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# Purified Pulps from Bamboo for Cellulose Industries

## INTRODUCTION

Prehydrolysis sulphate process is an established method for the preparation of high alpha pulps from pentosan rich raw materials. The same principle has been applied on bamboo by various workers (1-5) using different medium and different conditions during prehydrolysis. Hydrochloric (1), sulphuric (2-3) and nitric acid (4) and water (4,5) have been tried. Pulps in yields of 24-38 per cent with an alpha cellulose content of 93-97 per cent and pentosans content of 8-2 per cent were prepared by most of these investigators. However, in many of the cases the values for silica were not reported. The exceptionally high silica content in bamboo presents a special problem when producing a rayon grade pulp. This silica persists even after the prehydrolysis, cooking and bleaching stages. The silica level obtained in bleached pulp is much above than which can be tolerated for dissolving pulps. Karnik (6,7) prepared pulps from *Dendrocalamus strictus*, using water prehydrolysis sulphate process and obtained a pulp with the ash content of 600 ppm and silica content of 20 ppm. Probably this is the lowest silica level obtained in a pulp from bamboo. The reason

*High Alpha cellulose (94-98%) pulps were prepared from bamboo (*Dendrocalamus strictus*) using prehydrolysis — sulphate process and multistage bleaching procedure. The unbleached pulp yield was ranging from 36-38 per cent and bleached yields from 34-36 per cent. Except for the high silica content (0.13%), the purity of the bleached pulps was high and the pulps may be considered suitable for nitrocellulose, rayon, carboxymethyl cellulose and for other cellulose industries. Water, acid and alkali were tried as the medium for prehydrolysis. During prehydrolysis rather severe conditions were employed to bring down the pentosan content to 3 per cent and below. This was required because of the higher amount of alkali resistant pentosans present in bamboo. Temperature of prehydrolysis and the time of prehydrolysis was found to be especially effective in pentosans removal.*

*Removal of the Zero fibre fraction indicated that sufficient amounts of silica could be removed and the silica content in + 200 fraction, after discarding 14 per cent fraction of the whole pulp, was only 0.04 per cent when compared to 0.13 per cent in whole pulp. However, in actual practice this fraction cannot be discarded altogether as the bleached pulp yield will be reduced considerably. A certain amount of fibre fractionation coupled with repeated vortex cleaning may be effective in lowering the silica content to the acceptable limit without diverting too much of the valuable fibre for the paper making or sewerage.*

could be partly found in the exceptionally low silica content of the bamboo used by him.

Although sufficient work has been reported on the preparation of rayon grade pulp from bamboo and one mill in Kerala is actually working with bamboo as the raw material, still the information is far from complete. In many cases inadequate information is available about the type and quality of material used and this might have contributed to differences in yield figures, bleachability and also the chemical characteristics. Differences could be also accounted for depending on whether the bamboos were used in fresh condition or subjected to storage and/or air dried. Also the chemical composition of bamboo reported by different investigators

shows considerable variation. The differences in the values for ash and silica are quite significant. Vyas (8) reported for *Dendrocalamus strictus* that it is the parenchyma cells, node annuli and epidermis cells which are rich in ash. The ash content of the epidermis cells was exceptionally high, 27.7 per cent and consisted of about 98 per cent silica. Differences in the ash content had been reported for the top and bottom internodes. In a separate study this has been corroborated by the work of Horio(3). This indicates that even the method of making the sample to be used for analysis can lead to differences. The general convention of using — 40 + 60 fraction entails the possibility of at least some of the parenchyma cells being not included in analysis

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and, therefore, may not give a good average for ash, silica and other constituents. For this and other reasons it was felt that a systematic investigation is required for the type of bamboo available and is grown in North Kanara district, for evaluating its suitability for dissolving pulp. The present study was carried out with this objective in mind.

