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DENSIFICATION AND STABILIZATION OF OIL PALM STEM BY TREATMENT WITH TWO POLYMERS

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WAN ASMA IBRAHIM. 1989. Densification and stabilization of oil palm stem by treatment with two polymers. Effects of treating oil palm wood blocks with two polymers, polymethyl methacrylate (PMMA) and polyglycidyl methacrylate (PGMA) were studied. With both polymers higher loadings were observed for lower density samples. PMMA treated samples showed better dimensional stability. Location of polymers in the wood structure was studied with SEM. It showed partial and fully filled vessels and parenchyma tissues.

Key words: Densification - dimensional stabilization - oil palm stem -polymethyl methacrylate - polyglycidyl methacrylate

Introduction

With replanting oil palm plantations in Malaysia, more than 1 million m^3 of oil palm stems will be available annually after 1990 (Mohd. Hussin *et al.* 1986). At present, there is no economic use of this material for structural purposes due to its poor mechanical properties. The high moisture content in its green condition causes distortions during drying (S. Salem unpublished).

However, polymers can be injected into the wood structure to improve its dimensional stability and mechanical properties. Various vinyl type polymers gave dimensional stability and improved decay resistance of wood (Choong & Barnes 1969). Chemicals such as anhydrides, epoxides, formaldehyde, diisocyanates and esters were bonded to wood structure by reacting with the hydoxyl groups available. This also improved the wood's dimensional stability and resistance to biological attack (Rowell 1983). Wood polymer composites are also clean and aesthetically appealing with high compression strength, hardness and abrasion resistance (Meyer 1982).

This paper investigates the feasibility of treating oil palm stem material with monomers and subsequently polymerizing it *in situ*, and the impact of the treatment on initial density and dimensional stability of the treated material.

Materials and methods

Oil palm stem

A 35-*y*-old oil palm stem cut 1.5 *m* above the base was taken from a plantation in Batang Berjuntai, Selangor, Malaysia. The bark was discarded and the outer part of the stem (0 - 20 *cm* from periphery) was separated from the inner part (20 - 40 *cm* from periphery). Samples of dimensions 2 x 2 x 6 *cm* were prepared and dried in an oven with the temperature being increased slowly at 10°*C* intervals every four days until the moisture content was below 10% to avoid serious distortions to the samples. The core was not taken due to severe distortions during drying.

Chemicals

The two monomers used were methyl methacrylate (MMA) with 0.6% azobisisobutyronitrile (AIBN) initiator and glycidyl methacrylate (GMA) with 0.8% benzoyl peroxide (Bz_2O_2) initiator. The monomers were obtained from a commercial supplier and used without further purification. The solvent used to prepare the various concentrations of monomers was dimethyl ketone (DMK).

Method

The oil palm wood blocks were evacuated at 3 - 6 *mm* Hg for 1 *h* at ambient temperature, after which the monomer was introduced and the blocks were left to soak for 1 *h*. After soaking, the monomer was drained and the blocks were wrapped up individually in aluminium foil. They were allowed to cure in the oven at 65°*C* for 24 *h*. The cured samples were then unwrapped and left for another 12 *h* in the oven in order to drive away uncured monomer. The weight and density of the blocks were recorded before and after treatment.

Testing

Determination of polymer loading (% PL) was by weight difference. Antishrink efficiency (% ASE) was carried out by soaking the samples in distilled water for 24 *h* and the measuring the swelling. Values were calculated according to the following formulae (Stamm 1964):

$$\%\,\mathrm{PL} = \frac{\mathrm{Wt} - \mathrm{Wo}}{\mathrm{Wo}} \times 100 \qquad (1)$$

and,

$$\%\,\mathrm{ASE} = \frac{\mathrm{St} - \mathrm{Sc}}{\mathrm{Sc}} \times 100 \qquad (2)$$

where **Wo** is the oven dried weight of sample before treatment, **Wt** is the oven dried weight of treated sample, **Sc** is the volumetric swelling of untreated sample and **St** is the volumetric swelling of treated sample.

Results and discussion

Impregnation parameters

The impregnation parameters such as evacuation strength and duration, and soaking time used in this experiment were chosen following a preliminary study that gave an optimum polymer loading (Table 1). Soaking time of 1 *h* was chosen since the value of polymer loading was not very significant between 1 and 2 *h*.

Table 1. Preliminary results obtained from treatment of oil palm stem (inner part) using methyl methacrylate with different combinations of impregnation parameters

Evacuation strength (*mm* Hg)	Evacuation duration (*h*)	Soaking time (*h*)	Average polymer loading (%)
30	1	1	12.39
50	1	1	5.70
100	1	1	8.79
3 - 6	0.5	1	30.34
3 - 6	1	0.5	34.99
3 - 6	1	1	46.01
3 - 6	1	2	47.16
3 - 6	2	2	44.02

Density

The inner part of the oil palm stem has a lower density than the outer part (Killmann & Lim 1985). This variation in density of the samples affected the uptake of the monomer. Higher polymer loading levels were shown in lower density samples giving a higher increase in the density (Table 2). Linear regressions were obtained for initial density versus polymer loading for both treatments. A higher R^2 value was obtained for polymethyl methacrylate (Figures 1 & 2).

Polyglycidyl methacrylate (PGMA) gave higher polymer loading than polymethyl methacrylate (PMMA) by 25.7 and 193.6% for inner and outer part of the material respectively (Table 2). This can be explained by the difference in their vapour pressures where a higher vapour pressure of MMA allows higher monomer loss from impregnated samples during curing. That the lower density material was able to absorb more monomer giving higher polymer loading levels, can be explained by the presence of more parenchymatous tissues than vascular bundles. These tissues act like a sponge for the absorption of monomers. In oil palm, the number of vascular bundles increases outwards from the centre of the stem (Killmann & Lim 1985, Lim & Khoo 1988).

