLE.
- THIS PULP CAN BE USED AS REINFORCEMENT PULP OF AGRO RESIDUE PULP.

Biotechnological Application of Enzymes for making Paper Pulp from Green Jute/Kenaf (the whole plant)

PROJECT COMPLETION REPORT (PCR)

FC/RAS/00/153

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CONTENTS

Annex 3 - Final report of Central Pulp and Paper Research Institute (CPPRI), India

Annex 4 - Final report of CentreTechnique du Papier (CTP), France

Annex 5 - Final report of Institute of Bast Fiber Crops (IBFC), China

Annex 6- The Economic and Financial Analysis Study

Annex 7 - Dissemination workshop and list of participants

Glossary

AOX	-	Absorbable Organic Halide
APMP	-	Alkaline-Peroxide-Mechanical-Pulping
APXP	-	Alkaline-Peroxide-Extruder-Pulping
BOD	-	Biological Oxygen Demand
C	-	Chlorination (Cl_2)
CEH	-	Chlorine-Alkali-Hypochlorite
COD	-	Chemical Oxygen Demand
CTMP	-	Chemi-Thermo-Mechanical-Pulping
D	-	Chlorine dioxide bleaching (D)
DED	-	Chlorine dioxide-alkali-chlorine dioxide
E	-	Alkaline extraction (NaOH)
E_0	-	Alkaline extraction reinforced with oxygen
ECF	-	Elemental Chlorine Free
H	-	Hypochlorite bleaching (Na or Ca)
L	-	Laccase (enzyme)
LE	-	Laccase followed by alkali
OCEH	-	Oxygen-chlorine-alkali-hypochlorite
ODED	-	Oxygen chlorine dioxide-alkali-chlorine dioxide
OXECH	-	Oxygen-xylanase-alkali-chlorine-hypochlorite
OXEDED	-	Oxygen-xylanase-alkali-chlorine dioxide-alkali-chlorine dioxide
P	-	Hydrogen peroxide bleaching
RMP	-	Refiner Mechanical Pulping
TCF	-	Total Chlorine Free
TMP	-	Thermo Mechanical Pulp
X	-	Xylanase (enzyme)
XCEH	-	Xylanase-chlorine-alkali-hypochlorite

XDED	-	Xylanase-chlorine dioxide-alkali-chlorine dioxide
XE	-	Xylanase followed by alkali
XECEH	-	Xylanase-chlorine-alkali-chlorine dioxide-alkali-cholrine dioxide
XEDED	-	Xylanase-alkali-chlorine dioxide-alkali-chlorine dioxide
XRP	-	Extruder-Refiner-Pulp
Z	-	Ozone bleaching

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (WHOLE PLANT)

Executive Summary

Production of jute/kenaf in Asia

Annual world production of jute, kenaf and allied fibers is around 3 million MT. About 90% of the world production originates in Bangladesh, China, India and Thailand. In addition to fiber 1.6 million MT of leaves and 8.00 million MT of sticks are also produced amounting to total biomass production of 12.6 million MT. Jute and Kenaf provide livelihood for millions of growers, industrial workers and traders in the region.

Traditional uses of jute

Jute is traditionally manufactured into final products by methods involving spinning and weaving. Compared to technologies adopted for other fibers and textile industries, jute production and processing techniques have remained very much unchanged. The traditional jute products' markets such as packaging materials for agricultural products (including sacks, bags, carpet backing cloth, packaging for fertilizers, cement and chemicals) are being eroded by synthetic substitutes. As a result, diversification of the uses of jute has been the main thrust of efforts aiming at identifying new major market outlets. One alternative to which a great deal of attention has been given is the possible utilization of jute and kenaf in pulp and paper production. Extensive research at various institutes and pulp and paper mills indicates that most conventional pulping and bleaching techniques are suitable for jute and/or kenaf pulping.

Consumption of paper in selected jute/kenaf producing countries

The demand for paper and paperboard has increased sharply in Bangladesh, China, India and Thailand. The per capita consumption of paper and paperboard in the region is such that there is an urgent need to develop new sources of fibers raw material for pulp and paper production.

Background

There has been recently a renewed worldwide interest for annual plants including jute and kenaf, as a raw material for pulp and paper. The stem of jute and kenaf consists of two fibrous components, both of which are suitable for producing paper and paperboard products. The bark fiber is about 2.5 mm in length and constitutes 25 to 35% by weight of the stem. The shorter core fiber is about 0.6 mm in length and constitutes 60-65% by weight of the stem. Both are suitable for quality papermaking. The bark is similar to softwood fibers while the core fiber has strength properties similar to that of hard wood fibers. In Bangladesh, the Bangladesh Chemical Industries Corporation (BCIC) is the major user of fibrous raw material in the country and use bamboo, wood and bagasse as raw materials for the production of pulp and paper.

The Project

The project described in this report was initiated in January 2001 and terminated in May 2004.

Funding Agency

The common Fund for Commodities (CFC) provided the major part of the funding for the implementation of the project with co-financing from the governments of France and Bangladesh.

Development Objective

To assess the technical and economic feasibility and environmental sustainability of biotechnological processing of jute and kenaf for the commercial production of high quality pulp and paper.

Participating Institutes

The project involved collaboration of the Agro-technology & Food Innovations (A&F), The Netherlands, Centre Technique du Papier (CTP), France, the Central Pulp and Paper Research Institute (CPPRI), India, the Institute of Bast Fiber Crops (IBFC) and Yuanjiang Mills, China, the Bangladesh Chemical Industries Corporation (BCIC) and Bangladesh Jute Research Institute (BJRI), Bangladesh.

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (WHOLE PLANT)

Executive Summary

Optimization of pulping

The conditions of pulping in laboratory scale have been optimized through the use of two main chemical processes (Soda-AQ and Kraft) to produce bleachable grade pulp of Kappa number 20, which is considered to be suitable for good quality paper. Good quality pulp was produced with yield in the range of 46%-48%.

Biopulping results

- Application of biotechnology in the chemical process reduces the Kappa number by 20%.
- Desired Kappa numbers can also be obtained by reducing the alkali charge by approx 9% in Soda-AQ-pulping.
- Cooking time can be reduced from 120 minutes to 60 minutes in the Kraft process and from 90 minutes to 60 minutes in the Soda-AQ process. As a result, mill throughput can be considerably increased.
- Physical properties of paper (burst, tear and tensile index) can be improved significantly (20-40%) in biopulping process thus obtaining a better quality paper.

Bleaching results

- Bleaching was conducted with the conventional bleaching sequences CEH- (Chlorine alkali hypochlorite), ECF (Elemental Chlorine Free)-Chlorine dioxide-alkali chlorine dioxide and TCF (Total Chlorine Free) sequences with and without enzyme.
- The target brightness of 80% ISO was achieved in most of the sequences.

The use of enzyme (xylanase) in the bleaching sequences reduces the chlorine requirement by 15%. Chlorine can be reduced by 30% if xylanase treatment is followed by alkali and by 40-45% if it is used in conjunction with oxygen.

Storing and Black Liquor Management

The results of the project show that jute black liquor is suitable for evaporation to high solid concentration and for further processing in the recovery boiler. It has high carbon content (38.1%), high calorie value (3438 cals/gram), low viscosity at high solid concentration and very low concentration of non-process elements concentrations. This makes it suitable for chemical recovery operations.

Whole jute is relatively free of fungal contamination if stored after drying at moisture contents below of 15%. In case of fungal attack, a number of fungicides are effective.

Pilot Scale and Commercial Trial

Optimization of pulping was followed by a large scale (14 MT) and a commercial trial (80 MT). In Bangladesh, whole jute plants were chipped using the available mill chipper after necessary adjustment. After the production of pulp, bleached paper was produced using the conventional sequence of bleaching (40-42 MT) in the existing paper machine. The quality of the resulting paper was found suitable for wrapping and different grades of writing paper. The physical properties of the unbleached and writing paper were superior to paper made from bamboo and tropical wood. These results were corroborated by a pilot scale trial conducted in India using chemical processing.

The original planned commercial scale trial for the production of chemical pulp from kenaf could not be performed as planned. Therefore it has not been possible to compare the pulp characteristics of jute and kenaf against each other. The inability to conduct such comparative study regarding the yield, cost and physical properties of paper from jute vis-à-vis kenaf is a shortcoming that needs to be addressed in the future. However, it is expected that jute can produce better pulp than kenaf, because the fiber (bark) to stick ratio is 1:2, whereas fiber (bark) to stick ratio of kenaf is around 1:3. Ultimate fiber length of bark of both kenaf and jute is around 2 mm whereas that of core is less than 1 mm. Moreover, the price of whole kenaf in Bangladesh/India is comparatively less. Therefore, it is perhaps a preferable raw material in terms of raw materials for the paper industry.

TMP process results

- The resulting pulp had weak mechanical properties. However, the pulp bleaching led to 70% ISO brightness with 5% hydrogen peroxide charge.

- A chelation stage was necessary prior to the bleaching stage. Furthermore, three commercial enzymes were tested prior to the bleaching stage with little effect.

APMP process results

- Pulps were obtained with different chemical charges resulting in pulp of mechanical properties suitable for newsprint papers. The brightness target of 60-65% ISO was achieved.
- The best chemical charge was 3% sodium hydroxide and 1% hydrogen peroxide for the impregnation stage and 3% hydrogen peroxide and 1.5% sodium hydroxide applied at the bleaching stage. These chemical charges can only be slightly reduced.
- The yield of mechanical pulping was 80%. This paper is suitable for newsprint.

High yield pulping experiments using extruder and refiner and as well as mechanical pulping trials by APMP process showed that refiner pulping of jute is superior to extruder pulping in terms of energy consumption, mechanical performance and structural performance of pulp and paper. On the other hand, extruder pulping of jute is superior to mechanical pulping in terms of opacity. Fungal pre-treatment of jute in the refiner mechanical pulping can reduce energy consumption by approximately 20-25% with improvement in strength properties and brightness.

APMP pulp was shown to be much stronger and brighter than thermo-mechanical pulp and can be used for newsprint paper. The yield of pulp was around 80% and the brightness 60-65% ISO.

Economic pre-feasibility study

The study concluded that:

1. The sale of fine paper from chemical pulp and newsprint paper from mechanical pulp in the Bangladesh domestic market is the best option if it is supported by government through reduction or exemption of import taxes for chemicals and/or financial assistance on VAT, Corporate Tax, etc. The construction of Pulp Mill in the EPZ may constitute such government assistance.

2. Production of paper and pulp from kenaf under the current conditions prevailing in India seems to be the most attractive commercial option.

3. A more detailed feasibility study is necessary in order to validate the numerous assumptions that were made in the study (e.g. prices of raw materials, inland freight, interest rate, local tax and sales prices for pulp and paper, etc.) assumptions, and also include costs of cultivation, the logistics of storing the raw materials as well as market demand.

PROJECT COMPLETION REPORT (PCR)

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (THE WHOLE PLANT)

I. Project Summary

1.1 *Project Title:* Biotechnological Application of Enzymes for Making Paper Pulp from Green Jute/Kenaf (The Whole Plant)

1.2 *Number:* FC/RAS/001/153

1.3 *Project Executing Agency (PEA):* United Nations Industrial Development Organization (UNIDO)

1.4 *Location:* Bangladesh, China, India, France and the Netherlands

1.5 *Starting Date:* 01.01.2001

1.6 *Completion Date:* 31.05.2004

1.7 *Financing:*

Total Project Cost: US$ 1,493,260

CFC Financing (Grant): US$ 888,260

Co-financing by other donors: Government of France US$ 110,000 European Commission and Government of Bangladesh US$200,000

Counterpart contribution from participating countries/institutes: US$295,000

The details of the counterpart contributions from participating institutes are:

International Jute Study Group (IJSG)	US$ 10,000
Bangladesh Jute Research Institute (BJRI), Bangladesh	US$ 30,000
Bangladesh Chemical Industries Corporation (BCIC), Bangladesh	US$ 70,000
Institute of Bast Fiber Crops (IBFC), Yuanjiang (Hunan), China	US$ 20,000
Centre Technique du Papier (CTP), France	US$ 50,000
Central Pulp and Paper Research Institute (CPPRI), India	US$ 55,000
Agrotechnology & Food Innovations (A&F), The Netherlands	US$ 60, 000
	Total US$ 295,000

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (WHOLE PLANT)

I- Project Summary

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (WHOLE PLANT)

II – Background & Context

PROJECT COMPLETION REPORT (PCR)
BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (THE WHOLE PLANT)

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II. Background and Context in which the Project was Conceived

Conventional jute and kenaf products are now facing severe competition due to the emergence of synthetic substitutes. The diversification of jute/kenaf uses is very much of an imperative for the survival of the jute/kenaf industry. Demand for pulp and paper has increased significantly in the jute/kenaf growing countries, while their limited forest resources are further dwindling. The substitution of conventional raw material for pulp and paper by jute and/or kenaf would be both timely and beneficial to the rural economy and the environment.

Jute fiber is traditionally manufactured into final products through methods involving spinning and weaving. Compared to technologies adopted for other fibers and textile industries, jute production and processing techniques have remained very much unchanged. The traditional jute products' markets such as packaging materials for agricultural products (including sacks, bags, carpet backing cloth, packaging for fertilizers, cement and chemicals) are being eroded by the use of products based on synthetic substitutes. Diversification of the uses of jute by identifying major new market outlets is therefore essential to fend off further decline of the jute sector. One alternative to which a great deal of attention had been given in the recent past is the possible utilization of jute and/or kenaf in pulp and paper production. Extensive research at various institutes and pulp and paper mills indicates that most conventional pulping techniques are suitable for jute/kenaf pulping.

Annual world production of jute and allied bast fiber (kenaf) is around 3 million tons (**Table 1**). In addition to fiber, 6.5 million tons of sticks are also produced. Therefore, subject to meeting several technical and economic criteria, surplus jute/kenaf production can be directed for the paper industry.

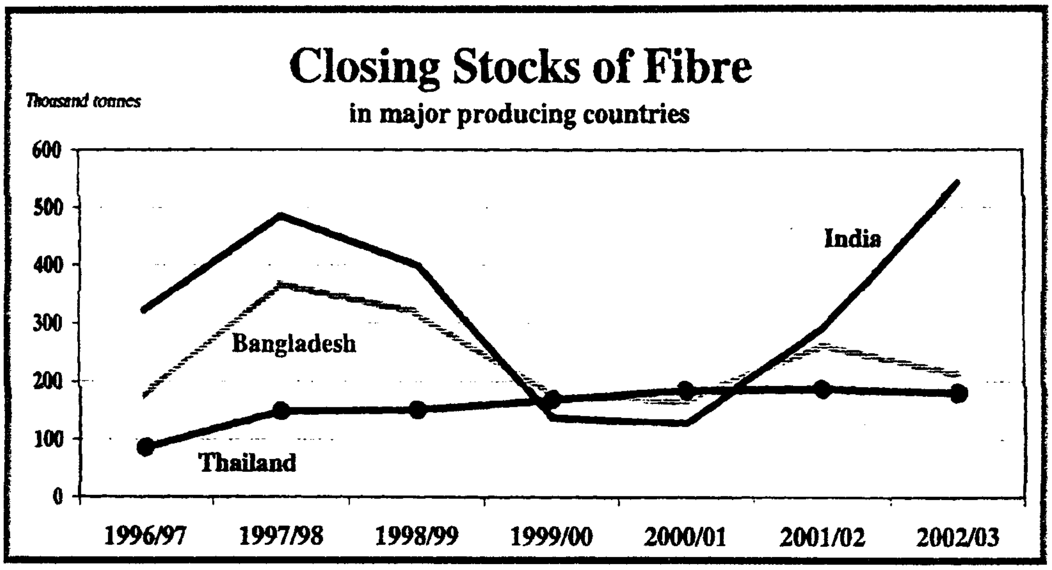
Table 1: World Production of Jute and Kenaf

Country	Area '000 ha	Jute ('000 MT)		Kenaf ('000 MT)	
		Fiber	Stick	Fiber	Stick
World	-	2,612.7	5,225.4	433.7	1,301
Bangladesh	426	777	1,554	--	--
India	1070	1,778	3,556	202	606
China	56	--	--	130	390
Thailand	19	--	--	30	90
Nepal	11	16	32	--	--

Source: *FAO, jute, kenaf and allied fibers June 2003. CCP: JU/HF/ST/2003/1.

**Calculated from Dempsey James, M. Fiber Crops, 1975. A University of Florida Book

The statistics of the last five years of closing stocks of fiber in major producing countries, like, Bangladesh and India show that fiber is available at the end of each season. This surplus jute can, in theory, be used for the pulp and paper industry.



Source: FAO - CCP: JU/HF/ST/2003/1.

The project specifically aims at developing biotechnological processes, which would be applicable in processing of jute into pulp and paper products, i.e. biopulping for the pretreatment of the raw material and enzyme-aided bleaching for achieving reduction in chemical and/or energy consumption. These processes are virtually unpracticed in the pulp and paper industry in the developing world albeit the fact that the use of biotechnology in the sector has been reported to have significant economic and environmental advantages[1]. Of the process stages studied and developed, the application of enzymes in bleaching are already being used in several mills worldwide (producing 500-1000 tons of pulp/day), whereas the biopulping technology has so far only been tested in pilot trials in quite large scale (about 50 tons/day)[2].

