A Fundamental Study on Whole-Tree Pulping of *Acacia mollissima* Wild.

Koji MURAKAMI and Daisuke YOSHINO

モリシマアカシアの全木パルプ化に関する基礎的研究

村 上 浩 二・吉 野 示 右

Résumé

In order to accumulate the fundamental data related to whole-tree utilization, a pulping study was made on each component from a tree of acacia (*Acacia mollissima* Wild.) in relation to tissue elements and papermaking properties. It was shown that acacia is one of the most attractive species for whole-tree pulping, that it, the bast fibers of acacia bark have larger fiber length than the wood fibers. The bark of acacia does not contain any elements which cause a trouble in papermaking, except the presence of dark spots in the unbleached whole-tree kraft pulp.

要 旨

全木パルプ化に関する基礎的データを蓄積する目的で，モリシマアカシア各部位をパルプ化し，組織構成要素および紙質と関連づけて研究した。その結果，アカシア樹皮の師部繊維は木繊維より大きい繊維長を持ち，これが全木パルプシートにおける紙力向上に寄与することから，アカシアが全木パルプ化に適した樹種であると推定し得た。なお，樹皮には製紙に際して悪影響を及ぼすと考えられる要素がほとんど存在しないが，未さらし全木パルプには易漂白性の褐色斑点が存在する。

1. Introduction

It is well known that the plant of Leguminosae family grows well even in barren soil because of its ability of nitrogen fixation. A hardwood tree belonging to this family, *Acacia mollissima* Wild., was introduced for making a woodland in the Shirahama Experimental Forest, Kyoto University Forest, in which the soil was very poor for common plantation. The result was satisfactory, that is, the acacia trees grew relatively fast and improved the soil conditions[1]. Therefore, the acacia is an effective species for a plantation in barren land, and is an attractive candidate for whole-tree pulping[2,3,4] as a raw material.

In the present paper, a pulping test was made on a tree of acacia (*Acacia mollissima* Wild.) to accumulate the fundamental data related to whole-tree utilization[5,6,7]. The tree harvested was divided into several parts such as bole, branches and bark. The results of pulping and handsheet tests for each component are presented.

2. Experimental

An acacia tree, 17 year-old *Acacia mollissima* Wild. growing in the Shirahama Experimental Forest of Kyoto University Forest, was cut down at May, 1982, and divided into several parts within a few days of falling. The harvested tree was about 14.3 m height and 17.3 cm breast-height diameter.

Chemical analysis of each component was made according to TAPPI Standards. Furthermore, in order to determine the portion of fibrous and non-fibrous elements of the wood and bark, holopulp was prepared by peracetic acid treatment[8], and classified on a dynamic drainage jar with a serial mesh of screens under monitoring by a light microscope.

Chips having 3×30×30 mm size were kraft-pulped in a laboratory scale under the following conditions; 18.0% active alkali, 20.0% sulfidity and 5:1 liquor to chip ratio at the maximum temperature of 170°C for 2 hours. The never-dried pulp was beaten in a PFI mill for prescribed revolutions. Handsheet test was made according to TAPPI Standards.

3. Results and Discussion

3.1 Characteristics of each component

Weight distribution of components in the sample tree is shown in Table 1. Since a preliminary experiment showed that the leaves are unsuitable as an additional fiber resource, the leaves were omitted from this investigation.

The results of chemical analysis are summarized in Table 2. Ash and extractives contents of the bark were considerably higher than those of the wood. Corresponding to this, reducing sugar contents decreased from the bole wood through the branch wood to the bark. The difference between two Klason lignin contents of the bark shows that the bark contains a substantial amount of 1% sodium hydroxide solubles which insolubilize during 72% sulfuric acid treatment followed by boiling in dilute acid as suggested in elsewhere[9].

The holopulp from each component was prepared carefully without any loss of fines by peracetic acid treatment. Size distribution of the holopulp in addition to holopulp yield is

Table 1. Harvest of components in a tree of acacia (*Acacia mollissima* Wild.)

Component	Bole		Branches, >2 cm diam.		Branches, <2 cm diam.	Leaves
	Wood	Bark	Wood	Bark	Wood + Bark	
Green weight, kg	138.1	23.4	22.4	6.9	10.6	28.7
Oven dry weight, kg	74.6	10.7	10.7	3.1	4.5	12.2
Yield based on whole tree, %	64.4	9.2	9.2	2.7	3.9	10.6

Table 2. Chemical analysis of acacia components

Component	Ash, %	Ethanol-benzene solubles, %	Hot water solubles, %	Reducing sugar (as glucose), %	Lignin, %	
					a)	b)
Bole wood at breast height	0.2	3.8	4.3	77.2	16.8	-
Bole wood at middle part	0.3	3.7	3.9	73.2	18.3	-
Branch wood, >2 cm diam.	0.5	3.5	5.2	67.3	18.1	-
Branch wood+bark, <2 cm diam.	2.9	7.5	13.3	51.8	19.0	13.9
Bole bark at breast height	2.4	34.9	20.6	28.2	11.3	5.2
Bole bark at middle part	2.4	31.7	17.9	26.6	11.9	5.1
Branch bark, >2 cm diam.	2.7	21.6	20.8	33.4	13.6	7.0

a) Klason lignin content determined on extractive-free sample.
b) Klason lignin content determined on 1% NaOH extracted sample of extractive-free meal.

