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Impregnation of bamboo (*Gigantochloa scortechinii*) strips with low-molecular-weight phenol formaldehyde resin

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Abstract: A study was undertaken to impregnate bamboo strips (*Gigantochloa scortechinii*) with low-molecular-weight phenol formaldehyde resin (LMwPF). The bamboo samples were taken from the basal and middle portions of the culm. Upon treatment with LMwPF using vacuum process, the weight percent gain (WPG) and moisture content (MC) of the treated bamboo strips were evaluated. The WPG of the impregnated strips increased when the duration of soaking in the resin increased. After 120 min of soaking, the WPG increased by 4.51 per cent and 7.52 per cent for basal and middle portions, respectively. The MC of the treated strips gradually decreased from the original mean of 20 per cent to 5 per cent after drying in an oven at 60°C for 12 h. The optimum drying duration was approximately 9 h, beyond which the treated samples started to warp.

Key words: Bamboo strips, low-molecular-weight phenol formaldehyde, impregnation.

INTRODUCTION

There are many possible ways to enhance the properties of bamboo before it can be further manufactured into value added products. One possibility is to treat it with water soluble resin which upon heating will be converted into insoluble material that cross-links to the wood. Such methods have been reported to be effective for bamboo with significant increase in strength properties and higher dimensional stability due to the presence of resin within the cell wall (Deka *et al.*, 2003). Mahlberg *et al.* (2001) also found a significant improvement in the mechanical properties and dimensional stability of wood fibre when impregnated with polypropylene. Gindl *et al.* (2003) treated wood with melamine-formaldehyde (MF) and found that the resins improved surface hardness and weathering resistance. Furuno *et al.* (2004) stated that phenolic resin penetrated wood cell walls, thus resulting in improvement in dimensional stability and decay resistance in the wood. In an earlier study, Imamura

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et al. (1998) revealed that the deposition of polymer within the woody cell walls would increase the decay resistance as well as dimensional stability of the treated material.

Low-molecular-weight phenol formaldehyde resin (LMwPF) treatment has been widely used to impart dimensional stability of wood. Impregnation with LMwPF improves the decay and termite resistance (Kajita and Imamura, 1991, Poo *et al.*, 1999, Deka *et al.*, 2003). It has been documented that the efficacy of the PF resin treatment is markedly influenced by the molecular weight of the resin used. This is because the molecular size of impregnating chemical would determine the degree of the chemical penetration into the cell walls (Ryu *et al.*, 1993).

This paper reports the results of impregnation of bamboo (*Gigantochloa scortechinii*) strips with LMwPF using a vacuum process. The effect of soaking and drying times on weight percent gain (WPG) and moisture content (MC) of the impregnated bamboo strips is also discussed.

MATERIALS AND METHODS

The material used in this study was 4-year-old *Gigantochloa scortechinii*, which was collected from the Forest Research Institute Malaysia (FRIM), Kepong, Malaysia. Only the basal (internodes 4 to 6) and middle (internodes 13 to 15) portions of the culms were used in the study since only these sections could give adequate wall thickness (more than 8 mm) for strip preparation. The culms were cut and split into 25 mm wide strips using a sizing and splitting machine. The splits were then air-dried to about 12 per cent MC and planed to 4 mm thickness on a single side-planing machine. The final size of the specimens was 25 x 20 x 4 mm. Both ends of the samples were coated with epoxy paint to prevent excessive penetration from the transverse direction. The LMwPF resin used for the impregnation was supplied by Malaysian Adhesive Chemical (MAC).

Impregnation of bamboo strips

The samples were impregnated with LMwPF by a vacuum process. Each sample was weighed before it was placed in a glass vessel. The samples were first immersed in LMwPF and then a vacuum of 750 mm Hg was applied for 1 h. The samples were left in the LMwPF solution for either 30, 60, 90, 120 or 150 min. The samples were then rinsed and wiped with a cloth, and weighed prior to drying at 60°C. The drying time was varied from 3 to 12 h. The WPG or chemical retention was determined using the following equation (Schneider and Brebner, 1985; Deka *et al.*, 2003):

$$\text{WPG}\ (\%) = \frac{(W_t - W_u)}{W_u} \times 100$$

where, Wt = weight of treated bamboo strips, and Wu= weight of bamboo strips before treatment.

