VACUUM-PRESSURE TREATMENT OF RUBBERWOOD *(HEVEA BRASILIENSIS)* USING BORON-BASED PRESERVATIVE

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SALAMAH, S. & MOHD DAHLAN, J. 2008, Vacuum-pressure treatment of rubberwood *(Hevea brasiliensis)* using boron-based preservative. Rubberwood is highly susceptible to biodegrading organisms. To minimize this problem, effective preservative treatment needs to be carried out immediately to ensure that the timber is fully protected. Generally, a pressure treatment process would be adopted to force high preservative loading into the outer layer of the timber, followed by natural diffusion process of the preservative into the core area during seasoning. Apart from pressure intensity and pressure duration, timber sizes and concentration of preservatives used would largely influence the effectiveness of pressure impregnation process. In this study, four different thickness of rubberwood were selected viz. 25 × 25 mm, 50 × 50 mm, 75 × 75 mm and 100 × 100 mm, and 600 mm long. The samples were treated with 1, 2, 3 and 4 % w/w boron preservatives using the vacuum-pressure impregnation process. The determination of preservative loading in the wood samples was based on a modified method of Japanese Agriculture Standard for Plywood 1985 using Inductively Couple Plasma Spectrometry.

Keywords: Full-cell process, chemical analysis

SALAMAH, S. & MOHD DAHLAN, J. Rawatan tekanan vakum kayu getah *(Hevea brasiliensis)* menggunakan bahan awet berasaskan boron. Kayu getah sangat rentan terhadap organisma perosak kayu. Untuk mengurangkan masalah ini, proses rawatan yang berkesan perlu dilaksanakan dengan serta-merta bagi memastikan kayu tersebut dilindungi sepenuhnya. Secara amnya, proses rawatan tekanan memaksa muatan bahan awet yang tinggi ke dalam lapisan luar kayu diikuti dengan proses resapan biasa bahan awet ke dalam teras semasa proses penyimpanan. Dalam kajian ini, empat jenis ketebalan dipilih iaitu 25 × 25 mm, 50 × 50 mm , 75 × 75 mm dan 100 × 100 mm dengan panjang 600 mm. Sampel dirawat dengan bahan awet boron pada kepekatan 1, 2, 3 dan 4% w/w menggunakan proses pengisitepuan tekanan vakum. Penentuan kandungan boron dalam kayu adalah berdasarkan kaedah yang diubah suai daripada Piawaian Pertanian Jepun untuk Papan Lapis 1985 menggunakan Spektrometri Plasma Gandingan Aruhan.

INTRODUCTION

Rubberwood in green condition is very prone to attack by fungi, while in dry condition, susceptible to wood borers (Hong *et al.* 1982). In order to maintain quality, freshly sawn timbers have to be protected with suitable preservatives if they are not processed immediately. Generally, the timber is momentarily immersed in a mixture of preservative solution containing fungicide and insecticide to protect the outer layer against infestation by wood borers and fungi. However, this procedure only provides temporary protection for the timber as it allows only shallow penetration of preservatives. The depth of preservative penetration will depend very much on the type and solution strength of wood preservatives used and the moisture content of the timber during the treatment process (Tam & Daljeet 1985, Salamah *et al.* 1987, Salamah *et al.* 1988).

When further processing of timber is carried out such as conversion into furniture components, the machining process would remove the protective layer of preservative and expose fresh untreated surfaces. In this case, complete protection of timber is necessary and in-depth studies on the type of preservatives, appropriate solution strength and treatment process to achieve full preservative penetration are required. Dip-diffusion process using boron-based compounds is the most simple and cheapest method of treating freshly sawn rubberwood, but it requires long treatment time to give complete preservative penetration throughout the cross-section of timber (Zaitun

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et al. 1990). Due to time constraints in sawn rubberwood treatment and industrial demand for a cost-effective process, a vacuum-pressure impregnation method is the most viable option. Pressure treatment will give much better chemical loading, deeper and more uniform penetration of preservative in a short time (Tan *et al.* 1980, 1983, Hong *et al.* 1982, 1987, Salamah *et al.* 1987, 1988, Hong & Liew 1989). Currently, the solution strength used by rubberwood processors in pressure impregnation processes varies from 1 to 4% w/w at 12 to 14 bars pressure for about an hour. After pressure treatment, the timber is kiln dried to appropriate moisture content for further processing. The time interval between preservative treatment and kiln-drying process varies from a few days to two weeks.

