Dissolving Pulp from Bamboo

Masao HORIO and Michihiro TAKAHAMA*

(Horio Laboratory)

Received August 19, 1958

The fundamental researches and a semi-commercial scale tests by the prehydrolysis-sulfate process were carried out on manufacturing dissolving pulp from the bamboo. The prehydrolysis at 170°C for 1hr. with an addition of 1% H_2SO_4 followed by sulfate cooking with 25% cooking liquor at 170°C for 1hr. is optimum. Multi-stage bleaching process including chlorin dioxide processing is recommendable. The total yield is about 25%. This pulp has high α cellulose content, and low pentosan content. This investigation has convinced us of the success in producing dissolving pulp of high quality from the bamboo on economical base.

INTRODUCTION

We are the first to discover and publish how to manufacture dissolving pulp by sulphate process, whereby we could obtain pulp of high α-cellulose content from hard wood and resinous soft wood. This invention was realized as early as 1943. This new process was industrialized with great success in 1952 by the Nippon Pulp Co., Ltd. with close connection with us. The capacity of the plant (Yonago Mill of the campany) is 30,000 tons per year. There are further plans of manufacturing dissolving pulp by this new sulphate process.

Recently, we happened to know that some Southeast Asian countries were interested in producting dissolving pulp from bamboo, and we were asked to help developing of pulp industry in those countries by applying thereto our new process. Along this line, we started a series of further investigation on the process. Being a dissolving pulp for rayon industry, the pulp thus produced should be tested for formation of rayon filaments. We have proceeded experiments on rayon filaments formation and also on weaving and dying properties of the filaments.**

The present report deals with the the results obtained from the tests carried out in laboratory scale and in semi-commercial scale.

PART I. FUNDAMENTAL RESEARCH

1. Chemical Composition of the Bamboo

The bamboo used in the present experiments has an average diameter of 34 mm. It is solid up to about one meter from the root and the hollow space

* 堀尾正雄, 高浜通博

** On this occasion we thank for the cooperation shown by the Teikoku Rayon Co., Ltd.

Table 1. Chemical composition of the bamboo.

Components (%) \ Part	Root	Top	Middle	
			Outside	Inside
Water*	8.98	8.58	9.72	10.80
Ash	1.79	2.25	3.75	1.46
Alcohol-benzene extracts	2.11	5.11	7.07	6.29
Pentosa	17.18	18.69	16.89	16.20
Yield of holo-cellulose	72.65	73.43	76.30	76.00
α-Cellulose in holo-cellulose	70.09	67.49	64.70	62.30
Pentosan in α-cellulose	22.83	23.01	21.25	19.63
Lignin	28.01	25.14	26.03	20.85

* Abnormally small water content would be due to the drying during transportation.

Table 2. Composition of ash.

SiO_2	65.9%
K_2O	18.9〃
MgO	9.7〃
CaO	3.7〃
Oxides of Fe, Mn, Cu, P	Slight
Oxides of Sr, Al	Trace

starts to appear and becomes larger toward the top. The thickness of the wall at the top is about 10 mm. Table 1 shows the chemical composition of the bamboo.

The bamboo was found to have a chemical composition similar to that of hard wood. However, it should be noted that the bamboo has enormously high alcohol-benzene extracts. The difference in chemical composition in various parts of the bamboo is very slight as shown in Table 1. The ash content of the bamboo is also greater than that of the wood. The main constituents of the bamboo ash are silicates as shown in Table 2.

About 66% of ash is silicates, of which about 12% is dissolved during the prehydrolysis process, about 85% during the sulphate cooking, and the remaining 3% stays in the unbleached pulp. Because of the relatively high silicates content in the black liquor, some consideration may be necessary on recovering the black liquor in the commercial scale operation.

2. Microscopic Structure of the Bamboo

Microscopic observations of the structure of the bamboo were made by examining the cross, tangential and radial sections. Figs. 1, 2 and 3 show the respective section. Fig. 1 shows the interfascicular bundle surrounded by parenchyma. The structure is quite different from that of the wood. As can be seen in Figs. 2 and 3 parenchyma, vessels and prosenchyma are ranged longitudinally. In case of the wood, the parenchyma forming the medullary rays run crosswise to the fiber cells arranged in the longitudinal direction, but