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1 Dr. G.M.Scott, Dr. M. Akhter and Dr. T.K.Kirk, "An update on Biopulping Commercialization", TAPPI 2000 Pulping/Process & Product Quality Conference, Nov. 5-8, 2000, Boston, USA.

2 Dr. Liisa Viikari, "Enzymes in the Pulp and Paper Industry", TAPPI 2000 Pulping/Process & Product Quality Conference, Nov. 5-8, 2000, Boston, USA.

One of the main objectives of the project is the identification of the most promising biotechnological processes by comparing them against the standard chemical and mechanical pulp manufacturing processes employed by the industry and assessing their applicability in the context of opportunities and capacities of jute-producing countries in the developing world.

Conventional pulping is the process by which wood is transformed into a fibrous mass. Existing commercial processes are generally classified as mechanical, chemical or combined (chemical and mechanical).

Chemical pulping

Chemical pulping accounts for 75% of the world pulp production of which 90% is produced by the dominant Kraft process. The objective of chemical pulping is to degrade and remove all of the lignin thus leaving behind most of the cellulose and hemicullose in the form of intact fibers. In practice chemical pulping methods are successful in removing most of the lignin; they also degrade certain amount of hemicelluloses and cellulose so that the yield of pulp is low compared to mechanical pulping, usually between 40 and 50% of the original raw materials. In chemical pulping, the wood chips are cooked with the appropriate chemicals at elevated temperature and pressure. The two principal methods are alkaline kraft process and the acidic sulphite process. The kraft process is dominant because of advantages in chemical recovery and pulp strength.

Mechanical pulping

Until recently, the most common method of mechanical pulping was the ground wood processes where a block of wood is pressed lengthwise against a grinding stone. This has been superseded by what is known as the Refiner Mechanical Pulping (RMP). This process involves shredding and grinding chips of woods between the rotating disk of the refiner. RMP has undergone substantial development in the past few years. New installations now employ thermal (and/or chemical) pre-softening of the chips to modify both the energy requirements and pulp properties. For example, Thermo Mechanical Pulp (**TMP**) is usually much stronger than RMP and contains very little screen reject material. Mechanical pulping processes have the advantage of converting up to 95% of the dry weight of the wood into pulp, but they require substantial amounts of energy to accomplish this. However, mechanical pulps form opaque paper with good printing properties but the sheet is weaker than chemical pulps and discolours easily on exposure to light because of the high lignin content.

Traditionally, newsprint-quality paper has been produced by mixing 75% ground wood and 25% chemical pulp although more recently the percentage of chemical pulp has been further reduced. In industrialised countries newsprint-quality paper is nowadays made out of combinations between TMP and recycled paper. At present, several mills produce newsprint-quality paper consisting of 100% recycled material.

TMP processes have been augmented by the addition of sodium sulphite, in a process, called chemi-thermo-mechanical pulping (CTMP), or by addition of NaOH instead of sodium sulphite. These latter pulps are called alkaline-thermo-mechanical pulps (ATMP).

The latest development is to replace sulphite by alkali and peroxide, which is more environments friendly. This process is known as alkaline-peroxide-mechanical-pulping (APMP). Mechanical pulping has the disadvantage of being capital and energy intensive and yields paper of lesser strength. These disadvantages limit the use of mechanical pulping in some grades of paper only. Increasing environmental awareness has made it necessary to investigate methods for reducing the amount of energy, sulphur and chlorine containing compounds. This has led to the development of biopulping and biobleaching.

Biopulping

Biopulping is defined as the treatment of wood or other lingocellulosic material with natural lignin-modifying/degrading fungi prior to pulping. Pre-treatment of chips reduce the energy requirement (in mechanical pulping), chemical requirement and cooking time (in chemical processes) and improve the handsheet physical properties.

Research work and mill trials until now have been focused on the application of enzymes for the pulping and bleaching of wood. The application of enzymes has shown encouraging results regarding their efficiency vis-à-vis other traditional bleaching techniques. Biobleaching allows substantial savings in overall chemical costs and reduces chlorinated organic materials in pulp and effluents thus providing an attractive alternative to conventional processes.

The application of biotechnological methods on wood has been shown to reduce energy consumption by 20 to 30% and improve the burst and tear indices. Application for bio-technological methods on wood in the chemical process of pulping[3] and bleaching has also been reported to reduce chemical consumption and cooking time. Reduction of chemical consumption would have positive impact on the environment by minimizing the levels of Absorbable Organic Halide (**AOX**) and chlorides in the bleaching plant effluents. On the other hand, enzymes could effect selective changes in pulp and paper properties, which would provide market advantages and benefits to the pulp and paper industry[4].

Jute and kenaf, being annual crop, could be used as a raw material to substitute hard and softwood (e.g. bamboo, bagasse etc.) for making pulp and paper. Green jute and kenaf are known to have higher content of pentosans (xylans) than hardwoods and softwoods. The use of enzymes such as xylanases has been shown to improve bleaching by facilitating the reaction of the bleaching chemicals with lignin. Studies also demonstrated that the treatment with enzymes is more efficient in terms of reduction of chemical requirements and emissions for hardwood than for softwood pulps. As green jute has more pentosans (20% to 25%) than hardwoods (12% to 18%), it is reasonable to expect that the results of enzyme treatment of green jute or green jute pulp would be at least as good as or better than those obtained with hardwoods.

As early as 1994/1995 BCIC conducted commercial production trials of pulp from green jute plant in four paper mills. During these trials a number of problems were encountered relating to chipping and storing of green jute and deterioration of the quality of the pulp.

Whole kenaf pulping has been conducted in Thailand and China and studies on the production of Chemo-Thermo-Mechanical Pulp (CTMP) from whole kenaf conducted in the USA and Canada

[3] Paper Age February, 1991

[4] Lew Christov, "Potential of some hydrolyzing and oxidative enzymes for pulp and paper production and modification", TAPPI 2000 Pulping/Process & Product Quality Conference, Nov. 5-8, 2000, Boston, USA

have demonstrated that exceptionally high quality pulp can be produced at a production cost lower than that of the typical pine thermo-mechanical pulp[5]. Studies on the production of newsprint paper have been carried out in India and the properties of the sheets were comparable to commercial newsprint[6].

Jute pulping through the application of biotechnological methods, if proven economically and technically feasible, will open up a potentially large market which might absorb not only the existing surplus production of jute in the producing countries, but may also require additional production capacities to meet growing demand of jute fiber with wider implications for the farming and working populations in terms of generating additional job opportunities and incomes.

The broad objective of the project was, therefore, to develop biotechnological applications of enzymes for the large-scale production of pulp with a view to opening up new market outlet for jute while, at the same time, reducing the production costs through energy savings and the polluting effects of chemical effluents.

The Key Commodity Issues Addressed and their Relevance to the Strategy of the Sponsoring International Commodity Body (ICB):

The sponsoring ICB recognizes the importance of promoting alternative uses of jute in view of the shrinking market share in the traditional jute products sectors in order to maintain and/or enhance the income of poor farming populations, generate additional job opportunities through the generation of demand for the oversupply of fibers, and substitute the sharply increasing imports of pulp by pulp produced from domestic resources.

[5] Jon G. Udell, "General feasibility study: keaf newsprint system", American National Publication Association, University of Wisconsin, USA, September 1980.
[6] Dr. A. Panda, « Need for technological improvements in processing of jute and kenaf fiber for pulp and paper making", National Consultant, UNDP, CPPRI, India

Development Objective

To assess the technical and economic feasibility and environmental sustainability of biotechnological processing of jute and kenaf for the commercial production of high-quality pulp and paper.

Specific Project Objectives and Expected Outputs:

Objective - 1: To identify and collect micro-organisms and processes currently being used in different pulp and paper mills and select suitable ones for jute biopulping

Expected Output:

- Comparative study to identify suitable micro-organisms and processes for jute biopulping.
- Collection of micro-organisms used for biopulping of wood.
- Selection of micro-organisms for biopulping and biobleaching of jute.
- Selection of microbial strains that will mostly satisfy the overall objective of the project.

Objective - 2: Determination of optimal biopulping and biobleaching conditions

Expected Output:

- Procedures for the production of enzymes and their application in preparing handsheets.
- Optimization of pulping in chemical and mechanical processes.
- Reduction of chemical and energy inputs in the chemical and mechanical pulping through the application of bioprocesses.
- Reduction of toxic chemical effluents by biobleaching.

Objective - 3: To manage the black liquor produced during pulping and effluents generated during bleaching and identify suitable methods for green jute storage

Expected Output:

- Reduction of discharges of hazardous chemical effluents.
- Identification of appropriate storage conditions for green jute/kenaf.

Objective - 4: Large-scale trial application of enzymes

Expected Output:

- Pilot and commercial scale trial of chemical pulping to produce unbleached and bleached paper.
- Writing paper of brightness above 80% ISO.
- Pilot scale trial of mechanical pulping for the production of newsprint grade paper with brightness above 60% ISO.
- Preliminary assessment of the techno-economic viability of the developed bioprocesses.

Objective - 5: Dissemination of results and completion of the project

Expected Output:

- Draft project completion report (PCR)

Targeted Beneficiaries and Extent of Benefits

Bioprocesses are expected to generate new opportunities for the jute industry thus sustaining demand for raw jute/kenaf and stabilizing prices with concomitant increase of farmers' income. The paper and pulp industry is expected to benefit from the reduction of costs and application of environmentally sustainable processes.

The primary beneficiaries of this project will be the main jute/kenaf producing countries. In particular the project will benefit marginal and small farmers of rural communities involved in jute/kenaf production and utilization. Potentially, a larger number of countries would also derive benefits from technology transfer emanating from the project.

Project –Budget

The total fund allocation for the project was US$ 1,493,260 of which the Common Fund for Commodities contributed US$ 888,260. The Governments of France and Bangladesh contributed US$110,000 and US$ 200,000 respectively. The participating institutions made in-kind contributions worth US$ 295,000.

Management and Implementation Arrangements

The Consultative Committee of CFC, at its 20th Meeting held from July 28 to August 1, 1997, reviewed the project proposal on "biotechnological application of enzymes for making paper pulp from green jute/kenaf (the whole plant)" and recommended it for approval. The Common Fund for Commodities (CFC), the International Jute Organization (now IJSG) and the United Nations Industrial Development Organization (UNIDO) signed an implementation agreement in 1999. UNIDO was assigned as the Project Executing Agency, hereinafter referred to as **PEA**. The International Jute Study Group, Bangladesh, (IJSG), was assigned as the supervisory body. A Project Leader was appointed from January 2001 to supervise the overall technical activities of the project in consultation with the PEA.

The project involved collaboration of the following parties:

Bangladesh Chemical Industries Corporation (BCIC)
Institute of Bast Fiber Crops, China, (IBFC)
Central Pulp and Paper Research Institute, India, (CPPRI)
Centre Technique du Papier, France, (CTP)
Agrotechnology & Food Innovations, The Netherlands, (A&F)

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (WHOLE PLANT)

III– Project Implementation

III. Project Implementation and Results Achieved

1. Project Implementation

Preparation, efficiency and effectiveness of project implementation including project management

The project was formally initiated in January 2001 through the signing of Memoranda of understanding between the PEA and the five parties specifying the terms of reference for the specific activities to be undertaken by each party. These are summarized in the table below.

No.	Activities	Institutes
A	Identification of microorganisms and inventory of processes currently used in pulp and paper mills and selection of suitable strains for jute biopulping.	BCIC
B	Comparative studies of different microorganisms used in various pulp and paper mills in Europe, USA, and Canada.	BCIC
C	Optimization of pulping in chemical process.	BCIC, CPPRI, CTP & IBFC
D	Biopulping in chemical and mechanical process.	BCIC, CPPRI, A&F and IBFC
E	Bleaching with and without enzyme in various sequences.	BCIC, CPPRI, CTP, A&F and IBFC
F	Management of black liquor and effluent management.	CPPRI and A&F
G	Storing of green jute/kenaf	IBFC
H	Pilot scale trial (chemical/mechanical)	A&F, CTP and CPPRI
I	Large-scale trial.	BCIC

Some adjustments of the above work plan was deemed necessary as a result of project exigencies in accordance with the decision of the mid-term review meeting, which was held in December 2002. Prior to the mid-term review meeting an independent reviewer was appointed by CFC, in 2002, to review progress and recommend actions. The work plan for 2003 was thus amended taking into account the recommendations of the independent reviewer and the exigencies of the project. Accordingly, it was decided that activities for 2003 would involve:

Mechanical Pulping

Mechanical pulping for newsprint grade pulp out of whole jute would be through the Alkaline Peroxide Mechanical Pulping (APMP) the latter being optimized and fine tuned by CTP and A&F.

Chemical Pulping

Commercial trials would be conducted in Karnaphuli Paper Mills Limited (KPM) (using whole jute) and in IBFC (using whole kenaf), while pilot scale trials would be conducted at CPPRI.

Biobleaching

BCIC under the supervision of the PL would conduct bleaching trials with various commercial and developed enzymes at CTP. These trials should be replicated at KPM, CPPRI and IBFC.

2. Project Results

OBJECTIVE 1:

To identify and collect micro-organisms and processes currently being used in different pulp and paper mills and select suitable ones for jute biopulping.

Target

- Inventory of processes currently being used in research institutes and paper mills.
- Isolation and collection of suitable microorganisms for biopulping.

Results Achieved

- Microorganisms suitable for biopulping were identified (**Annex–2, Appendix–F & G**).
- Nine (9) strains were selected for biopulping out of twelve (12) strains that were isolated (in Bangladesh and India) and collected (from USA and Europe) strains.

- 3 strains were selected for the production of xylanase for biobleaching. The experimental procedure is shown in **Annex–2, Appendix–A**.

OBJECTIVE 2:

Determination of optimal biopulping and biobleaching conditions

Target

A. To produce bleachable grade pulp of Kappa No. 20 (considered to be suitable for good quality pulp) by two chemical processes. (Soda-AQ and Kraft process).

Assigned Institutes: IJSG/BCIC, CPPRI, CTP and IBFC (Kenaf)

B. Application of biopulping in chemical/mechanical processes to reduce chemical requirements, cooking time and energy.

Assigned Institutes: IJSG/BCIC, A&F, CPPRI and IBFC

C. To achieve brightness of 80% ISO while reducing the chemical requirements in various bleaching sequences by the application of commercial and locally isolated enzymes.

Assigned Institutes: BCIC, CPPRI, CTP and IBFC

D. To achieve brightness above 60% ISO suitable for newsprint paper in the mechanical pulping with and without commercial enzyme.

Assigned Institutes: A&F and CTP

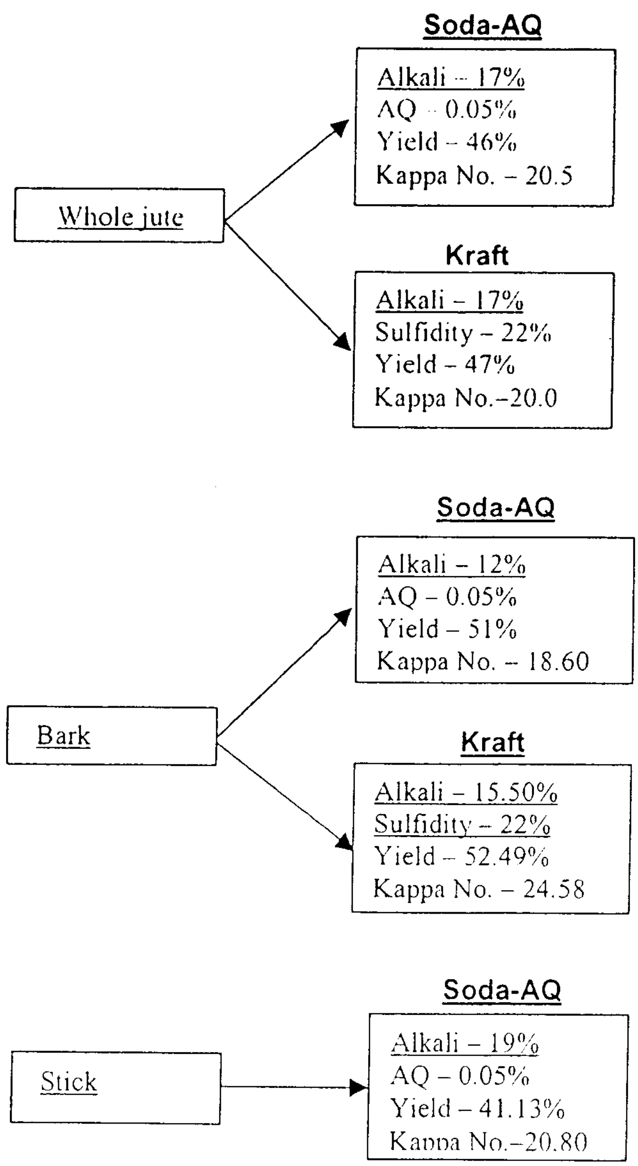
Results Achieved

A. Optimization of Pulping

A number of experiments were conducted at Karnaphuli Paper mills, BCIC (Bangladesh Chemical Industries Corporation), CTP (Centre Technique du Papier), CPPRI (Central Pulp and Paper Research Institute) and IBFC (Institute of Bast Fiber Crops) to produce pulp with Kappa No. 20 in order to optimise the conditions of pulping, by varying the liquor ratio with jute chips in the Soda-AQ process and the requirements of alkali in both the Soda and Kraft processes.

