Studies on Semikraft Pulps from *Sasa senanensis*

Part I. Selection of the Cooking Conditions and Comparison with Birch and Larch Semikraft Pulps

By

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ササのセミ・クラフトパルプの研究 (第1報)

蒸解条件の選定と，シラカンバ，カラマツのセミ・クラフトパルプとの比較

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Introduction

It is well known that scarcity of pulpwood has recently been remarkable in Japan. The increasing demand of the wood is obliged to use a huge quantity of waste lumber and small-size wood for the production of pulp. In view of the situation, a big bamboo grass (*Sasa senanensis*) wildly grown abundantly in mountain recesses of Hokkaido, Japan, is considered a potential raw material for the pulp and paper industry. It is informed that total area of forest covered with *Sasa senanensis* amounts to about 700,000 ha, comprising some 60 tons per ha on an average in Hokkaido, according to Forestry Agency of Japan[16]. It is also shown that the bamboo is taken away now for afforestation at a vast cost. However, it grows and matures annually with a sufficient growth by choice of cold places.

Concerning the fundamental studies on *Sasa*, FUKUYAMA has presented the data pertaining to its value as a forest resoures[15),16),28),43)]. Many studies[10),11),17)~20),28),43),46),44)~46),48)] on chemical or physical properties of *Sasa* have been previously reported. The papers have shown that the composition of *Sasa* is similar to that of hardwood in the main components and that *Sasa* has a high specific gravity and a similar fiber length to hardwood. In regard to the *Sasa* pulps, several studies[8),9),12)~14),21),27),28),43)] have been also reported on alkaline, neutral sulfite semichemical and kraft processes and their properties. The results of these studies have revealed that *Sasa* may be easily cooked under some mild conditions, but the pulps are obtained in lower yield and give weaker strength than those of wood.

In a recent tendency of pulping, it may be said that many species of hardwood have been used on a large scale for the pulp production[2),3),24)~26),29),31),32),36)~39),41),52)], and that a kraft process has been expanding very rapidly along with NSSC process, because of the following advantages[4),5),35)]; (1) any species of wood and woody plant can be used, (2) cooking time is short, (3) high pulp

strength is obtained, (4) the recovery of spent liquor is relatively easy, (5) therefore, there are little pollution problems.

However, disadvantages of the pulping are shown in poor colour of the pulp and lower yield, especially in case of *Sasa* pulp, compared with conventional semichemical pulping.

In this point of view, semikraft (or kraft semichemical), pulping has been developed as improving method using several kinds of hardwood by some workers[33)~35),51)]. The purpose of the present study is to apply the semikraft method to *Sasa senanensis* on a laboratory scale and investigate the yield or chemical and physical properties of the pulps. The authors have already informed a few reports on this study[47),49),50)].

Instead of conventional kraft cooking of 18 to 23% active alkali[13),24),29),38)], a maximum charge of 15% was chosen in the investigation together with 10 and 5% alkali, employing cooking temperatures of 150, 160, 170, and 180°C at each concentration level. The other cooking factors were set down to general kraft procedure so that the effect of change of alkali charge and the temperature on yield and the properties of the pulps could be evaluated.

For comparison purposes, water cookings of the *Sasa* were carried out at each temperature, while white birch (*Betula platyphylla* var. *japonica*) and Japanese larch (*Larix leptolepis*) pulps were prepared under the same conditions and furnished for the same tests.

I. Samples

1. Locality and Form

The culms of *Sasa senanensis* used for the study were obtained from Teshio Experimental Forests of Hokkaido University, in August, 1964. Cutting area was 6.75 m², in which about 60 kg of the culm weight were produced (corresponding to 88.7 tons per ha). The size appeared medium for *Sasa senanensis*, since an average height was 3.3 m and diameter at butt end was 2.0 cm.

A white birchwood (*Betula platyphylla* var. *japonica*) used was together obtained at the same place. It was 36 years in age, 16.0 m in height and 23.0 cm in breast height diameter.

A Japanese larchwood (*Larix leptolepis*) used was obtained from Experimental Forest Tree Nursery in the Campus of the University, in August, 1964. It was 17 years in age, 11.1 m in height and 14.0 cm in breast height diameter.

2. Preparation of Chips and Chemical Composition

The culms of *Sasa* and these two kinds of wood barked were cut in a laboratory chipper and the chips were screened to the fine and oversize pieces. Samples of the screened chips were dried for a week so that the moisture content was reduced to about 10%, and packed in polyethylene bags.

The proximate chemical composition of 60 to 100 mesh fraction of the samples determined by standard procedures[7)] is shown in Table 1.

Table 1. Chemical composition of samples (%)

	Ash	Extractives with				Holocellulose	Cross & Bevan Cellulose	Total pentosan	Methyl pentosan	Lignin
		Cold water	Hot water	1% NaOH	Alcohol benzene					
Sasa	1.97	4.0	9.8	27.9	4.3	62.6	50.1	27.1	1.2	19.1
Birch	0.14	1.5	3.4	18.3	2.5	79.2	58.7	29.1	1.6	18.4
Larch	0.44	3.2	5.9	12.2	2.7	67.8	48.5	15.4	5.8	28.6

A comparison of the values obtained from the composition of these samples indicates that *Sasa* is rich in ash and extractives, and considerably similar in pentosan and lignin contents to the birchwood, or a hardwood. It may be stated that the chemical properties of the *Sasa* are common to those of general bamboo grasses or whole *Gramineae*.

II. Experiments

1. Cooking

Air-dried chips corresponding to 500 g of oven-dried were cooked in a 4-*l* laboratory stainless digester. Semikraft cooking liquors were made according to each condition by diluting a concentrated liquor prepared in advance, consisting of 50 g per liter of active alkali concentration as sodium oxide and 25% of constant sulfidity. The liquor to chip ratio was maintained at 3.0 for the *Sasa* and at 3.5 for the two kinds of wood. The cooking conditions chosen by the differences of active alkali charges to the chips and of cooking temperatures are shown in Table 2. Every cooking time to and at the temperature was always for 1 and 1.5 hr, respectively. No spent liquors were included in any digester charge.

The cooked chips were sufficiently washed on running water and dewatered in a centrifuge. The cooking yield was calculated by weighing the pulp and determining its moisture.

From a portion of the waste liquor, a final pH of cooking was measured

Table 2. Cooking conditions

Active alkali (%) / Cooking temperature (°C)	15	10	5	0
150	S, B and L	S	S	S
160	S, B and L	S, B and L	S, B and L	S
170	S	S, B and L	S	S
180	S	S	S, B and L	S

Note; S, *Sasa* B, birch L, larch.
Sulfidity, 25%, Liquor to chip ratio, *Sasa*: 3.0, birch: 3.5, larch: 3.5.
Cooking time to the temperature, 1.0 hr.
Cooking time at the temperature, 1.5 hr.

by a glass electrode pH-meter.

2. Defibration and Screening

The cooked chips were defibrated in a laboratory Sprout-Waldron 12-inch disc refiner equipped with 12527 A of plate pattern, in about 10% of chip consistency on moisture free base. Clearance between the plates was held at 0.1 mm in case of a defibration of the *Sasa* cooked-chips. The birch and larch cooke-dchips were defibrated by progressive multi-stage treatments with following clearance; the former was carried out with 0.4 and 0.1 mm, and the latter with 2.0, 0.6, 0.1 and 0.1 mm, succesively.

After defibration, the pulps obtained were also washed and dewatered in the centrifuge. The defibrating yield was similarly determined by above-mentioned, and the pulps were screened through 8-cut plate of a flat screen, and if there was any significant amount of rejects, they were again defibrated and then combined.

3. Chemical Analysis of Pulps[7]

The screened pulps were furnished for chemical analysis of main components after preparing their sheets and cutting them into small pieces.

Holocellulose; Oven-dried pulps of 2.5 g were treated with sodium chlorite and acetic acid by modified WISE'S method. Its treatment was repeated twice for the *Sasa* pulps, three times for the birch ones and four times for the larch ones.

Alpha-cellulose; Oven-dried holocellulose of 0.5 g obtained above were used for the purpose. Alpha-cellulose was determined according to the standard procedure.

Pentosan and methyl pentosan; Oven-dried pulps of 1 g were used. The determination of pentosan and methyl pentosan contents was based on phloroglucine method.

Lignin; Oven-dried pulps of 0.5 g were used for the determination of lignin content according to the standard procedure.

4. Beating and Sheet Formation

The pulps screened were beaten and their freeness was gradually reduced in a 10-*l* Rabus type beater, manually closing a clearance between roll and bed plate. A consistency of the pulps was 3 to 5% on moisture free base. At an interval of 5 or 10 min, a portion of the pulps was taken out and the freeness was measured with a Canadian Standard freeness tester till about 200 ml, and at the same time four or five sheets of each freeness-stage were made on a TAPPI type sheet machine for the measurement of physical properties of the pulps.

5. Tests for Physical Properties of Handsheets

Measuring thickness and weight of the sheets, specimens were prepared for the test of brightness, tensile, bursting and tearing strengths, as shown in Fig. 1, according to modified TAPPI Standard[42].

Since the brightness and these strengths vary with the freeness, the values were based on the pulps at 400 mℓ and 200 mℓ of the freeness for the expression

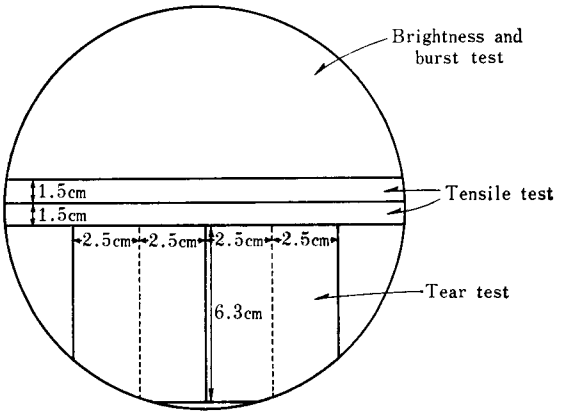


Fig. 1. Preparation of specimens.

of the properties.

Testing instruments and calculation formulas employed are as follows:

Thickness (1/100 mm) ····· Dial micrometer thickness gauge

Basis weight (g/m^2) ····· Chemical balance

Brightness (%) ····· Hunter reflectometer

Tensile strength (kg) ····· Schopper tensile tester

$$\text{Breaking length (km)} = \frac{\text{Tensile strength}}{15 \times \text{Basis weight}} \times 1000$$

Bursting strength (kg/cm^2) ····· Mullen burst tester

$$\text{Burst factor} = \frac{\text{Bursting strength}}{\text{Basis weight}} \times 100$$

Tearing strength (g) ····· Elmendorf tear tester

$$\text{Tear factor} = \frac{\text{Tearing strength of 16 sheets}}{\text{Basis weight}} \times 100$$

All the tests were carried out under 65% of controlled relative humidity and 20°C of temperature.

6. Measurements of Fiber Length and Microscopic Photographing of Pulp Fibers

The *Sasa*, birch and larch pulps obtained under the cooking condition of 15% active alkali at 160°C were furnished for the measurements of fiber length. About 500 fibers were measured for each pulp with a Nikon projector and estimated in the length and the length to width ratio. The projector of 50 and 20 magnifications was used for the observation of fiber.

