Jute An Alternative Raw Material For Packaging Paper

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ABSTRACT

Search for non-wood lignocellulosic fibres began in early seventy as a result of sudden surge in the demand of paper and in subsequent years need for capacity expansion necessitated the search for alternative fibrous raw materials. Extensive research work undertaken by CPPRI(central Pulp and Paper Research Institute) & UNDP reported that for jute and other plants belonging to the jute family kenaf, mesta etc. both the fibre alone and the whole plant produced good quality pulp and paper.

Since January 2001, the former IJO, presently the International Jute study Group (IJSG) had implemented a project on utilization of whole jute /kenaf as raw material for pulp and paper, involving five nations namely, Netherlands, France, China, Bangladesh and India. It recommended that jute and kenaf are good alternative raw material for paper and pulp. Quality of paper from jute and kenaf is similar to that of bamboo and other soft wood pulp. The pulping process studied were sodaAQ and Kraft process. NIRJAFT has been working independently on utilization of jute as an alternative raw material since last three decades. It has been observed that jute pulp produced by modified soda-AQ process (ASAM Process) is superior to the kraft pulp. To make jute acceptable as a raw material for pulp and paper, we have to adopt a pulping process which does not have the drawbacks of kraft process but gives paper of better strength, easy bleachability and without the environmental drawbacks i.e., obnoxious smell of mercaptan gas.

Today we find that jute is not used as a raw material for paper and pulp in small scale paper mills and handmade paper units. It is because jute requires chopping which is laborious and pulping by a method which should be user and environment friendly. NIRJAFT has now developed a pulping method which can be used for both unbleached and bleached paper. The process is not only user friendly but is also eco-friendly, as no obnoxious gas is released or emitted after pulping. Similarly the effluent released can be used for isolating high-dry ligno-sulphonates which has a number of industrial applications.

The average productivity of jute is 1.6-1.9 tons/hectare and India produces 1.5 million tons of jute annually along with 3 million tons of jute stick and 6.2 million ton of whole jute plant on dry weight basis. India's food production has increased from 8million tons in 1950-51 to 238 million tons presently. Although NIRJAFT has no role in the food production of the country, it owes a huge responsibility for transportation and packaging of food grains. There was a time when the bulk of the food grain was transported by gunny bags. Now as a result of competition from synthetics bags, jute is loosing its pristine glory.

Unbleached paper produced from jute can be used as a packaging material in the form of multilayered paper bags for cement, laminated paper bags for food grains and fertilizer. Corrugated boards obtained from unbleached paper can be used for packaging and transportation of consumer durables, home appliances, and electronic products, fruits, fast food (viz. pizza) and a large number of items. Similarly tetra packs for beverages. The high burst index for jute and whole jute pulp makes jute a preferred raw material for corrugated boards.

Introduction

Jute is one of the most important bast fibres in India and is second in production to cotton. Jute plants are annually grown herbaceous plants. The height ranges from 2-5 meters and diameter of stalk ranges from 1.2 to 1.5 cm. It grows both on high and lowland, withstands water logging and can be sown and harvested enabling the cultivators to raise a crop of transplanted rice after the jute harvest in June and July. It is essentially a monsoon or rainy season crop.

Jute grows in India, Bangladesh, China and Brazil. The major jute producing States in India are West Bengal, Assam, Andhra Pradesh, Bihar and Orissa. The economy of these parts revolves around jute. Jute fibre production is about 1.5 million tons per annum for an average yield of 1.6 ton /hectare. It is estimated to be obtained from 25 million Ton of Green whole jute plant which on drying would give 6.2 million ton of dry whole jute plant and 3.7 million ton of dry jute stick.

Traditional jute products are facing severe competition due to synthetics. There is an urgent need to develop new products for jute and allied fibres and their respective markets. The forest resources of jute growing countries are very limited. With increase in the population of thee countries, pressure on land has increased which has resulted in the large scale destruction of forests.

The stem of jute consists of two fibrous components, both of which are suitable for producing paper and paper board products. The bark (fibrous part) is suitable for quality paper making and is similar to softwood fibers. Core (stick) has strength properties similar to hardwood pulps.

Although the economics of pulp production favour wood, most of the developed countries and many of the developing countries do not have adequate wood plant fibre available for every type of paper from tissue to liner board and even newsprint.(1)

At present straw, bagasse and bamboo are the leading non-wood fibres being used from a quantity standpoint, but many others are being used for speciality pulps and have special properties which are not found in any of the best wood pulps(2)

Cotton rags used in handmade paper has relatively longer fibres and is much less expensive., whereas, cotton linters have short fibres. Cotton rag fibres are typically 10-45 mm long, while cotton linters are 1-2 mm long. Jute grown in subtropical areas such as India and Bangladesh have long and strong fibres. It can very well replace cotton rags in handmade paper industry, it can also be used as speciality paper and packaging paper(3).