## EXPERIMENTAL

(i) **Material used:** The *Dendrocalamus strictus* variety available in North Kanara forests was used. The mature bamboos cut in the forest, were brought to the mill and stored in a stack of suitable size. The bamboos were subjected to storage for 10 months during which period they were exposed to climatic variations prevalent in Dandeli. The stored and dried bamboos were used throughout the present investigation. However, for comparison an isolated prehydrolysis — sulphate cooking experiment was carried out with green bamboo chips as well. The bamboos were chipped in mill chipper and about 25 kg of chips of fairly uniform size were prepared, after discarding the over-size chips and dust. The chemical analysis was obtained after disintegrating the chips in a disintegrating mill till all the material passed through 60 mesh. The fraction retained on 80 mesh was used for analysis. Ash and silica values were determined on the whole powdered sample without subjecting to sieving. The results of the analysis are recorded in Table I.

ii) **Pulping equipment:** Prehydrolysis and cooking experiments were carried out in a rotary digester of 16 litre capacity, electrically heated, tumbling at 2 rpm and fitted with a stainless steel liner.

iii) **Prehydrolysis procedure:** Prehydrolysis studies were carried out using bamboo chips equivalent to 1.5 kg (O.D.) for

**Table I Proximate Chemical Analysis of Bamboo.**

(— 60 + 80 fraction).		
Cold water solubility	2.10	%
Hot water solubility	3.82	%
1% NaOH solubility	17.80	%
Alcohol-benzene (1:2) solubility	1.62	%
Water solubility after alcohol-Benzene leaching	2.64	%
Total pentosans	17.20	%
Lignin corrected for ash	25.62	%
Alpha cellulose * corrected for ash and resistant pentosans	45.89	%
Pentosans in alpha, basis bamboo chips	3.45	%
Ash	4.92	%
Silica	3.32	%

All values expressed on moisture free basis. The values for ash and silica are given for unfractionated sample.

\*Alpha cellulose was isolated from chlorite holocellulose. Chlorite holocellulose was prepared according to the method of Sen Gupta, A. B., Majumdar, S. K., and Mac Millan, W. G., Indian J. Appl. Chem. Vol. 21, No. 3, 1958.

**Table II Prehydrolysis of Bamboo chips**

Cook No.	1	2	3	4	5	6	7
	Water	Acid	Acid	Acid	Acid	Acid	Acid
H <sub>2</sub> SO <sub>4</sub> added on chips, %	—	0.4	0.6	0.8	1.0	0.4	0.6
H <sub>2</sub> SO <sub>4</sub> concentration gpl.	—	1.11	1.67	2.22	2.78	1.11	1.67
Time at max. temp. mts.	120	75	75	75	75	120	120
pH of prehydrolysed liquor	3.9	3.9	3.4	3.2	2.5	3.7	3.3
Prehydrolyzed chips yield, %	82.2	89.9	87.1	84.2	84.0	83.3	83.0
Pentosans in prehydrolysed chips, %	9.5	11.0	10.8	10.1	9.6	9.3	9.3
Pentosans basis bamboo chips %	7.80	9.89	9.40	8.50	8.06	7.73	7.72
Constant conditions: Moisture in chips % 10.8 liquor: chips 3.6 : 1. Max. temp. °C 170, time to get maximum temp. mts. 120.							

each experiment. Water, acid and alkali were investigated as the medium for prehydrolysis. For acid prehydrolysis, effect of acid concentration, temperature and time was noted. In the first set of experiments (Table II) the digester at the end of treatment was relieved to 4 kg/cm<sup>2</sup> and the prehydrolysed liquor allowed to drain from the chips. The chips were given a wash with fresh water to remove residual acid, and then allowed to condition. The moisture content of the conditioned chips was determined and the yield calculated. A portion of the chips after

disintegrating was analysed for pentosan content, and the rest of the chips were used for kraft cooking. There was a time lag of about 24 hours between prehydrolysis and sulphate cooking of the prehydrolysed chips. In second set of experiments (Table IV) Kraft cooking was carried out immediately after draining the prehydrolysed liquor and giving the wash to the chips with a fixed quantity of water (O.D. weight of chips x 2 litres). The liquor to chips ratio was adjusted on the weight of the original bamboo chips.

iv) **Cooking procedure:** After the cooking was over the digester relieved to atmospheric pressure and the contents transferred to a disintegrator. The pulp was given a mild de-fibering action by the propellor of the disintegrator. The pulp was then centrifuged to a consistency of about 30 per cent. The pulp was granulated and weighed. A portion of the pulp was used for moisture determination from which the pulp yield was determined. The pulps were not subjected to any further cleaning (screening) operation and were analysed for ash, silica, pentosan (volumetric method T 223m-58) permanganate number and cuprammonium (1%) viscosity.