Microscopic photograph was taken for the above-mentioned pulps of each freeness stage from unbeating to about 200 mℓ, employing a Nikon SBR-Ke microscope.

III. Results and Discussion

1. Final pH of Liquors and Chemical Properties of Pulps

The data of final pH of the liquors, cooking and defibrating yields, the contents of main chemical components in the *Sasa*, birch and larch pulps and these contents based on the originals are shown in Table 3, together with each

Table 3. Cooking conditions, final pH, pulp yield and chemical components (%)

Pulp No.	Cooking conditions			Final pH	Yield		Holocellulose		α-cellulose		Total pentosan		Methyl pentosan		Lignin	
	Active alkali (%)	Sulfidity (%)	Temperature (°C)		Cooking	Defibrating	A	B	A	B	A	B	A	B	A	B
S 1	15	25	150	12.5	49.3	47.1	93.4	44.0	76.0	35.9	30.6	14.4	1.9	0.9	2.8	1.3
2	〃	〃	160	12.2	47.2	46.9	95.9	44.9	77.2	36.2	30.6	14.3	1.7	0.8	3.5	1.6
3	〃	〃	170	11.3	46.7	45.0	93.9	42.3	77.8	35.0	27.9	12.6	1.7	0.8	3.8	1.7
4	〃	〃	180	11.1	43.2	41.7	94.6	39.4	76.7	32.0	29.0	12.1	1.6	0.7	4.0	1.7
5	10	25	150	10.2	60.0	58.0	85.9	49.8	70.2	40.7	28.8	16.8	1.4	0.8	11.4	6.6
6	〃	〃	160	10.4	58.0	57.0	88.2	50.2	71.3	40.6	30.4	17.3	1.8	1.0	10.8	6.2
7	〃	〃	170	10.0	57.6	55.4	87.3	48.4	71.4	39.6	26.1	14.4	1.7	0.9	12.4	6.8
8	〃	〃	180	10.5	56.6	53.7	86.4	46.4	70.3	37.8	26.2	14.1	1.7	0.9	11.3	6.1
9	5	25	150	6.8	68.2	65.4	77.8	50.9	62.0	40.5	25.9	16.9	1.6	1.0	18.8	12.9
10	〃	〃	160	6.8	66.0	63.2	76.2	48.2	63.0	39.8	26.2	16.5	1.5	0.9	21.2	13.4
11	〃	〃	170	7.0	65.2	64.2	77.1	48.1	61.8	38.6	26.9	16.8	1.9	1.2	20.7	12.9
12	〃	〃	180	6.6	63.6	62.0	77.2	47.9	61.3	38.0	24.0	14.8	1.3	0.8	21.5	13.3
13	0	0	150	3.9	76.6	71.1	70.2	49.9	55.9	39.7	24.3	17.2	1.7	1.1	29.0	20.6
14	〃	〃	160	3.9	75.3	71.1	66.8	47.5	56.4	40.1	18.4	13.0	1.6	1.1	31.8	21.6
15	〃	〃	170	3.1	59.1	57.6	62.7	36.1	58.5	33.7	3.3	1.9	1.5	0.9	36.6	21.1
16	〃	〃	180	2.9	48.5	46.5	62.8	29.2	57.4	26.7	3.5	1.6	1.6	0.7	36.9	19.8
B 1	15	25	150	12.6	56.5	55.8	97.4	54.4	86.3	48.2	27.2	15.2	1.4	0.8	2.1	1.2
2	〃	〃	160	12.3	54.1	52.8	98.2	51.9	85.4	45.1	27.0	14.2	1.8	0.9	0.8	0.4
3	10	〃	160	10.1	72.2	69.6	82.9	57.7	69.6	48.4	24.1	16.8	1.5	1.1	16.9	11.7
4	〃	〃	170	9.8	72.0	69.3	82.7	57.3	68.6	47.5	24.7	17.1	1.6	1.1	15.9	11.0
5	5	〃	160	5.1	81.7	77.9	77.6	60.4	61.6	48.0	22.3	18.0	1.6	1.2	20.5	16.0
6	〃	〃	180	4.4	72.3	66.0	78.1	51.5	70.0	46.2	12.4	8.2	2.8	1.9	19.8	13.1
L 1	15	25	150	13.1	58.7	57.4	79.5	45.5	65.8	37.8	10.5	6.0	1.5	0.9	19.2	11.0
2	〃	〃	160	12.7	48.4	45.1	92.0	41.6	77.0	34.7	10.8	4.9	1.9	0.9	8.1	3.6
3	10	〃	160	11.1	67.0	61.4	74.3	45.6	60.6	37.2	10.6	6.5	2.6	1.6	23.2	14.3
4	〃	〃	170	10.8	65.9	60.7	76.3	46.3	62.9	38.2	9.9	6.0	2.4	1.5	22.3	13.5
5	5	〃	160	7.0	82.4	77.2	63.5	49.1	52.6	40.6	9.0	6.9	2.2	1.7	33.1	25.6
6	〃	〃	180	5.8	80.3	76.1	63.7	48.5	49.2	37.4	6.2	4.7	3.0	2.3	34.4	26.1

Note; A: Content in the pulps.
B: Content based on the original.

cooking condition.

a. Final pH

Within these ranges of the *Sasa* semikraft cooking condition, the maximum and minimum final pH of the cooking were obtained from S 1 and S 12, respectively. Involving water cooking, the pH of S 16 was the lowest. The relation between the final pH and the cooking conditions is shown in Fig. 2. It is naturally shown that the final pH was greatly affected by the active alkali added, and that at the same alkali levels the pH was a little lowered by elevation of cooking temperature. With 5% alkali and water cooking, the liquors showed near neutrality and acidity, respectively.

The maximum final pH in the birch and larch cooking was obtained from B 1 and L 1, while the minimum from B 6 and L 6, respectively. At the same cooking conditions, the pH value in the larch cooking was somewhat higher than that in the *Sasa* and birch cooking. It is considered that the alkali consumption in the larch cooking was low due to less hemicellulose content in the larchwood.

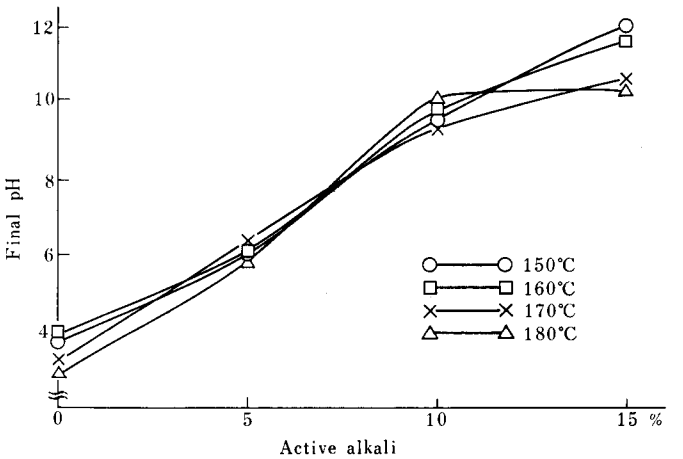


Fig. 2. Final pH of *Sasa* cooking and cooking conditions.

b. Yields

The maximum cooking yield of the *Sasa* was 68.2% of S 9 prepared under the mildest condition, while the minimum was 43.2% of S 4 done under the most severe one. The relation between the *Sasa* cooking yields and the conditions is shown in Fig. 3. It clearly shows that the yield was influenced by the alkali, but not so greatly by the temperature. In 5% active alkali level, for example, a difference in the yield between the temperatures of 150 and 180°C was at most 5 to 6%, while in 150°C level the difference between the alkalis of 5% and 15% amounted to about 19%. In the water cooking, however, the yield was so much affected by the temperature that the yield obtained at lower temperature was as high as 76.6%, but at higher one was remarkably lowered

to 48.5%. It is explained in the water cooking that carbohydrates were markedly dissolved by higher temperature into the liquor, owing to change toward a strong acidity of the liquor. The relation between the yields and final pH is shown in Fig. 4. It reveals the higher yield was obtained when the final pH was nearly neutral.

A defibrating yield was generally in proportion as some 2 to 3% lower than cooking yield. The difference between the cooking and defibrating yields in case

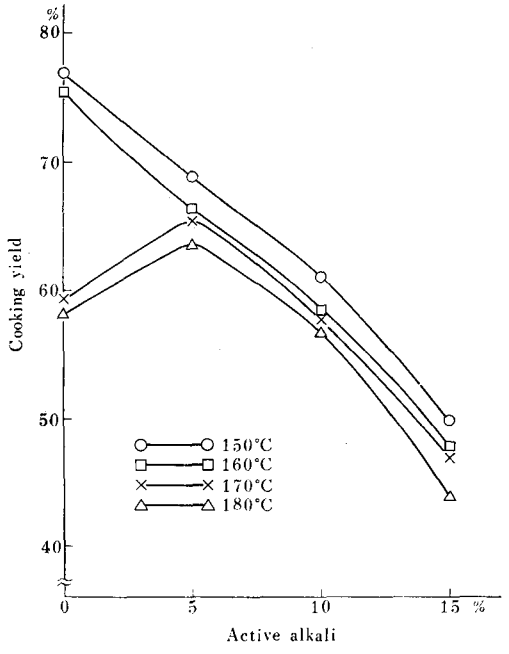


Fig. 3. *Sasa* cooking yield and cooking condition.

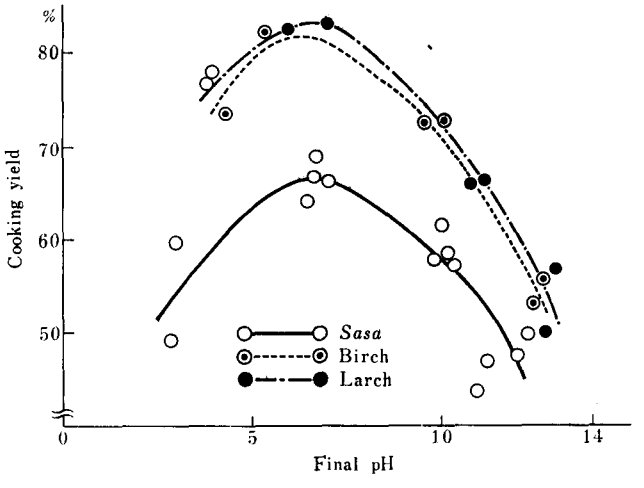


Fig. 4. Cooking yield and final pH.

of water cooking at lower temperatures, however, was to some extent greater than the difference by semikraft process. That shows the fine materials contained in the *Sasa*-cooked chips were much washed away with water through defibration and washing.

The maximum cooking yield of the birch and larch was 81.7 and 82.4% of B 5 and L 5, prepared under the mildest condition, while the minimum was 54.1 and 48.4% of B 2 and L 2 done under the most severe condition, respectively. In comparison of the yields of *Sasa* pulps with those of birch and larch pulps, the latters were without exception high at the same condition. It is shown from this result that the *Sasa* containes more materials dissolving into cooking liquor than the birch and larch wood. The difference between the cooking and defibrating yield in the wood pulps was somewhat less than in the *Sasa* pulps.