Chemical Composition Of Jute etc.

Jute and other fibres of jute family have attracted the attention of the paper industry, primarily because of the high quality of fibre. These annual plants contain about 35-40 % outer bast and 60-65 % inner core. The outer bast is characterised by strong and long fibre strands and the inner core contain short fibre and pith. Both the bast fibre alone and the whole plant produce good quality pulp for paper making. The comparative analysis of the fibre is given in Table I, which indicate the advantages of low lignin and high α-cellulose content. Further the low chemical demands and high cellulosic yields results in cost effective production of pulps.

Table 1
Chemical Composition Of Jute, Mesta And Bamboo

Sl. No.	CHEMICAL COMPOSITION	JUTE			MESTA			BAMBOO
		Whole Jute	Jute Fibre	Jute Stick	Whole Mesta	Mesta Fibre	Mesta Stick	
1	Holocellulose %	77	81.5	74.5	83.7	84.1	78.4	60
2	α-Cellulose %	-	60	41	-	60	38	57
3	Pentosan %	14	12	22	18.5	18	22.3	14
4	Lignin %	20	14	24	14	12.5	19.4	25
5	Ash %	-	1.6	0.8	-	0.8	0.7	2
6	Avg. Fibre length (mm)	-	2.5	0.8-1.0	1.67	2.31	0.95	2.5

Fibre Morphology

Fibre dimensions of conventionally used papermaking raw materials are recorded in Table 2. The average length of the jute fibre is similar to bamboo, but shorter than softwood. Average diameter of the jute fibre is less than softwood fibre. The jute fibre is thick walled with narrow lumen. Narrow fibre width accompanied by thick cell wall makes the jute fibre stiff compared to softwood fibre. High Runkel ratio of the fibre renders it more suitable for paper requiring high opacity. Coarseness of the fibre measured as mass per unit of fibre length indicates that jute fibres are less coarser compared to bamboo and softwood fibre, The non-fibrous cells having a shorter length (primary fines, having length <200 µm) are negligible compared to soft wood or bamboo pulps.

Table 2
Fibre Morphology Of Papermaking Raw Materials

Sl. No.	Fibre property	Unit	Jute Fibre	Soft wood	Bamboo
1	Fibre length	mm	2.8	3.5	2.5
2	Fibre diameter	µ	18	35.5	16
3	Wall Thickness	µ	5.2	3.8	6.6
4	Runkel ratio	-	1.6	0.14	0.8
5	Coarseness	mg/m	0.19	0.32	0.28
6	Fines (<200µm)	%	0.5	6.0	7.5

Intrinsic Fibre Strength

Intrinsic fibre strength of a papermaking fibre is the inherent strength of the fibre, which is a measure of the potential strength of paper obtainable from it. Intrinsic fibre strength of the different Indian paper making raw material is given in Table 3. Of the various raw materials, jute is the strongest fibre and it compares well with pine fibre, indication that it can be used for speciality papers requiring high strength.

Table 3
Intrinsic Fibre Strength Of The Different Indian Papermaking Raw Material

Sl. No.	Fibre Type	Zero-span Breaking length (Km)
1	Rice straw	6
2	Wheat straw	10
3	Bagasse	11
4	Eucalyptus	12
5	Bamboo	19
6	Jute	22
7	Pine	21

Materials And Methods

Raw material

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

Alkaline sulphite pulp of jute (ASP)

Jute pulp was prepared by alkaline sulphite pulping process in a rotary digester at 15% Na_2SO_3 and 3 % NaOH, using 1: 10 liquor ratio, at 160° and 120° for 2 hour, yield was 75-78 %.

Kraft Pulp of Jute (KP)

The jute samples were digested in a rotary digester at 17.5 % NaOH (and 6.5 % Na_2S) at 1: 10 liquor to material ratio, at 160^0 and 115^0 for 2 hour after rise of temperature.

Alkaline Sulphite Anthraquinone Methanol pulping of Jute(ASAM)

The jute samples were digested in a rotary digester at (20%) Na_2SO_3, 5% NaOH, (0.01%) AQ at 1:10 material to liquor ratio having 15 % MeOH, at Temp 160^0 and 115^0 for 2 hrs.

Bleaching of Jute Pulp

A portion of the unbleached pulp was bleached in a covered vessel using H_2O_2 (20 ml/l) at 1:20 material to liquor ratio, trisodium phosphate (5 g/l), NaOH (1g/l), sodium silicate ((10g/l) and non-ionic detergent (2g/l) for 1.5 h at 85-90^0 C. The pH was maintained at around 10. The bleached pulp was washed in normal water and neutralized with dilute acetic acid (2 g/l) and was given a final wash with for further processing.

