CHEMICAL MODIFICATION OF RUBBERWOOD FOR MEDIUM DENSITY FIBREBOARD

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TOMIMURA,Y., KHOO, K.C. & ONG, C.L. 1989. Chemical modification of rubberwood for medium density fibreboard. Rubberwood chips which have been soaked in water or a borax-boric acid solution were pulped under various conditions. The fibres from the untreated chips and produced under the mildest condition of 6 $kg\ cm^{2}$ steam pressure for 10 *min* were subjected to different chemical treatments and then made, as with the other fibres, into medium density fibreboard. With the use of urea-formaldehyde resin, the mechanical properties of the boards from chips soaked in boric acid - sodium borate solution showed a slight improvement compared to those of boards made from untreated chips. Some improvement in mechanical properties was also observed in boards made with urea-formaldehyde resin mixed with elemental sulphur. With the use of melamine-phenol-formaldehyde resin, boards made from acetylated fibres gave excellent water resistance but their mechanical properties decreased considerably. The same tendency was shown in boards made from fibres treated with formaldehyde.

Key words: Rubberwood - borax-boric acid - acetylation - formaldehyde - sulphur - fibreboard

Introduction

Rubberwood has become popular for furniture and is substituting traditional commercial species in Malaysia. Untreated rubberwood is susceptible to insect and fungal attack (Anonymous 1986) and blue stain infestation is especially serious (Peel & Peh 1960).

Although rubberwood has been demonstrated to produce good particleboard and medium density fibreboard , rubberwood tends to confer a poor water resistance on these panel products (Wong & Ong 1984). To improve the water resistance and hence the dimensional stability of the boards and to increase their resistance to insect and fungal attack, a chemical treatment may be necessary. Chemical modification of the fibres is one such approach in the case of fibreboards.

Acetylation and treatment with formaldehyde have long been studied as a means of improving dimensional stability of wood as well as particleboard (Yoshida *et al.* 1986). When wood is treated with formaldehyde, cross-linking is produced within the material. Furuya (1966) showed that the formaldehyde treatment could be successfully carried out by simple exposure to formaldehyde vapour. Meyer and Johns (1978) incorporated elemental sulphur in urea-formaldehyde resin in particleboard making and showed that it can replace a substantial proportion of the resin requirement. Elemental sulphur as an additive can improve board properties, especially dimensional stability and resistance to fungal attack. Borax-boric acid is usually used as fungicide for rubberwood (Anonymous 1986).

The efficacy and influence of chemical treatment by formaldehyde, sulphur or borax-boric acid on the properties of medium density fibreboard are not known. These are investigated in the present study using rubberwood as raw material.

Materials and methods

Materials

Wood samples from 21-year-old rubber trees (*Hevea brasiliensis* Muell-Arg.) taken from the Rubber Research Institute of Malaysia Experimental Station, Sungai Buloh, were debarked, sawn into strips and converted into chips using the Taihei chipper. The chips were dried in the sun and stored in sealed plastic bags before further processing.

Cooking and defibration

All fibres were prepared in the Asplund defibrator. Four conditions were employed, namely:

Cook	*kg cm*^{2}	*min*	Chips soaked in
1	6	10	water
2	6	10	3% borax-boric acid
3	8	10	water
4	10	5	water

Defibration was carried out during the last 2 *min* of each cooking condition. The fibres prepared under each condition were dried in an oven at *circa* 60°C. Screen analyses to determine the fibre size distribution and bulk density measurements were conducted on the fibres.

Acetylation of fibres

To improve their boardmaking properties , fibres produced at cooking condition of 6 *kg* cm^{-2} for 10 *min* were used as the starting raw material. The fibres, 150 *g* in weight , were placed in an erlenmyer flask and a mixture of acetic anhydride-pyridine (10:1, w/w) was added until the fibres were thoroughly wetted. The flask was placed in a water bath at 60°*C* for 12 *h*. After the reaction was over, the fibres were washed well with water until no acetic anhyride smell could be detected.

