MOULD RESISTANCE OF THE BAMBOO *Thyrsostachys siamensis* TREATED WITH OLEORESIN HEAT

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SUMMARY

The bamboo *Thyrsostachys siamensis* is one of the most common species growing mainly and also largely cultivated in South Vietnam. The culms are the main raw material of many bamboo companies for industrial manufacturing of round and laminated bamboo furniture for exportation. Bamboo has low natural durability against fungi and insects. Compared with wood, bamboo is easier to damage by fungi and insects. An effective and eco-friendly method is needed to improve their physical and chemical properties, and mould resistance. In this research, mould resistance of the bamboo species *Thyrostachys siamensis* treated oleoresin heat under different temperatures (120ºC to 140ºC) and durations (60 min to 120 min) was tested in laboratory and field condition. Oleoresin used in this study is extracted from *Dipterocarpus alatus.* In the laboratory experiment, mould growth on the specimens was evaluated 1, 2, 4 and 8 weeks after they were exposed to the inoculation with a conidia mixture of six moulds isolated from infected bamboos. In the field experiment, evaluation of mould growth on the samples was done 1, 2, 4 and 8 weeks after exposure at the storage site of Bamboo factory, Binh Duong. The results showed that oleoresin heat treatment with *D. alatus* oleoresin at equal to 140ºC for at least 60 min completely inhibited mould growth on the bamboo *T. siamensis.*

Keywords: bamboo *T. siamensis,* heat treated bamboo, mould resistance, oleoresin.

1. INTRODUCTION

The bamboo *Thyrsostachys siamensis* with its Vietnamese name "Tam Vong" is one of the most common species growing mainly as a forest in Vietnam and also largely cultivated in the provinces Binh Thuan, Gia Lai, Kong Tum, Lam Dong and Tay Ninh. The culms are the main raw material of many bamboo companies in South Vietnam for industrial manufacturing of round and laminated bamboo furniture for exportation.

Bamboo has low natural durability against fungi and insects compared with wood. In general, several fungi from the groups of moulds, ascomycetes and basidiomycetes colonize the culms of bamboos. Exposed bamboo is especially affected by moulds during storage, processing, transport in containers and its final use (Liese and Tang 2015). Manufacturers need cost-effective and also environment-friendly treatment methods for bamboo material for furniture production. Heat treatment is one of the treatments to improve the natural durability and dimensional stability of bamboo. Several studies of the heat treatment of wood and bamboo have been carried out in Asia, Europe (Jones *et al.,* 2019) and America. In Europe, the heat treatment process has long been used for timber treatment and in Asia it has been used for bamboo and rattan. These methods were commercialized in response to the increased environmental awareness that drives the industry towards reducing the use of chemicals.

Natural resin extracted from dipterocarp is considered one of the most important non-timber forest products of forest-adjacent communities in Southeast Asia (Evans *et al.,* 2003, Luu and Pinto 2007, Baird 2010, Laegaard 2010). Liquid resin is extracted mostly from *Dipterocarpus* species in Laos, Thailand, Vietnam and Cambodia, with *D. alatus* being the main source (Luu and Pinto 2007). In Vietnam liquid resin is collected mostly from *D. alatus* (Luu and Pinto 2007). Resin is used domestically for lighting and sealing boats, and commercially for paints, varnishes and perfume fixatives (Dao 2004, Evans *et al.,* 2003, Orwa *et al.,* 2009). Natural oil heat treatment is another alternative way in

treating bamboo without use of preservatives. This process is considered as eco-friendly treatment. Thermal wood/bamboo treatment involves temperatures of 100 - 300ºC (Jones *et al.,* 2019). Investigations on bamboo treated with oil heat/ hydrothermal of Leithoff and Peek (2001), Kamarudin and Sugiyanto (2012), Cheng *et al.,* (2013) and Hao *et al.,* (2021) showed that the durability of bamboo treated was improved, in which the fungal resistance was greatly enhanced.

The effectiveness of the natural oil heat treatment mentioned in these researches led us to investigate mould resistance of the bamboo species *T. siamensis* treated with oleoresin heat. Mould resistance of the bamboo treated were tested in laboratory and field condition.

2. RESEARCH METHODOLOGY

2.1. Materials

Mature 3-year-old bamboo culms of *T. siamensis* were collected from a factory of Bamboo Nature Company in Binh Duong Province. From fresh bamboo culms removed skin by machine sanding, samples of 380 mm length were taken.

Oleoresin extracted from *D. alatus* obtained from the Department of Chemical Engineering and Processing, Nong Lam University of HCMC. Property of the oleoresin extracted from *D. alatus* is presented in Table 1.

Table 1. Property of oleoresin extracted from *D. alatus*

Property	Oleoresin extracted from *D. alatus*
Specific Gravity	0.92
Viscosity	2.3cps
Oxidation stability	25 g m^{-3}
Boiling Point	255 - 260ºC
Color	Yellow

2.2. Oleoresin heat treatment

The bamboo samples were treated in hot oleoresin using a fabricated oil curing apparatus. The apparatus consisted of stainless-steel cylindrical vessel with 300 mm diameter and 400 mm length heated by electric plates connected to a thermocouple and digital temperature controller.

