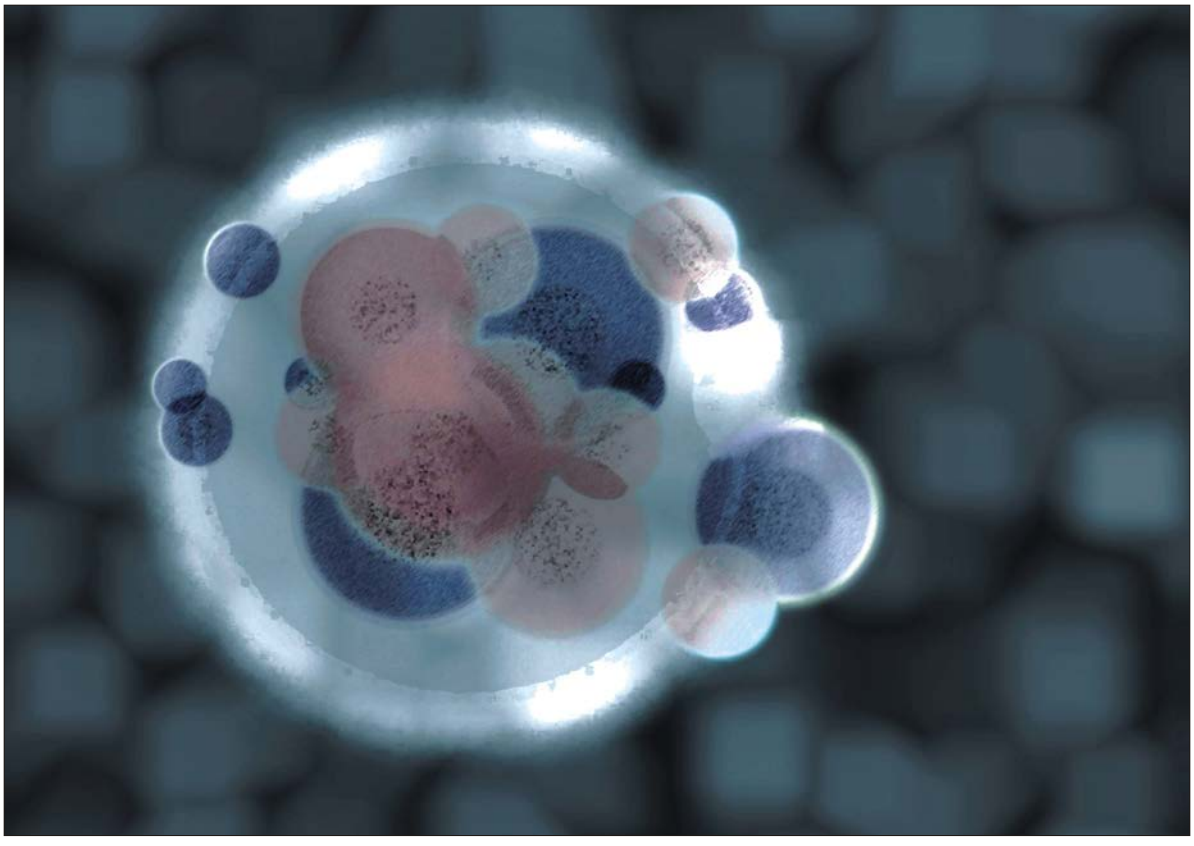

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Strength and Durability of Bamboo Treated Through an Oil-curing Process

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Abstract: Investigations on the strength and performance of an oil-cured bamboo *Gigantochloa scortechinii* in a 12 months ground contact tests show that the bamboo experienced some reduction in their strength properties and greatly enhanced the durability against biodegradation agents. The MoE value in bending strength were reduced by 13 to 42% in green and 3 to 29% in air-dried condition. In the MoR modulus in the bending strength, the value were reduced by 10 to 35% in green and 2 to 31% in air-dried condition. The compression strength were reduced by 18 to 33% in green and 14 to 27% in air-dried condition. The shear strength were reduced in the ranged between 16 to 58% in green and 14 to 54% in air-dried samples. An overall decreased in weight loss also occurred of oil-cured samples after 12 months of ground contact tests. Green condition sample recorded a decreased in weight loss between 4 to 33% and 4 to 33% in air-dried samples. Control samples that are composed of untreated bamboo and rubberwood experienced weight loss of about 48 and 40%, respectively. An oil-cured bamboo performed much better compared to those of untreated in the ground contact tests. The weight loss in term of percentage after 12 months tests varies from 4 to 34% with samples oil-cured at higher temperature and longer duration losing less weight.

