COMPARATIVE NET DRY SALT RETENTION AND PRESERVATIVES PENETRATION OF TREATED 2 AND 4 YEAR-OLD BAMBOO *Gigantochloa scortechinii*

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Abstract: Comparative preservatives net dry salt retention (NDSR) and preservatives penetration of 2 and 4 year-old tropical bamboo *Gigantochloa scortechinii* were studies. Three type of preservatives; ammoniacal-copper-quartenary, borax-boric acid and copper-chrome-arsenic were used in the study at 1%, 2%, 4& and 8% concentrations. Three type of preservation techniques; soaking, vacuum impregnation and high pressure sap-displacement were used in treating the bamboo. The results of the study show that the 2 year-old *G.scortechinii* had higher NDSR when compared with the 4 year-old culms across all the treatment processes. In between the various treatment processes, the vacuum pressure process gave the highest NDSR. This was followed closely by soaking and then at a somewhat lower NDSR by high-pressure sap-displacement process respectively. This suggests that the vacuum pressure process and the soaking process may be more effective in term of the NDSR values. The treatment processes ranked in the following order of decreasing NDSR: Vacuum Pressure > Soaking > High Pressure Sap-Displacement. The type of preservative played an important role in influencing the preservative NDSR. Between the 3 preservatives used in the study, BBA, which has high diffusion ability, gave the highest NDSR followed by CCA and ACQ respectively in the soaking process. CCA gave the highest NDSR in the vacuum pressure and high pressure sap-displacement process. There was a general proportionate relationship between the strength of preservative solution and NDSR in the treated culms. The top portion of the culm gave highest NDSR followed by middle and bottom portions respectively. The preservative penetration tests carried out indicated that there was a general proportionate relationship between NDSR and penetration.

INTRODUCTION

The epidermis of a bamboo culm consists of a thin and hard layer and is less permeable than the remainder of the culm in cross sectional area. Due to such differences in the anatomical structure, bamboo behaves differently from wood during treatment with preservatives. The vascular bundle plays an important role in preservative treatment. The axial flow is quite rapid in green bamboo, because of the end to end alignment of vessels. The vessels, which occupy about 10% of the culm volume (Liese, 1985 [4]; 1992, Kumar *et al.*, 1994 [3], Jayanetti and Follett, 1998 [2]) play an important role in influencing the penetration of preservatives to other surrounding tissues. The larger vessels (metaxylem) tend to absorb larger amount of preservative than the protoxylem (Kumar *et al.*, 1994) [3]. The degree of penetration decreases with distance from the conducting vessel increases. Thus, even when the vessels are filled to saturation point, the bamboo can still be vulnerable to insect or fungal attack if the preservative does not diffuse sufficiently into the main tissue of the culm (Jayanetti and Follett, 1998) [2].

Treatment processes found suitable for timber can also be applied to bamboo. A variety of traditional processes like water leaching, application of paint coating, brushing, swabbing, spraying, dipping, smoking, baking, etc. are also practiced for the protection of bamboo. A comprehensive investigation on the treatability of *G. scortechinii* by three preservative application methods (soaking, high-pressure sap-displacement, and vacuum pressure treatment) was carried out in this study. The aims of this study were to determine the chemicals retentions and their depth of penetration in the treated bamboo culms using selected preservatives at different concentration and preservation methods.

MATERIALS AND METHODS

Three hundred seventy two (372) bamboo culm were harvested from the Forest Reserve Area in Nami, Kedah. These culm samples which represent 2 age groups of 2 and 4 year-old culms were later cut into

3 lengths consisting of bottom, middle and top portions. A one-metre length sample was taken from the middle of each portion. Each sample consisting of 3 nodes and 2 internodes. These bamboo were divided into three groups for treatments which consist of vacuum impregnation, soaking and high pressure sap-displacement methods. Samples for high-pressure sap-displacement were treated within 7 days after harvesting. Those for soaking and vacuum pressure treatments were air-dried for 3 weeks.

