A Comparative Evaluation of Eight Species of Tropical Hardwoods For Bleached Kraft Pulps.

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ABSTRACT

The paper presents comparative data on, proximate chemical analysis, Kraft pulping characteristics, bleachability and paper Properties of both unbleached and bleached kraft pulps of the following species of tropical hardwoods: *Anogeissus latifolia, Acacia catechu, Boswellia serrata, Clesitanthus collinus, Diospyros molanoxylan, Pterocarpus marsupium, Terminalia tomentosa and Xylia xylocarpa.*

It has been found that all the species contained high amount of polyphenols (as determined by hot water/methanol extractive contents in wood meal) which are sometime responsible for high Klason lignin values in wood and also influence pulping characteristics/bleachability. The hot water extractive content varied from 8.1% for *A latifolia* to 16.4% for *B serrata;* whereas the methanol extractive content varied from 5.4% for *D melanoxylan* to 14.7% for *B sertata* The data on screened yield and kappa number indicated that the pulping characteristics were highly species dependent. *C, collinus, D. melanoxylan* and *P marsupium* could be pulped to kappa number 28 ± 1 with 15% active alkali as Na_2O; whereas the other five species yielded pulps of kappa number as high as 59. Cooking of *A. catehu, A. latifolia, X. xylocarpa T. tomentosa* and *B. serrata* with 17% active alkali did not reduce the kappa number to an appreciable extent The pulps thus obtained were of kappa number in the range of 40-48. The screened yield of unbleached pulp ranged from 38.3% for *B. serrata* to 48.9% for *P, marsupium.* The bleaching experiments showed that *X. xylocarpa C. collinus* aed *B. serrata* were not found suitable for bleached pulps, keeping the brightness attained and the ultimate bleached pulps yield in view. The data on the other species viz. *A. latifolia D. melanoxylan, P. marsupium, B. serrata* and *A. catechu* indicate that they are suitable for bleached kraft pulp.

A comparasion of data on tensile index, tear index and burst index of unbleached kraft pulps indicated that *A. latifolia* gave best results followed by *X. xylocarpa, B. serrata. T. tomentosa, A. catechu, P. marsupium* and *C. collinus* gave the lowest strength. The properties of bleached kraft pulps showed that all the species are suitable except *C collinus* and *T tomentosa* which was not evaluated. The best results were obtained with *X. xylocarpa.*

INTRODUCTION :

Tropical hardwoods are recognised as a source of raw material for cellulose fibres for paper industry. However, their commercial utilization has not reached the extent which can meet the increasingly growing shortage of fibrous raw materials There are several reasons for this. Our tropical hardwood forests are composed of a mixture of a number of species with diverse properties: a wide variation occurs in colour, density, morphological characteristics, extractives, hemicelluloses and chemical composition of lignin and its reactions in technical processes These inherent differences between and within species result in a highly hetrogeneous mixture for technical processing to obtain cellulose fibres for conversion into paper.

The object of the present exercise was therefore to provide comparative data on basic wood characteristics and their influence on pulping and paper making properties of tropical hardwoods, with a view to assist in their efficient utilization particularly in printing papers. As a part of this series, at the first instance eight species of tropical hardwoods which are commonly used in paper industry these days have been taken for evaluation.

In the recent publications from this laboratory Singh et al.[1,2] have reported about the chemical compostion of lignins and its influence on rate of delignification during kraft pulping of tropical hardwoods.

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It has been observed by them that the rate of delignification is proportional to the ratio of syringyl to guaiciylunits present in lignin and which varied from species to species.

This paper deals with the results of investigations carried out on comparative kraft pulping of eight species of tropical hardwoods obtnined from Ballarpur Industries limited (Paper Division) Table 1. The kraft pulps have been evaluated for their strength properties and bleachability followed by determination on physical properties of bleached kraft pulps.