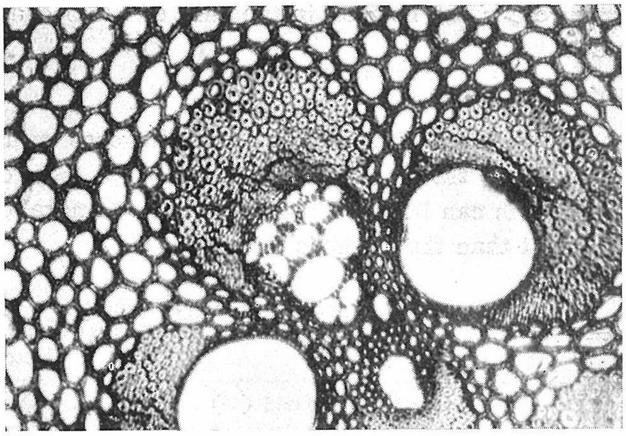

Fig. 1. Cross section of bamboo.

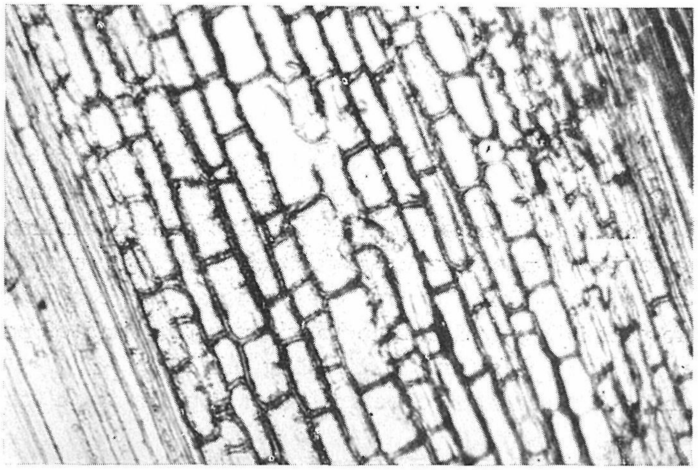

Fig. 2. Radial section of bamboo.

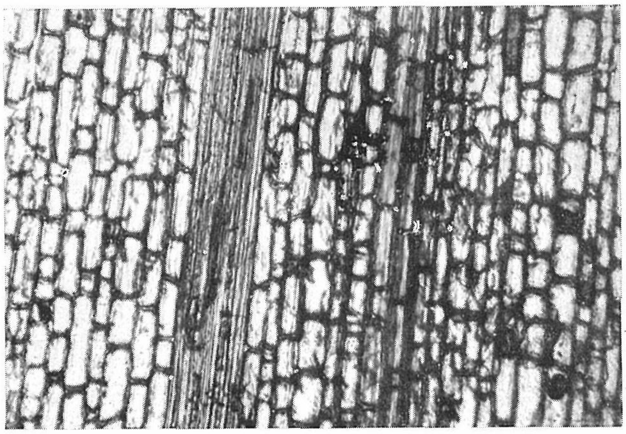

Fig. 3. Tangential section of bamboo.

such network structure can not be seen in the case of bamboo as parenchyma and fiber cells run in parallel.

3. Prehydrolysis of the Bamboo

Chips were cooked with water at 160°C as was the case with the wood before they were subjected to the normal sulphate cooking. The results obtained are shown in Table 3. As can be seen in the table, the removal of pentosan in bamboo is more difficult than that in beech.

Table 3. Removal of pentosan in prehydrolysis.

Prehydrolysis time (hr)	Bamboo		Beech	
	Pentosan (%)	Yield (%)	Pentosan (%)	Yield (%)
0	18.69	100	21.73	100
1	17.98	83.7	18.51	88.1
2	15.01	80.6	13.31	78.6
3	11.64	78.2	10.91	77.0
4	9.58	73.6	9.94	75.9
2 (Node)	15.44	83.1		

In the case of bamboo chips it takes longer time for completion of prehydrolysis than in the case of wood chips. At 160°C, it takes three hours for bamboo chips, while one hour is sufficient for pine chips. Considering the time required to raise the temperature to 160°C, the total time needed for prehydrolysis of bamboo chips is too much longer from the commercial point of view. Therefore, it is highly desirable to shorten the time of prehydrolysis. A series of experiments was carried out along this line.

