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Manufacture of Medium Density Fiberboard from Malaysian Fast Growing Tree Species and Bamboo

(Research note)

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Summary : The fast growing species, acacia, batai, yamane and bamboo were pulped for medium density fiberboard (MDF) by the Asplund defibrator under various steam condition. The characteristics of the fibers produced were examined and MDF was prepared from each species and mixture of them. It was shown that the steaming pressure and duration affected the power consumption in defibrator and the screen analysis of the fibers. The board produced, tested according to Japanes Industrial Standards, showed that acasia, yamane and bamboo could be processed at low steaming pressure and short steaming time for MDF manufacture. The MDF from batai had the best properties.

1. Introduction

Medium density fiberboard (MDF) is a relatively new panel product that made its first appearance in the sixties as a result of a recent development of the board industry in the United States. Despite of higher cost of production, MDF has several advantages over other wood-based panels so that the industry has expanded throughout the advanced and developing worlds. As a sheet material containing wood fibers bonded with a synthetic resin, MDF could be considered to be an intermediate between fiber hardboard and particleboard ; in fact MDF has several features found in these panel products.

A wide range of raw materials from normal pulpwood to mill and agricultural residues, generally difficult-to use materials, can be used as raw materials for MDF. On account of this versatility, countries poor in timber resources such as India and China are shifting to the production of MDF instead of plywood and particleboard. There is, therefore, a great optimism in the future of the MDF industry. In the U.S.A., for example, fiberboard production has increased steeply since 1970, due to the spread of MDF (MALONY, 1977).

Malaysia, which is abundant in timber resources and other ligno-cellulosic raw materials, has been concerned with the establishment of an MDF industry in the country. This is highlighted by the fact that in 1989 the first MDF mill was set up. The heavy reliance in the past on conventional panel products like plywood and particleboard retarded the shifting to MDF in this country.

Conscious of the potential threat to wood-based industries by the dwindling supply of raw

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material from the natural forests within the next decade, the Government of Malaysia has launched a full scale programme of reforestation in the Compensatory Forest Plantation Programme. Special attention has been paid to *Acacia mangium*, *Gmelina arborea* (yamane) and *Paraserianthes falcataria* (batai). Since these timbers are expected to play an important role in the supply of raw material to the wood-based industries in the near future, it is imperative that thier utilization potential be fully examined and exploited (PEH *et al.*, 1984).

In Malaysia, traditionally, bamboo has been considered as a weed in forest practice (WATSON *et al.*, 1961 ; CHIN, 1979). However, in the rural communities, bamboo has been used as fences for rice-field, vegetable baskets, poultry cages, plaiting wall-panels, bamboo blinds, barbeque skewers, umbrella handles and sources of edible shoots. Though several attempts to manufacture bamboo pulp were made (PEEL, 1959, 1962 ; SCHRUBSHALL, 1948), the main use of bamboo has been limited to rural industrial products as mentioned above. The reason for this is the problem of adequate supply and the lack of information on its technical processing and potential. In the attempt of quantifying the stocking of bamboo in northwestern Peninsular Malaysia in 1981, over 179 000 t air dried bamboo of Buluh Betong group and 185 000 t of other than those of the Betong group could be expected. In present work, Malaysian bamboo was also used as a raw material.

The purpose of this paper is to compare the suitability of the Compensatory Forest Plantation Species and bamboo for MDF manufacture since the properties of MDF from *Acacia mangium* (TOMIMURA *et al.*, 1987 ; MATSUDA *et al.*, 1988) and *Paraserianthes falcataria* (TOMIMURA *et al.*, 1988) has been reported elsewhere.

2. Materials and method

2.1 Wood collection and preparation

Four 5-year-old *Acacia mangium* trees were collected from a thinning operation in Batu Arang, Selangor. The height of the trees ranged from 22.0 m to 24.4 m with diameter at breast height from 21.5 cm to 26.3 cm. Due to the inavailability of samples of comparable age within convenient distance, wood samples of batai and yamane were taken from large trees of about 35-years old from Kampong Cubit in Sungei Buloh, Selangor and field of FRIM, Kepong, respectively. Bamboo (*Bambusa vulgaris*) were obtained from the wild, along the banks of Sungei Benus, Kampong Benus, Bentong. An average height of 90 culms collected was about 10 m. The external diameters of a culm was about 7.1 cm and the thickness of culm wall was about 1.6 cm. Wood samples were sawn into strips, chipped and separated into coarse and fine ones. The chips which passed through the screen with hole diameter 3.2 cm and retained on screen with hole diameter 1.9 cm were taken as chips of the proper dimensions for defibration.