After all, the yield of the *Sasa* semikraft pulps was greatly affected by the alkali, and in any case the *Sasa* pulps were inferior to the birch and larch ones in lower yield.

c. Chemical Components

Holocellulose content; As shown in Table 3, the maximum holocellulose content in the *Sasa* pulps was 95.9% of S 2, while the minimum 76.2% of S 10. Involving water-cooked pulps the content of S 15 was the lowest. On the contrary, Table 3 also shows the content based on the original was raised with decreasing the alkali charges. The relation between holocellulose or lignin content

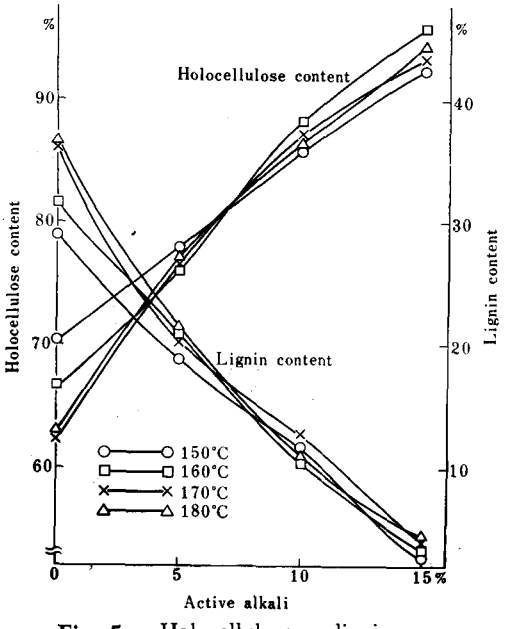


Fig. 5. Holocellulose or lignin content in the *Sasa* pulps and the cooking conditions.

in the *Sasa* pulps and the cooking conditions are shown in Fig. 5. Fig. 5 indicates that the holocellulose content was greatly affected by the alkali added, but hardly by the temperature, except water cooking. Furthermore, Fig. 5 shows that an increase of holocellulose is always accompanied with a decrease of lignin.

The maximum holocellulose content in the birch and larch pulps was 98.2 and 92.0% of B 2 and L 2, while the minimum was 77.6 and 63.5% of B 5 and L 5, respectively. In comparison with the three pulps the birch pulps generally showed the highest content, while the larch ones showed the lowest.

Alpha-cellulose content; As shown in Table 3, the maximum alpha-cellulose content in the *Sasa* pulps was 77.8% of S3, while the minimum was 61.3% of S 12. The relation between alpha-cellulose content in the *Sasa* pulps and the conditions is shown in Fig. 6. The trend of the change in the content is similar to that in the holocellulose content. With 15% alkali level, the content amounted to 76.0 to 77.8%. On the other hand, with 5% level, it decreased to 61.3 to 63.0%. But the content based on the original rised with decreasing the alkali charge.

The maximum alpha-cellulose content in the birch and larch pulps was 86.3 and 77.0% of B 1 and L 2, while the minimum was 61.6 and 49.2% of B 5 and L 6, respectively. In comparison with the three pulps, the content in the birch pulps showed the highest, while that in the larch pulps showed the lowest at the same condition. The content in the birch pulps based on the original was also the highest.

Pentosan content; As shown in Table 3, the maximum total pentosan con-

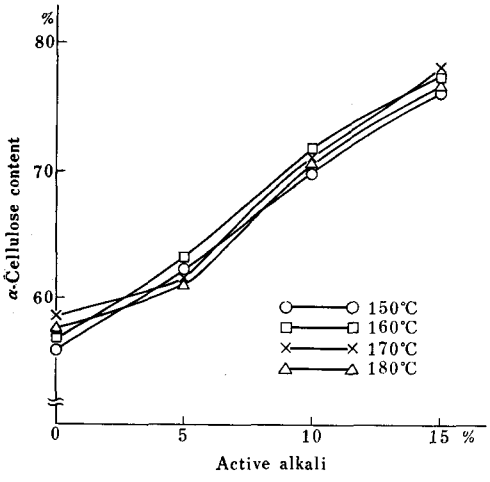


Fig. 6. *Alpha*-cellulose content in the *Sasa* pulps and cooking conditions.

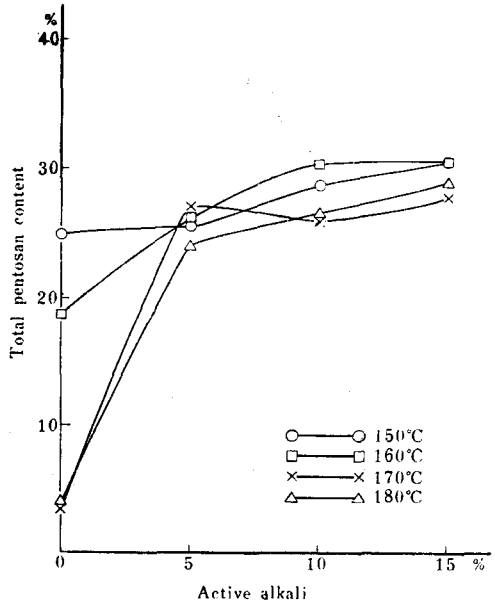


Fig. 7. Total pentosan content in the *Sasa* pulps and the cooking conditions.

tent in the *Sasa* pulps was 30.6% of S 1 and S 2, while the minimum was 24.0% of S 12. But the water cooking caused remarkably a dissolution of pentosan, especially by higher temperatures. The relation between the total pentosan content and the cooking conditions is shown in Fig. 7, which indicates that the content generally remained much in the pulp with higher alkali charge and a little with lower charge or by the water cooking. The trend of the change in the pentosan content is also somewhat similar to that in the holocellulse content. The content based on the original showed higher values in case of the pulps obtained under the condition of 5 and 10% alkali at 150 and 160°C. Methyl pentosan content in the *Sasa* pulps was always low and showed little difference with one another.

The maximum total pentosan content in the birch and larch pulps was 27.2 and 10.8% of B 1 and L 2, while the minimum was 12.4 and 6.2% of B 6 and L 6, respectively. In comparison with the three pulps, the content in the *Sasa* pulps showed the highest. On account of the lower pentosan in the larchwood by nature, the content in the pulps was naturally the lowest.

Lignin content; As shown in Table 3, the maximum lignin content in the *Sasa* pulps was 21.5% of S 12, while the minimum was 2.8% of S 1. The relation between lignin content and the cooking conditions is also shown in Fig. 5. The change of the content was just reversed to that of the holocellulose content, and it was remarkably decreased with elevation of alkali charge but not much by elevation of the temperature, except the water cooking. Since the water cooking almost left lignin and dissolved carbohydrates the amount of lignin in the pulps was considerably increased. It appears that the relative increase of the lignin content with the water cooking was especially shown by higher temperatures, due to lower pH of the liquor. The low content of lignin based on the original was also shown in the pulps prepared by the high alkali charge, and about the same content as the original was found in case of the water cooking.

The maximum lignin content in the birch and larch pulps was 20.5 and 34.4% of B 5 and L 6, while the minimum was 0.8 and 8.1% of B 2 and L 2, respectively. The lignin content in the larch pulps was generally high since the larchwood itself has a high lignin content. In comparison with the three pulps the best delignification was given in the birch pulps.

After all, it is shown that the chemical properties of the *Sasa* pulps were a little inferior to that of the birch pulps and much superior to that of the larch pulps in a point of the high holocellulose content.

2. Physical Properties of Pulps

a. Freeness

Initial C. S. freeness of the *Sasa*, birch and larch pulps after flat-screening is shown in Table 4.

The range of the initial freeness was 735 to 600 mℓ. Little difference in

Table 4. Initial freeness of the pulps

Pulp No.	C. S. freeness (mℓ)	Pulp No.	C. S. freeness (mℓ)	Pulp No.	C. S. freeness (mℓ)
S 1	675	S 11	720	B 5	625
2	660	12	670	6	650
3	615	13	665	L 1	730
4	600	14	620	2	690
5	665	15	730	3	700
6	700	16	735	4	725
7	725	B 1	665	5	710
8	640	2	650	6	705
9	725	3	630		
10	665	4	620		

the freeness was found among the three pulps and with changes of the cooking condition.

All the strength of the pulps varies with their freeness. The relations between the freeness and some strengths of the pulps are shown in Fig. 8. From this result the strengths increased to some freeness-stage with beating the pulps. Tear factor of this larch pulp showed a maximum at 650 mℓ freeness, while in case of the *Sasa* pulps this attained to a maximum after 20 to 30 min of the time or at 500 to 400 mℓ freeness, then gradually lowered. Tensile and bursting strength had a maximum at 200 mℓ or so. Discussions on physical properties of the pulps are mainly made on the pulp sheets of 400 and 200 mℓ freeness.

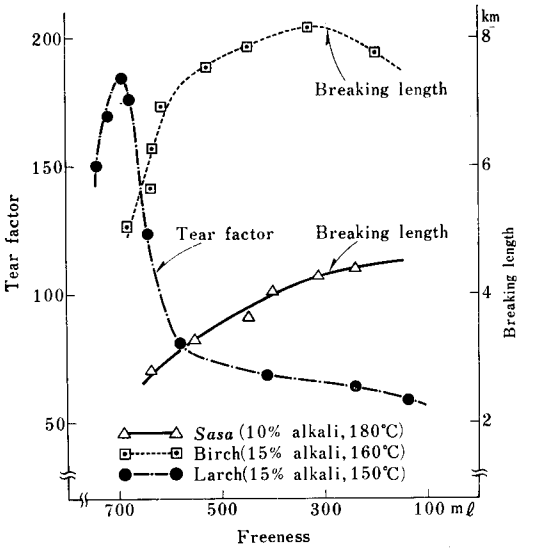


Fig. 8. Some physical strengths changed by freeness of the pulps.

b. Brightness and Strengths

Data of brightness, breaking length, burst and tear factors given from the handsheets of the *Sasa*, birch and larch pulps at 400 and 200 mℓ freeness are shown in Table 5. The data of the maximum values regardless of the freeness are shown in Table 6.

Brightness; As shown in Table 5, the maximum brightness value of the *Sasa* pulps was obtained from S 2 at 400 mℓ freeness, prepared under the con-

Table 5. Physical properties of the pulps at 400 and 500 mℓ freeness

Pulp No. \ Freeness (mℓ)	Brightness (%)		Breaking length (km)		Burst factor		Tear factor	
	400	200	400	200	400	200	400	200
S 1	22	21	3.6	4.9	2.6	3.6	170	130
2	26	23	3.6	4.8	2.6	3.4	165	152
3	17	16	3.9	4.6	2.8	3.0	124	76
4	17	16	4.7	5.1	3.1	3.2	153	97
5	16	15	3.5	4.1	2.6	2.9	80	57
6	15	15	3.6	4.0	2.4	2.9	90	63
7	14	13	3.4	3.9	2.3	2.6	97	53
8	14	13	4.0	4.4	2.6	3.1	70	70
9	14	13	2.5	3.4	1.4	1.8	64	44
10	14	13	2.5	3.5	1.6	1.9	79	43
11	14	13	2.9	3.4	1.7	2.1	68	50
12	14	14	2.9	3.6	1.9	2.2	96	57
13	16	17	0.8	1.5	0.2	0.6	25	30
14	13	14	1.6	2.4	0.8	1.1	57	41
15	8	9	2.2	2.8	1.2	1.7	55	45
16	8	8	2.1	2.6	1.2	1.7	51	48
B 1	20	19	6.5	6.1	5.2	4.3	84	63
2	18	16	8.1	7.2	5.7	4.5	72	56
3	10	8	5.8	5.8	4.3	3.3	74	54
4	9	7	5.7	6.3	4.1	3.5	82	51
5	12	11	3.9	4.3	2.2	2.4	84	44
6	11	10	3.6	3.1	2.8	1.7	80	60
L 1	15	13	4.5	4.8	2.6	2.8	66	61
2	12	12	6.7	5.3	4.7	3.0	85	72
3	13	12	3.8	4.0	2.5	2.4	71	52
4	10	8	4.1	3.6	3.4	3.0	80	44
5	11	11	2.5	2.7	1.4	1.7	72	58
6	10	9	3.2	3.3	2.1	2.1	80	54

dition of 15% alkali at 160°C, while the minimum was obtained from S 8 to S 11 at 200 mℓ, prepared with lower alkali. The water cooking at higher temperatures caused the lowest brightness. The relation between the brightness of the pulps and alkali charge at 160°C is shown in Fig. 9. The brightness value of the pulps was considerably high in 15% alkali level, but did not so much vary with lower alkali. Generally the value at 400 mℓ freeness was somewhat higher than that at 200 mℓ. Furthermore, the brightness also lowered with raising the temperature at the same alkali.

