Pulping And Light–ECF Bleaching Of Bagasse Mixed With Banana Pseudo Stem And Its Impact On Environment

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ABSTRACT

Alternate use of non-wood fibrous raw materials for bio energy is increasing day by day, competing with fiber requirement of pulp and paper industry. The pulp and paper industry started looking for the alternative fiber sources and one of them is Banana pseudo stem fiber which is presently under utilized. The major problem in use of Banana pseudo stem for pulp and paper making is the higher water content in pseudo stem and lower pulping yield leading to higher production cost. However, it is a better option for the mills which are located near the Banana growing belt where logistics work out favorably. The present study finds that unbleached pulp kappa number, brightness and yield for 10% and 5% Banana pseudo stem mixed with bagasse are 8.3 & 14.6, 39.0% & 31.5 % ISO and 51.54 and 52.22 respectively The Banana fiber mixed Bagasse pulp showed a good response to light-ECF bleaching with Ozone substitution. The Banana fiber mixed Bagasse pulp was bleached using DZEpD_1 sequence to 86.5% brightness. Addition of 10% Banana chips with Bagasse to produce unbleached pulp followed by DZEpD_1 bleaching sequence produced a pulp with requisite brightness, comparable strength with reduced environmental load especially the inorganic compounds which are difficult to treat by the conventional process.

Introduction

Forests in India are unable to meet the demand of fibrous raw materials for various forest and cellulose based industries. On the other hand, agricultural based non wood fibrous raw materials are increasingly used for various other purposes like bio-energy (1). The shortage of cellulose raw material is not only faced by the Indian paper industry, but also around the world (2). Apart from that, growing awareness about environment at different levels, increasing demand for paper, rising cost of available pulp wood, low fiber supply are major constraints to paper industry and opened the way for competitive alternatives to the well established wood fiber stocks.

In India, Banana is cultivated in 82,000 ha in Tamil Nadu followed by Andhra Pradesh (56,000 ha), Karnataka (42,000 ha) and Kerala (59,000 ha). In addition to fruit production, huge quantity of biomass is generated and this biomass is left behind in the fields. But it is well established fact that useful fiber from Banana pseudo stem and leaves, extracted on small scale, is used in textile industry and for preparing handicrafts, ropes etc., The use of short span non-wood raw material like Banana pseudo stem fiber could partially meet the fiber demand and even 5-10% market share could be highly profitable and environmentally acceptable (3). Banana chips in the pulping and paper making was studied by Guha (4), and Subrahmanyam (5) and concluded that the fiber of Banana stem is higher in strength properties as compared to other non wood materials. Heikal (6) developed Banana pulping with nitric acid. Dhake (7) succeeded in producing high yield chemi-mechanical pulp of Banana chip with NaOH pretreatment. Cordeiro (8) developed the soda - AQ pulping process for Banana stem. Manimaran (9) studied the bio-bleaching of Banana stem with xylanase. Li et. al., (10) detailed morphological information of Banana stem including pseudo-stem and pith using Confocal Laser Scanning Microscope observation. Paper and board manufacturing plant located in the vicinity of Banana growing belt can exploit the unique resources due its cost advantage especially the logistics because it contains more than 90% water. To understand impact of mixing Banana stem with bagasse pulping and bleaching studies were carried out by mixing 5% and 10% Banana pseudo stem with Bagasse and results are discussed in this paper.

Figure -1

Photographs of fReshly cut Banana chip and air dried Banana chip

Experimental

Raw material preparation: Freshly collected Banana pseudo stem was chipped into 2-3 cm chips and air dried at room temperature (Figure -1). De-pithed Bagasse collected from the Bagasse storage yard was then mixed thoroughly with required percentage of Banana chips and then packed in a polythene bag and kept for a day to get homogeneous moisture content.

Pulping: The mixture of de-pithed Bagasse and Banana chip was pulped (alkali charge 13% and 14 % as Na_2O, bath ratio: 1:5, cooking temperature: 170 ^{0}C, time: 20 min) in a rotary type electrically heated laboratory digester. At the end of the cooking, the contents of the digester were discharged into a bowl followed by sequential washing with de-mineralized water, disintegrated in a rod mill for 20 minutes, screened on a flat-slotted laboratory screen (slot widths 0.15mm), centrifuged, and then granulated. Total pulp yield, amount of screen reject, kappa number and black liquor properties were determined using TAPPI standard methods. After dewatering and fluffing, kappa number, percentage rejects, and total yield were determined.

