Bagasse-The Promising Alternative For The Future

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ABSTRACT

Growing demand for paper and paper products has increased the demand for fibrous raw materials. The depleting forest based woody raw materials has forced the industry to look for alternatives. Bagasse, the sugarcane residue, is found to be the best alternative, meeting the quality requirements for newsprint and fine paper manufacture. Certain inherent draw backs and peculiarities of bagasse need special treatment, by which bagasse can replace the conventional forest based raw materials. Bagasse takes an edge over other raw materials owing to its low kappa number and excellent bleachability, leading to lower pollutants.

INTRODUCTION

There has been an ever increasing demand for paper and paper products. The per capita consumption of paper in India is growing with increasing literacy and there has been a steady growth in demand for paper. This has led to an equivalent demand for fibrous raw materials of papermaking. In the Indian paper industry, divergent raw materials are being used for papermaking. With the fast depletion of forest resources, the availability of wood has become scarce. Ultimately, the industry is forced to depend on plantations to meet the wood requirement, which has met only limited success. The only alternative left out to meet the raw material shortage, is through non-wood fibrous raw materials like bagasse, straw waste paper etc. Among various non-wood plant fibre sources, bagasse occupies a commanding position. Bagasse has proved itself to be the most promising alternative for hardwoods. The projected usage of indigenous fibrous raw materials is given in **Table-1** (1).

Table-1

Usage of Indigenous Fibrous Raw Materials

Year	Forest based raw mat.	Bagasse	Straw	Waste paper
	(IN LAKH TONS)			
1994-95	31.46	31.00	7.50	5.17
2000-01	32.10	60.00	7.50	9.11
2005-06	32.10	90.00	7.50	13.87
2010-11	32.10	108.00	7.50	19.50
2015-16	32.10	126.00	7.50	27.00

As may be seen from the table, the availability and usage of forest raw materials and straw, is not going to increase and the thrust will be on the usage of abundantly available bagasse and recycled fibre in the form of waste paper. The projected production of paper from various indigenous raw materials is given in **Table-2** (1).

The production of bagasse based paper will be exceeding the wood based paper by the year 2005-06 and the production with the usage of recycled fibre will be exceeding the wood based

Table-2

Possible Production of Paper From Indigenous Raw Materials

Year	Forest based raw mat.	Bagasse	Straw	Waste paper
	(IN LAKH TONS)			
1994-95	12.10	5.60	2.50	3.88
2000-01	12.35	10.90	2.50	6.83
2005-06	12.35	16.36	2.50	10.40
2010-11	12.35	19.63	2.50	14.62
2015-16	12.35	22.91	2.50	20.25

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Table-3				
Fibre Pith Analysis of Whole Bagasse Depithed Bagasse and Pith				
		Whole Bagasse	**Depithed Bagasse**	**Pith**
Useful fibre	%	45-54	63-65	11-18
Pith	%	36-46	26-29	71-77
Water solubles	%	8-12	8-9	11-12
Fibre to pith ratio		1.2:1 to 1.6:1	2.2:1 to 2.6:1	0.15:1 to 0.25:1

by the year 2010-11. With the evident scope for rapid increase in bagasse based papermaking, it is quite pertinent to evaluate the in and out of bagasse, to make bagasse paper competitive on par with the wood based and imported softwood based fine paper grades. The paper discusses the potential of bagasse for papermaking.

BAGASSE-DEPITHING

Sugarcane is a seasonal crop and bagasse will be available only during the crushing season. Wet whole bagasse coming out of the sugar mill has a moisture content of 50-55%. It contains about 45-54% useful fibre and 50-55% pith. Only the fibre part is useful for papermaking, while pith, which is amorphous in nature, is not favourable for papermaking. Hence whole bagasse is depithed to remove as much pith as possible. Various methods are employed for depithing of bagasse which include moist depithing, wet depithing, dry depithing.

In the moist depithing, bagasse at 50-55% moisture is passed through rotating hammers, inside a screen basket. Pith being lighter, is thrown out of the screen basket and depithed bagasse gets collected at the outlet. Under optimum conditions, about 20% of the material is removed as pith. The fibre pith analysis of whole bagasse, depithed bagasse and pith is given in **Table-3.**

Wet depithing of bagasse involves disintegration of bagasse at low consistency with water, followed by dewatering through screens, aquaseparators and screw presses, during which the water solubles and pith are carried along with the drained water. In wet depithing also about 15-20% of the material is removed as pith. the combined effect of moist and wet depithing yields a bagasse of 65-68% useful fibre.