The MC was determined by oven-drying the samples. Data were statistically analysed using Statistical Analysis Software (SAS). The effects of soaking time and drying duration were further analysed by mean separation using Least significant difference (LSD) method at $P \leq 0.05$.

RESULTS AND DISCUSSION

The values of initial weight percent gain (WPG) for basal and middle portions of bamboo sample are shown in Table 1. Longer soaking duration increased the initial WPG quite substantially, in particular at 150 min. The increase was minimum in the basal portion. All the WPG values in the middle portion were higher than those in the basal, suggesting that cells at this part of bamboo have better absorption properties. Figures 1 and 2 show that the initial WPG of impregnated bamboo strips decreased drastically after 3 h of drying from an average of 19.4 per cent to 10.8 per cent and from 22.9 per cent to 13.7 per cent for basal and middle portions respectively. A marginal increment in WPG was noted for both the basal and middle portions after 9 h drying. It appears that LMwPF is stable and the resin volume of the treated samples remained the same after 9 h drying. At this stage, the LMwPF is assumed to be in a gel state and hence will be in an optimum condition for further curing upon heating at 140°C (Nor Yuziah, 2005).

A significant difference ($P \leq 0.05$) in WPG values was observed in samples from middle portion when the strips were soaked for 30 and 120 min, but no significant difference was found among the samples of basal portion. On the contrary, significant differences ($P \leq 0.05$) between basal and middle portions were found in samples soaked for 30 and 120 min. The same trend was also observed after 9 h drying which means that soaking duration influenced the WPG of bamboo strips after drying.

It is interesting to note that no significant difference was observed in WPG values

Table 1. Weight Percent Gain (WPG) of bamboo strips after impregnation

	Initial WPG (%)		After 9 h drying (%)	
Soaking duration (min)	Basal	Middle	Basal	Middle
30	17.44^{a}	18.38^{ab}	6.33^{a}	8.54^{ab}
60	18.66^{ab}	22.05^{ab}	6.78^{a}	8.51^{ab}
90	19.52^{ab}	22.31^{ab}	7.49^{ab}	9.31^{ab}
120	19.57^{ab}	25.4^{bc}	7.64^{ab}	10.51^{b}
150	21.95^{ab}	25.9^{c}	8.48^{ab}	11.01^{b}

Means with the same letter are not significantly different ($P < 0.05$)

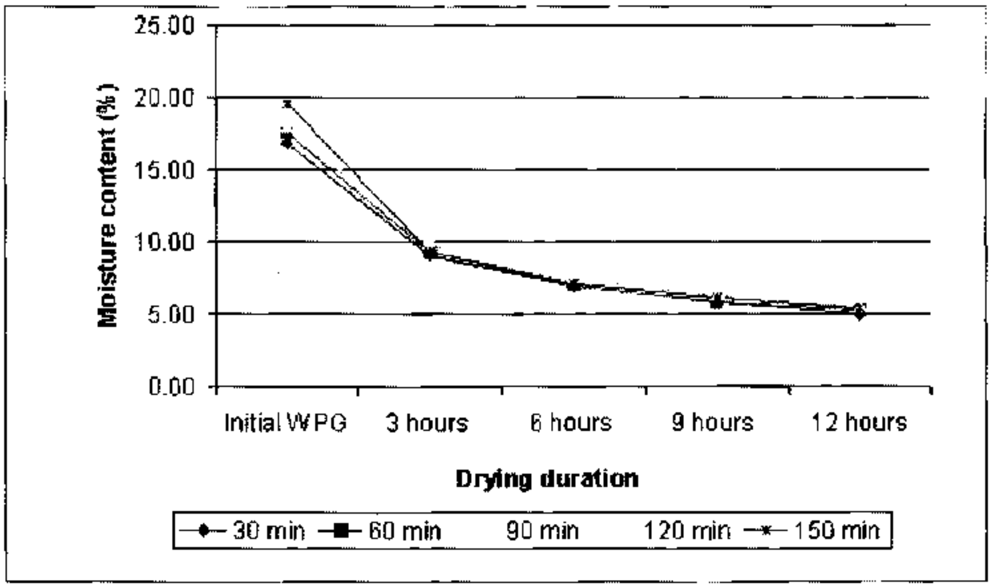

Figure 1. Weight percent gain of LMwPF in bamboo strips at basal portion after drying at 60°C.

