Holopulp Elements of Burmese Bamboos in Relation to Their Papermaking Properties

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製紙特性に関連するビルマ産竹材のホロパルプ構成要素

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Résumé

The characteristics of holopulp elements from five major species of bamboo grown in Burma were studied in comparison with two major species of Japanese bamboo. Various methods to obtain the bamboo holopulps were examined and the peracetic acid method was found to be the suitable method. From the classification of holopulp, the fractions retained on 60 and 100 mesh screen were composed of fiber elements and the fraction passed through 100 mesh screen contained almost non-fibrous elements. Within the seven species of bamboo used in this experiment, the holopulp yield as well as the percentage of fiber elements can be divided into three groups and these groupings are related with the type of vascular bundle of bamboo tissue.

要　　旨

ビルマ産および国内産の竹材数種を供試，それらから調製したホロパルプの構成要素の特徴を研究した。まず竹材ホロパルプの調製法を検討し，過酢酸法が適していることを認めた。ホロパルプの篩別を行った結果，繊維要素の殆んどは60および100メッシュ残留区分に，また非繊維状要素の大部分は100メッシュ通過区分に存在することが判明した。ホロパルプ収率および繊維要素の比率は3つのグループに分けることができ，この分類が竹材組織における維管束鞘の配列パターンと関連していることが推定された。

1. Introduction

Bamboo is the most important fiber resource for papermaking in tropical region of Asia, especially in India and Burma where about 300 species of bamboo are grown[1]. However, only two species of bamboo, *Cephalostachyum pergracile* and *Bambusa polymorpha,* are now practically used as a raw material for pulp industries in Burma and the annual production is about fifty thousand tons of bamboo pulp. On the other hand, it is reported that economically

extractable bamboo in Burma amounts annually to nearly five million tons[2]. For effective utilization of bamboo resources, it is very important to make clear the papermaking characteristics of bamboo pulps from a variety of bamboo species.

Although a number of research papers have been reported concerning bamboo pulp[3,4,5], more information is required to understand the papermaking properties of bamboo pulp. The present paper is one of the first thorough research on papermaking characteristics of Burmese bamboo pulp. The data on holopulp elements in addition to some tissue structure and chemical composition are presented.

2. Experimental

2.1 Materials

Five major species of Burmese bamboo from the Pegu Yoma Bamboo Forest, which is one of the most extractable area in Burma, were selected for this study. And two species of Japanese bamboo grown in the Kamigamo Experimental Forest Station of Kyoto University Forest, were used for comparison. Table 1 shows general dimensions of the samples.

Table. 1 General dimensions of different species of bamboo

Botanical name (Vernacular name)	Age, yr	Height, m	Diameter, cm		Chip density, g/cm³
			Base	Top	
Phyllostachys bambusoides (Madake)	1	6.8	7.2	2.2	0.63
〃 (〃)	6	5.6	7.0	2.0	0.62
Phyllostachys pubescens (Mosochiku)	1	6.2	4.2	2.2	0.83
〃 (〃)	5	4.4	3.6	1.1	0.64
Cephalostachyum pergracile (Tin wa)	3	5.1	5.3	3.8	0.60
Bambusa polymorpha (Kyathaung wa)	〃	5.1	5.3	3.6	0.69
Bambusa tulda (Thaik wa)	〃	3.8	3.3	2.3	0.70
Dendrocalamus longispathus (Wayar)	〃	6.8	7.4	4.6	0.67
Dendrocalamus membranaceus (Waphyu)	〃	—	—	—	0.77

2.2 Observation of bamboo tissues

Cross section of bamboo tissues having 20 to 50 μm of thickness were prepared and observed under a photomicroscope. According to Liese's classification method[1], it was confirmed that seven species of bamboo used in this experiment can be classified into three vascular bundle types, namely type I, type II and type III, as shown in Fig. 1.

2.3 Chemical analysis

The results of chemical analysis according to TAPPI standards are summerized in Table 2. It was found that the Burmese bamboos are lower in lignin content but higher in ash content in comparison with the Japanese bamboos.