Table 4 and Fig. 4 show the effects of the chip size upon the removal of

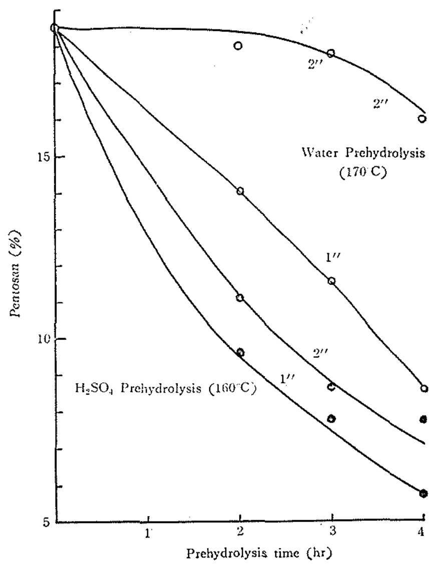

Fig. 4. Effects of chip size.

Table 4. Effects of chip size.

Chip Size	Medium	Temperature (°C)	Time (hr)	Yield (%)	Pentosan (%)
2″	Water	160	2	95.59	18.04
			3	95.16	17.74
			4	94.35	16.00
	H_2SO_4 1%		2	84.94	11.16
			3	81.64	8.63
			4	78.85	6.81
	H_2SO_4 2%		1	85.37	10.26
			2	80.16	7.02
			3	78.17	6.73
1″	Water	160	2	90.59	14.08
			3	89.17	11.52
			4	84.62	8.54
		170	2	83.31	8.07
			3	81.91	6.64
			4	80.44	4.97
	H_2SO_4 1%	160	2	82.80	9.60
			3	76.15	8.84
			4	75.50	5.66
		170	1	82.03	9.78
			2	78.66	6.65
			3	76.48	4.07

Chips were prepared by hand.

pentosan.

The smaller the chip size is, the higher is the efficiency of the removal of pentosan. The effect of chip size on prehydrolysis is more remarkable in the case of water-prehydrolysis.

In the case of water-prehydrolysis of the wood, the temperature should be lower than 160°C because of the condensation of lignin which makes the removal of lignin difficult in the following sulphate cooking process. This condensation of lignin is even more accelerated in the pressence of acid, therefore the temperature for acid prehydrolysis should usually be kept at 120°C, lower than that for water-prehydrolysis.

However, the behaviour of lignin in the bamboo was found to be entirely different from that in the wood, that is, the rate of condensation during the prehydrolysis process appeared to be very slow.

Based on these experimental results obtained in the case of wood, we have carried out a number of preliminary experiments on the prehydrolysis of the bamboo, and finally found a process especially suited for the bamboo. The process is to carry out the prehydrolysis at 170°C in the presence of sulfuric acid (1% of weight of chips). Under this condition no condensation of lignin occurred and the process did not affect cellulose at all, consequently the yield of pulp was kept very high. The discovery of this prehydrolysis process is undoubtedly one of the most important keys in industrializing the whole process.

Fig. 5 cleary shows the results of water and sulfuric acid prehydroysis.

Table 5 shows the effect of water content of chips ; no appreciable effect on prehydrolysis process was observed.

4. Sulphate Cooking of the Prehydrolyzed Bamboo

Table 6 and Fig. 6 show the results of the experiments on sulphate cooking using chips prehydrolyzed with water and with sulfuric acid respectively. Pentosan in unbleached pulp does not exceed 2%, that is less than that in ordinary sulfite dissolving pulp, and the the α-cellulose content is more than 97% in both cases. Judging from the values of permanganate number and the degree of polymerization of pulp, it can be seen that one hour is the proper time for

Table 5. Effect of water content of chips.

Chip size*	Medium	Temperature (°C)	Time (hr)	Yield (%)	Pentosan (%)
Dry	Water	160	2	90.27	12.99
			3	84.94	11.13
			4	83.79	9.45
		170	2	78.26	8.95
			3	75.65	5.32
			4	73.73	5.30
	H_2SO_4 1%	160	1	89.31	13.34
			2	83.87	9.07
			3	82.80	6.21
		170	1	80.27	10.70
			2	77.95	6.17
			3	75.27	4.05
Wet**	Water	160	1	91.90	16.60
			2	89.71	14.72
			3	86.25	11.61
		170	2	77.91	5.28
			3	76.02	5.10
			4	72.97	3.37
	H_2SO_4 1%	160	1	78.30	8.66
			2	74.69	6.81
			3	75.27	6.74
		170	1	77.91	8.21
			2	73.26	5.37
			3	72.60	5.06

* Chips were prepared by a chipper described above.

** Dipped in water over night.

Chip size is one inch long.