The effects of pressure duration on preservative penetration and distribution in local timbers were studied by Salamah and Shaharuddin (2000). While pressure intensity and duration would strongly influence the effectiveness of the treatment process, timber size and preservative concentration are also crucial factors. It is common for local rubberwood processors to treat various timber sizes using a single treatment schedule and at lower concentration of preservatives. Under this situation, thinner materials could be well penetrated by preservative solution, but more often than not the thicker stocks would be under treated. The objective of this study was to evaluate the effects of timber size and solution strength on boron preservative uptake in freshly sawn rubberwood using vacuum-pressure impregnation.

MATERIALS AND METHODS

Wood treatment

Fresh rubberwood logs of moisture contents between 65 and 70% were sawn into four sizes, *viz.* 2.5 × 2.5 × 600 cm, 5 × 5 × 60 cm, 7.5 × 7.5 × 60 cm and 10 × 10 × 60 cm. Twenty-four samples from each size group were weighed before (w1) and after (w2) preservative treatment. For preservative treatment, rubberwood samples which were end-coated with epoxy paint were loaded into the treatment cylinder and pressure treated with a mixture of disodium tetraborate decahydrate ($Na_2B_4O_7.10H_2O$) and boric acid (H_3BO_3) (1.54:1) solution using the selected treatment schedule (Table 1). Four different strengths of preservative solution *viz.* 1, 2, 3 and 4% w/w were used and each treatment consisted of 12 replicates.

Table 1 Treatment schedule of vacuum-pressure process

Treatment phase	Time
Initial vacuum (600 torrs)	30 min
Flooding of preservatives into treatment cylinder	15 min
Pressure period (1400 kPa)	1 hour
Draining out of preservatives from treatment cylinder	15 min
Final vacuum (600 torrs)	15 min

The chemical loading (CL) in the wood samples after impregnation and the chemical retention (CR) based on active compounds were calculated as follows:

$$CL \text{ (kg m}^{-3}) = \frac{w2 - w1 \text{ (kg)}}{\text{Volume of wood sample (m}^3)} \qquad (1)$$

$$CR \text{ (kg m}^{-3}) = \frac{\% \text{ Solution strength}}{100} \times CL \qquad (2)$$

All samples were air dried in the shade for at least one week before subjecting them to qualitative and quantitative tests.

Chemical analysis

A sample of about 100 mm thick was cut from the middle part of the air-dried wood sample (Figure 1). It was sectioned further into a few layers of 5 mm thick giving 3, 5, 7 and 9 layers for the 25, 50, 75 and 100 mm samples respectively. In this study, only the outermost and core layers were selected for chemical analysis.

Each layer of wood sample was ground up to 1 mm mesh size using a wet digestion process. The analysis work was conducted based on a modified method of the Japanese Agriculture Standard for Plywood (Anonymous 2003) using an Inductive Couple Plasma Spectrometer (Salamah & Shaharuddin 2000).

