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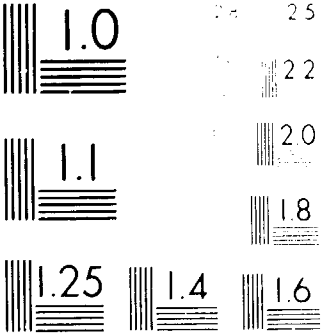
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RESEARCH IN PULP AND PAPERMAKING FROM INDIAN HARDWOODS *

by

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ABSTRACT

Improved utilization of hardwoods was the main objective of the UNDP/FAO - Government of India project, which was operational from January 1975 till December 1980. New laboratories for pulping, pulp processing, paper testing, microscopy and instrumental methods of analysis were installed and a research team was trained over the years 1975-1978. The pilot plant of the Forest Research Institute in Dehra Dun was upgraded by the addition of a new bleach plant, a chemi-thermo-mechanical unit and pulp refining equipment.

Research activities were commenced in 1978. One of the research projects is concerned with utilization of mixed hardwoods from the Bastar region (Central India) including species which are currently rejected by the local pulp and paper mills due to various difficulties. Improved methods to overcome some of these difficulties such as high Kappa number, precipitation of black liquor etc. are described. Blending of hardwood and bamboo pulps and separate vs. mixed refining is discussed.

INTRODUCTION

Bamboo, the traditional papermaking raw material in India is no longer freely available and the further expansion of the Indian pulp and paper industry is to be based on hardwoods and agricultural residues. Papermaking from hardwoods is a well-established technology in Australia and Japan. However, Indian hardwoods have different properties. Indian paper mills encountered difficulties in pulping some hardwoods or using more than 30% hardwood pulp in the papermaking furnish. This was discussed in the previous paper.

To assist the Indian pulp and paper industry in the utilization of lesser known raw materials a joint United Nations Development Programme (UNDP) - Government of India (GOI) Project: "Exploration and Identification of Alternative Raw Materials for Paper and Newsprint Manufacture" was operative in the years 1975-1980. The funds for the international components were provided by UNDP, while the executive agency was the Food and Agriculture Organization of the United Nations (FAO).

A new applied research centre was installed in the premises of the Forest Research Institute, Dehra Dun. The new laboratories are equipped with modern equipment for pulping, pulp processing, sheet making and paper testing as well as with special instruments, e.g., recording wet web tester, electronic drainage tester, microscopes with projection screen and photographic attachment, electronic fibre length counter, gas-liquid chromatograph, UV and IR spectrophotometers, etc.

The sulphate pilot pulp mill in Dehra Dun was upgraded by the addition of a chemi-thermo-mechanical pulping (CTMP) unit, pulp screening unit and a bleach plant. The existing paper machine was complemented by a Beloit Jones 12 inch double disc refiner.

The CTMP unit consists of a 2m^3 mild steel and a 11m^3 stainless steel digester, for pre-impregnation and/or digestion of chips, a Defibrator vertical preheater with Bauer rotary valve feeder for thermal treatment of chips, a pressurised refiner (Raffinator ROP 20) and an open discharge refiner (type RO 20). Each refiner is driven by a 200 KW motor. This unit provides the possibility of refining chips under mill conditions. The CTMP unit can be used for small scale batch experiments (30-50 kg. of chips) or for continuous pulping.

The screening unit consists of a Cowan KX35 centrifugal screen and a battery of centricleaners. The bleach plant consists of a chlorination tower, two high density chests and a 6 ft. x 4 ft. Dorr-Oliver washer. The bleach plant is operated batch-wise and accommodates the total output from one cook from the 11m^3 sulphate digester (about 800 kg. of pulp). This requires about 2000 kg. O.D. chips.

The pilot plant is equipped with sophisticated control, indicating and recording instruments. Flow and consistency of pulp is controlled by consistency controllers and magnetic flow meters. The media are exactly metered. Power consumption in refining is recorded.

RESEARCH IN UTILIZATION OF BASTAR HARDWOODS

One of the research projects undertaken was pulping of mixed hardwoods from the Bastar region in Central India, which is one of the major forested areas of the country. It comprises around 2300 km^2 of which 56% are under forest and contains a wide range of hardwood species and large stands of bamboo. Utilization of Bastar forest resources for papermaking has been studied by FAO in a pre-feasibility study. In 1970 Sandwell Management Consultants (Canada) in co-operation with the Madhya Pradesh Forest Development Corporation and Development Consultants (Calcutta) published an Investment Feasibility Study based on a programme of clear-felling and replanting approximately 2000 ha. per annum with tropical pines and producing writing and printing papers plus some timber. Sulphate pulping of both hardwoods and bamboo was envisaged using a 50% hardwood and 50% bamboo pulp furnish.