Standard Hand Sheets

Standard hand sheets of 60 GSM were made from all the three types of pulp i.e., bleached, unbleached after beating them in a Valley Beater to about 40^{0}SR freeness, using UEC hand sheet former.

Evaluation of Physical Properties

Tensile Index was determined by Tappi Test Method T 404 om-87, Bursting Index was determined by Tappi Test Method T 403 om-85 and Folding endurance of paper (Schopper type) was determined by Tappi Test Method T 423 0m-89, Tearing Strength by Tappi Test Method T 414 om-88 (4). The instruments used were Tensile Strength Tester Veb Thuringer Industriewerk, Raunstein (Germany), Double Fold Tester,UEC, Saharnpur, Bursting Strength Tester by UEC, Saharnpur and Tearing Strength Teater by UEC, Saharnpur.

Results and Discussion

The kraft process is the dominant wood pulping process (5) throughout the world. It is the most economic pulping process, gives the best strength properties. The draw backs are the obnoxious odour associated with even the most advanced mills, to be economical production capacity of 1000 tons per day or more is required, thus huge capital investment is required. The possibility of kraft smelt explosion prevents Tomlinson type recovery furnace as a result of safety factor. Residual lignin in kraft unbleached pulp is resistant to non-chlorine bleaching agents to achieve requisite whiteness. Use of chlorine, chlorine dioxide and chlorine containing chemicals cause environmental pollution. For this reason there is renewed interest in recent years to find alternatives to the kraft system that will yield pulp with kraft like strength properties, but without environmental drawbacks.

In the ASAM process carbohydrate dissolution rate is lower than that of lignin. This is due to lower alkalinity and the presence of methanol and anthraquinone which protects the carbohydrate. The dissolution of xylan does not exceed 30%, whereas, up to 80% of glucomannan is dissolved in ASAM cook of pine. The protection of the carbohydrate in the ASAM liquor results in a very high pulp viscosities (5).

Reactions with lignin using ^{14}C labelled methanol showed that about 99 % of the charged methanol can be recovered, only 1 % remains in the pulp. It can be assumed that in commercialscale operation, the ASAM process will be self-sufficient with regard to methanol (5).

The solubility of anthraquinone in presence of alkali is limited. This is the reason that during the heating phase of a cook, only a certain percentage of the charged anthraquinone can be analyzed. But when the cook reached its maximum temperature, all anthraquinone gets dissolved and then starts to decompose. At the end of the cook 20 % of the initial charge can be analyzed (5).

The high selectivity of the ASAM process results in approximately 10 % higer soft wood pulp compared to kraft pulp. In hardwood pulping this yield advantage is less evident (5). The selectivity of the process allows delignification to very low kappa numbers without degradation of the pulp (5).

The strength properties of ASAM pulps are superior to those of any kraft pulp. This is corroborated by the ASAM pulp made from jute vide Table 1 & 2. The high tensile strengths, which are based on the good bonding ability of the fibres, are mainly the result of the high hemicellulose content of these pulps. The ASAM process yields the highest hemicelluloses content in the outer cell wall layers, which are the primary (P) and outer secondary wall (S_1). The high tear strength of ASAM pulps is probably due to the smother pulping conditions, leaving the carbohydrates at a high degree of polymerization (5).

The high hemicelluloses content of ASAM pulps improves beatability. The strength development starts very quickly, meaning that beating can be stopped at low degrees, which saves energy and improves porosity and draining of the paper sheet (5).

Black liquor evaporation and methanol recovery

As discussed ASAM process does not require additional methanol. Methanol can be recovered directly from the digester and /or from the black liquor.

The ASAM black liquor is easy to concentrate to high dry-solid content. The viscosity of ASAM black liquor is lower than that of kraft black liquor, because of low molecular weight of lignosulphonates and their high degree of sulphonation.

To find the best pulping method for the three lignocellulosic raw materials obtained from jute cultivation (jute stick, jute fibre and whole jute plant), four different pulping methods viz., kraft process, alkaline sulphite process, modified alkaline sulphite Aq process (ASAM) and alkaline process were tried on the raw materials.

It was observed that in case of jute stick modified alkaline sulphite process (ASAM) gave the best pulp yield and highest strength characteristics. Vide Table 4.

