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Pulping of Tropical Hard-Woods

In order to meet the expectant shortage of bamboo, experiments were conducted on some of the Indian tropical woods having different physical nature and chemical composition. Densities and chemical composition of the woods were studied. Digestions were conducted with 100 per cent woods and mixtures of woods and bamboo. The pulping behaviour of the various woods and strength properties of the pulps were studied in comparison with bamboo by sulphate process.

Some of the hard woods tried, namely, Paper Mulbery (Broussonatia papyrifera), Bhendi (Kydia calycina) and a perennial shrub, Erandi Recinus communis) have been found to possess excellent pulping characteristics along with good pulp strength. Eucalyptus hybrid also gave good quality pulp at slightly more severe cooking conditions. Pacharam (Dalbergia paniculata), Khoken (Doubanga Sonneretoides) and Maharuk (Ailanthus excelsa) have also been found to be quite satisfactory. The remaining woods, Heddi (Adina cardifolia), Kindal (Terminalia paniculata), Nandi (Lagerstromia lanceolata), Jamba (Xylia xylocarpa), and Matti (Terminalia Tomentosa) require severe cooking conditions giving low yields. The strength properties of Heddi, Nandi and Kindal were satisfactory. Matti and Jamba being very dense, and also having high lignin content, were not suitable for producing chemical pulps.

In the mixed digestions, Paper Mulbery was found to blend well with bamboo. The remaining woods tried were giving considerable rejects in the pulp.

Beating time of the hardwood pulps were generally more than that of the bamboo pulps. The strength properties of pulps of Eucalyptus Hybrid and Paper Mulbery were found to be better than pure bamboo pulps except tear factor.

INTRODUCTION

Prior to the middle of ninteenth century, cotton was considered to be the main raw material for paper making. As the utility and demand for paper increased, pulp and paper technologists had to search for new sources of raw material. The discovery of Burgess, Tilghman and Dahl opened new horizons for the utilisation of the vast fibrous raw material present in the nature in the form of woods. Since then, much work has been done for the exploitation of coniferous wood and temperate hard woods for various kinds of paper in Europe and America. New pulping processes have been introduced to suit the particular requirement of the wood available in these countries. Though India saw its first paper mill in 1879, till 1925, India was depending upon only imported pulp for its paper production. After the researches of the Forest Research Institute, Dehra Dun, bamboo started replacing the imported pulp and till today remains the chief source raw material for pulp and paper making in India. To some extent bagasse and sabai grass are used for chemical pulp production and salai wood for ground wood pulp.

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Little work has been done for the commercial exploitation of tropical hardwoods. In this direction, pioneering work was done in Australia where varieties of Eucalyptus species like Eucalyptus qyqantia, Eucalyptus oblique, Eucalyptus regnaus, Eucalyptus caffilata, etc. have been successfully used as the main fibrous raw material since 1938. Those species have been used for producing chemical, mechanical and rayon grade pulps.

India's requirement of fibrous raw material in 1970 is expected to be of the order of 4 million tonnes which may rise to about eleven million tonnes by 1980 (2). At present the maximum quantity of extractable bamboo is only about two million tonnes. Considering the huge demand for fibrous raw material for paper, it is imperative that we should investigate all possible available sources. The requirement can be partly met by bagasse which is available to the extent of about 1.5 million tonnes per year. India has got vast forest resources with a total area of 270 thousand square miles, out of which 80 per cent area is occupied by deciduous wood. Only 10 per cent of this area is being exploited for the purposes of timber and miscellaneous uses. Mr. Shah is of the opinion that if only 10 per cent of this forest area is dedicated for paper industry, our requirement of 1980 can be met with (3). This vast forest area is spread over the length and breadth of the country, having diverse climatical conditions with varying rainfall and temperature of 32 to 430" and 45°C to well below 0°C respectively. Hence the varieties of plant species which can exist can be numerous. Gamble (4) puts the number of the wood species near 5000 out of which 2500 are trees. Out of the very many varieties, proper investigations have not been made about the suitability of these woods for pulp and paper production.

The pulping properties of the woods depend upon any factors, like the species of the wood, physical characteristics, anatomy, and chemical nature. The Conferous woods and the temperate hard woods are studied exhaustively in the Western countries and processes have been developed suitable to obtain required quantity of pulps from these woods. Though our forests are blessed with ample hardwoods (mostly tropical), we have not yet acquired adequate knowledge about their chemical composition and pulping characteristics. Pulping experts have recognised the differences between temperate hardwoods and tropical hardwoods in their chemical and physical structure and new efforts have to be made to exploit these woods for pulping processes. L. Wise (5) reports that the extractives and lignin content of tropical hardwoods are generally higher than those of the temperate hardwoods. The chemical nature of the lignins and pentosans are also said to be different. For comparison, the chemical analysis of some typical soft wood, temperate hardwood and tropical hardwood are given in: (6, 7). **(Table I).**

The chemical composition and physical nature like density, porosity etc. decide the pulping characteristics of a particular wood. The methods followed in the Western countries may not

TABLE I

ANALYSIS OF WOODS

		White spruce	Aspen	Salai
Density, lb/cft.		24.0	22.0	—
Holocellulose,	%	73.0	82.0	—
Alpha cellulose,	%	49.0	51.0	—
Cross and Bevan Celluloses,	%	61.0	64.0	50.7
Lignin,	%	27.0	17.0	27.3
Pentosans,	%	11.0	23.0	13.0
Ether solubles,	%	1.5	1.0	0.7
1% NaOH solubles,	%	12.0	19.0	15.5
Hot water solubles.	%	3.0	3.0	8.9
Ash	%	0.3	0.3	1.8