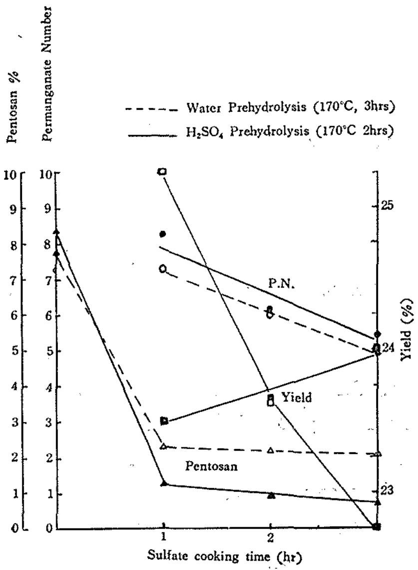

Fig. 5. Sulfate cooking.

Table 6. Sulphate cooking of prehydrolized bamboo.

Prehydrolysis	Sulphate Cooking: Cooling agent added for chips (%)	Tempe-rature (°C)	Time (hr)	Yield of un-bleached pulp (%)	Residue (%)	Analysis of unbleached pump: Perma-nagate number	Pento-san (%)	α-Cel-lulose (%)	Degree of Poly-meriza-tion
Medium : Water Temp. : 170°C Time : 3hrs. Pentosan content of prehydrolyzed chips : 7.87% Yield : 75.7%	25	165	1	24.5	1.20	9.07	2.16	98.2	1,010
			2	23.5	0.20	7.19	2.10	98.6	820
			3	23.3	2.00	6.34	2.03	98.1	657
	25	170	1	25.4	0.40	7.28	2.31	98.3	774
			2	23.7	0.80	6.00	2.20	97.7	617
			3	22.8	0.12	4.88	2.14	96.3	474
	22.5	170	1	26.1	0.90	10.54	1.99	98.0	1,007
	20.0		1	25.2	0.77	12.59	2.16	98.2	902
	17.5		1	24.8	1.10	14.20	2.01	97.6	812
Medium : 1% H_2SO_4 Temp. : 170°C Time : 2hrs. Pentosan content of prehydrolyzed chips : 8.40% Yield : 73.64%	25	165	1	24.3	0.35	8.93	1.14	96.6	734
			2	22.9	0.38	7.12	1.11	97.4	617
			3	24.9	None	5.89	0.93	96.4	504
	25	170	1	23.5	0.70	8.25	1.27	97.4	693
			2	23.7	0.04	6.15	0.98	97.4	487
			3	24.0	None	5.47	0.72	97.0	476
	22.5	170	1	23.7	0.12	8.79	1.06	97.9	833
	20.0		2	22.7	1.64	14.39	1.12	98.0	725
	17.5		3	24.3	1.56	12.09	1.14	97.4	730

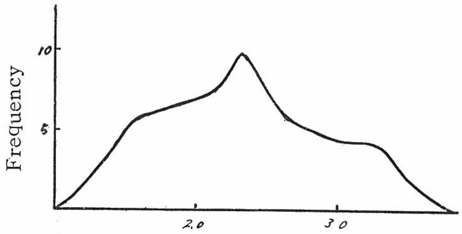

Fig. 6. Distribution of fiber length.

cooking in these cases.

The length of fiber is 2.2 mm on the average. Fig. 6 shows its distribution.

Freedom value (according to TAPPI) is 4.6. 0.1% slurry of pulp after filtered through nets of 40, 60, 80 and 100 mesh respectively and washed and the remained fiber on the filter shows the following results :

What passes through the net with 40 but is checked by 60 : 0.7%, what passes through the net with 60 but is checked by 80 : 0.4%, and what passed through the net with 80 but is checked by 100 : 0.19%.

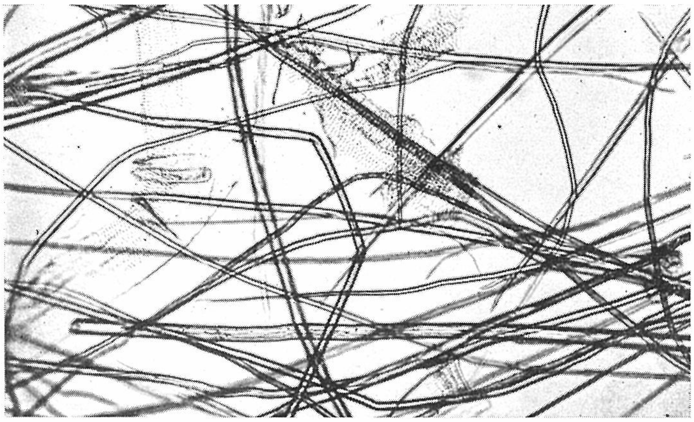

Fig. 7. Microscopic photo of bamboo fiber.