Table 6. Maximum value in physical properties of the pulps

Pulp No.	Brightness (%)	Freeness (mℓ)	Breaking length (km)	Freeness (mℓ)	Burst factor	Freeness (mℓ)	Tear factor	Freeness (mℓ)
S 1	24	570	5.0	210	3.6	210	193	490
2	28	610	4.9	150	3.5	200	175	455
3	18	615	4.7	190	3.0	190	130	450
4	19	560	5.2	160	3.3	160	194	430
5	16	665	4.2	200	2.9	200	93	500
6	16	660	4.0	205	2.9	205	106	465
7	14	725	4.2	165	2.7	165	98	490
8	14	640	4.4	235	3.2	235	80	560
9	14	665	3.5	185	1.9	185	64	400
10	14	635	3.6	190	2.0	190	84	440
11	14	540	3.5	215	2.2	215	69	415
12	14	605	3.6	220	2.2	220	98	405
13	17	600	1.5	200	0.6	200	40	395
14	14	585	2.5	185	1.2	185	80	370
15	10	640	2.7	230	1.8	230	57	485
16	8	640	2.5	205	1.7	205	60	340
B 1	25	640	6.7	350	5.2	350	114	640
2	24	640	8.3	330	5.8	330	133	630
3	12	630	5.9	260	4.4	440	108	630
4	10	590	6.4	210	4.2	425	108	510
5	13	600	4.8	215	3.0	260	94	600
6	12	630	3.9	250	2.4	490	96	580
L 1	17	660	4.9	240	2.8	240	184	650
2	16	680	6.7	330	5.3	330	194	630
3	13	700	4.2	295	2.6	460	198	700
4	11	720	4.1	400	3.5	300	175	720
5	11	710	2.8	240	1.7	195	105	660
6	10	705	3.8	260	2.5	260	143	570

If freeness was not considered, the maximum was 28%, obtained from S 2 at 610 ml freeness, as shown in Table 6.

The brightness value of the larch pulps was the lowest, while its trend of the birch pulps was a little close upon the *Sasa* pulps. Thus the *Sasa* pulps had the highest brightness under each condition.

Breaking length ; The maximum and minimum breaking length of the *Sasa* pulps were 5.1 km of S 4 at 200 mℓ freeness and 2.5 km of S 9 and 10 at 400 mℓ, respectively. The strength of the pulps prepared by the water cooking was further low. The relation between the breaking length of the pulps and the concentration of the alkali at 160°C is shown in Fig. 10, which reveals that the difference between the two *Sasa* pulps obtained with 15 and 10% alkali was a little, and that in water cooking the value was low. Furthermore, with reduction of freeness the strength increased.

Table 6 also shows the maximum was 5.2 km of S 4 at 160 mℓ freeness in disregard to the settled standard freeness.

Taking notice of the birch and larch pulps, the breaking length was greatly affected by the active alkali. For example, in case of the birch pulps, the strength obtained with 5% alkali was 3.6 km but with 15% increased to 8.1 km, i. e. over twice as high. The strength of these pulps was superior to that of the *Sasa* pulps prepared at the same condition. Comparison of the larch pulps with the birch ones showed that the value of the latters was rather higher than that of the formers. Consequently, of the three pulps investigated the birch

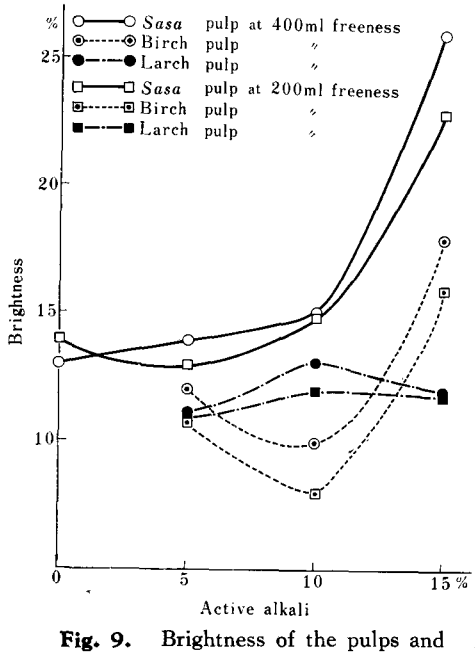


Fig. 9. Brightness of the pulps and active alkali at 160°C.

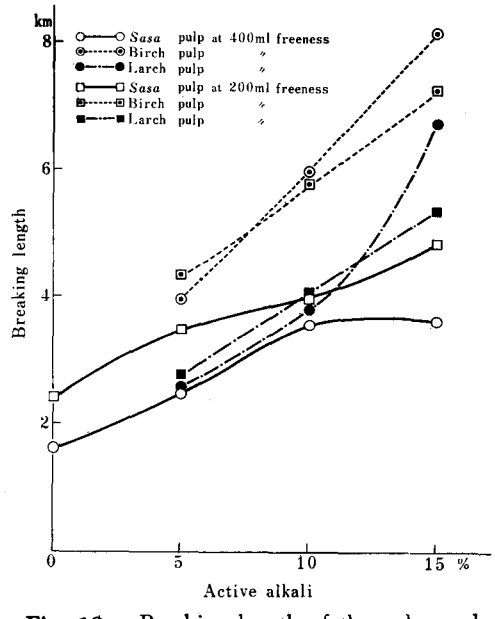


Fig. 10. Breaking length of the pulps and active alkali at 160°C.

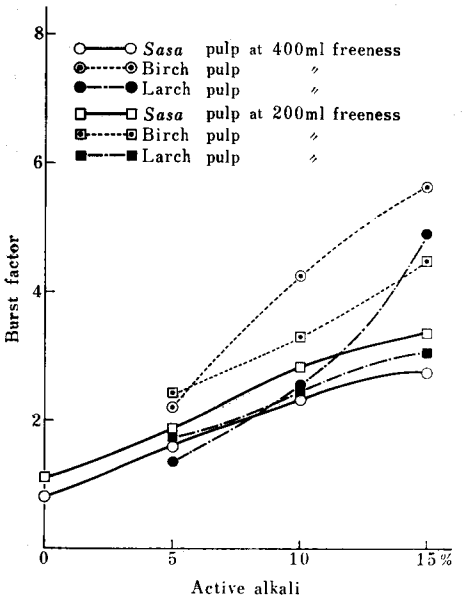


Fig. 11. Burst factor of the pulps and active alkali at 160°C.

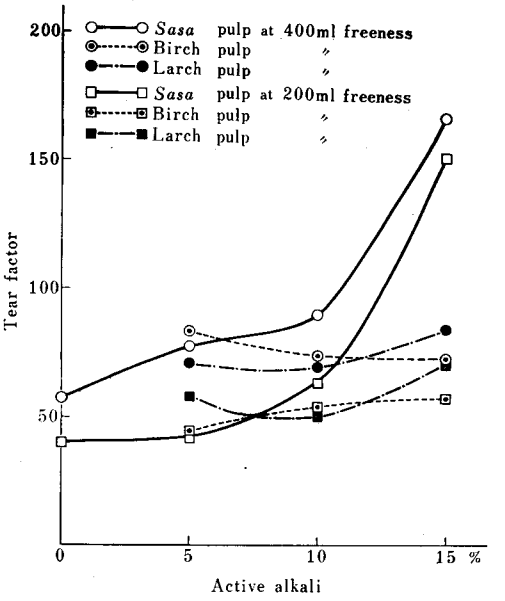


Fig. 12. Tear factor of the pulps and active alkali at 160°C.

pulps had the highest breaking length, followed by the larch and *Sasa* ones.

Burst factor; The maximum and minimum burst factor of the *Sasa* pulps were 3.6 of S 1 at 200 mℓ freeness and 1.4 of S 9 at 400 mℓ, respectively. The strength of the pulps by the water cooking also very low. The relation between the burst factor and the alkali concentration is shown in Fig. 11. The strength of the *Sasa* pulps did not largely vary with one another. The pulp at 200 mℓ freeness obtained with 10% alkali almost bore comparison with that obtained with 15%. With reduction of freeness the strength of the *Sasa* pulps likewise a little increased.

The maximum in disregard to the standard freeness was also the same as 3.6 of S 1 at 210 mℓ.

The burst factor of birch pulps showed a considerably high value, compared with the *Sasa* and larch pulps. The strength of the birch and larch pulps was also affected by the condition of the alkali concentration. Within the ranges of the birch pulps tested the strength obtained under 15% alkali level, was extremely increased, and superior to that of the *Sasa* pulps.

Tear factor; The maximum and minimum tear factor of the *Sasa* pulps were 170 of S 1 at 400 mℓ freeness and 43 of S10 at 200 mℓ, respectively. The pulps by the water cooking was a little low in the tear factor, compared with that with 5% alkali. The relation between the tear factor and the alkali concentration is shown in Fig. 12. The strength of the *Sasa* pulps was greatly influenced by the active alkali. That of these pulps obtained with 15% alkali

was so much high. However, even the *Sasa* pulps with 10% alkali, bore comparison with the birch and larch pulps with 15%. The maximum of the *Sasa* pulps found in Table 6 was 194 obtained from S 4 at 430 mℓ freeness. Generally the relatively higher freenesss showed the high tear factor and with further reduction the value was gradually decreased[6]. In comparison with the three pulps, Table 5 reveals the strength of the *Sasa* pulps was the highest in the lower freeness and it seems to be characteristic.

After all, within the ranges of these semikraft pulping, the *Sasa* pulps obtained with 15% alkali at lower temperatures attained to the best physical properties. The pulps at 200 mℓ freeness obtained with 10% alkali showed also a considerably high strength. Furthermore, the *Sasa* pulps were superior in brightness and tear factor and a little inferior in breaking length and burst factor to the birch and larch pulps.

3. Relations between Yield or Chemical Components and Physical Properties of the *Sasa* Pulps

It is interesting to investigate the relations between chemical and physical properties of the pulps, papers and boards on which some studies have been made[1),22),23),30)].

a. Yield and Physical Properties

There is a close relation between the yield and the brightness of the pulps. In general the less the yield is, the higher the value of the brightness becomes. It is clear the yield mainly lowered with decreasing the content of lignin which has been considered as the primary source of color, or reducing the brightness of the pulps. Since the pulps obtained by the water cooking at higher temperature, however, contained lignin and less carbohydrates, the pulp obtained was the worst in both the yield and the brightness.

