Utilisation of Indian Hardwoods for Different Grades of Pulp and Paper-A Review

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Introduction

The installed capacity of paper and Board mills is at present, of the order of 9.54 Lakh tonnes/year and the production during 1972 was 8.03 lakh tonnes. The proposed target for fifth five year plan for paper and paper-board newsprint, rayon grade pulp, paper grade pulp and straw and mill board, is given in Table-1.

TABLE-1

Targets for fifth five year plan

Sl. No.	Item	Installed Capacity (lakh tonnes/ year)	Production (lakh tonnes/year)
1	Paper & paper Board	15.00	13.3
2	Newsprint	4.00	3.5
3	Rayon grade pulp	2.30	2.05
4	Paper grade Pulp	1.00	0.75
5	Straw & Mill board	1.20	0.70
	Total :	23.50	20.30

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The cellulosic raw materials can be broadly classified into three main categories; (i) Forest products such as bamboo, grasses, soft woods and hard-woods, (ii) Agricultural residues, such as bagasse, wheat straw, paddy straw, and jute sticks and (iii) Industrial waste or by-product such as cotton waste, wood waste and jute waste. Best papers are still produced from cotton, linen and hemp, but from the view point of abundance and versatility, the soft woods are considered to be the best raw material available to Pulp and Paper Industry. The availability of softwood is however restricted in this country to the Himalayan region which is yet to be explored for commercial exploitation. Bamboo has been the mainstay for Indian Pulp and paper Industry and Sabai grass was the chief auxiliary raw material till the hardwood was introduced. Considering its availability in different parts of the country, the scope of using this raw material is now considered to be more than any other raw material.

Comparative availability of hardwoods and soft woods is indicated in Table 2

As observed by Mahalaha[1] 32 million cubic meters of hardwoods can be procured for various end uses including pulp and paper industry, provided adequate infrastructure is developed for the purpose.

Table-2

Estimated Availability of Hardwoods and Soft Woods.

Sl. No.	Item	Hard-woods	Soft-woods	Total
1.	Total forest Area, *million hectare*	—	—	75
2.	Workable Forest, Area *million hectare*	4.1	1.4	42.4
3.	Total Growing Stock (Standing volume), *million* m^3	2500	400	2900
4.	Estimated annual cut, *million* m^3	50	6.5	56.5
5.	Current Exploitation, *million* m^3	18	4.7	22.7
6.	Available surplus, *million* m^3	32	1.8	33.8

Eucalyptus wood which is being raised by planned plantation for specific use in pulp and paper industry may yield 0.5 million cubic meters by 1975 and about 6.00 million cubic meters by 1980-85. In comparison the estimated availability of Bamboo would be as shown in Table-3[1].

Table–3

Estimated Availability Of Bamboo

Sl. No.	State	Potential (Mill. Tonnes)	Available surplus (Mill. Tonnes.)
1.	Assam & Adjoining States	1.21	1.15
2.	Tripura	0.21	0.21
3.	Arunachal	0.20	0.20
4.	Bihar	0.20	Nil
5.	Orissa	0.43	0.28
6.	Madhya Pradesh	0.80	0.40
7.	Andhra Pradesh	0.25	Nil
8.	Maharashtra	0.30	0.04
9.	Mysore	0.47	Nil
10.	All other States	0.23	0.22
	Total	4.30	2.50

It is quite clear that 2.5 million tonnes of available surplus Bamboo would fall far short of the total requirement of raw materials, and increased use of hardwoods which is available in considerably larger quantities is not only advisable but imperative. As a matter of fact the value of Bamboo as a source of medium long fiber should be appreciated and its use should be restricted to the minimum as necessary admixture with hardwoods, and agricultural residues. The Indian Paper Industry has already adopted hardwoods to the extent of 25–30% of the total furnish. Considering the technolocial developments, both in regard to pulp and paper making techniques and machinery, it is expected that in a foreseable future, industry will be in the position to reduce Bamboo to the extent of 25% of the total furnish and thus 2.5 million tonnes of available bamboo can contribute to a total production of 4 million tonnes instead of only one million tonne based on 100% bamboo furnish.

History of Development

The use of wood for making paper pulp was invented in Germany in 1844[2] This was mechanical or ground wood pulp. Chemical pulping by soda process was started in America around 1854. Another process restricted till recently to soft woods alone, was invented by Tilghman in 1866. This is the sulphite process, which has been variously developed and now applied successfully for high yield pulping of hardwoods by Sodium Sulphite Semi-Chemical process. The original soda process has been modified to what is known as Snlphate or Kraft process and is applicable practically to all types of raw material irrespective of species. Other high yield pulping processes developed in recent years include Sulphate Semi-Chemical, Cold Soda, Chemi-Mechanical, and Chemie-ground.

The development in the process of using hardwoods fibers as principal raw material for paper has been due to persistent efforts made in Austrralia over several decades. The Associated Pulp and Paper Mills, Burnie, Tesmania, started commercial pulping of Eucalyptus[3] by Soda process in 1938. This was followed by pulping of Eucalyptus by sulphite process by Australian Paper Manufacturing Limited, at their Maryvale mill in 1939. Mechanical pulp for newsprint was attempted in 1941, by the Australian Newsprint Mill, Boyer, Tasmania. The Semi Chemical process were invesrigated on laboratary scale in 1934, but the process was exploited commercially in late fifties only.

