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Durability Assessment of Preservatives Treated *Bambusa vulgaris* in Unsterile Soil Burial Tests

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Abstract: Cultivated *Bambusa vulgaris* at internodes 6, 7 and 8 of 2 and 4 years old culms were chemically treated with preservatives Ammoniacal-copper-quaternary (ACQ), Borax-Boric Acid (BBA) and Copper-chrome Arsenate (CCA). Preservatives strength at 1, 2, 4 and 8% were introduced to the bamboo through vacuum impregnation, soaking and high pressure sap-displacement processes. Unsterile soil laboratory burial laboratory tests were then conducted on the bamboo blocks taken from internodes 7. At the end of the testing period (8 weeks), the 2 year-old *B. vulgaris* were found to experiences higher weight loss than the 4 year-old to attack of decaying fungi. The treatment process of vacuum impregnation proved to be better than soaking and high pressure sap-displacement with the treated blocks showing lower weight loss against decaying fungi. This is followed by soaking and high pressure sap-displacement processes. The 4% preservatives solution strength was found to be sufficient in controlling the decaying fungi.

Key words: *Bambusa vulgaris*, laboratory test, soft rot, resistance to decaying fungi and weight loss

INTRODUCTION

Bio-deterioration in bamboo are known to be caused by different types of microbiological destroying organisms (Gunnar *et al*., 2002; Razak, 1998; Liese, 1985). Decay is by far the most serious kind of microbiological damage since it can cause structural failure. To prevent or retard the development of decay in bamboo, preservative treatments are normally applied.

Laboratory tests are designed to determine over a short period of time with of the selected preservatives, concentration and application methods are effective against representative decay fungi chosen. The testing procedure is repeatable, simple and quick method of assessment.

In this investigation, the bamboo blocks are exposed to soil burial of a certain period of time. The weight loss of the bamboo blocks indicates the overall resistance of untreated and treated *B. vulgaris* following the principle of established standard tests such as EN 113 (Anonymous, 1982) and EN 807 (Anonymous, 1993) to decay by the various test fungi.

The decay study in unsterile soil laboratory burial was made as an attempt to assess their performance against the soft rot decay. This system has been used successfully by Dickson and Gray (1987). The unsterile soil laboratory burial method has the advantage of creating a simulated field situation in the laboratory whereby test samples are exposed to a natural microflora that includes all types of decay fungi and bacteria. The moist soil condition enhances the activity of soft rot fungi on test. In this study, an even moisture content of the soil was maintained. The study was based on the technique used by Gray (1986), with some modification.

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MATERIALS AND METHODS

Bamboo culms used in this study were taken from Kawang village areas in Sabah. They were harvested from the clumps cultivated by the village people. Within a week after felling, the bamboo were transported to UMS and a local private owned company for chemical process. Chemical process using Ammoniacal Copper Quaternary (ACQ), Borax and Boric Acid (BBA) and Copper Chrome Arsenate (CCA) were applied to the bamboo through soaking, vacuum pressure impregnating and high pressure sap-displacement processes at 1, 2, 4 and 8% concentrations. Bamboo blocks chosen were those in the middle of internode 7 of each culm. These blocks were then converted into 10×20 mm×culm wall thickness. The total numbers of test blocks investigated were 324 and these include bamboo 2 age-group, 3 number of treatments, 3 type of chemicals, 4 levels of chemical concentrations and 4 replications.

The following formula was used to calculate for the preservative Net Dry Salt Retention (NDSR) for the soaked and vacuum pressure treated samples:

$$\text{NDSR}(\text{kg m}^{-3}) = \frac{\text{Preservative uptake (1)}}{\text{Volume}(\text{m}_3)} \times \frac{\text{Treating solution concetration}}{100} \quad (1)$$

The test blocks were buried in unsterile garden soil obtained from an undisturbed area in the forest ground of Kawang Forest Reserve area. Two blocks were placed on 150 mL air dried soil in each (375 mL capacity) glass jar and buried with a further 100 mL soil. The assembly was moistened with water to 130% of the Water Holding Capacity (WHC) of the soil determined. The blocks were then placed in a dark conditioning chamber for 8 weeks at 27°C.