Table-4				
Fibre Pith Analysis of Bagasse At Different Stages				
		Whole Bagasse	**Depithed Bagasse**	**Digester feed Bagasse**
Useful fibre	%	45-54	63-65	65-68
Pith	%	36-46	26-29	24-26
Water solubles	%	8-12	8-9	8-9
Fibre to pith ratio		1.2:1 to 1.6:1	2.2:1 to 2.6:1	2.5:1 to 2.8:1
Losses in depthing			~20%	~15%

PITH CONTENT-INFLUENCE ON PULP QUALITY

The quantity of pith present in bagasse has got a say on the quality of pulp produced out of it. The fibre to pith ratio, which is taken as indicator for bagasse quality in terms of its pith content and fibre content, in whole bagasse, is governed by the nature of cane, its maturity and the milling process adopted. There are certain processes of separating the rind

Table-5				
Influence of Pith Content on Kraft Pulping				
		Whole Bagasse	**Depithed Bagasse**	**Double Depithed Bagasse**
Pith content in bagasse	**%**	**35**	**28**	**25**
Fibre to pith ratio		1.88:1	2.52:1	3.00:1
Pulp yield	%	52.2	55.0	56.2
Kappa number		18	14	10
Pulp brightness	%ISO	32	37	41
RAA of black liquor	gpl	2.4	3.8	4.8
Pulp freeness	ml CSF	420	460	490
Tensile index	Nm/g	68.6	70.2	72.5
Tear index	mNm^2/g	5.49	6.08	6.27
Burst index	$kPam^2/g$	3.65	3.90	4.41
Sc. coefficient	m^2/kg	25.4	27.0	28.5
Constant pulping conditions: 12% Na_2O, 170 ^0C, 7 kg/cm^2, 20 minutes				

Table-6

Quality of Bagasse From Different Layers of Stored Pile

(Bagasse stored under wet bulk method for one year)

		Fresh Bagasse	Top layer	Middle layer	Bottom layer
Useful fibre	%	65.0	18.0	60.0	65.0
Pith	%	26.0	59.0	30.0	27.0
Water solubles	%	9.0	23.0	10.0	9.0
Fibre to pith ratio		2.52:1	0.31:1	2.03:1	2.43:1
Brightness	%ISO	38-40	15-18	25-30	38-40
pH		5.0	2.5	3.5	4.0

fibre, prior to crushing, to prevent fibre damage. An optimised depithing is important to have a good quality depithed bagasse. The factors influencing the depither performance are the moisture content of incoming bagasse, the feed rate to depithers, the pith content in the undepithed bagasse, the thickness of the screen basket and the perforation size of the screen basket.

Maximum pith removal is desired for the following reasons. Bagasse with higher pith content gives a pulp of lower yield, higher kappa number. The chemical consumption is also high. (2)

Pith takes up chemicals, becomes gelatinous, causing difficulties in washing, screening and bleaching. It results in poor drainage of pulp and causes sticking problems in machine.

BAGASSE STORAGE-QUALITY IMPACTS

Bagasse will not be available throughout the year, it has to be stored at mill site, for uninterrupted operation of the plant. Bagasse after depithing, is stored in open yards, employing several methods. Moist bulk storage, wet bulk storage, baled storage, and dry storage are some of them. Among the various methods available, the wet bulk storage method enhances maximum storage in minimum area.(3)

In the wet bulk storage, bagasse after moist depithing, is conveyed to a boom stacker, wherein it is slurried to 3-4% consistency, with water, and dropped on asphalt topped floor. The excess water percolates out, which is collected back and reused.

Table-7

Quality of Bagasse From Different Layers of Stored Pile-Pulping Data

(Bagasse stored under wet bulk method for one year)

		Fresh Bagasse	Top layer	Middle layer	Bottom layer
Total Pulp yield	%	55.0	46.7	53.4	55.6
Screen Rejects	%	1.1	4.1	2.1	1.1
Kappa number		13.9	85.2	21.5	13.8
Unbleached pulp brightness	%	40.8	17.5	34.8	41.6
Black liquor					
pH		11.4	9.6	11.3	11.8
* TTA as Na_2O g/l		30.1	24.5	28.7	32.8
* RAA as Na_2O g/l		3.65	0.99	2.56	3.71

