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ORIGINAL ARTICLES

Assessment on the Durability Of Chemically Treated *Gigantochloa Scortechinii* In Accelerated Unsterile Soil Laboratory Tests

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ABSTRACT

Cultivated 2 and 4 years old *Gigantochloa scortechinii* culms of internodes 6, 7, and 8, were chemically treated with ammoniacal-copper-quaternary (ACQ), borax-boric acid (BBA) and copper-chrome arsenate (CCA) at 1, 2, 4 and 8% concentrations respectively. Three different methods of chemical treatment were introduced to the bamboo through soaking, vacuum impregnation and high pressure sap-displacement process. An accelerated eight weeks laboratory unsterile soil burial tests were then carried out on the bamboo samples. At the completion of the testing period, the 2 year-old *G. scortechinii* were found to experience higher weight loss compared to the 4 year-old as the results of the attack by decay fungi. Comparison between the treatment processes showed that the vacuum pressure treated bamboos experienced lower weight loss. The 4% preservatives solution strength was found to be sufficient in controlling the decay fungi in the bamboos.

Key words: Cultivated *Gigantochloa scortechinii*, chemical treatment, unsterile soil burial test, resistance decay fungi, weight loss.

Introduction

Different types of microbiological destroying organisms were known to be the caused in bamboo bio-deterioration (Razak, 1998; Liese, 1985). The greatest damages are done by fungi and to relative minor extent, bacteria. Decay is by far the most serious kind of microbiological damage since it can cause structural failure. It is virtually impossible to accurately assess the monetary loss caused by fungi in bamboo products since data are rarely kept. Chemical treatments are normally applied to prevent or delay the progress of decay in bamboo. Investigation of the decaying involved exposing the bamboo samples to soil burial for a certain period of time. The weight loss of the bamboo samples towards the end of the selected periods indicated the overall resistance of the treated and untreated *G. scortechiniii*. The diagnostic assessments follow the principle of established standard tests such as EN 113 (Anon., 1993), EN 807 (Anon., 1997) and ASTM D2017 (Anon., 1997) to decay by the various test fungi. Laboratory fungi tests are intended to determine over a short period of time the effectiveness of the treated bamboo samples against the selected representative decay fungi. The essence of this part of the test procedure is to use a repeatable, simple and quick method of assessment. This system has been used successfully by Dickinson and Gray (1987). The unsterile soil laboratory burial method has the advantage of creating a simulated field condition in the laboratory whereby test samples are exposed to a natural micro-flora that includes all types of decay fungi and bacteria. The moist soil condition enhances the activity of soft rot fungi on test samples. In this investigation, even moisture content of the soil was regularly maintained. The detail study was based on the technique used by Gray (1986), with some modifications.

Materials and Methods

Bamboo culms used in this study were taken from naturally grown bamboo clumps in the Forest Research Institute of Malaysia (FRIM) research plots in Gunung Reng areas in Jeli, Kelantan, Malaysia. Within a week after felling, the bamboo were transported to the Universiti Malaysia Kelantan (UMK) in Jeli Campus for chemical treatment process. Chemical process using ammoniacal-copper-quaternary (ACQ), borax-boric acid (BBA) and copper-chrome-arsenate (CCA) were applied to the bamboo through soaking, vacuum pressure impregnation and high pressure sap-displacement process at 1, 2, 4 and 8% concentrations. The bamboo samples chosen were those in the middle of internode 7 of each culm. These samples were then converted into 10 mm x 20 mm x culm wall thickness. Three hundred and twenty four bamboo test samples examined. These include bamboo of 2 age-group, 3 treatments techniques applied, 3 types of chemical used, 4 levels of chemicals concentrations used and 4 replications. The test samples were buried in unsterile garden soil obtained from an

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undisturbed area in the forest ground of Jeli District. Glass jars with volume capacity of 375 ml were used for this purpose. In each jar, two bamboo samples were placed on 150 ml of an air dried soil, and buried with a further 100 ml soil. The setup was moistened with water to 130% of the water holding capacity (WHC). The samples were then placed in a dark conditioning chamber for 8 weeks at 27°C.