2.4 Preparation of holopulp

As described in Section 3.1, the method of Leopold, first adopted by Poljak, was modified for the preparation of bamboo holopulp. The alcohol-benzene extracted thin shavings of bamboo sample (17×7×1 mm) were treated with 15.3% aqueous solution of peracetic

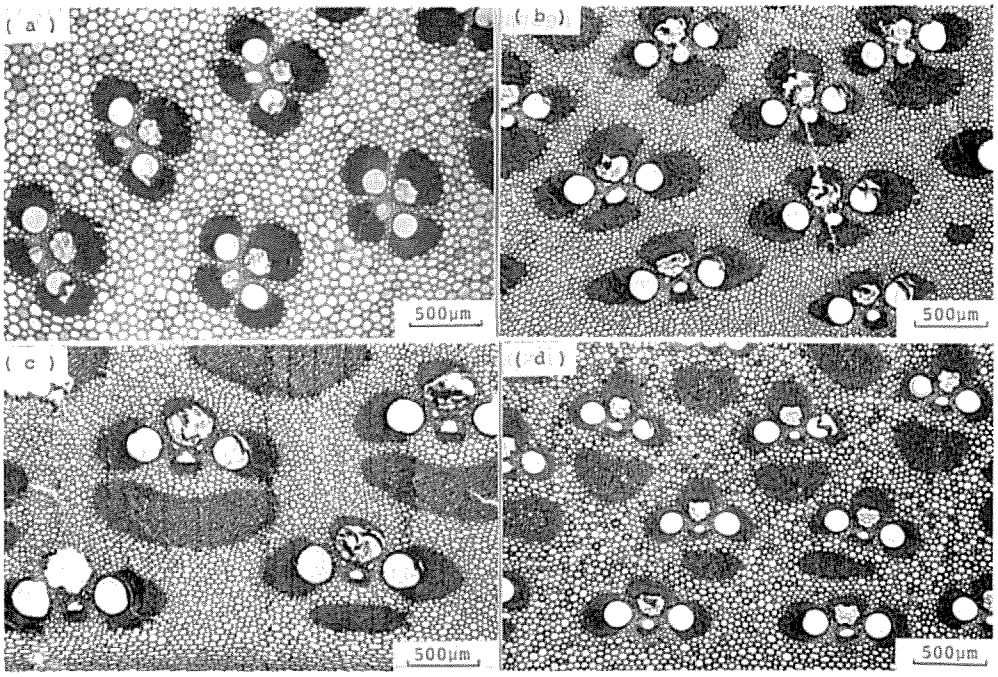

Fig. 1 The classification of vascular bundle type in bamboo species
(a) *P. bambusoides* (Type I) (b) *C. pergracile* (Type II)
(c) *B. polymorpha* (Type III) (d) *D. membranaceus* (Type III)

Note[1]:

Phyllostachys species was assigned as the Type I, which consists of one part (central vascular strand) and sclerenchyma sheaths as the supporting tissue.

Cephalostachyum species was assigned as the Type II, which is quite similar to the Type I, but sheath at the intercellular space is strikingly larger than other ones.

Bambusa and *Dendrocalamus* species were assigned as the Type III, which consists of two parts (central vascular strand and one fiber strand); fiber strand is inside the central strand and sheath at the intercellular space (protoxylem) generally smaller than the other ones.

Table. 2 Chemical composition of different species of bamboo (oven-dried basis)

Species	Age, yr	Ash, %	Alcohol-benzene solubles, %	Lignin, %	Pentosan, %	Holo-cellulose, %
P. bambusoides	1	1.09	1.37	25.56	21.56	67.62
〃	6	0.92	3.67	26.30	19.97	64.82
P. pubescens	1	1.69	2.43	26.51	21.73	63.34
〃	5	1.27	2.53	29.26	20.59	60.50
C. pergracile	3	2.10	4.10	23.10	20.80	63.74
B. polymorpha	〃	3.00	5.20	24.80	20.30	61.19
B. tulda	〃	2.00	3.10	23.20	23.30	67.93
D. longispathus	〃	1.81	3.55	25.30	18.15	66.96
D. membranaceus	〃	1.45	1.59	—	—	67.47

acid, which was freshly prepared as described by Poljak[6,7], at 80℃ for 30 min for each cycle of treatment. Three consecutive cycles of treatment, without washing and drying the shavings after each peracetic acid treatment, were carried out. The holopulp after the third treatment was followed by sodium borohydride reduction and defiberized by gentle mechanical agitation.