Three types of preservative at 4 level of preservative concentration were used for this investigation. All bamboo blocks were treated in the round form. The preservatives used were Copper-Chrome-Arsenic (CCA), Ammoniacal-Copper-Quat.(ACQ) and mixture of borax and boric acid (BBA at 1.54 : 1 ratio) at 1%, 2%, 4% and 8% concentration respectively. The initial moisture content of these bamboo were 65% approximately for high pressure sap-displacement method, and 35% approximately for soaking and vacuum pressure methods. Treatment methods used in this study were based on the techniques outlined by Kumar *et al.* (1994) [3] and Razak (1998) [6] with some modification. Preservative uptakes were calculated by the differences in weight between the pre-treatment weight of bamboo and the final weight after each treatment. Preservative uptakes calculated for the high pressure sap-displacement treated samples are discussed separately.

Soaking method

Culms samples for this treatment samples were soaked completely in dipping tanks containing solutions of water-soluble preservatives for 7 days to attain the maximum chemical retention (Sulthoni, 1983 [8], Sulthoni, 1988, Kumar, 1994 [3]). The 7 days soaking period were used based on studies conducted by Sulthoni (1983 [8], 1988). The solution enters the culm through the ends and through the sides. Small holes were punched using an iron rod through the diaphragms of the nodal regions to prevent the round bamboo samples from floating in the preservative solution and to ensure better treatment and enable satisfactory draining of treating solution.

Vacuum pressure method

Culm samples were placed in the treatment cylinder and treated under vacuum pressure condition. The treatment cycle adopted was as follows: -

Initial vacuum	-	600 mm Hg for 30 minutes (to take the air out of bamboo)
Applying Pressure	-	12 kg/cm^2 for 2 hours
Final vacuum	-	600 mm Hg for 30 minutes (to remove the excess preservative from the bamboo)

To prevent the round bamboo samples from collapsing under pressure and to ensure better treatment and draining small holes were punched using an iron rod through the diaphragms in the bamboo culms (Sonti, 1990).

High-pressure sap-displacement method (HPSD)

These culm samples were treated while in green conditions. The moisture content of the bamboos samples was approximately 65%. The bamboo samples were then placed in closed terminals of the high-pressure sap-displacement machine. A pressure of 2 to 5 kg/cm^2 were then applied to forced the solution containing preservatives to enter from one end of the bamboo through the other end. The treatment process took approximately 30 to 40 minutes and was stopped once there were no more liquid coming out at the other end of the culm samples. Probable reason why the liquid stopped coming out of the culm samples could be attributed to the clogging of the vessels by tyloses or other blockages.

Evaluation Of The Treatment

At the end of each treatment process the culm samples were taken out and excess liquid was drained offfor 30 minutes. The amounts of liquid absorbed by each sample were calculated by the difference in weight before and after the treatment.

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

$$\text{NDSR (kg/m}^3\text{)} = \frac{\text{Uptake (l)}}{\text{Volume (m}^3\text{)}} \times \frac{\text{Treating solution concentration}}{100}$$

Where, uptake is the amount of preservative absorbed by culm samples and volume is the volume of the culm samples.

After natural drying under cover (1 week) 2 replicate were cut transversely at 20 cm on both ends of the culm samples and the cut surfaces tested colorimetrically by spraying with chemical reagents. Figure 3 shows how treated culm samples were cut for preservatives penetration tests. The chemical reagents reacted with the preservatives in bamboo to give distinct characteristic colours. The chemical reagents used were the chrome azurol S solution for the detection of copper in the CCA and ACQ, and curcumin solution for the detection of boron. This is a qualitative analysis designed to determine the amount of preservative penetration in the treated bamboos. The results of the penetration tests will give an idea on the pattern of penetration by the preservatives in the treated culm samples. Table 1 shows the classification of the assessment that was used in the study.