v) **Bleaching:** Bleaching of the pulps was carried out in plastic bottles and the temperature was controlled by a thermostatic bath. For each experiment 50 g pulp (dry basis) was used. All through the bleaching stages only condensate water was used. The amount of chemicals was adjusted according to the permanganate number of the pulps and by the viscosity desired in the bleached pulp. The bleached pulps were analysed for shrinkage during bleaching, brightness, viscosity, ash, silica, solubility in cold 10 per cent, 18 per cent sodium hydroxide and hot 7.14 per cent NaOH solubility. The pentosan content and alcohol benzene solubility of the pulps were also determined.

vi) **Preparation of Nitrocellulose:** A weighed amount of shredded or powdered pulp was treated with a mixed acid for a definite period and temperature. The ratio of cellulose to acid was maintained at 1:50. After the nitration period was over the contents were immediately transferred to a sintered glass funnel, where excess of acid was pressed out. Care was taken that no air is sucked in through the nitrocellulose mat. The nitrocellulose was then dumped in ice cold water and repeatedly washed with fresh changes of

**Table III Sulphate Cooking of Prehydrolysed chips.**

Cook No.	1	2	3	4	5	6	7
Yield of pulp on prehydrolysed chips. %	43.5	40.0	40.9	41.3	40.3	41.7	41.8
Yield of pulp on bamboo chips.	35.7	35.9	34.8	34.8	33.8	34.7	34.7
pH of spent liquor	12.1	12.0	12.3	11.8	11.9	12.3	12.3
A.A. as Na <sub>2</sub> O gpl	15.2	15.4	16.0	14.6	16.1	14.4	17.2
KMnO <sub>4</sub> No. (40 ml)	15.5	14.5	14.0	15.3	14.3	14.7	14.0
Pentosans, %	2.82	3.8	3.0	2.2	2.0	2.50	2.10
Ash %	1.86	1.92	1.78	1.78	1.56	1.76	1.73
Silica, %	1.03	1.30	1.28	1.18	0.98	1.18	1.03
Tappi Viscosity cP 61	75	59	61	57	50	51	
% silica removed during prehydrolysis and cooking	88.9	87.7	86.6	87.6	90.0	87.6	89.2
Constant conditions:							
Moisture in prehydrolysed chips, %						46 — 48	
Liquor : chips (on prehydrolysed)						4 : 1	
Chemicals % (NaOH + Na <sub>2</sub> S)						26	
Maximum temperature, °C						166	
Time to get maximum temperature, mts.						90	
Time at maximum temperature, mts.						120	
Concentration of chemicals, gpl						65	

water. The nitro cellulose was further stabilised by boiling for about 8 hours in 0.02 per cent sodium carbonate solution. After the desired stabilisation, the nitrocellulose was dehydrated with alcohol. It was kept in this wet condition and only then analysis was done the samples were dried. The nitrogen content was determined by the Devarda-Alloy method.

vii) **Preparation of Carboxymethyl-cellulose:** The carboxymethyl cellulose was prepared by the wet process (Suspension method). The pulp was first powdered and then suspended in 95 per cent ethyl alcohol (pulp to liquid 1:16). The whole thing was well stirred (temp. 30°C) and then caustic soda solution (30 per cent w/w. cellulose to NaOH 1:1.26) was slowly added to the slurry while maintaining the temperature at 20°C. The slurry was held at this tempe-

ture for 30 minutes. The solid monochloro acetic acid (cellulose to acid 1:1.2) was then slowly added and after the addition was complete, the whole mixture was kept at 20°C for another 30 minutes. The temperature was then slowly raised to 55°C and the mixture kept stirred at 55°C for 5 hours. The surplus liquor was then pressed out and the cake of sodium carboxymethyl cellulose was allowed to dry in the air.

## RESULTS AND DISCUSSION:

The results of the analysis in Table I will show that the bamboo had an alpha cellulose content of 46 per cent and lignin content of 25.6 per cent. In this respect it resembles soft woods closely whereas the high pentosan content (17.2%) is typical of hardwoods. The ash and silica content is exceptionally high. The amount of alkali

