A Study on the Utilisation of Mixed Hardwoods in Admixture with Bamboo for Pulp Production-Its Advantages and Disadvantages

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The requiremnt of hardwoods by Pulp and Paper Industry would be steadily increasing in the years to come. The technology of hardwood pulping will, therefore, have to be developed in such a manner as to utilise whatever quality of hardwoods are available. Bengal Paper Mill is using since long large number of hardwood species without classification, in admixture with bamboo.

In this paper, laboratory studies along with results of 30–35% hardwoods mill pulp are described. These investigations show that miscellaneous timbers like end cuts from Match Industry or logs from Plywood Industry, can be used for pulp production. Also, the studies show that mixed hardwoods up to 60-80% can be used to produce kraft pulp in about50% yield with 12% active alkali charge for making fluting medium of reasonable physical strength properties. From the large scale use, it is established on firm footing that hardwood species, or mixture of hardwood species in admixture with bamboo, can be used for quality pulp production. Results have shown that quality of bamboo pulp–particularly in respect of strength properties, is not noticeably affected upto 30–35% mixed hardwoods.

This fact is further substantiated from the fiber fractionation data obtained with mill pulps, which have shown that bleached pulp possesses almost similar fiber length distribution with 30–35% hardwoods.

The factors, which have been found to affect mixed hardwoods pulping, appear to be :

1) wide density variations in wood species,
2) loss of inherent moisture content of wood, and
3) susceptibility of some species towards fungus/borer attack.

Introduction

The technology of hardwoods pulping is now established on firm footing. During the past ten years many Pulp and Paper Mills in India have supplemented shortage in supplies of conventional raw material by using commonly available hardwoods in admixture with bamboo. While hardwoods utilisation has come up in a big way, many mills are still sceptical both about the choice and its use. There is another group which although perfers to use but only those species which are best adaptable to their processing system, and tries to avoid processing mixture of different hardwood species. Technically it is very much true that hardwoods of widely varying physical characteristics should not, as far as possible, be blended but with a disheartening picture like ours, the situation demands that whatever is available should be utilized to fullest extent. The technology has therefore, to be developed in such a manner as to use all species together without discrimination. Our requirement of cellulosic raw material is steadily increasing. as the following figures show, it has to be met from the indigeneous cellulosic materials.

The position of industrial requirement of wood predicted by estimates of Planning commission indicates a great rise from 14 million M³ in 1970 to 50 million M³ in 1985. The requirement of pulp wood alone will be around 10 million M³ in 1985.

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Total Raw material requirement for Pulp and Paper Industry 1975–1980

Year	Raw material requirement in '000 tonnes					
	Bamboo	Hardwoods	Grass	Agricultural waste	Rags	waste Paper
1975	1770	1740	300	75	125	200
1980	1980	4460	350	150	200	350

Bamboo air dry and hardwoods 50% moisture content

As early as 1961 Bengal Paper Mill switched on to the commercial utilization of hardwoods in admixture with bamboo for the production of paper grade pulp. Since then blended mixture of different hardwood species and bamboo is in regular use. In the beginning we were careful to sort out different species and then mix them in cetrain proportions but later on tests revealed that this separation was unnecessary.

The fibrous raw material consumption at Bengal Paper Mill during the past three consecutive years is given below :

The results in each individual category are given and discussed in the following sections. It is however, important to mention here that in each category the pressure or temperature raisisng time includes about 90-120 minutes of impregnation at 125-130°C. As is known besides other parameters successful Pulping of hardwoods depends on degree of imprengnation which determines distribution of chemicals within the chip structure. Since hardwoods have such high density and small void volume in the chips, necessary amount of alkali to inner zones can only be provided by such a treatment.

Consumption of fibrous raw material at Bengal Paper Mill

S. No.	fibrous Raw material	Consumption tonnes 1970	1971	1972
1	Hardwoods	27,070	29,100	26,100
2	Bamboo	68,515	61,240	64,410
3	Bamboo to hardwoods	71.7:28.3	67.8:32.2	71.2:28.8

Laboratory Investigations With Some Hardwoods, Mixture of Hardwoods, And Hardwoods In Admixture with Bamboo.

