Tissue Elements and Their Papermaking Properties on Bark of *Cryptomeria japonica* and *Chamaecyparis obtusa*

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スギ・ヒノキ樹皮の組織構成要素とそれらの製紙特性

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Résumé

A pulping study was made on the bark of Sugi (*Cryptomeria japonica* D. Don.) and Hinoki (*Chamaecyparis obtusa* Sieb. et Zucc.) in view from pulp elements-papermaking property relation. Bark tissues of these species contain substantial amounts of bast fibers, in spite of little or no bast fibers in the bark from most of coniferous species. Kraft pulp from these barks gave a sheet having properties comparable to that from coarse softwood fibers. In the bark sheets, the thick-walled bast fibers tend to form framework of the structure, whereas the fibrous, thin-walled elements may contribute to the formation of well bonded sheets. There are no particular elements that will cause some trouble in sheetmaking.

要　旨

組織構成要素とそれらの製紙特性の関連という観点から，スギ・ヒノキ樹皮のパルプ化試験を行った。多くの針葉樹の樹皮がほとんどあるいは全くじん皮繊維を含まないのに対して，スギ・ヒノキ樹皮にはかなりの量のじん皮繊維が存在する。これらの樹皮から調製したクラフトパルプは，やや粗大な針葉樹繊維シートに匹敵する紙質のシートを与えた。シート中において，厚壁じん皮繊維はシート構造の骨格を形成する傾向を持つ一方，薄壁の繊維状要素（師細胞と薄壁じん皮繊維）は繊維間結合能の増大に寄与する。なお，製紙に際して特に問題となるような要素は見出されなかった。

1. Introduction

Because of the wood fiber shortages and the push for greater utilization of the forest resource, extensive researches have been made on whole-tree pulping[1)2)3)] and pulping of the young, rapid-growth trees[4)5)6)] from short-rotation forestry to obtain additional papermaking fibers. One of the most important problems encountered in these researches is generated by the presence of bark in wood chips. Large amounts of lignin, extractives and ash in most of bark lead to more alkali consumption in kraft cooking comparison with in normal wood chips, and consequently lower pulp yield. Furthermore, non-fibrous elements in bark pulps often tend to give poor quality of paper sheets. On whole-tree pulping, Powell et al.[2] showed that the additional alkali requirements by bark can be compensated for by the less alkali requirements of juvenile wood chips, and Marton et al.[3] suggested that considerable relief from the problem by the presence of bark is achieved by using oxygen instead of kraft pulping.

The morphological characteristics and content of fibrous elements in bark pulps vary remarkably from wood species to species. Harder et al.[7] reported on bark pulping results for 42 pulpwood species grown in North America. The present paper is one of a serial study to accumulate fundamental knowledge concerning bark pulps from Japanese species in view from pulp elements-papermaking property relation.

2. Experimental

The bark used for this study was collected in early spring, 1979, from the trees of Sugi (*Cryptomeria japonica* D. Don.) and Hinoki (*Chamaecyparis obtusa* Sieb. et Zucc.) growing in Kyoto prefecture, and divided into inner and outer bark parts. Extractives and ash contents in the bark were analized following TAPPI Standards. The bark tissues were observed by a light microscope in the form of stained cross section. For classification test of the bark elements, holopulp of the bark was prepared by sodium chlorite-acetic acid treatment,[8] and subjected to a dynamic drainage jar with various size of screen under monitering the effluent fractions by a light microscope.

Bark kraft pulp was prepared in a 4-litter laboratory digester. The conditions of kraft pulping for all samples were the same and as follows: 25% total chemicals, 24.7% sulfidity, 5:1 liquor-to-bark ratio, 170℃, and 120 min at the temperature. The pulp obtained was refined by a flat screen with 6 inch-cut screen plate, and delignified by sodium chlorite-acetic acid treatment.

The never-dried pulp was beaten in a stainless steel PFI mill for two levels of revolution counts, formed into laboratory handsheets, and tested following TAPPI Standards. Morphological characteristics of the handsheets were observed by a scanning electron microscope.

3. Results and discussion

3.1 Bark elements

The bark of Sugi (*Cryptomeria japonica* D. Don.) and Hinoki (*Chamaecyparis obtusa* Sieb. et Zucc.) contains substantial amounts of bast fibers[9], in spite of little or no bast fibers in the bark from most of coniferous species[7][10]. Figure 1 indicates the similarity between the bark tissues of Sugi and Hinoki. The two types of bast fiber, i. e.,