Treatment of fibres with formaldehyde

Fibres produced at cooking condition of 6 *kg* cm^{-2} for 10 *min* were treated with formaldehyde using the method of Furaya's (1966) to determine the effect of such treatment on the properties of the fibres in boardmaking. A mixture of 150 *g* of fibres , 20 *g* paraformaldehyde and 20 *g* ammonium chloride was placed in a 10 *l* desiccator which was then vacuum evacuated and heated at 100°*C* in an oven for 12 *h*.

Preparation of urea-formaldehyde resin containing elemental sulphur

Elemental sulphur was incorporated in urea-formaldehyde resin using the method proposed by Meyer and Johns (1978). Urea-formaldehyde resin (solids content 60%) and elemental sulphur (5:3, w/w) were mixed and diluted with water to a solids content of 60%. As the mixture was stirred vigorously in a homogenizer, 1% ammonium sulphate (based on resin solids) was added.

Manufacture of medium density fibreboard (MDF)

The adhesives used in boardmaking were urea-formaldehye and melamine-phenol-formaldehyde resins. The resin content for all boards was 13% (based on oven-dry fibres). Wax and hardener were not used. The fibres were contained in a plastic bag into which the resin was sprayed. The bag was agitated during the spaying to ensure proper mixing of the fibres with the resin. After spraying with resin, the fibres were passed through a Bauer refiner to obtain a homogeneous glue-fibre mix. All boards were hot-pressed at 160°*C* at a pressure of 30 *kg* cm^{-2} for 5 *min*. Board size was 20 x 20 x 0.5 *cm* and the target density was 0.7 *g* cm^{-3}. The boards made were tested according to the Japanese Industrial Standard (JIS) 5906.

Results and discussion

The results of screen analyses and bulk density measurements of the fibres made under each cooking condition are given in Table 1. Fibres from Cook

1, which had been prepared under the mildest condition, were chosen for chemical treatment since such treatment was expected to cause some fibre damage or changes to the fibre structure. Acetylation which caused an increase in fibre weight of 15.4%, also caused a change in fibre size. A large amount of fines was produced, with over 80% of the fibres being < 0.5 *mm* in length. Soaking chips in borax-boric acid solution prior to cooking produced a larger portion of fibres > 2 *mm* in length (Cook 2). Increasing the pressure from 6 $kg\ cm^{-2}$ using the water-soaked chips also produced a similar increase in this fibre fraction (Cooks 3 & 4). A large change in bulk density was noted after the chemical modifications of the fibres. In the treatment with formaldehyde especially, the highest increase in bulk density was recorded,from 0.049 $g\ cm^{-3}$ (Cook 1a) to 0.076 $g\ cm^{-3}$ (Cook 1c).This increase in bulk density is probably due to the deposition of the paraformaldehyde used in the reaction on the fibres, accounting for the weight increase of the fibres by 14.3%. Despite the weight increase in acetylation, the treated fibres gave the lowest bulk density. It was also observed that during the process of treatment, the solution turned brownish and the fibres became lighter in colour. Removal of extractives and some acetylated lignin is the likely reason for this change.

Table 1. Screen analysis and bulk density of rubberwood fibres prepared under different cooking conditions

Cook Number	Fibre Yield (%)	Screen size				Total (%)	Bulk Density ($g\ cm^{-3}$)
		> 2 *mm* (%)	2 - 1 *mm* (%)	1 - 0.5 *mm* (%)	< 0.5 *mm* (%)		
1a	93.5	32.5	22.5	13.8	31.2	100	0.049
1b		1.3	4.4	11.8	82.5	100	0.031
1c		26.2	27.1	12.0	34.7	100	0.076
2	93.3	47.2	15.1	7.5	30.2	100	0.048
3	94.2	36.5	25.3	12.2	26.1	100	0.044
4	92.5	55.9	11.9	6.8	25.4	100	0.043