TABLE—1

NAME OF SPECIES AND THEIR BASIC DENSITY

Sl. No.	Species	Basic Density
1.	Anogeissus latifolia	0.773
2.	Accacia catechu	0.975
3.	Boswellia serrata	0.394
4.	Cleistanthue collinus	0 659
5.	Diospyros melanoxylan	0.659
6.	Pterocarpus marsupium	0.734
7.	Terminalia tomentosa	0.825
8.	Xylia xylocarpa	0.766

EXPERIMENTAL

Basic Density :

The basic density of wood was determined as per IS specification 1708 (1969) by using the following formula :

$$\text{Basic Density} = \frac{\text{Oven dry weight}}{\text{Green Volume}}$$

Proximate Chemical Analysis :

For proximate chemical analysis, wood chips were distntegrated into wood meal of 60-80 mesh. All the analysis reported here were performed according to TAPPI standards. Methanol extractives were determined in similar manner as applied for alcohol–benzene extractives determination.

Kraft Pulping :

Pulping experiments were carried out in a series digester consisting of 2.5 L vessels rotating in an electrically regulated thermostatic polyethylene glycol. Wood chips of the size given in the paranthesis (6–27 mm. length and width 2–3 mm. thick and having a moisture content of about 10%) were used. The following cooking conditions were employed in all cases, excepting active alkali charge which was varied from 15–17% to produce pulps of lower kappa number for their evaluation for bleached grade kraft pulps.

Cooking Conditions

Chip charge	:	400 gm o.d.
Active alkali	:	15–17% as Na_2O
Sulphidity	:	25%
Chip to liquor ratio (including chip moisture)	:	1:3.5
Time to 100°C	:	15 min.
100°C to 170°C	:	105 min.
At 170°C	:	60 min.

Bleaching

The bleaching of pulps was done under identical conditions using CEH and CEHH sequences The chlorine demand of the pulps was determined on small scale experiments as follows :-

Unbleached pulp sample (20 gm o.d.) was treated with chlorine water at different levels of chlorine applications (the percentage of chlorine was varied from 0 22 to 0.30 times of kappa number). The residual chlorine was determined and plotted against the chlorine applied. The point of inflection was taken as chlorine demand of pulps.

Chlorination

After determining the chlorine demand, as described above, large scale chlorination of pulps (200gm o.d.) was carried out under the following conditions.—

Cl_2 (%)	: as per chlorine demand determined by miniscale bleaching (Table 4)
Time	: 60 min
Consistency	: 3 %
Temperature	: ambient

Extraction :

The extraction of the chlorinated pulp was carried out under identical conditions arbitrarily choosen as follows:—

NaOH	:	2%
Consietency	:	8%
Temperature	:	70±1°C
Time	:	120 min

Hypochlorite :

The hypochlorite stage was given to extracted pulps under the following constant conditions

Available Cl_2 in Ca'cium hypochlorite	:	2%
Consistency	:	8%
Temperature	:	40±1°C
Time	:	120
pH	:	10

In certain cases, where the brightness development was not adequate or was below 65, a second hypochlorite treatment using 2% of available chlorine keeping the other conditions constant was given. All the percentages expressed are on oven dry pulp.

Pulp analysis and evaluation :

The unbleached pulps were screened on a flat cut screen having slot of 0 3 mm. The percentage of rejects were determined by weighing after drying the rejects at 105±2°C in an oven for six hours. The yield of screened pulp was determined as usual in duplicate.

Kappa number of screened pulps was determined according to TAPPI standard No. *T 236—m—60* Both unbleached and bleached pulps were beaten in P F I. mill to different degrees of freeness according to ISO standard 5264 by charging 30 gm. o.d. pulp at 30% consistency, 177 N/cm beating pressure and 6.0 mater Sec relative speed. Hand sheets of 60±2 gsm were made on standard British sheet making machine. The sheets were pressed and air dried using standard proce dures. The physical testing of hand sheets for various strength properties were carried out after conditioning the sheets at 65±2% relative humidity and 27±1°C. The tests were performed according to ISO standards.

RESULTS AND DISCUSSION

Basic Density :

Table—1 shows that data on basic density of various species of tropical hardwoods investigated. It will be seen from data that these species represent a wide spectrum of variation in the basic density ranging from 0.394 for *Boswellia serrata* to 0.975 *Acacia catechu.* Based on these data these species can mainly be grouped Into two. The species having basic density sufficiently high (0.75) and the species of medium density, with the exception of *Boswellia serrata* which is a low density hardwood.