Bangladesh Chemical Industries Corporation (BCIC): Alkali as Na_2O

BCIC optimized the pulping conditions in both Soda-AQ and Kraft process using whole jute, bark and stick. The results below show that it is possible to obtain the desired Kappa No. 20 in both Soda-AQ and Kraft processes.

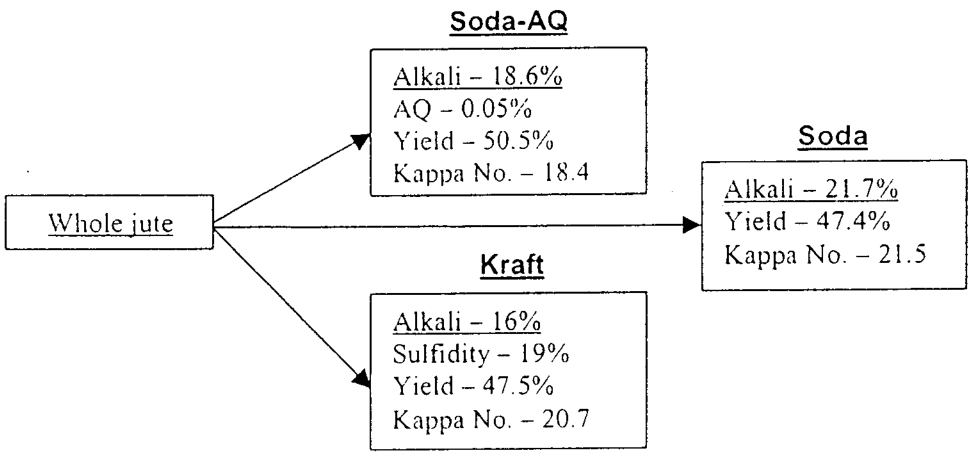


- Cooking temperature for both Soda-AQ and Kraft processes – 170°C.
- Cooking time for Soda-AQ process – 90 Minutes and for Kraft process – 120 Minutes.

The experimental details are shown in **Annex 2 – Appendix–B**

Central Pulp and Paper Research Institute (CPPRI): Alkali as Na_2O

CPPRI optimized the conditions of pulping in Soda, Soda-AQ and Kraft processes. In Soda-AQ process bleachable grade pulp of Kappa No. 18.4 was obtained. Similarly bleachable grade pulp of Kappa No. 20 was obtained in Kraft process using 16% alkali (Na_2O) and 19% sulfidity. The conditions for the optimization of pulping using whole Jute in Soda-AQ, Soda and Kraft processes are shown below.

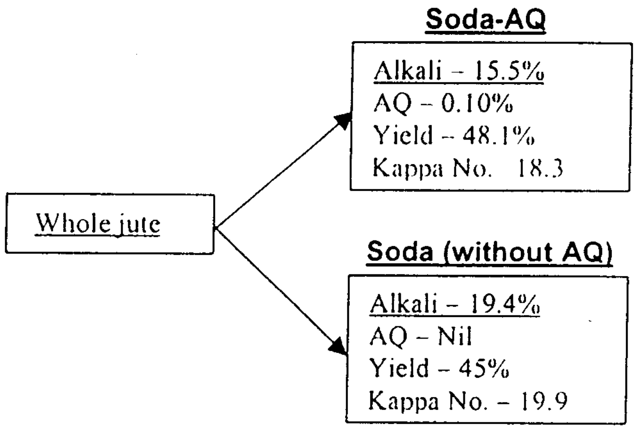


- Cooking temperature for both Soda-AQ and Kraft processes – 165°C.
- Cooking time for Soda-AQ and Kraft processes – 90 Minutes.

(Ref.: Annex 3 – table 8, 9 and page 10)

Centre Technique du Papier (CTP), France: Alkali as Na_2O

CTP optimized the pulping conditions in Soda-AQ and Soda (without AQ) process. The results given below show that higher yield (3% more) and lower Kappa number were achieved with the Soda-AQ processed as compared to the Soda process.

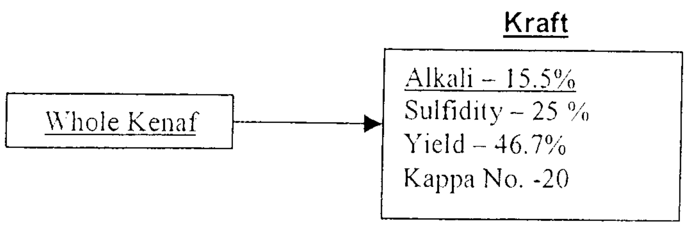


- Cooking temperature for both Soda-AQ and Soda (without AQ) processes – 170°C.
- Cooking time for both Soda-AQ and Soda (without AQ) processes – 120 Minutes

(Ref.: Annex 4 – table 1)

Institute of Bast Fiber Crops (IBFC): Alkali as Na_2O

IBFC also optimized the pulping conditions in the Kraft process using whole Kenaf. The results achieved from the optimization of pulping at IBFC is as under:



- Cooking temperature for Kraft process – 170°C.
- Cooking time for Kraft process – 55 Minutes

(Ref.: Annex 5)

The results of the pulping optimization-experiments are summarized in **Table 2** below.

Table 2: Summarized results of the optimization of chemical pulping

Stages	Soda-AQ				Kraft			
	Na_2O (%)	AQ (%)	Yield (%)	Kappa No.	Na_2O (%)	Sulfidity	Yield (%)	Kappa No.
BCIC – Whole Jute	17	0.05	46	20.5	17	22	47	20.0
BCIC- Bark	12	0.05	51	18.60	15.50	22	52.49	24.58
BCIC- Core	19	0.05	41.13	20.80	-	-	-	-
CPPRI – Whole Jute	18.6	0.05	50.5	18.4	16	19	47.5	20.7
CTP – Whole Jute	15.5	0.10	48	18.3	-	-	-	-
IBFC – Whole Kenaf	-	-	-	-	15.5	25	46.7	20

Soda AQ process: optimization of cooking conditions

- 170^{0}C for 90 minutes (BCIC)
- 165^{0}C for 90 minutes (CPPRI)
- 170^{0}C for 120 minutes (CTP)

Kraft process: optimization of cooking conditions

- 170^{0}C for 120 minutes (BCIC)
- 165^{0}C for 90 minutes (CPPRI and BCIC)
- 170^{0}C for 55 minutes (IBFC and BCIC)

B. <u>Biopulping Experiments</u>

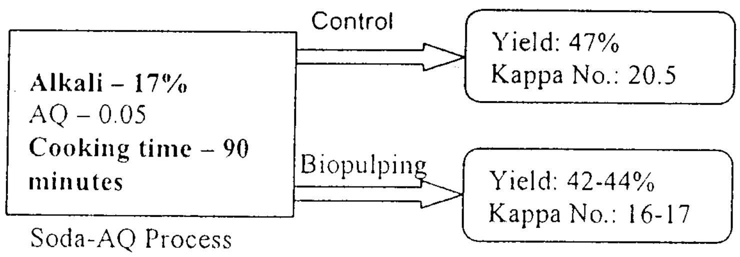
Biopulping experiments were conducted in conjunction with both chemical and mechanical processes. The findings of the experiments are summarized below.

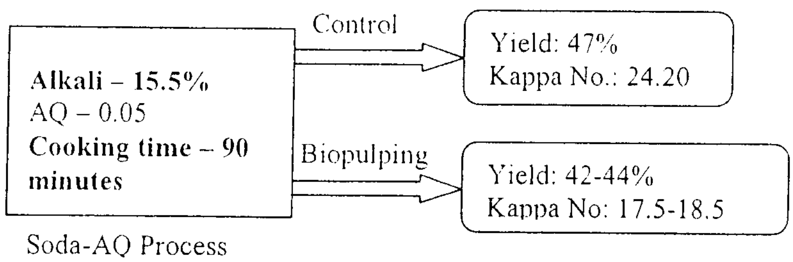
Biopulping in conjunction with the chemical process
Experiments conducted at BCIC and CPPRI

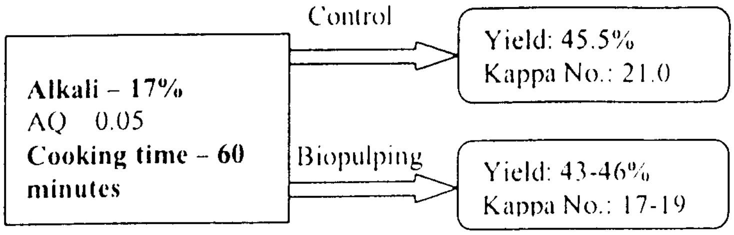
With the optimum conditions obtained at Karnaphuli Paper Mills Ltd., 61 biopulping experiments were conducted for bleachable grade pulp of Kappa No. 20 using 4 strains of *P. chrysosporium*, 2 strains of *C. subvermispora*, one strain of *F. lignosus* and 2 strains of ST (two unidentified microbial strains from CPPRI) in conjunction with both the Soda-AQ and Kraft processes.

In the Soda-AQ process, both the amount of alkali and cooking time were varied; while in the Kraft process only the cooking time was varied. Out of the nine strains, *F. lignosus* and *C. subvermispora* were found to be suitable for biopulping in both the Soda-AQ and Kraft processes.

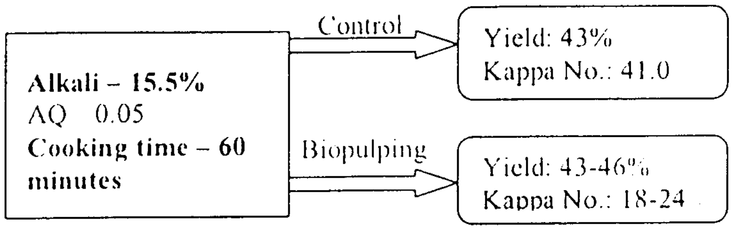
The average optimized results of the two strains in the biopulping process as well as the results of the control process are shown in the following diagram.



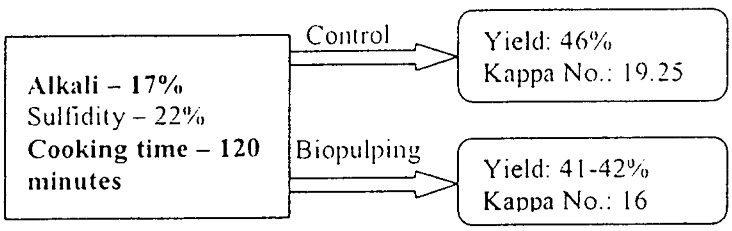




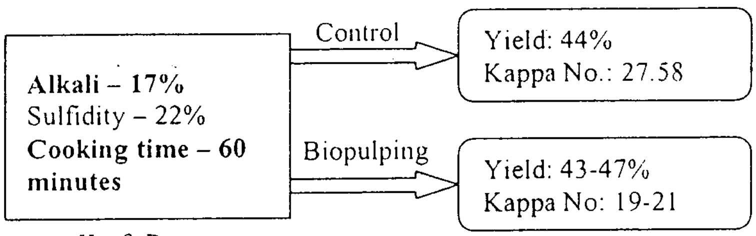
Soda-AQ Process



Soda-AQ Process



Kraft Process



Kraft Process

The results of the biopulping process can be summarized as:

- The Kappa number can be reduced by approximately 20% at the same cooking condition in both the Soda-AQ and Kraft processes. ***(Source: Annex-2, Table 15, 17 and 20).***
- The desired Kappa number (20) can also be obtained by reducing the alkali charge by 9%.
- Cooking cycles can be increased facilitating more throughputs in the existing mills.

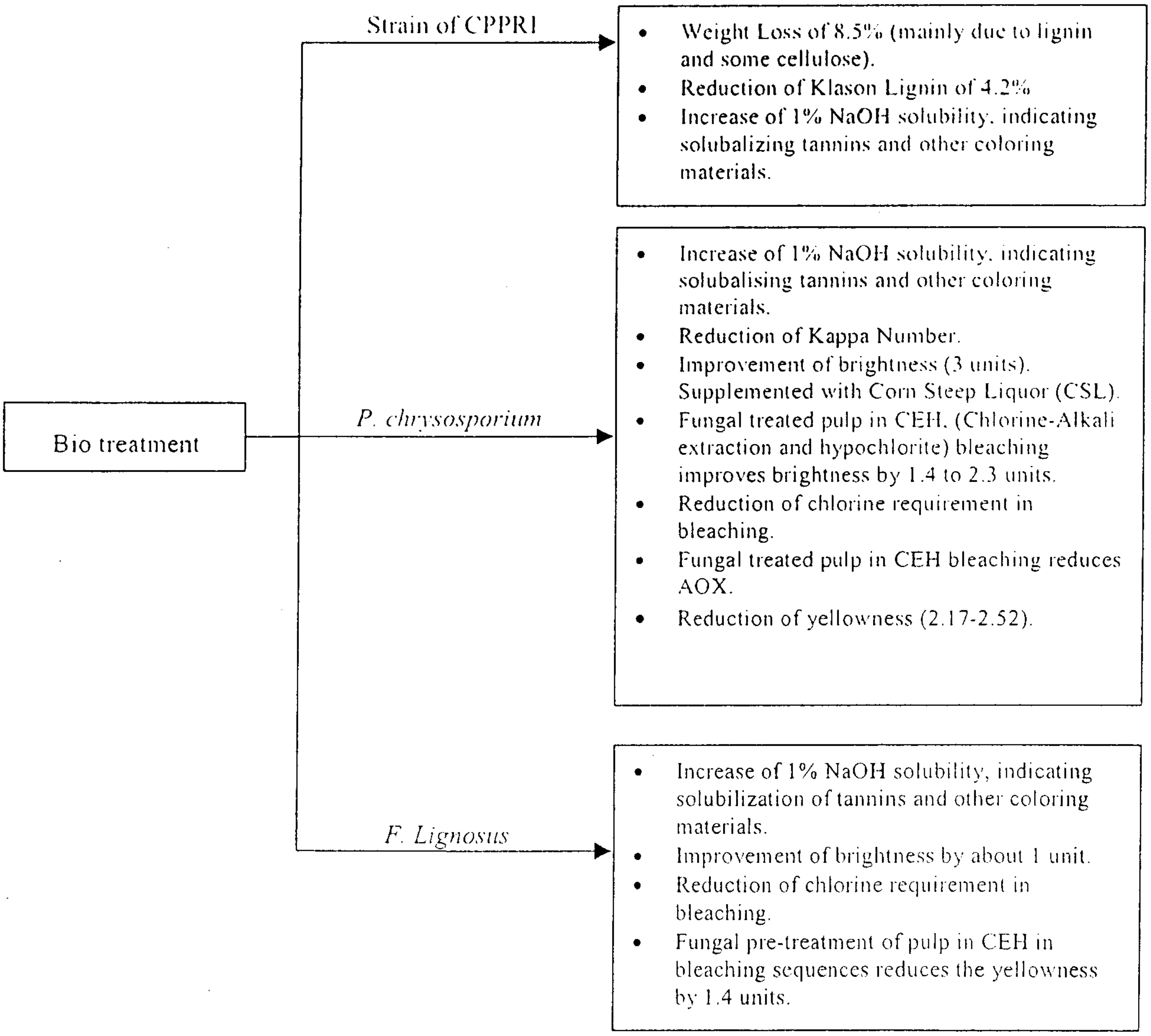
- The physical properties of paper (burst, tear and tensile indices) can be improved significantly (20-40%).

The details on the experimental procedure are shown in ***Annex 2, Appendix-C***.

<u>CPPRI</u>:

Biopulping experiment were conducted at CPPRI on whole jute using CPPRI – 1 and screened strains of IJSG, ***Phanerochaete chrysosporium*** **(PC)** and ***F. lignosus*** **(FL)**.