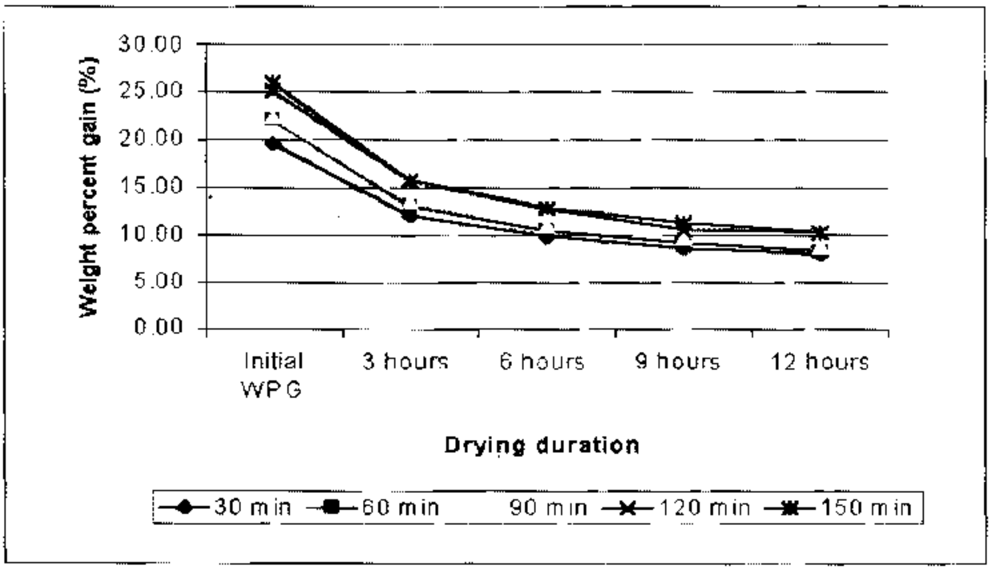

Figure 2. Weight percent gain of LMwPF in bamboo strips at middle portion after drying at 60°C.

after 90 min of soaking in resin for both basal and middle portions. This is probably because the lumen had already been fully saturated with LMwPF resulting in very little change in WPG values. According to Deka and Saikia (2000), it is possible that as the wood samples were fully bulked in the cell wall and beyond certain levels, the polymer might fill the wood lumen but this resulted in no further bulking of treated wood samples.

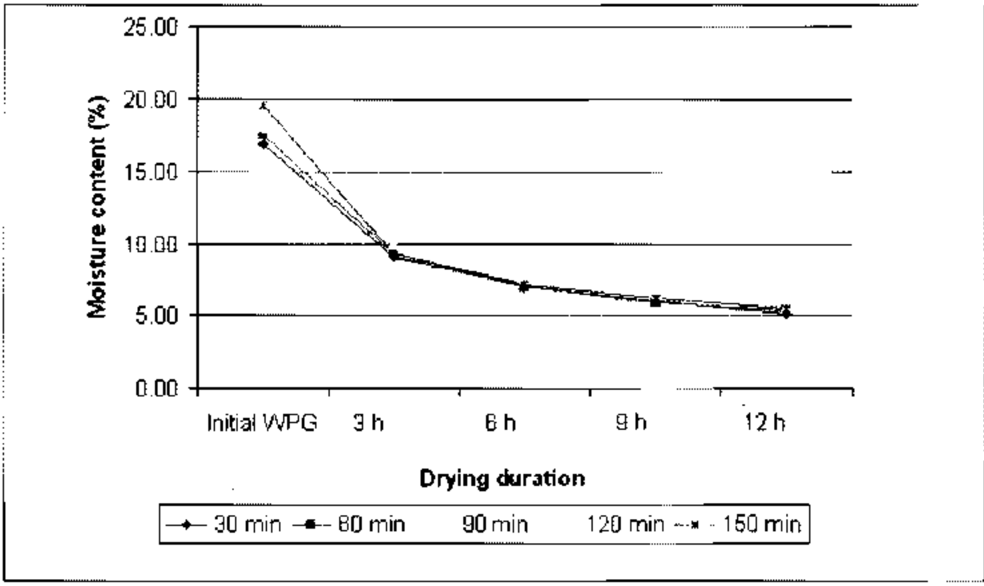

Figure 3. Moisture content of impregnated bamboo strips at basal portion.

