RESEARCH CORPORATION OF THAILAND

MISCELLANEOUS INVESTIGATION NO. 29

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REPORT NO. 1
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CHEMICAL PULP FROM BAMBOO

By Chien Chu* and Naiyana Niyomwan*

SUMMARY

Chemical pulp was prepared from bamboo (Thyrsostachys siamensis). The air dried bamboo culms were chipped and pulped by ammonium sulphite process in a tumbling digestor. The chips were cooked at liquor ratio 3:1 with 24.8 per cent ammonium sulphite solution buffered with 3.9 per cent ammonia at pH 8.9. The cooking condition was controlled by heating to 170°C in 2 hours and cooking at 170°C for 2 hours. The crude pulp was disc refined. The yield of pulp was 54.3 per cent on dry chip weight.

Bleaching to brightness 75 was done in 3 stage (CEH sequence) with 9 per cent available chlorine. The bleached yield was 42.0 per cent.

Handsheets prepared from the bleached bamboo pulp at 290 ml C.S.F. showed good quality.

Various species of bamboo in Thailand are discussed in respect to their potentials as raw material for pulp.

INTRODUCTION

Thailand is endowed with many species of bamboo in large areas of bamboo forests estimated at 1,782,000 hectares in the western and northern parts of Thailand bordering Burma (Wei-Chih Lin 1968). Bamboos are extensively used in Thailand for construction and for making furniture, fences, rafts, and household implements. Some edible bamboo shoots are consumed as vegetable.

The use of bamboo for pulp is rather limited in Thailand. The Kanchanaburi Paper Mill, a government enterprise, is the only paper mill producing paper from bamboo pulp by soda process. The mill has been in operation since 1939 producing 8 tonnes of paper for day. The small size and old equipment make the production cost very high and little or no profit can be derived from the operation.

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The development of bamboo forests in Thailand for pulp and paper holds great promise in view of the abundant reserve and short cutting cycle of bamboo under proper forest management. The need for more production of bamboo pulp in Thailand is apparent when the present drain of foreign exchange for imported pulp and its high cost are considered.

A small bamboo pulp mill at 50 M.T. bleached pulp per day would need over 130 M.T. bamboo culms on airdry basis. This calls for operation of extensive bamboo forests to assure sustained supply of bamboo culms. A good bamboo forest can yield about 10 tonnes of culms per hectare per year on the average. A 50 M.T. pulp mill would need about 5,000 hectares of bamboo forest.

BAMBOO FOR PULP IN THAILAND

In 1966 a FAO survey team conducted a preliminary survey of bamboo forests in Kanchanaburi province (FAO 1969). But forest inventories of bamboo in Thailand have not been completed.

In Thailand there are three main bamboo forest areas, i.e. Kanchanaburi province, Tak province, and Surat Thani province in the Malay Peninsula. The eleven important species of bamboo for pulp are clump types as follows (Wei-Chih Lin 1968):

(1) Thyrsostachys siamensis is abundant in Kanchanaburi province. It has been used for paper making by Kanchanaburi Paper Mill at about 9,000 tonnes per year. In 1964, the Royal Forest Department estimated the reserve of this species and other small culm bamboos at 1,301,062 tonnes.

(2) Bambusa arundinacea (giant thorny bamboo), found mainly in the western region near the Burma border with enormous reserves estimated to be over 250,000 hectares (FAO 1953). The Royal Forest Department reported great reserve in Kanchanaburi province in 1964 at 5,727,958 tonnes of this species and other big culm bamboos.

(3) Dendrocalamus giganteus (giant bamboo), found in the mixed forests of the Larn Sarng National Park, is outstanding for its large culms and edible shoots.

(4) Dendrocalamus asper, distinguished for its thick walls and edible bamboo shoots, is found widely cultivated in Thailand.

(5) Dendrocalamus strictus, in the western and northern regions is distinguished for its very thick or solid walls.

(6) Bambusa tulda (phai bong), is plentiful in Chiang Mai for bamboo handicraft. It has long fibre.

(7) Bambusa vulgaris, an ornamental type, is noted for its striated culms.

(8) Bambusa blumeana is usually planted for wind breaks on wet soil.

(9) Bambusa polymorpha is widely cultivated for its large culms and thick walls.

(10) Dendrocalamus longispathus (phai lammalok) grows on moist soil near banks of rivers. It has the longest fibre of all species of bamboo.

