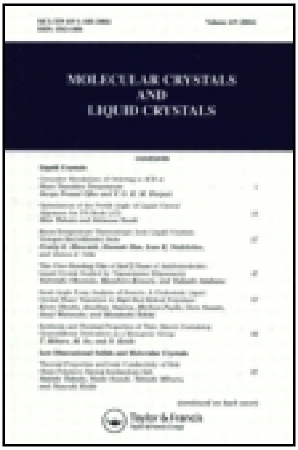

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Effect of Urea Concentration and Vacuum Treatment on Physical and Mechanical Properties of Methyl Metacrylate Bamboo

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Betung bamboo (Dendrocalamus asper) samples were obtained from Bogor area, Indonesia. The samples were air dried, and then immersed into methyl metacrylate-urea solution for 24 hours prior to irradiation. Urea was added into methyl metacrylate (MMA) with concentration of 1%, 3%, and 5%, and without urea as control. The samples were vacuumed at 35 mmHg for five minutes prior to immersion, and without vacuum were done as well as control. The samples were wrapped up with aluminum foil and then with polyvinyl sheet, and irradiated with ^{60}Co gamma ray with 40 kGy. After opening the wraps, the samples were dried in the oven at 70°C for 24 hours. For comparison, the samples of control or original bamboo were also prepared. The all samples were tested for physical and mechanical properties. Factorial randomized complete design 2×4 was used for analytical purpose the factors were vacuum treatment and urea concentration. The results showed that polymer loading of MMA-bamboo reached 10.7–12.8%, and the physical and mechanical properties were better than the origin. Vacuum treatment enhanced hardness only, and urea enhanced polymer loading and physical properties but reduced mechanical properties, and the addition of urea at 1% could be satisfied.

Keywords: bamboo; gamma radiation; MMA; urea; vacuum

INTRODUCTION

Indonesian betung bamboo (*Dendrocalamus asper*) has been planted by the people for building material, housing equipments, handicraft and other purposes. This bamboo has the advantages comparing to the other bamboos, the bamboo length can be 20 m with 20 cm in

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diameter at breast height, and the length between nodes is 40–60 cm and wall thickness of 1–1.5 cm [1]. Janssen [2] cited that the physical and mechanical properties of bamboo can be distinguished into three parts namely bottom, middle and top parts. Modulus of rupture and moisture content on the bottom part is high, in the middle part is lower but in the top part is higher again, and the length between nodes in bottom part is short, in middle parts is longer but in the top part shortens again.

Wood plastic composite has been investigating by some researchers, Hadjib *et al.* [3] made wood plastic from rubber-wood and methyl metacrylate (MMA), and irradiated with ^{60}Co gamma ray at 20 kGy dose. The wood had 195 kg/m^3 polymer loading, lower moisture content, higher density, and better for dimensional stability, MOE, MOR, compression and shear strengths. Radiation dose affects polymer loading as Bakraji *et al.* [4] mentioned that five low grade Syrian woods were impregnated with butyleneacrylate, acryl amide, and styrene using ^{60}Co gamma radiation at various doses 10, 20, and 30 kGy, and the results showed that wood plastic composite had better mechanical properties, and polymer loading was higher for higher radiation dose, and lower for higher wood density. For radiation dose application Ajji [5] mentioned that a good quality of polymer/pinewood composites can be achieved by impregnation of the wood with high monomer/polymer concentration, and the exposure of the samples to gamma doses; in some cases only 35 kGy is quite enough.

Additive such as urea can be used to enhance polymer loading, Garnett and Loo-Teck [6] mentioned that additive such as urea has been found to enhance yield under certain experimental condition for grafting of monomer such as MMA, and it is enhancing polymer loading. The other effort is vacuum to enhance polymer loading even it does not give satisfactorily result, Husain *et al.* [7] did research on impregnation of monomer MMA to Bangladesh fuel wood treated with vacuum (50 mm Hg) at 70°C for over 24 hours to remove water and methyl alcohol was used as swelling solvent and ^{60}Co gamma ray at 30 kGy was applied. The results showed that vacuum did not enhance properties, but methyl alcohol enhanced polymer loading, grafting, and mechanical properties. High polymer loading is expected to get better properties, Yildiz *et al.* [8] stated that full-loading, half-loading, and quarter-loading of monomer increased mechanical strength of maritime pine wood, and a higher polymer loading increased the strength. Furthermore, mixture of styrene and MMA resulted the best results comparing to styrene and MMA treated pine woods in strength and price as well.

As comparison to the other polymer, Lawniczak and Kozlowski [9] made composite bamboo-polystyrene with weight percent gain up to 20%, and the composites had 60% better static bending strength, and about 300% higher when tested in wet condition after soaking in water. Hardness is higher on the outside culm surface (wall) about 300% higher than natural bamboo from which composite was made. Moisture deformation of bamboo-polystyrene composite is twice lower from deformation of natural bamboo from which composite. In the same the water adsorption is thrice lower.

Referring to previous researches, bamboo plastic has better physical and mechanical properties, and methyl metacrylate bamboo is predicted having better properties too. The purpose of this research was to study methyl metacrylate betung bamboo properties and radiation was chosen for polymerization process. The ^{60}Co gamma ray radiation with 40 kGy was applied, and urea was added into MMA with concentration of 0%, 1%, 3%, and 5%. Some of physical and mechanical properties were measured.