Extractives and solubilities :

The determination of solubilities in 1% NaOH, hot water and methanol, in case of tropical hardwoods, bear special importance becuase the tropical hardwoods particularly the domestic ones contain appreciable amounts of polyphenols which exhebit wide variation both pualitatively and quantitatively and are of considerable signifiance from over all assessment of mixed hardwood for parpermaking. Polyphenols are known to provide additional nuclear positions for lignin condensation reaction during qulping thus making the black liquor more viscous and intricate which causes problem during recovery process.

Table—2 gives the data on the solubilities of polyphenolic extractives soluble in 1% NaOH, hot water and methanol. A perusal of these data indicates that there is a wide variation in the hot water and methanol solubles among the various species. The hot water soluble ranges from 5.6% for *Cleistenthus collinus* to 16 4% for *Boswellia serrote.* Similarly the methanol soluble range from 7.55% for *Anogeissus latifolia* to 14.7% for *Boswellia serrata.* It will be further seen that the values for hot water and methanol solubles are comparable with hot water and methanol soulbles are comparable with each other in case of all the species. This indicates that the solubilities in either of these solvents can be regarded as an indicative of proximate quantitative amounts of polyphenols in these species.

1% Caustic soda solubility is of importance in assessing the soundness of wood in respect of its decay and reflects on the amount of polyphenolic contents in wood. It will be seen from the data in table 2. that there existed a large variation in the value which ranged

TABLE—2

EXTRACTIVES AND PROXIMATE CHEMICAL ANALYSIS OF TROPICAL HARDWOODS*

Sl No.	Name of species	1% NaOH %	Hot water %	Methanol %	Klason lignin %	Holocellulose %	Pentosan %
1.	Accacia catechu	25.17	15.62	9.25	36 0	63.8	14.33
2.	Anogeissus latifolia	16.95	8.10	7.56	28.70	73.66	10.76
3.	Boswellia serrata	26.40	16.40	14.70	28.55	66.35	12.27
4.	Cleistanthus collinus	20.16	5.60	10.54	23.40	72.26	14.29
5.	Diospyros melanoxylan	14.25	12.35	5.25	31.0	68.0	11.78
6.	Pterocarpus marsupium	15.90	13.80	12.70	28.07	66.40	11.55
7.	Terminalia tomentosa	23.80	10.70	10.40	29.10	65.11	14.87
8.	Xylia xylocarpa	16 50	9.80	10.90	26.53	67.16	11.39

*%Expressed on Oven Dry Basis

from 14 25 for *Diospyros me'anoxylan* to 26 4% for *Boswellia serrata*. The values of 1% NaOH solubility, in general, were comparable to those usually found for tropical hardwood. All these data on solubilities indicate that the quantity of polyphenolic extractives were minimum in case of *Cleistanthus collinus* and *Diospyros melanoxylan* and highest in the case of *Boswellia serrata* and *Accacia catechu*. The values for other species were around 10%.

Lignin Content :

Klason lignin determination in case of tropical hardwood by usual standard method of sulphuric acid sometimes give abnormally high values becuase of the presence of high amounts of polyphenolic materials which are precipitated during 72% sulphuric acid treatment leading to contamination. Therefore, such values are misleading and one should be very wary in examining the values of Klason lignin particularly in case of tropical hardwoods. Table 2. indicates that in most cases the value is around 28%; *Cleistanthus colinus* have the lowest value of 23 4%, whereas in the case of *Aecacia catechu* and *Diospyros melanoxylan* the value is abnormally high i e. 36% and 31% respectively. This is an example of contamination of lignin with polyphenolic material during the determination procedure using 72% sulphuric acid. In an earlier publication (1,3) it has been reported that pre-extraction of wood meal with 0.5 NaOH yields more meaningful results on klason lignin value in case of Eucalyptus species as well as on tropical hardwoods.

