ENHANCING THE LIFESPAN AND DURABILITY OF BAMBOO (MAI PAI) IN THAILAND

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Received: 2023-08-26
Revised: 2024-02-06
Accepted: 2024-02-29

ABSTRACT

The purpose of this study was to identify local knowledge that can be used to treat bamboo to render it more resistant to fungi, termites, and snout beetles with the ultimate goal of extending its life, particularly for construction usage. The experimental setup focuses on three species of bamboo (Bambusa bambos bamboo, rough giant bamboo, and Bambusa vulgaris bamboo), three environments (darkroom (indoor not exposed to light), indoor, and outdoor), and five traditional approaches to preserve bamboo (allowed to dry naturally, baked without soaking, baked and then soaked in water, baked and then soaked in saline, and baked and then soaked in wood vinegar). All three species of bamboo, the treatments used, and the impact of local wisdom were statistically significant at the 0.05 level. To prevent fungal infestation, all three bamboo species were baked and then soaked in water or saline before being placed in a darkroom or another indoor environment to dry. Only Bambusa bambos bamboos was found to be suitable for using outdoors. For all three species of bamboo, baking followed by soaking in wood vinegar was found to provide great results in protection against the growth of fungus. However, the applied treatments did not yield protection against termites in any bamboo. The significance level of the finding that baking extends the useful life of bamboo is 0.05.

Keywords: Bamboo Lifespan Local wisdom; Bambusa bambos bamboo; Rough giant bamboo; Bambusa vulgaris bamboo

Introduction

Originating in Thailand, bamboo exists in several varieties, evincing significant genetic variation (Phuangchik, 2013; Chewpreecha et al., 2016), and Thai people have made use of this plant in dozens of ways for hundreds of years (Maneeoud, 2018). Bamboo is used in a wide range of everyday applications (Dumklang et al., 2020; Palombini & Nogueira, 2023). In fact, bamboo can be put to such a wide range of uses that it is often referred to as a “wonder plant.” In-home life, for example, is used for furniture instead of timber. Bamboo is also used to produce fibers for high-quality fuel, a context in which it is a practical kind of alternative power. Charcoal made from bamboo is of a superior grade in comparison with charcoal, which does not include this material in its composition and has been used in the building industry. Construction and decorating are two prominent applications. It is also applicable to a wide range of residential settings. As bamboo is a hardwood, the plant's trunk is robust but lightweight, flexible, and pliable. Bamboo is currently used in every sector of the design industry. Compared with constructing a building with concrete and steel, the cost of using bamboo straw is significantly lower. Bamboo straw can be used to produce food, basketry, furniture, and for the elements that make up a house, such as windows, pillars, or even roofs.

Due to its many benefits, natural bamboo is used in furniture, construction, packaging, and bridges. These benefits include quick development, ecological compatibility, 2-5 years maturity, regeneration capacities, good mechanical properties, hardness, and copious resources. However, natural bamboo has hydrophilicity and moisture resistance issues. To improve their biological durability, therapies, and changes are needed. Physical treatment is cheaper, more environmentally friendly, and easier to use than chemical and biological treatment, which pollute the environment. At this time, the harmful impact of chemicals on the environment and their negative consequences for human health have become an issue of great concern. In addition, environmental groups from across the United States have collaborated to outlaw the use of three of the most well-known and widely used wood preservatives: chromate copper arsenate (CCA), pentachlorophenol (PCP), and pentachlorophenol. It is well known that both CCA and PCP pose a significant risk to human health. For example, the Forest Research Institute of New Zealand has used foam pressed into wood to prevent the growth of wood fungi, which is safer and less expensive than using less effective chemicals.

According to a study by the Royal Forest Department of Thailand's Research Division, wax is more effective than pesticides in preventing the growth of wood-destroying fungi and mold when used as a coating on wood. Another effective treatment for preserving bamboo is wood vinegar derived from natural sources. Wood vinegar is a liquid generated from the gas and combustion of fresh wood burning in airless conditions. When the gas is cooled, it condenses into liquid (Wessapan et al., 2013). More than 200 distinct chemical components, including acetic acid, formic acid, and methanol, are found in wood vinegar (Rakmai, 2009). Formaldehyde, acetone, and phenol are beneficial chemicals in various industries, including agriculture, home cleaning, and animal production.

Additionally, some studies focus on wood preservatives that do not include creosote such that they consist of risk-free compounds—i.e., vinegar made from wood. As this kind of vinegar is toxic to snout beetles, using it to cure wood may protect the latter from insect destruction.