* - at 200 g/l total solids

Constant pulping conditions : 12% Na_2O, 170 ^0C, 7 kg/cm^2, 20 minutes

Table-8

Depithed Bagasse Vs Eucalyptus-A Comparison

		Depithed Bagasse	Eucalyptus Hybrid
1% NaOH solubility	%	32.0	17.0
Lignin	%	21.0	28.0
Holocellulose	%	69.0	67.0
Pentosans	%	23.0	17.0
Pulping chemicals	%	12.0	15.0
Pulp yield	%	54-57	44-45
Kappa number		10-12	22-24
RAA of black liquor	gpl	4.5-6.0	2.0-4.0

Bagasse is stored in huge piles of 10-15 m height. The quality of bagasse is not uniform throughout the pile. When a cut cross section of a stored bagasse pile is examined, three distinct brightness zones are observed. The top outermost layer over the surface, upto a depth of 1.5-2.0 metres, is the darkest, with the brightness of bagasse 15-18% ISO, as against 38-40% ISO for fresh depithed bagasse.

The following layers, just below the surface 2m layer, is brighter with the brightness ranging between 25-30% ISO. The innermost layer is found to be the brightest, equal to that of fresh depithed bagasse. The quality of the bagasse from different layers of the stored bagasse pile is given in **Table-6**.(4)

The data shows that the top surface layers is most affected upon storage, resulting in complete discoloration and degradation, making it even unsuitable for pulping.(4)

The severity of degradation of course depends on duration of storage and the weather conditions. The middle layer suffers little degradation while the inner most anaerobic core of the pile is preserved completely. Thus it could be stated that it is the aerobic environment and the microbial population specifically responsible for the discoloration and degradation.

PREVENTIVE MEASURES FOR DISCOLORATION AND DEGRADATION

Several methods are being employed, world over, to mitigate the degradation of bagasse storage, so as to ensure an uniform quality of bagasse. The methods adopted are Celotex, Ritter biological process, and Bagatex 20.(5)

The Ritter biological process is a unique successful method of wet bulk storage of bagasse, in which a biological fluid containing lactobacilli is mixed with a dilute suspension of bagasse. This enhances controlled fermentation and converts the residual sugars to lactic acid, maintaining a pile pH of 3.5-4.0, resulting in preservation of bagasse fibre. The Bagatex 20, on the other hand, basically involves rapid drying of bagasse in large bales at 50% moisture to 20% moisture, by adding a biochemical catalyst, which will accelerate but carefully control the fermentation of residual sugars.(5)

The aforementioned methods are oriented only toward reduction of quality losses and storage losses. The Ritter biological method does not guarantee preservation of brightness, which is very critical for mechanical pulp production.

Taking into consideration various factors influencing the brightness of bagasse upon storage, low consistency, low pH and anerobic conditions are the most favourable. Recycled water used for bagasse storage, is rich in sugars and microbial population, and thus accelerates the rate of discoloration and degradation. Biological processes thus do not guarantee total preservation and several chemical treatment methods tried, like chlorine water addition, Sodium bi sulphite treatment, tried on bench scale showed encouraging results.(5)

Table-9

Depithed Bagasse Vs Eucalyptus-Comparison of Pulp Properties

		Depithed Bagasse	Eucalyptus Hybrid
Pulp freeness	ml CSF	450	410
Bulk	cc/g	1.55	1.73
Tensile index	Nm/g	65.7	70.6
Tear index	mNm^2/g	5.6	7.3
Burst index	$kPam^2/g$	4.0	4.4
Brightness	% ISO	80.0	75.0
Sc. coefficient	m^2/kg	33.0	57.0
Initial Wet Web Tensile index	Nm/g	0.7	0.9

Table-10			
Depithed Bagasse Vs Eucalyptus-Comparison of Printability Properties			
		Depithed Bagasse	**Eucalyptus Hybrid**
Brightness	%ISO	80	75
Cobb	g/m^2	25	14
Sc. coefficient	m^2/kg	33	57
Smoothness	ml/min	110	220
Roughness	μ	3.2	4.6
Porosity	ml/min	220	2400
Oil absorbency	g/m^2	24	67
K&N number		54.2	79.1
Print quality	%	86.2	88.4
Show through	%	27.2	13.9

Bagasse storage being inevitable, for flexible fibre and loosening of adhered pith, minimum storage period will be one- of the steps to minimise the discoloration and degradation of the top layers, preventing it from becoming totally unsuitable for pulping.

