Improved Pulping of Mixed Hardwoods from Central India

RAO, A. R. K.,* PANT, R.,* MOHAN RAO, N. R.,* SHARMA, Y. K.,* WATSON, A. J.,* KULKARNI, A. G.,* FELLEGI, J.,*

SUMMARY

Sulphate pulping and bleaching of Central Indian hardwoods were carried out in the laboratory to obtain information helpful to get over the difficulties reported by Indian Pulp and Paper Industry while using larger proportion of tropical hardwoods (more than 30%). The samples were classified into four groups based on diameter (0-10 cm, 11-30 cm, 31-50 cm and above 50 cm) to find out the effect of age on pulping and papermaking characteristics. A forest composite sample was also pulped and bleached. Further, pulping characteristics of top, middle and bottom portions and branches of five species were determined to find out if they differ. In addition, simple modifications in washing procedure were tried to obtain pulps of acceptable Kappa number from some nonpulpable species, for example, *Terminalia tomentosa*. The results were encouraging.

Black liquors from the cooks of tropical hardwoods were studied for rise in viscosity and precipitation characteristics with increase in concentration due to evaporation. The black liquor from forest composite cook could be evaporated to higher concentrations without precipitation than those from composite samples of diameter classes.

INTRODUCTION

In view of the existing raw material situation, the Indian Pulp and Paper Industry has to depend more on utilizing the Indian tropical hardwoods to meet the growing requirements. The Central Indian zone is an important forest area consisting of rich resources of tropical hardwoods. Already, the mills located in this area are using various species of hardwoods for manufacturing pulp and paper. The present practices and trends seem to be on segregation of pulpable and nonpulpable species which calls for enormous amount of work in obtaining the raw materials. The practicable way is using the raw material in the composition existing in the forests. It may not be possible even to obtain a forest composite sample as the forestry department allows the extraction of raw material for pulp and paper industry only after the species useful for the more valuable purposes like timber (which also gives higher revenue) are extracted. In some instances trunks are used for different purpose and only lops and tops are available for the pulp and paper industry. Further, certain species used in mixture for pulping give rise to certain difficulties with regard to bleaching and black liquor problems. Therefore, systematic investigations were undertaken in project laboratories to study the following aspects of pulp and paper characteristics of Central Indian hardwoods. Sulphate pulping and bleaching of hardwoods were carried out to find the effect of age, to establish if there is any deviation in the pulping and papermaking characteristics of lops and tops and to attempt improved methods of bringing down the Kappa numbers of nonpulpable species.

*UNDP/FAO/GOI Project, Hindustan Paper Corporation, New Delhi (India).

RAW MATERIAL

Twenty nine hardwood species were collected from the Central Indian forests (Bastar area). These are listed in Table--I. As per diameter classes, the grading has been done as follows :

0-10 cm. dia	—	diameter class 1
11-30 cm. dia	—	diameter class 2
31-50 cm. dia	—	diameter class 3
above 50 cm. dia	—	diameter class 4

It was decided to exclude diameter class 1 from pulping studies as the proportion of bark compared to the wood material in the sample was very high and also not much wood volume from this diameter class is expected to be available for the pulp mills.

Composite for each diameter class and forest mixture were prepared by mixing the chips in the

TABLE–I

COMPOSITE SAMPLES OF DIFFERENT DIAMETER CLASSES

Code No.	Name of the species	Diameter Class 2	Diameter Class 3	Diameter Class 4
01	Tectona grandis	3.41	7.87	—
02	Shorea robusta	8.84	17.29	24.22
03	Terminalia tomentosa	12.18	18.17	27.56
04	Pterocarpus marsupium	4.50	5.39	14.99
05	Dalqergia latifolia	0.49	0.61	—
07	Diospyros melanoxylon	10.18	8.14	10.06
08	Bridelia squemosa	0.51	—	—
09	Anogeissus latifolia	16.19	8.55	—
10	Emblica officinalis	2.09	—	—
12	Lagerstroemia parviflora	4.59	1.94	—
14	Syzizium cumini	1.34	2.50	—
16	Xylia xylocarpa	3.70	2.45	—
18	Boswellia serrata	2.88	4.97	—
19	Schrebera switenioides	1.25	1.49	—
20	Lannea grandis	1.78	2.01	2.26
21	Garuga pinnata	0.61	0.54	—
24	Schleichera trijga	0.44	1.89	8.76
25	Madhuca latifolia	3.32	—	—
27	Adina cordifolia	0.40	8.61	3.97
28	Mitragyna parviflora	0.36	1.38	3.11
30	Terminalia chebula	2.25	1.02	—
32	Salmalia malberica	0.27	0.49	—
33	Sterculia urens	0.39	—	1.85
42	Buchanania lanzan	3.37	—	—
50	Dalbergia paniculata	1.04	1.61	2.84
52	Dillenia indica	0.89	1.44	—
63	Cleistanthus collinus	10.49	1.60	0.39
75	Soymida febrifuga	0.70	—	—
79	Ziziphus xylopyra	1.09	—	—
	Total ..	99.55	99.96	100.01
	Forest composite	53	33	14

Mixtures were prepared on the volume basis.

proportion as these wood species exist in forest area. This is described in detail elsewhere[1]. Compositions of mixture of each diameter class and forest mixture are recorded in Table-I.

Some of the 29 hardwood species listed in Table-I are well known timber species and will not be available to the pulp and paper mills as such. Only lops and tops and off cuts from saw mills of these species will be available, for pulping purpose. It was, therefore, decided to evaluate the pulping characteristics of different portions of some of the timber species. Bottom, middle, top and branch portions of the trees of following five species were collected from the forests :

1. *Shorea robusta*
2. *Terminalia tomentosa*
3. *Pterocarpus marsupium*
4. *Diospyros melanoxylon*
5. *Anogeissus latifolia.*

EXPERIMENTAL

PULPING

The laboratory pulping of all the samples was carried out in a series digester, in which six cooks in bombs each of 2.5 litres capacity can be carried out at a time. Necessary care was taken to eliminate any small variation in the chip composition between the

bombs. All the pulping experiments were carried out under the following constant conditions :

Wood chips charged in each bomb		= 400 g. (o.d. basis)
Active alkali as Na_2O,	%	= 17.0
Sulphidity,	%	= 25.0
Liquor to wood ratio		= 3 : 1

Cooking schedule

Raising time from room temperature to 100° C ,	min.	= 30
Raising time from 100° C to 170° C ,	min.	= 105
Time at 170° C ,	min.	= 120
H factor		= 2130

At the end of the cooking, the black liquor was drained off and the chips were broken by hand and then boiled for ten minutes with eight litres of hot water. This was followed by disintegration for ten minutes under hot conditions (about 80° C). The pulp was finally washed with hot water at about 80° C until the filtrate was almost colourless.

The pulp was screened on a Lambort screen and the pulp yield was determined. Kappa numbers of the pulps were determined on screened pulps according to standard TAPPI method T-236-0S-76.

BLACK LIQUOR ANALYSIS

Black liquors were examined for total solids and residual alkali. Standard TAPPI method T-625-ts-63 was followed. Black liquor viscosity was determined using a Brookfield synchro-lectric viscometer at 80° C varying the solid contents from 35% to 55%. Swelling volume ratio of the black liquor was determined using the method of Oye and co-workers (2).

PULP BLEACHING

A standard CEHH bleaching sequence was used for all the pulps. The bleaching was carried out under optimum conditions according to procedure described in an earlier laboratory study (3).

The intrinsic viscosity determinations on bleached pulp were carried out in CED solution according to SCAN-C-15:62 method.

PULP EVALUATION

Physical properties of the unbleached and bleached pulps were evaluated by beating in PFI mill to various degrees of freeness, under standard conditions as per ISO DP 5264 i.e.

Beating pressure	— 17.7 N/cm
Relative speed	— 6.0 m/s
Beating consistency	— 10% on weight basis
C.S.F. measurement	— ISO DP 5267

Hand sheets for testing were made as per ISO DP 5269 and were dried on plates in stack under standard conditions of ISO standard R-187. Physical testings were carried out as per following ISO standards.

Test	Standard	Unit
Tensile index	ISO 1924	Nm/g
Tear index	ISO 1974	$mN.m^2/g$
Burst index	ISO 2758	$kPa.m^2/g$
Bulking thickness	ISOR 438	cm^3/g
Air resistance	ISODIS 3687	s/100 ml
Folding endurance	ISODIS 5626	Kohler-Molin
Brightness	ISO 2470	
Opacity	ISO 2471	

POST COLOUR NUMBER

Brightness was measured after keeping the brightness sheet in forced circulation oven at 105° C for four hours. Initial brightness was also measured.

$$\text{P.C. number} = 100 \left[\frac{(1-R\infty_2)^2}{2R\infty_2} - \frac{(1-R\infty_1)^2}{2R\infty_1} \right]$$

$R\infty_1$ = diffuse reflectance factor before aging.