The relation between the yield and the strengths has a similar trend to that above-mentioned. The pulps of about 50% yield, for example, have some 4.0 km of breaking length and these in the forties percent-yield have over 100 of tear factor at 400 mℓ freeness. In case of the water cooking at higher temperatures every strength was very low in spite of lower yields.

b. Holocellulose Content and Physical Properties

The brightness was greatly affected by the holocellulose content in the pulps. The relation between the holocellulose content and the brightness is shown in Fig. 13. In the ranges of the content during 60 to 80% the difference was not so large, but the value considerably increased in the nineties-percent content.

The relations between the holocellulose content and breaking length, burst factor and tear factor of the *Sasa* pulps are shown in Fig. 14, 15, and 16, respectively. In any cases the strengths became high with increasing the content in the pulps. The breaking length and burst factor are almost in direct proportion to the content, while the tear factor is about duplicate proportion to

the content.

c. Lignin Content and Physical Properties

The brightness was also markedly affected by the lignin content in the

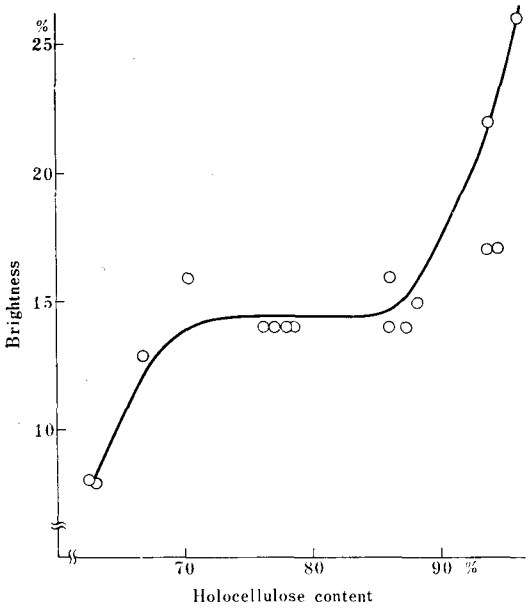


Fig. 13. Holocellulose content and brightness of the *Sasa* pulps at 400 mℓ freeness.

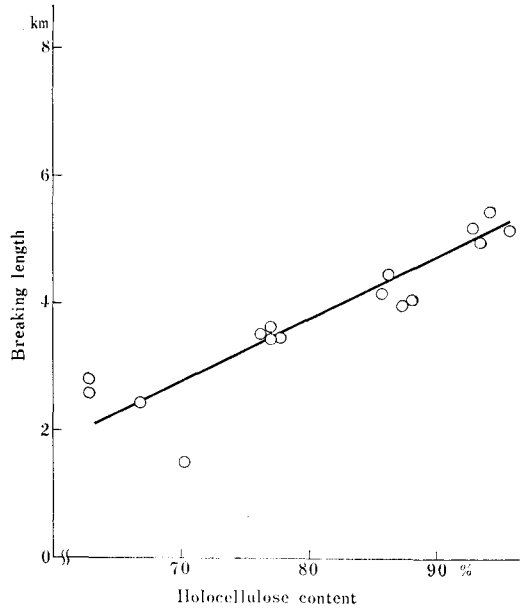


Fig. 14. Holocellulose content and breaking length of the *Sasa* pulps at 400 mℓ freeness.

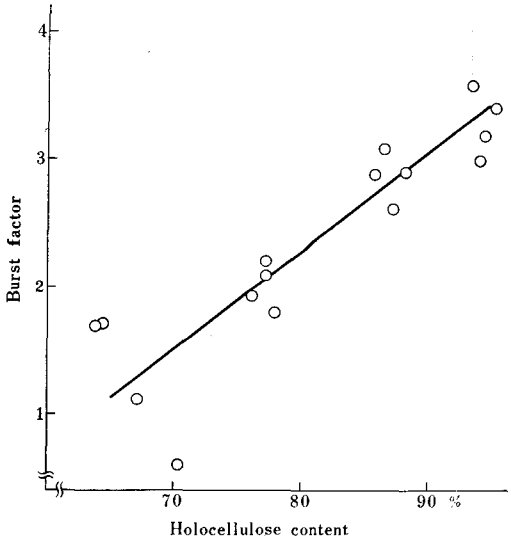


Fig. 15. Holocellulose content and burst factor of the *Sasa* pulps at 200 mℓ freeness.

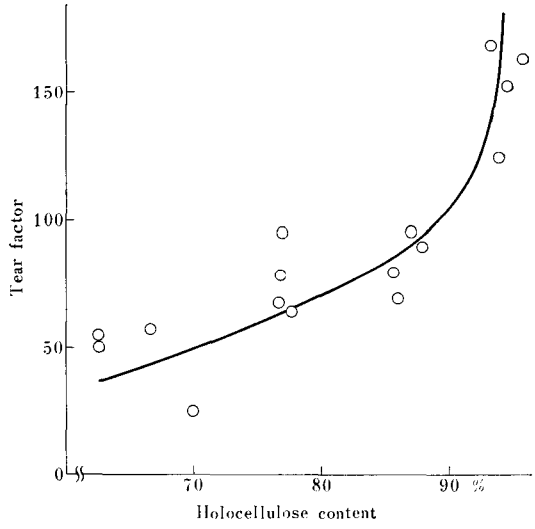


Fig. 16. Holocellulose content and tear factor of the *Sasa* pulps at 400 mℓ freeness.

pulps. The relation between the lignin content and the brightness is shown in Fig. 17. The brightness of the pulps containing below 10% lignin became high, while that containing 10 to 30% of lignin hardly varied.

The relations between the lignin content and the breaking length, burst

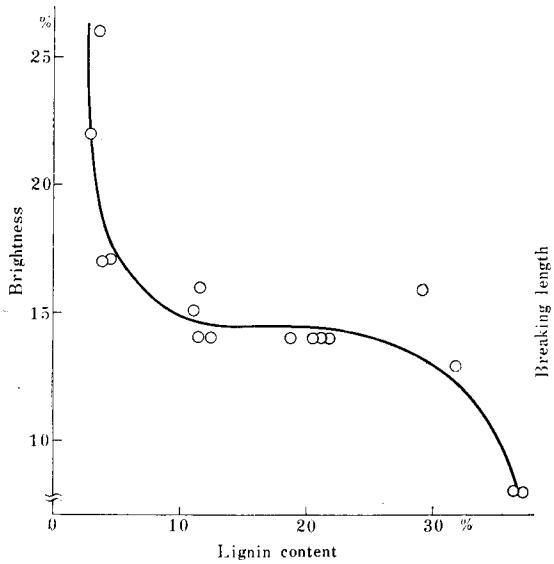


Fig. 17. Lignin content and brightness of the *Sasa* pulps at 400 mℓ freeness.

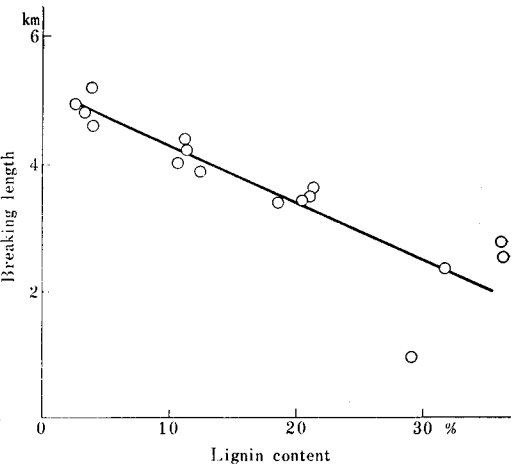


Fig. 18. Lignin content and breaking length of the *Sasa* pulps at 200 mℓ freeness.

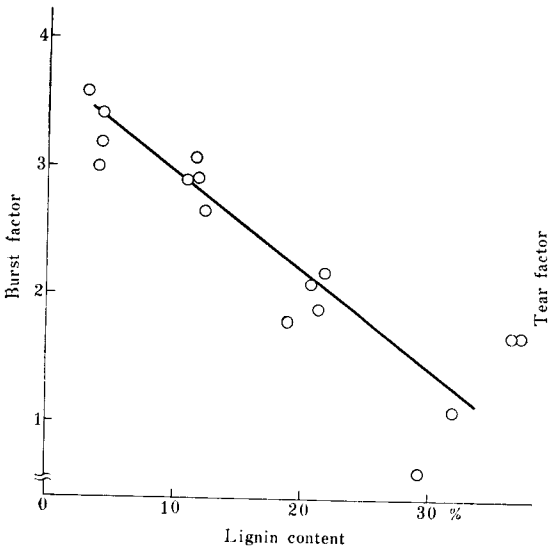


Fig. 19. Lignin content at burst factor of the *Sasa* pulps at 200 mℓ freeness.

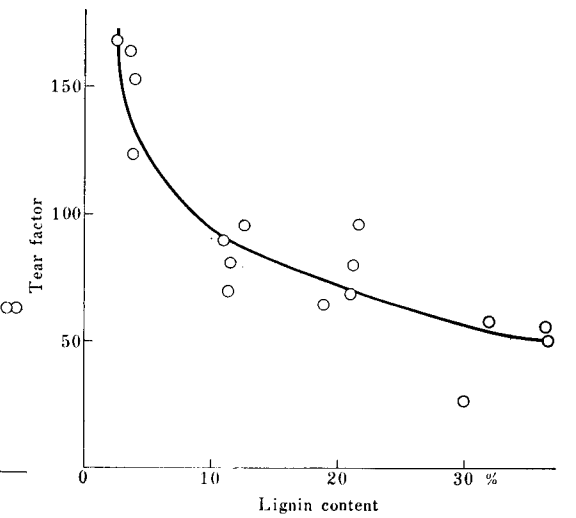


Fig. 20. Lignin content and tear factor of the *Sasa* pulps at 400 mℓ freeness.

factor and tear factor are shown in Fig. 18, 19, and 20, respectively. In any strengths the value lowered with increasing the content. The value of the breaking length and burst factor descends in a straight line with an increase of this content, while that of the tear factor is in about inverse proportion to the content.

d. Holocellulose to Lignin Content Ratio and Physical Properties

More distinct relation between the brightness and the chemical components was obtained by using the ratio of holocellulose to lignin content than using the holocellulose or lignin content alone. Fig 21 shows that the brightness of the pulps is gradually increased with elevating the ratio.

The relations between the ratio and the breaking length, burst factor or tear factor are shown in Fig. 22, 23, and 24, respectively. When the ratio becomes over 10, or ten times as high, the value of the breaking length and

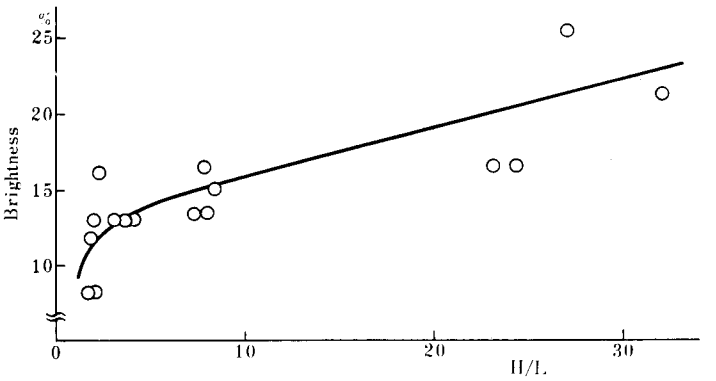


Fig. 21. Holocellulose to lignin content ratio in the *Sasa* pulps and brightness.