COMPARISON OF BAGASSE WITH HARDWOOD

Bagasse, as an alternative for forest based woody raw materials, has several advantages and some disadvantages. Depithed bagasse has several positive features over hardwoods.(6)

Bagasse has an open structure. The lignin content is lower and pentosan is comparatively higher than Eucalyptus hardwood. Bagasse requires lower pulping chemical and the pulp yield is significantly higher than hardwood. The kappa number of the bagasse pulp is between 10-12 for 12% Na_2O pulping chemicals, while hardwood is able to give a pulp of 22-24 kappa number only even with 15% Na_2O chemicals. The comparison of the pulp properties show that bagasse pulp has a lower bulk, lower tear and lower scattering coefficient in comparison to hardwood pulp (6).

The bleachability of bagasse pulp is better, requiring low chemical charge, because of the low kappa number of the unbleached pulp. The bleaching response is excellent.

At the same kappa number also, hardwood pulp responds poorer than bagasse, to bleaching. The lower kappa number and better bleachability of bagasse result in lower bleach chemical requirement, consequently lower pollutant generation during bleaching. A simple three stage CEH bleaching is sufficient to reach a brightness of 85% ISO.

PRINTABILITY ASPECTS OF BAGASSE PULPS

The printability characteristics of bagasse pulp in comparison to hardwoods is given in **Table-10**, which shows lower ink absorbency and K&N number, for bagasse pulp.

Owing to the low bulk and low scattering coefficient of bagasse, the print show through is high.

Table-11				
Technology Advances in Bagasse Pulping-Anthraquinone Aided Pulping of Bagasse				
		Soda	**Soda-AQ**	**Kraft**
Chemicals as Na_2O	%	12	12	12
Anthraquinone	%	--	0.1	--
Pulp Yield	%	56.4	56.7	56.8
Kappa number		18.6	10.8	10.6
Brightness	%ISO	37.0	38.6	37.9
Viscosity	cPs	16.2	18.1	26.0
Tensile index Nm/g		75.95	82.28	84.54
Tear index mNm^2/g		5.41	5.27	5.44
Burst index $kPam^2/g$		4.88	5.13	5.04
Constant pulping conditions : 12% Na_2O, 170 ^0C, 7 kg/cm^2, 20 minutes				

Table-12			
Technology Advances in Bagasse Pulping-Oxygen Delignification of Bagasse Pulp			
		Kraft	**Kraft-Oxygen**
Chemicals as Na_2O	%	12	8
Pulp Yield	%	56.1	58.2
Kappa number		11.0	9.8
Brightness	%ISO	40.7	41.5
Viscosity	cPs	22.9	22.8
Tensile index	Nm/g	83.00	85.00
Tear index	mNm^2/g	5.90	6.45
Burst index	$kPam^2/g$	3.30	3.60
Conditions for Kraft	: 170 ^0C, 7 kg/cm^2, 20 minutes		
Conditions for Oxygen deligification	: 120 ^0C, 10% consistency, 60 minutes, O_2 pressure 5 kg/cm^2		

Table-13	
Technology Developments in Bagasse Pulp Bleaching Short TCF Sequences	
Initial Pulp : 12 % Kraft, 10 kappa number	
SEQUENCE	**BRIGHTNESS %ISO**
$O - H_{0.5} - D_1$	85.9
$O - H_1 - D_1$	89.7
$OP_2 - H_1 - D_1$	90.4
$Q/OP_2 - H_1 - D_1$	90.8
$Q/P_2 - H_1 - D_1$	87.4
$Q/P_2 - H_2 - D_1$	90.1
$D_{2.5} - EOP - D_{1.25}$	89.2
$D_{2.5} - EP - D_{1.25}$	89.7
$D_{2.5} - EO - D_{1.25}$	89.2
Q refers to chelation stage	

Achieving low cobb values is also difficult for bagasse pulp.(7)

TECHNOLOGY ADVANCEMENTS FOR BAGASSE PULPING

Considering the environmental air pollution during the kraft pulping, alternative sulphur free pulping methods are quite promising for bagasse. Anthraquinone aided soda pulping of bagasse, results in pulp quite similar to kraft.(8)

The hydrogen sulphide and mercaptan emanating from the kraft process can be totally prevented by switching over to anthraquinone aided soda pulping. The pulp yield, pulp properties need not be sacrificed.

Another promising option available is the kraft oxygen process. Pulping to higher kappa number with lower chemicals, followed by Oxygen delignification gives a pulp of lower kappa number at improved yield and enhanced strength properties(8).