$R\infty_2$ = diffuse reflectance factor after aging.

RESULTS AND DISCUSSIONS

PULPING OF MIXED HARDWOODS

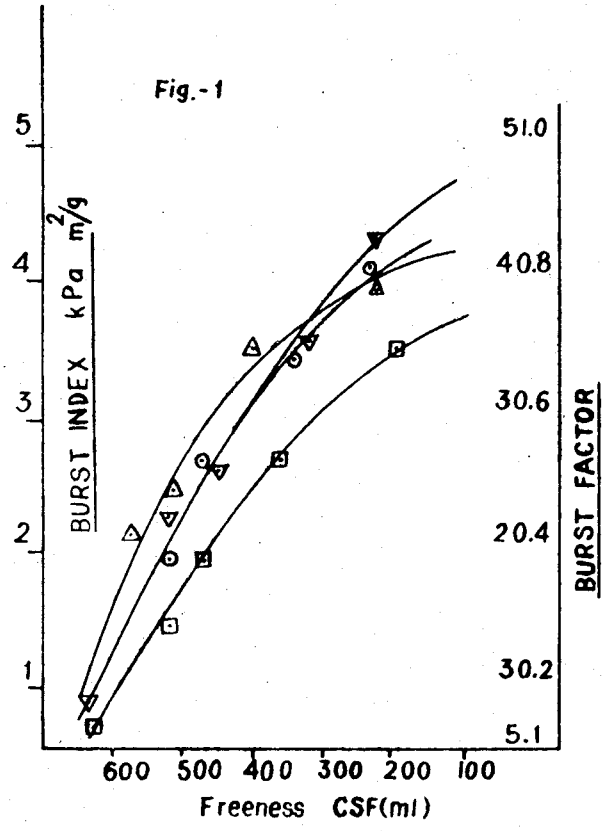
All the composite samples yielded practically shive free pulps. As can be seen from Table-II there was slight variation in the yields of pulp. As expected Kappa number of the pulp from diameter class 2 composite was the lowest and that of the diameter class 4 composite was the highest. The Kappa number of the forest composite was 27. Thus the quality of the pulp obtained was quite satisfactory.

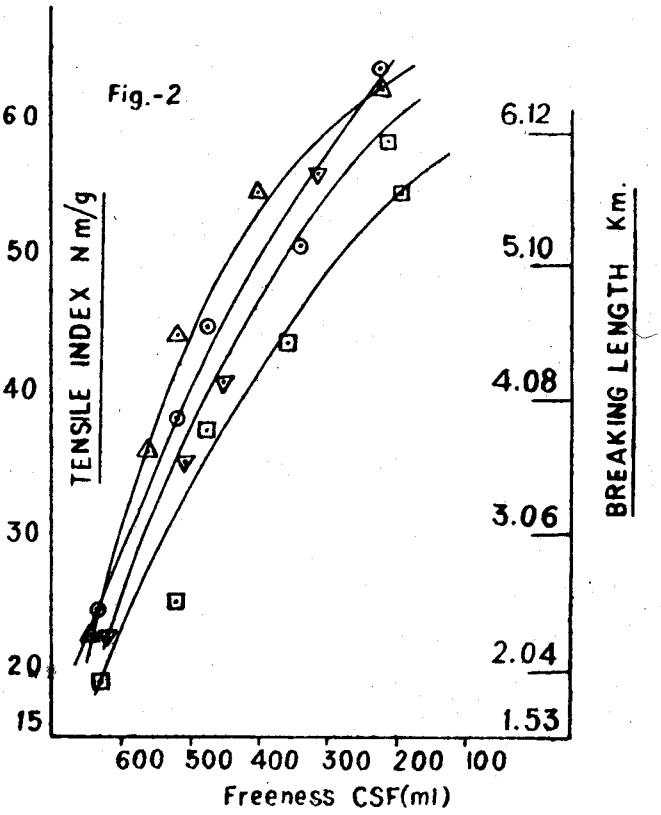
PULP BLEACHING

Bleaching was carried out using CEHH sequence. Bleaching data are recorded in Table-III. During bleaching no special problems were encountered. All the pulps could be readily bleached to brightness levels between 74.1% and 78.1% Elrepho. The hydrochlorite intake was less in case of pulp from diameter class 4 composite and hence the brightness development was poor when compared to the pulps from other diameter class composite and forest composite. This may be due to the fact that large diameter class trees are older than the others, and it is a recognized fact that older trees require more cooking chemicals and produce pulps which are more difficult to bleach. In the forest mixture, the proportion of lower diameter class woods was considerably higher than the larger diameter class woods.

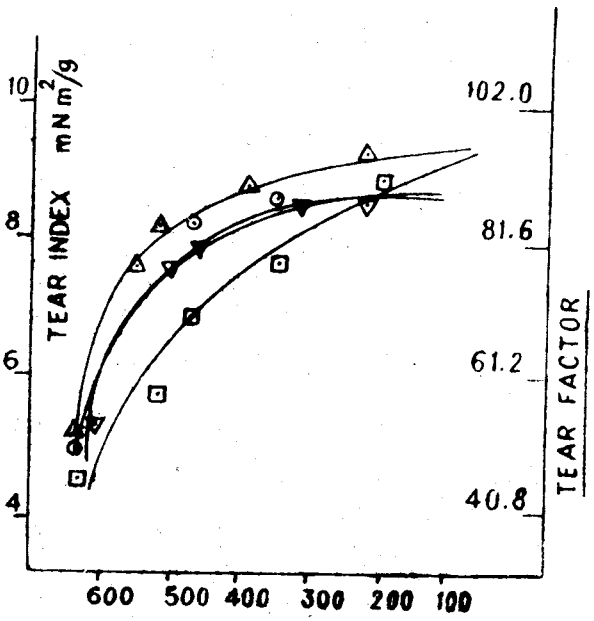
Pulping and bleaching behaviour of forest mixture was therefore quite satisfactory and a brightness of 78.1% Elrepho could be obtained.

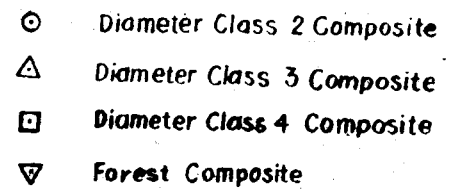
The strength properties of the unbleached and bleached pulps are shown in Figs. 1 to 13. From Figs. 1 to 6, it is seen that pulps produced from diameter class 2 and 3 possessed similar strength characteristics whereas pulps produced from diameter class 4 composite had slightly inferior strength characteristics. The pulps produced from forest composite had strength properties nearer to those of the pulps from diameter class 2 and 3. As can be seen from Figs. 7 to 12 there was a slight fall in strength properties on bleaching, particularly the Tear index of the pulps was lowered considerably. It is therefore considered necessary to carry out further bleaching experiments including the use of chlorine dioxide so that the bleached pulps of still better properties could be produced.





←Fig. - 3





Figs. 1 to 3. Freeness-Burst Index, Tensile Index, Tear Index Relationship of Mixed Hardwoods Pulp (Unbleached).

BLACK LIQUOR STUDIES

Examination of the black liquors from different diameter composites and forest composite was carried out with respect to their evaporation characteristics and viscosity during concentration. Results are recorded in Table-IV. For comparison, results from the black liquor of poplar wood have also been included. A perusal of data given in Table-IV shows that the inorganinc contents of the black liquors from different hardwood composites were very similar. The viscosity values for the black liquors from various composites are on the lower side. It is also observed that the precipitation point for the forest composite black liquor is higher than the precipitation points of the black liquors of other diameter class composites.

PULPING OF LOPS AND TOPS

A study of the pulping of different portions of the trees of five hardwood species revealed that in all the cases well cooked pulps could be obtained from all the portions of tree. As can be seen from Table-V and Fig. 14, the pulp yield variation from different portions of the tree was not very significant except in case of *Shorea robusta,* where branches gave much lower yield compared to other portions. From Fig. 15 it is observed that there was only slight variation in the Kappa numbers of the pulps from different portions of the tree. Except in the case of *Terminalia tomentosa,* bottom portion of the tree gave pulp of very high Kappa number (53.2) whereas the Kappa number of the pulp from branches was low (25.4).