Table 1: Visual classification of preservative penetration

Penetration	Grading	Condition
Nil	1	No penetration.
Slight	2	Less than 25% of cross-sectional area penetrated.
Moderate	3	25% - 50% of cross-sectional area penetrated.
Heavy	4	50% - 75% of cross-sectional area penetrated.
Complete	5	More than 75% of cross-sectional penetrated.

(based on Malaysian Standard MS 833: 1984 – Method for the qualitative analysis of wood preservative and treated timber) [1]

RESULTS AND DISCUSSIONS

Soaking method

The overall data for preservative net dry salt retention (NDSR) by soaking method in the 2 and 4 year-old *G. scortechinii* are presented in Table 2 and Table 3.

Table 2: Preservative NDSR (kg/m^3) in 2 year-old bamboo by soaking method

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	1.03	1.39	1.71
	2%	2.31	2.90	3.79
	4%	4.41	4.59	5.81
	8%	8.95	9.84	10.58
BBA	1%	2.51	2.60	2.85
	2%	3.92	4.24	5.01
	4%	6.49	7.32	8.84
	8%	12.33	14.90	15.66
CCA	1%	2.13	2.26	2.40
	2%	3.71	4.09	4.79
	4%	5.29	5.87	6.51
	8%	10.20	11.12	11.49

Table 3: Preservative NDSR (kg/m^3) in 4 year-old bamboo by soaking method

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	1.11	1.29	1.49
	2%	1.93	2.03	2.50
	4%	3.84	4.46	4.75
	8%	8.19	8.76	9.29
BBA	1%	1.91	2.15	2.40
	2%	3.52	3.58	3.79
	4%	4.83	5.19	6.16
	8%	10.34	11.03	12.84
CCA	1%	1.50	1.99	2.26
	2%	3.03	3.49	3.69
	4%	4.72	5.21	6.26
	8%	8.84	9.92	10.78

Table 4: Analysis of Variance for NDSR using soaking method

S.V.	Sum of square	d.f.	Mean square	F-ratio	Sig. Level
Age	83.955	1	83.955	180.313	**
Chemicals	234.736	2	117.368	252.074	**
Concentration	4075.423	3	1358.474	2917.632	**
Height	85.439	2	42.719	91.750	**

** significant at P<0.01

The analysis of variance is presented in Tables 4. The classification of the preservative penetration for the soaking process treatment is tabulated in Table 5 and Table 6.

Table 5: Preservative penetration class in 2 year-old culms by soaking method

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	2	2	2
	2%	2	2	2
	4%	2	3	3
	8%	3	3	4
BBA	1%	2	2	2
	2%	2	3	3
	4%	3	4	4
	8%	5	5	5
CCA	1%	2	2	2
	2%	2	2	3
	4%	2	3	3
	8%	3	3	4

Table 6: Preservative penetration class in 4 year-old culms by soaking method

Preservatives	Solution strength	Height of bamboo culms		
		Bottom	Middle	Top
ACQ	1%	2	2	2
	2%	2	2	2
	4%	2	2	3
	8%	2	3	4
BBA	1%	2	2	2
	2%	2	2	3
	4%	3	3	4
	8%	4	5	5
CCA	1%	2	2	2
	2%	2	2	3
	4%	2	2	3
	8%	3	3	4

See Table 1 for classification

Vacuum pressure method

The data for NDSR for culm samples by vacuum pressure are presented in Table 7 and Table 8.