Bleaching: Chlorine dioxide followed by Ozone bleaching was carried out at 4% pulp concentration at room temperature and 45°C for 30 minutes. During chlorine dioxide/Ozone bleaching, the chlorine dioxide was added first into the pulp suspension and followed ozone into the ozone mixture. The Hydrogen peroxide reinforced extraction stage was done at 10% concentration at 70 °C for 70 minutes. The initial pH was maintained at 10.5. The percentage of alkali was maintained at 0.3% and the hydrogen peroxide was added 0.8%. Final stage bleaching with chlorine dioxide was done at 70 °C by maintaining a consistency and pH at 10.0% and 4.0 respectively for 90 minutes. The bleaching was done in sealed plastic bags and they were placed in a thermostatic water bath. Bags were kneaded on several occasions during bleaching to maintain uniform concentration of chemicals throughout the pulp. The pH in extraction stage was adjusted by adding sodium hydroxide in the beginning to maintain the required pH. After each stage of bleaching, the pulp was washed initially with the same amount of hot water and then fresh water on a Buchner funnel under suction for collecting the filtrate samples for different effluent analysis and pad was slush dried for further analysis.

Pulp characterization: At all stages brightness, kappa number and strength properties of the pulps were carried out as per TAPPI Standard methods. Brightness was measured with an Optical spectrometer by using white tiles as standard one. For calculating tear, tensile and burst indices, the hand-sheets were made as per ISO DP 5269 and dried on plates in standard conditions and conditioned at 27 $\pm$ 1°C and 65 $\pm$5% relative humidity and tested according to TAPPI standards. Hand-sheet properties are reported on an oven dry basis.

Results and Discussion

The moisture content of the fresh Banana Pseudo stem was about 90%. In comparison with the traditional raw materials used in the pulp and paper making Industry, it was found that holo-cellulose in Banana stem was much lower for example wood and bamboo fibers (11, 12). But, it is still higher than straw (13). However, Banana stem had lower lignin content than wood and straw. While the ash and extractive contents in Banana stem were higher than wood fibers and lower than straw. Because of its acceptable content of cellulose, hollo-cellulose and low lignin content, Banana stem has potential applications in paper-making. The juice extracted from the Banana stem has relatively high organic compounds and sugars which can be utilized for making other by products like cadis, sugar cakes or it can be utilized to convert into biogas by anaerobic treatment to generate renewable energy. The sugars and organic compounds present in the juice contribute chemical oxygen demand of around 6000 mg/lit, which can be used to generate the bio-energy like biogas and use in lime kiln as renewable energy to replace furnace oil. Since the energy is generated

Table 1

Results and pulPing conditions of BaGassE and Banana fiber mixture cooking.

S. No	Parameters	Unit	Bagasse with 5% Banana fiber	Bagasse with 10% Banana fiber
1	Bagasse	%	95	90
2	Banana	%	5	10
3	Chemical addition	%	13.0	14.0
4	Liquor ratio		1:4	1:4
5	Cooking temperature	°C	170	170
6	Screened pulp yield	%	51.54	52.22
7	Screened pulp rejects	%	1.16	1.47
8	Kappa number		14.6	8.3
9	Unbleached Pulp Brightness	% ISO	31.50	39.00

Table - 2

Results of $DZEPD_1$ bleaching sequence and bleaching conditions

Bagasse and Banana stem 5%

Bleaching sequence	Cy %	ClO_2 %	NaOH %	H_2O_2 %	O_3 %	Temp. °C	Time min	End pH	Bri. %
DZ	4.0	1.00	0.00	0.0	0.4	45	4	4.9	51.0
EP	10.0	0.00	0.30	0.8	0.0	70	70	9.3	70.5
D1	10.0	0.60	0.00	0.0	0.0	90	90	3.5	84.2

Table 3

Results of $DZEPD_1$ bleaching sequence and bleaching conditions

BaGassE and Banana stem 10%

Bleaching sequence	Cy %	ClO_2 %	NaOH %	H_2O_2 %	O_3 %	Temp. °C	Time min	End pH	Bri. %
DZ	4.0	1.00	0.00	0.0	0.3	45	3	4.0	61.3
EP	10.0	0.00	0.30	0.8	0.0	70	70	10.6	78.4
D1	10.0	0.50	0.00	0.0	0.0	70	90	4.2	86.5