As mentioned earlier, the bamboo has been the main source of raw material in India since its introducation in 1918 at India Paper Pulp Co. Naihati, near Calcutta. The hardwoods were first introduced in the same mill as a waste product from ply wood factories in early forties. Simul Wood *Bombax malabaricum* var, *Salmalia malabaricum* or silk cotton wood which was being used in ply wood factories found its ready use in making paper pulp. The pulping process applied was a modified sulphite process using magnesia as the base, and according to the available records it was first such commercial utilisation, ever made in the world.

Investigation on pulping of hardwoods by soda and Sulphate process commenced at Cellulose and Paper Branch, Forest Research Institute, Dehradun in 1950. Several species were successfully pulped in the laboratory followed by pilot plant trials, which encouraged the paper industry at large, for utilisation of this novel raw material in their paper furnish. The National Newsprint and Paper Mills Limited, Nepanagar was started in 1953 based on Salai wood (*Boswellia serrata*) which was found in abundance in Madhya Pradesh. The Sal *(Shorea robusta)* and other woods were pulped by sulphate process in 1962 at Bengal Paper Mill Co. Ltd., Raniganj. Sal is being successfully pulped by Sulphite process with Mg-base at India Paper Pulp Co., Naihati. The jute sticks, which is a hardwood to all intent and purpose, but belongs to the

TABLE–4

Fibre characteristics and proximate analysis of Some of the Indian Hardwoods

S. No.	Species	Fibre Dimensions		Proximate analysis (All results are expressed as a percentage of the O.D. raw material)									
				Solubilitie									
		Av. length (mm)	Av. Diameter μ	Cold Water	Hot Water	1% NaOH	Alcohol Benzene	Ash	Pentosan	Lignin	Cross & Bevan Cellulose	Holo Cellulose	Reference
1.	*Accacia decurrens* (green wattle)	0.86	14.0	1.69	2.26	15.64	1.07	0.36	19.36	21.24	63.17	—	4
2.	*Anthocephalus cadamba* (Kadamb)	1.21	28.0	3.42	5.32	19.77	2.32	1.27	15.58	23.09	59.88	—	4
3.	*Boswellia Serrata* (Salai)	0.88	24.0	6.3	8.9	15.5	4.3	1.0	13	27.3	50.7	—	4
4.	*Bombax malabaricum*	1.96	28	3.0	5.3	17.7	2.4	1.15	11.3	26.8		65.4	16
5.	*Casuarina equisetifolia* (Casuarina)	1.08	11	3.8	6.5	21.7	3.4	0.9	19.2	23.2	56.7	—	4
6.	*Cochlospermum gossypium*	0.94	17	6.4	7.3	17.5	5.7	0.93	15.2	27.5	—	68.3	16
7.	*Dillenia pentagyma*	—	—	3.5	5.3	16.10	2.41	1.15	10.90	34.71*	—	74.78*	39
8.	*Erythrina Suberosa*	1.30	44	3.2	4.35	11.3	11.0	1·79	12.6	20.0	66.4	—	18
9.	*Eucalyptus citriodora* (5 year old tree)	—	—	—	4.24	—	1.10	—	21.8	22.8*	—	77.8*	36
10.	*Eucalyptus globulus* (Blue gum)	1.11	14	2.34	3.51	15.64	2.15	0.25	15.52	20.27	60.95		4
11.	*Eucalyptus grandis*	0.82	14	1.16	1.45	10.8	1.28	0.39	11.2	21.9	65.5		4
12.	*Eucalyptus robusta*	0.90	10	3.4	3.7	13.8	2.8	0.4	11.0	33.0	57.4		4
13.	*Eucalyptus tereticornis* (Mysore gum grown in Madras)	0.73	12	4.7	13.4	37.0	1.18	0.32	14.12	24.7	50.58		4
14.	*Eucalyptus tereticornis* (Mysore gum grown in U. P.	0.83	16	1.8	13.8	16.4	1.11	0·51	15.8	28.3	53.4		4
15.	*Eucalyptus torelliana*	0.71	9	6.2	12.05	13.7	2.69	0·45	15.3	24.9	57.3		6
16.	*Garuga pinnata*	1.15	25	3.7	9.6	21.5	3.1	1.65	15.0	21.0	—	68.0	16
17.	*Kydia calycina*	—	—	0.7	2.7	12.3	2.35	1.12	13.1	27.0*	—	81.1*	38
18.	*Lannca coromandelica*	0·94	17	6.4	7.3	17.5	5.7	0.93	15.2	27.5	—	68.3	16
19.	*M. azedarach* (Bakain)	—	—	5.14	7.42	18.29	4.08	0.80	15.5	25.7*	—	80.8*	41
20.	*Paper Mullbery*	0.82	30	4.2	7.93	17.96	1.92	1.08	16.4	23.26	59.18		4
21.	*Populus ciliata*	—	—	—	3.82	—	2.26	1.80	19.9	23.9*	—	81.2*	35
22.	*Populus nigra*	C—	—	—	4.04	—	1.66	0.62	20.6	24.5*	—	76.0*	35
23.	*Sesbania grandiflora* (4½ yrs old)	—	—	3.8	6.3	15.7	2.7	1.9	15.8	21.5	—	68.2	19
24.	*Sterculia urens*	1.75	28	1.4	2.7	17.3	2.1	0.65	17.0	25.6	—	70.4	16
25.	*Sterosperm suaveslens* (Poompadiri wood)	—	—	2.1	7.03	18.4	5.38	1.326	13.2	31.0*	60.0	68.61*	40

* On Extractive Free Samples.