Table 3. Size distribution of wood and bark elements defibrated by peracetic acid treatment

Component	Holopulp yield, %	Fraction in mesh, % in weight			
		>60	60-100	100-200	<200
Bole wood	62.1	98.3	1.5	0.1	0.1
Branch wood, >2 cm diam.	62.9	96.3	2.2	1.4	0.1
Branch wood+bark, <2 cm diam.	50.0	90.6	4.9	2.3	2.2
Bole bark	26.7	81.4	3.9	6.7	7.8
branch bark, >2 cm diam.	30.6	63.4	0.9	11.7	24.0

shown in Table 3. The bark holopulps, especially the bole bark, contain a considerable amount of fines passed through a 100 mesh screen, while the wood holopulps contain a very small amount of fines which originated from parenchyma tissue.

The fraction of wood holopulps retained on the 60 mesh screen is composed of sound fibers and few vessel elements, whereas the 60-100 mesh fraction contains short fibers and fiber fragments. In the bark holopulp, the 60 mesh fraction is composed of a mixture of bast fibers and a few mass of parenchyma cells which are difficult to defibrate even in a strong kraft cooking condition. Almost all elements in the fraction passed through the 100 mesh screen can be assigned to the category of fines. It should be emphasized that the bast fibers of bark have larger fiber length than the wood fibers but smaller in lumen diameter, that is, number average fiber length is 1.0 mm of the wood fibers and 1.6 mm of the bast fibers with more than 5.0 Runkel ratio.

3.2 Yield and papermaking properties of kraft pulp

The results of kraft pulping and handsheet tests are summarized in Table 4.

PULP YIELD The result of the whole-tree cooking shows that 47.0 kg of the unscreened, unbleached kraft pulp will be obtained from the sample tree, except the leaves. This value approximately coincides with that of 48.2 kg calculated from the results of

Table 4. Yield and qualities of kraft pulp from acacia components

Component	Pulp yield, %	Kappa number	Brightness, %	PFI mill rev.	Freeness (CSF), ml	Sheet density, g/cm³	Tensile index, Nm/g	Burst index, kPam²/g	Tear index, mNm²/g
Bole wood	51.5	12.3	51.2	0	640	0.46	29.4	0.9	4.5
				5000	450	0.58	62.0	2.8	8.8
				10000	385	0.59	70.8	3.3	9.2
				40000	172	0.65	85.6	5.3	10.5
Branch wood, >2 cm diam.	47.7	13.2	51.8	0	530	0.48	32.8	1.0	2.4
				5000	330	0.62	60.8	2.5	5.2
				10000	310	0.60	71.8	3.5	6.5
				40000	214	0.61	66.7	3.1	4.6
Branch wood + bark, <2 cm diam.	41.0	17.7	39.6	0	395	0.50	44.6	1.7	4.1
				5000	212	0.59	64.3	3.0	5.4
				10000	195	0.60	73.4	3.8	5.1
				40000	233	0.61	76.6	3.9	5.9
Bole bark	20.2	74.8	9.8	0	291	0.40	38.9	1.8	11.4
				1000	135	0.45	51.2	2.4	9.9
				5000	101	0.45	55.4	2.9	10.3
Branch bark, >2 cm diam.	23.5	38.6	17.8	0	465	0.43	42.8	2.0	7.9
				1000	196	0.47	56.8	2.8	9.0
				5000	104	0.49	60.7	3.6	8.9
Whole-tree chips	45.4	13.9	39.7	0	590	0.49	38.4	1.2	5.1
				5000	355	0.61	73.5	4.0	8.1
				10000	320	0.61	76.0	4.4	8.7
				40000	146	0.65	90.3	5.2	8.6

separate cooking test of individual component using the same cooking conditions. The pulp may consist of 79.7% from the bole wood, 10.6% from the wood of branches having more than 2 cm diameter, 3.7% from the small branches containing bark, and 6.1% from the bole and branch bark.

Cooking yield of the kraft pulp for each component is in the order of reducing sugar contents, that is, the bole wood, the branch wood, the small branches containing bark, the branch bark and the bole bark. The bark pulp is remarkably higher in Kappa number and lower in brightness than the wood pulp. The unbleached pulp from the whole-tree chips is nearly the same in Kappa number but remarkably lower in brightness than that from the branch wood. The whole-tree pulp contains a number of dark spots which originate from mass of parenchyma and cork cells. However, the dark spots disappeared easily by sodium chlorite-acetic acid treatment.