A perusal on data of pentosan and holocellulose contents indicates that the value are in the range what is usually found for hardwoods.

Pulping characteristics :

Table 3 gives an account of the results of kraft pulping of these tropical hardwoods under identical conditions. It will be seen from the data on screened yield and kappa number that the pulping characteristics were highly species dependent. Some of the species viv; *Cleistanthus collinus*, *Diospyros melanoxylan* and *Pterocarpus marsupium* could be pulped to kappa number value 28±1 using 15% active alkali as Na_2O, indicating thereby their suitability for evaluation for bleached grade kraft pulps. There were cases where under these constant conditions of pulping with 15% of active alkali as Na_2O the species yielded pulps of kappa number as high as 59. *Accacia catechu*, *Anogeissus latifolia* and *Xylia xylocarpa* gave such results. *Terminalia tomentosa* and *Boswellia serrata* also resulted in pulps of high kappa number values 48 and 40 respectively.

In case of *Anogeissus latifolia*, *Boswellia serrata*, *Xylia xylocarpa* and *Accacia catechu* the species which did not yield bleached grade kraft pulp (kappa number less than 30) with 15% active alkali charge, cooking

with 17% active alkali also could not reducs the kappa number to a desired level for evaluation for bleached grade kraft pulps. The value ranged from 40 for *Angogeissus latifolia* to 48 for *Accacia catechu*. However, these species were also evaluated for bleached grade kraft pulps using pulps obtained with 17% active alkali for comparision purpose. It will be further seen from data that the unbleached pulp screened yield with 15% active alkali varied from 38.3% for *Boswellia serrata* to 48.9% for *Pterocarpus marsupium*. As regards screened rejects the value for *Anogeissus latifolia* were abnormally high i e. 10.7% while in case of all other species the percentage was within the normal range.

Bleaching :

The bleaching experiments were carried out on the pulps having kappa number less than 28±1 for the species viz; *Gleistanthus collinus*, *Diospyros melanoxylan* and *Pterocarpus marsupium*. In. case of other species pulps obtained with 17% active alkali were taken for evaluation (kappa number ranging from 40 to 48).

Table 4 gives the data on bleached pulp yield and brightness of bleached pulp. At the first instant all the kraft pulps were bleaehed under the identical conditions using CEH sequence. The pulps which could not be

TABLE—3

KRAFT PULPING OF TROPICAL HARDWOOD

Sl. No.	Name of species	Active alkali	% Unscreened Yield		Screened Yield %		Rejects %		Kappa Number	
			15%AA	17%AA	15%AA	17%AA	15%AA	17%AA	15%AA	17%AA
1.	Accacia catechu		41.63	46.90	40.2	40.32	1.43	6.58	59.2	47.9
2.	Anogeissus latifoila		56.78	45.35	46.04	44.76	10.74	0.59	59.3	40.2
3.	Boswellia serrata		41.58	36.67	38.33	35.42	3.25	1.25	39.46	41.2
4.	Cleistanthus collinus		41.16	—	40.05	—	1.11	--	28.8	—
5.	Diospyros melanoxylan		43.11	42.48	42.69	42.08	0.42	0.4	27.2	24.7
6.	Ptero carpus marsupium		49.41	—	48 99	—	0.46	—	29 84	—
7.	Terminalia tomentosa		46.29	—	45.69	—	0.60	—	48.7	—
8.	Xylia xylocarpa		48.22	47.21	46.56	45.96	1.66	1.25	58 2	46.8

TABLE—4

YIELD AND BRIGHTNESS OF BLEACHED KRAFT PULPS

Sl. No.	Name of species	Total chemicals as Na_2O,%	Kappa number	%Chlorine demand	Bleaching Sequence	Bleached Yield %	Bright-ness
1.	Accacia catechu	17	47.9	11.4	CEHH	35.79	73.3
2.	Angoeissus latifolia	17	40.2	9.6	CEH	39.60	78.5
3.	Boswellia serrata	17	41.2	10.7	CEH	27.6	78.1
4.	Cleistanthus collinus	15	28.8	8.0	CEH	34.36	68.5
5.	Diospyros melanoxylan	17	24.7	6.4	CEH	35.43	75.2
6.	Pterocarpus marsupium	15	29.84	9.0	CEH	41.22	72.5
7.	Xylia xylocarpa	17	46.8	11.3	CEHH	41.94	67.5

bleached to the brightness about 70 were given a second stage hypochlorite treatment to improve brightness.