Key words: *Gigantochloa scortechinii*, oil-curing process, biodegradation, weight loss, durability

INTRODUCTION

Bamboo being a cheap, fast growing plants and possess high mechanical properties among woody materials is being considered as an alternative to wood. However, bamboo is easily susceptible to fungal or insect attack[1]. The properties of bamboo will deteriote rapidly if the material is not treated with preservatives[1,2]. The used of preservative in bamboo has been recognized as necessary and important if they are to be considered for utilization in furniture and construction purposes[2]. However, the used of preservatives is not always effective as bamboo is not easily treated[3].

An alternative technique of treating bamboo by means of oil-curing process has been studied by several researchers in Europe, Africa and Asia. Their initial finding indicates that this technique is effective in enhancing the bamboo durability against insects and fungi biodegradation. However, the effectiveness of this technique depends largely on the type of oil that is to be use as the heating medium. Oil with high boiling point is normally preferred.

An investigation in the oil-curing process using palm oil as the heating media has been conducted by Razak *et al.*[4]. The study shows positive results as the oil-cured bamboo possess good resistance against insects and fungi attacks. This is supported by an earlier studies conducted by Leithoff and Peek[5] on the heat treated temperate bamboo using linseed oil.

This study explored an alternative eco-friendly method in protecting bamboo from biodegradation by means of heating process. A common and well known bamboo species, *Gigantochloa scortechinii* were selected for the study and subjected to high temperature condition using palm oil as a heating media. The temperature applied were 140, 180 and 220°C with exposuring duration of 30, 60 and 90 min, respectively depending on types of testing. The treated bamboos were tested for their performance based on residual strength and durability properties.

MATERIALS AND METHODS

Bamboo samples: *G. scortechinii* has been identified as one of the most important and extensively used species in the bamboo industry and is the most widely distributed in Peninsular Malaysia. *G. scortechinii* grows in closely and densely tufted clumps. The culms are stiffly erect with branches growing from the mid-culm node upwards. Branching consists of small and subequal branches. The

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culm is 15-20 m tall and 8-12 cm in diameter. The internode is 40-50 cm long with wall thickness of 4-12 mm[6].

All bamboo culms used in this study were taken from the Forest Research Area in Nami, Kedah in Malaysia. There are about 500 ha of natural bamboo stands in Nami and about 20 ha has been developed by FRIM, Forest Department Malaysia and the International Development Research Centre, Canada (IDRC) under the "Management of Natural Bamboo Stands Project" since 1988. Almost all of the bamboos found in this area are of *G. scortechinii.*

Bamboo culms of known age were taken from randomly selected clumps. All culms used in this study possess diameters ranging from 8 to 10 cm. They were harvested immediately after the rainy season. Investigations indicated that bamboo harvested during this period contained a very minimum amount of starch[1,7]. All together about 100 bamboo culms consisting of four-year old were harvested. For practical purposes only internodes 6, 7 and 8 were used for the study.

Within a week after harvesting, all the culms samples were taken to FRIM for drying, oil-curing treatment and for subsequent investigations. Two sets of samples were investigated. The first set consists bamboo samples in green condition with average moisture content of 65% and the second set consists samples in air-dried condition with moisture content average 14%.

Oil-curing process: The oil-curing process of the bamboo were done using an electrical oil-curing machine. Palm oil was used as the heating medium as it is organic in nature, easily available and has high boiling point. The palm oil was first heated up to a temperature of 60°C. Then the bamboo samples were submerged in the heated oil by placing them in a metallic cage. Bamboo samples were taken out at 140, 180 and 220°C interval after 30, 60 and 90 min of exposure. A control panel was used in controlling the temperature and the duration of the process. A procedure developed by Wahab *et al.*[8] was adopted in this study with modification to suit for bamboo.