Table 2. Average values of density increase, polymer loading (%) and antishrink efficiency (%) in different regions of oil palm stem material treated with polymethyl methacrylate and plyglycidyl methacrylate

Polymer type	Oil palm stem material region	Average density increase ($g\,cm^{3}$)	Average polymer loading (%)	Average antishrink efficiency (%)
PMMA	Outer	0.230	26.7	42.1
	Inner	0.284	83.1	50.5
PGMA	Outer	0.282	78.3	32.6
	Inner	0.375	104.4	38.2

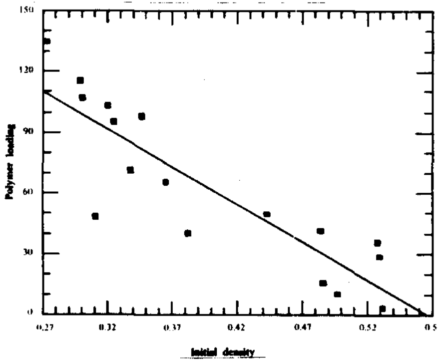

Figure 1. Regression of MMA polymer loading (%) versus initial density ($g\,cm^{3}$) (Regression line: Y = 210.6 - 372.1X, R^2 value= 76.24%)

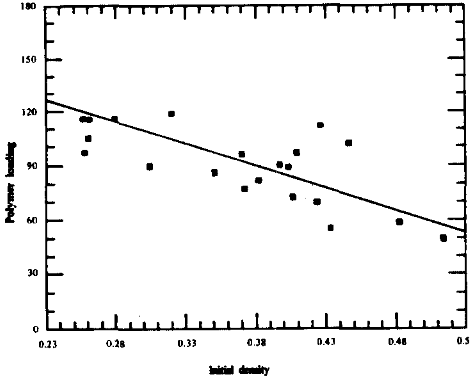

Figure 2. Regression of GMA polymer loading (%) versus initial density ($g\,cm^{3}$) (Regression line: Y = 182.6 - 244.6X; R^2 value = 55.04%)

Three concentrations of monomers of 100, 50 and 10% were used. Results discussed are based on the 100% concentration treatment since lower concentrations gave less pronounced results where the weight change after curing was insignificant.

Stabilization

Higher antishrink efficiency (ASE) of treated samples reflects improvement in stability. Average ASE values of 46.3 and 35.4% were recorded for PMMA and PGMA treated material respectively (Table 2). There is no significant difference in the ASE values between the higher polymer loading levels of the inner samples and the lower polymer loading levels of the outer samples which shows that the extent of stabilization is characteristic of the polymer used. PMMA stabilizes the wood material by bulking the vessels and the cell wall with no chemical reaction taking place. It serves as a moisture barrier and reduces further swelling of the wood (Stevens & Schalck 1978). In the case of GMA, the epoxy group present in the molecule is expected to react with the hydroxyl group of the cellulose to bring about crosslinking reaction between the monomer and substrate. However, in doing this, it produces more hydroxyl groups making the substrate more hydrophilic. The polymer then undergoes hydrolysis (Figure 3). This may be the cause of the lower stabilizing effect of PGMA treated material. PMMA shrank during polymerization by about 21% of the monomer volume, which means that 21% of the volume accessible to monomer in the cells or vessels will not contain polymer (Noah & Foudjet *et al.* 1988). We would then expect partial filling of some of the vessels with polymers (Figure 4). Also, the stability of the samples will decrease as the samples react to changes in temperature and humidity.

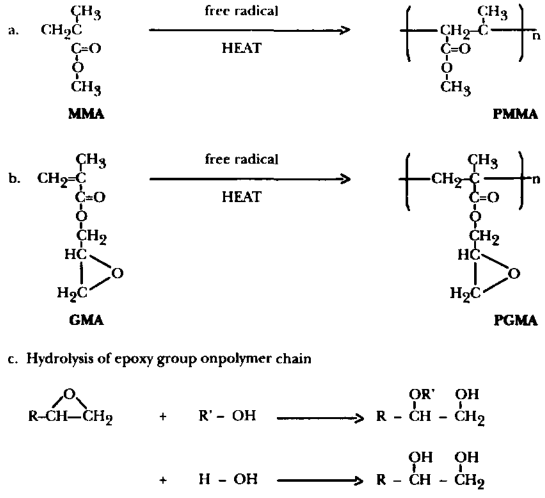

Figure 3. Polymerization reactions

Figure 4. A close-up view of a vascular bundle with an empty and filled vessels side by side (Magnification: 242 ×)

Figure 5. Cross section of PGMA treated oil palm stem material showing scattered vascular bundles embedded in ground parenchyma tissues with fully and partially filled vessels (Magnification: 24.2 ×)

Distribution of polymers

The location of polymers in the samples was investigated using a scanning electron microscope. The distribution along the axis of the treated samples was homogenous since the sample was small. Some vessels were totally filled whereas some were partially filled. This was also true with the parenchymatous cells (Figures 4 & 5).

The difference in polymer loading levels was also seen in the SEM photographs where for higher polymer loading level a higher percentage of vessels and parenchymatous tissues were filled with polymers.

Conclusions

Oil palm stem material treated with monomers and thermally polymerized gave different values of polymer loading levels. Lower density material showed higher values resulting in a greater increase in density. However, regardless of the polymer loading levels and final density, the improvement in dimensional stability of the material was not prominent. Polymethyl methacrylate (PMMA) was able to stabilize the oil palm material better than polyglycidyl methacrylate (PGMA).

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