METHODS

Polystyrene Bamboo Preparation

Betung bamboo (*Dendrocalamus asper)* was taken from Bogor area, 60 km from Jakarta, Indonesia. The samples were cut to certain sizes according to testing sizes, physical and mechanical tests. The air dried samples were dried in the oven at 70°C for 24 hours, and then vacuumed at 35 mm Hg for 5 minutes, and immersed in methyl metacrylate and urea solution for 24 hours subsequently. For treatment purpose, some of samples were not vacuumed, and the concentration of urea solution had four levels, namely 0, 1, 3, and 5 percents.

The bamboo were wrapped with aluminium foil and in the outer part with polyethylene plastic sheet, and then irradiated with ^{60}Co gamma ray with dose of 40 kGy. After radiation process, the samples were put in the oven at 70°C for 24 hours, and then conditioned for two weeks. For comparison purpose, the original bamboo or untreated bamboo samples as control were also prepared.

The replication for each treatment was six samples, so the amount of samples tested was $2 \times 4 \times 6$ (vacuum treatment, urea doses, and replication) = 48 samples, excluding the original bamboo samples. Factorial 2 by 4 in completely randomized design was used for analysis of variance purpose, and t-test was used for comparing poly-MMA bamboo properties to the original.

Testing Methods

The physical and mechanical properties tested were moisture content, water adsorption, density, swelling, shrinkage, modulus of elasticity, modulus of rupture, compression parallel to grain and tensile strength, and hardness.

RESULTS AND DISCUSSIONS

Physical and mechanical properties of poly-MMA and untreated bamboos are shown at Table 1. Polymer loading reached 10.7–12.8%, and this value is lower comparing to Hadjib *et al.* [3] which impregnated MMA to rubber wood, because the density of betung bamboo is higher than the rubber wood, as Bakraji *et al.* [4] mentioned that higher wood density reached lower polymer loading. To get more polymer loading, longer time of vacuum and followed by pressure could be suggested, so the monomer could enter wood more. Vacuum did not affect polymer

TABLE 1 Properties of Polymethyl Metacrylate Bamboo

		Urea doses				Bamboo	
Properties	Treatment	0%	1%	3%	5%	MMA	Origin
Polymer loading (%)	No-Vacuum	10.67	12.84	12.67	12.42	12.02	–
	Vacuum	10.83	12.47	12.49	11.75		
Density (g/cm^3)	No-Vacuum	0.79	0.76	0.76	0.77	0.77	0.71
	Vacuum	0.79	0.80	0.73	0.77		
Moisture content (%)	No-Vacuum	8.93	8.63	8.35	8.49	8.75	11.84
	Vacuum	8.80	9.02	8.96	8.84		
Water adsorption (%)	No-Vacuum	29.57	20.76	24.74	23.76	24.62	25.15
	Vacuum	31.36	21.26	20.96	24.54		
Swelling (%)	No-Vacuum	5.75	3.66	2.04	2.14	3.41	11.98
	Vacuum	6.64	1.79	2.66	2.57		
Shrinkage (%)	No-Vacuum	5.52	5.30	5.02	5.09	5.33	10.19
	Vacuum	6.32	4.83	5.74	4.80		
MOE (1,000 kg/cm^2)	No-Vacuum	116	117	118	117	115	108
	Vacuum	120	113	106	113		
MOR (kg/cm^2)	No-Vacuum	1117	889	915	900	943	811
	Vacuum	1032	971	798	971		
Compression (kg/cm^2)	No-Vacuum	735	656	678	659	695	633
	Vacuum	763	630	758	678		
Tensile (kg/cm^2)	No-Vacuum	1491	1407	1320	1455	1434	1263
	Vacuum	1548	1468	1441	1339		
Hardness (kg/cm^2)	No-Vacuum	793	539	635	616	670	551
	Vacuum	800	691	578	706		

loading, but urea did, whereas the addition of urea enhanced 15.7% polymer loading.

Physical and mechanical properties of poly-MMA bamboo are better than untreated bamboo, as indicated by higher density and lower moisture content, water adsorption, swelling, and shrinkage, and also higher MOE, MOR, compression, tensile, and hardness. The density of poly-MMA bamboo increased 8.6% comparing to untreated bamboo, and resulted decreasing 26% moisture content, 2.1% water adsorption, 72% swelling, 48% shrinkage, and increasing 6.3% MOE, 17% MOR, 9.8% compression, 14% tensile, and 22% hardness.

Vacuum treatment did not affect polymer loading significantly, and it affected hardness only, but the other properties were not affected. The hardness of poly-MMA bamboo reached 694 kg/cm^2 and untreated was 646 kg/cm^2, so the vacuum treatment increased 7.4% of hardness.

Urea as additive and swelling agent enhanced polymer loading 15.7% comparing to untreated bamboo, and resulted better physical properties as indicated by lower water adsorption 25.6%, swelling 60% and shrinkage 13.3%, but it reduced mechanical properties such as MOR 15.7%, compression 9.7%, tensile 7.5% and hardness 21.2%. The addition of urea was enhancing polymer loading, this result the same Garnett and Loo-Teck [6], and among the urea concentrations were not different, and urea addition at 1% could be satisfied referring to the bamboo properties.

CONCLUSIONS

From discussion above it can be concluded as follow:

1. Polymer loading reached 10.7–12.8%
2. Physical and mechanical properties of MMA bamboo were better than the origin.
3. Vacuum treatment enhanced hardness only, but not for the other properties.
4. Urea enhanced 15.7% polymer loading and physical properties but reduced mechanical properties, and the addition at 1% could be satisfied.

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