TABLE–5

Digestion conditions and strength properties of pulps, from Some of the Indian Hardwoods for writing and printing papers

Sl. No.	Specie of Wood	Digestion Conditions					Yield of pulp%	Permanganate No/ Kappa No.	Strength properties of pulp						Reference
		Total alkali (%)	NaoH: Na_2S or Sulphidity (%)	Bath Ratio	Digestion temp. °C	Digestion Time (hrs)			Type of Pulp	Breaking length (m)	Burst factor	Tear Factor	Double folds	Brightness (MgO= 100)	
1.	*Accacia ducurrens* (green wattle)	24.0 (a)	2 : 1	1 : 4	162	6.0	53.0 bl	—	bl	6980	35.9	58	—	—	4
2.	*Anthocephalus cadamba* (Kadam)	20.0 (a)	3 : 1	1 : 4	170	4.0	48.2 bl	—	bl	8060	45·6	99	—	77	4
3.	*Boswellia serrata*	22.0 (a)	2 : 1	1 : 5	162	6.0	45.4 bl	—	bl	6070	37.7	65	—	—	4
4.	*Bombax malabaricum*	15.0 (b)	—	—	140	3.25	58.0 ubl	134*	ubl	4680	29.5	106	117	—	16
5.	Bhendi	20.0 (a)	19.9	1 : 4	160	3.0	52.4 ubl	18.7	ubl	8700	80.2	77	—	—	17
6.	*Casaurina equisetifolia*	16.0 (b)	. : 1	1 : 3.5	162	6.0	50·3 bl	—	ubl	5750	40.0	103	—	78	4
7.	*Cochlospermium gossypium*	15.0 (b)	—	—	150	2.75	62.0 ubl	123*	ubl	4550	25.7	64	21	—	16
8.	Erandi	20.0 (a)	22.4	1 : 4	170	4.0	51.2 ubl	10.9	ubl	5792	45.5	63	—	—	17
9.	*E. camaldulensis*	20.0 (a)	3 : 1	1 : 4	153	4.0	41.1 bl	20.4	bl	4220	35.7	46	—	72	8
10.	*E. citriodora*	18.0 (a)	2 : 1	1 : 4	162	5.0	42.5 bl	—	bl	5141	30.0	53	—	60	7
11.	*E. globulus*	22.0 (a)	3 : 1	1 : 3	153	6.0	52.8 bl	—	bl	7340	47.6	85	—	72	4
12.	*E. grandis*	20.0 (a)	3 : 1	1 : 4	162	4.0	50.0 bl	—	bl	8920	60	66	—	76	4
13.	*E. robusta*	20.0 (a)	3 : 1	1 : 4	170	4.0	42.7 bl	—	bl	5500	46.2	103	—	68	4
14.	*E. tereticornis* (grown in Madras)	20.0 (a)	3 : 1	1 : 4	162	4.0	50.0 bl	—	bl	4840	34.2	69	—	75	4,5
15.	*E. tereticornis* (grown in U.P.)	15.4 (b)	3 : 1	1 : 4	162	4.0	46.7 ubl	21.4	ubl	5440	53.0	88	—	—	4,5
16.	*E. torelliana*	15.0 (b)	3 : 1	1 : 4	162	4.0	48.0 ubl	17.1	ubl	6830	43.0	90	110	—	6
17.	*Garuga pinnata*	16.0 (b)	—	—	150	3.0	60.4 ubl	92*	ubl	5720	39.2	85	270	—	16
18.	*Hevea brasiliensis* (Rubber wood)	20.0 (a)	3 : 1	1 : 4	170	4.0	41.5 ubl	21.5	ubl	7819	46·6	67	70	—	9
19.	*Lannca coromandalica*	15.0 (b)	—	—	160	2.75	50.4 ubl	80*	ubl	5310	31.1	68	44	—	16
20.	Paper mullberry	24.0 (a)	2 : 1	1 : 5	153	6.0	48.1 bl	—	bl	9010	48.2	82	—	—	4
21.	*Sterculia urens*	15.0 (b)	—	—	150	2.75	65.0 ubl	120*	ubl	4020	27.3	90	57	—	16
22.	Mixed Hardwoods	20.0 (a)	17.2	1 : 4	170	5.0	42.3 ubl	18.3	ubl	4000	20.1	47	—	—	17
23.	,,	24.0 (a)	25.0	1 : 4	153	4.5	44.1 ubl	—	ubl	3010	12.1	38	—	—	17
24.	,,	20.0 (a)	25.0	1 : 4	170	4.0	40.5 ubl	—	ubl	4420	21.9	44	—	—	17
25.	,,	20.0 (a)	25.0	1 : 4	162	4.0	46.7 ubl	—	ubl	3160	19.9	64	—	—	17

a = as NaOH, b = as Na_2O * Kappa No.

ubl = unbleached, bl = bleached

category of agricultural residues because of its cultivation as annual crop, was successfully used on commercial scale since 1961 in the same mill. The Bengal Paper Mill Co. Ltd., Raniganj has been the pioneer in pulping of bamboo and mixed hardwoods together not only by batch process but also in continuous digester. The mixed hardwoods are also used in substantial quantities in the furnish of kraft paper along with chir (*Pinus longifolia*) at Star Paper Mills Ltd., Saharanpur.