**Table IV Prehydrolysis SulphateCooking of Bamboo Chips**

COOK NO. Prehydrolysis medium	8 Water	9 Water	10 Acid	11 Alkali	12 Acid	13 Acid	14 Acid	15* Acid
Medium : chips	3.6:1	3.6:1	3.6:1	3.6:1	3.6:1	3.6:1	3.6:1	3.6:1
H <sub>2</sub> SO <sub>4</sub> /NaOH added on chips %	—	—	0.2	0.2	0.8	0.8	0.8	0.8
Concentration of H <sub>2</sub> SO <sub>4</sub> /NaOH gpl	—	—	0.6	0.6	2.22	2.22	2.22	2.22
Max. temp. °C	170	170	170	170	160	160	160	160
Time to get max. temp. minutes	120	120	120	120	90	90	90	90
Time at max. Temp. mts.	120	120	120	120	150	150	150	150
pH at end of prehydrolysis	3.9	3.9	3.6	4.0	3.3	3.3	3.3	3.3
<b>Cooking :</b>								
Chemicals % (NaOH + Na <sub>2</sub> S) on original bamboo chips	22	24	24	24	24	24	24	24
Sulphidity, %	25	25	25	25	25	25	20.4	20.4
Max. temp. °C.	170	170	170	170	175	164	164	164
Time to get max. temperature mts.	75	75	75	75	75	60	60	60
Time at max. temp. mts	120	120	120	120	120	180	150	150
Liq: chips (on original)	4:1	4:1	4:1	4:1	4:1	4:1	4:1	4:1
Yield % (on bamboo chips)	36.2	35.7	35.9	36.20	35.0	38.0	37.5	34.3

\* Green bamboo chips.

Moisture in green bamboo chips %30 (Cook No. 15)

Moisture in chips (Cook No. 8—14). 10.8%

**Table V Analysis of Prehydrolysed Sulphate Pulps**

COOK NO	8	9	10	11	12	13	14	15
KMnO <sub>4</sub> No. (40ml)	15.3	13.0	13.0	13.0	12.9	14.8	14.7	10.0
Pentosans %	3.32	3.40	2.90	4.10	2.75	3.0	3.0	2.5
Viscosity, cP	50	38	36	32	45	51	52	50
Ash, %	1.57	1.64	1.62	1.68	1.73	1.72	1.71	1.58
SiO <sub>2</sub> , %	0.86	0.75	0.87	0.85	0.87	1.07	0.85	0.48
% silica removed during prehydrolysis and cooking	90.7	91.9	90.6	90.8	90.8	87.6	90.4	—

resistant pentosans is also pretty high which dictates that severe conditions of prehydrolysis may be required to bring down the pentosan content to 3 per cent and below.

The effect of some of the prehydrolysis variables (Table II) such as the acid concentration and time of prehydrolysis, under constant conditions of cooking, on the final properties of pulps is given in Table III. It could be seen that as the acid concentration was increased from 1.11 gpl to 2.8 gpl (time at max. temp.

75 min.) the yield of prehydrolysed chips dropped from 90 per cent to 84 per cent and the extent of pentosans removal was increased to 55.7 per cent from 45.7 per cent (Fig. 1). This difference was finally reflected in the pentosan content of the pulps also. Seeing the conditions of prehydrolysis used for cook Nos 6 and 7 (Table II) and comparing them with those for cook Nos 2-5 (Table II), and the final properties of the pulps, it could be inferred that low acid concentrations (1.11—1.67 gpl)

with longer time of prehydrolysis (120 mts) exerts greater beneficial action with respect to the pentosans removal and keeping the unbleached pulp yield. It appears that the time of prehydrolysis is important, probably because with longer times of prehydrolysis, the accessibility of the liquid to solid surface is increased resulting in the greater removal of the hemicelluloses. This will be an important consideration especially with dried bamboo. The above reasoning is further substantiated

by the fact that even by using water prehydrolysis (cook No. 1) greater removal of pentosan was obtained than by using 0.4 and 0.6 per cent acid on chips, only because of the differences in time of prehydrolysis. This indicates that it may be preferable with dried bamboo chips to use low acid concentrations and longer time of prehydrolysis to achieve greater removal of non-cellulose carbohydrates.

It could be also seen that most of the prehydrolysed sulphate pulps are rich in ash and silica. The ash and silica content in unbleached pulps is about 1.7 per cent and 1.0 per cent respectively. No significant changes in the ash and silica content of the prehydrolysed sulphate pulps were observed over the range of sulphuric acid concentration investigated for prehydrolysis treatment.