There are many kinds of bamboo, including G.atrolviolascea, G.apsu, G.atter, D.asper, and Bambusa vulgaris. Of these five kinds of bamboo, Bambusa vulgaris has the highest proportion of cellulose (53.34%), whereas G.apus has the highest proportion of nitrogen content (0.33%), and G.atter the highest proportion of lignin (27.33%). This is a matter of some importance, as the extent of the damage to bamboo caused by termites has been connected to the chemical composition of different types of bamboo. However, in chemical treatment, rosin acid treatment effectively improves the mold resistance and WCA of natural bamboo materials. In recent studies of the chemical treatment, rosin treatment has received attention because it is environmentally friendly. Rosin treatment significantly reduces the MC of natural bamboo materials, increases their WAC, and ultimately improves their hydrophobicity (Su et al., 2021; Yang et al., 2023).

Research has shown that it is possible to dissipate transmitted electromagnetic wave (EMW) energy by inducing interfacial/dipolar polarization and conductive loss processes in many materials, such as timber and laminated composites. This can be achieved by placing an inorganic/polymer equivalent circuit on the material's surface. Concerning bamboo, Qiuyi et al. (2022) investigated the possibility of adding a TiO2@KH-570 coating to the material's surface by using polydimethylsiloxane to bridge the hydrogen link and the covalent bond. This coating improves the mechanical strength and surface hydrophobicity of the bamboo, renders it more effective in self-cleaning, and improves its resistance to aging and mildew. According to Jing et al. (2022), the microfibrillar aggregates of parenchyma cells vary at the subcellular scale, and parenchyma cells are more susceptible to ambient humidity changes than fibers. Their experiment showed that at a relative humidity of more than 40%, there were significant differences between the various components of bamboo in terms of the amount of moisture present.

The present study aims to identify local practices that support the durability of bamboo and thus extend its life, particularly for the purpose of construction. The Chai Badan District in Lopburi Province provided the research team with the bamboo used to build housing in the area. Bamboo is cut only in November and December when few snout beetles are active and only when it has been growing for at least three years. Our experiment used bambusa bambos, rough giant bamboo, and bambusa vulgaris, each belonging to a different bamboo genus. To fulfill the goal of extending the useful life of bamboo, each kind of bamboo was subjected to five experiments; each focused on trying a specific technique: natural release, air drying, baking, or water soaking. The treated bamboo was tested in three different environments: dry naturally, baked without soaking, baked and then soaked in water, baked and saline, and baked and then soaked in wood vinegar.

Materials and Methods

Materials

Bamboo sourced from the Chai Badan District in Lopburi Province, three species of bamboo—Bambusa bambos bamboo *(Bambusa bambos (L.) Voss)*, Rough giant bamboo *(Dendrocalamus asper (Schultes f.) Backer ex Heyne)*, and Bambusa vulgaris *(Bambusa vulgaris Schrad. ex H.Wendl.)*—each from a different genus were used in the experiments (Figure 1).