Polas (B. monosperma)

The wood is light (low density) and is highly susceptible to fungus attack The wood chips stored for just 24 hours in laboratory got infected by fungus.

The results recorded in Table I reveal that the wood is difficultly pulpable under the conditions mentioned therein. Although the unbleached pulp yield is acceptable, the presence of shives particularly difficultly bleachable ones, render the pulp non-uniform. It is probably due to shives that the permanganate number is also on the higher side.

The unbleached pulp obtained under the conditions cited in Table I. was beaten to 48°SR and physical strength properties of standard sheets made therefrom were determined. Results are recorded in Table III. The data show that the pulp possesses poor strength.

Bleaching with C. E. H.H. sequence produced a pulp which was not only dull in shade but also full of shives. Since processing of such kind of pulp is likely to result in erroneous conclusions no strength evaluation was done. From the observations in hand the wood does not appear very promising for commercial exploitation.

Keowra (Sonneratia apetala)

It is moderate sized evergreen tree of order litheracese. The wood is moderately hard. Its sapwood is gray and heartwood is reddish brown in colour. The wood has numerous medulary rays which are bent round the pores. It is found mostly in tidal creeks and littoral forests of Bengal.

TABLE–I
Pulping Characteristics of Some Hardwoods

S. No.	Local name & Botanical name	Active alkali %	Sulphidity %	Chips to liquor ratio	Conc. of cooking liquor gpl.	Time* to maximum temperature min.	Maximum temperature °C	Time at maximum temperature min.	Relieving time min.	Total yield min.	Screened yield %	Permanganate number	Remarks
1	Palas (Butea monosperma)	18.0	20.0	1:3.5	51.00	210	165	120	20	50 0	50.0	24.0	Pulp was not uniform contained shives.
2	Keowra (Sonneratia apetala	24.0	14.0	1:3.5	68.57	150	166	60	20	—	—	—	Merely softened chips. No. pulp
3	Baen (Avicennia officinalis)	22.0	15.5	1:3.5	62.85	150	166	60	20	42.5	42.2	23.0	Screened pulp was uniform.
4	Baen and Bamboo (40% Baen 60% Bamboo)	22.0	15.5	1;3.5	62.85	150	166	60	20	48.5	48.0	24.0	Screened pulp was uniform.
5	Parpat (Acer/Sp.) (70% Bamboo 30% Parpat)	22.0	16.5	1:3.5	62 85	150	166	60	30	42.5	42.0	12.0	Screened pulp was uniform
6	Casurina (Casurina equisetifolia)	22.0	15.0	1:3.5	62.85	130	165	90	20	50.6	50. 4	19.2	Mechanical defibration was essential to obtain homogeneous pulp.
7	Hardwoods waste from WIMCO	20,0	20.0	1 3.5	57.14	180	165	120	30	53.0	48.0	20.3	Quite uniform pulp was obtained on screening
8	Plywood waste	21.0	22.0	1:3.5	60.00	150	165	100	20	52.9	48.3	23.9	Screened pulp was uniform.
9	**80% mixed Hardwoods 20% Bamboo	16.1	20.4	1:3.5	46.00	150	165	90	25	63.5	51.0	31.2	Pulp was not uniform.
10**	60% mixed Hardwoods40% bamboo	16.1	20.4	1:3.5	46 00	150	165	90	20	60.7	48.9	29.0	Pulp was not uniform.
11	60% Hardwoods+30% Bamboo+10% cryptomaria	22.0	16.1	1:3.5	62.85	75 (without impregnation)	170	240	20	49.0	44.0	14,0	Rejects were mostly due to uncooked bamboo knots. Pulp uniform.
12	Mill Pulp 70% Bamboo 30% mixed Hardwoods	19.5	17.2	1:3.5	55.71	150	166	90	—	45 0	42.5	16.0	Pulp was uniform