(11) Dendrocalamus latiflorus is distinguished for its large culms, thick walls, long internodes, and edible bamboo shoots.

TABLE 1
FIBRE LENGTH AND FIBRE THICKNESS OF BAMBOO CULMS OF THAILAND
(Kaichiro 1966)

Bamboo species		Age	Length (L) (min)			Width (W) (μ)			L/W
Scientific name	Local name		max.	min.	mean	max.	min.	mean	
Bambusa arundinacea	phai pa	1	3.795	0.660	1.799	49.0	1.0	23.3	78
		2	4.125	0.495	2.096	34.3	1.0	22.8	92
		3	3.125	0.825	2.096	34.3	1.0	19.9	105
Thyrsostachys siamensis	phai ruak	1	4.290	0.660	2.211	21.2	0.9	17.6	126
		2	3.630	0.825	1.729	28.3	1.0	21.0	82
		3	3,300	0.660	1.505	29.4	1.0	22.1	62
Dendrocalamus longispathus	phai lammalok	1	5.270	1.240	3.092	30.0	0.9	18.5	167
		2	4.950	0.825	2.624	30.8	0.9	20.9	125
		3	4.950	0.990	2.878	58.6	1.0	24.0	120

Bamboo fibre sizes are in the range of 1.5-3.0 mm in length and 18-24 μ in width. The fibre length/width ratios are about 70-120, whereas coniferous wood has fibre length usually above 3 mm but fibre length/width ratios under 100. Thus bamboo fibres can make fine paper of good strength.

Chemical composition of bamboos varies with species but they are in the following range of values (FAO 1953):

Composition	Per cent
Cellulose (Cross and Bevan)	57 - 63
Lignin	22 - 30
Pentosans	16 - 21
1% NaOH solubles	17 - 23
Ash	1 - 3

BAMBOO AS A CROP FOR PULP

The demand of long fibre pulp indicates a need for a source that could produce fibre several times faster than common coniferous pulpwood. The bamboos have great potential to satisfy this need since it has been recorded that some bamboos would produce about six or seven times more raw material per acre annually than coniferous pulpwood. An estimated yield per hectare per year of 24 tonnes of dry bamboo at a rational price of 400 baht per tonne (US $20) would bring an annual gross income to the bamboo growers of approximately 9,600 baht (US $480) per hectare of forest land per year or about 1,600 baht per rai. A bamboo pulp mill may draw on the natural bamboo resources as raw material in the initial stage. For a long-range plan, bamboo plantations should be established with selected species of bamboo well known for yield and fibre quality. The following species have been reported for their outstanding high yield of culms per unit area (McClure 1966):

(1) Melocanna baccifera

This bamboo is native in Chittagong, East Bengal, Pakistan. Well established forest can yield 25 tonnes airdry culms per hectare per year for annual production of 13 tonnes airdry chemical pulp per hectare. The fibre length is 1.9-4.5 mm and mean fibre width 56-57 μ.

(2) Gigantochloa verticillata

This species, found in Java, showed a total increment of substance in the four years old harvested culms corresponding to a yield of more than 9 tonnes of airdry chemical pulp per hectare per year.

(3) Bambusa vulgaris

This species is available in Thailand. It produced at Saint Augustine, Trinidad, over 9 tonnes of chemical pulp per hectare per year on a 3 - year cutting cycle.

(4) Phyllostachys bambusoides (giant timber bamboo)

This species is cultivated in Japan and is distinguished for its large culm. Annual yield of 24 tonnes of dry culms per hectare was reported.

Besides the above species, Guadua augustifolia found in Colombia and Ecuador, and Ochlandra travancorica in South Travancore, India are exotic species well known for their culm quality. Thus nursery stocks should be established for some exotic species.

The species of bamboos selected for pulp should have edible young shoots. By selective harvesting of the young shoots, the average distance between culms can be kept at a level corresponding to optimum utilization of fertilizers and high yield.

The present price of bamboo culms at 120 baht per tonne at Kanchanaburi Paper Mill is very low for paper making. The usual price of bamboo culms for pulp in Taiwan is about 400 baht ($20) per tonne delivered on airdry basis. The paper industry in Thailand can afford to pay a higher price for bamboo culms if improvement of pulp production with less chemicals and higher yield can be achieved in bamboo pulp mills of economical size.