The figure below summarizes the experiment results:

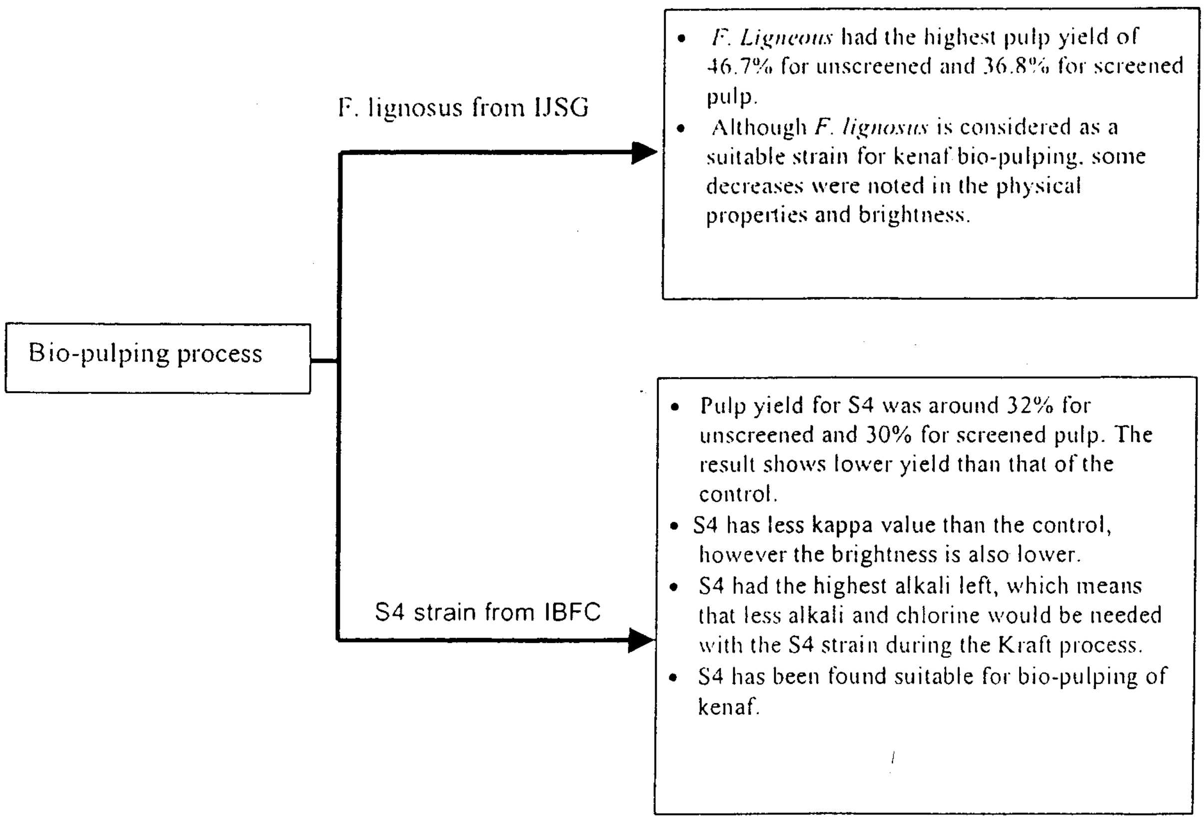


(Ref.: Annex 3 – table 10, 11, 12, 13, 14, and 15)

IBFC:

IBFC found 2 microbial strains, S4 (isolated by IBFC) and *F. lignosus* (collected from IJSG), suitable for biopulping of kenaf. The treated kenaf was found more suitable for mechanical pulping than the untreated controls.

There has been some difficulty in quantifying conclusively the effect of different strains during the biopulping process. Essentially, each enzyme responded differently to different treatments. The overall qualitative conclusions are summarized in the figure below.



(Ref.: Annex 5 – Figure 6, 7 and 8)

Biopulping in conjunction with the mechanical process

Experiments conducted by A&F

The F. lignosus strain supplied by the project leader was used. The findings on the effect of incubation time and the F. lignosus pre-treatment on simulated (PFI-mill) Refiner Mechanical Pulp (RMP) of green jute are summarized in the following.

- Pre-treatment of simulated RMP green jute pulp with F. lignosus results in 10 to 20% savings in energy at the same level of pulp strength properties or beating degree and a 1 to 3% ISO higher brightness.
- Treatment with *P. chrysosporium* leads to higher strength properties than with *F. lignosus* at equal beating degree.
- Incubation time of the fungus of 12 to 14 days has greater effect on the beating degree and strength properties as compared to incubation time of 10 days with no decline of the pulp quality. Losses due to fungal treatment are about 12.3%. These losses may be due to the degradation of lignin and cellulose.

(Ref.: Annex 1:page-62 and 64)

In a further study, simulated Alkaline Peroxide Mechanical Pulps (APMP) produced in a PFI mill and pre-treated with the fungus *F. lignosus* showed no statistically significant differences between treated and untreated pulp . However, additional small-scale experiments with more homogeneous size distribution and a further reduction of jute to smaller pieces results in significant differences. Size reduction followed by an additional coarse refining step in 12 inch refiner leads to more uniform dimensions of the shortened jute, a more homogenous mixture of jute bast and core, 2.7% higher brightness and an easier running of the PFI-mill. In this refining stage 100 kWh per ton was used. The results of the experiments are highlighted below:

- The simulated APMP-process consumes about 25% less energy and results in better paper properties than the RMP process, whereas the fungal treatment saves at least an additional 5%.
- The losses caused by the consecutive treatments are 16.4 % for the untreated and 21.7% for the fungal-treated green jute. The difference between treated and

untreated jute is much smaller than with the RMP process. Apparently most of the mass that is degraded by fungi is also removed by bleaching. This means that the main part of the losses caused by the fungal treatment is also removed in the bleaching step.

- The alkaline peroxide treatment raises the brightness of both the treated and untreated pulp to a level of 60 to 65% ISO. No clear effect of the treatment on the brightness could be measured above this level.

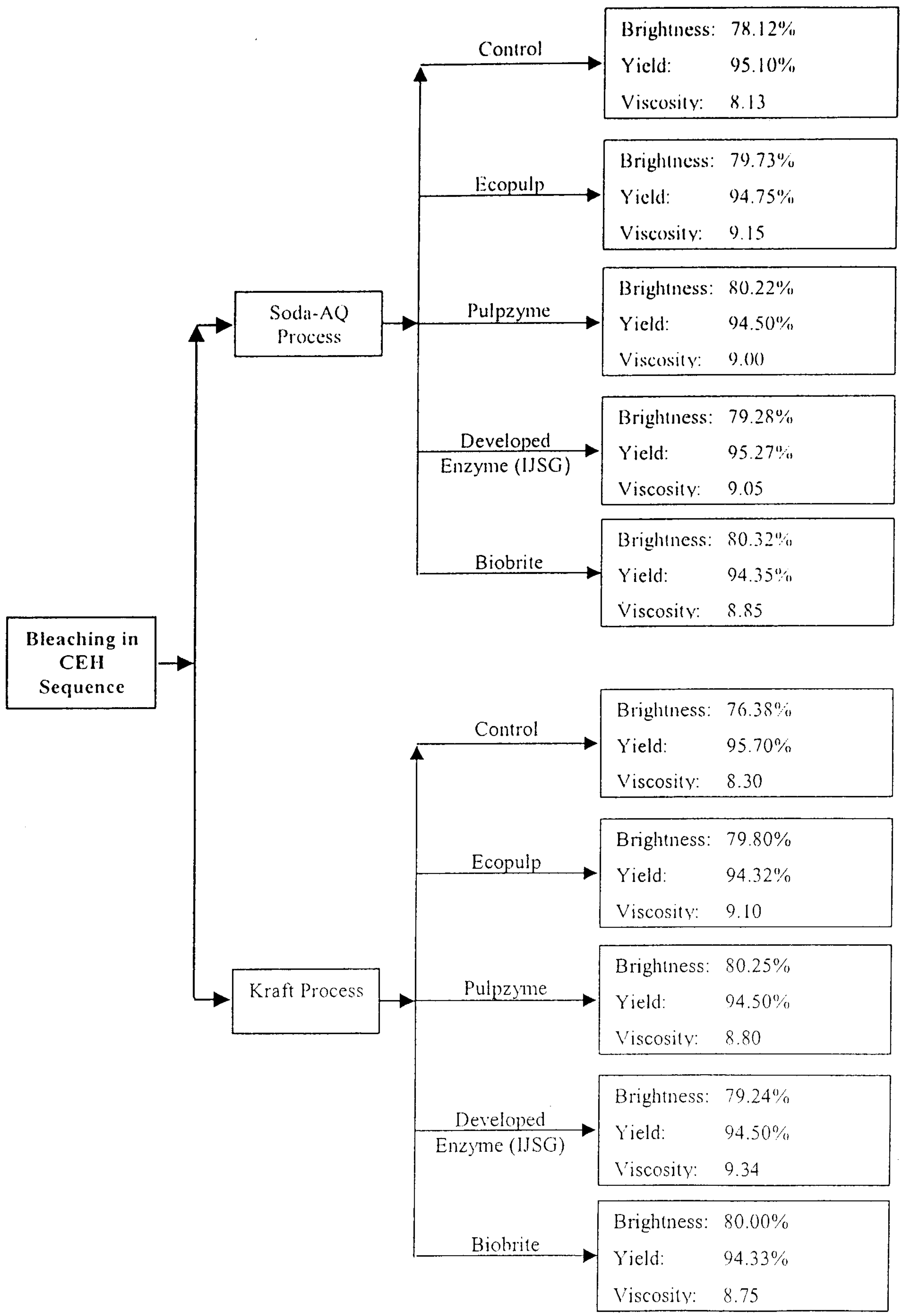
(Ref.: Annex 1: page-71-74)

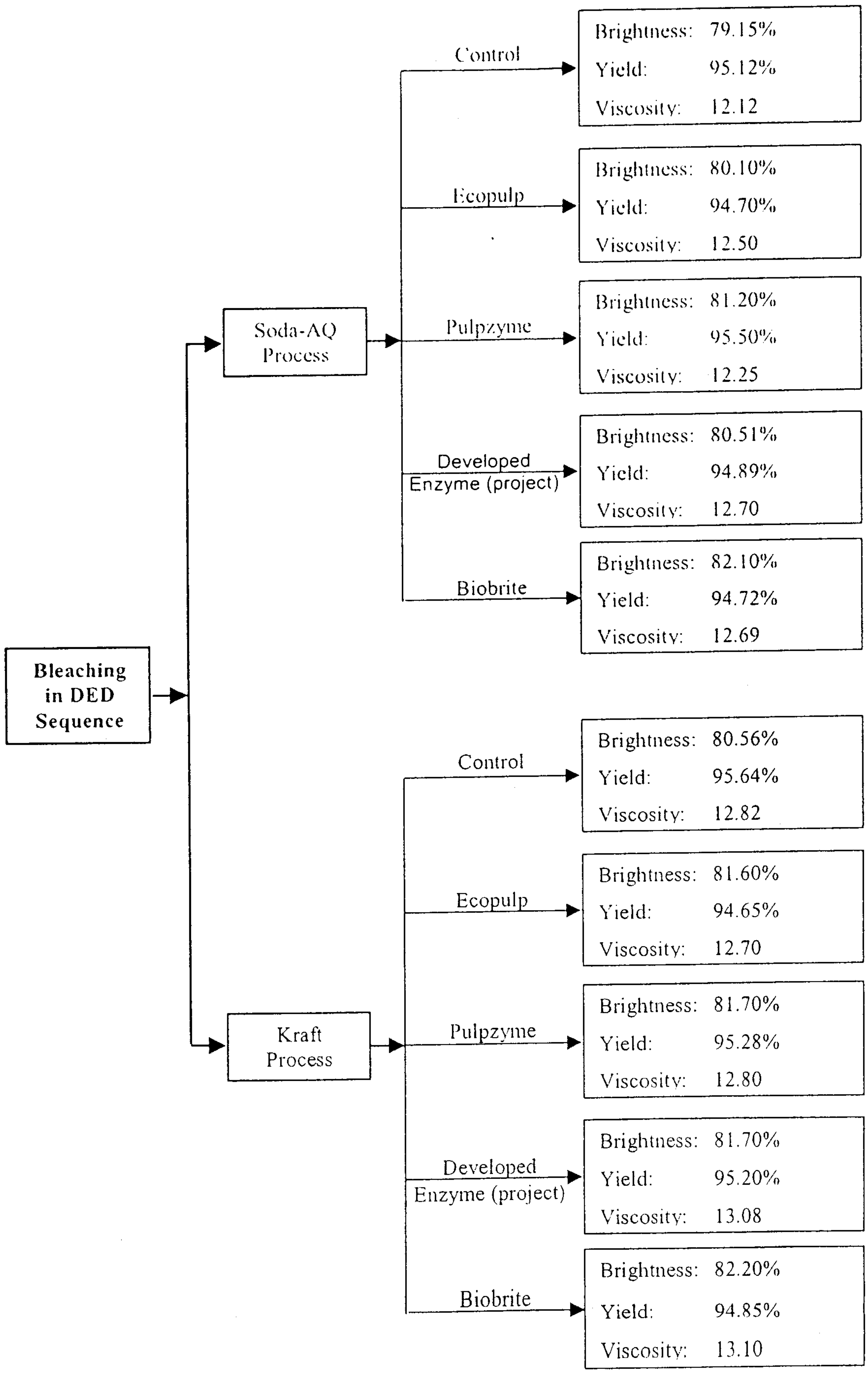
C. ***Bleaching Experiments:***

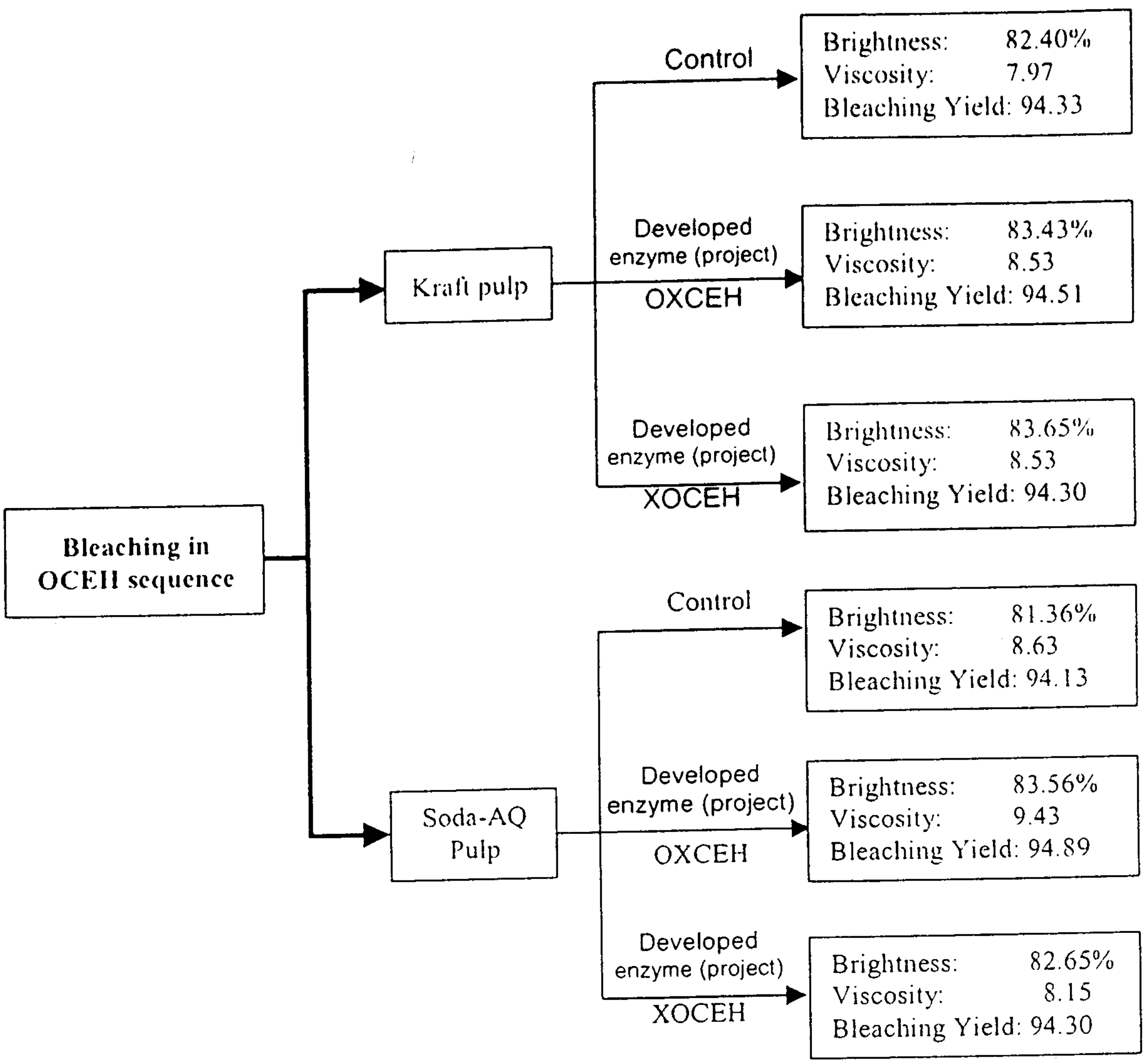
<u>BCIC:</u>

Bleaching experiments were conducted in conventional Chlorine-Alkali-Hypochlorite (CEH), Elemental Chlorine Free (ECF), Chlorine dioxide-alkali-chlorine dioxide (DED) and Oxygen-Chlorine-Alkali-Hypochlorite (OCEH) sequences with and without enzyme.

The results of bleaching in CEH, DED (in other words ECF) and OCEH sequences following the Kraft and Soda-AQ processes by BCIC show that enzyme treatment improves both brightness and viscosity.