*Includes 90-120 minutes impregnation at 120°-130°C

**Experiments with these furnishes were carried out for high yield kraft pulp.

TABLE–II
BLEACHING DATA

S. No.	Local name & Botanical names	Chlorination: Chlorine charged %	Chlorination: Time at Temp. min °C	Chlorination: Chlorine consumed %	Alkaline Extraction: Alkaline Charged %	Alkaline Extraction: Time at Temp. min. °C	Alkaline Extraction: Alkali consumed %	Hypochlorite I: Chemical charged as Cl %	Hypochlorite I: Time at Temp. min °C	Hypochlorite I: Chemical consumed %	Hypochlorite II: Chemical charged as Cl%	Hypochlorite II: Time at Temp. min. °C	Hypochlorite II: Chemical consumed %	Remarks
1	Palas (Butea monosperma)	7.0	45 min. at 28°C	6.3	2.0	60 min. at 60°C	2.0	2.5	120 min. at 35°C	2.5	2.5	180 min. at 35°C	2.5	Pulp was shivy.
2	Baen 40% (A. officinalis) and Bamboo 60%	6.0	30 min. at 30°C	6.0	2.0	45 min. at 70°C	2.0	4.0	120 min. at 35°C	4.0	2.0	180 min. at 35°C	2.0	Pulp was uniform.
3	Parpat (Acer Sp.)	4.32	30 mni. at 35°C	4.3	2.0	45 min. at 70°C	2.0	2.26	150 min. at 35°C	1.89	0.62	180 min. at 35°C	0.3	Pulp was uniform.
4	Casurina (Casurina equisetifolia)	6.6	3o min. at 35°C	6.5	2.0	45 min. at 68°C	1.2	3.3	150 min. at 35°C	3.12	1.0	180 min. at 35°C	0.6	Pulp was uniform.
5	Hardwoods waste form WIMCO	7.0	45 min. at 28°C	7.0	2.0	60 min. at 55°C	2.0	2.5	120 min. at room temperature	2.5	2.5	180 min. at 35°C	2.0	Pulp was uniform.
6	Plywood waste	—	—	—	—	—	—	—	—	—	12.0	300 min. at 35°C	11.5	Pulp was uniform.
7	Mill pulp (70% Bamboo+30% mixed hardwoosd)	7.0	30 min. at 35°C	6.5	2.0	45 min. at 65°C	2.0	5.0	90 min. at 42°C	4.4	1.5	150 min. at 40°C	1.4	Pulp was uniform.
8	Mill pulp (70% bamboo and 30% mixed hardwoods) bleached in Laboratory	6.6	30 min. at 35°C	6.4	2.7	45 min. at 70°C	2.7	4.5	150 min. at 35°C	4.4	1.9	180 min. at 35°C	1.4	Pulp was uniform

Note: Pulp consistency during Chlorination 2.5–3.0%
Alkaline extraction 8–10 %
Hypochlorite I 8–10 %
Hypochlorite II 8–10 %

The debarked logs were chipped in commercial chipper. The chips were air dried and thereafter cooked by sulphate process. Cooking conditions and other relevant data is recorded in Table. I

Results indicate that even 24 percent charge of chemical which is very much on the higher side, is not sufficient to cook the chips. Merely surface softened chips were obtained on digestion which could not be defiberised even on vigorous agitation. It shows that the wood will not be suitable for making pulp even under severe conditions of digestion. Hence it was aot commercially exploited by us.

Baen *(Avicennia officinalis)*

It is shrub or small tree of order *Verbenaceae*. It has thin grayish brown bark. Wood is brown, hard in alternate layer of pore-bearing tissue and loose large-celled tissue without pores. The wood is brittle and is used generally as fire wood.

Baen wood chips were cooked independently as well as in admixture with bamboo (Baen : Bamboo 40:60). Conditions of cooking are recorded in Table I. The unbleached pulps obtained were beaten to 45° SR. Standard sheets of 100 percent Baen could not be made due to poor sheet strength. However standard sheets of Baen-Bamboo pulp were made and were tested for physical strength properties (Table III).