Calculation of required water content as a percentage of the WHC for decay test using soil were made using the following formula as outline by the method of ASTM D2017 (Anon. 1997).

$$\text{Water to add (gm)} = \frac{(1.3\ \text{WHC} - \text{MC}) \times M_3}{100 + \text{MC}} \quad \text{(Eqn. 1)}$$

where: WHC = water holding capacity of soil (%m/m), MC = moisture content of air dried soil (%m/m),

M_3 = air dry mass of 250 ml. soil to fill glass jar.

The following formula was used to calculate for the preservative net dry salt retention (NDSR) for the soaked and vacuum pressure treated samples:

$$\text{NDSR (kg/m}^3\text{)} = \frac{\text{Preservative uptake } (l)}{\text{Vol. (m}^3\text{)}} \times \frac{\text{Treating solution concentration}}{100} \quad \text{------ (Eqn. 2)}$$

At the completion of the 8 weeks period the samples were removed from the soil, wiped gently with a soft brush to remove 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 hours while the samples for microscopy were fixed and stored in the Formalin Acetic Acid (FAA) solution. Procedure of testing was made in accordance to the European Standards EN 113 (Anon., 1982) and EN 807 (Anon., 1993).

Results:

The mean weight loss of the unsterilize laboratory soil burial and the control samples are presented in Tables 1 and 3 respectively. Preservative net dry salt retention (NDSR) (kg/m^3) of 2 and 4 year-old *G. scortechinii* bamboo treated by soaking, vacuum pressure impregnation and high pressure sap-displacement process are shown in Table 2. The results show that the weight losses experienced by the control samples are relatively higher than those of the chemically treated samples. Among 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 samples shows lower weight loss followed by ACQ and BBA treated samples. These are supported by the analyses of variance shown in Table 4.

Table 1: Weight loss (%) in unsterilized soil burial tests of *G. scortechinii* after 8 weeks of exposure period.

		Preservative		
Preservative concentration		ACQ	BBA	CCA
Weight loss of bamboo(%)				
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)
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)
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)
* HPSD				

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)

*HPSD is the high pressure sap-displacement process, values in brackets are the standard deviation.

Table 2: Net dry salt retention of preservative (kg/m^3) of 2 and 4 year-old *G. scortechinii* bamboo treated by soaking, vacuum pressure impregnation and high pressure sap-displacement process.

Chemical	Treatment process	2 year-old	4 year-old
ACQ (1%)	Soaking	1.39 (0.72)	1.29 (0.57)
	Vacuum	3.23 (1.02)	2.96 (0.86)
	HPSD*	1.05 (0.64)	1.15 (0.37)
ACQ (2%)	Soaking	2.90 (0.45)	2.03 (0.58)
	Vacuum	6.45 (1.46)	4.54 (1.31)
	HPSD*	2.06 (0.38)	1.93 (.042)
ACQ (4%)	Soaking	4.59 (0.95)	4.46 (1.04)
	Vacuum	9.93 (2.61)	7.89 (2.12)
	HPSD*	4.32 (0.68)	4.04 (0.94)
ACQ (8%)	Soaking	9.84 (2.84)	8.76 (1.94)
	Vacuum	21.38 (3.95)	14.75 (3.82)
	HPSD*	8.44 (1.99)	8.31 (1.79)
BBA (1%)	Soaking	2.60 (0.88)	2.15 (0.31)
	Vacuum	3.22 (1.06)	2.62 (0.19)
	HPSD*	1.27 (0.48)	1.16 (0.09)
BBA (2%)	Soaking	4.24 (1.22)	3.58 (0.12)
	Vacuum	6.30 (1.98)	4.41 (0.15)
	HPSD*	2.18 (0.28)	2.15 (0.48)
BBA (4%)	Soaking	7.32 (2.36)	5.19 (1.86)
	Vacuum	9.36 (2.73)	7.65 (2.75)
	HPSD*	5.30 (1.57)	4.78 (1.24)
BBA (8%)	Soaking	14.90 (2.37)	11.03 (2.78)
	Vacuum	20.05 (3.65)	14.07 (3.15)
	HPSD*	8.99 (2.58)	7.56 (2.02)
CCA (1%)	Soaking	2.26 (0.37)	1.99 (0.51)
	Vacuum	3.73 (0.85)	2.86 (0.68)
	HPSD*	1.20 (0.52)	1.08 (0.35)
CCA (2%)	Soaking	4.09 (0.89)	3.49 (0.97)
	Vacuum	7.74 (1.75)	4.93 (1.05)
	HPSD*	2.50 (0.68)	2.31 (0.57)
CCA (4%)	Soaking	5.87 (1.84)	5.21 (0.96)
	Vacuum	12.15 (2.68)	8.46 (2.63)
	HPSD*	5.14 (1.78)	4.93 (0.79)
CCA (8%)	Soaking	11.12 (3.21)	9.92 (2.64)
	Vacuum	24.64 (5.25)	19.62 (4.93)
	HPSD*	10.91 (2.52)	9.46 (3.18)