2.2 Defibration and boardmaking

The Asplund defibrator was used to prepare fibrous raw stock for MDF. Chips were pre-soaked in water over a night and processed in batches, each batch constituting 300g of oven-dry weight.

The chips were steamed at the following pressures and durations :

Steaming pressure : 6, 8, 10 kg/cm^2

Steaming time : 5, 10, 15 min.

After steaming, coarse fibers were picked out by screening and fibers were dried in an oven at 40-50℃. An attempt was made to determine the yield of fibers by carefully collecting the fibers from the defibrator after each steaming. Power consumed in the defibration process was measured by Hioki recorder.

Acacia, yamane, batai and bamboo boards were prepared from the fibers prepared under different steaming conditions. Another set of boards were made from an admixture of the fibers prepared from acacia and yamane under different steaming conditions.

All boards made were single layer. The target density for boards of single species was 0.5-0.7 g/cm^3, that for the boards prepared from the fibers being a mixture of the two species was set at 3 levels (0.60, 0.67, 0.75 g/cm^3) to determine the influence of density on the board properties. Urea resin was used as an adhesive, the amount of which was fixed at 10% for the boards of single species. In the boards of mixed fiber the levels of resin used were 7%, 10%, 13% on the basis of the dry weight of fiber ; in addition 2% wax was incorporated together with ammonium chloride as hardener at 1% of the resin level. The condition of hot pressing was 160℃ for 10min at 20 kg/cm^2 with spacers for all boards. Board size was $30 \times 25 \times 1.2$ cm. Boards were conditioned at 20℃, 65% R.H. before testing according to the Japanese Industrial Standard JIS A 5906. The formaldehyde release from boards of the mixed fiber was measured by the perforator method.

3. Results and discussion

3.1 Fiber preparation and screen analysis

Although the Asplund defibrator was designed primarily for wet fiberboard making, it was adapted in the present study to prepare fibers for dry process fiberboard. Several difficulties were encountered in the use of this equipment. Firstly, it could only take a load of up to 300 g air dried chips per batch of steaming and to prepare sufficient pulp for a given set of conditions, a continuous operation of up to 8 batches was needed. Chips were steamed in a laboratoric defibrator for 5-15 min and fiberized for 1min by grinding at the end of steaming. It was found to be important to use small chips of uniform dimensions. Even such chips were used, the pulps produced were generally shivery and not uniform ; at higher steaming pressure this phenomenon was observed to take place although to a lesser degree. In every batch a handful of coarse undefibred chips were picked out. The yield of pulp steamed under various conditions was measured carefully as much as possible. In order to get precise value of pulp yield in this experiment the weight loss of chips after steaming without action of grinding in the defibrator was measured. The result is shown in Figure 1. The yield of the chips decreased with an increase of steaming pressure. The drop in yield was caused probably by the degradation of carbohydrate and the loss of volatile compounds.

In the study on power consumption during defibration, it was shown that the acacia pulp at a steaming pressure of 8 kg/cm^2 for 5 min consumed more power than that at 6 kg/cm^2 for 10 min. Power consumption decreased remarkably at steaming pressure of 8 kg/cm^2 for 15 min. Compared with acacia, yamane required less power to produce pulp at the same steaming condition. Figure 2 shows the energy consumption for defibration excluding machine drive energy of 15 kw, in three species and each pressure level. Table 1 shows the result of the screen analysis of the fibers. The fibers prepared from *Acacia mangium* on steaming at 8 kg/cm^2 for 5 min were coaser significantly than those prepared at the same pressure for 10-15 min.