TABLE—II

PULPING DATA OF CENTRAL INDIAN MIXED HARDWOODS

Sl. No.	Particulars	Composite of diameter class 2	Composite of diameter class 3	Composite of diameter class 4	Forest composite
1.	Screened pulp yield, %	45.2	43.4	42.7	43.4
2.	Rejects, %	0.4	1.0	0.7	1.1
3.	Kappa number of the pulp	26.8	28.0	29.3	27.0
4.	**Black liquor**				
	(i) pH	11.2	11.3	11.0	11.2
	(ii) Total solids, % w/w	20.10	20.48	20.56	19.74
	(iii) Residual active alkali as Na_2O, gpl (at 200 gpl total solids)	6.74	8.88	10.13	7.44

TABLE—IV

BLACK LIQUOR STUDIES ON COMPOSITES OF DIFFERENT DIAMETER CLASSES AND FOREST COMPOSITE

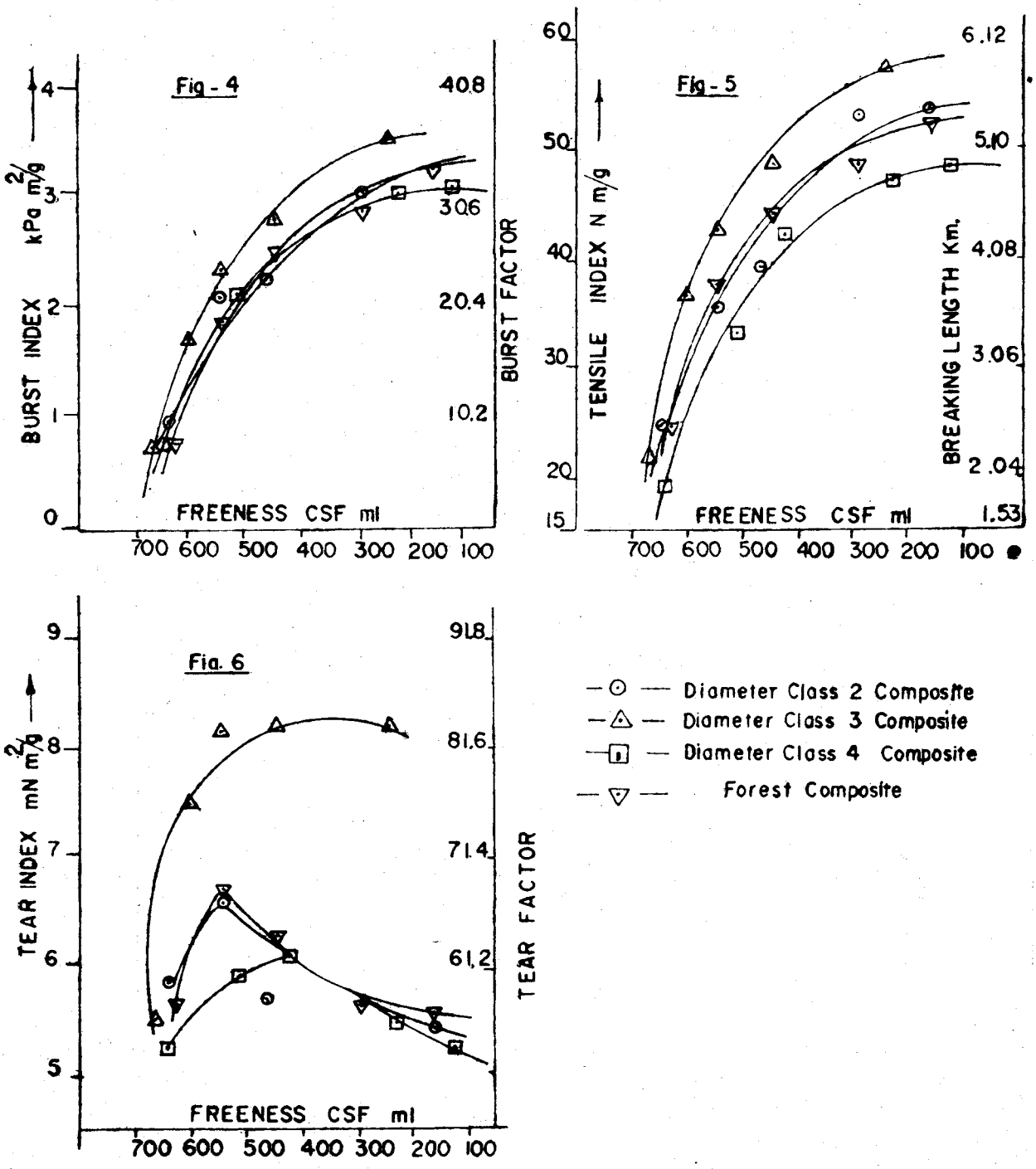
Sl. No.	Black liquor samples from	Residual active alkali gpl Na_2O at 200 gpl	Total solids %	pH	Inorganics as NaOH %	Brookefield viscosity at 80°C at % solids, cps 35	40	50	55	Precipitation point at % solids
1.	Diameter class 2	6.74	20.10	11.2	30.0	2.9	4.9	20	68	36.9
2.	Diameter class 3	8.88	20.48	11.3	29.7	4.3	8.1	37	100	39.8
3.	Diameter class 4	10.13	20.56	11.0	29.7	3.0	5.9	27	72	37.5
4.	Forest composite	7.44	19.74	11.2	29.9	3.3	5.9	23	59	40.3
5.	Poplar (*Populus deltoides*)	5.74	14.80	11.1	27.6	4.1	5.5	26	81	No precipitation

TABLE—III

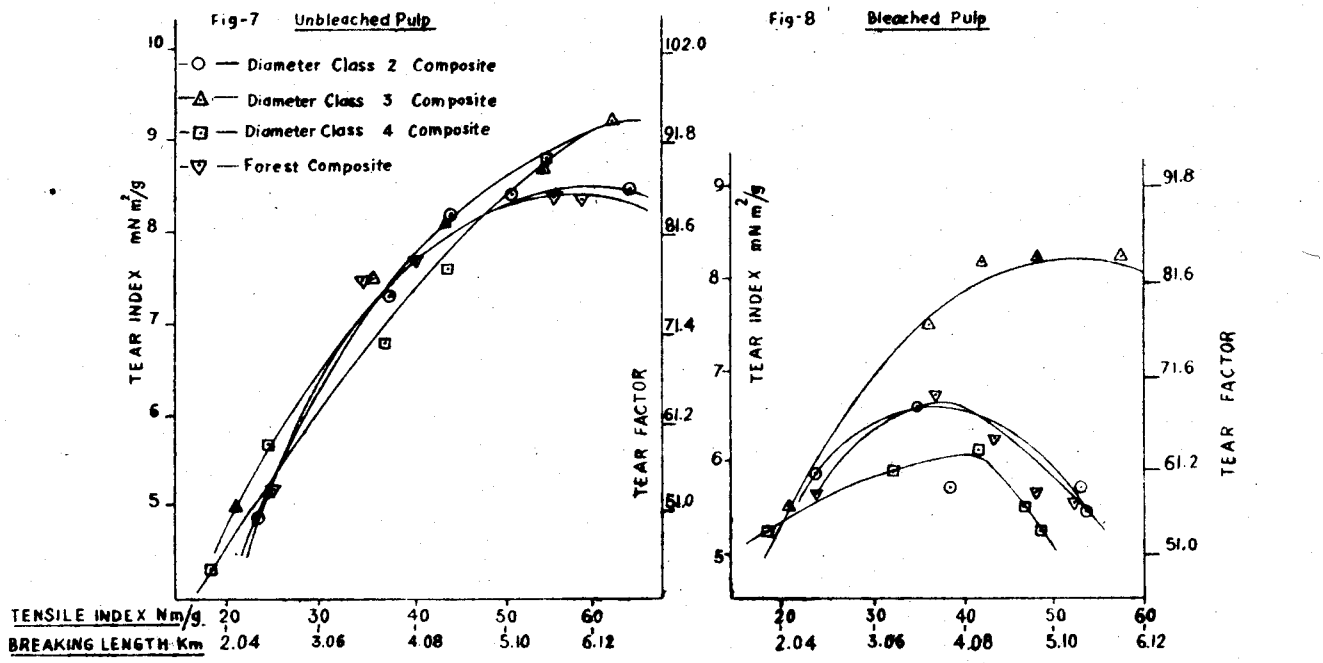
BLEACHING STUDIES OF CENTRAL INDIAN MIXED HARDWOODS