The hardwoods, because of their occurrence in mixed forests, are best utilised as mixed hardwoods rather than by individual species which are rather impractical to collect and utilise commercially. The following is a summary of investigations on utilisation of hardwoods for four major grades of pulp and paper, *viz.* (A) Writing and Printing Papers (B) Newsprint (C) Wrapping Papers, and (D) High Alpha Pulps.

(A) Writing and Printing Papers

The chemical pulp from different hardwoods was made by Sulphate process at FRI, Dehradun, under conditions given in Table-5[4] Results of Pilot plant trials are also included in the same place.

Many types of Eucalyptus wood namely, *Eucalyptus tereticornis*,[4-5] *E. grandis*[4], *E. torelliana*[6], *E. globulus*[4], *E. citriodora*[7], *E. robusta*[4] and *E. camaldulensis*[8], and *Hevea brasiliensis*[9] (Rubber wood) were also tried and the results are included in Table–5

The effect of age on pulping properties was investigated for 3 years and 6 years old Mysore hybrid[5] and the results are given in Table–6:–

TABLE-6

Details	3-years old wood	6-years old woods
Total Chemicals, % as Na_2O	14.0	14.0
Bath ratio	1:4	1:4
Digestion Temp. °C	162	162
Digestion Period	4 hrs.	4 hrs.
Unbleached pulp yield, %	51.3	49.3
Burst factor	52.2	44.6

At the instance of the Bengal Paper Mills Co. Ltd., Raniganj, further investigation work on pulping mixtures of mixed hardwoods and bamboo by neutral sulphite semi-chemical, sulphate semi-chemical and sulphate processes were carried out at FRI, Dehradun in 1963 and 1965[10,11]. The yield of sulphate semi-chemical pulps was found to be lower than that of NSSC process but strength properties were better. Mixtures containing 40% of mixed hardwoods and 60% bamboo were cooked with 15.5% alkali as Na_2O having bath ratio 1:4, sulphidity 25%, cooking temperature 170°C, and cooking time 4 hrs. including 90 minutes to raise the temperature to 170°C. The yield of unbleached pulp is reported to be 43% and permanganate no. 18. The laboratory trial results are summarised in Table–7.

Based on the above investigations, cooking of a mixture of mixed hardwoods and bamboo in the ratio 40 : 60 was started commercially in Kamyr continuous digester in June 1967, thus pioneering the pulping of mixtures of bamboo and mixed hardwoods in kamyr continuous digesters in the world.

Mention has already been made about the use of hardwoods for making kraft paper at Star Paper Mills Ltd., Saharanpur. Starting with twisted pine in the year 1962 this mill had to use mixed hardwoods in increasing proportions to make up the shortage of raw materials and now has been able to use hardwoods to the extent of 70% in the furnish.

In the laboratories of Sirpur Paper Mills Ltd., various species of hardwoods were cooked using four-stage and two-stage steaming process. In four-stage steaming process, a total cooking cycle of 4½ hrs. was followed for some of the cooks. The 4½ hrs. included, ½ hour from room temperature to 110°C, 1½ hrs. at 110°C 1 hr. from 110 to 170°C, and 1½ hrs. at 170°C. In the similar manner different combinations of four stage steaming process were used for cooking hardwoods[12-15] for making paper

TABLE-7

Strength Properties of unbleached pulp from different mixtures of bamboo and mixed hardwoods

S. No.	Mixture		Breaking length meters	Tear factor	Double fold	Brust factor
	Wood	Bambo				
	%	%				
1.	100	—	7000	96	240	51.6
2.	80	20	6650	96	120	44.9
3.	60	40	5820	108	133	39.0
4.	50	50	6870	120	158	42.0
5.	40	60	8290	126	601	51.2
6.	20	80	9400	125	500	60.2
7.	—	100	6800	152	900	56.9

grade pulp. From the investigation results it has been concluded that *Sterculia urens* or Tapsi gives fairly strong and bright pulp. It required low alkali (16% as Na_2O T.A.A.) to produce an easy bleaching pulp. This pulp could be compared with bamboo and Salai pulp in strength properties and yields. Slenderness ratio of Tapsi Fibre (174) approached to that of Bamboo fibre (190). It can be observed from the datas given in Table 8, that pulp from Tapsi wood is better than pulp from salai wood.

TABLE–8

S. No.	Raw material	Burst factor	Tear factor	Breaking length, meters	Double folds
1.	*Sterculia urens* (Tapsi)	35.5	80	5380	120
2.	Bamboo	26.1	48	4615	55
3.	Salai (*Anduk*)	26.8	60	5320	16

Five different hardwoods of Andhra Pradesh were also pulped by semi-chemical pulping process for paper grade pulp at West Coast Paper Mills Ltd., Dandeli[16] It. may be observed from Table 5 that *Garuga pinnata* is better from the point of yield and requirement of cooking chemicals but the strength properties of the bleached pulps are next to *Sterculia urens*.

Laboratory trials on sulphate pulping of tropical hardwoods were also undertaken at West Coast Paper Mills [17]. Pulping of 100% hardwoods and mixtures of hardwood and Bamboo was carried out. Some of the hardwoods namely paper mulberry *(Broussonetia papyrifera) Bhendi* and perennial shrub *Erandi*, were found to have excellent pulping properties and pulp obtained had good strength characteristics. Mysore hybrid also gave good pulp under slightly severe cooking conditions. In the mixed cooking paper mulberry was found to blend well with bamboo. The results are given in table—5.