In Thailand, bamboo forests have low yearly culm yield of about 1.5-2.5 tonnes per hectare under the existing conditions. Ueda (1966) stated that at least double the present yield of culms can be expected by means of thinning, proper cutting, and other improvements in forest management. He estimated that by applying skilful thinning to 80,000 ha, which represents 10 per cent of the 800,000 ha of bamboo forests in the

Kanchanaburi region alone, it would be possible to cut 240,000 tonnes (airdry weight) of culms each year to make 80,000 tonnes of paper annually.

In natural bamboo forests, annual new culms and dead culms reach an equilibrium. With proper management, dead culms should be eliminated. In Khao Hin Lop even with some utilization, dead culms represented 18.5-28.5 per cent of the total culms. All culms which have reached three years old are losing their vitality and should be harvested for pulp before they die. Otherwise it is a waste of natural resource.

METHOD

Many industrial processes for pulping bamboo have been reported. The soda process has been used widely in small paper mills in Taiwan with shredded bamboo slivers prepared from fresh bamboo culms. Soda pulp is quite difficult to bleach. Such pulp is generally half bleached to a cream colour for making native Chinese writing paper.

The kraft process is limited to large pulp mills with chemical recovery system. The process has been used in India for production of bleached bamboo pulp at 100 M.T. per day. It is considered the best for high strength paper and good bleachability of pulp.

The magnefite process has found applications in Taiwan and India, but does not appear very successful. It requires a long cooking cycle of 14 hours with low yield of 45 per cent as unbleached pulp.

At present, the Kanchanaburi Paper Mill uses the soda process for daily production of about 8 tonnes of bleached bamboo pulp. Airdry bamboo chips are cooked in two tumbling digestors at liquor ratio 4:1 with 20 per cent caustic soda and 2.5 per cent sulphur. The cooking cycle is heating to 170^{o}C in 5 hours for good impregnation and cooking at 170^{o}C for 2 hours. The crude pulp is blown to a chest and washed. The crude pulp is diluted and flows through a sand riffle to a Jonsson screen. The screening rejects are returned for further cooking. The yield of unbleached pulp is about 42 per cent. The pulp is bleached for 5 hours in two poachers with calcium hypochlorite solution containing 10 per cent available chlorine based on pulp weight. The bleached yield is 74 per cent on unbleached pulp or 31 per cent on dry chip weight. The high consumption of cooking chemicals, at 64.5 per cent caustic soda and 8 per cent sulphur based on bleached pulp, makes the operation of this mill very expensive.

Pulping bamboo by an ammonium bisulphite process for semi-chemical pulp was studied by Chien Chu (Chu 1952). Its application to the production of chemical pulp is a modification of this process. This features the use of ammonium sulphite cooking solution buffered with ammonia to pH 8.8-9.0. This process has resulted in higher yield of chemical pulp with good quality and less consumption of chemicals when compared with conventional alkaline processes for bamboo.

The ammonium sulphite process appears to give better penetration than most other pulping processes for bamboo. No comminution of bamboo culms was needed. In fact, mechanical comminution of bamboo culms by rolling and crushing to open internodes and fibre bundles is very severe to the fibres and produces excessive fines with loss of yield and pulp strength.

EXPERIMENTAL AND RESULTS

Preparation of chemical pulp

In a laboratory 5 litre stainless steel tumbling digestor, 550 g airdry bamboo chips of *T. siamensis* were cooked at liquor ratio 3:1 with 24.8 per cent ammonium sulphite solution buffered with 3.9 per cent ammonia at pH 8.9. The solution was prepared by absorbing SO_2 gas in a 2 per cent NH_3 solution until the total SO_2 concentration reached about 4 per cent. The pH value of cooking solution was adjusted to reach 8.9 by adding more ammonia as 25 per cent NH_3 solution. Thus the total volume of cooking solution was 1,405 ml. It had a concentration of 4.3 per cent SO_2 and 4.0 per cent NH_3 on w/v by analysis. The level of application of chemicals for pulping was about 11.1 per cent in term of SO_2, and 10.2 per cent in term of NH_3 on airdry chip basis.

The digestor with automatic temperature control and electric heating was charged with bamboo chips and the ammonium sulphite solution, and heated after venting any air to about 170°C in 2 hours. The chips were cooked at 170°C for 2 hours. At the end of the cooking the digestor pressure was released by blowing to atmospheric pressure for 10 minutes. The softened chips were washed on a 60 mesh screen and refined in a 12" laboratory single disc refiner with 0.03" clearance between plates. The pulp produced was washed, screened, and centrifuged. The yield of pulp was 54.3 per cent on dry chip weight. The pulp had light yellow colour with good unbleached brightness.