Strength: Eighty *G. scortechinii* culms samples consisting of green and kiln-dried bamboo and 5 replicate were used in the study. Strength tests of shear, compression parallel to grain and static bending were conducted using the Shimadzu Computer Controlled Universal Testing Machine on split bamboo. These tests were conducted in the Structural and Mechanical Laboratory in Forest Research Institute Malaysia (FRIM). The preparation of the test blocks and methods were made according to the ASTM D 143-52[9] with modification. There is no universal standard method of tests for evaluating the mechanical properties of bamboo. All testing blocks were conditioned to 12% moisture content prior to testing. This was done by placing the test blocks in a conditioning chamber and controlling the relative humidity, temperature and air-circulation for 2 weeks until the required equilibrium moisture contents were obtained. The blocks were tested in the split form and the sizes used were; (1) Shear strength parallel to the grain: 40x20 mm x bamboo culm wall thickness; (2) Compression strength parallel to the grain: 60x20 mm x bamboo culm wall thickness; and (3) Static bending: 300 mm x bamboo culm wall thickness.

Durability: The bamboo samples for this test were taken from the treated bamboo described earlier. These blocks were converted into 100 mm x 10 mm x culm wall thickness and were chosen from internode 6 of each culms. This test was conducted based on ASTM: D 1758-74 (1974) and procedure developed by Jackson[10] with some modification to suit for bamboo testing.

The test stakes were buried upright with 4/5 of their length in the ground. They were installed 200 mm apart within and between rows and were distributed randomly based on Randomized Complete Block Design. The test stakes were exposed to the decay hazard as well as termites. The tests were monitored for a period of 12 months. The stakes were installed during the dry season. The testing site for the field/grave-yard study was located in Melaka, Malaysia. The site is located in a lowland area. The site is an ex-agriculture land having hot and humid climate throughout the year with an average daily temperature vary from 21 to 32°C and average rainfall of about 2540 mm.

The stakes were inspected at the end of the 12 months period. The criteria for testing were based on the weight lost experienced by the stakes. The stakes were conditioned to 12% MC before and after the ground contact tests.

RESULTS AND DISCUSSION

Strength: The results on the strength properties tests of bamboo samples before and after treatments are tabulated in Fig. 1 to 8. Figure 1 and 3 shows the MOE of the bending strength on oil-cured green bamboo at 140, 180 and 220°C at 30, 60 and 60 min duration of treatments. Figure 2 and 4 shows the MOR of the bending strength. The maximum compression strength of the green and air-dried samples are shown in Fig. 5 and 6. The shear strength between the two condition of the bamboo are shown in Fig. 7 and 8. Comparisons were made between the green and air-dried bamboo samples.

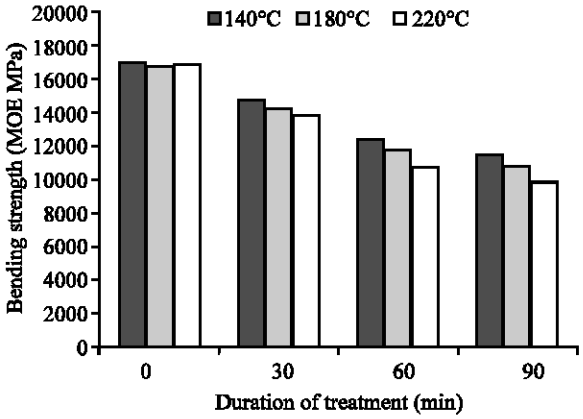

Fig. 1: MOE (MPa) in bending strength on oil-cured green bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

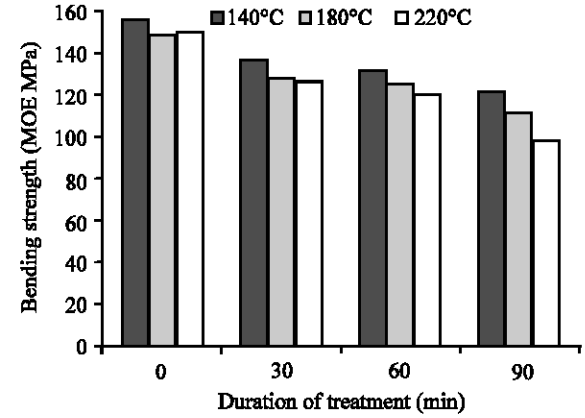

Fig. 2: MOR (MPa) in bending strength on oil-cured green bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