Sl. No.	Particulars	Diameter class 2	Diameter class 3	Diameter class 4	Forest composite
	Kappa number of the pulp	26.8	28.0	29.3	27.0
1.	**Chlorination**				
	Chlorine added on pulp, %	6.0	6.25	5.75	6.5
	Initial pH	2.3	2.1	2.1	2.3
	Final pH	2.0	2.2	2.2	2.2
	Chlorine consumed on pulp, %	5.47	6.07	5.73	6.06
2.	**Alkali extraction**				
	Alkali applied as sodium hydroxide, %	1.25	1.25	1.50	1.50
	Initial pH	10.7	11.0	10.7	10.7
	Final pH	10.2	10.7	10.4	10.5
	Colour of the effluent (at pH 7.6) (absorbance at 465 nm)	1.6	1.7	2.2	2.0
3.	**Hypo I stage**				
	Hypochlorite applied as chlorine, %	1.9	1.8	3.5	2.5
	Buffer added as sodium hydroxide to maintain pH 9.0, %	0.8	0.7	1.05	0.87
	Hypochlorite consumed as chlorine, %	1.62	1.78	2.60	2.17
4.	**Hypo II stage**				
	Hypochlorite applied as chlorine, %	1.0	1.0	1.0	1.0
	Buffer added as sodium hydroxide to maintain pH 9.0, %	0.3	0.3	0.3	0.3
	Hypochlorite consumed as chlorine, %	0.43	0.38	0.49	0.33
5.	Yield loss during bleaching, %	14.8	12.3	16.6	12.5
6.	Total chlorine applied, %	8.90	9.05	10.25	10.00
7.	Total chlorine consumed, %	7.52	8.23	8.82	8.56
8.	Total sodium hydroxide used, %	2.35	2.25	2.85	2.67
9.	Brightness of the pulp, % Elrepho	77.0	77.0	74.7	78.1
10.	Intrinsic viscosity of the pulp, cm^3/g	365	421	340	370
11.	Post colour number	2.7	3.3	2.8	3.1

Constant conditions :		Chlorination	Alkali extraction	Hypo I stage	Hypo II stage
Consistency,	%	3.0	8.0	8.0	8.0
Temperature,	°C	30	60	50	50
Time,	min.	30	60	120	120



Figs. 4 to 6. Freeness – Burst Index, Tensile Index, Tear Index Relationship of Mixed Hardwoods Pulp (Bleached).



Figs. 7 & 8. Tear Index—Tensile Index Relationship of Mixed Hardwoods Pulp (Unbleached and Bleached)

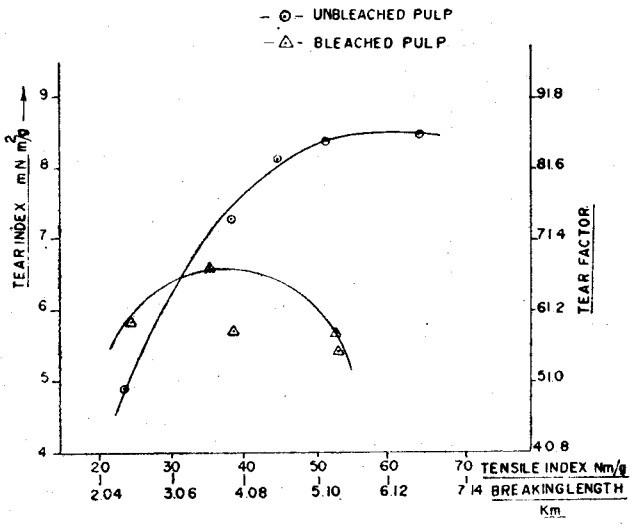


Fig. 9. Tear Index—Tensile Index Relationship for Diameter Class 2 Composite Pulp.

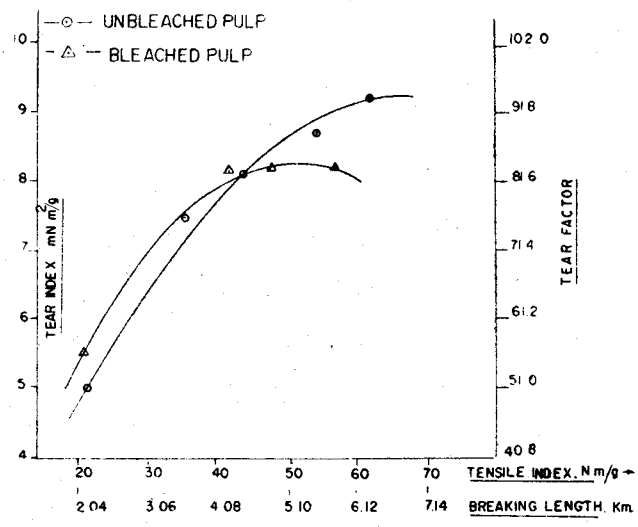


Fig. 10. Tear Index—Tensile Index Relationship for Diameter Class 3 Composite Pulp.

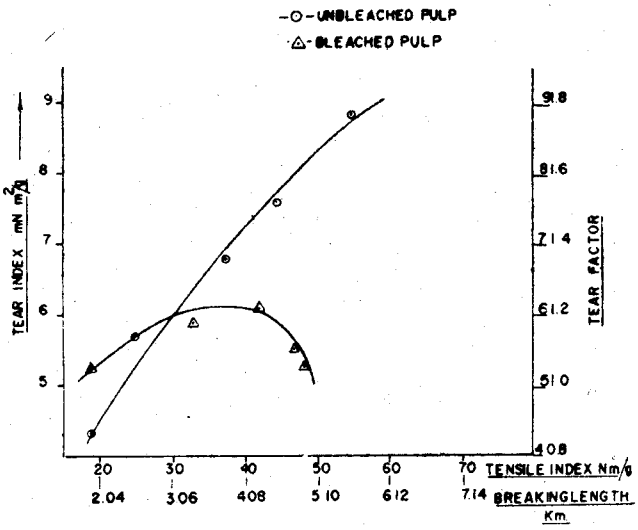


Fig. 11. Tear Index - Tensile Index Relationship for Diameter Class 4 Composite Pulp.

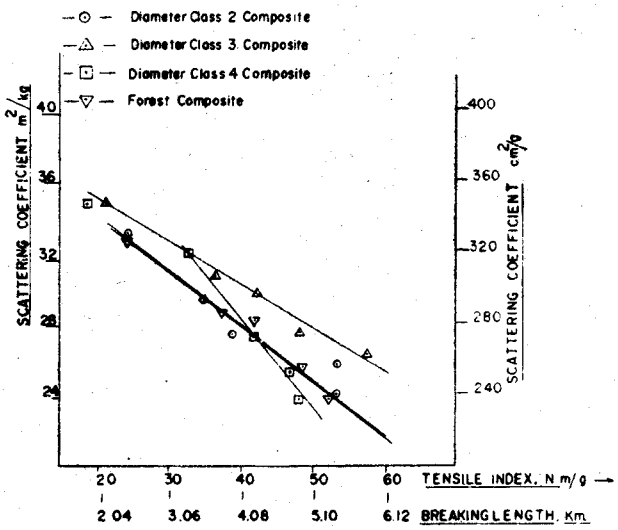


Fig. 13. Scattering Coefficient – Tensile Index Relationship for Mixed Hardwoods Pulp (Bleached).

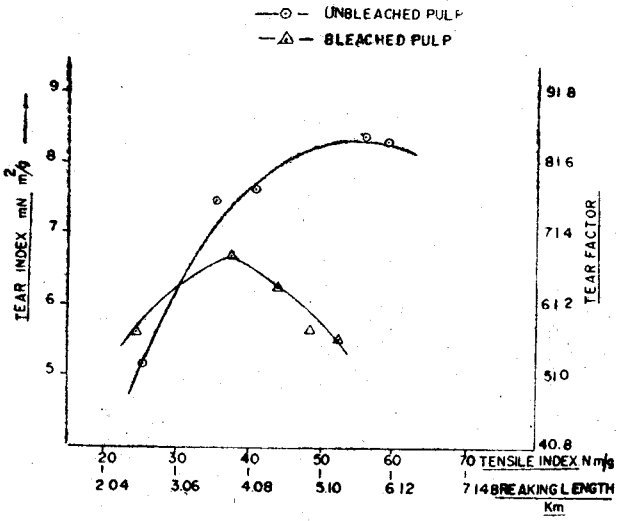


Fig. 12. Tear Index - Tensile Index Relationship for Forest Composite Sample Pulp.