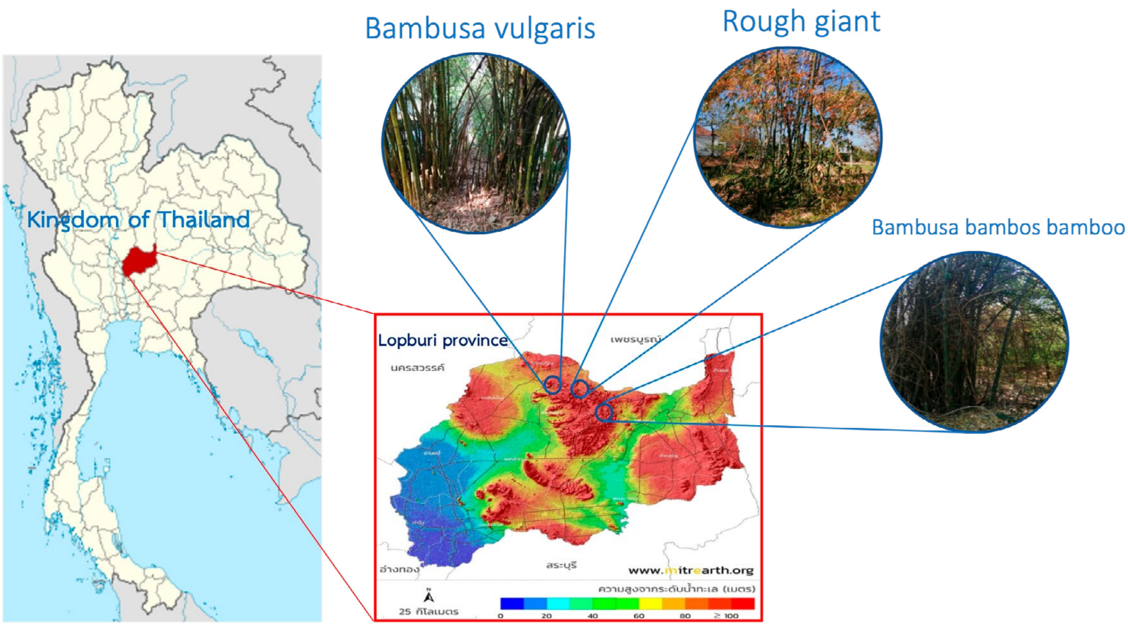

Figure 1 Three species of bamboo sourced from Lopburi province, Thailand. (Adapted from Sangkittipaiboon et al. (2015))

Methods

The utilization of a Randomized Complete Block Design (RCBD) is a statistical methodology employed for the purpose of designing a pragmatic experiment. The testing approach used for pairwise comparisons of several treatment groups, known as Fisher's least significant difference (LSD) process, is implemented in Microsoft Excel. This methodology involves evaluating the disparities between the population means for each pair by independently sampling each set, utilizing samples from the three distinct bamboo species as previously mentioned. Fisher's least significant difference (LSD) test was employed to analyze a specimen from each of the three samples in each of the five experimental configurations utilized. Each specimen, with dimensions of approximately 25 mm in width, 500 mm in length, and 10 mm in thickness (with variations in thickness observed across different species), was buried at a depth of 2,000 mm in the earth at the designated test location. Data was gathered over a period of 12 months from the designated test site, during which specimens were subjected to testing for the presence of fungus and termites. The naturalness of both bamboo samples was assessed by evaluating the levels of fungal development, moth infestation, and termite infestation in three distinct circumstances including outdoor, indoor, and indoor.

Process to extend the lifespan of bamboo

In the current investigation, the oven is consistently held at a constant temperature of 103 ± 2ºC for the purpose of baking. Additionally, the oven is equipped with a fan to facilitate air circulation and a vent that provides for the discharge of moisture and water vapor. The bamboo is prepared for further processing by being chopped to the desired proportions and left to air-dry for a period of 45 days, as per the subsequent processes as shown in Fig. 2.

Method 1	Method 2	Method 3	Method 4
Bake only. Place the bamboo in the oven to bake. The amount of moisture in the bamboo does not exceed 10–14 % (Figure 2).	Bake and soak in water. Bake the bamboo in an oven for how long. The moisture content in the bamboo between 10 and 14%. Then soak the bamboo in water for one month.	Bake and soak in saline. Bake the bamboo in an oven for how long? The bamboo has a moisture level of between 10 and 14%. Then soak the bamboo in water containing 20% salt for 30 days.	Bake and soak in wood vinegar. Bake the bamboo in an oven in an oven for 1 day. The bamboo has a moisture level of no more than 10–14%. Then soak the bamboo in wood vinegar containing 20% for 30 days.

(a) Bamboo specimens (b) Cutting and trimming bamboo specimens (c) Bamboo specimens for testing

Figure 2 Processing bamboo specimens for testing.

Methods for extending the life of bamboo

Three specimens of Bambusa bambos, often known as Rough Giant Bamboo, and Bambusa vulgaris were positioned in a raised orientation against a wall within an indoor space characterized by low illumination. Furthermore, three samples of Bambusa bambos, often known as Rough Giant Bamboo, and Bambusa vulgaris were inserted into the ground. namely at a depth of 200 mm. Outdoor observations of any alterations in the specimens were conducted after a duration of 12 months. The bamboo specimens were appropriately labeled in accordance with a predetermined process to facilitate their identification.

(1) Prevent fungus.

By collecting samples of the three designated kinds of bamboo through the process of cutting. The recommended method for drying branches and leaves is to arrange them in a natural drying environment, such as under a roof outdoors, for a duration of 14 days. It is advisable to trim the branches to a width that is approximately 25 times the length of the bamboo species, specifically measured 500 mm in length and 5 mm in thickness. Measure the bamboo specimen using a vernier caliper. Cut and weigh a small piece of bamboo and then bake the bamboo specimen. Place the bamboo in an electric oven that has the ability to change and regulate the temperature. Examine the oven to ensure that a temperature of (130 ± 2°C) is maintained for 24 hours after the electric burner has been turned off. Allow the bamboo to come down to room temperature. Measure the bamboo specimen using a vernier caliper.

Step 1	Step 2	Step 3	Step 4
Place nine specimens of each type of bamboo and maintain in an area with natural air circulation for one month.	Soak nine specimens of each type of bamboo and place in a bucket of water to soak for one month.	Soak nine specimens each of bamboo, in a bucket of water containing 20% salt for 30 days.	Soak nine specimens of each type of bamboo for 30 days in a bucket of water containing 20% wood vinegar.