Preliminary laboratory studies have been made over the past decade by the Forest Research Institute in Dehra Dun and by the Swedish Forest Products Laboratory, but these were confined generally to unbleached pulp and did not include black liquor and papermaking studies. Some commercial experience is available from mills adjacent to the region which over the last few years have been using small amounts in sulphate pulping mixed with bamboo. These mills have encountered some difficulties in processing some species and have tended to exclude those which they regarded as unsuitable for pulping. The objective of the present investigation was the utilization of all species.

One of the problems encountered is high Kappa number of unbleached pulp from some species. Pulping of one of these species, Terminalia tomentosa, was the subject of a preliminary study. The Kappa number of the unbleached sulphate pulp was around 45-50 even with the use of high alkali charges, thinner chips or two-stage cooking. Examination of the pulp under the microscope revealed that many of the fibre lumen and vessels contained a coloured liquid which indicated that the conventional laboratory washing procedures (tap water on a Buchner funnel with suction) was not adequate. Washing with hot dilute alkali reduces Kappa number considerably, but is too expensive. A similar effect can be achieved by hot water washing with intermediate mixing in hot water, which indicates the importance of the diffusion processes. This should be taken into consideration in industrial practice.

Pulping of mixed hardwoods

The main study was aimed at the pulping of mixed hardwoods. Representative samples from two catchments of the Bastar region were collected. The sampling plan was based on the results of the Pre-investment Survey of Forest Resources. About 100 species were listed but only 31 species, present at 0.4% or higher, were sampled in four diameter classes (1) 0-10 cm, (2) 11-30 cm, (3) 35-50 cm and (4) 51 cm and over. Because there was only a small volume of wood in diameter class (1) this was not included, reducing the total number of samples to 214. The basic density of chips from the various species was in the range 500-600 kg/m^3. Results of laboratory pulping of mixed hardwoods are shown in Table 1.

Table 1

Pulping of Bastar hardwoods

	Screened yield (% on OD wood)	Kappa No.	Residual active alkali (g/l Na_2O at 200 g total solids)
Forest composite	43.4	27.0	7.4
Diam. class 2 composite	45.2	26.8	6.7
Diam. class 3 composite	43.4	28.0	8.9
Diam. class 4 composite	42.7	29.3	10.1

Pulping conditions: 17% active alkali as Na_2O, 25% sulphidity

3:1 liquor ratio,

30 min. to 100°C, 105 min. to 170°C,
120 min. at 170°C

H factor = 2130

The forest composite was then pulped using range of active alkali charges at 2130 H Factor and the cook made at 16% Na_2O (Kappa No. 28.6, screened yield 43.8%, residual alkali 5.9 g/l) selected as representing optimum pulping conditions.

The "lops and tops" and corresponding stem samples of the important saw log species were also pulped under the standard conditions with 17% Na_2O. Generally speaking the stem samples gave higher Kappa Nos. than the lops and tops except for Shorea robusta which showed the reverse behaviour and gave a significantly lower Kappa No. than the other woods. There were no great differences in the strength properties of the unbleached pulps from different parts of the trees.

Bleaching and properties of bleached pulps

Bleaching processes were studied for the production of both medium (76-78% ISO) and high (ca 85% ISO) brightness pulps. In the former case the schedules CEHH, CED and D/CEDED were studied; in the latter CEHD, CEHED, CEDED, D/CEHD and D/CEDED. Results are summarized in Table 2.

Table 2

Summary of laboratory bleaching results for forest composite sample

Schedule	Total chlorine added. (%)	Total NaOH added (%)	Brightness ISO (%)	Instrinsic viscosity (cm^3/g)	Post-colour No.
CEHH	9.1	2.7	74.2	546	2.5
D/CEDED	9.1	3.0	73.7	789	1.9
CEHD	11.1	2.6	82.1	620	2.2
D/CEHD	11.1	2.5	82.2	694	2.7
D/CEHED	11.1	3.5	82.1	617	2.4
D/CEDED	11.6	3.0	84.8	683	1.6

To give an appreciation of the value of the bleached Bastar sulphate pulp two of the bleached samples are compared in Table 3 with some hardwood pulps in normal commercial use, evaluated by the same methods. The commercial pulps were three eucalypt pulps from Portugal and Australia and a beech sulphite magnefite pulp from Sweden.

Table 3

Comparison of bleached Bastar sulphate pulp with commercial hardwood pulps

Pulp	Bulk (cm^3/g)	Burst index ($kPam^2/g$)	Tensile index (Nm/g)	Tear index (mNm^2/g)	Brightness ISO (%)	Specific scattering coefficient (m^2/kg)
Bastar						
CEHH	1.32	3.5	54	6.3	71	26
D/CEDED	1.35	3.7	54	9.3	75	25
Commercial						
hardwood	1.24	2.7	47	6.7	78	24
pulps (range of 3 samples)	1.25	4.8	74	9.9	81	28

The Bastar hardwoods pulps are within the range of the overseas commercial hardwood pulps except for brightness. However, their strength properties tend to be towards the lower end of the range. It should be borne in mind that this comparison is between dry-lap overseas pulp and never-dried laboratory pulps from the Bastar woods. Comparison on the same basis would increase the slight strength disadvantage of the Bastar pulps probably by 10%.