It is also seen from Table-V that in case of *Shorea robusta, Terminalia tomentosa* (Figs. 17 to 19) and *Diospyros melanoxylon,* the pulps from different portions of the tree possessed generally similar strength properties, when compared at 300 ml CSF. In the case of *Pterocarpus marsupium,* pulp from branch portion possessed slightly better strength properties than the pulps from the other portions of the tree, and in case of *Anogeissus latifolia* (as can be seen from Figs. 20 to 22) branch portion pulp possessed slightly inferior strength characteristics (particularly the Tear index was very low) than the pulps from other portions.

Black liquor data is presented in Table-VI and Fig. 16, and viscosity total solids relationship of the black liquors of two species viz. *Terminalia tomentosa* and *Anogeissus latifolia* are shown in Figs. 23 and 24. From these results it is seen that in general the black liquors from pulping of different portions of tree donot differ to any significant extent with respect to their viscosities, swelling volume ratios and precipitation characteristics.

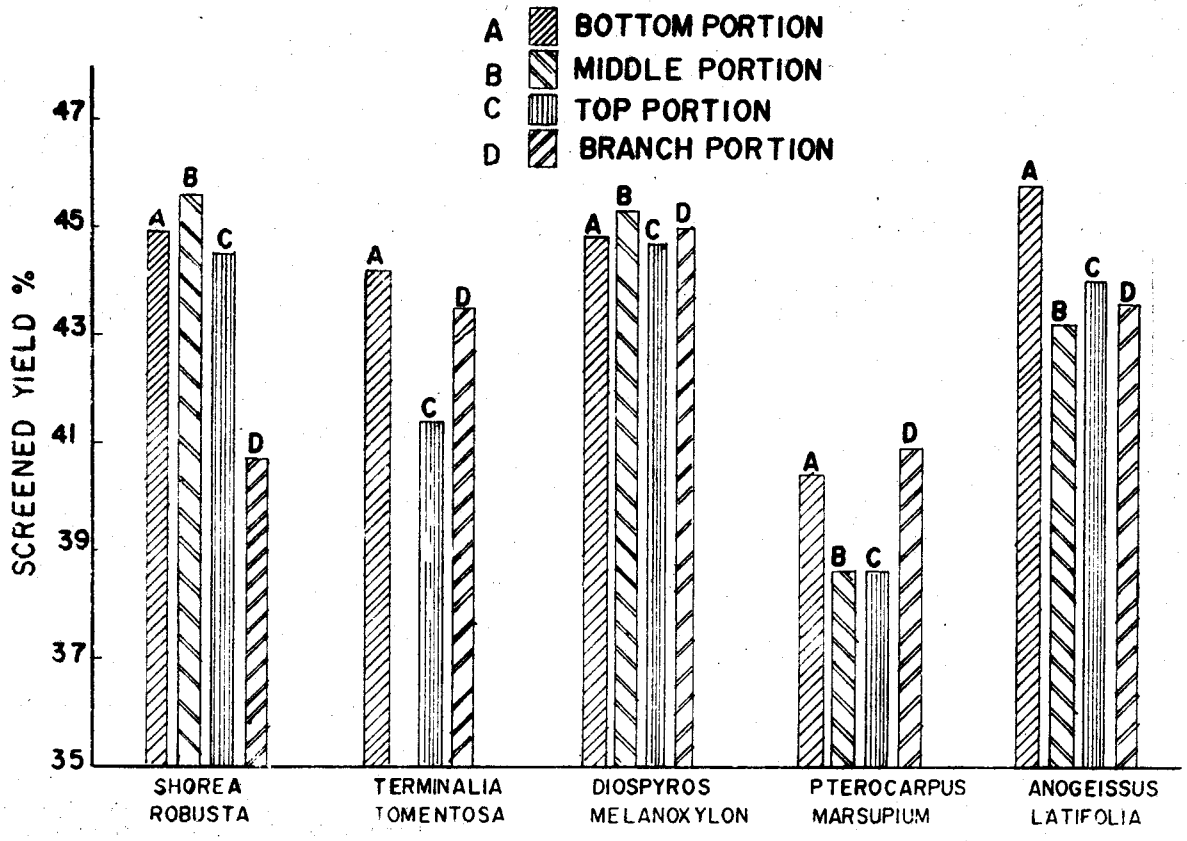


Fig. 14. Screened Yield Variation with Different Portions of the Tree.

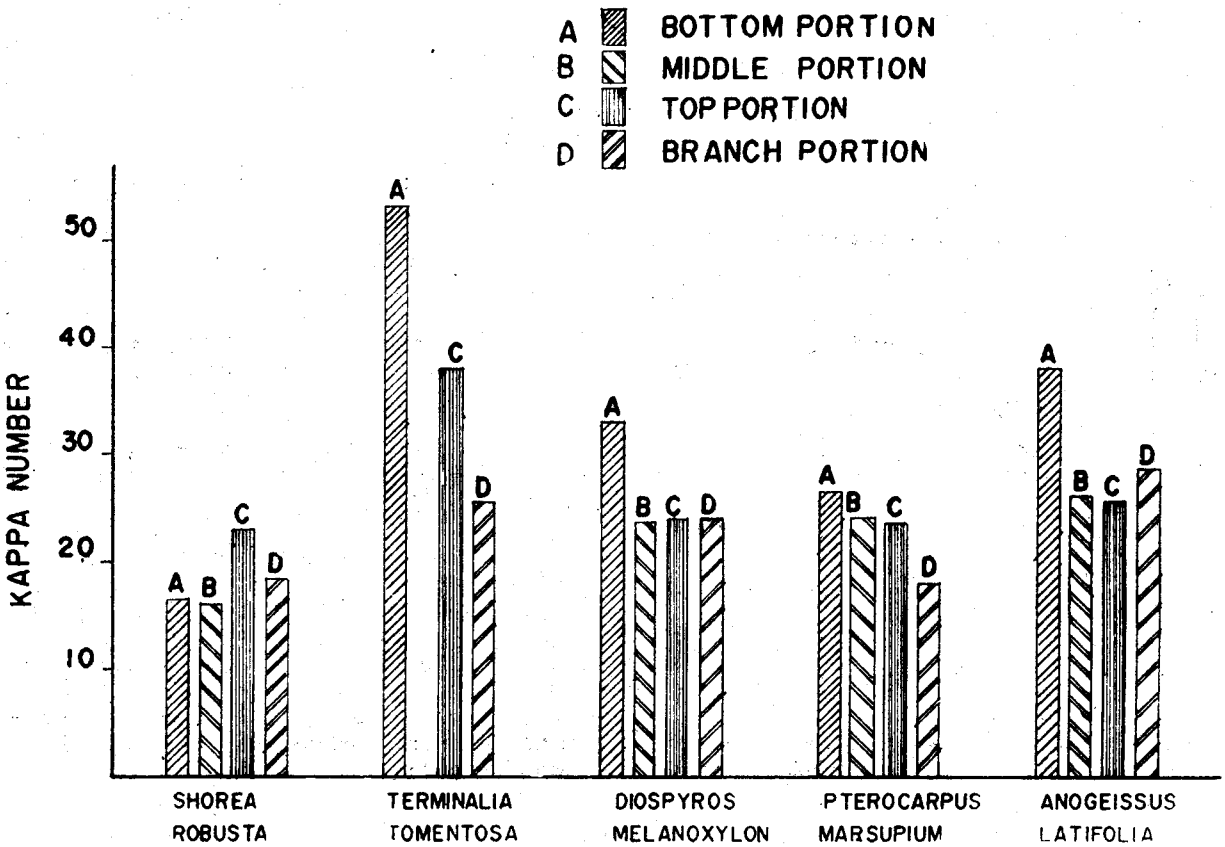


Fig. 15. Kappa Number Variation with Different Portions of the Tree.

From these investigations, it is revealed that the use of lops and tops in the hardwood mixture will not have significant adverse effect on the pulp yield, Kappa number, pulp strength characteristics and black liquor properties.

PULP WASHING STUDIES

Terminalia tomentosa is one of the major hardwood species occuring in the Central Indian forests. This species has been reported to be one which poses problems during pulping and bleaching operations.