In *Gmelina arborea* and *Paraserianthes falcataria* screen analysis gave almost same results at each steaming condition. The former species was rich in fine fraction. In both species other

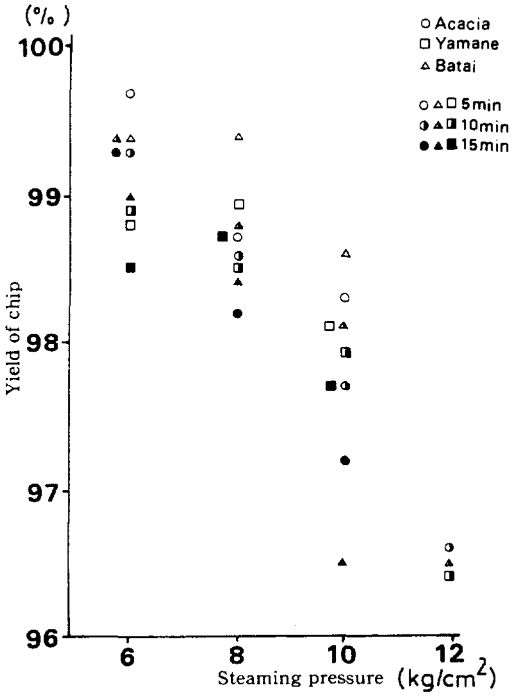

Fig. 1　Yield of chips after steaming

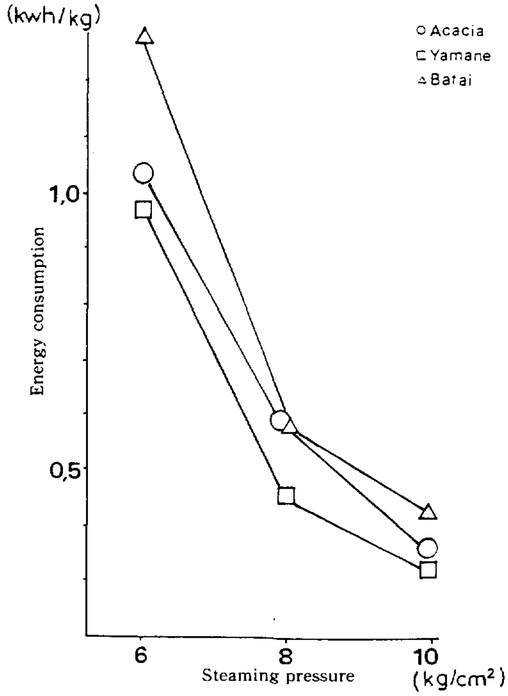

Fig. 2　Energy consumption for defibration after 10 min cooking at each steaming pressure

Table 1.　Screen analysis of fibers from acacia, batai, yamane and bamboo (% by weight)

Species	Steaming condition	Screen size (mm)				Bulk density (g/cm^3)
		Under 0.5	0.5–1.0	1.0–2.0	Over 2.0	
Acacia	6 kg/cm^2 (10 min)	50.3	19.7	19.1	10.9	0.015
	8 kg/cm^2 (10 min)	52.6	30.4	13.5	3.5	0.017
	10 kg/cm^2 (10 min)	61.0	24.5	12.8	1.7	0.018
	8 kg/cm^2 (5 min)	34.2	25.0	25.8	15.0	0.015
	8 kg/cm^2 (15 min)	59.1	27.2	11.2	2.5	0.020
Batai	6 kg/cm^2 (10 min)	21.7	14.1	32.1	32.1	0.031
	8 kg/cm^2 (10 min)	33.7	21.6	18.4	26.3	0.026
	10 kg/cm^2 (5 min)	22.8	21.0	32.4	23.8	0.030
Yamane	6 kg/cm^2 (10 min)	68.9	12.3	12.5	6.3	0.026
	8 kg/cm^2 (10 min)	68.4	16.5	10.8	4.2	0.025
Bamboo	6 kg/cm^2 (10 min)	32.7	39.7	26.4	1.4	0.145
	8 kg/cm^2 (10 min)	51.0	28.0	17.1	3.9	0.098
	10 kg/cm^2 (5 min)	49.9	18.9	8.3	22.9	0.069

Note : Vibration time 30min
　Weight of pulp 15g (Air dried)

fraction except fine one gave almost the same proportion. In the case of bamboo, the longest fibers were obtained on steaming at 10 kg/cm^2 for 5 min. More than 20% of the fibers were longer than 2 mm in length. On this steaming condition fibers had the lowest bulk density which was less than half of these obtained on steaming at 6 kg/cm^2 for 10 min. On the other hand, on the steaming at 6 kg/cm^2 for 10 min a large portion of fibers ranged from 0.5 mm to 2 mm in length, having the highest bulk density.