Blending of hardwood and bamboo pulp:

Bamboo pulp is used as reinforcement pulp in India. The Bastar feasibility study presumes 50% of bamboo pulp in the furnish. Properties of bleached hardwood and bamboo pulp bleached by CEHH and D/CEDED sequences refined in PFI mill to various CSF levels are presented in Table 4. Bamboo pulps bleached with chlorine dioxide have tearing strengths comparable with those of softwood pulps. Hypochlorite bleaching however causes a considerable decrease in tearing strength. In another study, it was found that the tearing strength of bamboo pulps bleached with hypochlorite could be improved by pretreatment with hypochlorite prior to chlorination (H/C). Tensile, burst and wet web strengths of bamboo pulp are lower than those of softwood pulps.

The variables in blending experiments were: (1) the bleaching process (CEHH and D/CEDED), (2) mixed and separate refining, and (3) the freeness level of the components. In Table 5, the results of the blending experiments using 50% bamboo pulp are compared at a freeness of around 350 ml, the aim freeness for the mixed pulps after separate refining. This demonstrates the advantages of the D/CEDEH bleaching particularly in respect of tear. Separate refining also gave improvements in tear for the furnishes containing 50% and 70% bamboo but not for furnish containing only 30% (slide). The importance of keeping the freeness of the bamboo component high to achieve maximum tear in separate refining is also apperent.

Table 4

Properties of bleached hardwood forest composite and bamboo pulps

	PFI rev.	CSF	Burnt index (kPa.m²/g)	Tensile index (Nm/g)	Tear index (mN.m²/g)	Brightness ISO (%)	Specific scatt. coefi. (m²/kg)
Hardwood forest composite							
CEHH	0	615	1.15	25.0	5.20	74.6	35.4
	1000	500	2.50	43.0	6.55	74.3	30.0
	2000	415	3.20	49.0	6.60	73.1	27.9
	4000	255	3.60	56.5	6.20	71.7	26.8
	8000	155	3.95	57.0	6.05	71.1	25.1
D/CEDED	0	635	0.55	14.0	4.35	82.9	36.2
	1000	530	1.90	32.5	7.30	79.4	32.8
	2000	505	2.45	40.0	8.20	76.8	30.4
	4000	415	3.20	49.0	9.15	74.7	28.0
	8000	250	3.90	56.0	9.40	74.5	24.0
Bamboo							
CEHH	0	690	1.00	21.5	10.0	78.0	27.0
	1000	575	2.50	39.5	15.4	75.1	24.6
	2000	470	3.60	47.0	14.3	74.4	23.2
	4000	315	4.20	54.0	11.4	72.6	22.7
	8000	125	4.70	61.0	10.3	69.3	20.6
D/CEDED	0	690	0.70	21.0	12.1	82.6	27.3
	1000	625	2.30	39.0	17.8	82.6	25.8
	2000	560	3.00	46.0	21.0	92.2	25.6
	4000	425	3.90	56.5	19.1	80.3	22.5
	8000	235	5.20	63.0	18.0	80.1	21.4

Table 5

Properties of bamboo - hardwood pulp blends (50:50)
(at approximate 350 CSF)

Component		Burst index	Tensile index	Tear index	Initial wet web tensile	Wet web TEA	Vessel pick No.
Bamboo CSF	Hardwood CSF	($kPam^2/g$)	(Nm/g)	(mNm^2/g)	(Nm/g)	(Nm/g)	No. per $2000mm^2$
		Mixed beating CHH pulps					
		3.2	51	9.2	0.72	96	17
		Mixed beating D/CEDED pulps					
		4.0	58	13.0	0.76	79	11
		Separate beating CEHH pulps					
590	135	3.2	49	10.5	0.63	49	8
435	255	3.2	49	10.2	0.65	59	9
		Separate berting D/CEDED pulps					
565	190	3.5	56	15.6	0.66	68	6
425	250	3.9	54	15.1	0.62	64	4

Wet web strength data given in Table 5 suggests that (1) CEHH bleaching is preferable to D/CEDED, (2) mixed beating is preferable to separate beating, and (3) in separate beating bamboo should be well-beaten.

These results are almost the converse of those found for the effects of mixed and separate beating on tearing strength. The wet web strength tests are most usefully compared with those of other furnishes. The calculated initial wet web strength of a furnish consisting of 70% bleached commercial eucalypt pulp and 30% bleached pine commercial pulp was 0.7 Nm/g and wet web TEA 76 mNm/g. It can be seen from Table 5 that these levels of wet web strength were achieved in this study for some of the hardwood-bamboo blends.