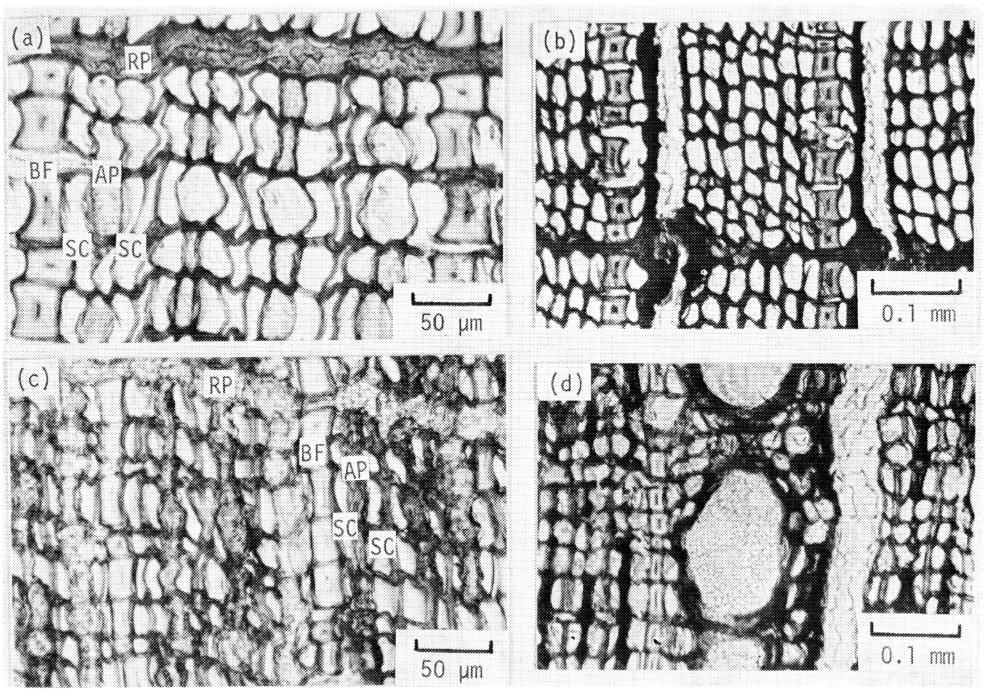

Fig. 1. Cross section of bark tissues.
Inner bark (a) and outer bark (b) of Sugi (*Cryptomeria japonica* D. Don.), and inner bark (c) and outer bark (d) of Hinoki (*Chamaecyparis obtusa* Sieb. et Zucc.) . BF : bast fiber, SC : sieve cell, AP : axial parenchyma and RP : ray parenchyma.

thick-walled bast fiber and thin-walled bast fiber, are present in these bark tissues, but sclereids, or stone cells, are absent.

The carefully holopulped elements were classified using a dynamic drainage jar with various size of screen. The fractions retained on 60 and 100 mesh screen consist of fibrous cells and their fragments, i. e., sieve cell, thin-walled bast fiber and thick-walled bast fiber (Fig. 2). The thick-walled bast fibers have about 4 mm of mean length and 5–10 μm of cell wall thickness, whereas the cell wall thickness of thin-walled bast fibers is comparable to that of the sieve cells. In a pulp suspension, the thin-walled fibrous elements tend to form floc in consequence of entanglements with the rigid bast fibers because of their large fiber length and great flexibility. Most part of the fractions through 100 mesh screen consist of parenchyma cells for the inner bark and of parenchyma cells and cork cells for the outer bark, and come almost within the category of fines. However, there are no particular elements, such as clumps of phelloid cells in the outer bark of Akamatsu (*Pinus densiflora*)[11], that will cause some trouble in sheetmaking.

Table 1 shows results of the classification test for the holopulped elements. In comparison with the inner bark, portion of fines fractions in the outer bark increased due to the presence of fine cells formed in the phellogen.

