Mixed Pulping of Certain Annual Non-wood Plants with Wood and Bamboo: Evaluation of Pulp Properties

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ABSTRACT

Mixed pulping of three different fast growing annual non-wood plants viz. Sesbania aculeata, Tephrosia candida and Hibiscus sabdariffa with a perennial fast growing plant - Populus deltoides and a bamboo - Dendrocalamus hemiltonii were studied. The ratios of non-wood to wood/bamboo chips were maintained at 20:80, 40:60, 50:50, 60:40 and 80:20. The plants were also digested alone for comparative study.

S. aculeata, H. sabdariffa and T. candida when digested with P. deltoides, the yields as well as physical strength properties of pulps sheets did not show much difference at chip ratios 20:80 to 60:40. The bleached pulp yields at these ratios varied between 0.5-1.0% and the physical strength properties of the paper sheets viz. tensile index varied between 1.1-6.4 Nmg^{-1}, burst index 0.3-0.99 k pam^2g^{-1} and tear index 0.75 -1.05 mNm^2g^{-1}. It was also observed that the yields and pulp quality gradually declined with the increased ratio of non-wood chips in the mixes. Again at these ratio of non woods and bamboo, high yield of pulp with good physical strength properties of paper were obtained. At the above ratios, the pulp yields varied within a narrow range between 1.7-2.4% and physical strength properties of paper sheets such as tensile index varied between 0.6-2.4 Nmg^{-1}, burst index 0.04.0.05 $kpam^2g^{-1}$ and tear index 0.7-1.5 mNm^2g^{-1}. The brightness of the bleached pulp sheets of non-wood and wood mixes were between 75-79% and the pulp viscosity (cp) ranged between 13.8 to 17.8. The drainage time of the pulp was found comparatively high with increase in non-wood chips in the mixes. It was also observed that the non-wood pulp fibres were easily mixed with wood pulp fibres than that with bamboo pulp fibres as evident from the scanning electron microphotographs.

INTRODUCTION

The utilization of non-wood plants for the manufacture of pulp and paper has expanded in recent years. The non-wood plant fibres are morphologically quite different from those of wood fibres. The pulp derived from these plants have the problems of poor drainability, poor retention and poor wet web strength, poor dimensional stability and so on (1, 2). The non-wood fibres are, therefore, very diverse in their properties. Mixed pulping of non-woods with bamboo and other conventional wood species may minimize

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the above problems. Advantages of mixed pulping over normal pulping have been established in case of certain species of hard wood and soft wood (3). Some work on mixed pulping of agro waste (4), wood and bamboo (5), and reed and bamboo (6) have been reported. The evaluation of pulp and paper making characteristics of some potential fast growing non wood plants like Sesbana aculeata (7), Hibiscus sabdariffa (8) and Tephrosia candida (9) have also been carried out. But work on mixed pulping of these annual plants with fast growing perennial plants and bamboo have not been reported so far.

A study was therefore, undertaken in the laboratory on mixed pulping of a few annual plants with wood and bamboo to ascertain the mixing proportions of chips at which quality pulp for paper making can be produced. The data in respect of pulp yields and physical strength properties of pulp sheets at different ratios of chip mixing are presented in this paper.

EXPERIMENTAL

RAW MATERIALS

A Populus deltoides (Poplar) plant of five years old and matured non - wood plants viz Hibiscus sabdariffa, Tephrosia candida and Sesbania aculeata of 180 days old were colected from the experimental farm of Regional Research Laboratory, Jorhat and used for this work. A matured bamboo-Dendrocalamus hemiltonii was also collected from a forest nearby Jorhat area.

The annual plants and the bamboo were harvested above the ground, while stem portion (above breast height) of P.deltoides was taken.

PHYSICO-CHEMICAL PROPERTIES

The proportions of various wood elements like fibre, vessel, parenchyma and ray etc of the plant samples were determined as per procedure suggested by Purvis et al (10). The proximate chemical analyses of the plant materials were carried out by adopting Tappi methods (11). For analysis, the air dried plant materials (12% moisture) were converted to powder in a Wiley mill and then sieved to standard size of -40 BSS and +60 BSS.