It will be seen from the data on brightness that the pulps from *Cleistanthus collinus* and *Xylia xylocarpa* could only be bleached to a brightness value of 68, whereas for the other species the brightness attained ranged from 73.3 *Accacia catechu* to 78.5 for *Anogeissus latifolia*. The bleached pulp yield ranged from 27.6% for *Boswellia serrate to* 41.9% for *Xylia xylocarpa*. These data indicate that *Boswellia serrata* although can be bleached to a high degree of brightness of 78.1 may not be economic for manufacture of bleached grade from yield point of view. Similarly *Xylia xyocarpa* and *Cleistanthus colltnus* were not found suitable from bleaching point of view. The data on the other species viz; *Anogeissus latifolia, Diospyros melanoxylan, Pterocarpus marsupium, Boswellia serrata* and *Accacia catechu* indicate that they are suitable for bleached grade kraft pulping taking in to consideration the brightness attained and the bleached pulp yield obtained.

Pulp Properties :

Papermaking potential of a pulp is defined as the range and extent of strength properties that are attainable using a given pulp. The results are usually expressed as a function of beating with the introduction of intropolation to certain levels of freeness. Both unbleached and bleached kraft pulps were evaluated at different degrees of freeness and the strength properties were intropolated at 250 ml. C.S.F. for comparative assessment. Fig. 1 to 3 represent the changes in strength properties with freeness for unbleached and Fig. 4 to 6 for bleached kraft pulps, sespectively. Table 5 gives the data on the values of the strength properties at 250 ml. C.S.F.

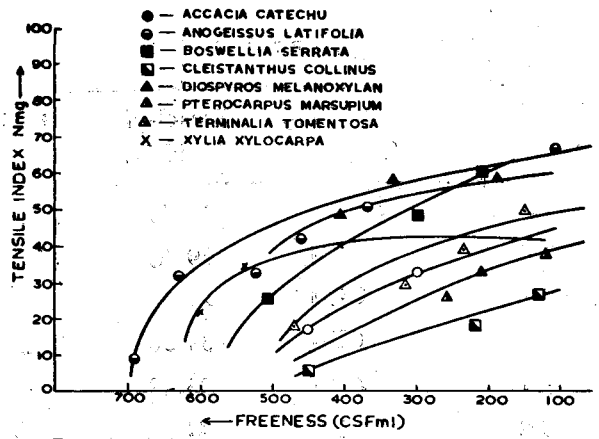


Fig 1—RELATIONSHIP BETWEEN TENSILE INDEX AND FREENESS OF TROPICAL HARDWOODS PULP (UNBLEACHED)

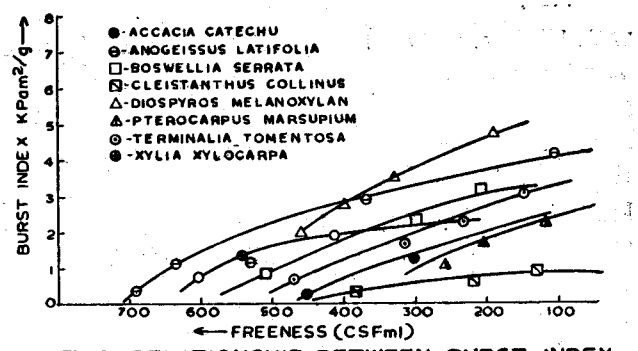
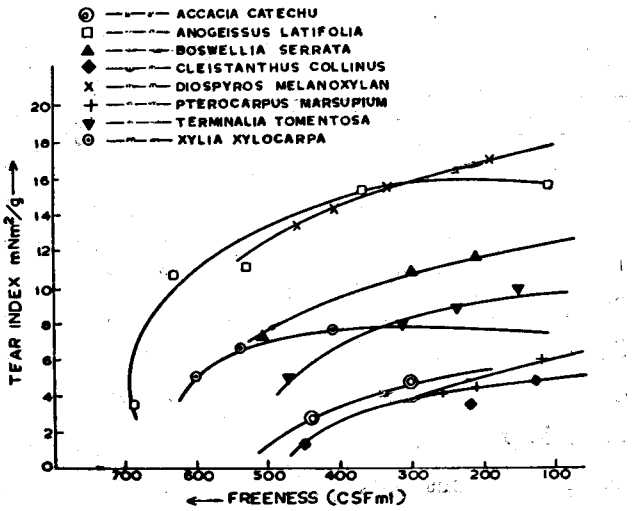