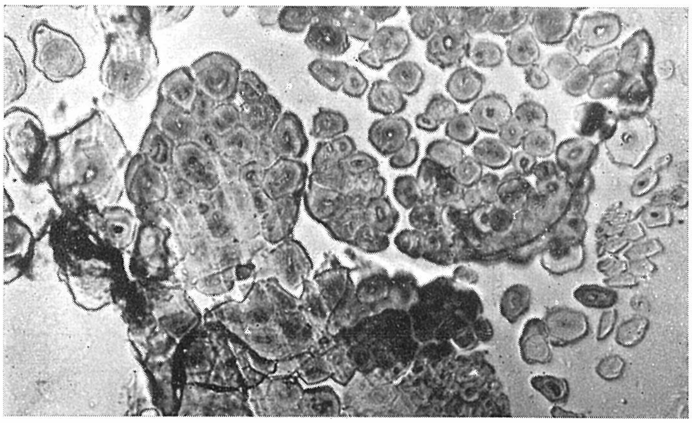

Fig. 8. Microscopic cross section of bamboo pulp (prehydrolysis with water).

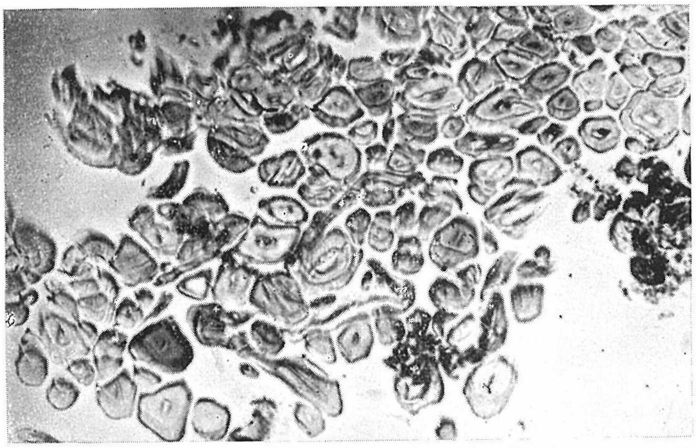

Fig. 9. Microscopic cross sections of bamboo pulp (prehydro with H_2SO_4).

Fig. 7 shows a microphotograph of the fiber of the bamboo pulp.

Fig. 8 shows a microphotograph of pulp made by the sulphate cooking in which the prehydrolysis is carried out with water and Fig. 9 shows that of the pulp obtained by the indentical method in which prephydrolysis, however, is carried out with an addition of 1% of H_2SO_4, and both pictures were taken

Table 7. Experimental conditions of multistage bleaching of bamboo pulp.

A)

	Stage	Consistency of pulp (%)	Added chemicals	Temperature (°C)	Time (hr)	pH
1	Chlorination	3.5	a . B*×0.8 b . B×0.6	20	0.5	>1.5
2	Extraction by NaOH	5.0	2% of pulp	65	0.5	—
3	Hypochlorite	5.0	a . B×0.2 b . B×0.4	40	1	<9.0
4	Extraction by NaOH	5.0	1% of pulp	65	0.5	—
5	Hypochlorite	5.0	1% of pulp	40	1	<9.0
6	Extraction by NaOH	5.0	1% of pulp	65	0.5	—
7	Hypochlorite	5.0	0.5% of pulp	40	1	<9.0
8	Extraction by NaOH	5.0	0.5% of pulp	40	1	<9.0

B)

	Stage	Consistency of pulp (%)	Added chemicals	Temperature (°C)	Time (hr)	pH
1	Hypochlorite	5	a . B*×0.8 b . B×0.6	30	1	<9.0
2	Chlorination	3.5	a . B×0.2 b . B×0.4	20	0.5	>1.5
3	Extraction by NaOH	5	2% of pulp	65	0.5	—
4	Hypochlorite	5	1% of pulp	40	1	<9.0
5	Extraction by NaOH	5	1% of pulp	65	0.5	—
6	Hypochlorite	5	0.5% of pulp	40	1	<9.0
7	Extraction by NaOH	5	1% of pulp	65	0.5	—
8	Hypochlorite	5	0.5% of pulp	40	1	<9.0

* B=P.N.×0.355×1.4×0.8.

after the pulp having been dyed in 0.05% Malchite Green. It is clear that Fig. 8 still shows an appreciable amount of pentosan (dyed part), whereas no pentosan is observed in Fig. 9, showing the greater removal of pentosan by the addition of H_2SO_4.