Bleaching in CEH Sequence
Soda-AQ Process
Control
Brightness: 78.12%
Yield: 95.10%
Viscosity: 8.13
Ecopulp
Brightness: 79.73%
Yield: 94.75%
Viscosity: 9.15
Pulpzyme
Brightness: 80.22%
Yield: 94.50%
Viscosity: 9.00
Developed Enzyme (IJSG)
Brightness: 79.28%
Yield: 95.27%
Viscosity: 9.05
Biobrite
Brightness: 80.32%
Yield: 94.35%
Viscosity: 8.85
Kraft Process
Control
Brightness: 76.38%
Yield: 95.70%
Viscosity: 8.30
Ecopulp
Brightness: 79.80%
Yield: 94.32%
Viscosity: 9.10
Pulpzyme
Brightness: 80.25%
Yield: 94.50%
Viscosity: 8.80
Developed Enzyme (IJSG)
Brightness: 79.24%
Yield: 94.50%
Viscosity: 9.34
Biobrite
Brightness: 80.00%
Yield: 94.33%
Viscosity: 8.75


Bleaching in DED Sequence
Soda-AQ Process
Control
Brightness: 79.15%
Yield: 95.12%
Viscosity: 12.12
Ecopulp
Brightness: 80.10%
Yield: 94.70%
Viscosity: 12.50
Pulpzyme
Brightness: 81.20%
Yield: 95.50%
Viscosity: 12.25
Developed Enzyme (project)
Brightness: 80.51%
Yield: 94.89%
Viscosity: 12.70
Biobrite
Brightness: 82.10%
Yield: 94.72%
Viscosity: 12.69
Kraft Process
Control
Brightness: 80.56%
Yield: 95.64%
Viscosity: 12.82
Ecopulp
Brightness: 81.60%
Yield: 94.65%
Viscosity: 12.70
Pulpzyme
Brightness: 81.70%
Yield: 95.28%
Viscosity: 12.80
Developed Enzyme (project)
Brightness: 81.70%
Yield: 95.20%
Viscosity: 13.08
Biobrite
Brightness: 82.20%
Yield: 94.85%
Viscosity: 13.10



(Ref.: Annex 2 – table 28, 29, 30, 31, 32 and 33)

The results of the biobleaching process can be summarized as:

- Reduction of active chlorine by 9-12% in CEH and by 15-17% in DED.
- Reduction of AOX in the effluent is due to reduced chlorine requirement. AOX decreases in proportion to the decreasing chlorine usage.
- Increase in effluent's BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand), indicating that the effluent is more amenable to biological degradation. There is an increase in the bleach effluent resulting from the release of low molecular weight xylose from the pulp.

- Application of xylanase in OCEH sequence, before and after oxygen, does not reduce the chlorine requirement, but the brightness is improved by 2-3 units when xylanase is used after oxygen in Soda-AQ.
- The three commercial enzymes and the one isolated locally by the project leader reduce the Kappa number and improve the brightness.

The details of the experimental procedure are shown in ***Annex-2, Appendix-D.***

Centre Technique du Papier (CTP)

Bleaching experiments were conducted in conventional (CEH), Elementary Chlorine Free (DED) and Total Chlorine Free sequences. Experiments were also conducted with and without commercial enzyme (Xylanase from NOVO and Laccase).

Table 3: Brightness, bleaching yield and viscosity in various bleaching sequences

Pulp	**Soda**			**Soda-AQ**		
Bleach Sequences	**Brightness (%) ISO**	**Bleaching Yield (%)**	**Viscosity (%)**	**Brightness (%) ISO**	**Bleaching Yield (%)**	**Viscosity (%)**
CEH	82.2	94.4	6.5	80.9	93.7	8.5
DED	**81.3**	**95.4**	**12.8**	**81.7**	**94.3**	**23.8**
OP	71.5	95.9	8.5	69.9	95.3	14.2
OZP	87.5	89.5	3.8	85.8	90.1	5.2
XE CEH	80.4	91.0	7.6	80.2	91.5	10.0
LE CEH	79.9	93.2	7.3	79.9	92.3	9.6
XLE CEH	81.7	91.1	7.0	81.9	89.0	10.4
XLE DED	82.5	93.1	14.0	83.0	90.1	23.4
XLE OQP	69.6	91.2	8.1	80.0	90.0	15.0

The findings of the experiments can be summarized as follows:

- Reduction of Kappa number (30 to 35%) when Xylanase is used followed by alkali.
- Reduction of Kappa number is about 50% when two enzymes (Xylanase and Laccase) are used followed by alkali.

- There is no change of viscosity with the enzyme treatment.
- The DED sequence showed the highest brightness.
- The ECF and TCF sequences with xylanase – laccase improved the brightness and physical properties of handsheets.

(Ref.: Annex 4 – table 2, 3, 4, 5, 9, 10, 13 and 14)

CTP also conducted bleaching experiments in CEH, DED, OCEH and ODED sequences with Soda-AQ and Soda-AQ pretreated pulp with *C. subvermispora*.

Table 4: Brightness, bleaching yield and viscosity in various bleaching sequences with untreated pulp and treated pulp (*C. subvermispora*).

Pulp	Soda-AQ			Soda-AQ (pretreated with *C. subvermispora*)		
Bleaching Sequences	Brightness (%) ISO	Bleaching Yield (%)	Viscosity (%)	Brightness (%) ISO	Bleaching Yield (%)	Viscosity (%)
CEH	80.0	94.5	7.1	83.3	94.7	6.6
DED	83.6	96.8	12.0	85.2	95.3	10.9
OCEH	84.8	92.2	5.9	86.8	92.0	5.5
ODED	87.1	90.7	10.2	87.4	91.7	10.0

The summarized findings of the experiments are as follows:

- Application of oxygen reduces the chlorine requirement in the CEH sequence by 50% to 40% with untreated and treated pulp respectively.
- Oxygen delignification in untreated and treated pulp improves the brightness by 4.8 and 3.5 units respectively.
- Brightness was higher in the DED than the CEH sequences in both the treated and untreated pulp.
- Prior application of oxygen in DED improves the brightness from 83.6% to 87.1% and 85.2% to 87.4% with untreated & treated pulp.

(Ref.: Annex 4 – table 28, 29, 30 and 31)

CTP also conducted bleaching experiment with xylanase(X), enzyme followed by alkali (XE) and alkali followed by CEH.

All these experiments were conducted with Soda-AQ pulp and pretreated Soda-AQ pulp.

The results of these trials are summarized in the following table in terms of brightness, bleaching yield and viscosity in the Soda-AQ (untreated) and Soda-AQ (pretreated with *C. subvermispora*) processes.

Table 5: Brightness, bleaching yield and viscosity in various bleaching sequences with xylanase on untreated and treated (*C. subvermispora*) pulp

Pulp	Soda-AQ (untreated)			Soda-AQ (pretreated with *C. subvermispora*)		
Bleaching sequences	**Brightness (%) ISO**	Bleaching Yield (%)	Viscosity (%)	**Brightness (%) ISO**	**Bleaching** Yield (%)	Viscosity (%)
XCEH	80.6	93.23	6.5	83.2	93.09	6.5
ECEH	81.0	96.16	6.2	84.1	95.37	6.0
XE CEH	82.5	94.44	6.5	85.5	93.72	6.1
XEDED	83.9	93.1	14.9	85.1	94.4	15.5
OXECEH	84.8	91.0	6.5	87.4	89.0	6.1
OXEDED	86.1	92.5	11.1	87.0	93.1	12.8

(Ref.: Annex 4 – table 36, 37, 43, 44, 45 and 46).

Table 6: Reduction of Kappa Number

Stages	**Initial**	X	XE	O	**OXE**
Kappa No. of pulp 1 (Soda-AQ)	19.5	17.2	12.1	8.2	6.3
Kappa No. of Pulp 2 (Pretreated Soda-AQ with *C. subvermispora*)	16.2	14.9	12.3	9.0	6.7

(Ref.: Annex 4 – table 47).

Table 7: % of Cl_2 charge

Stages	CEH	DED	XEDCEH	XEDED	OCEH	ODED	XECEH	OXEDED
Pulp 1(Soda-AQ)	6.0	7.2	4.1	5.5	3.0	4.5	2.3	4.1
Pulp 2 (Pretreated Soda-AQ with *C. subvermispora*)	5.0	6.4	4.0	5.6	3.1	4.8	2.4	4.3

(Ref.: Annex 4 – table 48).

CTP also conducted bleaching experiments in XECEH sequence involving enzyme application in Kraft process.

Table 8

Stages	Kraft Pulp			Biotreated Kraft Pulp		
Bleaching Sequences	**Brightness (%) ISO**	**Bleaching Yield (%)**	**Viscosity (%)**	**Brightness (%) ISO**	**Bleaching Yield (%)**	**Viscosity (%)**
XECEH (Untreated pulp)	81.4		8	81.7		8.2
XECEH (Biotreated pulp)	83.7		6.4	83.9		6.4

The results of these trials are summarized as follows:

- Xylanase reduces the Kappa number more than the alkali extraction.
- Xylanase followed by alkali reduces the Kappa number more effectively, as addition of alkali helps to remove other soluble components.
- Pretreated Soda-AQ pulp reduces the Kappa number. This is because the initial Kappa number of treated pulp is less than that of the untreated pulp.
- Xylanase reduces chlorine use by 10% whereas alkali extraction reduces it by 12%.
- Alkali extraction reduces chlorine use by 12% (pretreated) and 18% (untreated).
- Xylanase followed by alkali reduces chlorine use by 25% (pretreated) and 39% (untreated).
- There is a drop of viscosity (from 8.3 to 6.5) with XECEH sequence.

- Application of oxygen reduces chlorine use by 50% and 38% in the conventional and ECF bleaching sequence respectively.

- Oxygen followed by enzyme results in reduction of chlorine by 62% and 43% in conventional and ECF sequences respectively.

- The pulp produced with treated chips bleaches to higher brightness.

- The ECF bleaching sequence results in less COD and BOD.

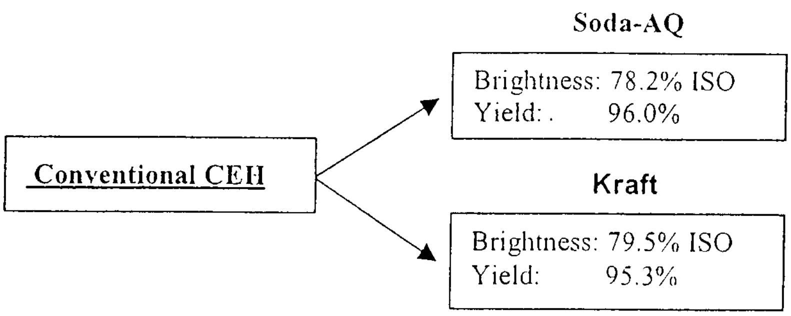
- Oxygen delignification prior to bleaching reduces chemical consumption significantly.

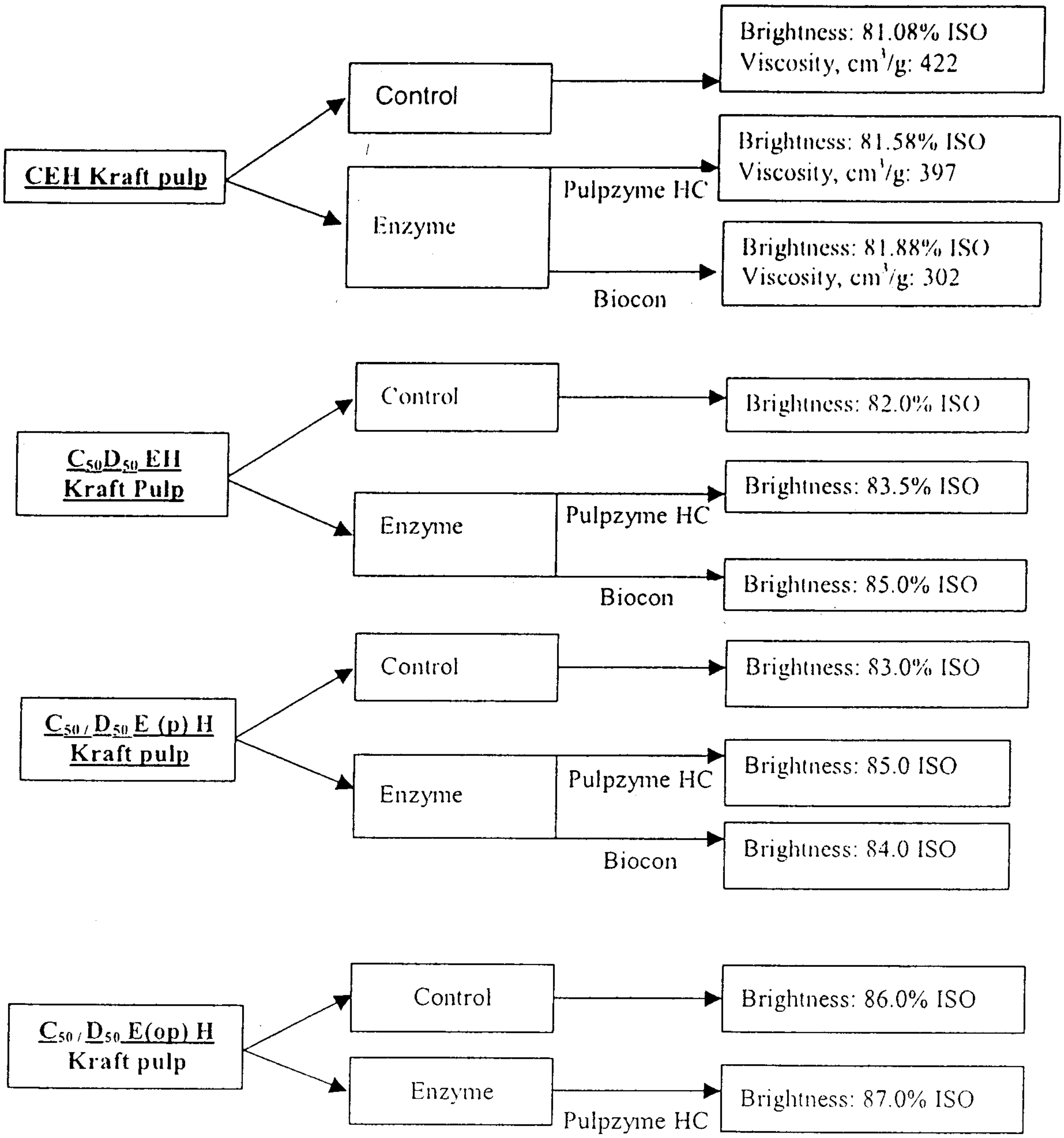
- There is an increase of COD & BOD in the effluents prior to the bleaching sequences by O, XE and OXE.

(Ref.: Annex 4 – table 36, 37, 38, 43, 44, 45, 46, 47, 48, 49, 54 and 55)

CPPRI

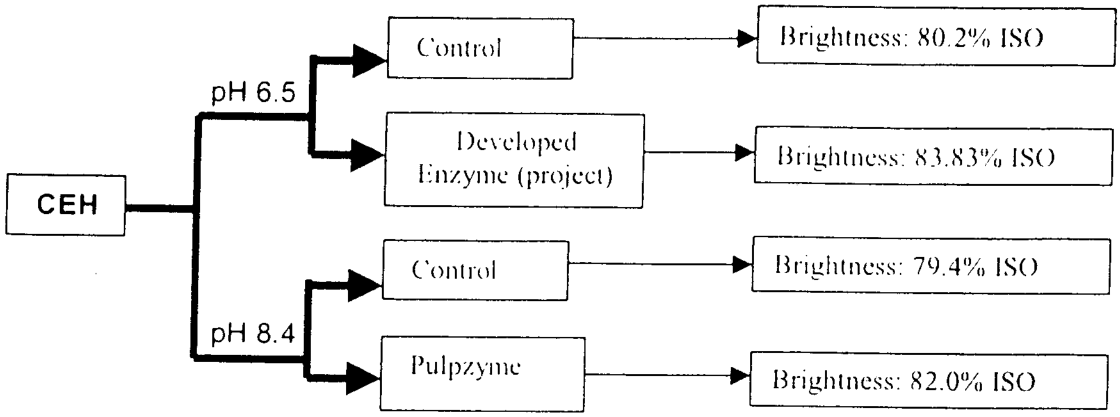
Bleaching experiments were conducted with Soda-AQ and Kraft pulp. CPPRI also conducted bleaching of Kraft pulp in CEH, C_{50}/ D_{50} EH, C_{50}/ D_{50} E $(_P)$H and C_{50}/ D_{50} E $(_{OP})$H sequences using two commercial enzymes. The summary of the results is presented below.