PULPING

The plant materials were cut into chips of -25.4, +12.5 mm size for the pulping experiments. The chips were digested in a rotary stainless steel digester of 10 l capacity. For each cook, 500 g OD chips were taken. 15-17% cooking chemicals at 20% sulphidity and material to liquor ratio 1:4 were employed at temperature 163±2°C for 3 hr. The time to reach

TABLE-1

Physical composition of plant materials

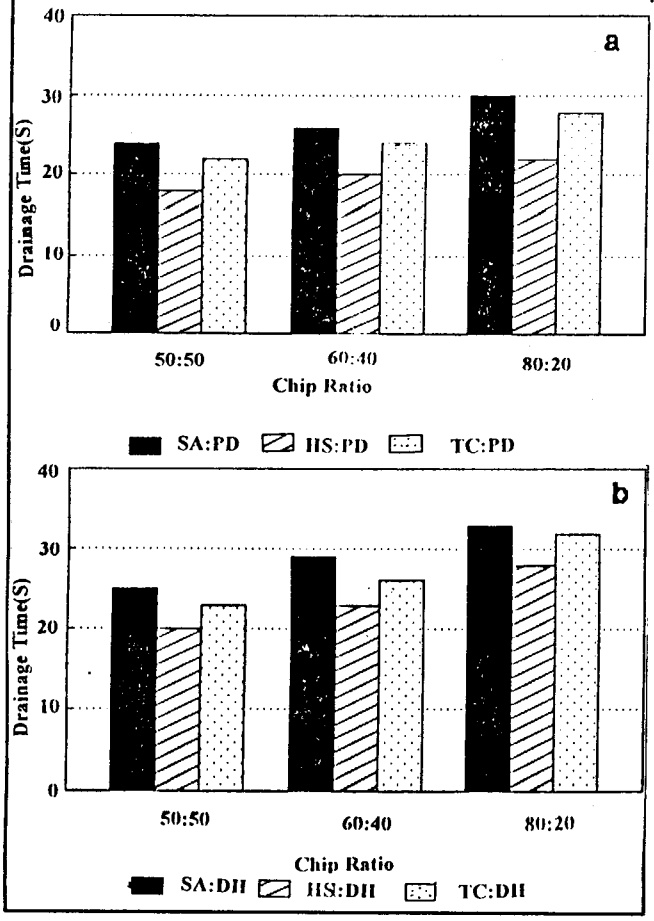
Sl. No.	Plant species	Particulars						
		Density of chips g/cc	Wood content by weight (%)	Bark content by weight (%)	Fibre content (%)	Vessel content (%)	Paren-chyma (%)	Ray-element (%)
1.	*S. aculeata*	0.35	58.61	20.75	62.42	10.22	19.30	8.12
2.	*H. sabdariffa*	0.30	49.87	45.70	69.51	13.54	18.71	9.70
3.	*T. cadida*	0.38	51.33	46.55	58.80	17.61	15.12	1.96
4.	*P. deltoides*	0.50	99.72	-	40.50	8.20	50.00	2.28
5.	*D. hemiltonii*	0.47	72.63	18.24	61.90	21.09	9.95	7.24

TABLE-2

Chemical consitituents of plant materials

Plant species	Particulars							
	Klassan lignin (%)	Cellulose (%)	Holo-cellulose (%)	Hemi-cellulose (%)	Alpha cellulose (%)	Alcohol-Benzene solubility (%)	Ash (%)	Pentosan (%)
S. aculeata	20.60	57.20	72.00	23.80	48.70	3.70	1.28	18.80
H. sabdariffa	19.25	56.75	71.41	22.81	47.28	3.88	1.40	18.51
T. cadida	21.30	48.20	68.78	18.75	46.81	7.50	1.31	18.30
P. deltoides	20.20	58.82	78.26	20.52	48.80	2.82	2.83	20.20
D. hemiltonii	24.00	48.75	78.00	18.56	40.80	2.85	1.00	17.30

Fig. 1



maximum temperature was 90 min. After the digestion, the pulp was washed properly with fresh water till free from alkali. The kappa and $KMnO_4$ numbers for each batch of unbleached pulp were determined (11).