5. Bleaching of the Bamboo

In order to find out effective bleaching process, we have carried out experiments to compare two multistage bleaching processes, namely one with hypochlorite together with chlorine dioxide.

1) **Multistage Bleaching of Unbleached Bamboo Pulp,** Out of various combinations of multistage bleaching we took two representative processes as shown in Table 7.

Table 8. Analytical data of bleached pulp.

Method		Cosumption of chlorine (%)	Yield (%)	Pentosan (%)	α-Cellulose (%)	Degree of Polymerization	Whiteness (%)
A	a	5.09	93.2	1.58	97.3	668	75.5
	b	5.42	91.6	1.34	97.2	620	80.8
B	a	5.61	94.1	1.47	97.2	630	78.0
	b	6.11	93.6	1.62	97.4	634	80.8

Table 8 shows the experimental results. The chemical analysis of the unbleached pulp used in the experiment is as follows :

Permanganate Number	12.88
Pentosan	1.21%
α-Cellulose	97.6 %
Degree of Polymerization	1,050

As shown in Table 8, there has scarcelly been any appreciable difference between the two. In hyprochlorite bleaching it is hardly possible to raise whiteness over 80%.

2) **Multistage Bleaching together with chlorine dioxide.** For bleaching of sulphate pulp, the chlorine dioxide treatments are recently being adopted in commercial level especially to intensify whiteness. We investigated the chlorine dioxide treatment with the special purpose for improving the whiteness of the bamboo pulp.

The sample in Table 9 was obtained by removing lignin from the unbleached pulp by the chlorination and the extraction by NaOH, pulp consistency being 10% after the third stage.

When the pulp went through five-stage bleaching with hypochlorite, it attained whiteness at 83.1% ; on the other hand, when it was subjected to chlorine dioxide treatment in the sixth stage, the whiteness was improved up to 87.9% without any sign of cellulose degradation. In either case the result is far more satisfactory than the case in which the pulp is treated by multistage bleaching with hypochlorite alone. In this connection, special mention must be made

Table 9. Experimental condition and data of multistage bleaching together with chlorine dioxide.

		A	B	C	D	E	F	G	H
1	Chlorination	Consistency of pulp 5% Temperature 20°C Time 30min. Amount added PN×0.355×1.4×0.8×0.8							
2	Extraction by MaOH	Consistency of pulp 5% Temperature 20°C Time 30min. Amount Added 2% NaOH of pulp							
3	Chemicals	Hypochlorite						ClO_2	
	Amount added	PN×0.355×1.4×0.8×0.2						0.75	
	Temperature (°C)	40						70	
	Time (min.)	60						120	
4	Chemicals	NaOH		ClO_2	NaOH	ClO_2	NaOH	ClO_2	NaOH
	Amount added	1		1.25	1	0.75	1	0.50	1
	Temperature (°C)	70		70	70	70	70	70	70
	Time (min.)	30		120	30	120	30	120	30
5	Chemicals	$Ca(ClO)_2$	$Ca(ClO)_2$		$Ca(ClO)_2$	ClO_2	ClO_2		ClO_2
	Amount added				1.25	0.50	0.70		0.50
	Temperature (°C)	40	40		70	70	70		70
	Time (min.)	30	60		120	120	120		120
6	Chemicals		ClO_2				ClO_2		
	Amount Added		1.0				0.30		
	Temperature (°C)		70				70		
	Time (min.)		120				120		
Whiteness (%)		83.1	87.9	85.5	87.0	85.5	86.1	84.5	89.1
Degree of polymerization		700	730	970	940	820	900	970	800
α-Celluloses (%)		97.7	96.0	97.4	97.9	98.0	97.6	98.1	97.9

to the fact that, when the pulp is put through the combination bleaching of ClO_2-NaOH-ClO_2, the pulp becomes nearly as white as ordinary sulphate dissolving from wood. From these experimental data we have come to the conclusion that the chlorine dioxide treatment is decisively suited for the bamboo pulp.

PART II. SEMI-COMMERCIAL TESTS

After carrying out the fundamental expreiments as described in the previous part, we have started semi-commercial tests in our pilot plant, Horio Laboratory, the Institute for Chemical Research, Kyoto University, in order to obtain further information on the industrialization of this process.

The pilot plant has a capacity of 100 kg of chips per batch.

1. Chipping of the Bamboo

As shown in our fundamental experiments, the chip size does play an important role in the cooking process. Therefore, in order to obtain uniform quality of pulp, special attention must be paid to the chipping of bamboo. We have tested several chipping methods from the point of getting higher quality of chips as well as the economical point of view. The conventional chipping process, in which we split bamboo longitudinally by a pressing roller and cut them crosswise gives chips of satisfactory quality but because of the complicate processer it can not be applied economically. On the other hand, the ordinary chipper for wood does not give satisfactory results.