Baen-Bamboo unbleached pulp was bleached with C.E.H.H. sequence. Conditions of bleaching and other details are recorded in Table II. Bleached pulp so obtained was quite uniform and had acceptable brightness. Bleached pulp was beaten to 40° SR and standard sheets were

Table-III

Strength Properties of Unbleached Pulp

S. No.	Local names Botanical name	°SR	Burst factor	Breaking length m.	Tear factor	Folding endurance Double folds
1	Palas (Butea monosperma)	48	27.0	4250	69	12
2	Baen 40% + Bamboo 60% (A. Officinalis)	45	41.0	6200	143	235
3	Parpat (Acer Sp.)	40	36.0	4552	78	80
4	Casurina (Casurina equisetifolia)	42	42.0	7280	80	116
5	Hardwood waste from WIMCO	45	50.0	6980	43	61
6	Plywood waste	40	51.0	7060	44	797
7	80% mixed hardwood 20% bamboo	45	27.0	4580	83	15
8	60% mixed hardwood 40% Bamboo	45	33.0	5100	91	29
9	60% Hardwoods + 30% Bamboo+ 10% cryptomaria	44	38.0	6000	75	317
10	Mill Pulp 70% Bamboo + 30% Hardwoods	45	44.0	6450	137	35

Table-IV

Strength Properties of Bleached Pulp

S. No.	Local name & Botanical name	°SR	Burst factor	Breaking length m.	Tear factor	Folding endurance Double fold
1	Baen 40% + Bamboo 60% (A. Officinalis)	40	24.0	5160	129	128
2	Parpat (Acer Sp.)	40	27.5	4590	35	78
3	Casurina (Casurina equisetifolia)	45	38.5	5630	34	244
4	Hardwood waste from WIMCO	45	46.0	6440	33	16
5	Plywood waste	38	43.0	6120	33	322
6	Mill Pulp 70% Bamboo + 30% Hardwood	45	38.0	6100	100	10
7	Mill Pulp-bleached in laboratory 70% Bamboo +30% Hardwoods	48	36	6610	140	—

made. Physical strength properties of the standard sheets were determined and are recordcd in Table IV. Results recorded in Table I and III indicate that unbleached pulp of satisfactory strength can be made using 40% Baen timber and 60% Bamboo in acceptable yield. The pulp is readily bleachable (Table II) and bleached pulp possesses satisfactory physical strength properties. The preliminary observation indicates that the wood in admixture with bamboo can be commercially exploited for pulp production.

Parpat (*Acersp.*)

It is a moderate sized deciduous tree. The wood is light reddish brown, moderately hard and close grained. It has uniformly distributed small pores.

Debarked logs were chipped manually and the chips were conditioned in open atmosphere. Air dry bamboo chips were mixed with Parpat in ratio of 70 : 30 Bamboo : Parpat. Sulphate digestion was carried out in laboratory tumbling autoclave. The conditions of cooking, alkali charge etc. is recorded in Table I.

Unbleached pulp obtained under these conditions was uniform. It was bleached with C.E.H.H. sequence. The conditions of bleaching are recorded in Table II. Unbleached and bleached pulps were beaten in Lampen mill to 40° SR. Standard hand sheets were made and were tested for physical strength properties. (Table III and IV).

The results show that Parpat when used with bamboo upto 30 percent, yields unbleached pulp of satisfactory properties (Table I and II). The pulp was found to be readily bleachable and the bleached pulp possessed satisfactory strength properties (Table III and IV).

Casurina (*Casurina equisetifolia*)

It is large evergreen tree, with rough brown bark. The wood is redd'sh brown, very hard with cracks and splits. Its pores are moderate sized and are much subdivided. Medullary rays are very fine, uniform and equidistant. The Casurina though indegeneous only on the eastern coast of the Bay of Bengal has become one of the important coastal trees of India.