Table 4

Strength properties of unbleached and bleached Banana fibre mixed Bagasse pulp

S.No	Parameters	Unit	Unbleached Pulp		Bleached Pulp	
			5% Banana fiber	10% Banana fiber	5% Banana fiber	10% Banana fiber
1	CSF	ml	345	200	260	150
2	Bulk	ccg^{-1}	1.43	1.54	1.29	1.51
3	Tensile Index	Nmg^{-1}	55.8	58.3	51.20	55.8
4	Tear Index	mNm^2g^{-1}	5.65	6.17	5.34	6.36
5	Burst Index	$kPam^2g^{-1}$	5.2	4.3	4.72	4.43
6	Brightness	%ISO	25.6	26.8	79.7	76.6
7	Opacity	%	91.9	97.3	67.4	69.0
8	Sc. Coefficient	m^2kg^{-1}	17.7	23.1	19.8	22.8
9	Yellowness	%	35.1	36.0	3.20	5.60

internally it would reduce the specific energy consumption of final product to comply with Perform Achieve and Trade (PAT) target.

Properties of unbleached Banana fiber mixed Bagasse pulp are presented in Table 1. The unbleached pulp kappa number, brightness and yield for 10% and 5% Banana pseudo stem mixture is 8.3 & 14.6, 39.0% &31.5 % ISO and 51.54 and 52.22 respectively.

Ozone is found to be a useful bleaching agent to convert ECF to Light-ECF and has many advantages especially with reference to the environmental benefits (13, 14, 15, and 16). Light ECF bleaching with 1% Chlorine di oxide followed by 0.4% and 0.3% Ozone was applied in first stage for 5% Banana fiber mixed Bagasse and 10% Banana mixed Bagasse respectively. The first stage brightness was higher in 10% Banana fiber mixed Bagasse pulp, with 14% cooking chemicals, has higher brightness i.e. 61.3% against the 51.5% for 5% Banana fiber mixed Bagasse cooked with13% chemicals due to high kappa number indicates insufficient chemical charge in cooking. The brightness difference continued after extraction as well as final D_1 stage. The final D_1 stage brightness was found to be 86.5% for 10% Banana fiber mixed Bagasse pulp and 84.2 % for 5% Banana mixed Bagasse pulp respectively (Table -2 and 3).

Table - 5: Results of bleaching effluent of Banana fiber mixed Bagasse pulp

S.No	Parameters	Unit	Bleached								
			Banana Fibre & Bagasse DZ		Bagasse Do	Banana Fibre & Bagasse EP		Bagasse EoP	Banana Fibre & Bagasse D1		Bagasse D1
			5%	10%		5%	10%		5%	10%	
1	pH		3.4	4.5	2.3	8.3	9.3	9.2	3.5	4.9	2.6
2	Colour	Pt. Co.	960	40	440	1300	250	180	50	50	120
3	Total solids	mg/l	1748	1864	3024	2734	2384	2720	1052	990	786
4	Total Dissolved solids	mg/l	1496	1390	2714	2416	2238	1538	688	522	690
5	Suspended Solids	mg/l	252	474	210	318	146	182	364	468	96
6	Total Dissolved solids Inorganic	mg/l	334	340	2058	686	502	692	278	296	320
7	Chemical Oxygen Demand	mg/l	1488	1209	1504	457	395	1272	382	268	372
8	Total Hardness	mg/l	528	540	490	160	40	30	300	350	200
9	Calcium Hardness	mg/l	300	308	240	104	32	10	160	200	100
10	Magnesium Hardness	mg/l	228	232	250	56	8.0	20	140	150	100
11	Chlorides	mg/l	332	232	600	48.0	40	60	230	270	400
12	Sodium	mg/l	30	50	400	190	180	600	65	53	100
13	Potassium	mg/l	2.0	2.0	32.0	2.0	2.0	0.0	2.0	2.0	0.0
14	Conductivity	μmhos	1099	1060	5026	785	707	2086	903	628	1450

The strength properties like tensile, tear and burst indices are given in Table 4. The 5 % Banana fiber mixed Bagasse pulp has slightly higher burst. On the other hand 10% Banana fiber mixed Bagasse pulp has higher tear and tensile strength. This confirms that Banana fiber would enhance Chemical Bagasse pulp strength properties. The results of high pH chlorine dioxide followed by Ozone bleaching of Banana mixed Bagasse pulps have higher strength values than the ECF bleached mill scale Bagasse pulp. The results confirm that DZEpD1 Banana mixed Bagasse pulps are stronger than the regular ECF bleached Bagasse pulps but has lower scattering coefficient. The 5% Banana fiber mixed Bagasse pulp has lower bulk when compared to 10% Banana fiber mixed Bagasse pulp. This indicates that increasing Banana fiber would enhance the bulk properties considerably, which is better for high quality paper making process especially with Bagasse pulp.