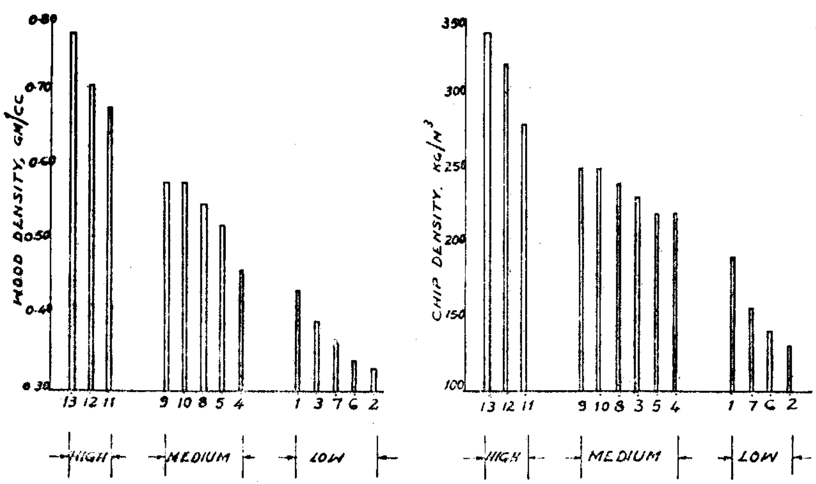

Fig. 1 Densities of woods and chips

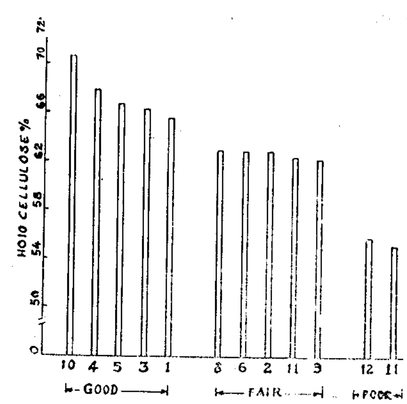

Fig. 2 Holocellulose contents of woods

TABLE II
Density & Fibre Dimensions

Wood No.	Botanical name	Local name	Wood Density (O.D. basis) g/cc.	Chip density (O.D. basis kgs/m3	Fibre length mm.	Fibre diameter microns
1.	Broussonatia papyrifera	Paper Mulbery	0.432	190	0.96	21
2.	Recinus communis	Erandi	0.330	130	1.23	25
3.	Bambusa Arundinacea	Dowga bamboo	0.390	230	2.20	18
4.	Kydia calycina	Bhendi	0.458	220	1.17	25
5.	Eucalyptus Hybrid	Nilgiri	0.520	220	2.87	12
6.	Doubanga sonneretoides	Khoken	0.340	140	1.23	35
7.	Ailanthus Excelsa	Maharukh	0.367	150	1.14	41
8.	Adina cordifolia	Heddi	0.550	240	1.22	56
9.	Termanalia paniculata	Kindal	0.580	250	1.01	49
10.	Dalbergia paniculata	Pacharam	0.580	240	0.83	19
11.	Lagerstromia lanceolata	Nandi	0.680	280	1.10	80
12.	Xylia xylocarpa	Jamba	0.710	320	1.01	14
13.	Terminalia Tomentosa	Matti	0.756	340	1.00	35
14.	Mixed woods (Matti+ Jamba + Kindal) (1 + 1 + 1)	—	—	—	—	—

ideally suit our woods. Some experiments are being conducted about our woods here and there like the Forest Research Institute, Dehra Dun, and various mill laboratories, but the commercial exploitation has not been so far quite significant. At present the only wood which is being used on a large scale for pulping is boswellia serrato (Salai) at the Nepa Mills for ground woodpulp manufacture. Some plant scale trials are being conducted at the West Coast Paper Mills now and then for chemical pulping and paper making. On account of difference in the physical and chemical nature of the bamboo and the hardwoods and the lack of separate equipments, some difficulties had been experienced to process these woods. Those are enumerated in an earlier paper (8).

In order to study the possibility of pulping some tropical hardwoods largely available, some work was undertaken at West Coast Paper Mills Ltd., Dandeli. The woods chosen were of diverse nature having very high to very low densities like matti and Khoken (Doubanga), respectively very fast growing woods like Paper Mulberry or Eucalyptus hybrid to slow growing species like Heddi or Kindal, typically giant trees like Jamba or Matti to perennial shrubs like Erandi (Resinus communis).

A brief description of the various woods chosen is given below (9, 10):

1. **Broussonatia papyrifera (Paper Mulbery):** Grows in India, Malaya, Japan, China, pacific islands. Easy to raise, grows from seeds or stumps in well drained sandy loamy soil. It is a soft and fast growing species. It can thrive in different soils and climatic conditions.

2. **Recinus communis (Brandi):** There are two varieties: one grown as an annual crop for its seeds. This occurs as a small shrub. The other is a perennial variety which grows to a small tree with greyish brown bark. The wood is white, soft and light with a large central pith. This variety is scattered throughout India. It requires free soil for its growth. The second variety was used in our experiments.