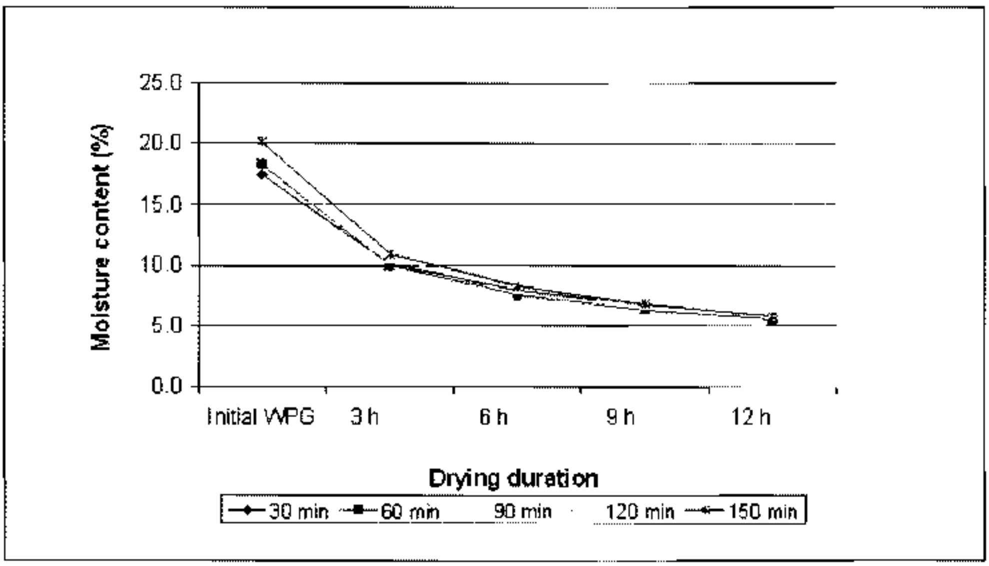

Figure 4. Moisture content of impregnated bamboo strips at middle portion.

On the other hand, the WPG value of treated strips taken from the middle portion was higher than that from the basal which may be attributed to the influence of vascular bundle distribution and parenchyma ratio present. According to Hamdan (2004), the distribution of vascular bundles was higher at middle compared to basal portion. Espiloy (1987) and Abd. Latif (1995) also noticed that the middle portion of bamboo culm has small vascular bundles with denser arrangement. Similar results were reported also by Liese (1998), in his studies on *Phyllostachys makinoi*, where he found that the number of vascular bundles per unit area increased with the increasing height.

The trend in MC of WPG during drying of impregnated strips is shown in Figures 3 and 4. The results show that there was a sharp decrease in MC from the observed initial WPG up to 3 h and gradually decreased thereafter. The trends were similar for both basal and middle portions of bamboo culms after impregnation. The MC reduced from an average of 20 per cent to 5 per cent. However, the optimum duration of drying was not more than 9 h before the samples began to warp. This observation is in good agreement with Mayer (1983) where it has been suggested that the optimum drying temperature of treated samples was 60°C. After 9 h of drying, the MC became constant. This could be attributed to the pre-cure and condensation of LMwPF in bamboo strips. According to Rowell (1983), once the cell wall of the treated samples is bulked fully with chemicals, no further expansion or contraction occurs in response to moisture.

CONCLUSION

The findings from this study revealed that the WPG of bamboo strip impregnated with LMwPF resin varies with the height of the culms. The WPG of bamboo also increased as the soaking time increased. The middle portion of the bamboo culms absorbed more resin than the basal. The MC of the treated bamboo decreased drastically when it was dried for 3 h at 60°C, and it gradually decreased when it was dried to 12 h. However, drying beyond 9 h, the treated samples started to warp.

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