Statistical analysis was carried out using SAS Package Version 6.11. Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) were performed on data at $p < 0.005$.
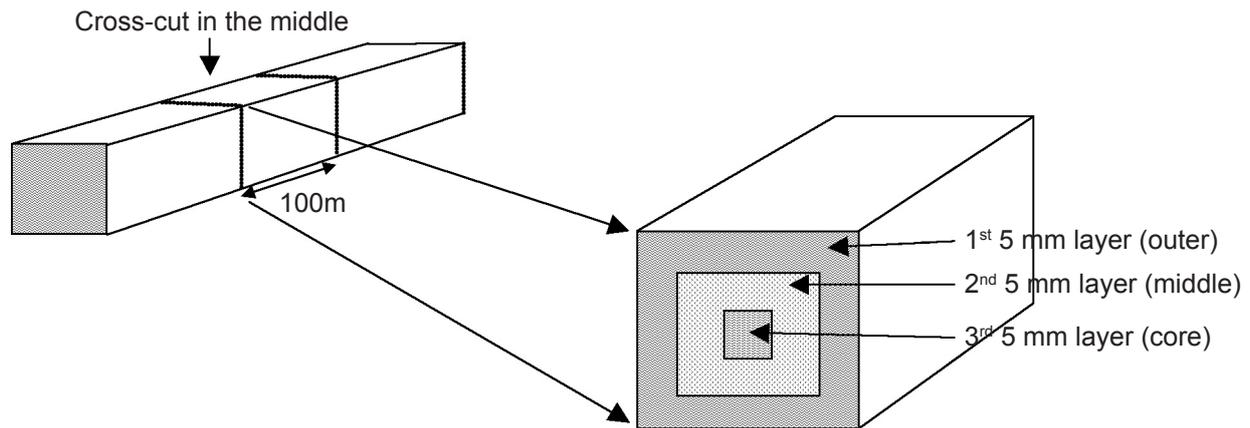
Figure 1   Sampling procedure for chemical analysis for 25 mm thick sample

RESULTS AND DISCUSSION

Chemical absorption and retention based on weighing method

The amount of preservative solution absorbed by the rubberwood sample was in the range of 209 to 240 kg m^{-3} regardless of wood size or solution strength used (Table 2). ANOVA results confirmed that wood size and solution strength had no significant effect on preservative uptake (Table 3). Fresh rubberwood has an upper limit of absorbing water-based preservatives as the presence of moisture in the timber may act as a physical barrier to chemical solution penetrating deep into the timber. Porosity or void volume of timber would determine the maximum amount of treating solution that can be impregnated into the wood structure (Nicholas & Siau 1973). Therefore, when the moisture content of rubberwood was excessively high above the fibre saturation point, it would be impossible to obtain a higher preservative retention as the void volume was significantly reduced.

The amount of active compound absorbed by the wood sample, also known as chemical retention, was calculated based on Equation 2. The results are presented in Table 4. It was observed that different solution strengths had a significant effect on chemical retention (Table 5). Further analysis using the DMRT demonstrated that when the solution strength increased, correspondingly more chemical would be retained in the wood samples (Table 6).

Chemical retention based on chemical analysis

The amount of boric acid equivalent (BAE) detected on the outermost layer of samples treated with all the four solution strengths (1, 2, 3 and 4%) were much higher than the minimum amount required to protect the timber from any wood borers (Table 7). For highly susceptible timber such as rubberwood, the minimum amount of boron needed for effective protection against wood borers should not be less than 0.2% BAE (Zaitun *et al* 1990, Salamah & Shaharuddin 2000). It is also apparent that the analytical values of %BAE retention in the outermost layer (Table 7) were very much lower than the calculated amount as given in Table 4. Differences between analytical and calculated values indicated that chemical retention based on the latter can only be used as an estimate of the treatment process. When the actual amount of BAE retention is needed as an indication of the effectiveness of the treatment process, determination by chemical analysis should be adopted (Salamah & Shaharuddin 2000).

Timber size had no significant effect on the amount of BAE retained at the outermost layer (Table 8). In contrast, BAE retention in the same wood layer was highly influenced by solution strength. In this case, more amount of BAE was detected when higher solution strength was used in the treatment process as indicated by the DMRT (Table 9). The BAE values in the outermost layer were about 0.3 and 1.3% when 1 and 4% solution strengths were used respectively.

The higher amount of BAE in the outermost layer cannot be used as an indication that

Table 6   Duncan's Multiple Range Test on the effects of solution strength on chemical retention based on the active compound

Solution strength (%)	Chemical retention	N
1	2.145 a	48
2	4.333 b	48
3	6.536 c	48
4	8.870 d	48

Means followed by the same letter do not differ significantly at p < 0.05.