Casurina logs were debarked, chipped and kept in open for air drying. The air dry chips were cooked with 22% active alkali at 165°C for 90 minutes (Table I). The unbleached pulp so obtained–which contained softened chips, was mechanically defiberised to obtain uniform pulp.

The unbleached pulp was bleached with C.E.H.H. sequence (Table II). Bleached pulp was quite uniform and possesed acceptable brightness. Both unbleached and bleached pulps were beaten to 42° and 45° SR respectively in Valley beater. Standard sheets were made and physical strength properties were determined. A close scrutiny of results in Table III & IV reveals that the unbleaehed as well as bleached pulps made from Casurina possess good strength properties.

It is a commercially exploitable hardwood species, and is being used at our mill in substantial quantity.

Hardwood waste from WIMCO

A consignment of different species of hardwood in the form of timber ends, rejected as waste by WIMCO, was investigated.

The wood was chipped in Voith chipper. 44% of the chips obtained under normal operating cond'tions were of size bigger than 1½". However, for the experiment chip size ranging between 1" to ½" were used. The conditions chosen for pulping are recorded in Table I. On screening uniform pulp was obtained, The pulp yield was 48 percent at a permanganate number 20.3. The unbleached pulp was bleached with C.E.H.H. sequence. Under the conditions as shown in Table II, it was possible to bleach the pulp without any difficulty to an acceptable degree of brightness with a total bleach consumption of 11.5%. Unbleached and bleached pulps were beaten to 45° SR and important physical strength properties of the standard sheets made thereform were tested. Results are recorded in Table III & IV.

The data recorded in the table I–IV reveal that the hardwood waste from WIMCO can be pulped using 20 percent active alkali charge and other cooking conditions, as recorded in Table I, to a satisfactory yield and physical strength. Bleachability of the pulp was normal and physical strength of bleached pulp was also found satisfactory.

Plywood waste

In plywood industry after the peeling of the vaneers, the residual log is rejected, These waste wood logs were investigated as pulp wood.

Three different wood types chosen from the consignment, were chipped separately and mixed thoroughly thereafter. Chips were air dried and digestion was carried out as per details given in Table I. Under the conditions, high yield (48.3%) of both unbleached and bleached pulps were beaten to 40°SR. The standard hand sheets of approximately 60 gsm. were made and tested for physical strength properties (Table III & IV).

The physical strength properties (Table III & IV) indicate that unbleached as well as bleached pulp possess excellent strength properties. Except for the tear factor. the other strength properties of unbleached pulp are nearly comparable with that of Casurina unbleached pulp. The results indicate that material can be exploited commercially in admixture with other hardwoods for making pulp.

High yield kraft pulp from mixed hardwoods and bamboo

A study was undertaken to find out suitability of a mixture comprising of commonly available hardwood species and bamboo toward its fluting medium making properties and also to find out how much proportion of hardwoods can be tolerated in the furnish without influencing the sheet strength properties.

The consignment of hardwood *chips* used for the study mostly comprised of Salai (*Boswellia serrata,*), Eucalyptus species, and Akashmani (*Acacia auriculiformis*), besides a small proportion of lesser known hardwoods. These woods were chipped together and blended with bamboo in varying proportions. In this report results obtained with two mixtures namely, 80 percent hardwoods plus 20 percent bamboo, and 60 percent hardwoods plus 40 percent bamboo, are recorded in Table I and II.

The results of this study have shown that fluting medium of reasonable strength properties (the strength properties were found to be dependent upon percentage of hardwoods in the mixture) can be produced from the mixture with 12.5% active alkali charge and total time cycle of 4 hours at 165°C.

Kraft Paper from mixed hardwoods, bamboo, aud cryptomaria mixture

Since kraft paper in satisfactory strength particularly tear, could not be made under the conditions studied in the earlier experiments with mixed hardwoods and bamboo, an investigation was undertaken with various mixture of Bamboo, Hardwoods and Cryptomaria–a long fibered soft wood.