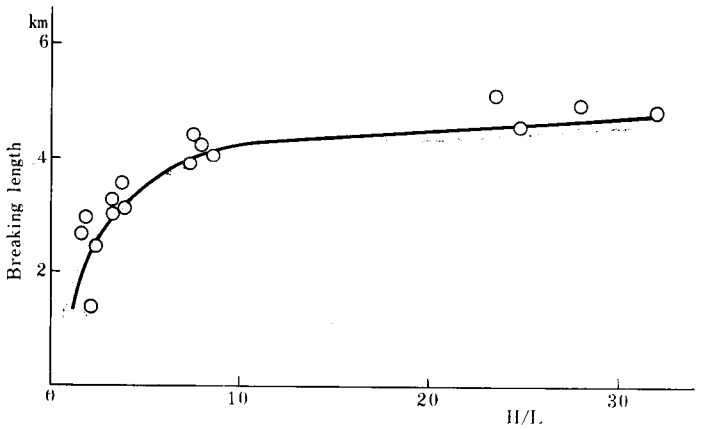


Fig. 22. Holocellulose to lignin content ratio in the *Sasa* pulps and breaking length.

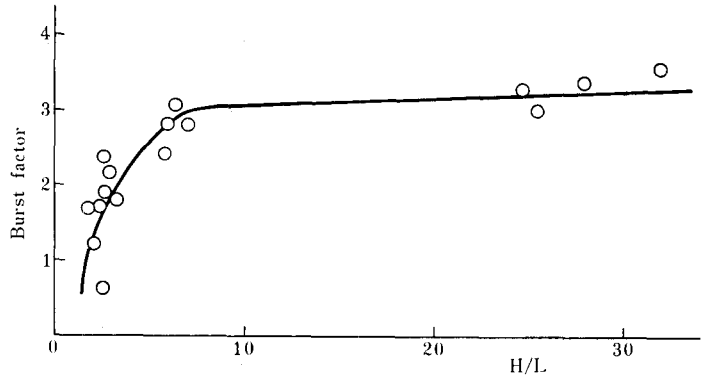


Fig. 23. Holocellulose to lignin content ratio in the *Sasa* pulps and burst factor.

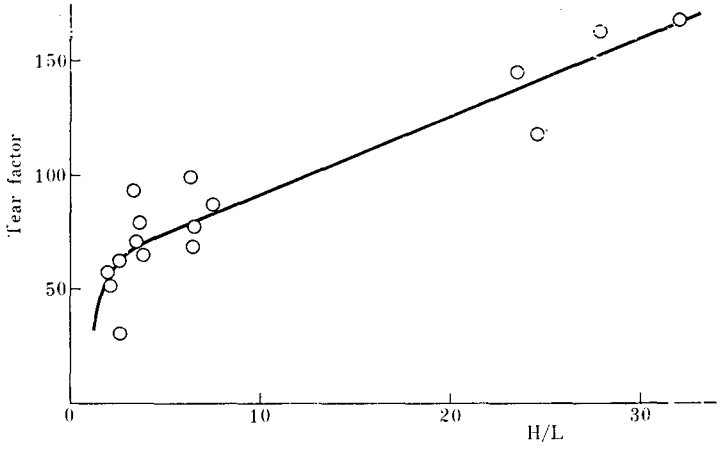


Fig. 24. Holocellulose to lignin content ratio in the *Sasa* pulps and tear factor.

burst factor does not almost vary and runs parallel to the transversal axis.

4. Comparisons of the *Sasa* Semikraft Pulps with Kraft Pulps

a. Comparison with *Sasa* Kraft Pulps

According to FUKUYAMA[13], the yield of *Sasa* kraft pulps were 36.0 and 41.4%, obtained with 24.1 and 23.9% alkali at 178 and 165°C, respectively. The values were as low as about 10 to 5%, compared with that of the semikraft pulps obtained with 15% alkali at 150 to 170°C. The strength in the pulp of 36.0% yield at 410 mℓ freeness was as follows ; breaking length, 4.56 km, burst factor, 2.36 and tear factor, 151. Comparison with those of the semikraft pulps shows that the pulps obtained with 15% alkali has sufficient strengths and that *Sasa* is easily cooked under some mild conditions. Furthermore, it is shown that the pulp having a yield of 59.4% obtained with 11.9% alkali at 164°C, reveals 3.69 km in breaking length, 2.00 in burst factor. These data

bear some resemblance to those of the semikraft pulps obtained with 10% alkali.

b. Comparison with Hardwood Kraft Pulps

According to KAWASE[26] the yields of such various kinds of hardwood pulps as a white birch, a Doronoki poplar, a Lombardy poplar, a Yachidamo ash and a black locust are 47.5, 47.9, 44.5, 43.8, and 46.0%, respectively by a kraft process of 24% active alkali at 170°C. The yields resemble in some degree that of the *Sasa* semikraft pulps obtained with 15% alkali. The strengths of the hardwood pulps at 400 mℓ freeness were 4.5 to 5.9 km in breaking length, 2.4 to 3.2 in burst factor and 63 to 107 in tear factor. Comparison with those of the *Sasa* semikraft pulps shows that the properties are similar to each other in breaking length and burst factor but the *Sasa* pulps are considerably superior to the hardwood pulps in tear factor.

5. Fibers of Pulps

a. Fiber Length and Length to Width Ratio

Distributions of fiber length of the *Sasa*, birch and larch pulps are shown in Table 7 and Fig. 25, using some bast fiber, wood fiber and tracheid in the three pulps, respectively, obtained under the condition of 15% active alkali at 160°C.

The length of the *Sasa* fiber was in the range of 0.3 to 2.6 mm and 1.26 mm on an average. Furthermore, as width of the fiber was 14.6 μ, the length to width ratio amounted to 86.3, the value of which shows a slender shape.

An average fiber length of the birch and larch pulps was 1.07 and 2.18 mm, respectively. That of the former is similar to the *Sasa* fiber, while that of the larch seems a little short, compared with an ordinary larch fiber. The range of the birch fiber length was so narrow that the fraction of 0.9 to 1.1 mm occupied 48.6% on the whole. The average ratio of length to width in the two kinds of wood pulp fiber was 45.1 and 49.4, respectively.

Table 7. Fiber length distribution of fibers of the pulps

	Numbers	0.3–0.5 (mm)	0.6–0.8 (mm)	0.9–1.1 (mm)	1.2–1.4 (mm)	1.5–1.7 (mm)	1.8–2.0 (mm)	2.1–2.3 (mm)	2.4–2.6 (mm)	2.7–2.9 (mm)
Sasa	506	7	58	149	142	87	41	16	6	0
Birch	506	7	69	246	157	25	2	0	0	0
Larch	506	0	0	8	48	89	98	86	59	46

	3.0–3.2 (mm)	3.3–3.5 (mm)	3.6– (mm)	Max. (mm)	Min. (mm)	Average (mm)	Fiber width (μ)	Fiber length to width ratio
Sasa	0	0	0	2.6	0.3	1.26	14.6	86.3
Birch	0	0	0	2.0	0.5	1.07	23.7	45.1
Larch	37	27	8	4.0	0.9	2.18	44.1	49.4

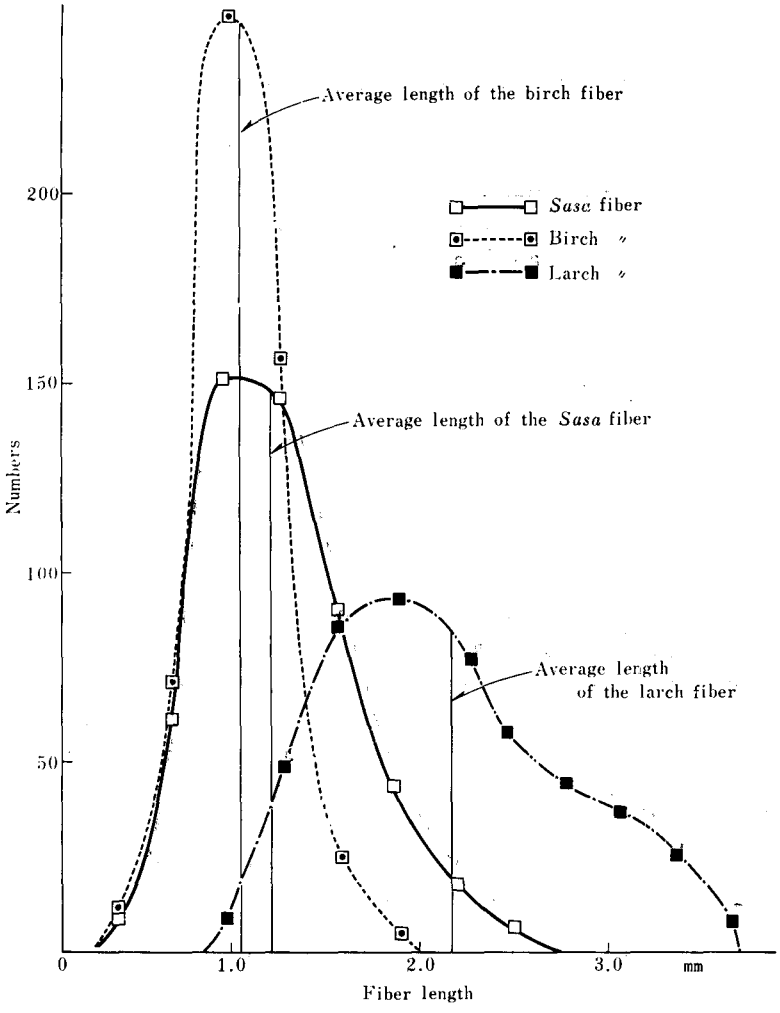


Fig. 25. Fiber length distribution in the three kinds of pulp fibers.

b. Photographs of Pulp Fibers

Photographs of the fibers in the *Sasa*, birch and larch pulps are shown in Photo 1, 2 and 3, respectively. The pulp fibers were also obtained under the condition of 15% alkali at 160°C.

It is shown that the *Sasa* consists mainly of bast fiber and parenchyma. The former was very slender like a needle, while the latter has several forms like a rectangle and an oval. Vessel was hardly observed because of a destruction of the thin membranes in the cell by the cooking. Photo 1-1 and 1-2 show the fibers obtained by cooking and defibrating after cooking, respectively. Photo 1-3 shows that the bast fiber began to bend by beating for 10 min. The fiber shown in Photo 1-6 is a little fibrillated. The pulp in Photo 1-7 had a high

strength property, while the pulp in Photo 1-9, the final beating stage of 120 mℓ in C.S. freeness, showed that the papermaking property was remarkably worse.

Comparison of the birch fiber with the *Sasa* one indicates the similar elements of the cell to each other, as shown in Photo 2. The birch and larch fibers, however, appeared to be a little soft and pliant even when unbeating. From every photo the *Sasa* has much parenchyma cells which seem to cause a lower yield on the pulping than the wood.