3. **Bambusa Arundinacea (Dowga)** Belongs to species Graminae. Trees usually large, thorny, with many stems tufted on a stout root stake; 80 — 100′ high, 6 —

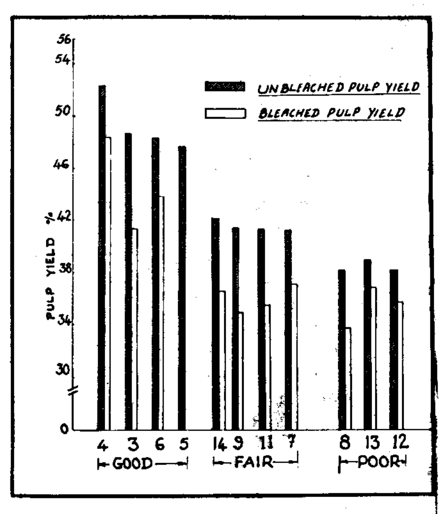

Fig. 3 Pulp Yields

TABLE NO. III

Chemical Analysis and Fibre dimensions of Hardwoods

Wood No.	Type of wood	Cold Water solubility %	Hot water solubility %	NaOH solubility %	Alcohol Benzene solubility %	Pentosans %	Lingnin %	Alpha cellulose %	Holo cellulose by difference %	Ash %
1.	Paper mulbery	5.47	6.37	23.9	23.9	18.70	22.60	39.5	65.5	2.5
2.	Erandi	5.54	5.94	23.3	3.38	21.56	21.80	40.5	62.8	1.06
3.	Dowga bamboo	3.12	4.21	21.85	3.42	18.12	24.13	44.82	66.2	3.12
4.	Erandi	2.80	3.38	12.13	2.34	16.33	25.74	48.72	67.72	1.70
5.	Eucalyptus (Nilgiri)	0.62	2.10	13.40	1.48	14.10	30.9	45.1	66.6	0.44
6.	Khoken	4.27	6.34	17.30	1.85	14.70	28.0	40.5	62.8	1.08
7.	Maharukh	—	—	—	2.37	15.10	29.3	—	—	2.30
8.	Heddi	2.91	6.55	16.14	4.36	14.50	29.2	37.5	62.9	0.57
9.	Kindal	5.68	7.65	19.00	2.17	12.15	30.10	40.4	61.2	0.82
10.	Pacharam	4.50	5.41	12.9	4.51	15.74	26.20	44.27	70.55	1.44
11.	Nandi	4.10	5.42	18.20	2.17	11.45	30.65	43.4	61.3	1.77
12.	Jamba	7.03	7.77	18.50	10.35	12.10	25.90	36.00	35.8	0.87
13.	Matti	3.08	6.13	26.05	7.31	10.55	32.35	35.0	55.1	2.6

Note: All values are expressed on oven-dry basis of wood.

7" diameter, nodes prominent; almost naked shoots armed at the nodes with 2-3 stout recurred spines 1" or more thick leaves 7-8" long and 1" wide. Internodes up to 18" long, walls thick. Stem coriaceous, variable in shape, striste with rounded tip and plaited margins, when young, golden hairs, branchlets bearing loose spikelets ½"-1" by 1/5". Life is about 30 — 40 years. Grown in Western ghats, Dangs in Gujarat and throughout India except the Himalayas.

4. **Kydia Calycina (Bhendi)**: A moderate sized tree with grey back, enfoliating in irregular flakes or long steps. Has little commercial uses, is abundant in certain forests, scattered throughout India; does not grow in arid regions. The tree is fast growing and short lived. Reaches a height of 30 to 50'. The seedlings reach 25 — 30 feet height in 5 years.

5. **Eucalyptus Hybrid (Nilgiri)**: This is a new species of eucalyptus evolved at the afforestation areas of Bangalore and Kolar about 40 years ago. Mr. Anderson (Australia) opines that the hybrid species is a mixed breed of Eucalyptus botryoides, Eucalyptus robusta and Eucalyptus transversa. This species adjusts, itself to varieties of soils and climatic conditions. It thrives well from sea coasts to altitudes of 4000' height and rain falls from 10" to 200". It is a fast growing species with a growth rate of 18" — 24" per year.

6. **Doubanga Sonneretiodes (Khoken)** Large deciduous tree with characteristic long horizontal branches drooping at the ends. Has greyish brown bark peeling off in thin flakes. Under forest conditions the tree forms a long bole which sometimes attains a girth of 18". Wood is yellowish, grey, soft and seasons well. Distribution eastern Sub-Himalayan tract ascending up to 3000 feet, Assam Manipur, Andaman and Nicobar. It is essentially a tree of moist warm climate, grown in forests with 50" 200" rain fall. After two years, the growth rate is fast with 5' per year.

7. **Ailanthus Excelsa (Maharukh)**: It is a large tree, growing 60 to 80 feet height, leaves equally or unequally pinnate, usually 8" — 12" or some times 2'-3' long. It is a soft and light quality wood. The wood is distributed throughout India.

8. **Adina cordifolia (Heddi)**: A tree with erect trunk and horizontal branches; brownish grey bark which are thick and furrowed. Leaves 4" — 10" long and as much broad. Flowers numerous. Growth scattered throughout India.

9. **Terminalia paniculata (Kindal).** A large tree; young parts

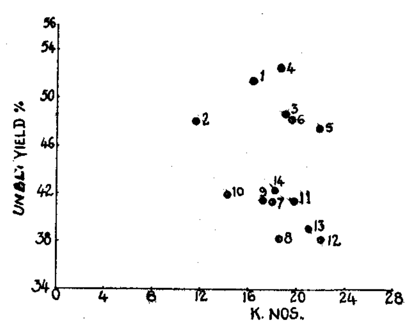

Fig. 4 Pulp Yields in relation to K. Nos.