Bamboo samples were completely submerged in the heated oleoresin. The treatment schedules were investigated with different temperature (120ºC, 130ºC and 140ºC) for various time (60 min, 90 min and 120 min) as suggested by RSM modes (Table 2). Each of the independent variables was coded by five different levels, where the treatment temperature and treatment times ranged from 116ºC to 145ºC and 48 to 133 min, respectively.

Each experiment for the oleoresin heat treatment and the reference, seven samples were used. There were total of 70 bamboo samples with 380 mm length were applied for the experiments.

The bamboo samples after treatment were dried and conditioned for further tests.

Table 2. Range and level of the variables

Range and level of actual and coded values	Temperature T (ºC) X_1	Time t (min) X_2
$+\alpha$	145	133
+1	140	120
0	130	90
–1	120	60
$-\alpha$	116	48

Untreated bamboo samples conditioned for eight weeks at 21°C and 65% relative humidity were used as controls.

2.3. Laboratory testing

From the bamboo samples treated and controls, specimens of 60 mm length were taken halfway between the internodes and split lengthwise.

Three specimens were placed in a small plastic box (12 x 12 x 6 cm) and exposed to artificial infection with a water-based mixture of conidia of six moulds *A. niger*, *A. flavus*, *A. oryzae*, *Aspergillus* sp., *Paecilomyces variotii*, and *Penicillium* sp. by using a small brush. These six moulds were isolated from infected bamboos and were identified by DNA-IIS sequencing at the Center of Wood Biology, Hamburg University. The exposure was done in an incubation room at 30°C and 75% RH. The development of mould growth on the surface of the specimens was assessed after 1, 2, 4 and 8 weeks according to the rating method based on the BSI 2005 (Table 3).

Table 3. Standard method for rating the infection on the surface

Rating		Description
0	0%	No growth
1	< 10% coverage	Slightly overgrown
2	10% - 25% coverage	Moderately overgrown
3	25% - 50% coverage	Severely overgrown
4	> 50% coverage	Very severely overgrown

2.4. Field testing

In the field test, the effective treatment schedules from the laboratory experiments were investigated. Bamboo samples of 380 mm were prepared in three replicates for each treatment. The bamboo samples were bundled and placed on supports over wet soil ground. After one day of exposure to natural infection, the samples were covered with a plastic sheet to avoid sunlight and drying. The test was carried out in a raw material storage area in the factory of the Bamboo Nature company, Binh Duong province. The field tests were carried out in three periods (I: Sep. - Oct. 2020, II: Nov. - Dec. 2020 and III: Apr. - May 2021). The development of mould growth on the surface of the samples was assessed after 8 weeks of each test period.

3. RESULTS AND DISCUSSION

3.1. Laboratory test

The results of the laboratory test for the mould resistance of the treated and untreated bamboo *T. siamensis* summarized in Table 4. The specimens treated at the runs 7, 8 and 9 did not show any infection, whereas the specimens of the runs 2 and 3 and the water-treated control led to severe or very severe mould growth.

RSM analysis demonstrate a significant effect of the treatment temperature and duration on the mould control efficiency (Fig. 1). When the temperature is higher than 130°C, the average control effect increases significantly. The treatment temperature impact remarkably on the mould resistance. The treatments with higher temperature are more effective. This confirms with previous studies of the antifungal effect of oil heat treatment by Leithoff and Peek (2001), Kamarudin and Sugiyanto (2012), and our results are also in agreement with Cheng *et al.,* (2013) and Hao *et al.,* (2021) who mentioned that bamboo treated oil heat were prevented mould. The mould resistance of bamboo is noticeably enhanced with increased heat treatment temperature and time. This is principally associate to the blocking of internal channels for nutrient exchange, and the degradation of polysaccharides and starch after oil heat treatment.

Table 4. Infection value of treated bamboo *T. siamensis* in the laboratory test

Run	Temperature T (°C) X_1	Time t (min) X_2	Exposure time			
			After 1 week	After 2 weeks	After 4 weeks	After 8 weeks
1	116	90	1	3	3	3
2	120	60	2	3	3	3
3	120	120	1	2	2	2
4	130	48	0	1	1	1
5	130	90	0	0	1	1
6	130	133	0	0	1	1
7	140	60	0	0	0	0
8	140	120	0	0	0	0
9	145	90	0	0	0	0
Control	-	-	3	4	4	4