The data were obtained through the examination of fungal activity in each of the bamboo specimens under three different conditions: indoor, darkroom, and outdoor. At regular intervals of 30 days, the fungal incidence proportion was assessed in relation to the fungal incidence proportion detected in the original bamboo.

(2) Prevent snout beetles.

Each of the three specified species of bamboo was acquired and shaped by removing the branches and foliage. The bamboo should be allowed to undergo natural drying indoors, preferably under a shelter, for a duration of 15 days. The specimens were cut with approximate dimensions of 25 x 500 x 5 mm, with the thickness varied according to the specific species. Utilize a vernier caliper to quantify the dimensions of the bamboo specimen. The bamboo specimens should be subjected to a controlled baking process by being positioned within an electric oven equipped with temperature regulation capabilities. This oven should be capable of sustaining a temperature of 103 ± 2°C for a duration of twenty-four hours subsequent to the deactivation of the electric burner. Ensure that the bamboo is brought to ambient temperature. Utilize a vernier caliper to ascertain the dimensions of the bamboo specimen. The objective is to gather a total of nine specimens for each kind of bamboo, specifically Bambusa bambos, also referred to as bamboo grove, and Bambusa vulgaris. Following this, utilize organic methods to eradicate the gathered specimens. The information was gathered by comparing regions of bamboo that had been afflicted by moths in three separate settings: indoors, in a darkroom, and outside. These areas were compared to areas of bamboo that had not been infested by moths.

Step 1	Step 2	Step 3	Step 4
Leave 27 samples of each kind of bamboo to aerate naturally for 1 month.	Soak 9 of each kind of bamboo in a bucket of water with 20% salt for 30 days.	Soak 9 of each kind of bamboo in a bucket of water and orange juice for 30 days	Soak 9 of each kind of bamboo in a bucket of wood vinegar and for 30 days.

(3) Determining the durability of bamboo

To assess the durability of bamboo and develop construction methods that are suitable for it, we facilitated the participation of snout beetles, fungi, and termites in the degradation of experimental bamboo. The resulting disintegration was then categorized into different levels of durability.

Excellent	Very good	Moderate	Not good	Useless
No damage discovered (0) 0%	Slight damage (1) (not more than 10%)	Moderate damage (2) (11–30%)	Very damaged (3) (31–50%)	Unusable (4) (more than 50%)

(4) Examination of community knowledge concerning bamboo preservation

In order to collect knowledge regarding community practices aimed at prolonging the durability of bamboo for construction applications, this study focuses on three types of bamboo: Bambusa bambos bamboo, Rough giant bamboo, and Bambusa vulgaris bamboo. These bamboo species are naturally abundant in the Chai Badan District of Lopburi Province, where they are extensively utilized in construction activities. Due to the limited activity of snout beetles during the winter season, the harvesting of bamboo often takes place in the months of November and December. The methodology employed at the local level for determining the age of bamboo is rather straightforward. There are five methods for enhancing the longevity of bamboo. One of these approaches involves utilizing an oven that is equipped with a vent system, which serves the purpose of facilitating air circulation and enabling the dissipation of moisture and water vapor. There are five potential approaches to the following:

a. Cut the bamboo to the required size and air-dry for 45 days.

b. Place the bamboo in an oven with the temperature maintained at 103 ± 2°C. The bamboo's moisture level is between 10 and 14%.

c. Bake and soak the bamboo in water (tap water). Place the bamboo in an oven with temperature maintained at 103 ± 2°C.

d. The bamboo has a moisture level between 10 and 14% and is soaked in water for 30 days.

e. After heating for 24 hours, the bamboo has a moisture level of between 10 and 14%. It is then soaked in water for 30 days to achieve as follows:

f. Bake the bamboo and then soak it in a saline (sea salt) solution. The bamboo's moisture level is between 10 and 14%, steeped in 20% salt water for 30 days.

g. Bake and soak wood vinegar. The bamboo has a moisture level between 10 and 14% and is steeped for 30 days in 20% wood vinegar.