Table 7: Preservative NDSR (kg/m^3) in 2 year-old bamboo by vacuum pressure

Preservatives	Solution strength	Height of bamboo culms		
		Bottom	Middle	Top
ACQ	1%	2.87	3.23	3.69
	2%	4.95	6.45	7.21
	4%	9.15	9.93	10.73
	8%	15.29	21.38	23.46
BBA	1%	2.81	3.22	3.44
	2%	4.50	6.30	6.89
	4%	8.84	9.36	10.57
	8%	14.66	20.05	22.75
CCA	1%	3.47	3.73	3.85
	2%	5.63	7.74	8.65
	4%	10.54	12.15	14.53
	8%	18.85	24.64	27.35

Table 8: Preservative NDSR (kg/m^3) in 4 year-old bamboo by vacuum pressure

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	2.62	2.96	3.08
	2%	4.32	4.54	5.96
	4%	7.75	7.89	9.07
	8%	13.18	14.75	15.29
BBA	1%	2.54	2.62	2.79
	2%	4.21	4.41	5.12
	4%	7.15	7.65	8.22
	8%	12.86	14.07	14.87
CCA	1%	2.74	2.86	3.52
	2%	4.86	4.93	5.93
	4%	7.20	8.46	10.80
	8%	18.53	19.62	24.46

See Table 1 for classification

Table 9 shows the analysis of variance for NDSR using the vacuum pressure method.

Table 9: Analysis of Variance for NDSR using vacuum method.

S.V.	Sum of square	d.f.	Mean square	F-ratio	Sig. Level
Age	455.963	1	455.963	163.809	**
Chemicals	360.321	2	180.161	64.725	**
Concentration	12513.046	3	4171.015	1498.481	**
Height	410.232	2	205.116	73.690	**

** significant at $P<0.01$

The classification of the preservative distribution and penetration for the vacuum pressure process treatment are tabulated in Table 10 and Table 11.

Table 10: Preservative penetration in 2 year-old culms by vacuum pressure

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	2	2	3
	2%	2	3	3
	4%	3	3	4
	8%	4	4	5
BBA	1%	2	3	3
	2%	3	3	4
	4%	4	4	4
	8%	5	5	5
CCA	1%	2	2	3
	2%	3	3	4
	4%	4	4	4
	8%	5	5	5

Table 11: Preservative penetration in 4 year-old culms by vacuum pressure

Preservatives	Solution strength	Height of bamboo culms		
		Bottom	Middle	Top
ACQ	1%	2	2	2
	2%	2	3	3
	4%	3	3	3
	8%	4	4	5
BBA	1%	2	2	3
	2%	3	3	4
	4%	3	4	4
	8%	4	5	5
CCA	1%	2	2	3
	2%	3	3	4
	4%	3	4	4
	8%	4	5	5

See Table 2 for classification

High pressure sap-displacement method

The normal practice of calculating the amount of liquid absorbed by the difference in weight before and after treatment of each culm samples does not work in the high pressure sap-displacement method. In this process the pressure is applied to force liquid to enter into one end of the culm and the sap in the culm is forced out from the other end. Therefore the liquid is only replacing the sap in the culm samples.

In order to calculate the actual amount of the liquid, the following assumptions have been made:
It is assumed that the liquid occupied about 90% of the overall volume of the vessel in *G. scortechinii*. The amount of liquid occupying this volume plus the difference in weight before and after treatment was assumed to be the amount of liquid absorbed by the culm samples. Vessel make up about 10% of the overall volume in bamboo (Liese, 1985) [4].

$$VCP = (\text{Culm cross-section} \times L \times (9/100)) + (A)$$

Where, VCP- volume occupied by preservative,
L - the length of the treated culm, factor 9/100 is the 90% volume occupied by preservative in vessel of the overall culm volume,
A - the difference in weight before and after treatment.

The data after transformation by the above procedure for culm samples treated by high-pressure sap-displacement are presented in Table 12 and Table 13. The NDSR with the 2% solution strength by high pressure sap-displacement treatment is shown in Figure 9. Figure 10 shows NDSR breakdown for preservative concentration at 1%, 2%, 4% and 8% at the middle portion of 2 and 4 year-old *G. scortechinii* culms. Figure 11 shows the rating of preservative penetration test conducted on culm samples treated at 2% solution strength and Figure 12 shows penetration rating at middle portion at various solution strengths.