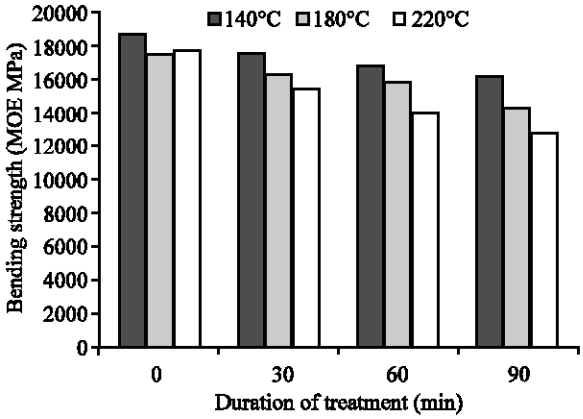

Fig. 3: MOE (MPa) in bending strength on oil-cured air-dried bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

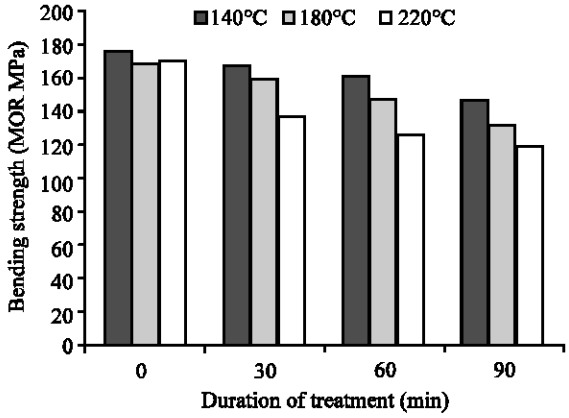

Fig. 4: MOR (MPa) in bending strength on oil-cured air-dried bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

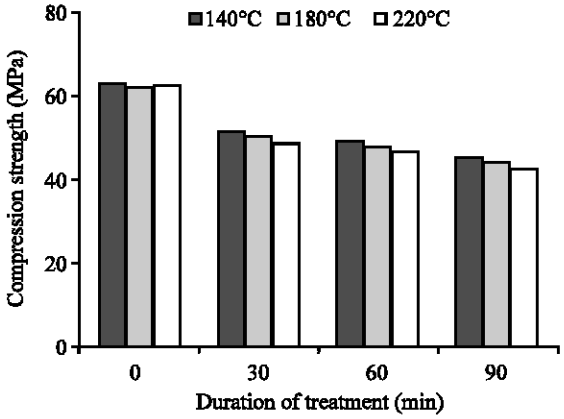

Fig. 5: Maximum compression strength on oil-cured green bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

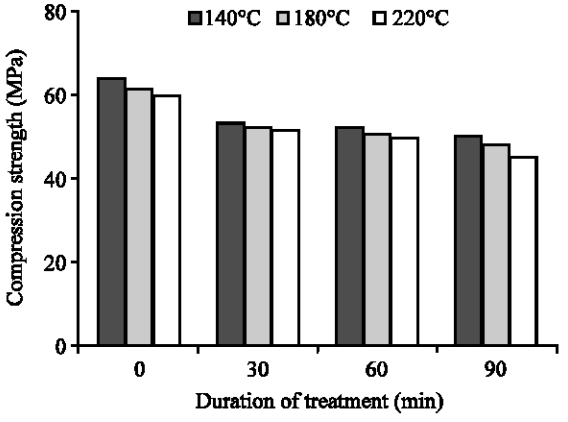

Fig. 6: Maximum compression strength on oil-cured air-dried bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