BLEACHING

Bleaching of the different batches of unbleached pulp were carried out in the sequence - chlorination (C), alkali extraction (E) and hypochlorite treatment (H). For chlorination 5.2-6.8% active chlorine was applied with 91-97% consumption. Alkali extraction was carried out with 2-2.5% NaOH at pH 10.5-10.8 for different batches of chlorinated pulps. Hypo-chlorite treatment was given at 3-4.2% total chlorine with 91.5-97.2% chlorine consumption.

PULP EVALUATION AND HAND SHEET MAKING

The pulps were beaten in a laboratory valley beater at 1.5% consistency and sheets of 60±2 GSM were formed in a British Standard laboratory hand sheet forming machine. The hand sheets were dried under pressure and strength properties were evaluated at 65±2% RH as per Tappi methods (11). The brightness of pulps of different batches were measured in a digital Reflectance Spectrophotometer and the results were expressed in terms of MgO=100.

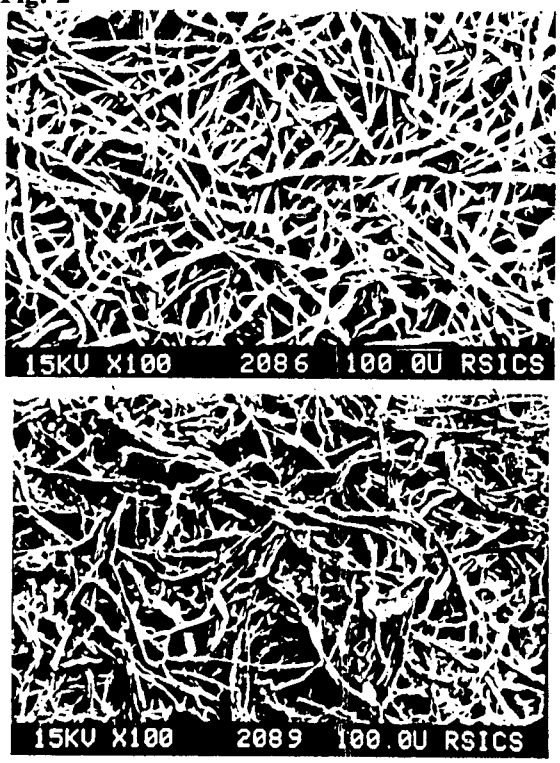
TABLE-3

Kraft pulping conditions and strength properties of pulp sheets made from mixed chips of annual plants and P. deltoides.