TABLE IV PULPING OF HARD WOODS AND DOWGA BAMBOO

Wood No.	Name of wood	Active Alkali NaOH + Na_2S as such %	Sulphi-dity %	Wood : Liquor	Cooking Temp. °C.	Time to raise Temp. Hrs.	Cook ing time Hrs.	Unbld pulp yield % on CD wood	Regects %.	Permangan-ate No.	*Bleach consumption % cl on pulp	Bld. pulp yield % on CD wood.	Brighiness of Bl pulp %	1% Cupra-mmonium viscosity of bid pulp ops.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Paper Mulbery	20.0	21.8	1:3	160	2.0	1.0	51.5	3.2	16.3	7.5	48.1	80	47.0	Well cooked.
2. a)	Erandi	22.0	22.4	1:4	170	2.0	2.0	51.2	1.2	10.9	4.2	47.1	77.0	19.0	Soft cooked.
b)	Erandi	20.0	22.4	1:5	170	2.0	2.0	48.0	2.4	11.6	4.6	45.8	77	30.5	Well cooked.
c)	Erandi	20.0	22.4	1:3.5	160	2.0	1.0	43.1	12.5	20.7	7.4	38.6	77.5	78.0	Cooked chips were passed through refiner to get uniform pulp.
3. a)	Dowga Bamboo	22.0	21.0	1:3:5	170	1.5	4.0	45.8	nil	14.7	5.8	39.5	77	21.5	Well cooked.
b)	Dowga Bamboo	20.0	22.5	1:3.5	160	2.0	1.0	48.0	3.1	19.0	9.7	41.4	78	42	-do-
4.	Bhendi	20.0	19.9	1:3.5	160	2.0	1.0	52.4	2.6	18.7	6.9	48.4	79	43	-do-
5. a)	Nilgiri	22.0	23.9	1:2.5	155	1.5	1.0	47.4	0.4	21.9	...	...	...	...	-do-
b)	Nilgiri	20.0	23.9	1:2.5	155	1.5	1.0	48.8	0.5	25.4	11.9	44.9	80	23.5	-do-
6. a)	Khoken	22.0	18.0	1:4.5	170	1.5	4.0	48.2	1.0	19.6	7.7	43.8	76	...	-do-
b)	Khoken	20.0	25.0	1:3.5	160	2.0	1.0	52.5	3.1	30.8	18.6	44.8	79	21	Hard cooked.
7.	Maharukh	22.0	15.6	1:3.5	170	1.5	4.5	41.2	1.5	18.9	10.5	37.1	70	...	Well cooked.
8. a)	Heddi	22.0	17.2	1:3.5	170	1.5	4.0	38.2	nil	18.6	7.7	33.8	75	11.0	-do-
b)	Heddi	20.0	21.5	1:3.5	160	2.0	1.0	41.5	6.2	31.1	17.8	32.8	78	78	Cooked chips were passed through refiner to get uniform pulp.
9. a)	Kindal	22.0	17.2	1:3.5	170	1.5	4.0	41.4	1.5	17.2	8.0	34.9	78.5	7.7	Well cooked.
b)	Kindal	20.0	25.0	1:3.5	160	2.0	1.0	54.6	nil	36.5	27.8	41.8	75	21.0	Cooked chips were passed thr. refiner to get uniform pulp.
10.	Pacharam	19.0	21.9	1:3.25	170	1.5	2.5	41.8	nil	14.2	6.1	38.9	75	...	Well cooked.
11. a)	Nandi	22.0	17.2	1:3.5	170	1.5	4.0	41.3	0.9	19.8	9.2	35.5	76	9.1	
b)	Nandi	20.0	21.5	1:3.5	160	2.0	1.0	54.2	nil	36.3	22.4	38.5	79.0	16.5	Cooked chips were passed through refiner to get uniform pulp
12.	Jamba	22.0	17.2	1:3.5	170	1.5	4.0	38.2	2.1	22.0	11.8	35.7	77.0	8.3	Well cooked.
13.	Matti	30.0	23.5	1:3	170	1.5	3.0	39.0	nil	21.0	9.8	36.9	71.0	...	
14.	Mixed woods (Matti + Jamba +Kindal, 1+1+1)	20.0	17.2	1:3	170	1.0	4.0	42.3	2.2	18.3	8.4	36.6	78.0	7	Predigested with black liquor at 135°C for 45 minutes.

TABLE IVA
BLEACHING CONDITIONS

Sequence	Consistency	Chemical on pulp basis	O. D. Retention time, hr.	Temp. °C	pH
Chlorination	3.0	70% of total chlorine demand.	1	Ambient.	1.3—1.5
Alkali extraction	5.0	2.5% as NaOH	1	55	
Hypochloride	5.0	30% of total chlorine demand	2-2-5	40	8.5—9.0

rusty tomentos. One of the most common trees in North Kanara District. Scattered throughout India.

10. **Dalbergia Paniculata (Pacharam):** This is a broad leaved species available in large quantity in Andhra Pradesh.

11. **Lagerstromia lanceolata Nandi):** Large tree 30-50 feet height with ash coloured bark peeling off in large strips. It is a heavy wood used as timber. Leaves 1"—2".

12. **Xylia xylocarpa (Jamba):** It is a heavy wood used as timber and widespread on the western Ghats.

13. **Terminalia tomentosa (Matti):** This is an erect growing tree sometimes reaching eighty feet in height, trunk straight, bark rough, deeply cracked. Young parts are more or less clothed with yellowish brown pubescence. Common in the jungles at the foot of the Ghats. Scattered throughout India in the moist region. Used for railway sleepers and timber. The bark is used for tanning.