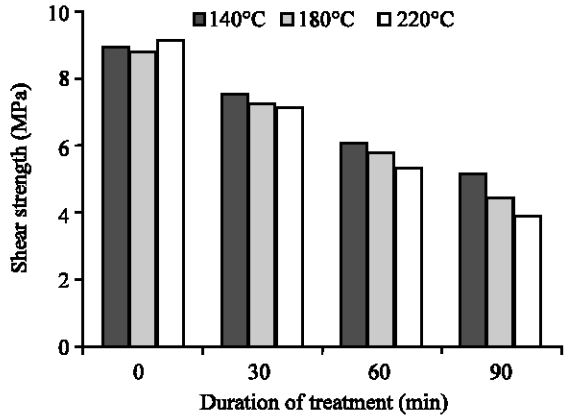

Fig. 7: Shear strength on oil-cured green bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

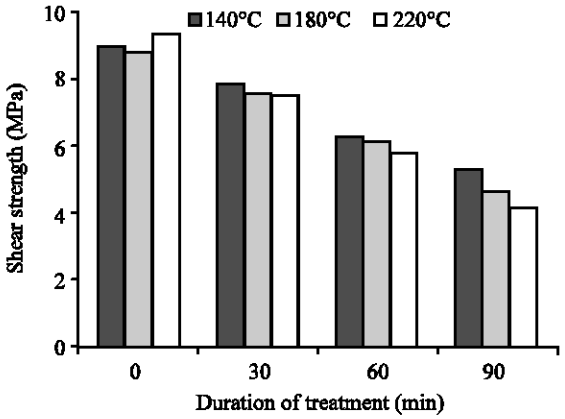

Fig. 8: Shear strength on oil-cured air-dried bamboo at 140, 180 and 220°C at 30, 60 and 90 min duration of treatments

Reduction in the strength properties of the oil-cured bamboo occurred in the ranged of 2 to 58%. These reduction are however dependent on the condition of the bamboo used, amount of heat and duration applied to them. These reduction in strength are still acceptable as they are within the range of strength reduction of those bamboo or other woody materials that were chemically treated with preservatives.

The results of the study conducted on the treated bamboo samples shows that the strength within them were reduced from their original value. The amount of the strength reduced are dependent on the amount of heat and duration of the treatment applied. Generally, the higher the temperature and duration applied the higher will be the strength reduced from the bamboo.

There are significant differences in bending, compression and shear strengths between green and air-dried bamboo, the oil-curing process duration and the various temperatures applied (Table 1).

Table 1: Summary of analysis of variance on physical and mechanical properties of oil-cured bamboo at different condition, treatment duration and temperature applied

	F-value and statistical significance		
Source of variation	Bamboo condition	Treatment duration	Temperature
Modulus of rupture	78.20**	28.54**	37.47**
Modulus of elasticity	287.03**	72.91**	40.30**
Compression	14.71**	20.57**	4.38**
Shear	7.08*	181.64**	14.66**
Durability	0.83 ns	47.00**	480.79**

ns is not significant, *significant at $p<0.05$, **highly significant at $p<0.01$, Bamboo condition is referred to bamboo at green or air-dried condition, Treatment duration is referred to exposure period of 30, 60 or 90 min, Temperature is referred to temperature at 140, 180 or 220°C

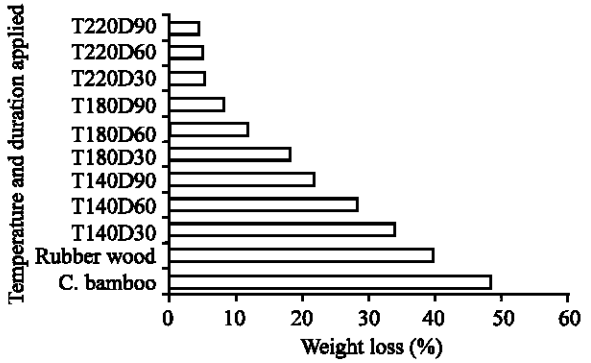

Fig. 9: Means weight loss of oil-cured green bamboo after 12 months of grave-yard tests

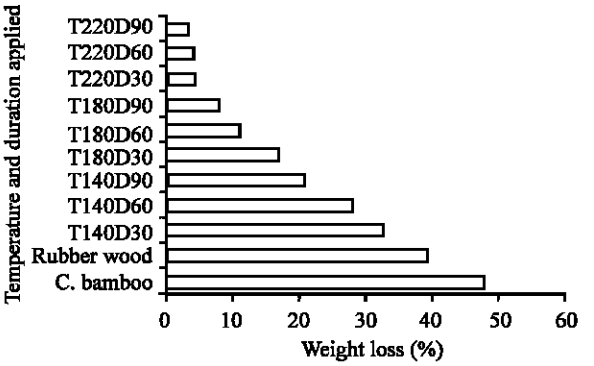

Fig. 10: Means weight loss of oil-cured air-dried bamboo after 12 months of grave-yard tests