Conclusions

The semikaft pulps were prepared from the culms of *Sasa senanesis* under various conditions. The yield, chemical and physical properties of the pulps were investigated and compared with those of *Sasa* water-cooked pulps, and of the birch and larch pulps prepared at the same conditions, or with previous data on *Sasa* and hardwood kraft pulps. The conclusions reached can be expressed as follows;

1. The yield of the *Sasa* semikraft pulps was greatly affected by active alkali added. With increasing the charge it considerably lowered. For examples, with 15, 10 and 5% alkali the yield was the forties, fifties and sixties percent, respectively. But the yield did not so much vary with changes of the temperature at the same alkali level. The water cooking of the *Sasa*, on the contrary, showed a considerable decrease of the yield with higher temperatures. Furthermore, the *Sasa* was sufficiently cooked under the mild condition and the cooked chips were easily defibrated by an operation of the refiner with 0.1 mm clearance.

In comparison with the wood pulps, it is unavoidable that the yield of the *Sasa* pulps was always low because the *Sasa* itself has constituently high extractives. However, even the *Sasa* semikraft pulps obtained with 15% active alkali increased by about 5% in the yield, compared with *Sasa* conventional kraft pulps.

2. Within these ranges of the semikraft procedures, the *Sasa* pulps cooked under the condition of 15% alkali at lower temperatures had the most excellent chemical properties in point of the highest holocellulose and the lowest lignin content. Generally fall of the alkali charge and elevation of the temperature brought the decrease of holocellulose and the increase of lignin in the pulps.

In comparison with the wood pulps, the chemical properties of the *Sasa* pulps was a little inferior to those of the birch pulps, but superior to those of the larch pulps prepared under each cooking condition.

3. The physical properties of the *Sasa* pulps were also affected by the alkali charge. The pulps prepared with 15% alkali showed the best properties.

In comparison with the wood pulps, the *Sasa* pulps at 400 and 200 mℓ freeness were superior in brightness and tear factor to the birch and larch pulps.

These *Sasa* pulps prepared with 15% alkali showed almost similar physical properties to those of *Sasa* kraft pulps with about 24% alkali.

4. Fiber length of the *Sasa* pulps was 1.26 mm on an average and ranged from 0.3 to 2.6 mm. The length of the *Sasa* fibers considerably resembles that of the birch fibers and is a little longer. The value of the ratio of the length to width was extremely large. The photographs showed that the *Sasa* fiber was like a needle and that the appearance of the fiber changed with beating in a marked degree.

5. After all, the *Sasa* semikraft pulps prepared with 15% active alkali at the lower temperatures had the most excellent chemical and physical properties, if their lower yields were disregarded. The *Sasa* pulps prepared with 10% alkali and beaten sufficiently showed higher yields by over 10% and a little lower strength than the pulps prepared with 15% alkali. Furthermore, the condition of 5% alkali seemed to be a good one in point of the further high yields having the strength to some extent.

Literature

1) AHLM, C. E. and LEOPOLD, B.: Tappi, **46**, 102 (1963).
2) AURELL, R.: Svenk Papperstidn., **67**, 529 (1964).
3) AXELSON, S., CROON, I. and ENSTRÖM, B.: ibid., **57**, 525 (1954).
4) BROWNING, B. L.: The Chemistry of Wood, 475, John Wiley & Sons (1963).
5) CASEY, J. P.: Pulp and Paper, **1**, 213, Interscience (1960).
6) CASEY, J. P.: ibid., **3**, 1317, Interscience (1963).
7) Forest-Products Institute of Tokyo Univ.: Experiment of Forest Products Chemistry, 91, Sangyo- tosho (1956).
8) FUKUYAMA, G., KAWASE, K. and SATONAKA, S.: Transactions 63rd Meeting Japanese Forestry Soc., 339 (1954).
9) FUKUYAMA G., UJIIE, M. and TOSAKA, K.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc., **4**, 1 (1955).
10) FUKUYAMA, G. KAWASE, K. and SATONAKA, S.: Res. Bull. College Exp. Forests, Hokkaido Univ., **17**, 271 (1955).
11) FUKUYAMA, G., KAWASE, K. and SATONAKA, S.: ibid., **17**, 295 (1955).
12) FUKUYAMA, G., KAWASE, K. and SATONAKA, S.: ibid., **17**, 321 (1955).
13) FUKUYAMA, G., KAWASE, K. and SATONAKA, S.: ibid., **17**, 337 (1955).
14) FUKUYAMA, G., KAWASE, K. and SATONAKA, S.: ibid., **17**, 359 (1955).
15) FUKUYAMA, G.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc., **9** 90 (1960).
16) FUKUYAMA, G.: ibid., **10**, 178 (1961).
17) HANZAWA, M., UJIIE, M. and IKEDA, N.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc., **5**, 52 (1956).
18) HANZAWA, M. and UJIIE, M.: Transactions 2nd Meeting Japan Wood Res. Soc., 58 (1956).
19) HANZAWA, M. and UJIIE, M.: Transactions 4th Meeting Japan Wood Res. Soc., 115 (1957).
20) HANZAWA, M. and UJIIE, M.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc., **6**, 63 (1957).
21) HANZAWA, M. and KAWASE, K.: ibid., **9**, 64 (1960).

22) HANZAWA, M., UJIIE, M. and TOSAKA, K.: ibid., **9**, 62 (1960).
23) HANZAWA, M., UJIIE, M. and NIIRO, O.: J. Japan Wood Res. Soc. **9**, 62 (1963).
24) HARTHER, N.: Svensk Papperstidn. **65**, 535 (1962).
25) JACOPIAN, V.: Zellstoff u. Papier, **7**, 326 (1958).
26) KAWASE, K., UJIIE, M. and TOSAKA, K.: Res. Bull. College Exp. Forests, Hokkaido Univ., **20**, 239 (1959).
27) KAWASE, K. SATONAKA, S. and UJIIE, M.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc., **10**, 117 (1961).
28) KAWASE, K., SATONAKA, S., UJIIE, M. and FUKAI, S.: Business Data College Exp. Forests, Hokkaido Univ., **10**, 1 (1964).
29) KOCH, P. P., SAPP, J. E. and MCCRAY, R. L.: Tappi, **41**, 349 (1958).
30) KUBÄT J.: Das Papier, **18**, 98 (1964).
31) LIBBY, C. E.: Pulp and Paper Science and Technology, **1**, 160 McGraw-Hill (1962).
32) MACLAURIN, D. J. and WEBER, W. B.: Tappi, **36**, 553 (1953).
33) MACLAURIN, D. J. and PECKHAM, J. R.: ibid., **36**, 557 (1953).
34) MACLAURIN, D. J. and WHALEM, J. R.: ibid., **37**, 143 (1954).
35) MIGITA, N.: Wood Pulp, 73, 117, Asakura (1955).
36) PETTERSON, S. E. and RYDHOLM, S. A.: Svensk Papperstidn., **64**, 4 (1961).
37) SAARNIO, J. and GUSTAFSSON, C.: Papper och Trä, **35**, 65 (1953).
38) STACIE, J. H. and GUIDE, K. G.: Tappi, **46**, 141 (1963).
39) SADLER, H. and HRUSCHKA, A.: Holzforschung, **14**, 83 (1960).
40) TAKAHASHI, E. and SHIRAHAMA, K.: Bull. Hokkaido Univ. Agr. and Forestry, **97**, 335 (1929).
41) TODA, H., KIJIMA, T. and HAMADA, T.: J. Jap. Tappi, **15**, 381 (1961).
42) The Japan Polymer Res. Soc.: Test Method for Polymer Material (2) 271, Kyoritsu (1958).
43) UJIIE, M.: A Dissertation for Master's Degree (1955), unpublished.
44) UJIIE, M.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc, **7**, 55 (1958).
45) UJIIE, M.: Res. Bull. College Exp., Forests Hokkaido Univ., **20**, 279 (1959).
46) UJIIE, M. and SAKAGAMI, E.: Transactions Hokkaido Branch Meeting Japanese Forestry Soc., **11**, 64 (1962).
47) UJIIE, M. and MATSUMOTO, A.: ibid., **13**, 1 (1964).
48) UJIIE, M. and YOSHIKAWA, T,: J. Japan Wood Res. Soc., **11**, 59 (1965).
49) UJIIE, M. and MATSUMOTO, A.: Transactions 15th Meeting Japan Wood. Res. Soc., 149 (1965).
50) UJIIE, M. and KIKUCHI, K.: Transactions 16th Meeting Japan Wood Res. Soc., 163 (1966).
51) VÁMOS, G., LENGEL, P. and MÉRO, T.: Svensk Papperstidn., **67**, 529 (1964).
52) YELLNER, S. and ENSTRÖM, B.: ibid., **60**, 549 (1957).

摘　　要

北海道大学天塩地方演習林産のササ (*Sasa senanensis*) を用いて，次表の条件によりセミ・クラフト蒸解をおこなった。

同時にその水蒸煮と，シラカンバ，カラマツ材の同一セミ・クラフト条件による蒸解もおこなった。えられたすべてのパルプは，化学的および物理的試験に供され，比較対照の結果つぎの結論がえられた。

活性アルカリ添加率 (%) (Na_2O として，絶乾チップに対し)	蒸解温度 (°C)
15	150, 160, 170, 180
10	150, 160, 170, 180
5	150, 160, 170, 180

液比 3.0　硫化率 25%
蒸解温度到達時間 1時間　同温度保持時間 1.5時間

1. ササセミクラフトパルプの収率は活性アルカリ添加率に大きく影響され，その減少に従って，収率は著しく上昇した。例えば，活性アルカリ 15, 10 および 5% の場合，収率はそぞれれ，40% 台，50% 台，および 60% 台となった。一方その収率は蒸解温度によってはそれ程変化しなかった。これに対してササの水蒸煮では，高温の場合に著しい収率の低下が見られた。しかしながら，ササはいずれの条件でも比較的充分に蒸解されており，唯一回のリファイナー処理で容易に解繊された。

木材パルプと比較した場合，ササは常に同一条件で収率は低く，これはササ自体，抽出物にとむため，蒸解過程での溶出量が大となるものと思われる。しかし，ササセミクラフトパルプは一般のササクラフトパルプにくらべて，5% 内外その収率は高かった。

2. この条件の範囲内では 15% 活性アルカリの比較的低温での蒸解によってえられたササパルプは，ホロセルロース含有率の高い点と，脱リグニンの充分な点で，最良の化学的性質を有していた。しかし，一般にアルカリ添加率の低下と，蒸解温度の上昇によって，パルプのホロセルロースの減少と，リグニンの増加がもたらされた。

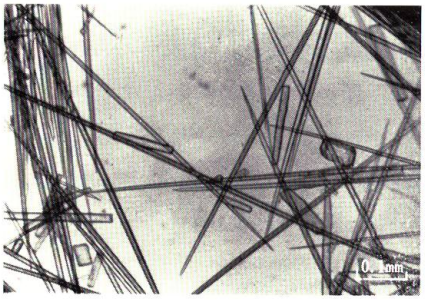
木材パルプと比較した場合，ササパルプの化学的性質はシラカンバパルプのそれよりも僅かにおとるが，カラマツパルプにくらべかなりすぐれていた。