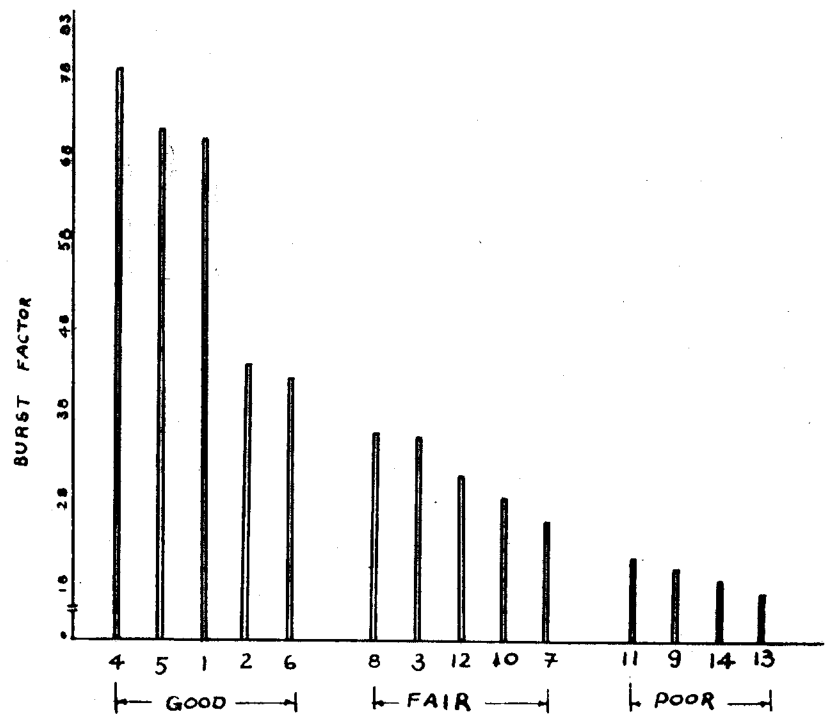

Fig. 5 Burst factor

EXPERIMENTAL

The different varieties of woods used in these experiments were collected from the near about forest area except Pacharam, which was received from Rajahmundry. Eucalyptus hybrid and Paper Mulbery of 5 to 6 years age was from West Coast Paper Mills' Nursery and were having diameter of 4" to 6". Recinus communis was received in the form of stumps of about 2" diameter. The wood billets were debarked and further used for all testings and analysis.

The woods were tested for wood density, chip density, and chemical composition. For density measurements, wood billets of 4"—5" diameter and about 1 ft. length with flat cut surfacer were used. A portion was sliced and cut into chips for moisture determination. For all our density determination, billets with 10 — 12 per cent moisture were used and the densities were expressed as oven dry weight per unit volume of the airdry billets with this moisture. Volume measurements were made by water displacement method. Chips densities were found by determining the weights in air of chips occupying 10 litres volume in a suitable container. The densities are given in **Table II.**

The bleached pulps were evaluated for fibre dimensions by determining the number average of 200 fibres, and these are shown in table No. II. In all the histogram and graphs shown in this paper, the figures pertain to the wood number in Table II.

TABLE V
Strength Properties of Pulps

Wood No	Type of wood	Active alkali as such	Bulk c.c./gm. 35°SR	Bulk c.c./gm. 45°SR	Breaking length mtres. 35°SR	Breaking length mtres. 45°SR	Stretch, % 35°SR	Stretch, % 45°SR	Burst factor 35°SR	Burst factor 45°SR	Tear factor 35°SR	Tear factor 45°SR	Schopper Double Folds 35°SR	Schopper Double Folds 45°SR
1.	Paper Mulbery	20	—	1.19	—	9680	—	5.7	—	71.9	—	29.2	—	125
2.	Erandi	22	—	1.17	—	5790	—	3.6	—	45.5	—	62.8	—	53
3.	Dowga bamboo	20	1.51	1.45	5890	5940	4.0	3.6	37.9	37.3	53.0	61.0	6	6
4	Bhendi	20	—	1.22	—	8700	—	4.9	—	80.2	—	77.2	—	536
5	a) Nilgiri	22	1.41	1.32	10280	11130	5.8	6.0	50.8	56.5	72.1	66.7	74	10
	b) Nilgiri	20	1.26	1.22	7500	8350	—	5.7	—	71.9	—	29.2	—	25
6.	Khoken	22	—	1.26	—	6370	—	1.0	—	43.8	—	67.0	—	6
7.	Maharukh	22	—	1.65	—	46.30	—	2.1	—	27.0	—	99.1	—	20
8.	Heddi	22	1.43	1.36	4990	5580	3.7	1.2	35.1	37.5	70.5	65.0	36	42
9.	Kindal	22	1.47	1.33	4210	4160	3.0	3.5	22.1	21.3	70.5	54.7	4	3
10.	Pacharam	19	—	1.92	—	3790	4.5	—	29.9	—	—	54.0	—	18
11.	Nandi	22	1.43	1.42	4060	4080	3.5	3.7	22.3	22.8	44.0	42.9	5	4
12.	Jamba	22	—	1.41	5130	—	3.4	—	32.6	—	—	59.6	—	10
13.	Matti	20	—	—	—	4300	—	1.5	—	18.5	—	40.6	—	3
14.	Mixed woods Matti+Jamba+Kindal, 1+1+1)	20	—	—	—	4000	—	—	—	20.1	—	47.0	—	2

For chemical analysis, representative samples of wood chips were splitted to small pieces and disintegrated in a hammer mill. The powder was sieved and the fraction between 60 and 80 mesh was used for the proximate chemical analysis. All chemical analysis were conducted according to TAPPI Standard Methods. The chemical analysis of the woods are given in **Table III.**

The woods were chipped in the factory chipper and chips of 2—3 cms in length were sorted out for use in all the experiments. The chips were air dried to a moisture content of about 14 — 18 per cent before digestion. Chips corresponding to 1 kg. o.d. weight were used in each experiment. Digestions were conducted by the sulphate process using white liquor from the Soda Recovery plant and weak black liquor as the make up liquor. Material to liquor ratio of 1:2.5 to 1:3.5 were employed. Digestions were conducted in a 15 litre capacity laboratory autoclave which was electrically heated. The charge was brought to the cooking temperature during 1.5 to 2 hours. The digester was being relieved intermittently during this period to remove air. Digestions at maximum temperature were conducted for 1 to 4 hours after which, the pressure was brought down by relieving steam. The contents were quantitatively transferred to a diffused type washer with agitator and a 40 mesh screen. After dilution with fresh water and mixing, the black liquor was drained. The process of dilution and washing was repeated until the drain liquor was nearly colourless. The pulp was then transferred to a hydroextractor (centrifuge) and further washed free of all alkali. The mats formed were shredded into granules and separated from the uncooked pieces (rejects).