The pulp was bleached with 9 per cent available chlorine in 3 stages to brightness 75 with a bleached yield of 42.0 per cent on dry chip weight as follow:

(1) Chlorination with 7 per cent available chlorine for 1 hour at 30°C and 3 per cent pulp consistency. The chlorine was generated from sodium hypochlorite solution acidified to pH 1.8 with dilute hydrochloric acid.

(2) Caustic extraction for 1 hour at 50°C with 2.0 per cent caustic soda at 10 per cent pulp consistency.

(3) Hypochlorite bleaching in sodium hypochlorite solution with 2 per cent available chlorine for 2 hours at 35°C and 10 per cent pulp consistency.

(4) Acid washing with 0.5 per cent SO_2 for ½ hour at 5 per cent pulp consistency at 30°C.

<u>Handsheets from bamboo pulp</u>

The bamboo pulp was evaluated by making handsheets for physical tests. The bleached pulp had an initial freeness of 880 ml Canadian Standard Freeness (C.S.F.). Beating the pulp in a laboratory Hollander beater at 0.3 per cent pulp consistency for 7 minutes reduced the freeness to 290 ml C.S.F.

For making writing paper from the bleached bamboo pulp, the ingredients in the pulp furnish after beating consisted of the following in the order of addition:

(1) 0.1 per cent brightening agent "Whiten"*

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* A fluorescent dye from Japan.

(2) 2 per cent fortified rosin size

(3) 5 per cent kaolin clay

(4) 2 per cent tamarind kernel powder

(5) 3 per cent aluminium sulphate

Handsheets were tested by TAPPI method in a testing laboratory maintained at 23°C and 50 per cent R.H. The physical test results are shown in Table 2.

TABLE 2
PHYSICAL TESTS OF HANDSHEETS
FROM BAMBOO PULP

Pulp Furnish	Bleached bamboo pulp by ammonium sulphite process
Basis weight, g/m^2	54.7
Brightness	75
Breaking length, m	7173
Burst factor	40.7
Tear factor	92.1
Folding endurance	310
Density	0.79

DISCUSSION

The ammonium sulphite process for bamboo consumes moderate amounts of pulping chemicals. To produce bleached pulp at a yield of 42.0 per cent based on dry chip weight, the stoichiometric chemical consumption is about 13.2 per cent sulphur and 24.2 per cent ammonia, or a total of 37.4 per cent based on bleached pulp weight. The conventional soda process for bamboo pulping gives a bleached yield of 31 per cent on dry chip weight. This needs about 72.5 per cent pulping chemicals based on the weight of bleached pulp. Thus the ammonium sulphite process with much less consumption of pulping chemicals may operate economically without a chemical recovery system. Besides, the waste liquor from ammonium sulphite pulping may be saved and used for soil conditioning and fertilizer. Other possible uses are to serve as binder for animal feed pellets and as tanning agent for leather industry. Also the ammonia may be recovered by dry distillation of the concentrated waste liquor with lime. Further investigation on the economics of recovering ammonia should be undertaken.

The minimum size of a kraft mill with a complicated recovery system is usually 200 tonnes of pulp per day. But a medium-sized bamboo pulp mill above 50 tonnes per day by ammonium sulphite process could have a simple wet combustion recovery system. The Dorr-Oliver and Copeland systems are more recent developments for neutral semi-chemical and ammonia-base pulps. The Copeland system by fluid bed technique was reported to give for wood pulp, better than 75 per cent ammonia recovery and more of the sulphur as sulphur dioxide (Copeland and Hauway 1963).

No bleaching is required to make wrapping paper with a light creamy yellow colour from the unbleached bamboo pulp. It may serve as a substitute for imported kraft pulp.

CONCLUSION

Chemical pulp can be produced from bamboo chips of *Thyrsostachys siamensis* by ammonium sulphite process with a pulp yield at 54 per cent on chip weight. The level of pulping chemicals applied is 24.8 per cent ammonium sulphite buffered with 3.9 per cent ammonia. The bleach consumption for the pulp in CEH 3-stage bleaching is about 9 per cent chlorine for a bleached yield of 42 per cent and brightness 75. The bleached pulp can serve well in making writing paper and the unbleached pulp is suitable for making wrapping paper.

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