2.5 Classification test for bamboo holopulp

The holopulp prepared carefully without any loss of fines, was subjected on a dynamic drainage jar with prescribed mesh screen to classify the holopulp elements.

3. Results and discussion

3.1 Methods for preparation of bamboo holopulp

An attempt to obtain bamboo holopulp by the chlorite method failed because of the strong resistance of bamboo tissues for defibration. Leopold has shown that the peracetic acid method, modified by a subsequent sodium borohydride step, gives superior holocellulose fibers with 93-100% recovery of major polysaccharides and a minimum of carboxyl groups for pinewood[8].

In order to simplify the procedure of the peracetic acid method, a proposed procedure was compared with Leopold's procedure. The proposed method is a continuous one without hot water soaking and air drying after each cycle of treatment, while both the processes are included in Leopold's procedure.

Table 3 shows the percentage of insoluble materials after each treatment. After three

Table. 3 Comparison of procedures in the peracetic acid methods (*P. pubescens*)

Number of treatment	Yield of insolubles, %	
	Leopold's procedure	Proposed procedure
1	68.5	68.5
2	59.3	61.2
3	50.0	50.1

cycles of peracetic acid treatment, the defibrated holopulp was finely obtained. No significant difference in holopulp yield was detectable between the two procedures. The value of 50± 0.1% was about 10% less than the original holocellulose content determined for the bamboo meal. Pentosan content of the insoluble materials of *P. pubescens* after peracetic acid treatment is shown in Fig. 2. This indicates that large part of the difference between the holocellulose content and holopulp yield may be caused by dissolution of pentosan during peracetic acid treatment. Since there is no other suitable method to prepare bamboo holopulp, the proposed procedure was used for investigation of bamboo holopulp elements.

3.2 Elements of bamboo holopulp

Bamboo pulp contains substantial amounts of parenchyma cells in addition to fibers and vessel elements. To separate these pulp elements, the holopulp was classified using a dynamic drainage jar.