At the end of the 8 weeks period the blocks were removed from the soil, wiped gently with a very soft brush to remove as much as possible of the soil as well as adhering fungal hyphae. The samples were then weighed to determine their moisture content. The samples for weight loss and total bamboo consumption were then placed in an oven at 105±2°C for 24 h.

All tests were carried out at UMS and FRIM mycology laboratories. The studies were conducted from July 2004 to June 2005. Procedure of testing were made in accordance to the European Standards EN 113 (Anonymous, 1982) and EN 807 (Anonymous, 1993).

RESULTS

The mean weight loss of the unsterilized laboratory soil burial and the control blocks are presented in Table 1 and 3, respectively. The preservative Net Dry Salt Retention (NDSR) of the 2 and 4 year-
old *B. vulgaris* bamboo treated by soaking, vacuum pressure impregnation and high pressure sap-

Table 1: Weight loss in unsterilized soil burial tests of *B. vulgaris* after 8 weeks of exposure period

Treatment process	Preservative concentration (%)	Preservative ACQ	BBA	CCA
Vacuum pressure				
	1	11.1 (3.93)	12.9 (3.03)	10.4 (2.68)
	2	4.1 (1.04)	4.9 (0.68)	3.3 (0.63)
2 year-old	4	0.7 (0.10)	0.9 (0.13)	0.6 (0.05)
	8	0.1 (0.00)	0.1 (0.00)	0.0 (0.01)
	1	9.3 (2.85)	11.9 (1.96)	9.1 (1.68)
	2	2.9 (0.68)	3.6 (0.07)	2.8 (0.92)
4 year-old	4	0.3 (0.07)	0.7 (0.1)	0.2 (0.04)
	8	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Soaking				
	1	12.4 (4.13)	13.5 (2.91)	10.8 (2.35)
2 year-old	2	4.9 (0.87)	5.2 (1.07)	4.0 (0.74)
	4	0.7 (0.11)	1.1 (0.21)	0.6 (0.16)

Table 1: Continued

Treatment process	Preservative concentration (%)	Preservative ACQ	BBA	CCA
	8	0.1 (0.02)	0.1 (0.00)	0.1 (0.01)
	1	10.4 (2.68)	12.6 (2.22)	10.0 (2.08)
4 year-old	2	3.1 (0.92)	4.1 (0.65)	2.9 (0.71)
	4	0.3 (0.09)	0.8 (0.09)	0.3 (0.04)
	8	0.1 (0.00)	0.1 (0.00)	0.1 (0.00)
High pressure sap displacement				
	1	13.0 (2.56)	13.9 (3.03)	11.5 (1.84)
	2	5.5 (1.94)	5.8 (2.05)	5.3 (0.92)
2 year-old	4	1.5 (0.21)	2.0 (0.23)	0.8 (0.02)
	8	0.2 (0.02)	0.2 (0.01)	0.1 (0.00)
	1	11.2 (2.09)	12.9 (1.98)	11.1 (1.72)
	2	4.3 (0.83)	4.8 (0.16)	3.7 (0.19)
4 year-old	4	0.9 (0.07)	1.0 (0.12)	0.7 (0.03)
	8	0.1 (0.00)	0.1 (0.00)	0.1 (0.00)

Mean of 6 replicates, Standard deviations are given in brackets

Table 2: Preservative retention (kg m^{-3}) of 2 and 4 year-old *B. vulgaris* bamboo treated by soaking, vacuum pressure impregnation and high pressure sap-displacement process