1a: untreated fibres
1b: acetylated fibres
1c: fibres treated with formaldehyde

The properties of the urea-formaldehyde boards tested are shown in Table 2. In board Number 2 where elemental sulphur was incorporated in the resin used , there was no drop in the mechanical properties but instead produced a slight improvement in the internal bond and thickness swelling. Meyer and Johns (1978) suggested that part of the sulphur reacts chemically with the resin forming after curing a CH_2-S bonding which may produce polymers with very good chemical and mechanical properties. Board Number 3, made from chips soaked in borax-boric acid solution did not display any drop in properties either. Compared to board Number 1, there was a marked improvement in the bending strength (from 323 *kgf cm*$^{-2}$ to 352 *kgf cm*$^{-2}$) and water resistance (from 10.1% to 8.1%). The presence of an acidic substance (boric acid), had the effect of accelerating the cooking process by increasing the rate of hydrolysis of the carbohydrates and the breakdown of the lignin. Hence, treating wood chips with borax-boric acid would allow not only the cooking to be carried out at milder conditions (*e.g.* lower cooking pressures) but it may also confer on the boards some degree of resistance to fungal attack. A marginal improvement in water resistance was also demonstrated in boards made from fibres which had been produced at higher temperatures (boards Number 4 & 5).

Table 2. Properties of medium density fibreboard bonded with urea-formaldehyde resin

Cook Number	Board Number	Density (*g cm*$^{-3}$)	MOR (*kgf cm*$^{-2}$)	MOE (x 1000 *kgf cm*$^{-2}$)	IB (*kgf cm*$^{-2}$)	TS (%)
1a	1	0.710	323	29.3	10.2	10.1
	2*	0.690	335	32.1	14.0	8.4
2	3	0.699	352	32.2	11.2	8.1
3	4	0.703	302	31.2	10.9	9.4
4	5	0.696	310	30.3	9.6	8.9

* Board 2: Urea-formaldehyde resin used contained elemental sulphur
MOR = Modulus of rupture; MOE = Modulus of elasticity; IB = Internal bond; TS = Thickness swelling; Abbreviations follow for next table.

Table 3 shows the properties of boards made with melamine- phenol-formaldehyde resin. Compared to board Number 6 made from untreated fibres, a marked drop in thickness swelling was recorded in board Number 7 which was made from acetylated fibres. Concurrently, there was a distinct decrease in bending strength and internal bond of the board. Nevertheless the acetlylated board also showed good resistance to boiling. In board Number 8 which was made from fibres treated with formaldehyde, a decrease in thickness swelling was also produced although to a lesser extent than in board Number 7. However, the drop in bending strength was drastic. The internal bond was also lower compared to the untreated board Number 6. This was not compensated by increased resistance to boiling. The main reason for this is the degradation on the fibres brought about by hydrogen chloride formed from the ammonium chloride used as catalyst. Thus it is not advisable to use an acidic catalyst in this treatment with woody materials. If it is to be applied at all, a non-acidic catalyst should be substituted.

Table 3. Properties of medium density fibreboard bonded with melamine-phenol-formaldehyde resin

Cook Number	Board Number	Density	MOR	MOE	IB	TS	(After 2 *h* of boiling)	
				(x 1000			MOR	TS
		(*g cm*$^{-3}$)	(*kgf cm*$^{-2}$)	*kgf cm*$^{-2}$)	(*kgf cm*$^{-2}$)	(%)	(*kgf cm*$^{-2}$)	(%)
1a	6	0.700	209	23.0	7.4	8.3	80	13.7
1b	7	0.698	161	20.6	3.5	2.1	84	10.2
1c	8	0.688	81	12.9	5.6	4.1	26	9.1

Conclusion

Rubberwood chips soaked in 3% borax-boric acid solution prior to defibration produced medium density fibreboard with improved strength and water resistance properties compared to untreated chips. The incorporation of sulphur in the resin used for medium density fibreboard manufacture also produced better boards compared to the use of the pure resin and this provides possible savings on the expensive resin. Chemical modification of the fibres through acetylation and formaldehyde treatment do not appear to produce overall positive results apart from a marked improvement in water resistance.

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