Mixed hardwoods, bamboo and chips were collected from the chipper house at random. Crypromaria logs with bark, were received from our North Bengal Organization. Logs were manually debarked and chipped in mill chipper. After air drying the hardwoods, bamboo, and crypto-maria chips were mixed in varying portions and the results obtained with 60:30:10, hardwoods bamboo: eryptomaria mixture are recorded in Table I.

Sulphate digestion was carried out in laboratory tumbling autoclave under conditions cited in Table I. Screened unbleached pulp–which was quite uniform, of 16 permanganate number in the range of 44.0 percent yield was obtained. The 5.0% screening rejects were found to be entirely due to uncooked bamboo knots. The unbleached pulp strength properties at 44° SR are recorded in Table III.

In general, results of these sets of experiments, have shown that by adjusting cooking conditions or mixture composition of the furnish, optimum kraft pulp in good yield and higher (as compared with bamboo and hardwoods mixture) strength properties can be produced. Results of these exhaustive studies will be published in due course.

Mill Pulp (65–70% Bamboo + 35-30% Hardwoods) Bengal Paper Mill has Kamyr continuous digester with heat diffusion washing. The chips from hardwoods and bamboo are stored separately and the composition of chips charged to digester is generally kept around 65–70% Bamboo and 35–30% hardwoods. The charge of active alkali based on chips is 18–21% and the cooking conditions are so regulated as to produce pulp in about 45% yield at 16–18 Permanganate Number. The conditions that are currently being followed in Kamyr; along with strength properties of unbleached and bleached pulps, are shown in Table I, III and IV.

It can be seen from the few exapmples cited in the above sections, that some hardwoods do not respond well to cooking chemicals and therefore cannot be commercially exploited. The sheet strength data show that while some hardwood species produce a pulp that can be fibrillated and hydrated to a dense sheet-which gives high strength properties e. g. Casaurina, some species like Palas only produces more or less a filler type pulp with little hydration and internal bonding.

Mixed Hardwoods and Non-Uniformity of Pulp Obtained Therefrom

It is observed both from large scale-and laboratory pulping studies that a mixture of chips from different hardwood species–which possesses near about similar chemical composition but differ widely in density, generally cannot be cooked uniformly. What could be the reason for this kind of non–uniformity ?

Thus, under any appropriate set of condition, one portion of the mixture comprising of high density wood, remain comparatively uncooked, while the other portions comprising of medium and low density woods of the mixture produce well cooked and overcooked pulps. The net effect is–the final pulp from such a mixture is heterogeneous in character. The reason for this could perhaps be due to the fact that woods of these kinds generally show wide morphological differences. Since vessels fibers, and other cellular tissues in woods of high density are known to be compactly arranged as compared to woods of lower density, such heterogenity can therefore, be reduced by choosing hardwoods which possess near about similar density.

Again, there are examples of denser hardwoods which are readily pulpable in moist state but not so easily in a dry state. It is found that at comparable degree of delignification dried wood requires higher chemical charge, some what severe cooking conditions, and give lower yield of pulp as compared to fresh 'wet' wood with high inherent moisture content. Obviously, the reasons for this are factors like : higher compactness of cellular elements, physical changes brought about by escape of moisture etc. which affect penetration and diffusion of cooking liquor during pulping.

A typical example of this phenomenon could be found in casurina–a high density wood. (Density 0.93 at 10–12% moisture).

	Active alkali charge%	Cooking conditions	Permanganate Number	
Casurina (10-12% moisture)	22.0	90 min. at 165°C	19.2	mild mechanical defiberisation is required.
Casurina(35% moisture)	15.5	nearly identical (as above)	19.0	Pulp easily defiberised.

It is therefore, possible to relate the non–uniformity of pulp to,

1. wood morphology,
2. inherent moisture content of wood, and
3. wood density.