3. 2 Board properties

The properties of the MDF made are given Table 2 and Table 3. The better quality boards can be produced on lower steaming pressure. On steaming at 6 kg/cm^2 and 8 kg/cm^2 for 10 min, yamane showed an overall superior quality. On the former condition, acacia MDF having higher density more than 0.730 g/cm^3 could not surpass in strength properties yamane MDF having density of 0.68 g/cm^3. Only in water absorption and thickness swelling were the acacia MDF slightly better. Yamane gave boards which satisfy the board requirements of Japanese Industrial Standard, JIS type 200 and JIS type 150.

The best board was produced from acacia on steaming under 8 kg/cm^2 for 5 min, the minimum time to produce pulps for boards that satisfied the requirements of JIS type 150. Extending the steaming time from 5 min to 10 min or 15 min did not produce any improvement in the board properties. On steaming at 6 kg/cm^2 for 10 min or 15 min, acacia also gave the boards which met the specification of JIS type 150 but the properties were inferior to those obtained on steaming at 8 kg/cm^2 for 5 min. Increasing the steaming pressure to 10 kg/cm^2 did not lead to any significant improvement in board properties.

It is important to take into consideration the temperature at inner part of board during hot pressing to grasp the curing process of resin. Figure 3 shows the increase curve of the temperature at the center of a board during hot pressing. The temperature reached around 108℃ within 3 min, when the 12 mm thick mat of mixed fiber containing 15% moisture was pressed to the board of 0.67 g/cm^3 density. This increase of temperature seems to be faster than the case of particleboard. Under the same condition the center of particleboard was found to be at 103℃ after 3 min.

The bamboo board produced on steaming at 6 kg/cm^2 for 10 min showed the biggest bending strength. Steaming under the higher pressure than 6 kg/cm^2 was probably too drastic for the preparation of fibers from bamboo. It cause a degradation of bamboo fibers. The boards prepared on steaming at 6 kg/cm^2 for 5 min with density of 0.5, 0.6 and 0.7 g/cm^3 met the JIS specifications for 50-type, 150-type and 200-type boards, respectively, in the classification of fiberboards based on bending strength. However, boards prepared on steaming at 8 kg/cm^2 for 10min with density of 0.5 g/cm^3, and 0.6 g/cm^3 and the boards prepared on steaming at 10 kg/cm^2 for 5 min with density about 0.6 did not meet the specifications for the 50-type and 150-type respectively. The internal bond increased with the increase of board density. All boards, especially with the density of 0.7 g/cm^3, had excellent internal bond more than 9 kg/cm^2. At each density level, boards prepared on steaming at 6 kg/cm^2 for 10min had the best internal bond and boards prepared on steaming at 10 kg/cm^2 had the lowest. This may be due to the degradation of bamboo fiber by drastic steaming condition. However, the internal bond exceed 4 kg/cm^2, satisfying the JIS 200-type board. In the internal bond, bamboo is an excellent raw material for MDF. The water resistance of the boards from bamboo was also excellent. In each steaming

Table 2. Properties of medium density fiberboard of acacia and yamane

Species	Steaming condition	Density (g/cm^3)	MOR (kg/cm^2)	MOE ($\times 10^3 kg/cm^2$)	Internal bond (kg/cm^2)	Water absorption (%)	Thickness swelling (%)	JIS board type
Acacia*	$6 kg/cm^2$ (10 min)	0.730	275	26.7	3.9	31.7	6.3	150
	$8 kg/cm^2$ (10 min)	0.683	221	24.0	2.4	53.8	7.3	50
	$10 kg/cm^2$ (10 min)	0.684	202	23.2	2.5	46.2	7.3	50
	$8 kg/cm^2$ (5 min)	0.714	319	33.2	3.4	37.0	6.4	150
	$8 kg/cm^2$ (15 min)	0.710	284	23.3	2.8	43.8	7.8	50
	$6 kg/cm^2$ (15 min)	0.708	283	28.1	3.0	40.0	6.0	150
Yamane*	$6 kg/cm^2$ (10 min)	0.682	293	27.6	5.6	37.2	7.3	200
	$8 kg/cm^2$ (10min)	0.687	235	22.5	3.1	33.5	8.7	150
Acacia/Yamane**	7% resin	0.682	174	22.2	2.4	29.5	7.0	50
		0.670	197	21.0	2.7	22.7	5.7	50
		0.749	261	29.0	4.1	19.8	8.6	200
	10% resin	0.597	220	22.5	6.2	29.6	4.7	200
		0.660	277	27.6	4.1	20.9	4.6	200
		0.743	320	30.6	6.0	17.8	5.5	300
	13% resin	0.602	214	22.6	3.8	24.7	5.7	150
		0.664	290	28.4	5.8	23.8	4.5	200
		0.740	359	35.6	5.7	21.3	4.3	300