(5) Apply indigenous knowledge to increase the longevity of bamboo

To extend the lifespan of bamboo for building purposes, this experimental design draws on traditional wisdom. To achieve the goals of the research, a method is created to lengthen bamboo's durability in proportion to the types of situations in which it will be employed. Extending the bamboo is the first stage in preparing it for usage. There are five potential approaches to the following:

a. After the bamboo has been prepared, cut it to size and let it dry naturally for 15 days.

b. The bamboo is baked in an oven whose temperature is steady at 103 ± 2°C and can be controlled by air currents that may circulate. A consistent temperature should be maintained inside the oven, and a vent for moisture and water vapor should be left. The bamboo's moisture level is between 10 and 14%.

c. Bake and soak in water. Bring bamboo to an oven capable of maintaining a consistent temperature of 103 ± 2°C, in which air may flow, for baking. A consistent temperature should be maintained inside the oven, and a vent for moisture and water vapor should be left. To have the bamboo's moisture content between 10 and 14 %, soak the bamboo in water for 30 days.

d. Bring bamboo to an oven capable of maintaining a consistent temperature of 103 ± 2°C, in which air may flow, for baking. A consistent temperature should be maintained inside the oven, and a vent for moisture and water vapor should be left. Bake and soak in saline. The bamboo's moisture level is between 10 and 14%, steeped in 20% salt water for 30 days.

e. Bake and soak in wood vinegar. Bring bamboo to an oven capable of maintaining a consistent temperature of 103 ± 2°C, in which air may flow, for baking. A consistent temperature should be maintained inside the oven, and a vent for moisture and water vapor should be left. The bamboo has a moisture level between 10 and 14% and is steeped for 30 days in 20%v/v wood vinegar.

The aforementioned bamboo preparation was tested to the test in three diverse environments: indoor, outdoor, and darkroom.

a. Several specimens of Bambusa bambos, bamboo stems, and Bambusa vulgaris, each measuring approximately 25 mm wide by 500 mm long, with the thickness varies depending to the species. On a piece of colored lacquered fabric tape, write the code that has been established for each species, and then connect that tape to each sample (Figure 3).

b. Soak some of the Bambusa bambos bamboo, Rough giant bamboo, and Bambusa vulgaris bamboo samples in 20% wood vinegar and some of the samples in 20% salt for 30 days in a darkroom. Then dry the samples for 24 hours at a constant temperature of 103 ± 2 °C in an oven with a vent for moisture and water vapor to escape. The moisture level of the bamboo is between 10 and 14 %, and the bamboo is unprocessed and natural.

c. In the open air, Bambusa bambos bamboo, Rough giant bamboo, and Bambusa vulgaris bamboo have been soaked in 20% wood vinegar, 20% salt water, and 30 days of water, and then dry for 24 hours in a temperature-controlled oven. Air may flow within the oven at 103 ± 2°C to maintain a constant temperature, and there should be a vent for moisture and water vapor. The moisture level of the bamboo is between 10 and 14%, and the bamboo is unprocessed and natural. Depending on the type of bamboo, the sample size of bamboo is usually 25 mm wide × 500 mm long × 25 mm thick. The code is ready to be written on bamboo tape, lacquered cloth, and stitched 200 mm below the earth's surface (Figures 4 and 5).

(a) Bamboo specimens during testing (b) Bamboo specimens after testing

Figure 3 Multiple samples of three species of bamboo before snout beetle treatment (R) and after snout beetle treatment.

(a) Bamboo specimens during testing (b) Bamboo specimens after testing

Figure 4 Depicts the snout beetle protection concept for bamboo in a darkroom setting.

(a) Bamboo specimens during testing (b) Bamboo specimens after testing

Figure 5 Depicts the durability and protection against snout beetles that degrade outdoor bamboo design and recording of changes every month for a year

(6) Experimental analysis and discussion

The data collected from the experimental treatment were subjected to analysis using a Randomized Complete Block Design (RCBD). To assess the differences between the population, mean for each pair of outcomes, Fisher's Least Significant Difference (LSD) statistical approach was employed. This involved independently sampling each set and comparing the resulting findings. Utilizing a sample group of three distinct bamboo species, the study incorporated three experimental settings, namely indoor, darkroom, and outdoor environments. Additionally, the production of moths was conducted at one of the experimental sites. This discussion pertains to the real-life evaluation of fungal infections and termite infestations, with specific reference to the five treatment methods applicable to bamboo: natural treatment, dry treatment, dried treatment, and water soaking treatment. The process involves first drying the substance, then soaking it in a saline solution, and subsequently drying it again before soaking it in wood vinegar. Utilizing a statistical analysis through the employment of the SPSS software application prior to data input can serve as a preventive measure against the increase of mold, moths, and termites.

Results and discussion

Utilizing the experimental methodology established, an analysis was carried out to assess the effectiveness of localized techniques in the preservation of bamboo for construction purposes. This section provides a description of the outcomes obtained from our experimental investigations.