In an earlier study ([3]), it was observed that *Terminalia tomentosa* species could be pulped very well with 17% chemicals, but the Kappa number of the pulp was very high (above 45). Changing the cooking schedule or increasing the chemical charge was of no advantage as regards to pulp Kappa number. Microscopic study of the pulp revealed that the fibres contained appreciable amounts of colouring material (extractives) in their lumen, which were only slightly soluble in cold water. This colouring material was thought to be responsible for the high Kappa number of the *Terminalia tomentosa* pulp. The investigations were, therefore, carried out to establish optimum washing procedure so that the pulp of lower Kappa number from *Terminalia tomentosa* could be obtained. The study was conducted by carrying out three cooks of *Terminalia tomentosa* under identical cooking conditions specified in experimental section. At the end of the cook, pulps were washed separately in the following manner :

(i) The pulp was drained off surplus black liquor, treated with cold water, disintegrated for ten minutes and washed with cold water until the filtrate was almost colourless.

(ii) The pulp was drained off surplus black liquor, treated with boiling water for ten minutes, disintegrated for ten minutes under hot conditions, filtered and washed with boiling water until the filtrate was almost colourless.

(iii) Black liquor was not drained. Boiling water was added to the pulp containing black liquor and the contents boiled for ten minutes, disintegrated for ten minutes under hot conditions and then filtered and washed as in (ii) above.

From Table–VII, it is seen that the Kappa number of the pulp obtained by conventional washing with tap water at ambient temperature was high (45.0),

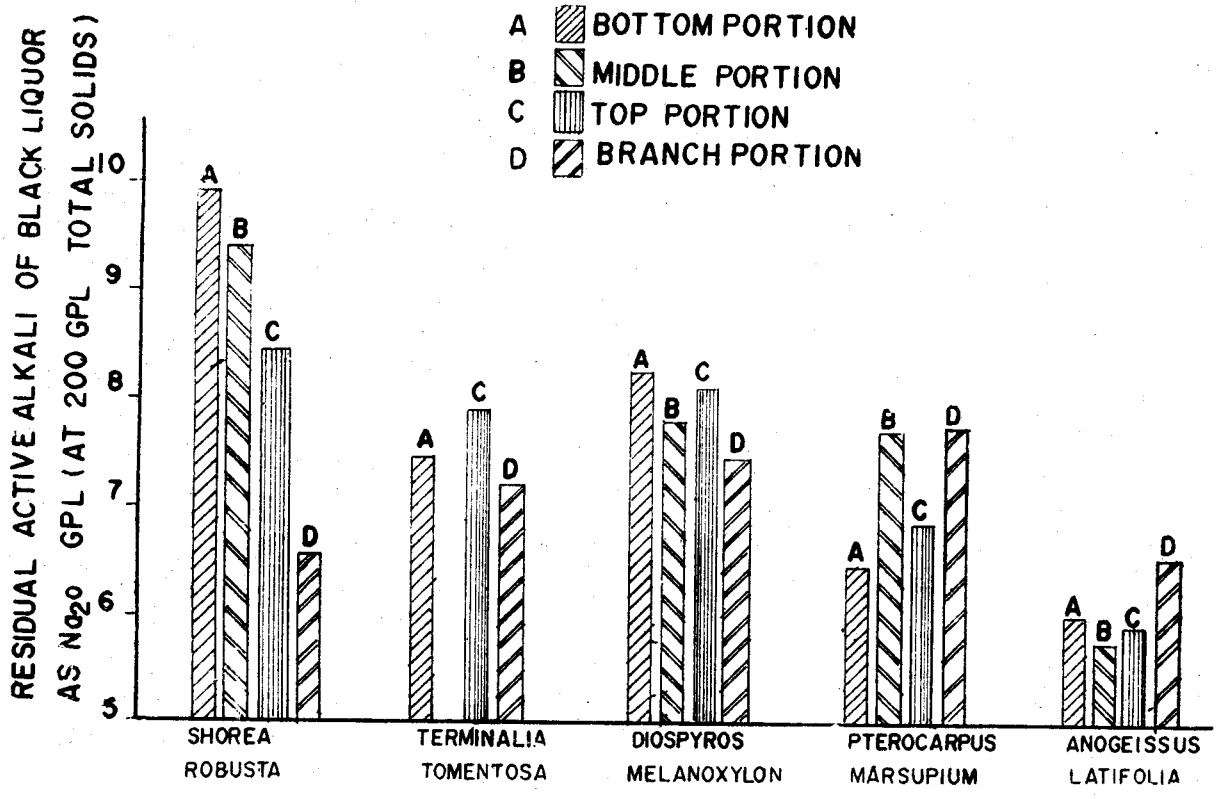
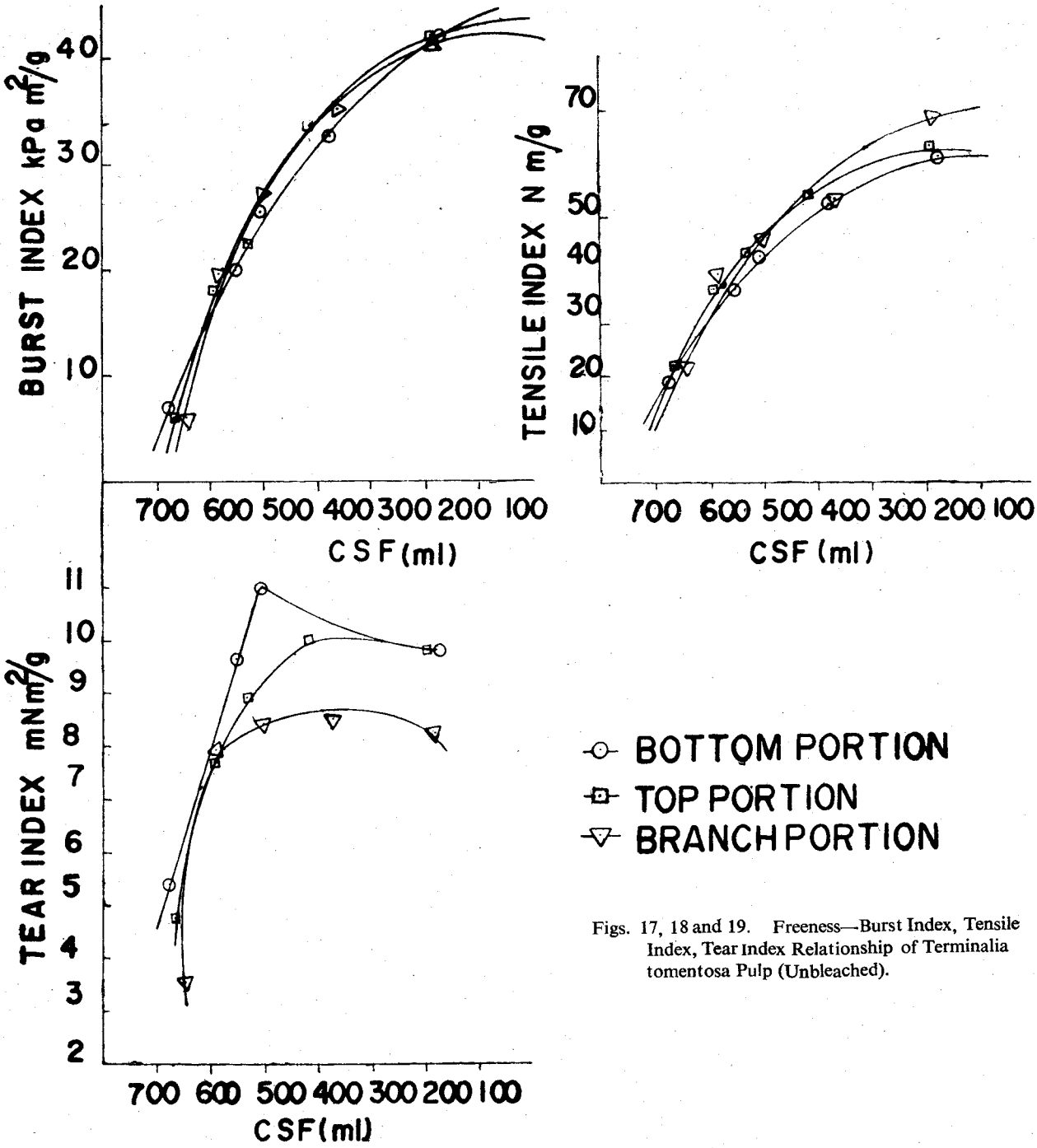
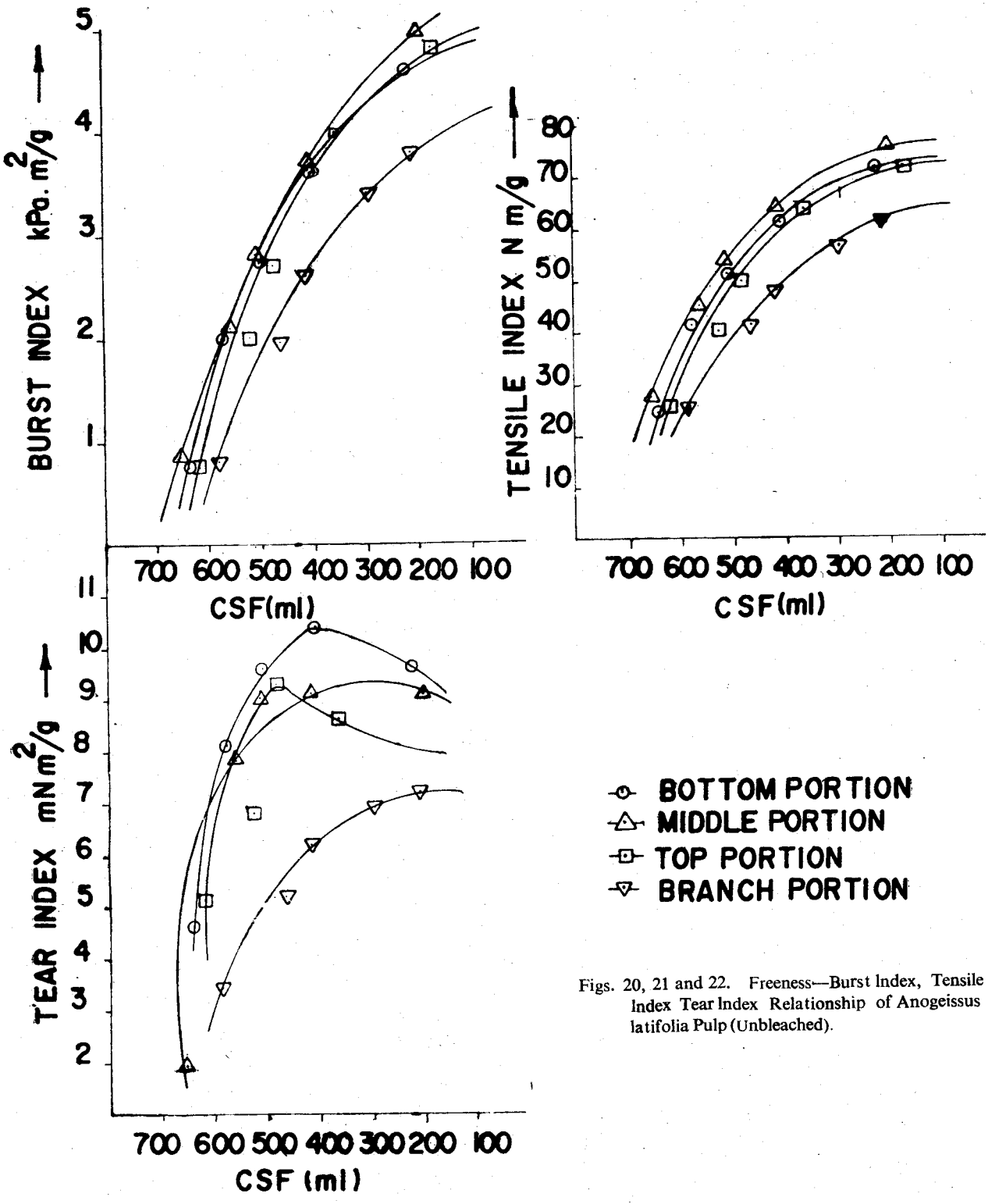