In order to obtain chips of higher quality with better efficiency, we have specially designed a chipper for the bamboo.

2. Preparation of Dissolving Pulp from Bamboo

Series (1). In order to determine the cooking conditions we have made several separate experiments. The prehydrolysis was carried out in two ways, one with water and the other with H_2SO_4, and the prehydrolysis time was found to be two hours for the former and one hour for the latter at the temperature of 170°C for both cases. Tabie 10 is a list of the experimental data.

Table 10. Semi-commercial tests I.

	Experimental No.	6	7	8	9	10
Prehydrolysis	Medium	H_2SO_4 1%			Water	
	Temperature (°C)	170°C				
	Time Required to Reach the Temperature (hr)	1				
	Time at the Temperature (hr)	1			3	
	Total Time (hr)	2			2	
Sulphate Cooking	Amount Added (%)	25				
	Liquor Ratio (kg/l)	4.5				
	Temperature (°C)	170				
	Time Required to Reach the Temperature (hr)	1.5				
	Time at the Temperature (hr)	1	2	3	1	2
	Total Time (hr)	2.5	3.5	4.5	2.5	3.5
Unbleached Pulp	Yield (%)	26.70	26.34	23.21	27.0	25.5
	Residue (%)	0.26	0.10	0.06	0.4	0.39
	Permanganate Number	10.07	7.23	5.72	10.77	8.98
	Pentosan (%)	2.06	1.46	1.33	3.31	2.48
Unbleached pulp	α-Cellulose (%)	93.10	97.3	96.8	98.7	98.0
	Degree of Polymerization	960	650	587	1,065	830
	α-Cellulose (%)	93.7	92.4	89.9	93.4	89.6
	α-Cellulose (%)	5.2	8.1	7.6	4.5	4.6
	α-Cellulose (%)	1.6	0.9	1.8	1.6	1.5
	Ash (%)	0.7	0.47	0.42	0.36	0.51
	Alcohol Benzene Extracts (%)	0.06	0.42	0.26	0.11	0.14
	Pentosan (%)	2.26	1.41	1.28	2.22	2.12
	Degree of Polymerization	500	430	420	515	460

As discussed in the previous parts, prehydrolysis of the bamboo with addition of H_2SO_4 gives excellent results, namely, higher efficiency in the removal of pentosan and higher yield.

For sulphate cooking, one hour was found to be optimum, giving permanganate number 10. The α-cellulose content of the bleached pulp thus obtained was 93.5% with the yield of 24-25%, and the yield of the unbleached pulp was 27-28%. Almost no residue was found in the cooking.

Series (2). We repeated the production of pulp according to the optimum conditions as determined is Series 1. The results are shown in Table 11.

The α-cellulose content of the unbleached pulp thus obtained was always between 97% and 98%, the average degree of polymerization was 700-800 and the pentosan content was less than 2%. In the bleached pulp showed the α-cellulose content was 93-94% and the average degree of polymerization was 500-600. The lower average degree of polymerization for bleached pulp is probably due to the degradation of cellulose by the attack of hypochlorite on bleaching. By chlorine dioxide bleaching we could expect over 97% of α-celluose. A small amount of alcoholbenzene extract and a traceable amount of ash were found in the pulp.

Table 11. Semi-commercial tests II.

	Experimental No.	11	12	13	14
Prehydrolysis	Medium	H_2SO_4 1%			
	Temperature	170°C			
	Time required to reach the temperature (hr)	1.0			
	Time at the temperature (hr)	2.0			
	Total time (hr)				
Sulphate Cooking	Amount added (%)	25%			
	Liquor ratio (l/kg)	4.5			
	Temperature (°C)	170			
	Time required to reach the temperature (hr)	1.5			
	Time at the temperature (hr)	1.0			
	Total time (hr)	2.5			
Unbleached Pulp	Yield (%)	27.8	27.43	28.26	27.52
	Residue (%)	0.26	0.23	0.26	0.25
	Permanganate number	8.55	10.00	9.66	9.70
	Pentosan (%)	1.38	1.58	2.36	2.28
	α-Cellulose (%)	98.0	97.80	98.5	98.2
	Degree of polymerization	870	971	1,170	1,120
Bleached Pulp	α-Cellulose (%)	93.9	93.7	93.6	93.2
	β-Cellulose (%)	4.6	5.5	5.5	4.7
	γ-Cellulose (%)	1.5	1.8	1.5	1.5
	Ash (%)	0.66	0.51	0.82	0.44
	Alcohol-benzene extracts (%)	0.12	0.09	0.17	0.11
	Pentosan (%)	2.13	1.97	1.74	2.14
	Degree of polymerization	500	640	504	570

Viscose prepared from the pulp obtained under this condition could be filtered as easily as those prepared from pulp obtained from pine or beech by the same process.