In case of jute fibre comparative pulping study by the three pulping methods i.e., kraft process, alkaline sulphite process and modified alkaline sulphite process (ASAM) showed that the modified alkaline sulphite process (ASAM) gives better

Table -4
Jute Stick

S.No.	Sample	Yield (%)	Freeness °SR	G.S.M.	Folding	Tensile index Nm/g	Burst index $KPam^2/g$	Tear index mNm^2/g
1.	Alk Sulphide 160°C, 3 hr	48.7	40	62	10	61.17	2.43	3.23
2.	Alk Sulphite 160°C, 3 hr	48.95	45	61	4	62.18	2.44	3.28
3.	(ASAM)MeOH + AQ 160°C, 3 hr	50.32	40	58	5	84.56	3.74	3.76
4.	NaOH, 17 % 160°C,3 Hrs	47.8	45	61	3	58.96	2.44	3.27

yield and strength compared to the kraft process. When the temperature of pulping was reduced to 120^0. there was an increase in yield and strength property and the modified alkaline sulphite process (ASAM) was found to be the best among the three processes. When the temperature was further reduced to 115^0 in case of the modified alkaline sulphite process (ASAM), there was an increase in yield and strength properties and a high increase in burst index. This shows that jute fibre pulp will be a highly sought after raw material for unbleached liner paper used in corrugated fibre board. Vide Table 5.

Table-5

Sl. No.	Pulp	Yield %	Fold No.	Tensile Index Nm/g	Burst Index $KPa.m^2/g$	Tear Index $mN.m^2/g$
Unbleached jute Fibre Pulp						
1.	Alkaline Sulphite pulp , 160^0	69	15	47.46	3.0	12.90
2.	Kraft pulp , 160^0	59	5	46.10	1.90	11.90
3.	ASAM MeOH-AQ , 160^0	62	25	61.17	2.75	13.55
Bleached jute Fibre Pulp						
Sl. No.	Pulp	Yield % (after digestion)	Fold No.	Tensile Index Nm/g	Burst Index $KPa.m^2/g$	Tear Index $mN.m^2/g$
1.	Alkaline Sulphite pulp Bleached, 160^0	69	63.6	46.86	2.76	14.0
2.	Kraft pulp Bleached, 160^0	59.73	33	40.24	2.50	12.0
3.	ASAM MeOH-AQ Bleached, 160^0	63.0	43	41.42	2.66	14.0
Unbleached jute Fibre Pulp at 115^0						
Sl. No.	Pulp	Yield %	Fold No.	Tensile Index Nm/g	Burst Index $KPa.m^2/g$	Tear Index $mN.m^2/g$
1.	ASAM MeOH-AQ-20% 1:24,115^0	82	1154	75.94	5.47	8.06
2.	ASAM MeOH-AQ-20% 1:15,115^0	81	661	73.69	5.59	9.52
6.	ASAM MeOH-AQ-20% 1:10,115^0	80	1041	83.98	6.57	7.28

Table -6
Whole Jute Plant (WJP)

	Alk-Sulphite 160^0 WJP	Enzyme treated Alk-Sulphite 160^0 WJP	ASAM** 160^0 WJP	Enzyme treated ASAM** 160^0 WJP	Kraft 160^0 WJP	Enzyme treated Kraft 160^0 WJP	Alkal. 160^0 WJP	Enzyme treated Alkal. 160^0 WJP
Tensile Index Nm/g	76.29	53.32	70.93	53.79	69.75	55.33	68.61	31.09
Tear Index mNm^2/g	4.0	4.92	4.75	5.16	3.33	4.62	3.94	4.91
Burst Index $KPam^2/g$	3.35	2.29	3.02	2.59	2.41	2.87	2.99	1.16
Fold no.	4	9	5	14	6	25	6	10
Yield %	66.85		68.22		67.1		66.0	

In case of jute whole plant modified alkaline sulphite process (ASAM) again showed better yield and strength characteristics compared to the kraft process, whereas the enzyme treated jute whole plant showed a general loss of strength properties . Vide Table 6.

Conclusion

Annual production of jute is 1.5 million ton, jute stick is 3 million ton and that of the whole jute plant is 6.5 million ton, all are excellent raw materials for paper and pulp. This has been revealed by different studies conducted by IJO & IJSG, the pulping process studied were kraft and sodaAq. Studies at NIRJAFT also showed that jute can be pulped by alternative pulping process which gives strong paper. Through-out the world there is a search for an alternative pulping method that will give paper as strong as kraft paper without the environmental drawbacks. There is urgent need to develop an alternative pulping process by a comparative study of different pulping processes.

Majority (about 65%) of jute produced is used for sacking which is used for packaging and transportation of food grain and sugar. However this is primarily because of the Jute packaging material Act 1987 (JPMA). Since jute is a cash crop and the farmers need cash before the festive season even in the absence of the above act, the jute farmers will continue to grow the plant. This is because jute is grown between the two crops and does not require much attention.

Jute can still serve the purpose of packaging and transport the food grains and other consumer goods, if we can convert jute to high strength packaging paper or corrugated boards.

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