Table 12: Preservative NDSR (kg/m^3) in 2 year-old bamboo by HPSD

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	0.99	1.05	1.56
	2%	2.01	2.06	2.13
	4%	4.30	4.32	6.99
	8%	8.40	8.44	9.55
BBA	1%	1.17	1.27	1.29
	2%	2.12	2.18	2.38
	4%	5.22	5.30	5.59
	8%	8.90	8.99	10.47
CCA	1%	1.18	1.20	1.24
	2%	2.17	2.50	2.81
	4%	4.71	5.14	5.22
	8%	9.74	10.91	11.29

Table 13: Preservative NDSR (kg/m^3) in 4 year-old bamboo by HPSD

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	1.04	1.15	1.32
	2%	1.90	1.93	2.00
	4%	3.81	4.04	4.15
	8%	8.08	8.31	8.61
BBA	1%	1.09	1.16	1.18
	2%	1.94	2.15	2.23
	4%	4.67	4.78	5.76
	8%	7.52	7.56	7.65
CCA	1%	1.07	1.08	1.16
	2%	1.98	2.31	2.67
	4%	4.50	4.93	5.18
	8%	8.65	9.46	10.19

See Table 1 for classification

Table 14 shows the analysis of variance for NDSR using high-pressure sap-displacement method.

Table 14: Analysis of Variance for NDSR using HPSD

S.V.	Sum of square	d.f.	Mean square	F-ratio	Sig. Level
Age	21.462	1	21.462	76.850	**
Chemicals	18.652	2	9.326	33.393	**
Concentration	3333.569	3	1111.189	3978.820	**
Height	25.887	2	12.944	46.347	**

** significant at $P<0.01$

The classification of the preservative distribution and penetration for the high- pressure sap-displacement (HPSD) process treatment are tabulated in Tables 15 and 16.

Table 15: Preservative penetration in 2 year-old culms by HPSD

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	2	2	2
	2%	2	2	2
	4%	2	3	3
	8%	3	3	3
BBA	1%	2	2	2
	2%	2	3	3
	4%	3	4	4
	8%	4	5	5
CCA	1%	2	2	2
	2%	2	3	3
	4%	3	4	4
	8%	4	5	5

Table 16: Preservative penetration in 4 year-old culms by HPSD

		Height of bamboo culms		
Preservatives	Solution strength	Bottom	Middle	Top
ACQ	1%	2	2	2
	2%	2	2	2
	4%	2	3	3
	8%	3	3	3
BBA	1%	2	2	2
	2%	2	3	3
	4%	3	3	4
	8%	4	4	5
CCA	1%	2	2	2
	2%	2	3	3
	4%	3	3	4
	8%	4	4	5

See Table 1 for classification

DISCUSSIONS

Soaking Method

The results of the soaking method indicated that preservative uptake and retention were dependent on the types of preservative, the strength of the solutions, age and height of the bamboos culms. This is clearly shown by the analysis of variance in Table 4. NDSR increased with increase in preservative strength solutions as expected. Culm age and height in the culm played an important role in determining the preservative NDSR in the bamboos. As expected, the 2 year-old culms and the top and

middle of the culms contained more preservatives after treatments compared with the 4 year-old culms or the lower portions of the culms. This behavior can be attributed in fact to a lower basic density and lignification in the younger material. Basic density reflects the amount of cell wall material (Liese, 1985) [4]. The cell walls in the 2 year-old culms are much thinner than that in the 4 year-old culms. Therefore their potential to absorb more preservatives in their lumens is higher. As for the height of the bamboos culm, the absorption of the preservatives will also be influenced by the amount of vascular bundles present. As can be seen from Table 1 on the anatomical properties of the 2 and 4 year-old culms, the top portions have higher amount of vascular bundles than that found in the bottom and middle portion. The vascular bundles play an important role in absorbing preservatives and distributing them to the rest of the tissues in the culms.