*Resin content 10%.

**Fiber admixture of pulps in equal proportion from acacia ($8 kg/cm^2$ and $10 kg/cm^2$, 10 min) and Yamane ($6 kg/cm^2$ and $8 kg/cm^2$, 10 min)

MOR : Modulus of rupture

MOE : Modulus of elasticity

Table 3. Properties of medium density fiberboard of Batai and Bamboo

Species	Steaming condition	Density (g/cm^3)	MOR (kg/cm^2)	MOE ($\times 10^3 kg/cm^2$)	Internal bond (kg/cm^2)	Thickness swelling (%)	JIS board type
Batai*	6 kg/cm^2 (10 min)	0.419	86	9.5	2.5	8.3	50
		0.516	162	16.2	4.3	10.5	150
		0.634	313	30.8	8.9	10.2	300
	8 kg/cm^2 (10 min)	0.413	97	10.3	1.7	7.6	50
		0.501	171	16.6	3.1	8.6	150
		0.603	292	28.4	5.0	8.4	200
	10 kg/cm^2 (5 min)	0.398	78	7.9	1.2	7.6	50
		0.507	147	14.1	4.4	8.8	50
		0.602	227	23.6	4.6	9.4	200
Bamboo*	6 kg/cm^2 (10 min)	0.514	66	9.1	6.6	8.0	50
		0.606	172	20.0	13.3	8.1	150
		0.710	274	30.1	20.4	6.6	200
	8 kg/cm^2 (10 min)	0.509	31	7.5	4.5	8.1	–
		0.606	126	17.5	7.4	7.9	50
		0.712	220	28.6	11.7	7.0	200
	10 kg/cm^2 (5 min)	0.501	55	8.8	4.0	7.7	50
		0.608	142	19.2	4.7	8.4	50
		0.703	218	28.3	9.8	6.9	200

* Resin content 13%
MOR : Modulus of rupture
MOE : Modulus of elasticity

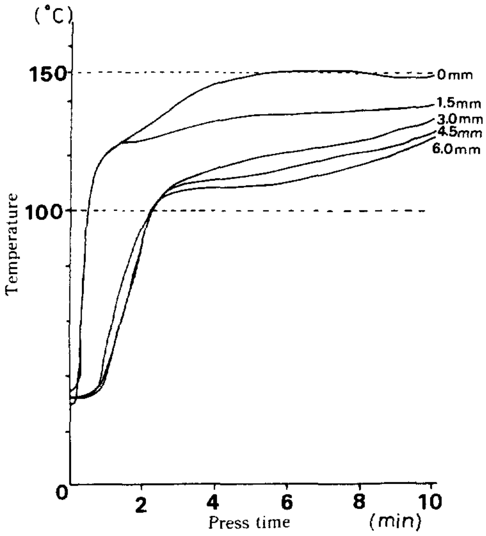

Fig. 3　Temperature at inner part of 12 mm board during hot press.
(mm) : From the surface

condition, boards with the highest density showed the best water resistance. The thickness swelling of those boards was lower than 7.0%. Moreover, all other boards also showed the thickness swelling lower than 8.5%. These values met the specifications of JIS which stipulates the thickness swelling less than 12%. Increasing steam pressure did not improve the water resistance of the boards. In order to obtain boards with acceptable properties, the chip had to be steamed at lower pressure than 6 kg/cm^2. The bamboo boards generally had excellent internal bond and water resistance when wax was used. The optimum steaming condition for the manufacture of bamboo boards was at 6 kg/cm^2 for 10 min and the boards density should be 0.7 g/cm^3.