Seshasayee Paper and Boards Ltd., Erode, was started in the year 1962 with an idea of using Bamboo and Bagasse in the ratio 70 : 30. Due to procurement problem of Bagasse at economical rate and shortage of Bamboo supply, mill started the search of suitable hardwoods. Laboratory and plant trials revealed that with *Accacia arabica* (*Babul*), Mysore hybrid and *Erythrina suberosa* (Dadup), the hardwood content in the furnish could be raised to 50% [18].

Another promising raw material for pulp and paper making is *Sesbania grandiflora* which is supposed to be indigenous to Northern Australia. This is found in South India growing along household compounds or in betel leaf gardens as shade and support to vines [19]. It is a leguminous tree, 3-9 meters high with 20-25 cm diameter at breast height. Flowering takes place in January-February. Wood is soft and white and characterised by a central position of very small circular pith. Its proximate analysis is included in Table—4. The suitability of this specie for paper making was established after carrying out extensive research work. The pulp was made by (i) Conventional Kraft (ii) Cold-Caustic, and (iii) Mono-Sulphite processes. Pilot plant trials were also carried out on semi-chemical pulping of this wood.

Laboratory trials on *Sesbania grandiflora*, were also conducted at the Mysore Paper Mills Ltd., Bhadravati [20]. Cooking conditions used are active alkali as NaOH 20%, Sulphidity 20%, cooking temperature 160°C, cooking period 2 hrs. The pulp of permanganate No. 16 with an yield of 43% was obtained. The comparison of strength properties of Bamboo pulp and the mixture of bamboo and *Sesbania grandiflora* pulp is given in Table 10. It may be observed that the admixture of Bamboo and *Sesbania grandiflora* pulp, shows satisfactory strength properties.

TABLE-10

S. No. Strength	100% Bamboo Pulp	Bamboo + *Sesbania grandiflora* (80:20) pulp.
1. Breaking Length, m	5150	4200
2. Burst factor	33	31
3. Tear factor	101	110
4. Double folds	47	69
5. Viscosity	29	34

B—Newsprint

Study of different species of hardwoods for making newsprint by different processes, has been extensively carried out at FRI, Dehradun. Out of 22 species of wood tried on

Voith experimental grinder, seventeen species were reported to be suitable. Species namely *Accacia ducerrens, Eucalyptus tereticornis, Melia azedarach, Sterculia alata* and *Casia siamea* gave dark coloured pulps[21]. The work carried out on *Eucalyptus grandis* grown in Kerala, at FRI, Dehradun has also been reported[22]. The laboratory and pilot plant scale trials were conducted for production of newsprint from two different furnishes, (i) 40% bleached cold soda pulp, 30%bleached ground wood pulp and 30%chemical pulp(all from *E. grandis)*, (ii) 50% bleahed groundwood pulp and 50% bleached chemical pulp (all from *E. grandis*). Both the furnishes gave satisfactory machine run.

Eucalyptus tereticornis (Mysore hybrid) was tried for newsprint grade pulp by N.S.S.C. and cold soda process at Institute of Paper Technology, Saharanpur[23]. Cold soda pulp were produced by treating the chips for two hours at room temperature with 7% caustic soda on O.D. basis. Liquor to solid ratio was maintained at 4.5 : 1. The chips were treated in the raffinator and a yield of 85% at 23 permanganate number was obtained. N.S.S.C. pulp was produced by cooking the chips with 13.5% soduim sulphite and 3.25% Na_2CO_3 at liquor to solid ratio of 4 : 1 in the laboratory autoclave. The cooking was carried out at 160°C for 155 minutes, with 90 minutes for raising thc temperature, 50 minutes at maximum temperature and 15 minutes for relieving. The cooked chips were treated in a raffinator. The yield and permanganate number were 78% and 24 respectively. Chemical pulp was obtained with 16% A.A. as Na_20, by cooking at 160°C for 165 minutes (90+60+15). The sulphidity was 20%. The yield, and permanganate number were 52% and 18.5 respectively with brighness about 40-44% The comparison of strength properties of sheets formed with that of imported and Nepa newsprint are given in table 11. Newsprint grade pulp from Mysore hybrid was also produced at F.R.I , Dehradun by admixture of mechanical pulp from Mysore hybrid and soda semichemical pulp from bagasse[24]. The investigations on Chemi-mechanical pulping of Mysore hybrid were carried out at West Coast Paper Mills, Dandeli[25]. The Chips were presteamed and then impregnated with sodium sulphite liquor. They were subsequently cooked in vapor phase and finally refined. The unbleached pulp yield was 81.5-85%with brightness of 41--45. It was found that this pulp can be used to the extent of 80% in newsprint furnish alongwith 20% bleached kraft pulp from bamboo.

At National Newsprint and Paper Mills, Nepanagar, experiments were conducted on cold caustic pulping of Salai (*Boswellia Serrata*)[26] with an aim to improve the newsprint furnish. They tried different chemical treatments including presteaming and chemical treatment of logs, use of chemicals during grinding, treatment of chips with steam and chemicals etc. Considering various factors, cold caustic soda pulp was found to be the best with alkaline grinding It was found[27] that it reduces the power requirement and improves the newsprint strength characteristics but it reduces the yield by 2.5% due to removal of tannin. During grinding the pH was maintained at 9.2 and NaOH used was around 2.5%.