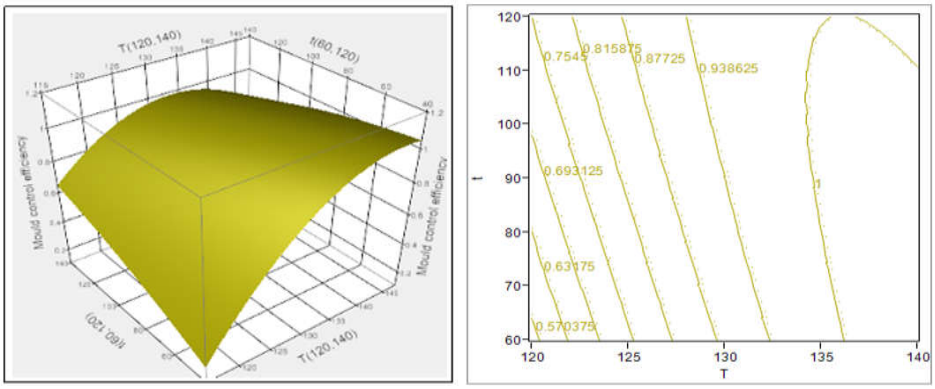

Fig. 1: The 3D-surface plot of mould control efficiency as function of temperature and time

3.2. Field test

Results of the field test are summarized in Table 5. Differences occurred in moulding between exposure periods. In treatment run 4 and control, the samples from the first period were more quickly overgrown by moulds due to the high relative humidity of about 90%. There were significant differences in anti mould efficacy of temperature treatments.

Generally, the results of this field test are similar to the laboratory experiments with smaller samples. The treatment schedules at equal to 140ºC for 60 min completely inhibited mould growth on the bamboo *T. siamensis*.

The results of the laboratory and field test prove that the bamboo treated with oleoresin heat is effective in inhibiting mould growth. This is confirmed with previous studies and also explained. Mould growth requires appropriate temperature, humidity, oxygen and nutrients. Chemical components play an important role in mould growth on bamboo, especially the sugar and starch with high content. The starch content decreases with the increase of oil heat treatment temperature and time. Furthermore, the formation of oil film on the surface of the treated bamboo, mould is also effectively prevented from entering the interior of the treated bamboo. Consequently, the mould resistance of the bamboo is improved.

Table 5. Infection value of treated bamboo *T. siamensis* in the field test

Run	Temperature T (°C) X_1	Time t (min) X_2	Test period	Exposure time			
				After 1 week	After 2 weeks	After 4 weeks	After 8 weeks
4	130	48	I	1	2	2	2
			II	0	1	1	1
			III	0	1	1	1
5	130	90	I	0	0	1	1
			II	0	0	1	1
			III	0	0	1	1
6	130	133	I	0	0	1	1
			II	0	0	1	1
			III	0	0	1	1
7	140	60	I	0	0	0	0
			II	0	0	0	0
			III	0	0	0	0
8	140	120	I	0	0	0	0
			II	0	0	0	0
			III	0	0	0	0
9	145	90	I	0	0	0	0
			II	0	0	0	0
			III	0	0	0	0
Control	-	-	I	4	4	4	4
			II	2	3	4	4
			III	3	3	4	4

4. CONCLUSIONS

The bamboo *T. siamensis* treated with oleoresin heat could completely prevent moulding. The mould resistance of bamboo is notably enhanced with increased heat treatment temperature. Treatments at the temperature of more than or equal to 140°C for at least 60 min are completely effective in inhibiting mould growth on this bamboo species.

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KHẢ NĂNG KHÁNG MỐC CỦA TRE TẦM VÔNG *Thyrsostachys siamensis* XỬ LÝ NHIỆT NHỰA DẦU TỰ NHIÊN

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TÓM TẮT

Tre Tầm vông *Thyrsostachys siamensis* là một trong những loài tre phổ biến và được trồng rộng rãi ở miền Nam. Tầm vông cũng là loại tre nguyên liệu chính sử dụng sản xuất đồ tre xuất khẩu. So với gỗ, tre có độ bền tự nhiên thấp, đặc biệt là khả năng năng kháng nấm mốc kém. Hiện nay các doanh nghiệp sản xuất sản phẩm tre xuất khẩu rất cần giải pháp xử lý bảo quản tre thân thiện môi trường. Trong nghiên cứu này, tre Tầm vông *Thyrsostachys siamensis* được xử lý bằng nhiệt nhựa dầu tự nhiên với các điểm nhiệt độ (120ºC đến 140ºC) và thời gian (60 phút đến 120 phút) khác nhau. Nhựa dầu tự nhiên sử dụng trong nghiên cứu được chiết xuất từ cây dầu rái *Dipterocarpus alatus.* Khả năng kháng mốc của tre được đánh giá dưới điều kiện phòng thí nghiệm qua và điều kiện thực tế tại khu vực nguyên liệu tre của nhà máy tre Bamboo Nature Bình Dương. Theo dõi và đánh giá diễn tiến nấm mốc phát triển trên bề mặt tre thí nghiệm được thực hiện 1, 2, 4 và 8 tuần. Kết quả cho thấy tre Tầm vông xử lý bằng nhựa dầu rái có khả năng kháng mốc tốt. Áp dụng những chế độ xử lý ở nhiệt độ bằng hoặc lớn hơn 140ºC với thời gian tối thiểu 60 phút, tre Tầm vông hoàn toàn kháng được nấm mốc.

Từ khóa: khả năng kháng mốc, nhựa dầu rái, tre Tầm vông, tre xử lý nhiệt.

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