More studies were made to study the effect of some other prehydrolysis variables on the final properties of pulps. It could be seen from Table IV that by reducing the temperature and increasing the time of prehydrolysis (cook No. 13 and 14) the yield of prehydrolysed sulphate pulp improved by about 1.5 per cent. For these cooks cooking temperature was also not very high. However, when the cooking temperature was increased to 175°C (cook No. 12) the yield of pulp dropped again. With green bamboo chips applying the same conditions of prehydrolysis and cooking as used in cook No. 14, a pulp with low permanganate number and low pentosan content was obtained. The yield of pulp was also low which indicated that conditions of prehydrolysis — cooking for green bamboo chips should not be the same as those used for dried and seasoned bamboo.

In order to compare the efficiency of sulphuric acid and sodium hydroxide during prehydrolysis, for pentosans removal, experiments were carried out

using 0.2 per cent acid on chips (cook No. 10) and also 0.2 per cent NaOH on chips (cook No. 11), the other conditions of prehydrolysis and cooking were maintained constant. The characteristics of the two pulps compare quite favourably except for the pentosan content. With acid prehydrolysis the level of pentosan in pulp (2.9%) was slightly on the lower side, when compared to an alkali hydrolysed pulp (4.1%). Also for the similar conditions of prehydrolysis and cooking, acid hydrolysis (cook No. 10) was better than water (cook No. 8 and 9), from the point of view of greater reduction in pentosan content and no adverse effect on yield and other properties of pulp. However, it may be stated that this is true because the conditions of acid hydrolysis used were quite mild. Bleaching studies were made on few of the pulps and the bleaching conditions used are given in Table VI. The total bleach consumption, shrinkage during bleaching, and the yield of bleached pulps was determined and the results are given in Table VII. It could be seen that the total bleach consumption for all types of pulps was approximately 6.0 per cent except for the pulp prepared from green bamboo chips where the consumption was only 3.8 per cent, obviously because of the low permanganate number. Further, it could be seen that under the conditions of bleaching studied no appreciable difference was found in the brightness of pulps. However, it is interesting to see from Table VIII, that variations in the bleaching sequences and the amounts of chlorine consumed in first hypochlorite stage has brought about greater changes in the hot 7.14 per cent NaOH solubility of the bleached pulps. The alpha cellulose content was also found to vary but the differences were not significant. The maximum level of alpha cellulose which could be at-

tained was 98 per cent and this was containing only 1.14 per cent pentosans. The ash and silica content in bleached pulps were found to vary very little,

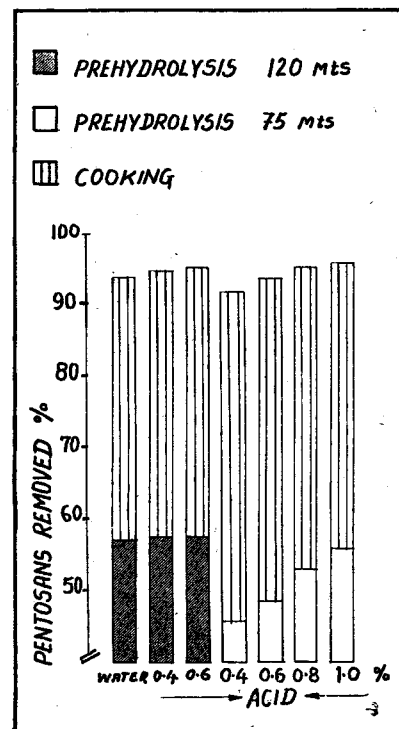


Fig 1 Effect of the amount of Acid added and the time of prehydrolysis at max. temp, on the removal of pentosans during prehydrolysis and cooking.

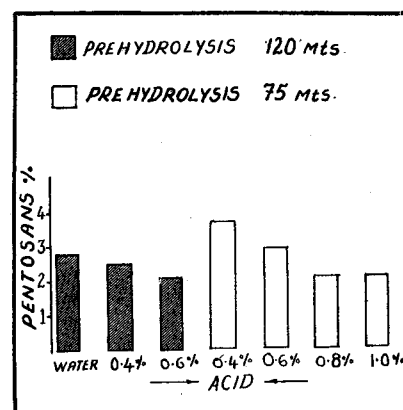


Fig 2 Effect of the amount of Acid added and the time of prehydrolysis at max. temp on the pentosan content of unbleached pulps.