PAPERMAKING PROPERTIES Since freeness of the bark pulp decreases considerably with progress of beating to cause a trouble in sheetmaking procedure, the bark pulp was beaten up to 5000 revolutions in a PFI mill. A novel phenomenon was found in the small branch pulp containing bark that the freeness value at well beaten state increases by beating. This may be due to the presence of very thin, small elements which become fragments by beating to pass the screen of a freeness tester.

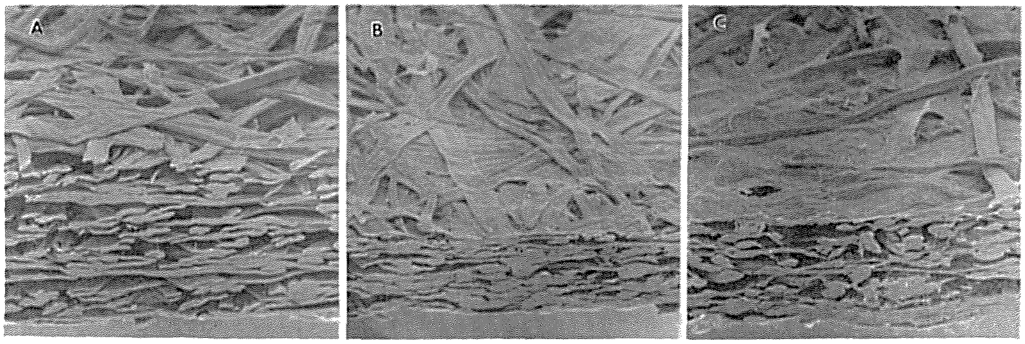

Fig. 1 Surface and cross-sectional image of handsheets from never-dried, unbeaten kraft pulp (×150)
A : Bole wood pulp sheet B : Small branch pulp sheet
C : Bole bark pulp sheet

The surface and cross-sectional image of unbeaten sheets is shown in Fig. 1. The fibers in the bole wood pulp have relatively thin cell wall to take a ribbon-like shape into the sheet. Fiber elements of the small branch pulp consist of juvenile wood fibers and bast fibers, but two kinds of fiber can not be distingushed each other in Fig. 1B. The cell wall of juvenile fibers is much thinner than that of bole wood fibers. The bast fibers in the bole bark pulp have thick cell wall and look like rather rigid into the sheet.

As seen in Table 4, both bark pulps from the bole and the large branches gave bulky sheets having low tensile and burst indexes but remarkably high tear index because of the presence of bast fibers. The sheets from the branch wood and the small branches containing bark have remarkably low tear index, which indicates the influence of the presence of very thin-walled fibers. It should be emphasized that sheet strength properties of the whole-tree pulp is comparable to those of the bole wood pulp. In the whole-tree sheets, the presence of bast fibers compensates for weakening effect by mixing of branch fibers and bark non-fibrous elements.

Acknowledgement

The authors express their appreciation to the stuffs of the Shirahama Experimantal Forest of Kyoto University Forest for their kind assistance of acacia tree harvesting.

References

1) Yoshikawa, K., Uenaka, K., Haya, K., Nasu, K., and Uenaka, M. : The foreign wood species introduced in the Shirahama Experimental Forest of Kyoto University Forest and their growth appearance, The Reports of the Kyoto University Forests, No. 14, 30-71 (1982)
2) Wiedermann, A. : Kraft pulping of several unbarked European hardwoods, Tappi, **55**, 8, 1209-1211 (1972)
3) Marton, R., Amidon, T. E., and Koeppicus, R. : Origins of some problems in whole-tree pulping, Tappi, **59**, 12, 107-112 (1976)
4) Resler, P. W., Marton, R., and Granzow, S. : Whole-tree pulping of a frost-hardy eucalypt, Tappi, **62**, 6, 61-64 (1979)
5) Einspahr, D. W. : The influence of short-rotation forestry on pulp and paper quality. I. Short-

rotation conifers, Tappi, **59**, 10, 53-56 (1976)

6) Einspahr, D. W. : The influence of short-rotation forestry on pulp and paper quality. II. Short-rotation hardwoods, Tappi, **59**, 11, 63-66 (1976)

7) Murakami, K., Hirako, H., Araya, K., and Imamura, R. : Fundamental study on whole-tree pulping of *Pinus densiflora*, Bulletin of the Kyoto University Forests, No. 51, 267-673 (1979)

8) Wai, N. W., and Murakami, K. : Holopulp elements of Burmese bamboos in relation to their papermaking properties, Bulletin of the Kyoto University Forests, No. 54, 236-242 (1982)

9) Chang, Y-P., and Mitchell, R. L. : Chemical composition of common North American pulpwood barks, Tappi, **38**, 5, 315-320 (1955)