The influence of the addition of wax and NH_4Cl hardener can be observed in the series of boards made with the admixture of acacia and yamane pulps. Water absoption dropped below 30% in all cases. Thickness swelling was improved below 6% when the resin contents of the boards were 10-13%. All boards passed at least JIS type 150 except when the resin content was 7% and the density was lower than 0.670 g/cm^3. The internal bond was a little lower than the requirement of JIS type 150 but they were enough for that of JIS type 50. At the highest density levels and at resin contents of 10-13%, the boards satisfied the requirements of JIS type 300. The boards made with 10% resin had better internal bond and water absorption than the board with 13% resin content but the latter was improved in the modulus of rupture and modulus of elasticity.

The considerable amount of formaldehyde was release from the MDF especially at resin content of 10% and 13% (49, 56 and 5 7mg/100 g for 7%, 10% and 13% resin MDF, respectively,). It must be noted, however, that the resin used in this study was not specially made for MDF. Lowering the ratio of formaldehyde to urea in urea resin or the use of certain additives which trap formaldehyde will decrease the release.

In a previous study (Tomimura *et al.*, 1987) it was revealed that 5-year-old acacia is suitable for MDF manufacture, even superior to some Japanese softwoods. It can be concluded that yamane is ranked higher than acacia. The properties batai MDF were previously investigated (Tomimura *et al.*, 1988). In this study, it was confirmed that batai MDF although it had low densities, it was apparently superior to either acacia MDF or yamane MDF, especially in the internal bond. The boards with densities of around 0.4, 0.5 and 0.6 g/cm^3 met the JIS type 50, type 150 and type 200 boards, respectively.

3.3 Scope of commercial utilization

The first MDF mill in Malaysia has just started by using solely rubberwood. The second MDF project, a bigger one, is expected to go on stream very soon. The mill will also use rubberwood as a raw material. Although rubberwood, especially as wastes, may be readily available in certain parts of the country at present, the time will not be far when this supply becomes restricted. This is underscored by the fact that the demand for rubberwood in many areas of utilization such as furniture, mouldings, etc. has been escalating in recent years. In MDF manufacture, the raw material must be available easily and cheaply, Since these two conditions that will not likely be met by rubberwood in the future, alternatives must be considered. This is where the Compensatory Forest Plantation species will come in useful. The technical studies presented here have confirmed their feasibility. Under the Compensatory Forest Plantation Programme, supply will be assured and the price will be competitive.

4. Conclusion

In the manufacture of medium density fiberboard, *Paraserianthes falcataria* (batai), *Acacia mangium* (acacia), *Gmelina arborea* (yamane) and *Bambusa vulgaris* (bamboo) are suitable raw materials. The best pulp were produced at lower steaming pressure and shorter time, ie. 8 kg/cm^2 for 5 min for acacia and 6 kg/cm^2 for 10 min for yamane, batai and bamboo. Yamane was a slightly better material than acacia species. It had better board properties and lighter color of the pulp and board. When pulps of acacia and yamane were mixed in equal proportions, boards made with the addition of wax and NH_4Cl gave a marked improvement, especially in the internal bond and dimensional stability. The best boards were produced at resin levels greater than 7% and density greater than 0.7 g/cm^3. It is recommended, however, that a resin level of 10% would be sufficient for most purposes whether using pulps from one species or from admixture. It may also safely be inferred from this experiment that batai would be a suitable material for MDF manufacture, much better than acacia or yamane. The low pulping yield, may be a slight set-back. The 4 species could possibly be ranked in decreasing order of suitability as follows :

batai-yamane-acacia, bamboo

The prospects of utilizing these species for the local MDF industry appear promising.

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（研究資料）

マレーシア産早生樹種及びタケを原料とする中密度ボードの製造

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摘　　要

マレーシア産早生樹種アカシア，ヤマネ，バタイ及びタケを原料として単独または組み合わせによりアスプルンドデファイブレーターで解繊し，中密度ファイバーボードを製造して，その性質を調べた。また蒸煮圧及び蒸煮時間が解繊エネルギーやファイバーの形状に及ぼす影響や含脂率及び密度がボードの材質に及ぼす影響も検討した。アカシア，ヤマネ，タケを原料とした場合低い蒸煮圧でかつ短時間の蒸煮が適していた。用いた原料の中ではバタイが最も優れていた。

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