Fig.2—RELATIONSHIP BETWEEN BURST INDEX Vs FREENESS OF TROPICAL HARDWOODS PULP (UNBLEACHED)



Fig,3—RELATIONSHIP BETWEEN TEAR INDEX VS (CSFml) OF TROPICAL HARDWOODS (UNBLEACHED)

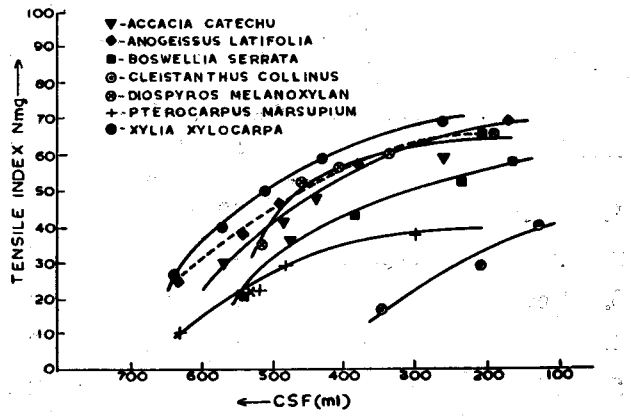


Fig.4—RELATIONSHIP BETWEEN TENSILE INDEX AND FREENESS (CSFml) OF TROPICAL HARDWOODS PULP (BLEACHED)

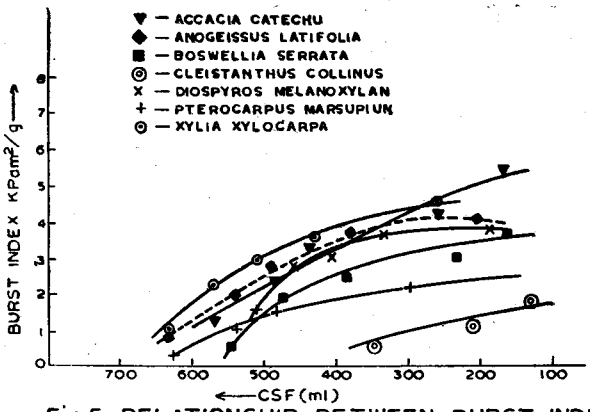


Fig 5–RELATIONSHIP BETWEEN BURST INDEX VS FREENESS (CSF ml) OF TROPICAL HARDWOODS PULP (BLEACHED)

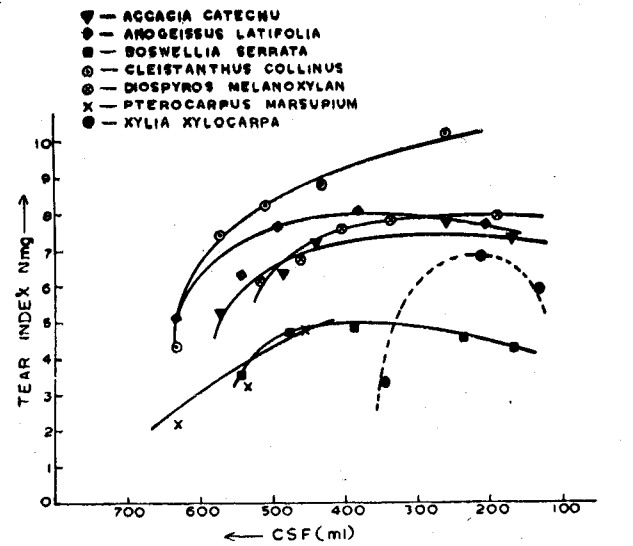


Fig 6 – RELATIONSHIP BETWEEN TEAR INDEX VS (CSF ml) OF TROPICAL HARDWOODS (BLEACHED)