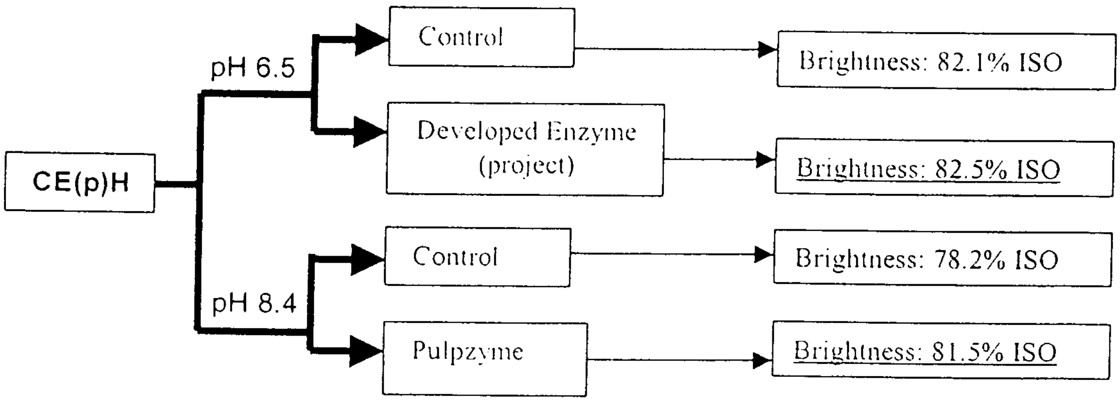


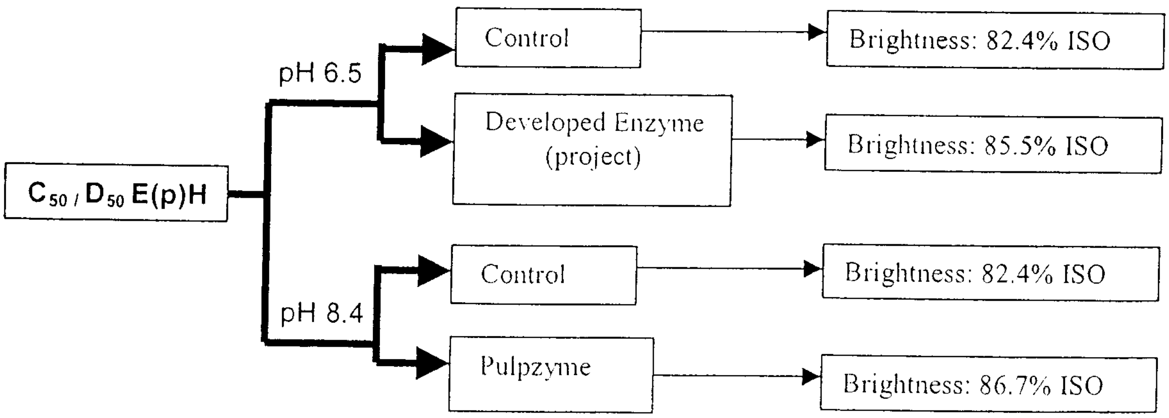


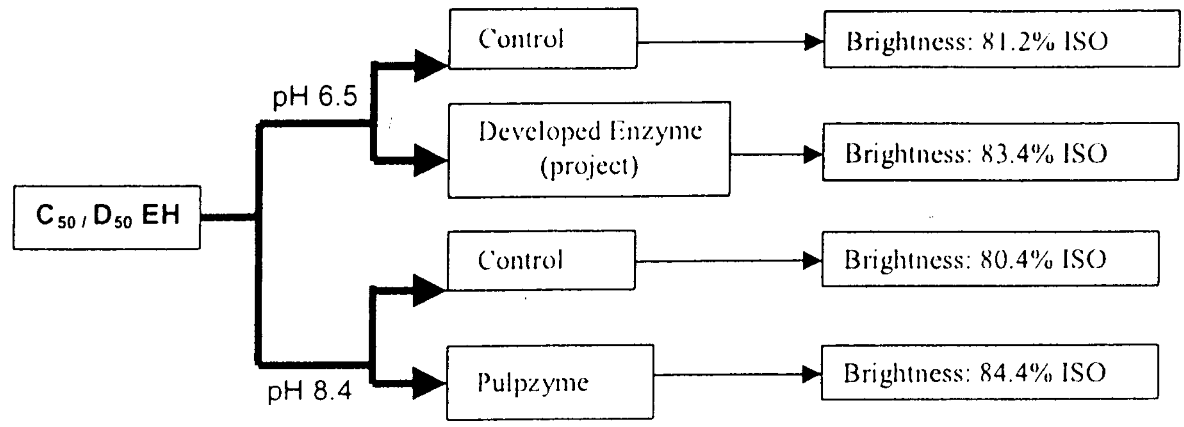
(Ref.: Annex 3 – table 17, 20, 28, 31 and 33)

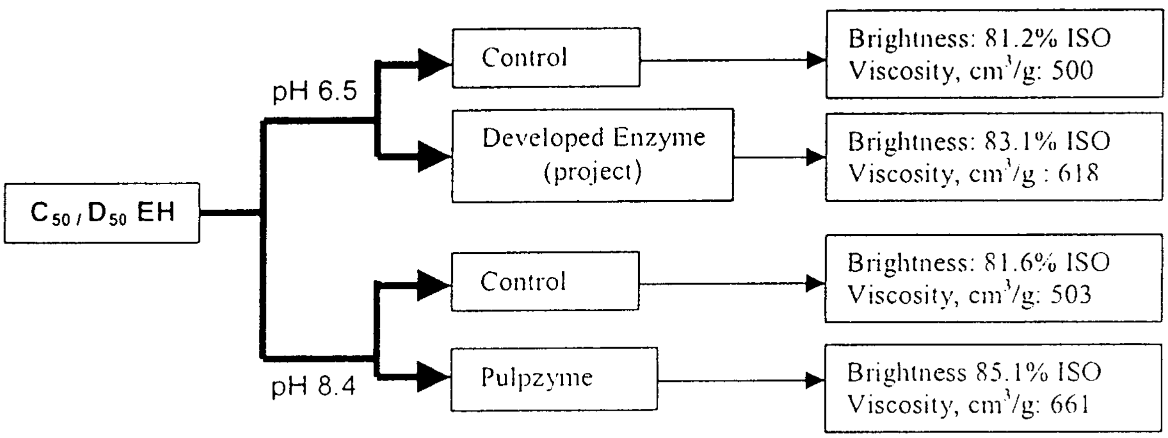
CPPRI also conducted bleaching experiments in various sequences with the pulp from the pilot plant scale trial (see below) using a commercial enzyme and also the one isolated in the course of the project.

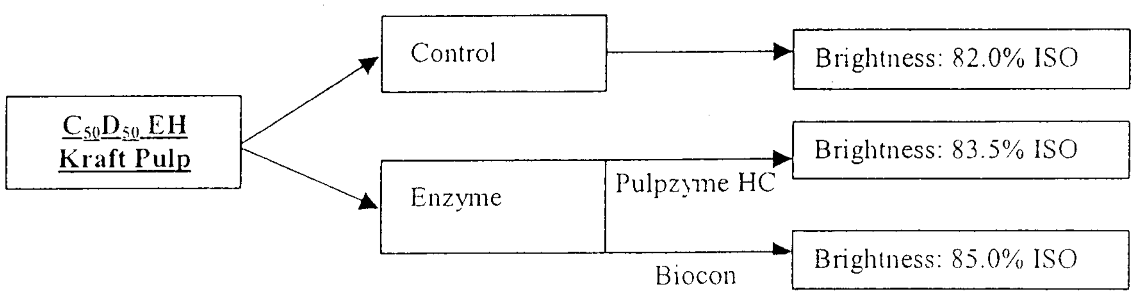

CEH
pH 6.5
pH 8.4
Control
Developed Enzyme (project)
Control
Pulpzyme
Brightness: 80.2% ISO
Brightness: 83.83% ISO
Brightness: 79.4% ISO
Brightness: 82.0% ISO


CE(p)H
pH 6.5
pH 8.4
Control
Developed Enzyme (project)
Control
Pulpzyme
Brightness: 82.1% ISO
Brightness: 82.5% ISO
Brightness: 78.2% ISO
Brightness: 81.5% ISO


C50 / D50 E(p)H
pH 6.5
pH 8.4
Control
Developed Enzyme (project)
Control
Pulpzyme
Brightness: 82.4% ISO
Brightness: 85.5% ISO
Brightness: 82.4% ISO
Brightness: 86.7% ISO


C50 / D50 EH
pH 6.5
pH 8.4
Control
Developed Enzyme (project)
Control
Pulpzyme
Brightness: 81.2% ISO
Brightness: 83.4% ISO
Brightness: 80.4% ISO
Brightness: 84.4% ISO


C50 / D50 EH
pH 6.5
pH 8.4
Control
Developed Enzyme (project)
Control
Pulpzyme
Brightness: 81.2% ISO
Viscosity, cm3/g: 500
Brightness: 83.1% ISO
Viscosity, cm3/g : 618
Brightness: 81.6% ISO
Viscosity, cm3/g: 503
Brightness 85.1% ISO
Viscosity, cm3/g: 661


C50D50 EH
Kraft Pulp
Control
Enzyme
Pulpzyme HC
Biocon
Brightness: 82.0% ISO
Brightness: 83.5% ISO
Brightness: 85.0% ISO

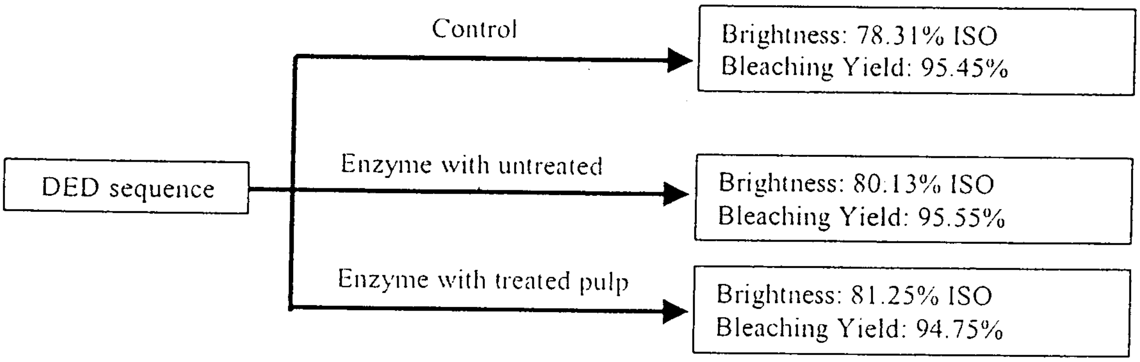
The results of the biobleaching process can be summarized as:

- Reduction of Kappa Number.
- Reduction of chemical requirements.
- Improvement of brightness.

(Ref.: Annex 3 – table 45, 46, 47, 48 and 49)

IBFC

Bleaching experiments were conducted following the Elemental Chlorine Free (ECF) sequence with and without enzyme using treated and untreated pulp.



(Ref.: Annex 5 – table 4)

The optimized results of the bleaching experiments in both Soda-AQ and Kraft processes, as well as with and without enzyme in various sequences has been compiled and are summarized in the following table. The table below shows that the XDED and OXCEH sequences conducted by BCIC produced desired results in terms of brightness in both Soda-AQ and Kraft processes. CTP optimized the bleaching conditions in the Soda-AQ process using the OCEH and XDED sequence that produced desired brightness of paper. Likewise, in the kraft process, CPPRI achieved the desired result using the $XC_{50}/D_{50}EH$, $XC_{50}/D_{50}E(p)H$ and $XC_{50}/D_{50}E(op)H$ sequences.

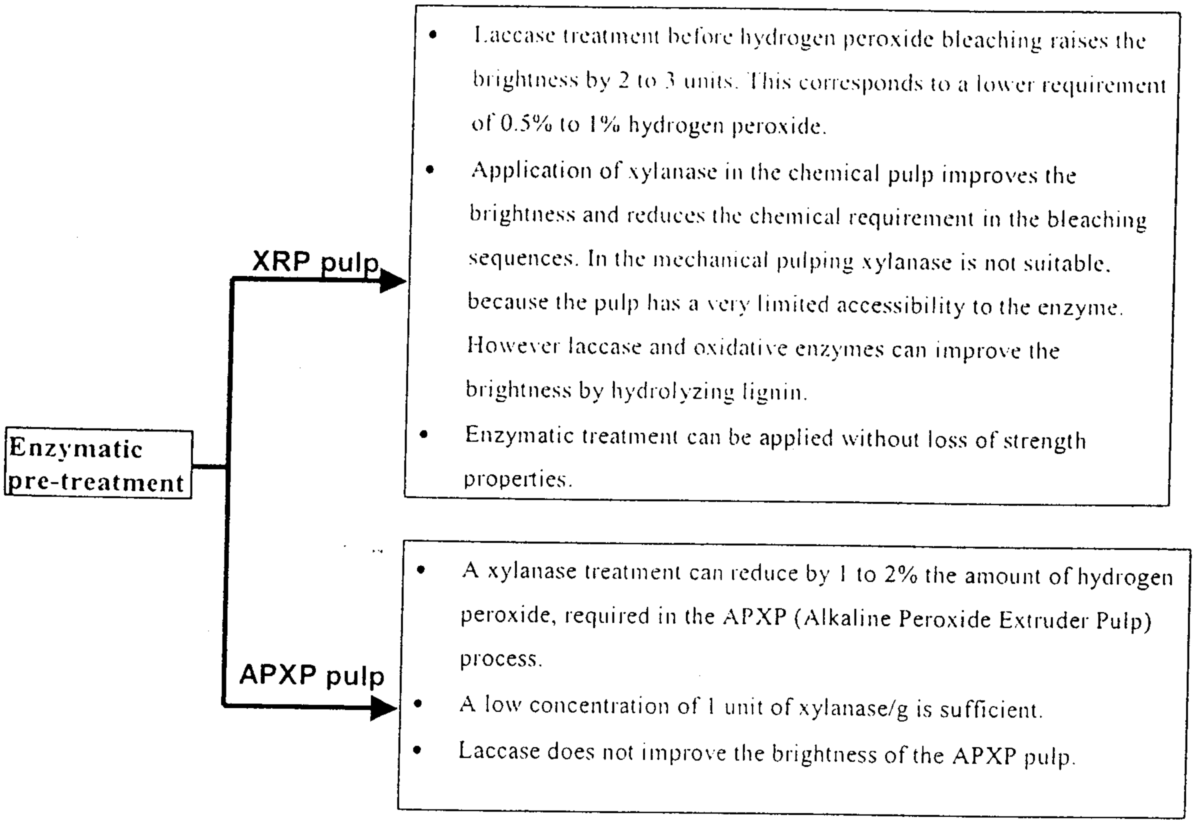
Table 9: Comparison of Brightness and Viscosity of Soda-AQ and Kraft pulp of different institutes (with control and enzyme):

Stages	Soda-AQ						Kraft					
Bleaching Sequence	BCIC		CTP		CPPRI		BCIC		CTP		CPPRI	
	Brightness (%) ISO	Viscosity	Brightness (%) ISO	Viscosity	Brightness (%) ISO	Viscosity	Brightness (%) ISO	Viscosity	Brightness (%) ISO	Viscosity	Brightness (%) ISO	Viscosity
CEH	78.12	8.13	80.9	8.5	78.2	-	76.38	8.3	-	-	81.08	422
XCEH	**79.2-80.3**	**8.85-9.15**		-	-	-	**79.2-80.2**	**8.75-9.34**	-	-	**81.58**	397
XECEH	-	-	80.2	10.0	-	-	-	-	81.4	8	-	-
DED	**79.15**	**12.12**	**81.7**	**23.8**	-	-	**80.56**	**12.82**	-	-	-	-
XDED	**80.5-82.1**	**12.25-12.70**	-	-	-	-	**81.6-82.2**	**12.72-13.10**	-	-	-	-
XEDED	-	-	**83.9**	**14.9**	-	-	-	-	-	-	-	-
OCEH	**81.36**	**8.63**	**84.8**	**5.9**	-	-	**82.40**	**7.97**	-	-	-	-
OXCEH	**83.56**	**9.43**	-	-	-	-	**83.43**	**8.53**	-	-	-	-
XC_{50}/D_{50} EH	-	-	-	-	-	-	-	-	-	-	**83.5**	-
XC_{50}/D_{50} E(p) H	-	-	-	-	-	-	-	-	-	-	**85.0**	-
XC_{50}/D_{50} E(op) H	-	-	-	-	-	-	-	-	-	-	**87.0**	-

D. Bleaching of mechanical pulping

A&F conducted experiments of enzymatic pre-treatment on brightness of green jute paper made from Extruder /Refiner Pulp (**XRP**) and from Alkaline Peroxide Extruder Pulp (**APXP**) using xylanase and laccase enzymes.

The conclusions of the experiments are as follows:



(Ref.: Annex 1 – page 34, 38 and 39)

Summary of Results Achieved under Objective 2:

Optimization of pulping

In this part of the project, BCIC (Bangladesh), CPPRI (India), CTP (France) and IBFC (China) have optimized the conditions of pulping in laboratory scale using two main chemical processes (Soda-AQ and Kraft) to produce bleachable grade pulp of Kappa number 20 (considered to be suitable for good quality paper). All the three institutes produced good quality pulp with 46%-48% yield.

Biopulping

- Application of biotechnology in the chemical process reduces the Kappa number by 15% and the cooking time.
- In both the Soda-AQ and kraft processes, cooking time can be reduced (from 120 minutes to 60 minutes in the Kraft process and from 90 minutes to 60 minutes in the Soda-AQ process). As a result, cooking cycles can be increased thus facilitating more mill throughputs.
- The physical properties of paper (burst, tear and tensile index) can be improved significantly (20-40%) in the biopulping process resulting in better quality paper.
- Application of biotechnology in mechanical pulping can reduce the energy requirements by 25%-30% and improve physical properties of the handsheet.

Bleaching

- The target brightness of 80% ISO was achieved in most of the sequences that were followed.
- Application of xylanase reduces the chlorine requirement by 15%.
- Application of xylanase followed by alkali reduces the chlorine requirement by 30%.
- Application of oxygen reduces the chlorine requirement by 40-45%.