The classification of the preservative penetration indicated the amount of preservatives present in the bamboo culms at the length of 20 cm from the ends of the culms used in the treatment process. Most of the preservatives were found to be located or scattered around the vascular bundles in and near the vessels.

The types of preservative used in the investigation also influenced the NDSR in the soaking treatments. BBA appeared to have a higher ability to penetrate in soaked bamboo, which increased the NDSR of the treated culms at the higher solution concentrations.

Vacuum Pressure Treatment

The results of the vacuum pressure method and the preservative penetration show some similarity with those by the soaking. CCA was found to give the highest preservative uptake and retention. No explanation could be given as to why CCA exceeded BBA in giving the highest uptake and retention. The amount of retention increased in line with the preservative concentration. The uptake and retention of ACQ was the least of the three preservatives. The top portion of the culm gave the highest preservative uptake and retention. This was followed by the middle and bottom portions respectively.

High Pressure Sap-displacement

This method gave the lowest NDSR and retention values compared with the previous two processes. The amount of NDSR obtained in treating the bamboos by the high-pressure sap-displacement treatment, suggest that this process may be less effective than the others. It should be noted that it was estimated here because of the nature of the treating process. However, the preservative penetration test did match those estimates. Details of the penetration test are shown in Table 19 and 20 at a cross-section of 20 cm from both ends of the treated bamboo culms. The location of preservatives was found to concentrated around the vessels.

The amount of net dry salt retention (NDSR) increased with preservative concentration. As in the vacuum pressure treatment, CCA gave the highest value of uptake and retention. The uptake and retention of BBA and ACQ followed these respectively. Between the portion of bamboo culm, the top portion gave the highest preservative uptake and retention. These were followed by middle and bottom portion respectively.

Overall Discussion

The analysis of variance for the overall NDSR between various treatments processes on *G.scortechinii* are shown in Table 17. The result shows that treatment by vacuum pressure gave the highest level of preservatives retention. This was followed by soaking and high pressure sap-displacement respectively. On the type of preservative, BBA gave the highest NDSR in the soaking treatment and CCA gave the highest NDSR in vacuum pressure and high pressure sap-displacement. The 2 year-old bamboo culms give higher NDSR when compared with the 4 year-old culms. The bottom portion gave the higher NDSR followed by the middle and top portions respectively.

Table 17: Analysis of Variance for Preservative Retention of 2 and 4 years old bamboo

S.V.	Sum of square	d.f.	Mean square	F-ratio	Sig. Level
Age	61.93	1	61.93	16.39	**
Treatments	530.87	2	265.44	70.23	**
Chemicals	209.02	2	104.51	27.65	**
Concentration	3167.49	3	1055.83	279.36	**
Height	64.86	2	32.43	8.58	**

** significant at P<0.01

CONCLUSIONS

The over-all results of the investigation indicated that the preservative uptake and the NDSR are dependent on the type of treatment process, types of preservatives, the strength of the solutions, age and height of the bamboos culms. The 2 year-old *G.scortechinii* had higher NDSR when compared with the 4 year-old culms across all the treatment processes. Between the various treatment processes, the vacuum pressure process gave the highest NDSR. This was followed closely by soaking and then at a somewhat lower NDSR by high-pressure sap-displacement process respectively. This suggests that the vacuum pressure process and the soaking process may be more effective in term of the NDSR values. The treatment processes ranked in the following order of decreasing NDSR:

Vacuum Pressure > Soaking > High Pressure Sap-Displacement.

The type of preservative played an important role in influencing the preservative NDSR. Between the 3 preservatives used in the study, BBA, which has high diffusion ability, gave the highest NDSR followed by CCA and ACQ respectively in the soaking process. CCA gave the highest NDSR in the vacuum pressure and high pressure sap-displacement process. There was a general proportionate relationship between the strength of preservative solution and NDSR in the treated culms. The top portion of the culm gave highest NDSR followed by middle and bottom portions respectively. The preservative penetration tests carried out indicated that there was a general proportionate relationship between NDSR and penetration.

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