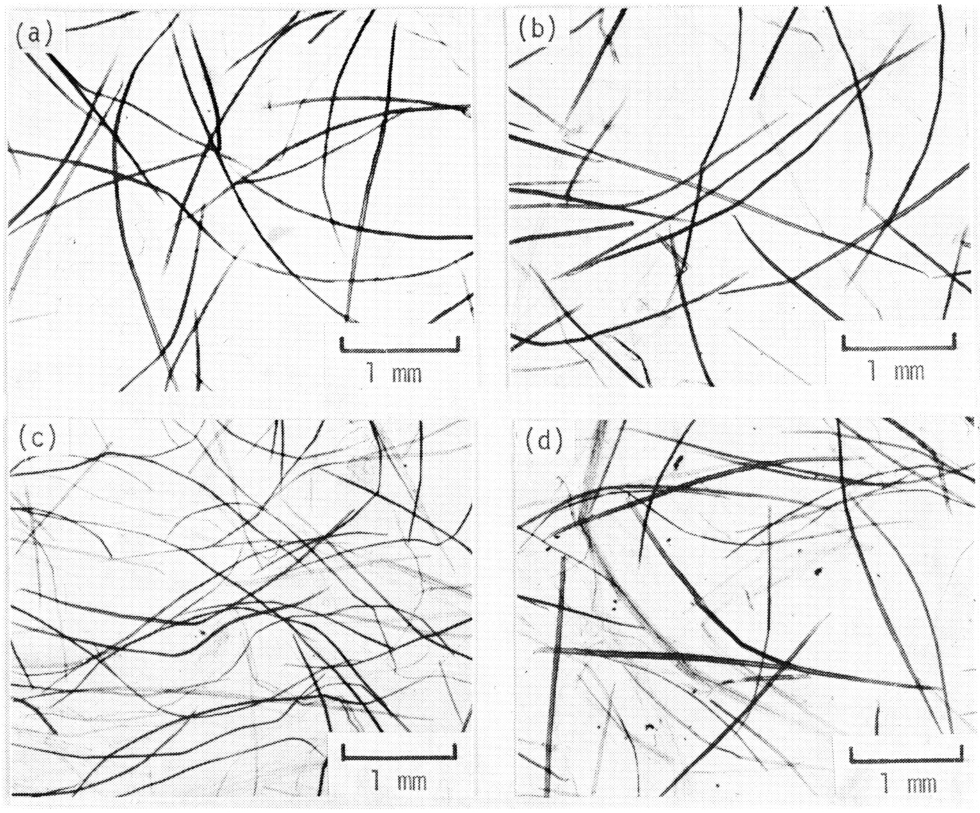

Fig. 2. Bark elements retained on 60 mesh screen.
Inner bark (a) and outer bark (b) of Sugi, and inner bark (c) and outer bark (d) of Hinoki.

Table 1 Size distribution of bark elements defibrated by sodium chlorite-acetic acid treatment

Fraction, mesh		>60	60-100	100-200	<200
Sugi	Inner, % (in weight)	75.8	11.5	4.9	7.8
	Outer, % (in weight)	79.4	3.9	1.8	14.8
Hinoki	Inner, % (in weight)	86.3	4.4	5.3	4.0
	Outer, % (in weight)	77.9	4.6	0.3	17.2

3.2 Yield and quality of kraft pulp

Table 2 summarizes pulp yield in comparison with some analytical data for the bark, and, also, indicates the similarity between Sugi and Hinoki in pulp yield. Considerable amounts of alcohol-benzene and hot water solubles were found in the bark, particularly in the inner bark, and lead to poor yield of pulp. The outer bark tends to be lower than corresponding inner bark in kraft pulp yield, despite higher in holopulp yield. It should be noted that most of the very fine cells such as through 200 mesh screen was lost during the washing and screening procedure in kraft pulping test.

Table 2 Bark analysis and pulp yield

		Bark			Holopulp	kraft pulp	
		Ash, %	Alcohol-benzene solubles, %	Hot water solubles *, %	yield, %	Cooking yield, %	Screened yield, %
Sugi	Inner	4.73	20.3	14.9	33.7	29.6	25.3
	Outer	0.29	7.0	5.1	38.5	23.6	19.6
Hinoki	Inner	4.72	11.6	15.1	32.2	27.0	25.2
	Outer	0.24	6.0	6.7	38.9	24.0	21.3