Durability of bamboo

The evaluation of the results was conducted using the Randomized Complete Block Design (RCBD) and Fisher's Least Significant Difference (LSD) statistical method. This methodology was employed to analyze the variations between the means of different populations, which were established through independent sampling of each respective group. The versatility of bamboo may be demonstrated by the utilization of three design environments, namely indoor, darkroom, and outdoor, and the examination of three focus species of bamboo, specifically Bambusa bambos bamboo, Rough giant bamboo, and Bambusa vulgaris bamboo. The methodology employed for using bamboo in construction will assess three key attributes pertaining to the durability of bamboo, namely its resistance to mold and termites, as illustrated in Table 1.

Table 1 Determination of bamboo's durability and building techniques

Fungi [n]

Place [e]	Type [a]	Natural process [i]		Drying process [j]		Drying process and after being soaked in water [k]		Saline [l]		Drying process of bamboo with wood vinegar [m]	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Indoor [f]	Bambusa bambos[b]	48.9967	23.81959	19.5000	11.98883	.0000	.00000	.0000	.00000	48.9967	23.81959
	Rough Giant Bamboo[c]	42.2333	19.51976	12.1900	.53113	.0000	.00000	.0000	.00000	42.2333	19.51976
	Bambusa vulgaris[d]	6.5867	.25658	.0000	.00000	.0000	.00000	.0000	.00000	6.5867	.25658
	Total	32.6056	25.02987	10.5633	10.43019	.0000	.00000	.0000	.00000	32.6056	25.02987
Darkroom [g]	Bambusa bambos	.2700	.26514	1.1033	.10263	.0000	.00000	.0000	.00000	.2700	.26514
	Rough Giant Bamboo	.8033	.02309	.7333	.28006	.0000	.00000	.0000	.00000	.8033	.02309
	Bambusa vulgaris	.5633	.28501	.1433	.24826	.1733	.30022	.0000	.00000	.5633	.28501
	Total	.5456	.30254	.6600	.46203	.0578	.17333	.0000	.00000	.5456	.30254
Outdoor [h]	Bambusa bambos	11.6533	2.05115	36.0167	4.18598	26.8067	2.16218	25.0700	.57166	11.6533	2.05115
	Rough Giant Bamboo	17.2033	3.01631	36.5467	4.07750	26.8367	2.96024	18.9167	1.14409	17.2033	3.01631
	Bambusa vulgaris	21.1533	7.23071	34.0467	1.97510	21.9367	.56083	21.7333	1.38601	21.1533	7.23071
	Total	16.6700	5.78611	35.5367	3.28844	25.1933	3.06661	21.9067	2.82940	16.6700	5.78611
Total	Bambusa bambos	20.3067	25.10402	18.8733	16.40392	8.9356	13.44686	8.3567	12.53826	20.3067	25.10402
	Rough Giant Bamboo	20.0800	20.59170	16.4900	15.97291	8.9456	13.49972	6.3056	9.47562	20.0800	20.59170
	Bambusa vulgaris	9.4344	9.85696	11.3967	17.01675	7.3700	10.92989	7.2444	10.88874	9.4344	9.85696
	Total	16.6070	19.51909	15.5867	16.13990	8.4170	12.20811	7.3022	10.64001	16.6070	19.51909

Snout beetles [o]

Place [e]	Type [a]	Natural process [i]		Drying process [j]		Drying process and after being soaked in water [k]		Saline [l]		Drying process of bamboo with wood vinegar [m]	
		Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD	Mean
Indoor [f]	Bambusa bambos	.0600	.04359	.1967	.03055	.1067	.02887	.0633	.00577	.0233	.01155
	Rough Giant Bamboo	.0767	.00577	.2300	.13000	.0900	.01000	.0667	.01155	.0300	.00000
	Bambusa vulgaris	.5067	.14572	.3667	.09452	.3167	.07095	.1867	.05033	.0867	.00577
	Total	.2144	.23212	.2644	.11304	.1711	.11602	.1056	.06616	.0467	.03082
Darkroom [g]	Bambusa bambos	.1167	.02082	.0933	.00577	.2933	.35233	.0733	.01155	.0000	.00000
	Rough Giant Bamboo	.1700	.02646	.1533	.04163	.1367	.02309	.1400	.04583	.0667	.01155
	Bambusa vulgaris	.5267	.11060	.4200	8.21656	.6167	.14844	.2633	.06807	.1567	.00577
	Total	.2711	.20152	.2222	.18667	.3489	.28568	.1589	.09320	.0744	.06839
Outdoor [h]	Bambusa bambos	.1367	.00577	.0900	.00000	.0333	.00577	.0400	.00000	.0000	.00000
	Rough Giant Bamboo	.1067	.00577	.1267	.02082	.0367	.00577	.0467	.00577	.0433	.00577
	Bambusa vulgaris	.9633	.20207	.3067	.07371	.1500	.10583	.1833	.01155	.0600	.01000
	Total	.4022	.43301	.1744	.10748	.0733	.07826	.0900	.07036	.0344	.02744