(C) Wrapping Papers

Sulphate pulping of various species of hardwoods with a view to manufacture wrapping paper, was investigated at various laboratories in the country. At FRI, Dehradun, laboratory scale experiments were carried out to produce chemical, semi-chemical and mechanical pulps from *Casuarina equisetifolia*[28]. After pilot plant trials it was found that the material is quite suitable for chemical and semi-chemical pulping. It was not found suitable for mechanical pulping because of high energy requirements and dark shade of pulp produced. Satisfactory wrapping paper was produced from 100% sulphate pulp of *Casuarina equisetifolia*. Cooking conditions and properties of unbleached pulp for one of the trials are included in table-12. Mixture of hardwoods from Maharashtra[29] Himachal Pradesh[30] and Andhra Pradesh[31] were also tried for production of wrapping papers. Mixed hardwoods from Maharashtra were cooked by sulphate process, and bleached unscreened yield varied from 41.6 to 47.2% under different cooking conditions. Strength of pulp was reported to be suitable for wrapping paper. Conditions of pulping and strength properties of unbleached pulp for one of the trials are included in table No. 12.

Six species of hardwoods from Andhra Pradesh were first cooked individually and then in a mixture, and pilot plant trials were carried out subsequently. Cooking conditions and strength properties for one of the trial runs are included in table-12. The pilot plant trials confirmed the laboratory results and it is reported that wrapping paper

TABLE-11

Comparison of Imported, Nepa and Eucalyptus Laboratory Newsprint Properties

Sl. No.	Characteristics	Standard	Canadian	Russian	Nepa	EUCALYPTUS				
						60% C.C+ 40%C	60% C.C. +30%C+ 10% IP	60% NSSC + 40% C	60% NSSC +30% C+ 10%IP	40% CC. + 60% NSSC.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.	Bulk, cc/g	2.45	1.661	1.785	1.879	2.52	2.35	1.71	1.74	2 43
2.	Breaking Length, m	3930	4150 MD 1910 CD	3770 MD 1690 CD	2500 MD 1560 CD	4170	4470	7590	7100	4880
3.	Tear Factor	82.1	34 MD 43 CD	32.7 MD 41.8 CD	44.9 MD 44.9 CD	31.8	38.9	40.3	40.0	32 4
4.	Double Folds	24.6	14 MD 5 CD	9 MD 4 CD	4 MD 3 CD	10	8	204	66	5
5.	Burst Factor	20.4	6.8	6.8	7.6	20.1	18.1	50.0	51.2	20.7
6.	Brightness,%	58.0	—	—	—	44.3	44.0	40.3	40.0	39.3
7.	Opacity, %	94.0	—	—	—	69.3	73.4	71.1	74.5	77.4

NOTE :—Standard figures were taken from ECO commission for Africa, FAO, SEC, January 5, 1965. Paper samples under columns 4 to 5 were obtained from the Hindustan Times New Delhi, cc=cold caustic soda pulp, NSSC=neutral sulphite Semi-Chemical pulp, IP=imported chemical pulp, and c=chemical Pulp.

could be manufactured, from 100% mixed hardwoods.

The investigation with Himachal Pradesh hardwoods revealed that good wrapping papers could not be manufactured from this pulp alone due to difficulty on machine and it was necessary to mix long fiber pulp with it for the smooth running of paper machine.

Pulping of Silver oak (*Gravillea robusta*) for wrapping and packing papers has also been reported[32]. It is reported that strength properties of unbleached pulp were fairly good and 100% Silver oak pulp could be utilised for manufacture of ordinary wrapping & packing papers. The cooking conditions and strength properties of unbleached pulp obtained in one of the trials are given in table-12.

(D) High-Alpha Pulps

The investigation work was carried out in various laboratories in the country for making high alpha pulps from eucalyptus and other hardwoods. In this field pioneering work has been done by Rayon and High Polymer Division, Birla Research Institute for Applied Sciences, Birlagram, Nagda. The investigation work was also carried out at Cellulose and Paper Branch, F.R.I. Dehradun, and Regional Research Laboratory, Jammu-Tawi. The investigation work on Bastar region hardwoods, was carried out at the Institute of Paper Technology, Saharanpur on behalf of F.A.O. for the manufacture of Rayon grade pulp, by prehydrolysis sulphate process. The rayon grade pulp is now being manufactured on commercial scale in this country from eucalyptus and mixed hardwoods by prehydrolysis sulphate process. Laboratory tests with mixtures of hardwoods[33] received from the Bengal Paper Mills, and *Eucalyptus tereticornis* (Mysore hybrid) grown in U.P.[34] were carried out at cellulose and Paper Branch, F.R.I., Dehradun for making high alpha pulps. The wood was prehydrolysed with water under different conditions of bath ratio, time, temperature etc. The hydrolysed material was then cooked by the sulphate process under different conditions. The yield of unbleached pulp was determined. The optimum conditions of water prehydrolysis stage and sulphate digestion are given in Table-13. The pulp was bleached by following CEHD sequence. The yield and analysis of the bleached pulp so obtained is also included in the same Table.