* After extraction with alcohol-benzene

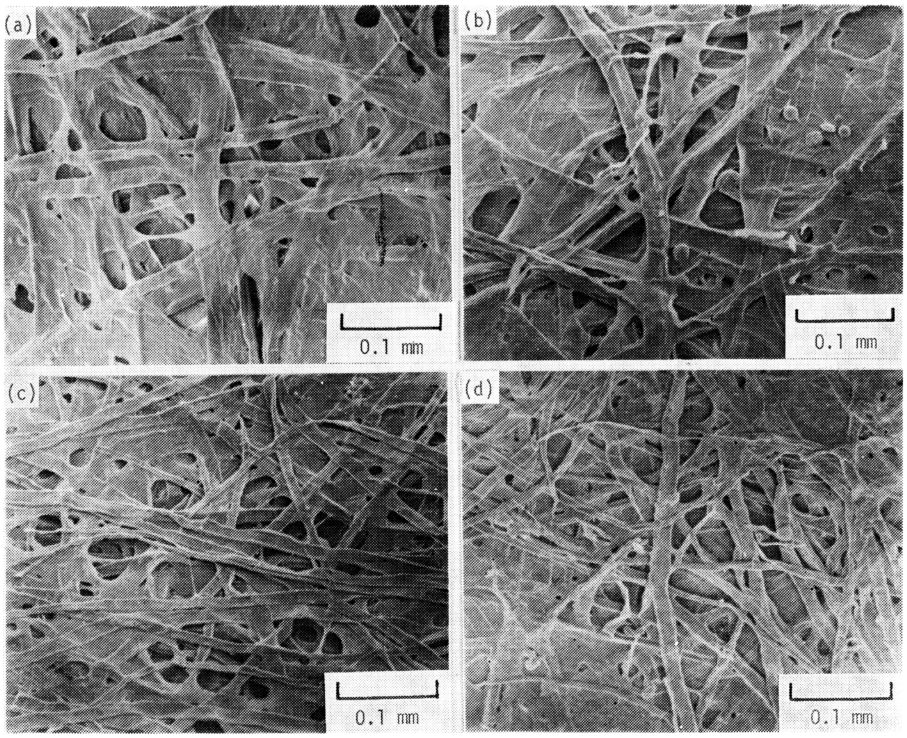

Fig. 3. Surface image of bark handsheets from never-dried, unbeaten kraft pulp. Inner bark (a) and outer bark (b) of Sugi, and inner bark (c) and outer bark (d) of Hinoki.

Kraft pulp from the bark of Sugi and Hinoki gave a sheet comparable to that from coarse softwood fibers such as Douglas fir (*Pseudotsuga taxifolia*). As mentioned earlier, the fibrous fraction of the bark pulp that will strongly affect the sheet properties can be subdivided into thick-walled and thin-walled elements. In sheetmaking, the thick-walled elements, i. e., thick-walled bast fibers, tend to behave somewhat like the latewood tracheids in softwood pulp and to form framework of the sheet structure (Fig. 3). The thin-walled elements, i. e., sieve cells and thin-walled bast fibers, have well flattened, ribbon-like shape into the sheets even at unbeaten condition, and make so contact with

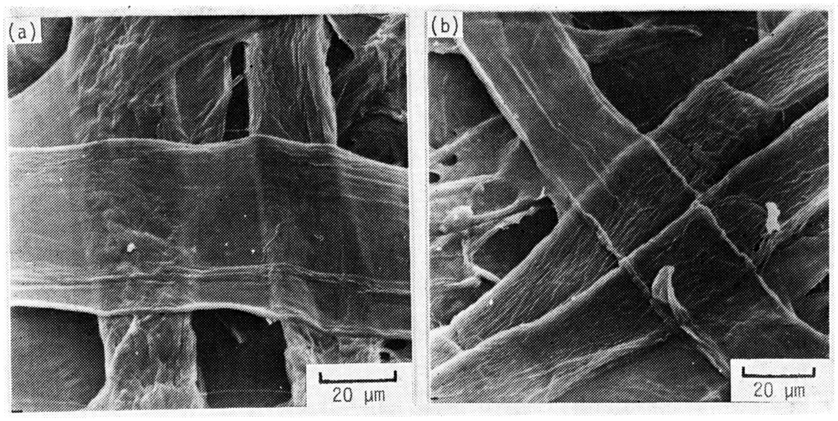

Fig. 4. Fibrous thin-walled elements on surface of unbeaten handsheets. Sugi inner bark (a) and Hinoki inner bark (b) .

Table 3 Handsheet test of bark kraft pulp

		PFI mill rev.	Freeness (CSF), ml	Sheet density, g/cm³	Breaking length, km	Burst factor	Tear factor	Folding endurance (MIT)
Sugi	Inner	0	550	0.40	5.04	0.79	285	49
		1000	351	0.45	7.12	1.05	336	374
		5000	204	0.50	8.73	1.60	288	749
	Outer	0	534	0.45	5.56	0.58	236	81
		1000	309	0.50	7.68	0.85	244	261
		5000	99	0.54	8.76	1.18	205	617
Hinoki	Inner	0	467	0.46	7.02	1.21	324	260
		1000	303	0.51	8.67	1.75	275	547
		5000	159	0.53	9.56	2.17	236	1048
	Outer	0	506	0.45	6.02	1.05	212	76
		1000	296	0.52	8.24	1.49	196	273
		5000	139	0.55	9.24	2.19	171	651

others as clearly visible the cell wall texture of the lower fiber through it (Fig. 4).

Table 3 summarizes results of handsheet test for the bark pulp of Sugi and Hinoki. An increase in sheet density with increasing of beating levels was not so great because of little or no flattening of the thick-walled bast fibers. Unbeaten handsheets from the bark pulp developed higher levels of breaking length and burst factor than those from usual softwood pulp, and this suggests that the presence of fibrous thin-walled elements may contribute to the formation of well bonded sheets. On the other hand, considerable amounts of long, thick-walled bast fibers in the bark pulp offered the sheets having very high tear resistance.

The thick-walled bast fibers of Sugi are slightly larger in fiber width than those of Hinoki as seen in Figs. 1, 2 and 3, and this would be reflected to sheet strength, that is, slightly low in breaking length, burst factor and folding endurance. Although the inner bark sheets have higher tear resistance than corresponding outer bark sheets, the strength properties of both sheets are comparable to those of softwood.

4. Acknowledgement

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