Table 1 (Cont.) Determination of bamboo's durability and building techniques

Snout beetles [o]

Place [e]	Type [a]	Natural process [i]		Drying process [j]		Drying process and after being soaked in water [k]		Saline [l]		Drying process of bamboo with wood vinegar [m]	
		Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD	Mean
Total	Bambusa bambos	.1044	.04216	.1267	.05477	.1444	.21149	.0589	.01616	.0078	.01302
	Rough Giant Bamboo	.1178	.04353	.1700	.08322	.0878	.04522	.0844	.04876	.0467	.01732
	Bambusa vulgaris	.6656	.26178	.3644	.13315	.3611	.22696	.2111	.05798	.1011	.04372
	Total	.2959	.30526	.2204	.14004	.1978	.21130	.1181	.08029	.0519	.0474

Termites [p]

Place [e]	Type [a]	Natural process [i]		Drying process [j]		Drying process and after being soaked in water [k]		Saline [l]		Drying process of bamboo with wood vinegar [m]	
		Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD	Mean
Indoor [f]	Bambusa bambos	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
	Rough Giant Bamboo	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
	Bambusa vulgaris	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
	Total	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
Darkroom [g]	Bambusa bambos	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
	Rough Giant Bamboo	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
	Bambusa vulgaris	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
	Total	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000	.0000	.00000
Outdoor [h]	Bambusa bambos	21.6733	.52166	40.3433	3.21013	31.9133	8.01644	54.2267	7.18176	37.0933	3.31044
	Rough Giant Bamboo	29.4133	7.24028	36.1467	2.58206	42.1333	4.92622	79.7567	18.85035	31.2267	1.30024
	Bambusa vulgaris	75.2500	42.40927	37.5067	9.54939	67.6867	21.78394	86.3667	23.46643	33.6800	.56205
	Total	42.1122	33.04135	37.9989	5.52080	47.2444	19.88496	73.4500	21.34135	34.0000	3.12287
Total	Bambusa bambos	7.2244	10.83981	13.4478	20.23542	10.6378	16.45239	18.0756	27.35009	12.3644	18.62038
	Rough Giant Bamboo	9.8044	15.14567	12.0489	18.11939	14.0444	21.21017	26.5856	40.97701	10.4089	15.62686
	Bambusa vulgaris	25.0833	43.18885	12.5022	19.35162	22.5622	35.55287	28.7889	44.74895	11.2267	16.84234
	Total	14.0374	27.29785	12.6663	18.50917	15.7481	25.23392	24.4833	37.21716	11.3333	16.42467

Notes: [a] Type refers to the type of bamboo species tested for three species. [b] Bambusa bambos bamboo means Bambusa bambos, scientific name Bambusa bamboos. [c] Rough giant bamboo means Rough Giant Bamboo, a scientific name. Dendrocalamus asper. [d] Bambusa vulgaris bamboo means Bambusa vulgaris, the scientific name Bambusa vulgaris "Vittata". [e] Place means a place is designed to simulate the environment of 3 places: indoor, darkroom, and outdoor. [f] "Indoor" means an umbrella with a canopy to protect from sun and rain. [g] "Darkroom" means a darkroom room wholly enclosed without sunlight and wind. [h] "Outdoor" means outdoors that is open and exposed to sunlight and wind. [i] Natural process refers to the experimental bamboo samples released naturally. [j] Dried means bamboo specimens that have been dried and left. Forty-five days were taken for testing. [k] Plain water means bamboo specimens that have been dried and left for 15 days and soaked in water for 30 days before being tested. [l] Saline refers to bamboo specimens that have been dried and left for 15 days, then soaked in 20% saline for 30 days before being tested. [m] Wood vinegar means bamboo specimens that have been dried and left for 15 days, soaked in 20% wood vinegar for 30 days, then subjected to experiment. [n] Fungi means fungi that occurs on black wood. [o] Snout beetles mean wood snout beetles are pests that destroy wood and make wood porous. [p] Termites mean termites are snout beetles that eat wood.

Impact of desiccation in a saltwater environment induces the proliferation of mold on bamboo surfaces

There was no evidence of the presence of fungi within any of the bamboo species under the conditions of darkness in the experimental circumstance. The fungal organism was found to be accountable for 18.91% of the issue at hand. Bamboo Tong and fungus accounted for 21.73% of the total in the outdoor design site. The proportion of contribution made by Bambusa vulgaris, an external design site, and fungi towards the establishment of an outdoor bamboo forest circumstance was recorded as 25.07% (Figure 6).