For determining unbleached pulp yield, duplicate samples were kept in the oven maintained at 105 + or minus 2°C for moisture determination till constant

TABLE NO. VI
PULPING OF HARDWOODS WITH BAMBOO

S. No.	Type of wood	Active alkali %	Sulphidity %	Both Ratio	Cooking Temp. C°	Cooking Time hrs.	Unbld pulp yield %	Rejects %	$KMnO_4$ No.	Bleach consumption %	Bld. pulp yield %	Brightness %	Viscosity cp.	Remarks.
1.	Bamboo + (Nandi + Kindal + Heddi) 90% + 10%	20.0	21.5	1:3.5	160	1+2+1	47.2	5.5	22.3	10.7	40.3	76.5	41.0	Predigestion conditions 11.4% A. A. temp. 105°C for 1 hr.
2.	Bamboo + (Nandi + Kindal) 90% + 10%	20.0	21.5	1:3.5	160	2+2+1	46.0	6.8	22.1	11.6	38.0	74.0	18.0	
3.	Bamboo + Kindal 90% + 10%	20.0	21.5	1:3.5	160	2+1	47.0	5.9	20.4	9.8	41.0	74.0	99.0	
4.	Bamboo + Heddi 90% + 10%	20.0	25.0	1:3.5	160	2+2+1	45.7	6.5	32.8	10.2	40.2	78.0	—	Predigestion of Heddi, A. A. 11.4%, temp. 105°C for 2 hrs.
5.	Bamboo + Heddi 90% + 10%	20.0	25.0	1:3.5	160	2+1	45.0	6.8	21.9	10.0	38.9	79.0	30.5	No predigestion.
6.	Bamboo + Heddi + Eucalyptus 80% + 10% + 10%	20.0	25.0	1:3.5	160	2+1	41.9	10.4	22.5	11.6	36.9	78.5	43.0	Moderately cooked containing many rejects.
7.	Bamboo + Paper mulbery 80% + 20%	20.0	21.8	1:3.5	160	2+2	48.8	1.6	17.2	8.3	44.4	78.0	18.0	Well cooked.

weight. The pulps were tested for TAPPI 40 ml permanganate number. When the chips were hard cooked, the whole pulps with the uncooked knots were refined in a Sprout-Waldron Disc Refiner and again washed in the centrifuge. The digestion condition and the results are given in Table IV for cooks of individual wood and in table No. VI for blends.

The pulps were then bleached by the conventional chlorination-extraction- hypochlorite sequence. For pulps which could not be bleached easily, two hypochlorite stages with intermediate washing were used. The bleaching conditions followed in all these experiments are shown in Table No. IVA. The bleached pulps were then tested for yield, brightness and viscosity. The results are given in Table Table No. IV.

The bleached pulps were then beaten in a TAPPI Standard Valley Beater to about 35 and 45° SR freeness and standard sheets were prepared on a British Standard Sheet Making machine. The sheets were air dried, conditioned and tested for strength properties. The strength properties of individual pulps are given in Table V.

Another series of experiments were conducted to observe the effect of digestion of bamboo mixed with woods. Two sets of experiments were conducted (1) Straight digestion with 10-20% wood chips precooked with part of white liquor for 1-2 hours at 100°C, digestion being further continued as earlier. For comparing the behaviour of the woods towards cooking bleaching and beating, experiments were conducted with 100% bamboo chips in a similar manner. The strength properties of the blends are given in Table VII.

The bleached pulps were evaluated for fibre dimensions by determining the average number of 200 fibres.

TABLE NO. VII
STRENGTH PROPERTIES OF STANDARD SHEETS
(Bamboo + hardwoods) Basis wt. gpm² = 57 — 61.

S. No.	Raw Material	Active alkali %	Bulk c.c./gm.		Breaking length Meters		Stretch %		Burst factor		Tear factor		Folding Edurance		
			35°C	45°C	35°SR	45°SR	35°SR	45°SR	35°SR	45°SR	35°SR	45°SR	35°SR	45°SR	
1.	Bamboo + (N + K + H) (90 + 10) %	20	1.47	1.41	5300	6040	4.2	5.0	40.4	43.5	86.2	74.5	57	61	
2.	Bamboo + (N + K) (90 + 10) %	20	1.61	—	5970	—	3.5	—	34.2	—	56.6	—	4	—	
3.	Bamboo + Kindal (90 + 10) %	20	1.61	1.53	4870	5590	3.9	4.1	34.8	30.4	61.2	58.8	17	14	
4.	Bamboo + Heddi (a) (90 + 10) %	20	—	1.55	—	5440	—	4.4	—	40.6	—	76.6	—	52	Predigested cook
5.	Bamboo + Heddi (90 + 10) % (b)	20	—	1.49	—	5740	—	4.3	—	40.2	—	65.7	—	53	
6.	Bamboo + Heddi + Eucalyptus (80 + 10 + 10) %	20	—	1.5	—	5970	—	3.1	—	38.2	—	67.9	—	9	
7.	Bamboo + Paper mulbery (80 + 20) %	20	—	1.52	—	5650	—	4.0	—	33.6	—	49.3	—	5	

DISCUSSION

The selection of a wood for pulping depends mainly on two factors economical and technical. For the former the wood should be available in plenty and should be easily accessible for exploitation. Indian hard wood forests are generally mixed ones and in a particular region to get a particular variety of wood for pulping purposes becomes impracticable.