ECF AND TCF BLEACHING OF BAGASSE PULP

Bagasse kraft pulp is easily bleachable with short CEH sequence to 85% ISO brightness. Owing to its low initial kappa number, bagasse pulp requires low bleach chemicals and pollutant generation is considerably low in comparison to wood pulp. Still, with the trend towards Elemental chlorine free sequences, short bleaching sequences involving chlorine di oxide tried resulted in a brightness of 90% ISO

Chlorine free bleaching, short TCF sequences were also promising for bagasse pulp to reach 80-85% ISO brightness levels.(9)

Sequences with Oxygen and peroxide in two

Table-14	
Technology Developments in Bagasse Pulp Bleaching Short TCF Sequences	
Initial Pulp : 12 % Kraft, 10 kappa number	
SEQUENCE	**BRIGHTNESS %ISO**
Q/EOP_2	80.9
$O-QP_{1.5}$	83.6
$(EOP_2)P_1$	80.5
$(EOP_2)P_2$	83.4

stage bleaching is capable of reaching target brightness of 80-85% levels.

PECULIARITIES OF BAGASSE

Being abundantly available, and because of several positive aspects, bagasse has proved itself to be the promising alternative for wood and bamboo. While it can comfortably substitute the shortfall in wood supplies, bagasse has some peculiar concerns to be attended, While using it on large scale.

Bulk density

Bagasse being a bulky material, it has a low bulk density of 50-70 kg/m^3 on OD basis. This necessitates large storage area. In the wet bulk storage of course, due to compaction in 15 m pile, the bulk density is as high as 150-180 kg/m^3.

Storage problems

As discussed earlier, the discoloration and degradation problem along with other problems like storage losses, wind losses, sugars and pith are to be given due consideration. Preserving brightness of bagasse, for mechanical pulp production, is the need of the hour. The brightness of the newsprint is governed by the brightness of the mechanical pulp, and the brightness of raw material plays an important role. It has to be ensured that always bright bagasse from inner layers is fed to refiners, to have acceptable brightness and economic bleachability.

Sand and stones

Bagasse being an agricultural residue, quite a lot amount of sand and stones get carried along with the incoming bagasse, which cause severe damage to the processing equipments. A good sand removal mechanism in definitely needed, to avoid the wear and tear of the agitators, refiner plates, screens etc. Systems such as destoners, sand riffler are employed to remove sand and stones in the bagasse reclaiming stage. The application of medium density cleaners for removal of sand carried over has been giving excellent results.

Bagasse handling system backwater and bagasse washing system backwater

Due to the presence of sugars, fermentation takes place during storage and acids are produced. The bagasse handling backwater is acidic and rich in sugars (~ 5 gpl), and has a very high BOD and COD. The effluent is biodegradable and an efficient system such as anaerobic digestion, to take care of the high BOD and COD is warranted. The bagasse washing effluent is also rich in dissolved organics and suspended materials like pith and fibre fragments, which necessarily have to be removed before treatment.

Because of low pH and high acidity of the filtrates, carry over of these filtrates into the pulping system comsumes higher chemicals and yield a pulp of higher kappa number and lower brightness.

Pulp washing-scaling problems

The residual sugars and like compounds in bagasse accelerates scaling with calcium deposits, during the washing operations. The presence of pith is deterrent to the washing process owing to its gelatinous nature and affects Brown stock performance leading to higher alkali carryover along with pulp, in comparison to wood pulp. The rate of scale formation can be minimised by usage of soft water or evaporator condensates which have low hardness.

Quality fluctuations

Bagasse being received from numerous sources, the quality bagasse is not uniform and always heterogenous. The storage of bagasse further complicates the problem, and ensuring uniform quality is difficult. The problem is more serious when bagasse is taken for mechanical pulping, where the initial brightness of bagasse is very important. The open structure of bagasse makes it prone to discoloration and degradation which leads to heterogenity in quality after storage.

CONCLUSION

Bagasse has its own advantages and drawbacks when compared to the conventional wood and bamboo varieties. But it is the only abundantly available and quite promising alternative, for fine paper grades. The case of bleachability of bagasse pulp and low kappa number makes it friendlier to the environment, than wood.

The inherent draw backs of bagasse pulp such as low bulk, and low scattering coefficient and higher print show through, have to be compensated by addition of high scatter components. Otherwise bagasse is as good as any other conventional wood or bamboo.

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