The investigation work was carried out at Regional Research Laboratory Jammu-Tawi, on laboratory

Table—12

Digestion Conditions and Strength Properties of Unbleached Pulp for Wrapping Paper from hard woods

Sl. No.	Cooking conditions and pulp Properties		*Casuarina equisatiolia* (Casuarina)[28]	Mixed hard woods from Maharastra[29]	Mixed hard woods from Andhra Pradesh[31]	Mixed hard woods from Himachal Pradesh[30]	*Gravillea robusta* (Silver Oak)[32]
1.	Total Chemical as Na_2O on O.D. Chips	%	18	14	14	14	16
2.	Sulphidity	%	3:1 (NaoH: Na_2S)	3:1 (NaoH: Na_2S)	3:1 (Na_2oH: Na_2S)	25%	25%
3.	Chips to liquor ratio		1:4	1:4	1:4	1:4	1:4
4.	Max. Temp.	°C	153	153	153	153	170
5.	Time to max. Temp.	min.	120	90	120	120	90
6.	Time at max. Temp.	min.	150	370	240	240	60
7.	Yield	%	54.2	44.7	47.2	44.7	47.7
8.	Permanganate No.	—	15.6	22.5	26.8	19.8	20.4
9.	Beating	C.S.F.	250	250	250	250	300
10.	Breaking length	Meters	7920	6150	7600	5110	8500
11.	Burst Factor		47.6	38.3	32.1	38.8	57.5
12.	Tear factor		115.0	85.0	90.3	135	65.0
13.	Folding endarance	Double folds.	7201	65	20	190	330

scale, for making high alpha pulps from Poplar [35]. (*Populus ciliata* and *P. nigra*) and *Eucalyptus citriodora* [36] by prehydrolysis sulphate process. The pulping conditions are given in Table—13. The pulps obtained were bleached by CEHD sequence. The characteristics and yield of the bleached pulp obtained in one of the trials are included in Table 13.

The investigation work was carried out at Rayon and High Polymer Division, Birla Research Institute for Applied Sciences, Nagda, on *Eucalyptus globulus* [37]. *Kydia calycina* (Pula) [38]. *Dillenia pentagyma* [39]. *Sterosperm suaveslens* (Poompadiri wood) [40]. *Melia azedarach* (Bakain) [41] and *Boswellia serrata* Rox (Salai) [42] for the manufacture of Rayon grade pulp. Prehydrolysis sulphate process was used for pulping these woods. The pulping conditions and characteristics of bleached and unbleached pulps for one of the trials are included in Table 14.

It is evident from the results shown in Table 14 that many species of Indian hardwoods can be successfully pulped by prehydrolysis sulphate process for the manufacture of high grade alpha pulps. Therefore, it would be desirable to utilise long fibred bamboo in paper furnish and suitable hardwoods for dissolving grade pulp as fiber length is not so important a factor for such pulps. The proximate analysis of the above raw materials processed for the manufacture of high alpha pulps are given in Table 4.

Conclusion

From the above discussions, it is clear that many species of Indian hardwoods are basically suitable for the manufacture of paper grade pulp, high alpha pulps and newsprint etc. The hardwoods can be suitably pulped by different processes for various end uses. Already good amount of success has been achieved on commercial scale in the direction of more and more hardwoods by paper, newsprint and rayon-grade pulp industry. Efforts should now be made to develop suitable equipment and processes, for commercial exploitation of various hardwoods available in the country.

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Table No. 13

Digestion conditions and properties of pulp obtained by prehydrolysis sulphate cooking from some hardwoods.

S. No.	Cooking Conditions and Pulp properties		*E. tereticornis*[34] (Mysore hybrid) grown in U.P.	Mixture of Hardwoods[33]	*E. citriodora*[36]	*Populus ciliata*[35]	*Populus nigra*[35]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	[A] Prehydrolysis Stage						
1.	Medium		Water	Water	Water	Water	Water
2.	Chips : liq.		1:5	1:4	1:4	1:6	1:6
3	Max temp	°C	153	165	160	160	160
4.	Total time.	hrs.	2	2.5	2	2.5	1.5
5.	pH of prehydrolysed liq.		4	3.5	3.1	—	—
6.	Pentosans in prehydrolised chips.	%	—	—	—	6.41	2.73
7.	Yield of prehydrolysed chips.	%	—	—	77	87.0	79.0
	[B] Cooking						
8.	Active alkali on B. D. chips	%	14.5*	16.0*	22**	24**	24**
9.	Sulphidity (NaOH : Na_2S)		3:1	3:1	3:1	3:1	3:1
10.	Chips : liq.		1:4	1:3	—	1:6	1:6
11.	Max. Temperature.	°C	153	162	160	160	160
12.	Time to max. temp.	min.	90	90	—	—	—
13.	Time at max. temp.	min.	150	150	—	—	—
14.	Total time	hrs.	4	4	3.5	4	4
15.	A.A. Consumed on B.D. chips as Na_2O	%	—	—	10.5	—	—
	[C] Unbleached Pulp						
6.	Yield.	%	43.2	35.5	36.5	39.4	40.0
7.	Permanganate No.		10	13.8	17.7	13.0[a]	—
8.	Pentosans.	%	—	—	3.29	3.28	2.55
	[D] Bleached Pulp						
19.	Bleaching Sequence,		CEHD	CEHD	CEHD	CEHD	CEHD
20.	Bleached pulp yield on raw mat.	%	32.3	30.74	31.2	32.0	33.0
21.	Alpha cellulose.	%	92.0	93.2	96.7	94.2	97.0
22.	Beta cellulose.	%	5.2	4.1	—	—	—
23.	Gamma cellulose.	%	2.8	1.1	—	—	—
24.	Pentosans.	%	2.88	2.39	2.90	3.07	2.44
25.	Ash,	%	0.10	0.08	—	0.84	0.87
26.	Viscosity cupramm.	Cp	14	—	—	—	—
27.	Brightness (MgO=100%)		89	86	—	—	—