Table VI Bleaching of Pulps

Cook No. Bleaching sequence	10 CEDHEH	10 CEHEDH	13 CEHDED	13 CE(C+NaOH) HD	14 CEH- DED	15 CEHDED
<b>Chlorination</b>						
Cl <sub>2</sub> added, %	3.76	3.76	4.25	4.25	4.25	2.50
Cl <sub>2</sub> consumed, %	3.50	3.50	4.00	4.00	4.00	2.50
<b>Alkali extraction I</b>						
NaOH added, %	2.0	2.0	2.5	2.5	2.5	2.0
Final pH	11.4	11.4	11.0	11.0	11.1	11.1
<b>Hypochlorite I</b>						
Cl <sub>2</sub> added, %	1.5	1.5	1.7	0.5	1.50	1.00
Cl <sub>2</sub> consumed, %	0.80	1.48	1.61	0.36	1.24	0.78
Final pH	10.5	10.0	9.2	10.5	10.8	10.9
<b>Hypochlorite II</b>						
Cl <sub>2</sub> added, %	0.5	0.5	—	—	—	—
Cl <sub>2</sub> consumed, %	0.25	0.25	—	—	—	—
Final pH	9.1	9.1	—	—	—	—
<b>Chlorine dioxide I</b>						
Cl <sub>2</sub> added, %	1.5	1.5	0.5	0.8	0.6	0.5
Cl <sub>2</sub> consumed, %	1.42	0.75	0.42	0.54	0.42	0.37
Final pH	4.0	4.1	4.5	4.6	5.1	5.0
<b>Chlorine dioxide II</b>						
Cl <sub>2</sub> added, %	—	—	0.40	—	0.3	0.3
Cl <sub>2</sub> consumed, %	—	—	0.30	—	0.18	0.19
Final pH	—	—	4.5	—	5.2	5.2
<b>Alkali Extraction II</b>						
NaOH added, %	1.0	1.0	0.6	—	0.6	0.6
Final pH	11.5	11.4	11.0	—	11.0	10.9
<b>CONSTANT CONDITIONS</b>	<b>SODIUM HYPOCHLORITE</b>		<b>CHLORINATION + CAUSTIC NEUTRALISATION</b>			
<b>Chlorination :</b>	Consistency, % 5		Consistency, % 4			
Consistency, % 3	Temperature, °C 40		Temperature, °C 30			
Temperature, °C 30	Time, Min. 120 I.		Cl <sub>2</sub> added, % 1.7			
Time, min. 60	Time, min. 60 II.		NaOH added after 1 min. 1.8			
<b>EXTRACTION</b>	<b>CHLORINE DIOXIDE</b>		<b>SO<sub>2</sub> Treatment</b>			
Consistency, % 5	(NaClO <sub>2</sub> + CH <sub>3</sub> COOH)		Consistency, % 2			
Temperature, °C 75 I Alkali	Consistency, % 5		Temperature, °C 28			
Time, min. 90	Temperature, °C 70		SO <sub>2</sub> added, % 0.5			
Temperature, °C 65 II Alkali	Time, min. 90 I		Final pH 5.4			
Time, min. 60	Time, min. 120 II		Time, min. 15.			

## Composition of Mixed acid

Physical form of pulp	HNO <sub>3</sub>	H <sub>2</sub> SO <sub>4</sub>	H <sub>2</sub> O	Ratio of cellulose: Acid	Time mts.	Temp. °C	Nitrogen content %	Yield %
1	2	3	4	5	6	7	8	9
Shredded	64.56	24.65	10.79	1 : 50	60	30	11.75	142
Powered	68.02	25.28	5.70	1 : 50	30	30	12.50	154

Table VII Bleaching Data

COOK NO. Bleaching sequence	10 CEDHEH	10 CEHEDH	13 CEHDED	13 CE(C+NaOH) HD	14 CEHDED	15 CEHD- ED
Total Cl <sub>2</sub> consumed, %	5.97	5.98	6.33	6.40	5.84	3.84
Cl <sub>2</sub> consumed in chlori- nation and hypo- chlorite stages, %	4.55	5.23	5.61	5.86	5.24	3.28
Av. Cl <sub>2</sub> consumed (added as NaClO <sub>2</sub> + CH <sub>3</sub> COOH) %	1.42	0.75	0.72	0.54	0.60	0.56
Shrinkage during bleaching %	5.2	4.4	5.3	6.0	6.0	3.5
Yield of bleached pulp on bamboo chips %	34.0	34.4	36.0	35.7	35.2	33.1