Series (3). We have made further tests for cutting down the time for prehydrolysis and sulphate cooking. The results in the case of 1/2 hour, prehydrolysis and 1/2 hour sulphate cooking are shown in Table 12. Under this condition, although the yield was increased by 1%, the *α*-cellulose content, the average degree of polymerization and the pentosan content were all aggravated, and viscose prepared from this pulp was found to be less filterable.

By these semi-commercial tests described above, we have confirmed the optimum condition under which the best quality of pulp from the bamboo is obtained at reasonable efficiency.

The only drawback is the presence of a little bit exessive ash in the dissolving pulp. This rather higher content of ash may be attributed to water used in the bleaching process and also, probably mainly, to the appreciable amount of ash in the original bamboo which is contained in its own composition and probably accumulated during the cutting and shipping operations. There is no need

Table 12. Semi-commercial tests III.

	Experimental No.	15	16	17	18	19
Prehydrolysis	Medium	H_2SO_4 1%				
	Temperature	170°C				
	Time required to reach the temperature (hr)	1.0				
	Time at the temperature (hr)	0.5				
	Total time (hr)	1.5				
Sulphate cooking	Amount added (%)	25				
	Liquor ratio l/kg	4.5				
	Temperature (°C)	170				
	Time required to reach the temperature (hr)	1.0				
	Time at the temperature (hr)	0.5				
	Total time (hr)	1.5				
Unbleached pulp	Yield (%)	28.72	29.3	28.56	28.80	28.95
	Residue (%)	0.40	0.30	0.26	0.28	0.31
	Permanganate number	10.57	13.50	10.79	12.16	12.63
	Pentosan (%)	3.09	2.91	2.26	2.55	2.14
	α-Cellulose (%)	97.9	97.9	97.8	97.3	98.4
	Degree of polymerization	1,270	1,490	1,190	1,280	1,270
Bleached pulp	α-Dellulose (%)	97.6	97.6	97.4	97.6	97.6
	β-Cellulose (%)	1.1	0.7	0.9	1.2	0.3
	γ-Cellulose (%)	1.3	1.5	1.1	1.1	1.9
	Ash (%)	0.50	0.29	0.23	0.45	0.43
	Alcohol benzen extracts (%)	0.24	0.30	0.12	0.05	0.13
	Pentosan (%)	2.74	2.86	2.06	3.55	3.10
	Degree of polymerization	940	1,000	1,000	900	900

of barking previous to the chipping as in the case of wood, but in order to remove the undesirable dirt from the bamboo, it may be suggested to wash bamboo in something like drum barker before chipping or to use some screener with centri-cleaner.

CONCLUSION

The results of the fundamental and semi-commercial tests for producing dissolving pulp from bamboo are summarized as follows :

(1) Prehydrolysis-sulphate process was used.

(2) For the prehydrolysis of bamboo, heating for one hour with addition of 1% H_2SO_4 at 170°C seems to be recommendable, although heating for two hours at 170°C with water gives the similar result.

(3) The optimum condition of sulphate cooking is one hour at 170°C with total alkali 25% against chips weight at the suffidity of 30%.

(4) Multistage bleaching process including chlorine dioxide processing is recommendable.

(5) The yield of bleached pulp by this process is 24-25%.

(6) The bleached pulp thus produced has high α-cellulose content and low pentosan content. Although rather high content of ash is observed in the pulp, it would be reduced by applying the methods suggested in this report.

REFERENCES

(1) M. Horio and Y. Fukuda, *J. Chem. Ind. Japan*, **46**, 1088, 1090, 1092 (1943); *ibid.*, **47** 127 (1944); Japan Patent, 157,964. Application Aug. 6, 1942, Issued Jul. 27, 1943.

(2) This Bulletin, **23**, 1 (1950).

(3) M. Takahama and V. P. Gohel, A study on a Semi-Commercial Basis of Rayon Grade Pulp (Kraft process) made from Bamboo, presented at the 53rd Semi-Annual Meating of the Institute on June 11th and 12th, 1955.