Cook No.	Mixed chips (Ratio)	Chemical charges as Na_2O (%)	Kappa No.	$KMnO_4$ No.	Unbleached pulp yield (Unscreened) (%)	Unbleached pulp yield (Screened) (%)	Bleached pulp yield (%)	Tensile index (Nmg^{-1})		Burst index ($Kpam^2.g^{-1}$)		Tear index ($mNm^2.g^{-1}$)		Folding endurance (Double folds)	
								UBPS	BPS	UBPS	BPS	UBPS	BPS	UBPS	BPS
	SA:PD														
1	0:100	18	22.0	-	50.6	49.7	46.9	74.7	69.5	8.90	7.30	12.2	8.9	855	775
2	20:80	18	21.9	-	48.5	48.8	46.0	73.3	69.1	8.70	7.00	11.6	8.2	910	820
3	40:60	18	21.0	-	47.8	47.3	45.0	72.0	68.0	8.55	7.00	09.8	7 9	950	845
4	50:50	18	-	19.8	47.2	45.9	44.1	70.0	65.3	7.01	5.85	07.7	6.0	1000	870
5	60:40	18	-	18.7	47.0	44.6	43.7	69.5	63.6	6.88	5.00	06.8	5.7	980	750
6	80:20	18	-	18.9	47.0	44.0	43.0	72.4	62.0	6.02	4.95	06.2	5.3	920	640
7	100:0	17	-	18.6	48.8	48.2	46.0	72.3	61.9	5.39	4.58	06.5	5.1	915	525
	HS:PD														
8	20:80	18	22.8	-	49.5	48.7	45.8	73.8	68.6	8.05	7.20	12.0	9.85	725	550
9	40:60	18	22.0	-	48.0	47.3	45.0	73.0	64.9	7.88	6.21	11.8	9.10	780	510
10	50:50	18	21.9	-	47.5	45.8	44.6	71.2	62.0	6.52	5.35	11.0	8.98	625	450
11	60:40	18	-	20.0	47.2	45.0	44.2	68.8	58.3	5.40	4.43	10.9	8.65	580	390
12	80:20	18	-	19.7	47.0	44.6	43.1	62.6	50.6	5.06	4.35	10.1	7.58	450	255
13	100:0	17	-	19.0	49.8	48.8	46.8	58.0	42.1	4.90	3.73	09.7	6.35	250	120
	TC:PD														
14	20:80	18	22.7	-	48.9	48.1	45.5	72.8	66.5	7.89	7.00	10.75	8.90	725	680
15	40:60	18	22.0	-	47.6	47.0	45.0	69.5	60.1	7.59	6.10	09.25	7.85	515	492
16	50:50	18	21.6	-	46.5	45.0	43.8	64.7	58.6	7.21	5.50	07.66	6.10	495	440
17	60:40	18	-	22.2	47.3	44.1	42.5	56.8	50.7	5.68	4.55	07.25	6.00	452	425
18	80:20	18	-	19.7	46.9	43.8	41.2	60.3	44.6	5.03	3.75	06.70	5.51	435	372
19	100:0	17	-	18.6	47.5	47.0	41.0	57.6	40.4	4.71	3.43	05.69	4.32	300	150

SA = *Sesbania aculeata* HS = *Hibiscus sabdariffa* UBPS = Unbleached paper sheets
PD = *Populus deltoides* TC = *Tephrosia candida* BPS = Bleached paper sheets.

Fig. 2



DISCUSSION

They physical composition of the plant materials are presented in Table I. The density of the chips of S. aculeata (SA), H. sabdariffa (HS)and T. candida (TC) were less than the chips of bamboo (D. hemiltonii) (DH) and P. deltoides (PD). The wood contents in the plants varied from 49.8-56.6%, while bark contents 20.7-46.55%. The elements like fibre, vessels, parenchyma, ray etc were examined under microscope and also recorded in Table 1. Bamboo was found to contain less fibre with high parenchyma tissue in their culms. The vessel elements were the lowest in bamboo (8.2%) and the highest in P.deltoides (21.09%).

The chemical constituents of the plant materials are given in Table 2. The cellulose contents in bamboo was found to be the highest (58.80%), whereas, in TC, it was the lowest (48.20%). The Klassan lignin varied between 19.25-21.30% in annual plants whereas in case of bamboo and PD the lignins were 24.00 and 20.20% respectively. Likewise, alpha-cellulose contents varied between 46.81-48.70% for annual plants, while for bamboo and PD, the alpha celluloses were 40.80 and 48.80% respectively. The bleached pulps with 75-79% brightness and the CED viscosities of 13.80-17.80 cp were obtained under standard bleaching conditions adopted.

Table 3 shows the pulping conditions and strength properties of pulps obtained from the mixed cooking of SA, HS and TC with PD. The chips of PD were mixed with the chips of the three annual plants in the proportions of 80:20, 60:40, 50:50,6 40:60 and 20:80. From table 3, it was evident that under similar digestion conditions, the pulp yields were slightly decreased with the increase in the proportion of SA, so also the physical strength properties of paper sheets though found to decrease but acceptable paper properties were obtained upto 80:20 ratio of SA and PD chips. Though at 20:80, the pulp yield was more but lower drainage was observed with pulp beaten to 40°SR, resulting uneven formation of paper.