Fig. 16. Residual Active Alkali Variation in Black Liquor with Different Portion of the Tree.



Figs. 17, 18 and 19. Freeness—Burst Index, Tensile Index, Tear Index Relationship of Terminalia tomentosa Pulp (Unbleached).



Figs. 20, 21 and 22. Freeness—Burst Index, Tensile Index Tear Index Relationship of Anogeissus latifolia Pulp (Unbleached).

TABLE—V

PULPING DATA OF DIFFERENT PORTIONS OF TREES

Sl. No.	Particulars	Shorea robusta (02)				Terminalia tomentosa (03)			Diospyros melanoxylon (07)			
		02/I Bot-tom	02/II Mid-dle	02/III Top	02/Br Bran-ches	03/1 Bot-tom	03/III Top	03/Br Bran-ches	07/I Bot. tom	07/II Mid-dle	07/III Top	07/Br Bran-ches
1.	Screened pulp yield, %	44.9	45.6	44.5	39.7	44.2	41.4	43.5	44.8	45.3	44.7	45.0
2.	Rejects, %	0.9	1.8	0.7	1.0	2.6	2.8	0.8	0.9	0.7	1.7	0.8
3.	Kappa number of the unbleached pulp	16.4	15.8	22.9	18.6	53.0	38.2	25.4	33.6	23.6	24.2	24.0
4.	**Black liquor**											
	(i) pH	11.2	11.0	11.0	11.0	11.1	11.1	11.1	11.1	11.1	11.1	11.1
	(ii) Total solids, % w/w	19.34	19.95	20.0	21.13	18.05	17.77	19.49	19.86	20.14	19.90	20.37
	(iii) Residual active alkali as Na_2O, gpl (at 200 gpl total solids)	9.89	9.42	8.46	6.53	7.43	7.91	7.19	8.23	7.82	8.08	7.43
5.	**Strength properties at 300 (ml) CSF**											
	(i) Burst index, $kPam^2/g$	3.25	3.30	3.70	3.50	3.70	3.90	3.85	3.35	3.70	3.50	3.40
	(ii) Tensile index, N.m/g	52.0	54.0	59.5	57.5	56.5	60.0	63.5	49.5	58.5	54.5	54.0
	(iii) Tear index, $mN.m^2/g$	10.20	10.30	10.10	9.30	10.00	10.00	8.70	8.25	7.70	6.60	6.30

TABLE—V (Contd.)

PULPING DATA OF DIFFERENT PORTIONS OF TREES

Sl. No.	Particulars	Pterocarpus marsupium (04)				Anogeissus latifolia (09)			
		04/I Bottom	04/II Middle	04/III Top	04/Br Branches	09/I Bottom	09/II Middle	09/III Top	09/Br Branches
1.	Screened pulp yield, %	40.4	38.6	38.6	40.9	45.8	43.2	44.0	43.6
2.	Rejects, %	0.9	1.5	2.0	0.6	1.8	2.3	1.8	0.7
3.	Kappa number of the unbleached pulp	26.3	24.2	23.4	18.1	37.9	26.0	25.4	28.7
4.	**Black liquor**								
	(i) pH	11.2	11.1	11.1	11.2	11.2	11.1	11.1	11.2
	(ii) Total solids, % w/w	20.75	21.04	21.45	20.87	19.21	19.11	19.77	19.85
	(iii) Residual active alkali as Na_2O, gpl (at 200 gpl total solids)	6.45	7.72	6.87	7.75	6.02	5.77	5.88	6.55
	Strength properties at 300 (ml) CSF								
	(i) Burst index, $kPam^2/g$	3.35	3.35	3.00	4.45	4.25	4.45	4.25	3.40
	(ii) Tensile index, N.m/g	56.0	60.0	55.0	70.2	68.5	72.0	67.0	57.0
	(iii) Tear index, $mN.m^2/g$	6.95	6.60	5.90	7.30	10.0	9.3	8.3	6.9

TABLE—VI

STUDIES ON BLACK LIQUORS FROM DIFFERENT PORTIONS OF THE TREES

Sl. No.	Particulars	Shorea robusta				Terminalia tomentosa			Diospyros melanoxylon			
		Bottom	Middle	Top	Branches	Bottom	Top	Branches	Bottom	Middle	Top	Branches
1.	Inorganic content, % as NaOH	32.03	30.96	31.49	—	29.30	29.58	31.68	29.49	29.14	29.14	30.12
2.	Swelling volume ratio, ml/g	3.4	10.5	12.7	27.0	6.0	23.0	16.0	24.0	24.0	22.0	42.0
3.	Brookefield viscosity at 50% solids content, cps	19.5	15.0	39.0	41.0	46.0	48.0	53.0	16.0	14.0	12.0	15.0
4.	Precipitation point at % solids	34.6	—	26.1	24.2	27.1	27.6	31.6	41.6	43.7	42.3	38.2