HPSD* is the high pressure sap-displacement process, values in brackets are the standard deviation.

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

Source of Variation	Sum of square	d.f.	Mean square	F-ratio
Age	32.5376	1	32.537	52.166 *
Chemical	55.9618	2	27.981	44.85 *
Treatment	22.2811	2	11.141	17.866*
Concentration	6039.6414	3	2013.214	3227.06 *

Table 3: Weight loss of control samples Control samples

	Weight loss (%)
2 year-old	31.9 (8.12)
4 year-old	27.8 (6.83)

Values in brackets are the standard deviation.

Figures 1 and 2 show some of the fiber cells being degraded as the results of the soft rot activities. These figures were taken by the used of the Electron Scanning Microscope.

Fig. 1: The cell walls of some of the fibers show indication of the soft rot decay cavities (see arrows) in bamboo treated with 2% ACQ by vacuum impregnation process (x 2,500, bar in line = 10 μm)

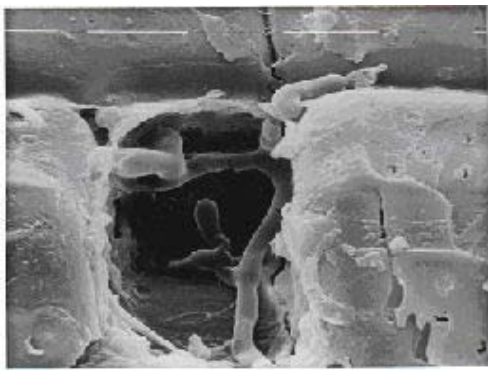

Fig. 2: A view showing several fungi hypae of the soft rot in the fiber cells lumen of bamboo treated with 1% CCA by soaking (x 2,500, bar in line = 10 μm)

Discussion:

The results of the unsterile soil laboratory burial showed a very similar pattern to that of the *G. scortechinii* samples tests in the monoculture soft rot study conducted by Razak (1998) and Othman (1993). The mean weight losses of the control samples varied between 27.8% and 31.9% depend on the age of the culms. These are relatively higher than the chemically treated bamboo samples where the mean weight losses for treated samples (depend on age, treatment, preservative and solution strength) varies 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 samples 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 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 inhibits decay development at the cell walls level in the bamboo.

Comparison in the weight loss of the bamboo samples treated with the different treatment techniques shows that those treated by vacuum pressure were more resistant than those treated by soaking and the high pressure sap-displacement. CCA treated samples showed slightly more resistance than the ACQ and BBA treated samples at equivalent solution strength. These are supported by the analysis of variance (Table 3) 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 $P<0.01$.

Bamboo samples 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 samples thus providing superior assessment. However, the chemical absorption and retention were also the highest in all of the bamboo samples treated by this process. The next higher chemical absorption and retention were by soaking process. As expected samples 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 samples treated by soaking process. Similar observations were also made by Razak (1998) and Razak *et al.* (2005).

Analyses on the various types of chemicals used in treating the samples indicate that the weight loss was somewhat higher in the boron treated bamboo samples 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 role in preventing the attack of decaying fungi. The 4% and 8% solution strength were regarded to be an 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 samples were less than 2% depending on type of treatment process.

Conclusion:

The cultivated bamboo *G. scortechinii* of age 2 year-old are more susceptible to attack of decaying fungi than the 4 year-old even though these bamboo contained the highest NDSR during the chemical treatment process.

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

The CCA and ACQ treated bamboo samples shows 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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