The higher pH in the first stage chlorine dioxide followed by Ozone bleaching of pulps has shown a positive impact on environmental conditions especially on inorganic pollutants, such as, total dissolved solids, Sodium and Chlorides. Further, the substitutions of Ozone with chlorine dioxide in the bleaching sequence reduced total load on environment to a large extent. However, as indicated in Table 5, the effluent colour is slightly higher in both DZ and EP stage of 5% Banana fiber mixed Bagasse pulp mainly due to high initial kappa number. COD load is also lower higher in EP stage effluent when compared to regular Bagasse pulp. The lower total dissolved solids, Sodium and Chlorides in the bleach plant effluent would help to recycle and closed loop system in the plant scale without much difficulty.

Conclusion

The Banana fiber mixed Bagasse pulp showed a good response to elemental chlorine free (ECF) bleaching with Ozone substitution. The Ozone addition does not cause any loss of strength properties. The 5 and 10% Banana fiber mixed Bagasse pulp could be bleached with $DZEpD_1$ sequence to 84.2 and 86.5% brightness respectively. The $DZEpD_1$ bleached 10% Banana fiber mixed Bagasse produces a pulp of higher strength than the 5% Banana fiber mixed Bagasse pulp.

The effluents of Banana fiber mixed Bagasse pulp showed reduction in COD and in- organics, such as, sodium and chlorides values due to the introduction of ozone substitution and initial higher pH chlorine dioxide bleaching and that would significantly reduce the environmental load to surrounding environment. Thus mixing of 10% Banana chip with Bagasse to produce unbleached pulp followed by $DZEpD_1$ bleaching sequence could produce a pulp with required brightness, comparable strength with reduced environmental load.

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References

1. Pachisia M. L. Presidential address Indian Paper Manufactures Association, XIth Annual General Meeting, 7th January 2011 Hotel Le Meridien, New Delhi

2. Raymond C.A., Greaves B.L: Developing breeding objectives for kraft and cold soda soak (CCS) pulping of eucalypts, CTIA/IUFRO International Wood Quality Workshop on "Timber management toward wood quality and end-product value", Quebec City, Canada, August 1822 (1997).

3. Young, Journal of Pulp and Paper 66 (7): 9 (1992).

4. Ghuha, S.R.D. India pulp and Paper 15(5): 311-315 (1960).

5. Subrahmanyan, V. and Siddappa, G. S. India pulp and paper 17(8):533-536 (1963).

6. Haikal, S. Indian pulp and paper 31(3): 5(1976).

7. Dhake ,J. D. and Sapkal, R. S. Indian pulp and paper 37(4):5-8 (1983).

8. Cordeiro , N., Belgacem, M.N., Torres, I .C. Moura, J.C.V.P. Industrial Crops and Products 19:147 (2004).

9. Manimaran , A. and Vatsala, T.M. Journal of Microbiology, Biotechnology, 34:745-749 (1983) .

10. Lie et. al., Bio resources 5(2): 576-585 (2010).

11. Gong, H.R. China wood based panels14 (3): 29-30 (2007).

12. Cai, W.X., and Tao, J.H. China pulp and paper Industry,28(1): (2007).

13. Gordon, G., and Bubnis B. Ozone Sci. & Eng. 21: 447-464 (2007).

14. Griffin, R., Ni , Y., and Van Heiningen, A.R.P. J. of Pulp and Paper Sci. 24 (4): 111-114 (1998).

15. J.L. Colodette, J. L., Salvador, E., Shah, P., and Campos de Brito, A. M. Appita Journal 54 (2): 226-233 (2001).

16. Herbert Sixta, Hand book of pulp, WILEY-VCH Verlag Gmbh & Co, KGAA Weinhem.