Similarly, PD chips when mixed with HS at 80:20 and 60:40 proportions, high pulp yields with good physical strength properties of paper sheets were obtained. The same trend was observed with TC (cook Nos. 14,15). The tensile, burst and tear indices were found to be 74.70 Nmg^{-1}, 8.90 $kpam^2g^{-1}$ and 12.20 mNm^2g^{-1} for unbleached and 69.50 Nmg^{-1}, 7.30 $kpa.m^2g^{-1}$ and 8.90 mNm^2g^{-1} for bleached pulp sheets respectively from pulp sheets made from PD alone. The tensile, burst and tear indices of bleached pulp sheets from 60:40 (SA:PD), were recorded at 63.6 Nmg^{-1}, 5.00 $kpam^2g^{-1}$ and 5.7 mNm^2g^{-1} respectively, while for pulp sheets made from mixed cooked pulp HS:PD (60:40) and TC:PD (60:40), the data were 58.3 Nmg^{-1}, 4.43 $kpam^2g^{-1}$, 8.65 mNm^2g^{-1} and 50:70 Nmg^{-1}, 4.55 $kpam^2g^{-1}$, 6.0 mNm^2g^{-1} respectively. These were higher in value than that obtained from 100% SA, , HS and TC pulps. (Cook Nos.7, 13 and 19) (Table 3), but lower than that obtained from PD pulp. In case of mixed cooking of SA with DH (Table 4), the yields of unbleached and bleached pulps were found to be within the range 37.00-43.90% and 34.00 -42.00% respectively. So also in case of HS and DH, the yields of unbleached and bleached pulps ranged from 36.60-43.70% and 34.20 -42.00% respectively. The yields of TC and DH mixed unbleached bleached pulps were in the range of 36.90 -41.00% and 35.40-39.70% respectively. The tensile indices for unbleached pulp sheets prepared in different ratio of SA:DH varied from 58.70-70.70 Nmg^{-1} and that of HS:DH and TC:DH from 63.20-70.60 Nmg^{-1} and 60.20-68.30 Nmg respectively. So also, tensile indices for bleached pulp sheets were obtained with in the range of 56.60 -68.60 Nmg^{-1} for different chip ratio of SA:DH, and that of HS:DH (61.30-67.10 Nmg^{-1}) and TC:DH (58.90-65.40 Nmg^{-1}). In the same way the burst indices for unbleached

TABLE-4

Kraft pulping conditions and strength properties of pulp sheets made from mixed chips of annual plants and Bamboo.