A comparasion on the data of the tensile index, burst index and tear index of unbleached kraft pulps (Table 5) indicates that *Anogeissns latifolia* and *Diospyros melonoxylan* both gave best results followed by *Xylia xylocarpa, Boswellia serrata. Terminalia tomentosa, Accacia catechu* and *Pterocarpus marsupium. Cleistanthus collinus* gave the lowest tensile index of 20.0. The highest tensile index was obtained with *A ogeissus latifolia* (60.2). The burst index ranged from 0.7, for *Cleistanthus collinus* to 4.24 for *Diospyros melanoxylan*. The tear index nanged from 5.0 for *Accacia catechu* to 16 5 to *Diospyros melanoxylan*. This comparision is in between the pulps obtained under identical condiiions using 15% active alkali.

TABLE—5

UNBLEACHED STRENGTH PROPERTIES AT 250 CSF

Sl. No.	Species	Tear index N.mg.	Burst index KPam²/g	Tensile index mNm²/g
1.	Xylia xylocarpa	7.8	2.3	43.0
2.	Boswellia serrata	11.2	2.8	43.0
3.	Diospyros melanoxylan	16.5	4.2	56.0
4.	Aneogeissus latifolia	16.0	3.6	60.0
5.	Cleistanthus collinus	8.8	0.7	20.0
6.	Petrocarpus marasupium	4.2	1.4	30.0
7.	Accacia catechu	5.0	1.8	36.0
8.	Terminalia Tomentosa	8.9	2.4	42 5

The comparative strength properties of bleached Kraft pulps at 250 ml C.S.F. were made on the pulps obtained from two types of unbleaceed pulps. One of kappa number 28±1 (in case of *Cleistanthus collinus, Diospyros melanoxylan* and *Pterocarpus marsupium.* Secondly of kappa number 40 to 48 (in case of *Anogeissus latifolia, Boswellia serrata, Xylia xylocarpa* and *Accacia catechu).* The data from table—6 indicati that

TABLE—6

STRENGTH PROPERTIES OF BLEACHED PULP AT 250 CSF

Sl. No	Name of pecies	Tear index N mg.	Burst index kPam°/g	Tensile index m Nm²/g
1.	Xylia xylocarpa	10.2	4.5	70.0
2.	Boswellia serrata	4.55	3.35	53.0
3.	Diospyros melanoxylan	7.9	3.85	64.5
4.	Anogeissus latifolia	7.8	4.15	65.0
5.	Cleistanthus collinus	6.7	1 25	28.0
6.	Pterocarpus marsupium	—	2.30	39.0
7.	Accacia catechu	7.8	4.20	63.5

Cleistanthus collinus and *Pterocarpus marsupium* are inferior to the rest of the species investigated, which gave satisfactory results on their suitability for production of bleached grade kraft pulps The values for tensile index ranged from 28 for *Cleistanthus collinus* to 70.0 for *Xylia xylocarpa*. The burst index ranged from 1.25 for *Cleistanthus collinus* to 4 5 for *Xylia xylocarpa* and the tear index from 4.5 for *Xylia xylocarpa* and the tear index from 4.5 for *Boswellia serrata* to 10.2 for *Xylia xylocarpo*.

References

1. Singh, S.V, Raj Kumari and Guha, S.R.D. *Indian Pulp and Paper*, April—May (1981).

2. Singh, S.V , Raj Kumari and Guha S.R.D. Indian Pulp and Paper Aug-Sept (1981)

3. Singh, S. V., Bhandari, S.S. and Rekha Bharati. *Ippta*, Annual Seminar held in Delhi (1981).