Table VIII Analysis of Bleached Pulps

Cook No. Bleaching sequence	10 CEDHEH	10 CEHEDH	13 CEHDED	13 CE(C+NaOH) HD	14 CEHDED	15 CEHD- ED
Tappi viscosity, cP	12.5	12.0	12.0	13.0	15.0	20
Brightness, %	86	85	86	85	85	85
Ash %	0.20	0.17	0.18	0.16	0.20	0.18
Silica, %	0.11	0.12	0.15	0.13	0.13	0.13
R %	96.97	96.26	94.24	94.60	95.96	98.0
R10 %	94.27	93.74	92.34	93.36	94.17	96.36
R18 %	97.60	97.43	97.23	97.17	97.62	98.27
S10—S18 %	3.43	3.69	4.89	3.81	3.35	1.91
Pentosans, %	3.0	—	2.80	—	2.96	2.51
Pentosans in alpha R %	1.43	1.40	1.41	1.44	1.41	1.14
EtOH : C <sub>6</sub> H <sub>6</sub> solubility (1:2), %	0.12	0.13	0.10	0.12	0.14	0.27
7.14 % NaOH solubility, %	6.83	9.98	14.15	10.88	9.19	5.88

Table IX Fibre Fractionation of Bleached Pulp

Silica in bleached pulp, %	0.13
Yield of fibre over 200 mesh, %	86
Silica in + 200 fraction, %	0.046
Silica basis original pulp, %	0.039
Yield of — 200 fraction, %	14
Silica in — 200 fraction, %	0.62
Silica basis original pulp, %	0.087

because of variations in conditions of bleaching. However, during bleaching silica dropped from 1 per cent to 0.13 per cent an appreciable reduction, but decidedly insufficient.

From the results of analysis given in Table VIII it could be seen that high grade dissolving pulps suitable for conversion to nitrocellulose, rayon, carboxymethyl-cellulose etc. have been obtained. Except for the ash and silica content which was determined to be higher than the limit specified for dissolving pulps, the pulps meet most of

the specifications required for dissolving pulps. The pulps were actually converted to nitro-cellulose and carboxymethyl cellulose. The conditions used for preparing nitrocellulose are given below. Bleached bamboo pulp (cook No. 10) was used for this purpose.

The carboxymethyl cellulose which was prepared under the conditions described in experimental part was having the degree of substitution of 0.5. The very fact that both the nitrocellulose and carboxymethyl cellulose could be prepared from pu-

rified bamboo pulp further supports that these pulps are amenable for conversion to cellulose derivatives.

#### Desilication of Bamboo pulp:

In order to reduce the silica content, a bleached pulp (cook No. 14) was subjected to fibre fractionation. The zero fibre fraction (-200) which consisted mostly of the parenchyma cells was removed. It will be seen in Table IX that the silica content by fibre fractionation dropped from 0.13% to 0.046% (+200 fraction), a significant reduction. However, there was a loss of about 14% of useful material which, if discarded, entirely will lower the bleached pulp yield by about 4.9%. The actual bleached pulp yield will then be as low as 30.3% compared to 35.2% for the unfractionated pulp. This suggests that the quantity of the zero fibre fraction to be discarded should be reduced, without impairing the effectiveness of silica removal. This could be achieved through limited fibre fractionation coupled, with repeated vortex cleaning.

#### CONCLUSIONS:

- (1) High grade pulps can be obtained from bamboo either by water or acid prehydrolysis — sulphate cooking and followed by a multistage bleaching procedure. The unbleached pulp yield ranges from 36—38% and bleached pulp yield from 34—36%.
- (2) Pulps with brightness of 85—86%, containing 94—98% alpha cellulose, 3% pentosans and 0.13% silica were obtained using acid prehydrolysis.
- (3) For efficient lowering of pentosans the time of prehydrolysis appears to be quite important especially with dried bamboo chips.
- (4) The silica content of the bleached pulps was much higher than which can be tolerated in rayon pulps. This indicates that other methods which may include both the chemical and mechanical are to be investigated to bring down the silica content to acceptable limits.

- (5) Purified pulps could be converted and used for acceptable quality nitro-cellulose, viscose, and carboxymethyl cellulose manufacture.

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