Fiber Fractionation Data

Average fiber length in commonly available hardwood species-generally used at our mill, varies from 0.7 mm to 1.6 mm and each individual species has its own-perhaps widely varying-fiber length distribution. In circumstances like those it was interesting to investigate as to how much variation does the mixture of bamboo and mixed hardwoods, containing hardwoods from 30-35%, brings in the overall fiber length distribution of the pulp. This kind of study became particularly important in a system like ours where the number of hardwoods consumed everyday comprise any where from 10 to 25 species.

As the amount of hardwoods utilized everyday in our process does not remain constant which in fact cannot be kept so due to operational handicaps, the studies were conducted over a considerable period.

In order to gather comprehensive data, unbleached pulp along with pulps from individual stages of CEHH, bleaching sequence, were collected and analysed for fiber length distribution in Clark Pulp Classifier Model M-56. Pulps were classified under the following conditions which were kept constant for all trials.

1. Amount of Pulp - 5 grams thoroughly dispersed and suspended in 2 litres of water
2. Time of classification - 5 minutes
3. Rate of flow of water - 7.5 lit./minute.

The results of these investigations are presented in Table V.

From the fractionation data it will be seen-quite interestingly, that the fiber length distribution pattern in all pulp is almost similar, irrespective of variations in processing conditions or variation in amount of hardwoods

Table—V

Stage Wise Fiber Fractionation Data of Mill Pulp Obtained From Admixture of 70% Bamboo and 30% Hardwoods

S. No.	Pulp	Screen size +14 mesh %	−14 +28 mesh %	−28 +48 mesh %	−48 +100 mesh %	−100 mesh %
1	Unbleached	7.64	37.64	22.08	14.73	17.97
2	Chlorinated	8.98	37.18	19.48	13.07	21.28
3	Alkali Extracted	6.40	37.22	22.11	14.20	20.07
4	Hypochlorite I	5.07	39.19	21.36	13.70	20.66
5	Hypochlorite II	5.29	37.46	21.92	14.00	21.31

Note—The results recorded are the mean average values of fourteen evaluations (on pulps collected on different dates) in each individual category.

percentage in the mixture. Thus, the fiber length distribution frequency of unbleached pulps is found to be similar to that of bleached pulps. Elaborating, the results of individual classification run over a period of days, indicate that variation in mixture composition or pulping and bleaching conditions or both combined do not reflect significantly on fiber length distribution. The finding has been interesting and useful in that it substantiates our contention based so far on experience that processing and operational difficulties would not be encountered and the quality of pulp irrespective of other considerations would remain practically uniform up to 30-35% hardwoods in the mixture.

Strength Development of Mill Pulps On Beating

On the basis of the finding that the unbleached and bleached mill pulps from 65-70% bamboo and 35-30% hardwoods show practically similar fiber length distribution, question of special interest was to determine whether it has any relationship with strength development on beating. The physical properties of these pulps were therefore, tested at 10 minutes intervals of beating in a Valley beater. The results obtained with increasing beating time are presented in table VI. It is seen from the data that breaking length and burst increased over the whole range of beating times studied and also the tear factor showed a marked increase up to 30 minute beating time. The maximum strength development in unbleached pulp occurs at about 30° SR and at about 38° SR in case of bleached pulp, beyond which the values appear to flatten off.

A comparison of unbleached and bleached pulps at the same level of freeness shows that some deterioration of strength properties particularly burst and tear resulted during the bleaching. The breaking length values appear to remain unaffected.

Although these are expected trends, from the data it is possible to show that over a wide range of freeness the strength values remain nearly similar both in unbleached and bleached mill pulps. From the data the range appears to be 30-40° SR. This phenomenon may be due to similarity in fiber length distribution in the two cases.

Effect of Micro-Organism, Borer Etc. On Wood Properties

Wood is susceptible to many types of natural degradation and decay. It is reported in literature that 10–20% pulp wood losses, depending on the quality of wood, occur on 2 to 5 years of storage.

As is well known, wood decay is slow digestion of cell wall material by the enzymes originating from the fungi. The two major actions, brought in by white and brown rot, involved in the cell wall destruction are hydrolysis and oxidation.