Chemical	Treatment process	2 year-old	4 year-old
ACQ (1%)	Vacuum	3.25 (1.02)	2.94 (0.86)
	Soaking	1.39 (0.72)	1.29 (0.57)
	High pressure sap-displacement	1.05 (0.64)	1.15 (0.37)
ACQ (2%)	Vacuum	6.45 (1.46)	4.54 (1.31)
	Soaking	2.90 (0.45)	2.03 (0.58)
	High pressure sap-displacement	2.06 (0.38)	1.93 (.042)
ACQ (4%)	Vacuum	9.93 (2.61)	7.89 (2.12)
	Soaking	4.59 (0.95)	4.46 (1.04)
	High pressure sap-displacement	4.32 (0.68)	4.04 (0.94)
ACQ (8%)	Vacuum	21.38 (3.95)	14.75 (3.82)
	Soaking	9.84 (2.84)	8.76 (1.94)
	High pressure sap-displacement	8.44 (1.99)	8.31 (1.79)
BBA (1%)	Vacuum	3.22 (1.06)	2.62 (0.19)
	Soaking	2.60 (0.88)	2.15 (0.31)
	High pressure sap-displacement	1.27 (0.48)	1.16 (0.09)
BBA (2%)	Vacuum	6.30 (1.98)	4.41 (0.15)
	Soaking	4.24 (1.22)	3.58 (0.12)
	High pressure sap-displacement	2.18 (0.28)	2.15 (0.48)
BBA (4%)	Vacuum	9.36 (2.73)	7.65 (2.75)
	Soaking	7.32 (2.36)	5.19 (1.86)
	High pressure sap-displacement	5.30 (1.57)	4.78 (1.24)
BBA (8%)	Vacuum	20.05 (3.65)	14.07 (3.15)
	Soaking	14.90 (2.37)	11.03 (2.78)
	High pressure sap-displacement	8.99 (2.58)	7.56 (2.02)
CCA (1%)	Vacuum	3.73 (0.85)	2.86 (0.68)
	Soaking	2.26 (0.37)	1.99 (0.51)
	High pressure sap-displacement	1.20 (0.52)	1.08 (0.35)
CCA (2%)	Vacuum	7.74 (1.75)	4.93 (1.05)
	Soaking	4.09 (0.89)	3.49 (0.97)
	High pressure sap-displacement	2.50 (0.68)	2.31 (0.57)
CCA (4%)	Vacuum	12.21 (2.68)	8.46 (2.63)
	Soaking	5.87 (1.84)	5.21 (0.96)
	High pressure sap-displacement	5.14 (1.78)	4.93 (0.79)
CCA (8%)	Vacuum	24.64 (5.25)	19.62 (4.93)
	Soaking	11.12 (3.21)	9.92 (2.64)
	High pressure sap-displacement	10.91 (2.52)	9.46 (3.18)

Mean of 6 replicates, Standard deviations are given in brackets

Table 3:Weight loss of bamboo control blocks

Control blocks	Weight loss (%)
2 year-old	31.8 (8.13)
4 year-old	27.9 (6.82)

Mean of 6 replicates, Standard deviations are given in brackets

Table 4: Analysis of variance on the weight loss of bamboo in laboratory unsterilized soil burial tests

SV	Sum of square	d.f.	Mean square	f-ratio
Age	32.5376	1	32.5376	52.156*
Chemical	55.9618	2	27.9809	44.852*
Treatment	22.2811	2	11.1405	17.858*
Concentration	6039.6414	3	2013.2138	3227.063*

*significant at $p<0.05$

displacement process are shown in Table 2. The results shows that the weight loss experienced by the bamboo control blocks are relatively higher than those of the chemically treated blocks In between the different treatment process, the bamboo treated by vacuum process shows lower weight loss followed by soaking and high pressure sap-displacement. In between the different chemical used, the CCA treated bamboo blocks shows lower weight loss followed by ACQ and BBA treated blocks. These are supported by the analyses of variance shown in Table 4.