Durability: The results of the grave-yard test conducted on oil-cured green and air-dried bamboo samples placed in ground contact for 12 months period are tabulated in Fig. 9 and 10. Bamboos are considered to have a very low natural durability. When placed in contact with soil, in

particular young bamboo culms or that has been insufficiently treated with preservatives, they will deteriorate rapidly by the action of a mixed population of soil microorganisms and termites. Even those regarded as adequately treated with preservative may still be colonized by fungi and termites although decay and the attack rates may be slower and patterns of fungal colonization of such bamboo may differ from untreated or less adequately treated bamboo.

There is an overall decreased in weight loss of oil-cured samples before and after 12 months tests. Green condition sample recorded a decreased in weight loss between 4 to 33% and in air-dried samples. Oil-cured bamboo performed much better compared to those of untreated in the ground contact tests. The weight loss in term of percentage after 12 months tests varies from 4 to 34% with samples oil-cured at higher temperature and longer duration losing less weight.

Control samples that are composed of untreated bamboo and rubberwood experienced weight loss of about 48 and 40%, respectively for the 12 months ground contact durability tests. The weight loss in bamboo are reduced once they are treated by the oil-curing process.

There is no significant differences in the condition of bamboo used in the study. Significant differences were observed in the treatment duration and at different temperature applied to the oil-cured bamboo (Table 1).

Bamboo that were oil-cured at 180°C and exposed for a duration of 60 min experienced an average weight loss of less than 12%. This temperature can be taken as an optimum temperature for effective treatment of bamboo through the oil-curing process using palm oil as the heating medium. Bamboo oil-cured at lower temperature experienced higher weight loss and are therefore not effective to withstand against fungi or insect attacked.

Bamboo oil-cured at temperature below 180°C can be consider for utilization but for an indoor usage. Further study will have to be undertaken in determination the optimum temperature and duration of treatment before these bamboo can be recommended for effective indoor usage

- The modulus of elasticity (MOE) value of oil-cured bamboo in bending strength is reduced by 13 to 42% from 16823 MPa to between 9775 to 14694 MPa in green condition and by 3 to 29% from 17886 MPa in air-dried condition to between 12764-17403 MPa. For the MOR, the value is reduced by 10 to 35% from 151 MPa to between 98-136 MPa in green condition and by 2 to 31% from 170 MPa in air-dried condition to between 118 to 167 MPa.
- The compression strength were reduced by 18 to 33% from 62.38 MPa in green condition to between 42.13 to 51.47 MPa and by 14 to 27% from 61.90 MPa in air-dried to 45.15-52.96 MPa.
- The shear strength were reduced by 16 to 58% from 9,02 Mpa in green condition to between 3.83 to 7.54 MPa and by 14 to 54% from 9. 25 MPa in air-dried condition to between 4.15 to 7.84 MPa.
- The green oil-cured bamboo experienced an average weight lost between 4 to 33% from their original weight before undergoing the 12 months period of ground-contact tests. Samples from the air-dried condition experienced an average weight lost between 4 to 33%. The untreated bamboo and rubberwood on the other hand experienced an average weight lost of 48 and 39%, respectively.
- Oil-curing process starting from 180°C and at a duration of 60 min are found to be effective in increasing the durability of bamboo. Bamboo samples that were treated from these temperature onward experienced an average weight lost of less than 12% compared to those that were treated at lower temperature and duration of treatment.
- For practical purposes, it is recommended that bamboo need to be oil-cured at temperature of 180°C and above for effective protection against fungi and insects attacked. Apart from increasing the durability of bamboo, the oil curing process can also be applicable in rapid drying and improving the colour of matured bamboo prior to utilization.

Based on the above finding it can be concluded that the oil-curing process can be used as an alternative in treating bamboo and other woody materials in prolonging their service life span to humen usage.

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