Table 7   Boric acid equivalent (% BAE) w/w in the outermost and core layers of freshly cut rubberwood after treatment process

	Sample thickness (mm)	% BAE (w/w) for different solution strength			
		1% w/w	2% w/w	3% w/w	4% w/w
Outermost layer	25	0.338 (0.016)	0.519 (0.027)	1.070 (0.072)	1.378 (0.058)
	50	0.333 (0.021)	0.523 (0.025)	1.000 (0.026)	1.319 (0.086)
	75	0.319 (0.011)	0.545 (0.024)	1.004 (0.013)	1.328 (0.095)
	100	0.317 (0.020)	0.553 (0.035)	1.048 (0.054)	1.338 (0.095)
Core layer	25	0.034 (0.007)	0.184 (0.010)	0.502 (0.019)	0.590 (0.017)
	50	0.010 (0.001)	0.087 (0.014)	0.188 (0.012)	0.253 (0.042)
	75	0.004 (0.003)	0.017 (0.003)	0.112 (0.003)	0.187 (0.012)
	100	0.000 (0.000)	0.000 (0.000)	0.014 (0.004)	0.014 (0.004)

Figures in parentheses are standard deviations.

Table 8   Analysis of variance for the effects of solution strength and sample size on % BAE retention in the outermost and core layers

Source of variance	Df	Outermost layer		Core layer	
		Means square	F value	Means square	F value
Size (S)	3	0.003	1.09 ns	0.225	1107 **
Solution strength (SS)	3	2.558	1063 *	0.159	785 **
S × SS	9	0.001	0.57 ns	0.035	170 **

* = Significant at p < 0.05; ** = significant at p < 0.01; ns = not significant at p < 0.05

Table 9   Duncan's Multiple Range Test for the effects of solution strength on % BAE retention in the outermost and core layers

Solution strength (%)	Outermost layer		Core layer	
	% BAE retention	N	% BAE retention	N
1	0.327 a	12	0.012 a	12
2	0.535 b	12	0.072 b	12
3	1.031 c	12	0.205 c	12
4	1.341 d	12	0.261 d	12

Means in the same column followed by the same letter do not differ significantly at p < 0.05.

Table 10 Duncan's Multiple Range Test for the effects of sample thickness on % BAE retention in the core layer

Sample thickness (mm)	% BAE retention	N
25	0.327 a	12
50	0.135 b	12
75	0.080 c	12
100	0.008 d	12

Means followed by the same letter do not differ significantly at $p < 0.05$.

the whole cross-section of timber is well protected against fungi and wood borers. Generally, during the process of converting timber into furniture components and other products, the machining process will remove the superficial preservative layer from the wood, exposing fresh inner wood surfaces (Mohd Dahlan *et al.* 1999, Sim & Said 1999). Therefore, the amount of BAE that remains intact in the timber after final wood processing activities is very crucial.

In evaluating the effectiveness of the treatment process, determination of the minimum amount of BAE in a given piece of timber should be directed towards the core area of the timber. From the results given in Table 8, it is evident that the amount of BAE in the sample core is highly dependent on sample size and solution strength used. Less amount of BAE was detected in the core region of thicker wood sample (Table 10). When 2% treating solution was used, it only sufficed to give 25 mm thick rubberwood the minimum BAE required (Table 7). For thicker material, higher solution strength was needed to attain the minimum amount of 0.2% BAE as shown by the 50 and 75 mm samples. However, 100 mm samples failed to achieve this amount even though treated using the highest treating solution of 4%. Under these treatment conditions, the BAE retention in 100 mm sample could be increased if higher treating solution was used and the pressure duration was extended. The effects of treating concentrations and pressure periods on preservative absorption in rubberwood were demonstrated in earlier works (Tan *et al.* 1983, Salamah *et al.* 1988, Hong & Liew 1989, Salamah & Shaharuddin

2000). Generally, for a diffusible preservative such as boron compounds, increasing the concentration or extending the time of pressure phase would correspondingly increase the BAE retention.

CONCLUSIONS

The present study showed that treatment parameters of 1 hour pressure and 2% solution of boron preservatives were only sufficient to treat 25 mm rubberwood timber to achieve 0.2% BAE in the core area. However, the same treatment parameters are being used widely by local rubberwood processors to treat various dimensions and thicknesses of rubberwood stocks. It is important that for effective treatment of thicker materials, higher concentration of treating solution and longer treatment time be adopted.

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