The Paper Maker for many years to come will have to depend upon these mixed wood forests till new forests are generated growing special type of wood suitable for pulping. With the existing conditions the Pulp Industrialists will have to manipulate utilisation of these woods to suit his system of manufacture. The wood to be economical for pulping in addition to the availability should have the following characteristics: (i) low chemical, and steam consumption during digestion, (ii) high pulp yield. The technological considerations are that the wood should be easily chippable and digestable, (iii) chemical composition of the wood to give stronger pulp easily bleachable, (iv) fibre dimensions and other characteristics to make strong paper on the paper machine without breakage.

The behaviour of the woods in the digestion along with other factors depends upon the physical nature like the compactness or density. The denser chips offer more resistance to the penetration of cooking liquor and such chips require severe conditions like higher concentration of chemicals, higher temperature and longer cooking time. The denser chips, however, occupy lesser volume and increase the capacity of the digester.

The woods discussed in the paper fall in the groups (i) dense woods, (ii) medium dense and (iii) light woods. In the first group fall Terminalia Tomentosa (matti), Xylia xyclocarpa (jamba), Lagerstromia lanceolata (nandi), and Terminalia peniculata (kindal). They have high wood densities from 0.58 to 0.76, low cellulose content, 55 — 61%, high lignin 26 — 32% and extractives 2 — 10%. These factors make the wood difficult to be pulped digested. They take high chemical consumption, higher cooking temperature and time and give low pulp yields, in the range of 38 to 41% which further reduce to 35 to 37% after bleaching. The drastic treatment in the digestion to get processable pulps have degraded the same, and this is evidenced from the low viscosities and strength properties of the pulps (vide table Nos. IV, V and VI figures 1 - 5).

These pulps when compared with pulps of other woods cooked to the same degree i.e. K. Nos. 19 — 22 due to the low yield and drastic digestion condition required make these woods unsuitable for pulping on technological and economic grounds. When cooked at milder conditions, lower chemicals, temperature and time, these woods have given hard pulps with K. Nos. as high as 36, bleach consumption 22 — 27 per cent chlorine and low bleached yields of 38 — 42 per cent.

When individually these woods are difficult to be digested for chemical pulps blending with bamboo chips which cooks at milder conditions makes it untenable as pulps become heterogenous with large amount of shives and rejects (vide table No. VIII). In some of the digestion mixed with bamboo these woods were predigested (soaked in alkali for 1 hour at 105°C) to help penetration of the cooking liquor. But this did not produce any beneficial results. Digestion of the mixed woods also has given similar results of low pulp yield and strength properties (vide Table Nos. V and VI).

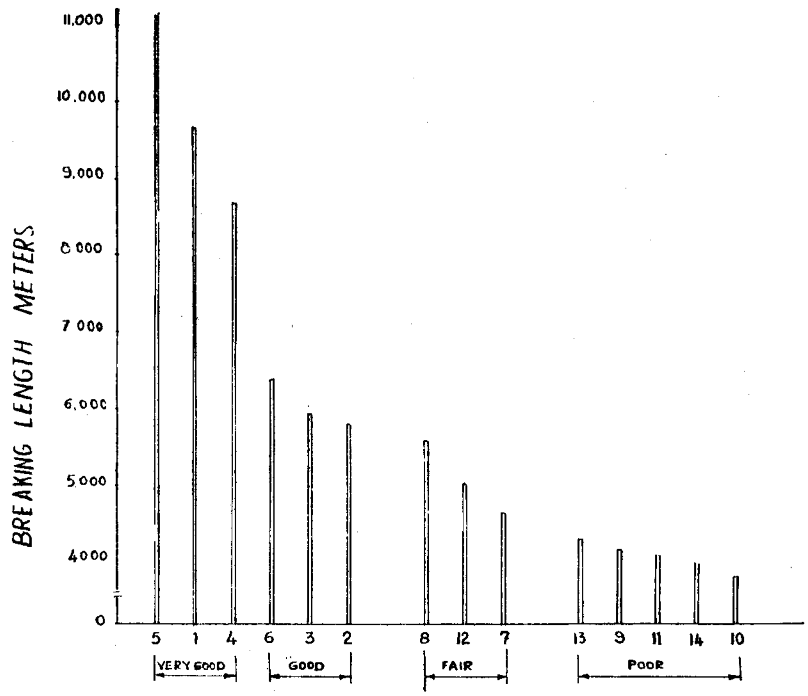

Fig. 6 Breaking length

(ii) **Medium dense woods:** These are Dalberigia paniculata (pacharam), Adina cardifolia (Heddi), Eucalyptus Hybrid (Nilgiri) and Kydia calycina (Behndi). These have wood densities from 0.46 to 0.58 g/ccs and chip densities 220 to 240 kg/m3, holocellulose content higher than the 1st group i.e. 63 - 71 per cent. These are comparatively easier to pulp. (vide table No. V). Nilgiri and Bhendi have given pulp yields in the range of 47-52 per cent which are quite high. The pulps produced in the case of bhendi and Nilgiri woods have high strength properties (vide table No. VI) comparable with soft wood pulps except tearing resistence, which is low due to the short fibre length. Heddi and pacharam give low yields. The strength properties of heddi and pacharam give low yields. The strength properties of heddi pulps are moderate whereas that of pacharam low. In mixed digestion with bamboo, Nilgiri and Heddi have produced heterogenous pulps with high rejects in the range of 6 - 10 per cent. All these wood pulps are easily bleachable and hence if the chips are digested separately, the pulp can be blended with bamboo pulp, bleached and further processed together and this will impart higher strength properties to the paper. In this way we can take advantage of the long fibre length of the bamboo pulp and good bond strength obtainable from Bhendi and eucalyptus pulps.