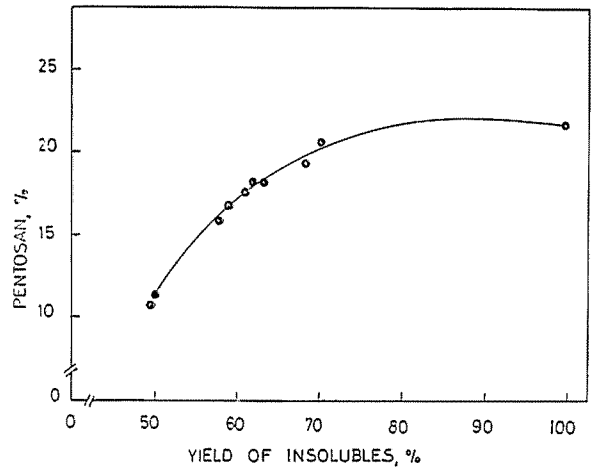

Fig. 2 Pentosan content of insoluble materials after peracteic acid treatment

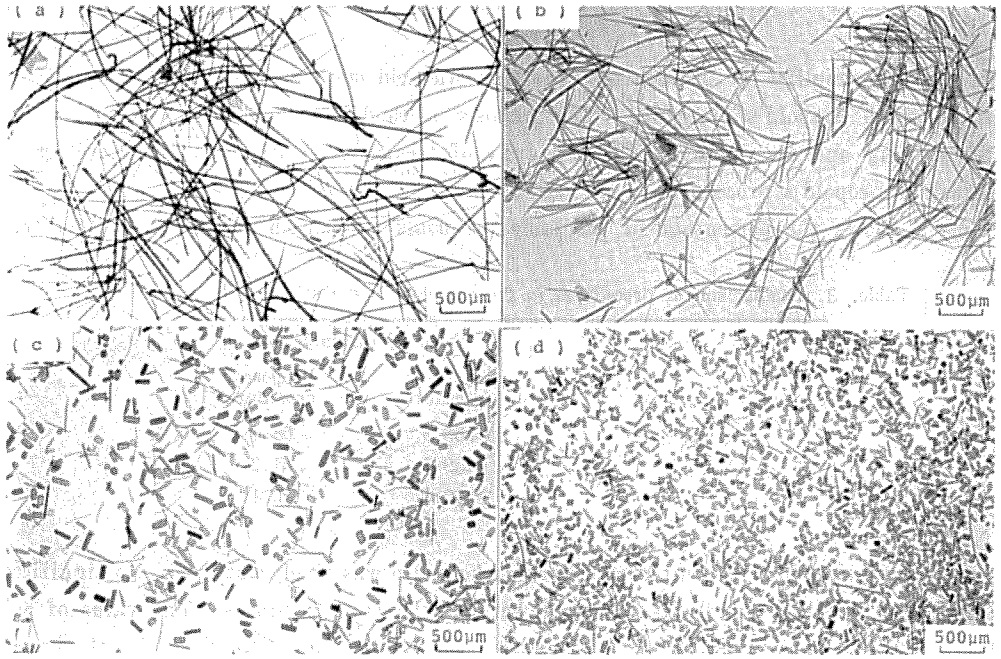

Fig. 3 Micrographs of a series of fraction of *D. membranaceus*
(a) on 60 mesh (b) 60-100 mesh (c) 100-200 mesh
(d) through 200 mesh

Figure 3 shows micrographs of a series of fraction of *D. membranaceus* given as an example. The fraction retained on 60 mesh screen is composed of sound fibers having about 1.85 mm in mean length and few vessel elements, whereas the 60-100 mesh fraction contains short fibers and fiber fragments, which were cut during the shaving preparation, having 0.8 mm in mean length. The elements which passed through 100 mesh screen consists of parenchyma cells and few fibrous fines. It seems that the amount of the

Table. 4 Results of the classification test of holopulp of different species of bamboo

Species	Age, yr	Part	Total yield, %	Weight fraction, %			
				On 60	60-100	100-200	Through 200
P. bambusoides	1	middle	59.23	36.47	0.70	10.27	11.80
〃	6	〃	43.77	31.10	1.19	4.04	7.45
P. pubescens	1	〃	51.07	32.55	1.90	9.40	7.22
〃	5	top	42.43	24.98	1.46	7.49	8.50
〃	〃	middle	44.54	25.80	0.67	10.19	7.89
〃	〃	bottom	44.63	25.84	0.92	10.19	7.68
C. pergracile	3	middle	57.75	42.29	0.13	6.38	8.95
B. polymorpha	〃	〃	55.41	37.13	0.45	0.66	17.17
B. tulda	〃	〃	56.52	38.83	0.21	6.19	11.29
D. longispathus	〃	〃	56.44	35.48	0.82	1.15	18.99
D. membranaceus	〃	〃	55.69	37.44	0.25	1.24	16.76

fraction on 60-100 mesh screen is approximately equal to the amount of fiber elements in the bamboo holopulp. The results of the classification test were presented in Table 4.

Liese and Mende have reported that the amount of parenchyma cells decreases with corresponding increase in the proportion of fibers, with increasing height of the culm[9]. However, there was no significant difference in the proportion of pulp elements of mature *P. pubescens* with increasing height of the culm. Moreover, the holopulp yield slightly decreased with increasing the height.

Of the Japanese bamboo species, the holopulp yield of juvenile bamboos are remarkably higher than those of mature bamboos. Although the new bamboo shoot attains its height and diameter growth during the first growing season, the total culm weight above the ground may still increase during additional growing seasons. The growth of bamboo would be completed three years after sprouting[10]. For this reason, a higher pulp yield in juvenile bamboo does not mean a higher production of pulp per unit area of bamboo forest.

For the middle part of mature culm, the holopulp yield of Burmese bamboo species were remarkably higher than those of Japanese species. From Table 4, the values of holopulp yield may be divided into three groups; this grouping is also fit for the total yield of fiber elements, i.e. retained on 60 mesh fraction plus 60-100 mesh fraction. Within the species used in the present experiment, it was found that the holopulp yield was closely related to the type of vascular bundle in bamboo tissues. The maximum yield was obtained from *Cephalostachyum* species which has the vascular bundle type II according to Liese et al.[1], whereas the minimum yield from *Phyllostachys* species having the vascular bundle type I and *Bambusa* and *Dendrocalamus* species having the type III is between them.

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