3. ササセミクラフトパルプの物理的性質もまた活性アルカリ添加率に左右された。一般的に 15% の添加率の場合，そのパルプは最良の物理的性質を有していた。

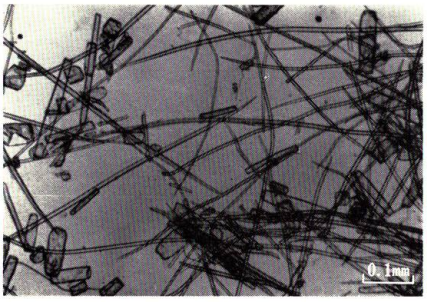
木材パルプと比較した場合，フリーネスが 400 と 200 mℓ のササパルプは，シラカンバとカラマツパルプより白色度と比引裂度においてはすぐれていたが，裂断長と比破裂度において僅かにおとっていた。一方 15% のアルカリ添加率で調製されたササパルプは，一般の 24% 添加率で調製されたササクラフトパルプと同様な物理的性質を有していた。

4. ササセミクラフトパルプの繊維長は平均 1.26 mm で，その範囲は 0.3 mm と 2.6 mm の間にあった。ササの繊維の長さはシラカンバのそれと大して変りがないが，僅かに長かった。しかし，繊維長とその幅との比は極端に大であった。写真はそれをよくしめし，ササの繊維は針のようであり，これが叩解時間とともに，その形態を著しく変化していった。

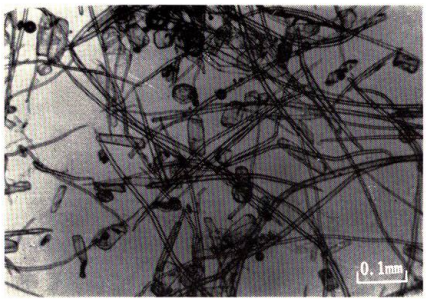
5. 結局，15% 活性アルカリで，比較的低温で調製されたササパルプに，低収率を無視すれば，その化学的および物理的性質から最高の条件といえる。また 10% の活性アルカリで調製されたパルプは，充分に叩解してあれば，僅かに強度が低いだけで，一般のクラフトパルプとくらべ 10% 以上も収率が高い点ですぐれている。一方 5% のアルカリを用いる条件はある程度の強度を有しつつ，一層の収率の向上が見られる点で，よい条件と思われる。



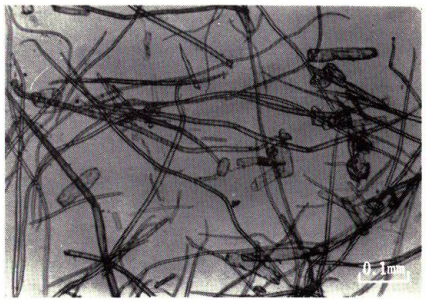
1-1 Cooking



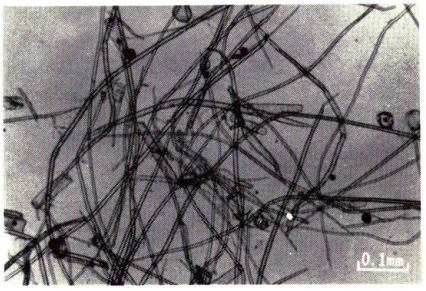
1-2 Defibrating (C.S.f. 690 mℓ)



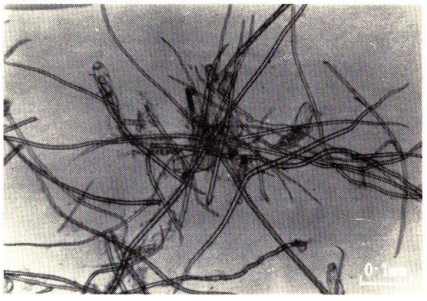
1-3 Beating for 10 min
(C.S.f. 670 mℓ)



1-4 Beating for 20 min
(C.S.f. 660 mℓ)

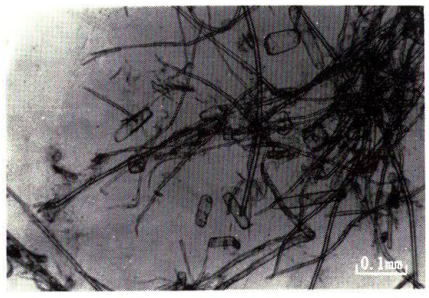


1-5 Beating for 25 min
(C.S.f. 650 mℓ)

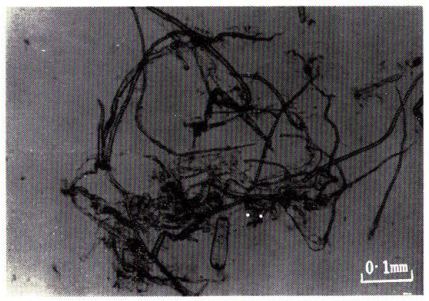


1-6 Beating for 30 min
(C.S.f. 500 mℓ)

1–7 Beating for 35 min
(C.S.f. 350 mℓ)

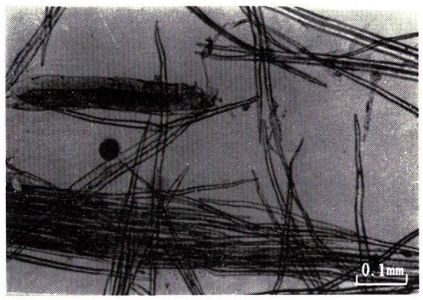


1–8 Beating for 40 min
(C.S.f. 200 mℓ)

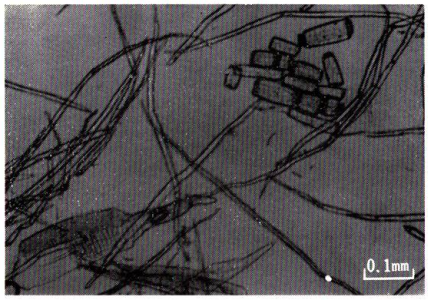


1–9 Beating for 45 min
(C.S.f. 120 mℓ)

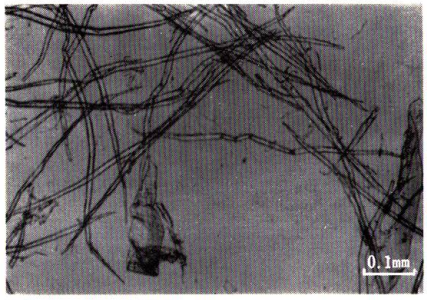
Photo 1. Microscopic photographs of the *Sasa* pulp.



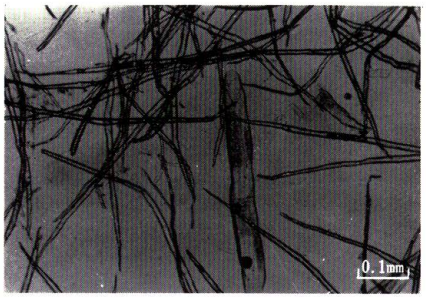
2-1 Cooking



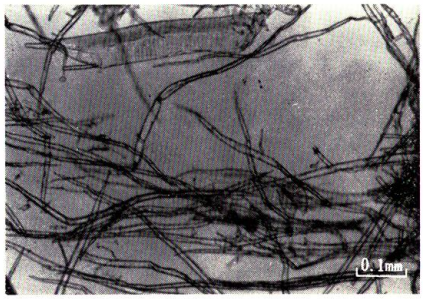
2-2 Defibrating
(C.S.f. 680 mℓ)



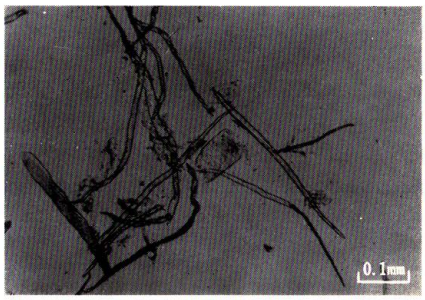
2-3 Beating for 10 min
(C.S.f. 640 mℓ)



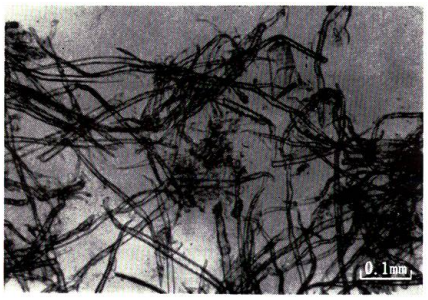
2-4 Beating for 20 min
(C.S.f. 635 mℓ)



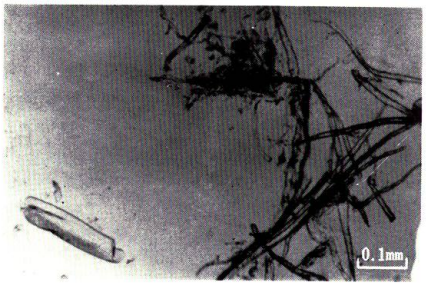
2-5 Beating for 25 min
(C.S.f. 625 mℓ)



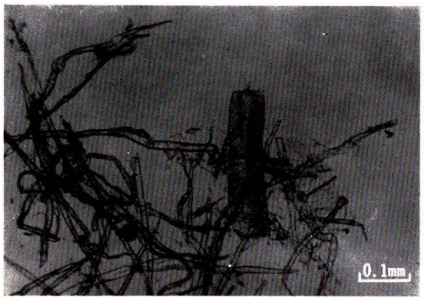
2-6 Beating for 30 min
(C.S.f. 530 mℓ)



2-7 Beating for 35 min
(C.S.f. 450 mℓ)



2-9 Beating for 45 min
(C.S.f. 220 mℓ)



2-8 Beating for 40 min
(C.S.f. 330 mℓ)

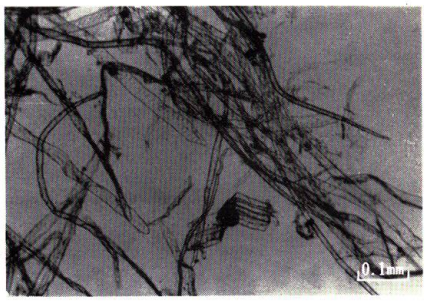
2-10 Beating for 50 min
(C.S.f. 150 mℓ)

Photo 2. Microscopic photographs of the birch pulp.

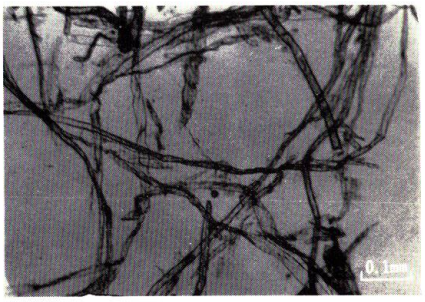
3-1 Cooking

3-2 Defibrating
(C.S.f. 680 mℓ)

3-3 Beating for 20 min
(C.S.f. 645 mℓ)



3-4 Beating for 25 min
(C.S.f. 590 mℓ)



3-5 Beating for 30 min
(C.S.f. 470 mℓ)

3-6 Beating for 35 min
(C.S.f. 365 mℓ)

3-7 Beating for 40 min
(C.S.f. 300 mℓ)

3-8 Beating 45 min
(C.S.f. 195 mℓ)

Photo 3. Microscopic photographs of the larch pulp.