DISCUSSION

The results of the unsterile soil laboratory burial showed a very similar pattern to that of the bamboo blocks tests in the monoculture soft rot study conducted by Gunnar *et al*. (2002), Razak (1998) and Othman (1993). The mean weight losses of the control blocks varied between 27.8 and 31.9% depending on the age of the culms. These are relatively higher than the chemically treated bamboo blocks where the mean weight losses for treated blocks (depending on age, treatment, preservative and solution strength) varied from 0 to 19.9%.

The 2 year-old culms were more susceptible to attack by decaying fungi than the 4 year-old culms even though they contained high NDSR of chemical. Similar observations were also made by Razak *et al*. (2005 and 2006). These are supported by the analyses of variance on the treated blocks in Table 4. As seen previously, the higher preservative uptake by the 2 year-old culms did not override the effect on the attack of the decaying fungi. The 4 year-old culms show consistently more resistance to the decaying fungi (namely soft rot) than the 2 year-old culms. According to Gunnar *et al*. (2002) and Othman (1993) this behavior was probably due to different chemical composition particularly increased lignin from approximately 24% in the 2 year-old to 28% in the 4 year-old culms. Levi (1965) noted that the presence of lignin forms a barrier that inhibit decay development at the cell walls level in the bamboo.

Comparison in between the different methods of treating the *B. vulgaris* shows that those blocks treated by vacuum pressure were more resistant to soft rot in unsterile soil than the soaking and the high pressure sap-displacement. CCA treated blocks showed slightly more resistance than the ACQ and BBA treated blocks at equivalent solution strength. These are supported by the analysis of variance (Table 4) which indicated that there were significant differences in the used of 2 and 4 year-old culms, different types of preservatives, different types of treatment process and different solution strength at $p<0.05$.

Bamboo blocks treated by the vacuum pressure process show less weight loss against the decay fungi. It is assumed that this process was able to give good chemical penetration into the cell walls throughout the bamboo blocks thus giving superior assessment. However, the chemical absorption and retention were also the highest in all of the bamboo blocks treated by this process. The next higher chemical absorption and retention was by soaking process. As expected blocks treated by high pressure sap-displacement process showed the least effective assessment against the decaying fungi but their assessment was not bad when compared to those blocks treated by soaking process.

Analyses on the various types of chemicals used in treating the blocks indicate that the weight loss was somewhat higher in the boron treated bamboo blocks even though the chemical uptakes in them were the highest compared with CCA and ACQ. This might be due to the leachability properties of BBA although, in all cases, control of decay was achieved at about 2% solution strength. The CCA and ACQ show good resistance against decaying fungi. This might be due to the fact that these two chemicals are fixed waterborne chemicals. As expected the chemical solution strength played an important in preventing the attack of decaying fungi. The 4 and 8% solution strength were seen to be effective in controlling the decaying fungi. However, considering the costing factor, the 4% solution strength should be sufficient in controlling the fungi since the weight loss in the tested blocks were less than the 2% solution strength depending on type of treatment process.

On the process of treatment, the high-pressure sap-displacement shows higher weight loss compared to other two. This is followed by soaking and vacuum pressure process, respectively. These are supported by the analyses of variances which shows that there are highly significant difference at $p<0.05$ between different treatment process. Similar observations were also made by Razak (1998) and Razak *et al.* (2006).

CONCLUSIONS

Bamboo *B. vulgaris* of age 2 year-old are more susceptible than the 4 year-old to attack of decaying fungi even though they contained slightly more NDSR during the preservatives treatment process.

The vacuum pressure impregnation process is the best method in treating bamboo against decaying fungi. Bamboo blocks treated by this process experiences the least weight loss when exposed to the 8 weeks of unsterile soil laboratory tests. This is followed closely by soaking and high pressure sap-displacement treated bamboo blocks.

The CCA and ACQ treated bamboo blocks show good resistance against decaying fungi with CCA performing slightly better than the ACQ.

The 4% preservatives strength solution of CCA and ACQ were found to be sufficient in controlling the decaying fungi.

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