The surface strength of papers from hardwood pulps poses a problem. Bastar hardwoods have a higher vessel pick ratio than commercial eucalypt pulps. Both separate refining and chlorine dioxide bleaching reduce the vessel pick.

Black liquor evaporation and burning

The difficulties encountered in hardwood black liquor processing include high viscosity, precipitation of solids during evaporation leading to evaporator tube blockages and poor black liquor burning.

In this study measurements of viscosity by a Brookfield viscometer at 80°C have been made over a solid range of up to 55% total solids. The black liquors were concentrated in a laboratory rotary glass vacuum flask evaporator under reduced pressure (0.5-0.6 kg/cm^2) at 96-99°C. With some black liquors nuclei formation was observed on the inner surface of the evaporator at a certain concentration followed by precipitation of some solids. The concentration where the latter occurs was taken as the precipitation point. Black liquor burning properties were determined by the method of Oye 1/. Dried black liquor solids were heated in a muffle furnace at 400°C for two minutes and the volume of the swollen mass measured, after cooling, by the use of small beads. Higher values indicate better burning properties.

The results of black liquor investigations are given in Table 6. The viscosity of the hardwood black liquors at high solids contents was not as high as for bamboo, but higher than for pine. Viscosity can be reduced by adding alkali to the black liquor.

The black liquors from hardwood forest composite samples all formed precipitates when concentrated to around 37-40% solids. Precipitation of solids could give rise to production problems and ways of overcoming it are being sought.

1/ Oye R.; Langfors, N.G.; Phillips, F.H.; and Higgins, H.G. APPITA Vol. 31, No. 1 33 (1977).

One approach to the precipitation problem is separation of colloidally unstable material by controlled flocculation at an earlier stage in the evaporation process and then removing it by filtration by centrifuging and feeding it directly to the contact evaporators or to the recovery furnace. Various flocculants have been studied to precipitate material which can be readily removed by filtration, sedimentation or centrifuging. An encouraging result was obtained when the readily precipitable solids from <u>Terminalia tomentosa</u> black liquor at 35% total solids were flocculated with 30 mg/l polyacrylamide and then removed by centrifuging. The remaining black liquor could be concentrated to 46% before precipitation occured. Without this treatment it could not be evaporated past 40% total solids.

If both hardwoods and bamboo are processed in a mill, it seems to be useful if the bamboo liquor is first evaporated to about 55% total solids and the hardwood liquor of 35% concentration then added. This mixture can be further evaporated to about 53% before precipitation occurs. At this concentration the liquor could be fed to the contact evaporator where the presence of the precipitate would not be so serious. This technique is being further studied to determine the extent to which it can be successfully applied.

In some recent experiments, the precipitation point has been shifted to higher solid concentration by using small amounts of detergents in pulping.

The swelling volume of Bastar hardwood forest composite black liquor was about 19 ml/g, which is lower than the swelling volume of <u>Pinus roxburghii</u> black liquor (47 ml/g)

<u>Table 6</u>

<u>Black liquor properties</u>

Wood	Residual active alkali (g/l Na_2O at 200 g/l total solids)	% inorganics as NaOH in total solids	Brookfield viscosity (cps) 50% t.s.	Brookfield viscosity (cps) 55% t.s.	Precipitation point (% t.s.)
<u>Bastar hardwoods</u>					
Dia. class 2	6.7	30.0	20	68	36.9
Dia. class 3	8.9	29.7	37	100	39.8
Dia. class 4	10.1	29.7	27	72	37.5
Forest composite	7.4	29.9	23	59	40.3
Bastar bamboo	8.1	32.1	85	347	None
<u>Pinus roxburghii</u>	8.9	32.7	18	37	None

CONCLUSIONS

Laboratory results indicate :

a) It is possible to pulp Bastar hardwoods without excluding major species provided improved hot water washing is applied.

b) A 50 : 50 bamboo : hardwood furnish, bleached by CEHH process would probably give acceptable strength and optical properties for printing papers. If separate refining were used and possibly if stronger bleached pulps could be made (using hypochlorite pretreatment or chlorine dioxide bleaching), then it should be possible to reduce the bamboo component to about 30%. If size press treatment is to be applied on the machine, then the need for separate refining to remove vessels is reduced.

c) High viscosity of black liquor can be overcome by keeping a sufficient level of residual active alkali in black liquor.

d) Problems with precipitation of solids at an early stage of evaporation can be reduced by controlled floculation or pre-evaporation of the bamboo black liquor.

It should be pointed out that pilot plant and mill experiments are required, as it is difficult to judge likely production scale performance only on the basis of laboratory tests.