Although, it is difficult to correlate the degree of decay in the chemical or physical property of wood, the published work available on the

Table—VI

Strength Properties of Mill Unbleached and Bleached Pulps at Different Freeness Values (65-70% Bamboo + 35-30% Mixed Hardwoods)

S.No.	Unbleached Pulp					Bleached Pulp				
	Beating time min.	Freeness °SR	Burst factor	Breaking length m.	Tear factor	Beating time min.	Freeness °SR	Burst factor	Breaking length m.	Tear factor
1	10	19	18.0	4660	69	10	18	26.0	5120	48
2	20	24	37.1	5860	84	20	25	33.0	6250	62
3	30	31	44.3	6610	108	30	38	35.0	6150	91
4	40	41	45.0	6840	73	40	48	36.0	6610	—
5	47	47	47.0	5740	81	50	60	38.0	6970	66
6	60	52	51.0	6150	74	—	—	—	—	—

subject indicates that use of decayed wood causes lower yield higher chemical consumption, shivy and difficulty bleachable pulp, weak pulp, or produces combined effect of any two or more of these factors. In our system the main problem is appearance of shives in the pulp probably from the decayed wood which due to size, number, and heterogeniety of hardwoods used, is difficult to locate.

Some of the hardwood species (local name), that are being currently used at Bengal Paper Mill, which are susceptible to fungus or borer attack, are listed in Table-7.

Table–7

A. Highly susceptible to fungus/ borer attack	Salai, palas, Dhaura, Bahera, Modey, Kekat etc.
B. Woods-that are affected only on prolonged storage	Harira, Barh, Jaman, Mahua, Kadam, Eucalyptus (with bark), Haldu etc.
C. Woods remaining practically unaffected	Kendu, Arjun, Akashmani, Manjari, Jarul, Teak, Casurina, Karanj, Tuda etc.

Conclusions.

While carefully examining the advantages and disadvantages of utilizing hardwoods in admixture with bamboo for large scale pulp production, it is experienced that advantages out-weigh the disadvantages, Hardwoods have been found good substitute of bamboo provided used judicously and in correct proportion with bamboo. Furthermore, hardwoods-which possess high carbohydrates content, are cheaper and much more readily available than bamboo. Most of the hardwood species, barring few extreme ones containing higher percentage of extractives or possessing higher or lower density etc., could be effortlessly pulped alone or in admixture with bamboo under normal mill operating conditions, or even milder conditions. Again, most of the species can be arbitrarily blended in proportions up to 30-35%, without any operational difficulty in pulping and bleaching, to obtain good sheet properties which in fact bamboo pulp alone is incapable to produce. Needless to point out here that hardwood pulp in the furnish improves texture, opacity, smoothness and physical properties of sheet. However, for obtaining best results care should be exercised in picking only those hardwood species which possess near about similar density. In such cases processing becomes easier and more homogenous product is obtained.

Laboratory scale experiment with miscellaneous hardwoods, industrial wood waste, etc. were carried out.

Some of them were recommended for commercial exploitation.

Quite encouragingly, fiber length distribution studies conducted on mill pulps produced from 30-35% hardwoods and 65-70%bamboo have shown that the fiber length distribution pattern in bleached pulp remains practically constant and is found to be independent of species or quantity variations.

The disadvantages of utilising hardwoods are that some of them e. g. Salai (*Boswellia serrata*), Palas (*B. monosper-na* etc. are highly susceptible to attack of fungus, termite and borer as a result these woods on pulping produce shivy and high permanganate number pulps in lower yields at higher chemical consumption. Such pulps have also been found to produce sheet of lower strength properties. Due to heterogeniety of hardwood stands it is not always possible to choose hardwoods those may be ideally suited for pulping purpose. For economic reasons. besides many other, it is neither feasible nor practicable to do so. In such circumstances adulteration has to be tolerated.

Inherent moisture content of wood, particularly in high density woods, is another improtant factor, the loss of which during transportation or storage makes some hardwoods unsuitaable which otherwise are quite suitable for pulping.

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