Cook No.	Mixed chips (Ratio)	Chemical charges as Na_2O (%)	Kappa No.	$KMnO_4$ No.	Unbleached pulp yield (Unscreened) (%)	Unbleached pulp yield (Screened) (%)	Bleached pulp yield (%)	Tensile index (Nmg^{-1})		Burst index ($Kpam^2.g^{-1}$)		Tear index ($mNm^2.g^{-1}$)		Folding endurance (Double folds)	
								UBPS	BPS	UBPS	BPS	UBPS	BPS	UBPS	BPS
	SA:DH														
20	0:100	17	23.6	-	44.8	43.9	42.0	71.6	69.8	4.8	3.9	14.2	11.3	175	153
21	25:75	17	21.2	-	42.7	42.2	41.6	70.7	68.6	4.6	3.7	13.8	10.7	220	189
22	40:60	17	21.0	-	41.2	40.5	39.2	68.1	66.2	4.0	3.2	11.7	9.8	380	275
23	50:50	17	-	19.7	39.9	38.9	35.4	62.9	60.8	4.2	3.8	9.8	7.2	420	350
24	60:40	17	-	18.5	38.3	37.5	34.9	61.0	58.9	4.9	4.2	8.2	6.8	500	450
25	80:20	17	-	17.2	38.0	37.0	34.0	58.7	56.6	4.6	4.0	7.3	5.5	500+	500+
	HS:DH														
26	20:80	17	22.7	-	45.8	43.7	42.0	70.6	67.1	4.6	4.3	13.4	12.0	200	182
27	40:60	17	21.6	-	44.6	42.2	40.6	68.4	66.5	4.4	4.1	12.1	11.3	268	197
28	50:50	17	20.5	-	42.8	40.0	37.9	67.0	66.0	4.2	4.0	10.8	9.9	350	210
29	60:40	17	-	18.8	40.7	38.3	36.4	65.1	63.0	4.8	4.0	9.2	8.6	380	248
30	80:20	17	-	17.5	38.8	36.6	34.2	63.2	61.3	4.6	3.8	8.8	7.9	460	320
	TC:DH														
31	20:80	17	23.8	-	42.6	41.0	39.7	68.3	65.4	4.63	4.54	12.9	11.2	180	148
32	40:60	17	22.1	-	41.2	40.2	38.2	66.6	63.7	4.60	4.50	10.2	9.7	275	189
33	50:50	17	21.0	-	39.8	38.0	37.1	64.9	61.0	4.48	4.15	9.7	8.6	370	225
34	60:40	17	-	19.2	37.2	37.0	36.3	61.8	60.2	4.40	4.00	8.2	7.8	410	300
35	80:20	17	-	19.0	37.0	36.9	35.4	60.2	58.9	4.35	4.00	6.1	5.7	450	380

DH = *Dendrocalamus hemiltonii*

and bleached pulp sheets varied from 4.00 -4.90 $kpam^2g^{-1}$ and 3.20 -4.50 $kpam^2g^{-1}$ respectively for all the ratio of chip mixing of SA, HS and TC with DH. So also, tear indices for unbleached pulp sheets prepared from the above proportions of chips were varied from 6.80 -12.00 mNm^2g^{-1} and that of bleached pulp from 6.10-13.80 mNm^2g^{-1}. The folding endurance data were also relatively in high order for pulp sheets prepared from the above chips mixes. The effects of chips ratio on drainage property of pulps are shown by bar diagram in Fig. 1 (a, b), at ratio 50:50, 60:40 and 80:20 for SA:PD, HS:PD and TC:PD respectively Fig. 1a) and for SA:DH, HS:DH and TC:DH at the same ratio (Fig. 1b). The drainage time of the pulps at 40°SR freeness had gradually increased with the increase of non wood chips in the mixes. At 50:50 ration (SA:PD, HS:PD and TC:PD), the drainage time varied from 18-24 sec, while for 60:40 and 80:20 mixes, the drainage time varied from 20-26 sec and 22-30 sec respectively. In cse of pulp obtained from mixes of SA:DH, HS:DH and TC:DH, at the same freeness, the drainage times were comparatively more. At 50:50, 60:40 and 80:20 ratios of SA:DH, HS:DS and TC:DH, the drainage time varied from 20-25 sec, 23-29 sec and 28-33 sec respectively.

Fig. 2 (a) showed the SEM of pulps in the ratio 40:60 of SA and DH, in which it was seen that non-wood fibres were distributed mostly in the upper surface of the pulp matrix which might be due to low density of the fibres compared to that of bamboo fibres. Bamboo fibres are distributed mostly in the middle and lower region of pulp matrix because of their high density. The fibres were mostly cylindrical and smaller in diameter, while non-wood fibres were flat. Fig. 2 (b) showed the SEM of pulp fibre matrix of pulp from mixed chips of SA and PD in the ratio 40:60. It was observed that the non-wood fibres are easily mixed with wod fibre and distributed evenly in the pulp matrix. Some short fibres were also seen in the pulp matrix which occupied in the cavities inside the pulp matrix.

CONCLUSION

From this study, it may be concluded that mixed pulping of fast growing annual non-wood plants with wood and bamboo produce pulps with high yields and pulp sheets with adequate physical strength properties can be made from such pulps without much drainage problem.

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