Sl. No.	Particulars	Pterocarpus marsupium				Anogeissus latifolia			
		Bottom	Middle	Top	Branches	Bottom	Middle	Top	Branches
1.	Inorganic content, % as NaOH	24.23	27.44	28.07	25.43	31.32	30.93	31.53	30.80
2.	Swelling volume ratio, ml/g	24.0	34.0	41.0	49.0	18.0	19.0	27.0	44.0
3.	Brookefield viscosity at 50% solids content, cps	28.0	33.0	20.0	30.0	12.0	16.0	26.0	26.0
4.	Precipitation point at % solids	43.6	40.1	48.1	44.3	35.8	34.5	40.3	39.7

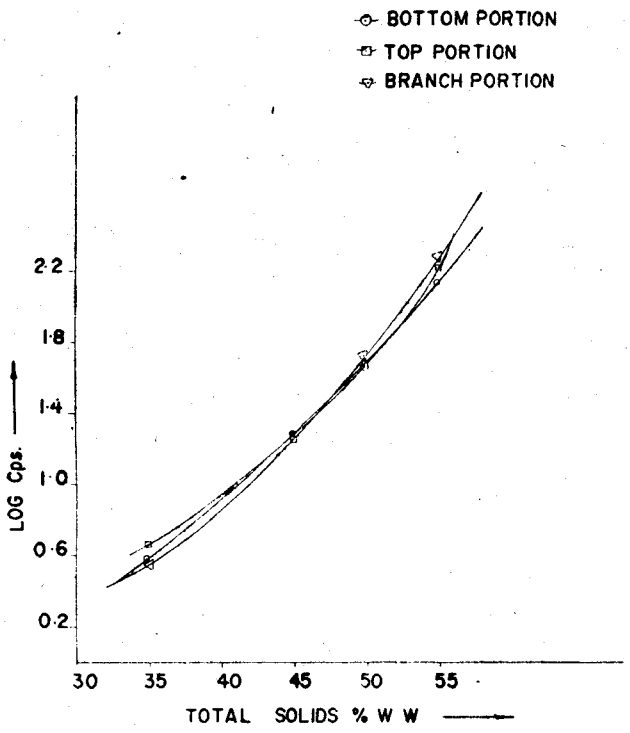


Fig. 23. Viscosity—Total Solids Relationship of Terminalia tomentosa (Lops And Tops) Black Liquor.

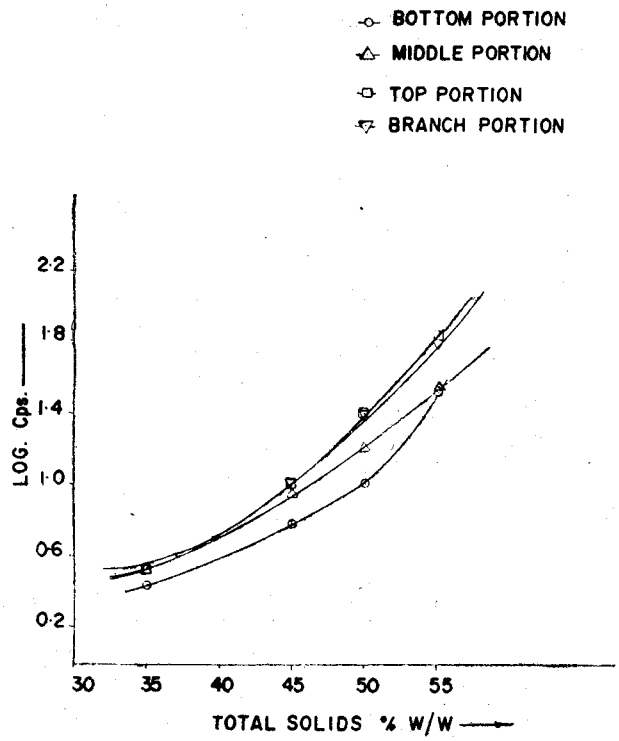


Fig. 24. Viscosity—Total Solids Relationship of Anogeissus latifolia (Lops and Tops) Black Liquor.

which could be reduced considerably by utilizing better washing technique. It is further seen from Table–VIII, that optimum chlorine requirement of the pulp decreased with decrease in Kappa number, the latter being achieved only by better pulp washing. Data recorded in Table–IX show that by treating the pulp with sodium hydroxide solutions, Kappa number could be further lowered. This effect was more pronounced in case of treatment of pulp with 1% NaOH compared to treatment with 0.1% NaOH.

TABLE—VII

PULPING DATA OF TERMINALIA TOMENTOSA

Sl. No.	Particulars	I	II	III
1.	Unscreened pulp yield, %	42.1	43.5	43.1
2.	Screen rejects, %	0.1	0.4	0.4
3.	Kappa Number	45.0	37.5	35.7
4.	**Black liquor**			
	(i) pH	11.2	—	—
	(ii) Total solids, % w/w	20.69	—	—
	(iii) Residual A.A. as Na_2O, gpl (at 200 gpl solids)	5.71	—	—

Washing treatments:

(i) Normal washing with cold water.

(ii) Hot washing after draining off the black liquor from the pulp in the beginning.

(iii) Hot Washing after boiling the Pulp along with diluted black liquor.

TABLE—VIII

STUDIES ON CHLORINE DEMAND OF TERMINALIA TOMENTOSA PULP

Pulp	Kappa number	Optimum chlorine demand (%)
I	45.0	11.20
II	37.5	10.05
III	35.7	9.30

TABLE—IX

EFFECT OF ALKALI TREATMENT ON KAPPA NUMBER OF THE PULP

Particulars	I		II		III	
	Before	After	Before	After	Before	After
1% Sodium hydroxide treatment						
Kappa number	45.0	30.8	37.5	28.8	35.7	28.0
0.1 % Sodium hydroxide treatment						
Kappa number	45.0	37.8	37.5	33.4	35.7	32.0

TABLE—X

ANALYSIS OF TERMINALIA TOMENTOSA PULPS

Sl. No.	Washing temperature °C	Kappa number —	1% NaOH solubility %	Klason lignin %	Acid soluble lignin %
1.	30	45.8	11.03	13.02	0.70
2.	80	37.9	9.50	7.90	0.68
3.	120	38.6	7.60	6.53	0.80

EFFECT OF TEMPERATURE ON PULP WASHING : Experiments were conducted to study the effect of temperature on pulp washing. Three cooks of *Terminalia tomentosa* were again carried out under identical conditions and the pulps were washed in the following manner :

(i) After draining off the black liquor, the cooked chips were treated with water at 30 °C for 30 minutes then disintegrated at 30 °C, filtered and washed with water at 30 °C.

(ii) After draining off the black liquor, the cooked chips were treated with water at 80 °C for 30 min. then disintegrated at 80 °C, filtered and washed with water at 80 °C.

(iii) After draining off the black liquor, 2 litres boiling water was added to the bomb and it was put back in oil bath and maintained at 120 °C for 30 minutes. (This includes 15 minutes to reach to 120 °C). At the end of this period, the pulp was disintegrated and washed with water at 80 °C.

A perusal of data recorded in Table–X reveals that by increasing the temperature of washing from 30 °C to 80 °C there is a considerable decrease in Kappa number. Alkali solubility and lignin content of the pulp were also lowered by increasing the washing temperature from 30 °C to 80 °C. On further increasing the temperature to 120 °C, no special advantage is observed with respect to Kappa number of the pulp.

From these investigations it can be concluded that by utilizing improved washing technique, pulps of lower Kappa number can be produced from *Terminàlia tomentosa* species.

CONCLUSIONS

1. Bleachable grade pulps in acceptable yields could be produced from Central India mixed hardwood composites of diameter classes 2 (11-30 cm.), 3 (31-50 cm.) and 4 (above 50 cm.) and forest composite, by cooking them with 17% active alkali as Na_2O at 170 °C.

2. The pulps when bleached by CEHH sequence attained brightness values varying from 74.7 to 78.1% Elrepho.

3. Pulp evaluation data revealed that the pulps produced from diameter class 4 composite were characterised by slightly inferior strength properties as compared to pulps from other composite samples. In all the cases the strength properties of the bleached pulps were lower than those of the corresponding unbleached pulp.

4. Black liquor studies show that forest composite black liquor can be concentrated without precipitation to higher solids content than the black liquors from diameter class composites.

5. Pulping studies on the lops and tops of five hardware species revealed that use of lops and tops in the hardwood mixture will not have significant adverse effect on the pulp yield, Kappa number, pulp strength characteristics and black liquor properties.

6. Washing studies carried out on *Terminalia tomentosa* pulp indicated that by utilizing improved washing technique pulps of lower Kappa number can be produced.

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