* As Na_2O
** As NaOH
a Kappa number

TABLE–14

Digestion Conditions and properties of pulp obtained by prehydrolysis sulphate cooking from some Hardwoods

S. No. (1)	Conditions and Pulp Properties (2)	(3)	*E. globulus* (4)		*Kydia calycina*[38] (Pula) (5)		*Dillenia pentagyma*[39] (6)	*Sterosperm suaveslens*[40] (Poompadiri wood) (7)		*M. azedarach*[41] (Bakain) (8)	*Boswellia*[24] *serrata* Rox (Salai) (9)
	[A] Prehydrolysis										
1.	Medium		Water	Acid (1.0 gpl H_2SO_4)	Water	Acid (1.5 gpl H_2SO_4)	Water	Water	Acid (1.4 gpl. H_2SO_4)	Acid(0.23 gpl H_2SO_4)	Acid(0.23) gpl H_2SO_4)
2.	Chips : liquor		1:5	1:5	1:5	1:5	—	1:4	1:4	1:4	1:3.5
3.	Max. temp	°C	160	160	170	165	170	165	160	165	195
4.	Time to max. temp.	Min	90	90	90	90	45	120	120	105	105
5.	Time at max. temp.	Min	60	60	90	60	120	60	60	90	60
6.	pH of prehydrolysed liq.		—	—	4.0	3.7	—	3.5	2.5	—	—
7.	Pentosans in Prehydrolysed chips.	%	—	—	8.0	7.8	5.5	6.9	7.5	7.8	—
8.	Yield of Prehydrolysed chips	%	—	—	86.0	84	—	80.8	78.9	80.48	76:13
	[B] Cooking										
9.	Active alkali as Na_2O on B. D. chips	%	14.0	14.0	20.0	20.0	16.0	16.0	16.0	15.0	17.0
10.	Sulphidity	%	18	18	25	25	19.7	18.0	23.0	18.91	18-19
11.	Chips : liquor		1:3.1	1:3.1	1:4	1:4	1:3.25	1:3.5	1:3.5	1:3.5	1:3·5
12.	Concentration of cooking liq. as Na_2O	Gpl	—	—	50.0	50.0	49.23	45.7	45.7	42.86	48.75
13.	Time to max. Temp.	Min	60	60	60	60	45	60	60	90	105
14.	Max. temp.	°C	157	155	157	157	160	165	165	195	165
15.	Time at max. temp	Min	120	120	150	150	135	120	120	90	90
16.	Free A.A. as Na_2O in B L.,	Gpl	—	—	—	—	9.61	—	—	9.92	15.19
17.	A.A. Consumed on. B. D. Chips.	%	—	—	—	—	12.87	9.8	9.8	11.52	11.68
	[C] Unbleached pulp										
18.	Yield	%	39.7	36.0	42.1	40.7	32.7	33.6	3 2.0	34.14	32.32
19.	Permanganate No.		6.4	6.3	9.4	7.8	12.8	9.6	10.3	9.1	11.1
20.	Pentosans	%	2.5	1.25	2.2	1.9	2.0	2.8	2.4	1.87	2.61
21.	Viscosity (1% Cupramm.)	Cp	62	41.5	52.5	41.5	36.6	27.4	30.0	36.92	30.45
	[D] Bleached puld										
22.	Bleaching Sequence		CEHD - SO_2		CEHD - SO_2		**	CHED - SO_2		CEDH	CEHED
23.	Bleached pulp yield on raw mat.	%	37.7	34.2	*	*	27.5	*	*	—	—
24.	Alpha cellulose	%	96.56	96.09	95.8	96.94	95.75	94.6	95.8	95.41	94.56
25.	Hemicellulose	%	4.0	3.5	4.45	3.867	4.25	2.7	5.1	—	—
26.	Beta cellulose	%	2.7	1.6	3.81	2.428	3.38	4.3	4.24	4.72	5.19
27.	Gamma cellulose	%	1.3	1.9	0.64	0.439	0.87	1.31	0.86	0.45	0.56
28.	Pentosans	%	2.3	1.3	2.2	1.74	1.69	2.8	1.7	1.72	2.62
29.	Viscosity (1% Cuparmm.)	Cp	14	10	10.5	8.5	13.6	10.6	12.4	9.52	12.00
30.	Copper number		0.35	0.44	0.35	0.263	0.28	0.23	0.32	0.33	0.36
31.	1% NaOH Solubilily	%	2.5	3.17	2.62	1.98	1.83	3.9	3.4	1.69	1.58
32.	7.14% NaOH Solubilily	%	7.5	8.68	8.57	7.55	6.95	6.0	8.71	8.87	7.85
33.	Brightness	%GE	90	90	>90	>90	91.5	86	86	89.1	87
34.	Ash content	%	0.071	0.051	0·3522	0.3934	—		0.334	0.33	0.3022

*Bleaching losses lab scale 5%

**CEHEDH—SO_2

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