Bleaching trials were conducted with four commercial and one isolated in Bangladesh in the course of the project. The efficacy of all the four enzymes was compared at BCIC and CTP. The results indicate that the efficacy of all 4 enzymes used did not vary greatly. However, the non-commercial enzyme in some of the bleaching sequences was marginally more effective. Among the four enzymes tried at CTP and BCIC, Biobrite seems more effective. At CPPRI in some sequences of bleaching the non-commercial enzyme showed better results while in other sequences the commercial enzymes produced better results.

OBJECTIVE 3:

To manage the black liquor produced during pulping and effluents generated during bleaching and identify suitable methods for green jute storage.

Target

- Reduce discharge of hazardous chemical effluents.
- Identify suitable methodology for storage of green jute.
- Develop suitable storing conditions for green jute.

Results achieved

Black Liquor Management

Experiments conducted at CPPRI

Effluent management in mills using kenaf and/or jute

Source of Waste Waters

In kenaf/jute-based mills, the major source of pollution is the bleaching section, if the mill is equipped with conventional soda recovery system. Besides the bleach plant effluent, the pollution load comes from weak washings and spillages from the pulp washing stages. Usually in modern mills it is expected that most of the paper machine effluent is reused/recycled in the mill after recovering the fiber in a fiber recovery unit such as primary clarifier etc.

Treatment Practices

(i) Primary Treatment

The effluent generated is usually first sent to a primary classifier for removal of suspended solids. Normally, the primary classifier removes 70-85% of suspended solids.

(ii) Secondary Treatment

After primary treatment the effluent is sent to the conventional secondary (biological) treatment system. If the mill has sufficient space then the effluent can be treated in an aerated lagoon. Where space is not sufficient, the effluent can be treated in an activated sludge system. The basic principles for both treatment systems are the same. The aerated lagoon requires long retention time and less operational cost, while an activated sludge system requires shorter retention time but needs more attention and requires comparatively higher operation & maintenance cost.

(iii) Tertiary Treatment

As a safeguard, in order to meet the discharge standards, the biologically treated effluents are further treated for removal of residual toxicity and colour.
(Ref.: Annex 3)

The management of black liquor generated during jute pulping revealed that jute black liquor is suitable for evaporation to high solid concentration and for further processing in the recovery boiler. It has high carbon content (38.1%), high calorie value (3438 cal/gram), low viscosity at high solid concentration and very low non-process elements concentrations. This makes it suitable for chemical recovery operations. However, the economic viability of such operations depends on mill size.

(1) Mill size: 30-50 TPD

For this category of paper mills, the chemical recovery system is not economically viable. Such mills can opt for the High Rate Biomethanation System followed by aerobic treatment. Lignin can be removed before biomethanation.

(2) Mill size: 50-100 TPD

In this category of mills, conventional chemical recovery is not economically viable as the capital and operational costs are very high. A fluidized bed type of chemical recovery system is preferable. In this type of chemical recovery system, chemicals in the form of soda ash can be recovered. No steam generation is possible in this recovery system. The process is suitable for mills using soda process for pulping.

(3) Mill size: 100-150 TPD

The Conventional Chemical Recovery System is recommended for this size of pulp mills with a cogeneration facility. Appropriate configuration of evaporators, recovery boiler etc. can be designed by considering the physico-chemical properties of the black liquor.

Storage of Green Jute/Kenaf Plants

A major constraint of using jute as a raw material for pulp and paper industry is that jute is an annual crop and harvested once a year, while pulp and paper industries are in operation round the year seven days a week. Therefore, jute plants are needed to be stored in large quantities in order to meet the demand of the paper mills. Normally, when the green plants are harvested, they are susceptible to microbial decomposition under the hot and humid climates in the harvesting season. In view of the above problems, storing protocol activities for green jute plant were initiated with the following objectives:

1) To isolate fungal strains responsible for the degradation of jute plants.
2) To find out the enzymes normally secreted by these organisms during rotting of jute plant.
3) To evaluate in vitro test the efficacy of some commercial fungicides in controlling the growth of these fungi.
4) To estimate the time required for reduction of moisture content (15-18%) after harvesting jute plant.
5) To develop proper model for storing dried jute plants.

Twelve (12) strains were isolated belonging to *Sclerotium*, *Aspergillus*, *Alternaria*, *Fusarium*, *Mucor*, *Macrophomina* and *Diplodia* sp. *Sclerotium* sp. was found to be the main strain for degradation of jute plants during harvesting. The maximum growth of *Sclerotium* is observed at 60-70% moisture content. *Sclerotium* does not easily grow on jute chips when the moisture content is 30% or less. The maximum growth of *Aspergillus* and *Macrophomina* is observed at 50-60% moisture level. Poor growth is observed at 25^{0}C and 40^{0}C for the strains *Sclerotium, Macrophomina* and *Aspergillus*.

Among the fungi tested, *Sclerotium* sp. Shows-higher PGase activity (6.5 IU/ml) compared to xylanase (4.48 IU/ml) and CMcase (1.0 IU/ml) while *Aspergillus* sp. shows the highest xylanase activity (5.2 IU/ml).

Application of fungicide

The degradation of lignocellulosic materials of jute by different fungi such as Sclerotium sp., Aspergillus sp., Mecrophomina sp. as well as without presence of any fungi was studied. After comparing the degradation by different fungi, five fungicides i.e. Dithane M-45, Vitavax, Bavistin, Cupravit 50WP and Tilt 250 EC were evaluated for their fungitoxicity against the isolated strains.

It was shown that Tilt and Diathane are most effective in arresting the growth of *Sclerotium sp.* and *Macrophomina sp.* Diathane (1000 ppm) and Tilt (250 ppm) were sprayed separately on the infected plant in15 days interval. Of these two fungicides Tilt showed the better results in terms of fungicidal effectiveness. No growth of fungi was observed after the application of fungicide on green jute plant during storing.

Reduction of moisture content

The time required for reduction of moisture content of harvested jute was also determined. It was observed that the moisture content decreased gradually taking 8-10 days to reach 15-18% moisture content in the field. It was also observed that if the jute plants were stored in direct contact with the soil fungal growth was found in the bottom layer the plant.

Storing of jute plant

To develop a proper model for storing dried jute plants in various field conditions, the following two procedures were followed one based on the storing protocol of kenaf developed by IBCF and the second developed by IJSG.

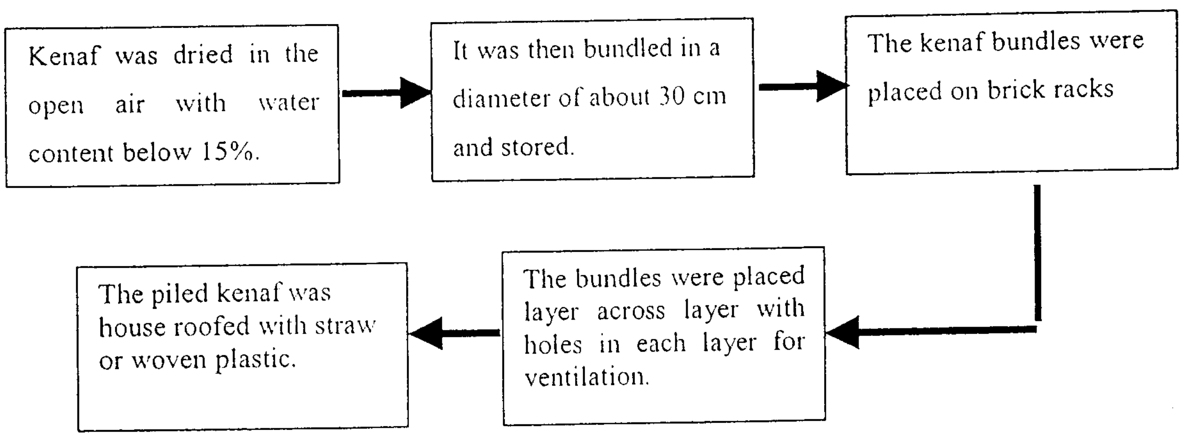
IBFC

The rate of microbial degradation (mildewing) of kenaf during storage depends on its water content and relative humidity (RH). The higher the water content and the ambient RH, the more susceptible it is for kenaf to get mildew and the faster is the growth rate of mildew. The experiments showed that if the moisture and RH of kenaf were controlled below 25% and 57% respectively, kenaf would not degrade even in the presence of mildew. However, it is difficult to control RH in open environments and it is therefore better to control the moisture content by drying the kenaf by aeration.

Fungicides are also effective in controlling kenaf mildewing. Of the 8 fungicides selected, Flusilaz, Mancozeb, Horizon and Thiophamate methyl were quite effective. Under RH of 100%, all treatments of fungicides on kenaf stored in the open air showed effective results in controlling mildewing. However, the best result was achieved with a combination of Flusilaz and Horizon. The mildew area on kenaf was less than 10% with the combined treatment of Flusilaz+Horizon, while with other treatments it was in the range of 20%.

IBFC conducted some small-scale experiments to identify the conditions of preventing kenaf mildewing.

The storing process was:

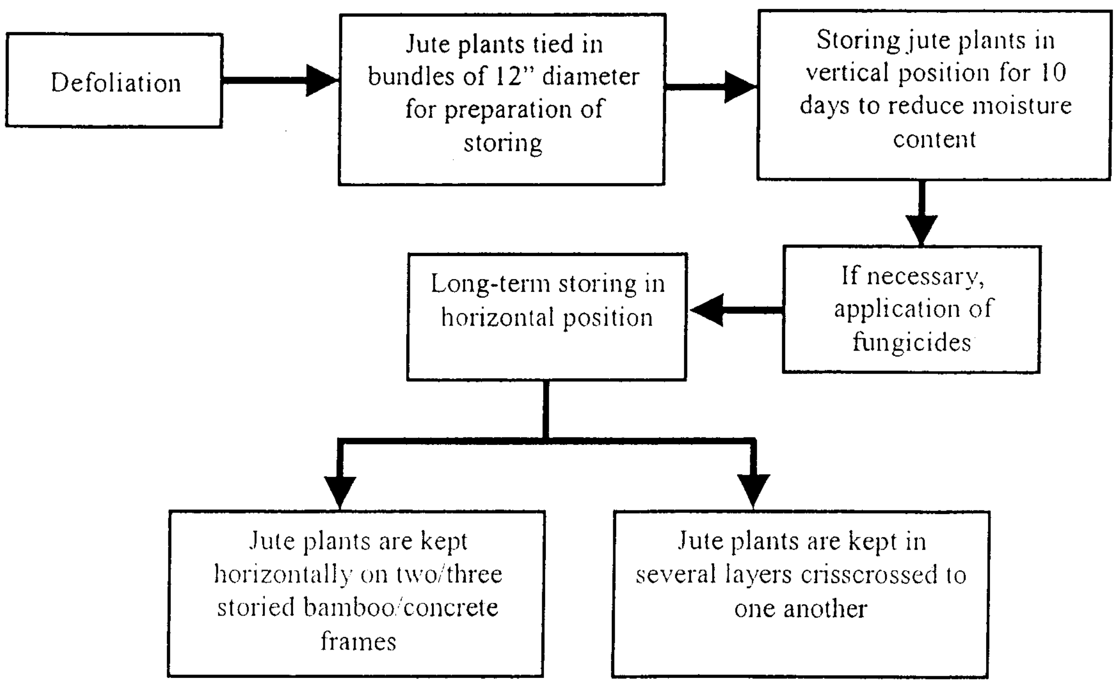


Polythene was used to cover the piled kenaf. After 9 months of storage through the long rainfall season, all kenaf was still fresh and there was little mildew. In addition, the practice of braided and fixed straw covering is cheap, environment friendly and easy to use. ***(Ref.: Annex 5)***

IJSG

After harvesting the jute plants, the moisture content of the plant is normally 65-75%. With this moisture content, if the jute plants are kept in horizontal position, the temperature rises up to 45-50^{0}C within 72 hours, which facilitates degradation by microorganism. In order to avoid growth of and degradation by microorganisms, the plants were bundled in a diameter of 12" and then kept in vertical position with a provision of flow of air. According to the experimental results, the moisture level of the plants drops to about 15-20% after 10 days.

Two models are suggested for long term storing with a minimum cost of investment. In one model the bundled jute plants are kept horizontally on two/three storied bamboo/concrete frames (picture). In another model, bundles of jute plants are kept in several layers crisscrossed to one another. Piled jute plants can be covered with a shade made of polythene sheet or straw to protect them from rain. The storing protocol for green jute plants is shown in the following diagram.



Summary of Results Achieved under Objective 3:

Storing and Black Liquor Management

Jute black liquor is suitable for evaporation to high solid concentration and for further processing in the recovery boiler. It has high carbon content (38.1%), high caloric value (3438 cals/gram), low viscosity at high solid concentration and very low non-process elements concentrations. This makes it suitable for chemical recovery operations.
Whole jute plant can be stored after drying the plant to a level of moisture content below 15%. In case of fungal attack, a number of fungicides are effective.

OBJECTIVE 4:

Large and commercial scale trial of whole jute plant for the production of pulp and paper.

<u>Target</u>

- Pilot and commercial scale trial of chemical pulping to produce unbleached and bleached paper.
  Assigned Institutes: BCIC and CPPRI
- To achieve brightness above 80% ISO suitable for writing paper.
  Assigned Institutes: BCIC and CPPRI
- Pilot scale trial of mechanical pulping suitable for the production of newsprint grade paper with brightness above 60% ISO.
  Assigned Institutes: A&F and CTP
- Establishment of techno-economic viability for utilizing whole jute for pulp and paper industry.

<u>Results achieved</u>

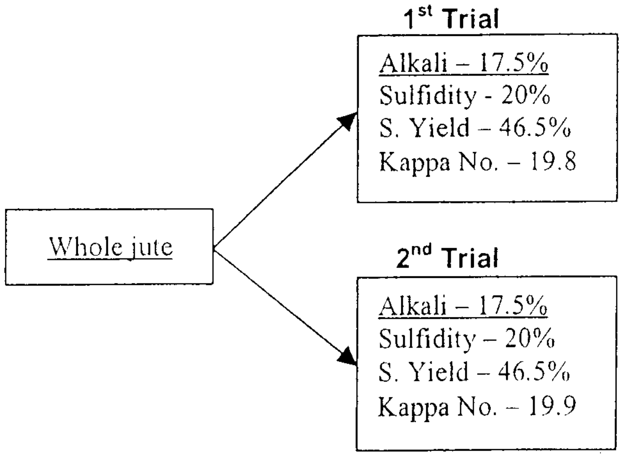
<u>BCIC:</u>

With the optimum conditions obtained at Karnaphuli Paper Mills Limited, BCIC conducted one large scale trial for the production of kraft paper (14 MT of dried jute plant which is equivalent to 56 MT of green jute plant) and one commercial trial for the production of writing paper (80 MT of dried jute plant equivalent to 320 MT of green jute plant). In these trials a stationery digester was used. For the production of kraft paper 12% alkali as Na_2O and 20% sulfidity were used. For the production of writing paper 15.5% alkali as Na_2O and 20% sulfidity were used. Bleaching of the washed, screened and refined pulp was conducted in the conventional bleaching sequence chlorine-alkali-hypochlorite (CEH). After the application of chlorine (0.22 of Kappa number of pulp) the pulp was washed and then alkali was used (2% NaOH). After alkali extraction, the pulp was again washed followed by hypochlorite (1.5%) treatment for final bleaching. Bleached pulp was used for making paper (70 gsm) in a paper machine of speed of 175-200 meter/minutes. The details on the experimental procedure are presented in **Annex-2, Appendix-E**.

- The yield of kraft pulp is 52%.
- The physical properties of kraft paper compared with that of bamboo are shown to be superior.
- The yield of pulp for writing paper is 45-48%.
- The physical properties of paper in the kraft process were compared with that of bamboo and hard wood are shown to be superior.
- The brightness of the paper is 80-83% ISO.
- Cooking temperatures and time of 1650C and 90 minutes respectively in both the trials.

CPPRI

CPPRI conducted two pilot scale trials of chemical pulping using the kraft process. The results of both the trials were almost the same. The results are shown below:



(Ref.: Annex 3 – table 40)

The pulp was used for bleaching in various sequences, such as: CEH, CE(p)H, C/DEH, C/DE(p)H. The results of the bleaching sequences are already been presented under Objective 2 of this report. The biobleaching experiments conducted have shown highly promising results in terms of reduction in Kappa number, reduction of chemical requirement during bleaching and improvement in brightness of the pulp. The data generated on enzyme pre-bleaching of jute provide new opportunities to adopt the technology as eco-friendly biotechnological application for papermaking from jute/kenaf.

A&F (Mechanical Pulping):

Green jute can be used to produce pulp with the APMP process. The energy input is very low compared to mechanical pulping of wood. A&F conducted mechanical pulping in 12 inch refiner.

- The alkaline peroxide process raises the brightness and strength properties of the hand sheets of green jute so much that it becomes suitable for newsprint. RMP turned out not to be suitable.
- APMP pulp (12-inch refiner) from green jute can be produced with only 25% of the energy needed to produce a TMP pulp for newsprint from wood.
- The average total yield after pressing, bleaching, refining and washing was 78.9%, which is comparable with the laboratory scale APMP experiment.