(iii) **Light woods:** Brossonatia Papyrifera (Paper mulbery) Ailanthus excelsa (Maharukh). Doubanga Sonneriotiodes (Khoken) Bambusa arundinacea (dowga bamboo) and recinus communis (Erandi) possess light densities in the range of 0.33 to 0.43 g/cc, chip densities of 130 to 230 kg/m3. Except ailanthus excelsa the remaining species could be digested to yield good chemical pulps at mild cooking conditions. With low temperature and cooking time Erandi and paper mulbery have yielded soft pulps with 11 and 16 K. Nos. and high yields of 48.1 to 51.5 per cent respectively. These pulps are easily bleachable and possess good strength properties. An earlier work on paper mulbery at the Forest Research Institute, Dehra Dun, is in line with our findings (II). Out of the remaining species dowga bamboo possess the best pulping properties. Khoken and Maharukh require still severe cooking conditions. In the case of Maharukh the pulp yield is low i.e. 41.2 per cent and also the strength properties compared with bamboo, whereas Khoken pulp possess higher strength. Paper mulbery is found to blend well with bamboo when the chips are cooked together.

In mixed digestions of wood and bamboo, it was found that the pulps were containing more rejects (uncooked knots and shives) as compared with bamboo pulps with the exception of paper mulbery. There was not much difference in the pulp quality when cooking was done with or without predigestion of the wood chips. The permanganate numbers of the mixed pulps were higher and the bleach consumption correspondingly high. Increasing the wood percentage in the digestion also increased the rejects in the pulp. The strength properties of the mixed pulps were found higher than that of pure bamboo pulps.

All the digestions in our experiments were conducted with 19 to 22 per cent active alkali on wood except in the case of Matti. This was done with a view to keep the inorganic load on the Chemical Recovery Plant under limits. We have obtained pulps of varying yields and permanganate numbers. Under similar conditions of cooking, hardwood pulps had higher Permanganate numbers compared with bamboo except paper mulbery and recinus communis. The hardwoods which could be easily digested with low alkali, temperature and time schedule have yielded pulps of higher strength. The hard wood fibres are shorter having average length varying from 0.83 to 1.23 mms. as compared with 2.2 mms of bamboo. The fibre diameters are too much varying. Some of the hardwood pulps, in spite of short fibre length, have exhibited very good strength properties. This can be attributed to the characteristic morphology of the fibre which contribute towards good bond strehgth development. It was found that hard wood fibres were taking longer beating time to attain a particular level of wetness. This has happened even when they appeared as mixtures with the bamboo pulp.

CONCLUSIONS :

Selection of some of the hardwoods for pulping purposes will be inevitable either on the grounds of scarcity of raw material or for getting special properties in the paper. The woods studied are the popular hard woods available in the South Indian region and our study was diverted towards the utilisation of these woods either individually or in mixtures with the woods and bamboo.

Out of the woods tried well cooked pulps with Permanganate numbers 18 - 22 and in good yields are obtained from Nilgiri, Bhendi. Kohken and bomboo. The pulps are also easily bleachable. Nilgiri pulps posses the highest strength and has very good potential as a pulp wood due to its availability, fast growing character as well as its versatility to grow in varying climates and regions. However, like all other hard woods its fibre length is low i.e. about 0.9 mm and this would mean that on fast moving machines some long fibred pulps will have to be blended.

Paper Mulbery and Erandi also have given high pulp yields even at lower K. Nos. and even at mild cooking conditions soft pulps are obtained. The pulps are easy bleachable and possess good strength. But the availability of the wood is limited. Paper Mulbery can be cooked together with bamboo without difficulty.

Out of the other woods, Maharukh, Nandi, Pacharam and Kindal offer moderate pulp yields, i.e. about 41 per cent; Nandi, Maharukh and Kindal require severe cooking conditions, whereas Pacharam can be cooked with still milder conditons. The pulps are well bleachable and possess moderate strength.

The wood densities and the chemical analysis, holocellulose, lignin and extractive contents gives an indication of the amanability of the woods for pulping. Heddi, Matti and Jamba are literally hard woods, require very severe cooking conditions and offer low yields. Strength properties of heddi pulps are moderate whereas that of Jamba and Matti are poor. Pulping of these woods will be uneconomical.

Digestion of mixed hard woods gives results comparable with those of individual woods. Except paper mulbery other woods are not compatible with bamboo in digestion since bamboo requires milder conditons and the woods with such conditions give high rejects in the pulp. If severe cooking conditions are adopted to avoid this difficulty the bamboo pulps would get degraded. Manmohan Singh, et al (12) have obtained similar findings in mixed cooking of bamboo with hardwoods of Bengal, for which high temperature and time were required to get suitable pulps.

Some of the hardwood pulps have higher strength properties compared with bamboo pulp. Hence blending these pulps with bamboo wil be beneficial to attain higher strength in the paper. Though difficulties may be experienced in running 100 per cent wood fibres on the paper machine, due to their short fibre length, the wood pulps have certain advantages as these contribute some favourable functional properties to the paper, such as good formation, printability, bulk, opacity, softness, smooth surface etc. which are essential for printing. Hence all efforts should be made to utilise the suitable woods in the pulp and paper industry and meet the shortage of the fibrous raw materials.

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IPPTA in Action Abroad

Mr. Majeed Mohiuddin with General Yakubu Gowan, head of state and commander-in-chief of federal republic of Nigeria (W. Africa) explaining the importance of Nigerian woods for pulp making.

Bombay-1.