CTP (Mechanical Pulping):

Jute as a fiber resource had to be tested in mechanical pulping processes. CTP used two mechanical pulping processes to determine the suitability of whole jute for high-yield pulping. One process is Thermo-Mechanical Pulping (TMP) and the other process is Alkaline Peroxide Mechanical Pulping (APMP). CTP's high yield pulp making pilot plant facility operates under industrial conditions and simulates a mill processes. The results obtained from pilot plant studies can be up-scaled directly.

The results of the TMP process are summarized below:

- The TMP pulp that was obtained had weak mechanical properties. However, the pulp bleaching leads to 70% ISO brightness with 5% hydrogen peroxide charge.
- A chelation stage is necessary prior to the bleaching stage. Furthermore, the three commercial enzymes were tested prior to the bleaching stage with little effect.

The results of the APMP process are summarized below:

- Pulps of different chemical charges are obtained leading to pulp of mechanical properties suitable for newsprint papers.
- The brightness target of 60-65% ISO is achieved.
- 3% sodium hydroxide and 1% hydrogen peroxide is the best chemical charge for the impregnation stage and 3% hydrogen peroxide and 1.5% sodium hydroxide for the bleaching stage. However, these chemical charges can only be slightly reduced.
- At about 100 ml CSF the total energy consumption was comparable for APMP with 3% NoOH in the impregnation and TMP (about 2000 kwh/t).

Results Achieved under Objective 4:
Pilot Scale and Commercial Trial

After the optimization of pulping, BCIC conducted one large-scale trial (14 MT) and one commercial trial (80 MT). Whole jute plants were chipped using the available chipper after necessary adjustment. After the production of pulp, bleached paper was produced using the conventional sequence of bleaching (40-42 MT) in the existing paper machine. With the existing facilities of the chemical pulping mill of BCIC, whole jute plant was used commercially for the production of pulp and paper. The quality of paper is suitable for wrapping and different grades of writing paper. Physical properties of unbleached and writing paper are superior to paper made from bamboo and tropical wood. CPPRI (India) also successfully conducted pilot scale trials using chemical processing.

The commercial scale trial of chemical pulp using kenaf, originally envisaged in the project, was not performed and therefore it has not been possible to compare the pulp characteristics of jute and kenaf against each other as well as conduct a comparative study regarding on the yield, cost and physical properties of paper from jute and kenaf. This is a shortcoming that needs to be addressed in the future. However, it is expected that jute can produce better pulp than kenaf, because the fiber (bark) to stick ratio is 1:2, whereas fiber (bark) to stick ratio of kenaf is around 1:3. Ultimate fiber length of bark of both kenaf and jute is around 2 mm whereas that of core is less than 1 mm. Moreover, the price of whole kenaf in Bangladesh/India is comparatively less. Therefore, it is perhaps a preferable raw material for the paper industry.

Pilot scale mechanical pulping (high yielding) conditions were also optimized CTP, and A&F. The yield of mechanical pulping was 80%. The paper is suitable for newsprint.

Up-Scaling of Biopulping

Initially in the laboratory scale, 61 biopulping experiments were conducted for bleachable grade pulp of Kappa number 20 using different microbial strains in the both the Soda-AQ and kraft processes.

Upscaling of biopulping took place at the IJSG and BCIC facilities. It was conducted by mixing jute chips with micro-organism in a ribbon mixture in a temperature controlled room. Locally indigenous materials (wheat bran and molasses) were used to reduce the pretreatment cost of biopulping.

A 50 kg trial was conducted with and without aeration. The results obtained from the trial were more or less same as the laboratory experiments in terms of reduction of the Kappa number, yield and improvement of physical properties. An additional trial was also conducted to verify these results. The summarized results are as follows:

Pulping experiments	Medium used with chips	Results achieved
8 biopulping experiments were conducted with variation of media using *F. lignosus*.	Glucose + salt solution	For both wheat bran and molasses as media ❖ Kappa number can be reduced by approximately 20% under the same cooking condition both in the Soda-AQ and Kraft processes. The physical properties of hand sheet (burst, tear and tensile indices) improved significantly (20-40%).
	Wheat bran	
	Bagasse	
	Molasses	
50 kg trail experiments with and without aeration using *F. lignosus*.	Wheat bran with and without aeration	There is no significant difference with and without aeration

Techno Economic Feasibility Study

The study was conducted by an independent consulting firm and made use of the data obtained in the course of the implementation of the project to calculate manufacturing costs of both chemical and mechanical pulp from jute and kenaf. The calculations made did not take into account the location of the mill site as this could not be specifically defined at this stage.-The location of the mill site is expected to have a major impact on manufacturing costs.

As a raw material, the cost of green jute was assumed at the level of Tk 1,000/green metric ton at the mill site, for green jute with moisture content of about 75% that needs to be dried to about 15% moisture content for processing. For the purposes of comparison, the cost of kenaf (whole plant) was also assumed at Tk 800/green metric ton under the same moisture condition as green jute. Under these conditions, the production of 1.00 Adt of pulp requires the processing of 2.38 Adt of green jute. It is assumed that a manufacturing capacity of 100 Adt/day is suitable for green jute pulp, considering economies of scale and 343 days of the mill operation.

Biopulping results in economies arising from reductions in chemical inputs, shorter cooking times and improvement of the physical properties of the fiber. The results of biopulping in both chemical and mechanical processes are quite encouraging but these results need to be corroborated by larger pilot scale trails for pulp and paper production where 14 days of pretreatment of the raw material with microorganism may be a problem in the case of production facilities of 100Adt/day.

Experimental results of biological bleaching show a reduction in the consumption of chlorine dioxide by 10-18% when xylanase is used for the first stage of multiple bleaching stages with a concomitant improvement in brightness. This results in cost savings of US$3.66/Pulp Adt. Given the fact that the purchase cost of xylanase is US$5.00/Pulp Adt, the savings from the reduction chlorine dioxide input is almost offset by the cost of xylanase. Should it be feasible to produce xylanase locally at a cost of US$1.50/Pulp Adt, then this would effectively result in cost saving of US$2/Pulp Adt.

The experimental results show that xylanase bleaching in the mechanical process is not sufficiently efficient to improve the brightness. Enzymes pretreatment is not suitable because, during impregnation, alkali removes xylans in the pulp.

The calculations made in the study included variable costs of raw materials, energy, chemicals and labour. Labour wages were calculated according to the variable exigencies of pulp manufacturing operations and the mill maintenance cost was estimated at US$23.00/Adt for general maintenance of the facility. Further, facility depreciation was calculated on the basis of 20 years for equipment and 30 years for building facilities, maintaining a book value of 10%. The LDC rate of interest on loans of 0.9% set by Japan Bank for International Cooperation (JBIC), i.e. 30 years repayment term with 10 years grace was used a the basis of calculation. The head office cost was calculated on the basis of the above interest rate assumptions, the inland freight cost to local market and a corporate tax at the rate of 37.5%.

The investment costs of a manufacturing facility for both chemical and mechanical pulp was calculated to be:

Chemical Pulp Facility:	US$ 77,382,000
Mechanical Pulp Facility:	US$ 59,604,800

The pulp mill construction schedule was assumed to commence two years prior to the commencement of the Pulp Mill Operation.

Manufacturing Cost

In view of the many variables used under the above assumptions, mill production costs were calculated using four different situations (see Tables below):

1. Case 1 - Jute using current costs of chemicals in Bangladesh
2. Case 2 - Jute using current costs of chemicals in India
3. Case 3 - Kenaf using current costs of chemicals in Bangladesh
4. Case 4 - Kenaf using current costs of chemicals in India

Estimation of the Jute Chemical Pulp Production Cost in Bangladesh (US$/Adt)

		Whole Jute		*Whole Kenaf*	
		Case 1	**Case 2**	**Case 3**	**Case 4**
Variable Costs	Raw materials	147	147	118	118
	Energy	37	37	37	37
	Chemicals	80	57	80	57
	Others	18	18	18	18
Total		**282**	**259**	**253**	**230**
Fixed Costs	Labor	10	10	10	10
	Maintenance	23	23	23	23
	Administration	5	5	5	5
	Depreciation	82	82	82	82
Total		**120**	**120**	**120**	**120**
Factory Manufacturing Cost		*402*	*379*	*373*	*350*

Mechanical Pulp Manufacturing Cost US$/Adt

		Whole Jute		*Whole Kenaf*	
		Case 1	Case 2	Case 3	Case 4
Variable Costs	Raw materials	77	77	62	62
	Energy	43	43	43	43
	Chemicals	78	65	78	65
	Others	14	14	14	14
Total		**212**	**199**	**197**	**184**
Fixed Costs	Labor	9	9	9	9
	Maintenance	20	20	20	20
	Administration	5	5	5	5
	Depreciation	60	60	60	60
Total		**94**	**94**	**94**	**94**
Factory Manufacturing Cost		*306*	*293*	*291*	*278*

On the basis of the calculations made, Case 4 appears to be the most feasible and competitive among the options.

The study concludes that the sale of fine paper from chemical pulp and newsprint paper from mechanical pulp in the Bangladesh domestic market is the best option if it is supported by government subsidies such as reduction or exemption of import taxes for chemicals and/or financial assistance on VAT, Corporate Tax, etc. The construction of Pulp Mill in the EPZ may constitute such government assistance.

This report was prepared on the basis of numerous assumptions such as prices of raw materials, inland freight, interest rate, local tax and sales prices for pulp and paper. A more detailed feasibility study is recommended that would validated these assumptions, and also include costs of cultivation, the logistics of storing the raw materials as well as market demand.

Feasibility Analysis in Each Case

	Intrest Rate	VAT	
Case A	0.9%	0.0	%
Case B	4.9%	0.0	%
Case C	0.9%	15.0	%
Case D	4.9%	15.0	%

Case1	Chemical Price Banglades	Jute
Case2	Chemical Price India	Jute
Case3	Chemical Price Banglades	Keanf
Case4	Chemical Price India	Kenaf

Interest Rate of 0.9% represents the rate applicable for Project under Yen-Credit from Japan
Interest Rate of 4.9% represents the rate appplicable for commercial reference in US$

	Chemical Pulp					Mechnaical Pulp			Fine Paper	News-print
	Case1	Case2	Case3	Case4	Case1	Case2	Case3	Case4		
Case A										
Factory manufacturing Cost	402	380	372	350	306	293	291	278	640	520
Intrest Cost	18	18	18	18	13	13	13	13	12	12
VAT	0	0	0	0	0	0	0	0	0	0
Other Head offe cost	15	15	15	15	13	13	13	13	18	18
Total Manufacturing Cost	435	412	405	383	332	319	317	304	670	550
Case B										
Factory manufacturing Cost	402	380	372	350	306	293	291	278	640	520
Intrest Cost	96	96	96	96	71	71	71	71	66	66
VAT	0	0	0	0	0	0	0	0	0	0
Other Head offe cost	15	15	15	15	13	13	13	13	18	18
Total Manufacturing Cost	513	491	484	461	390	377	375	361	724	604
Case C										
Factory manufacturing Cost	402	380	372	350	306	293	291	278	640	520
Intrest Cost	18	18	18	18	13	13	13	13	12	12
VAT	60	57	56	53	46	44	44	42	96	78
Other Head offe cost	15	15	15	15	13	13	13	13	18	18
Total Manufacturing Cost	495	469	461	435	378	363	360	345	766	628
Case D										
Factory manufacturing Cost	402	380	372	350	306	293	291	278	640	520
Intrest Cost	96	96	96	96	71	71	71	71	66	66
VAT	60	57	56	53	46	44	44	42	96	78
Other Head offe cost	15	15	15	15	13	13	13	13	18	18
Total Manufacturing Cost	573	548	539	514	436	421	418	403	820	682

Sale Price(Domestic Market)	600	600	600	600	425	425	425	425	870	720

Profit After Tax (TAX 37.5%)

Case A	103	117	122	136	58	66	68	76	125	106
Case B	54	68	73	87	22	30	32	40	91	72
Case C	66	82	87	103	29	39	40	50	65	57
Case D	17	33	38	54	-7	3	4	14	31	24

Red Letter indicates not feasible

Minimum Profit (after Tax) Level, Feasible for the Project
10%of the Annual return on Equity and repayment of the Loan during 20years

Chemical Pulp	56 US$/ADT
Mechanical Pulp	50 US$/ADT
Fine Paper	50 US$/ADT
Newsprint Paper	50 US$/ADT

OBJECTIVE - 5: Dissemination of results and completion of the project

A dissemination workshop was held in Dhaka, 11 May 2004 under the Chairmanship of the Secretary, Ministry of Jute, Government of the People's Republic of Bangladesh. The workshop was attended by the Ambassador of the Republic of France in Bangladesh; the Secretary, Ministry of Industries; the Minister for Industries; the Principal Secretary to the Prime Minister, Minister for Textiles and Jute and representatives of industry and NGOs.

The workshop was inaugurated by the Secretary General, International Jute Study Group, Dhaka. It was also attended by the Principal Project Manager, Common Fund for Commodities (CFC), representatives of IJSG, UNIDO, the collaborating parties and the Project Leader.

Target

The main findings of the report were presented at the workshop together with those of the economic pre-feasibility study. The presentations were followed by extensive debate. The minutes of the workshop and the list of participants are included in **Annex 7**.

Results achieved

The dissemination workshop was followed up by a meeting of representatives of CFC, IJSG, UNIDO, the collaborating parties and the Project Leader. The draft CPR was discussed and some amendment were proposed for the preparation of the final report. The draft CPR met with the overall agreement of all participants.

IV. Lessons Learned

There was some over-lapping in pulping and bleaching experiments. However, this had the trade off of confirming the reproducibility the experimental results.

As is expected with all applied research projects, new needs became apparent during the implementation of the project. Addressing these needs (e.g. scaling-up biopulping; conducting more detailed comparison between jute and kenaf processing) requires more time and resources.

The relatively large number of parties in the technical implementation of the project made coordination of activities rather difficult but obstacles were overcome in most part.

More emphasis should had been given at the inception of the project on economic aspects and therefore, introduce benchmarks against which the commercial viability of the developed technologies could be tested. The strategy in the development of a jute/kenaf based pulp mill must involve a critical analysis of supply and storage of the raw material, the pulping process technology, development and marketing of the product. Of these the project addressed adequately the pulping process technology and storage.

BIOTECHNOLOGICAL APPLICATION OF ENZYMES FOR MAKING PAPER PULP FROM GREEN JUTE/KENAF (WHOLE PLANT)

IV- Lessons Learned

V. Conclusions

V. Conclusions

1. In terms of physical properties jute and kenaf are suitable raw materials for the production of pulp and paper by the Soda-AQ and Kraft processes and can substitute bamboo and tropical hardwood.

2. Various grades of paper (wrapping and writing paper) can be produced in the chemical process using the existing chemical based paper mills.

2. Mechanical pulping conducted in the APMP process showed that newsprint grade of paper can be produced. However, the experiments were conducted in small scales and there is need to conduct more pilot scale trials using 1/2 MT of dried jute plant to ascertain the effectiveness and efficiency of the APMP process.

3. Biopulping experiments showed promising results in terms of reduction of energy and chemical requirements, and resulted in pulp with improved physical properties. Biotreated pulp was shown to reduce the Kappa number significantly. Consequently chemical treatment in bleaching can be reduced. The biopulping technologies developed could be effective in small-scale paper mills, manually operated paper mills (where normally jute is used and female workers are mostly employed) and in mechanical pulping (especially in the APMP process).

4. Enzymes can significantly reduce chemical requirement in the conventional and ECF bleaching sequence. Thus, enzyme application can make the product cost effective and environment friendly. Large-scale enzyme application should be conducted in existing chemical paper mills to generate awareness of the process.

VI. Recommendations

VI. Recommendations

1. Conduct further large-scale experiments to ascertain the efficacy of the APMP-mechanical pulping process as well as the effectiveness of biopulping.

2. Ascertain the impact of supply and storage-related factors (e.g. cost at the farm-level, maintenance of supply volume and quality, transportation and storage) on production costs.

3. Ascertain the impact of government policies on costs of production of pulp from jute/kenaf.

4. Determine mill capacities in relation to the overhead costs of production. The minimum economic size of a bleached softwood or hardwood chemical market pulp mill is about 700/800 t/d to compete in the international market. Such mills are unlikely to be installed in jute producing developing countries. Therefore, it is important to consider the potential of installing specialty pulp mills that can compete internationally with a capacity of 50-200 t/d.

5. In relation to points 2-4 above, a comprehensive pre-feasibility study would be appropriate.

6. Enhance the awareness of investors and/or mill managers of the potential of jute-derived pulp not only by itself but also as additive to conventional pulps to impart some special characteristics that cannot be obtained using wood pulp alone.

VII. Annexes

VII. Annexes

Annex 1- Final report of Agrotechnology & Food Innovations (A&F), The Nethelands

Annex 2- Final report of International Jute Study Group and Bangladesh Chemical Industries Corporation (IJSG/BCIC)

Annex 3 - Final report of Central Pulp and Paper Research Institute (CPPRI), India

Annex 4 - Final report of CentreTechnique du Papier (CTP). France

Annex 5 - Final report of Institute of Bast Fiber Crops (IBFC), China

Annex 6- The Economic and Financial Analysis Study

Annex 7 - Dissemination workshop and list of participants