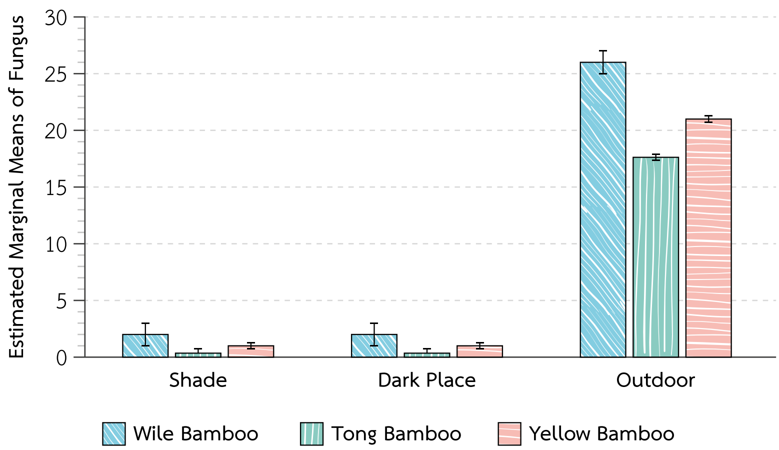

Figure 6 Quantity of mold present, bamboo species, and drying procedure all played a role in bamboo degradation.

Impact of moths in bamboo subjected to drying process with wood vinegar

The bamboo forest moth was not detected in either the darkroom or the outside habitat. The population of moths observed in the shadow of the bamboo forest constituted a mere 0.02% of the overall composition. The proportion of moths that were born constituted 0.03% of the overall population, while Bamboo Tong is renowned for its interior design concepts. Moths accounted for a mere 0.04% of the total contribution. An infestation of 0.06% of moths was detected in the exterior design of the Bamboo Tong. The study conducted by Bamboo Tong focused on the design of gloomy rooms, with a particular emphasis on the contribution of moths, which accounted for a little 0.06% of the overall percentage. Furthermore, the research explored the potential use of Bambusa vulgaris as a suitable material for outdoor architectural design. Moths accounted for a mere 0.08% of the total contribution, while Bambusa vulgaris served as a prominent choice for outdoor architectural design. Additionally, it was observed that moths accounted for 0.15% of the whole Bambusa vulgaris, darkroom decoration (Figure 7).

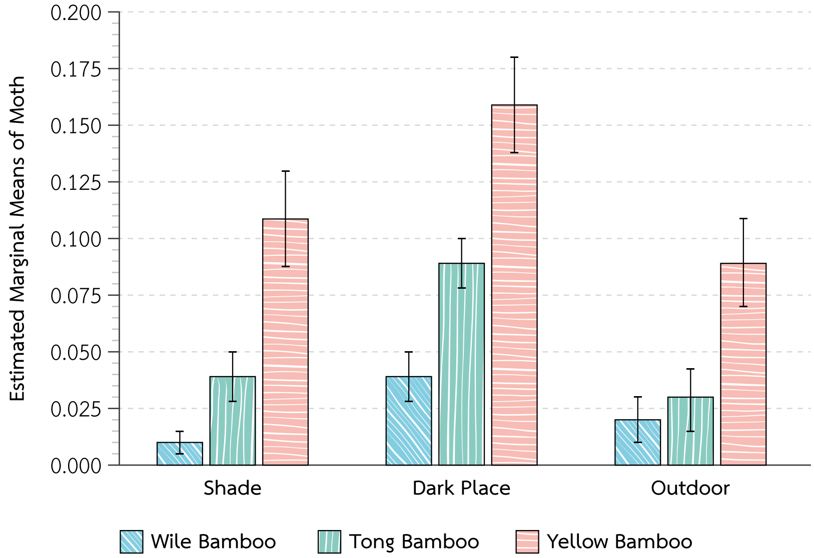

Figure 7 Incidence of moths for each type of bamboo associated with the drying process using wood vinegar

Impact of termites on the bamboo drying process in the presence of wood vinegar

There was no evidence of empirical support indicating the presence of termites within any of the bamboo species under the controlled conditions of the darkroom. Termites accounted for a proportion of 31.22%. Termites accounted for a proportion of 33.68% in the overall context. The allocation of 37.09% of the overall site was dedicated to the establishment of an outdoor bamboo forest environment, with significant emphasis placed on the phrases “Bambusa vulgaris,” “outdoor design location,” and “termites” (Figure 8).

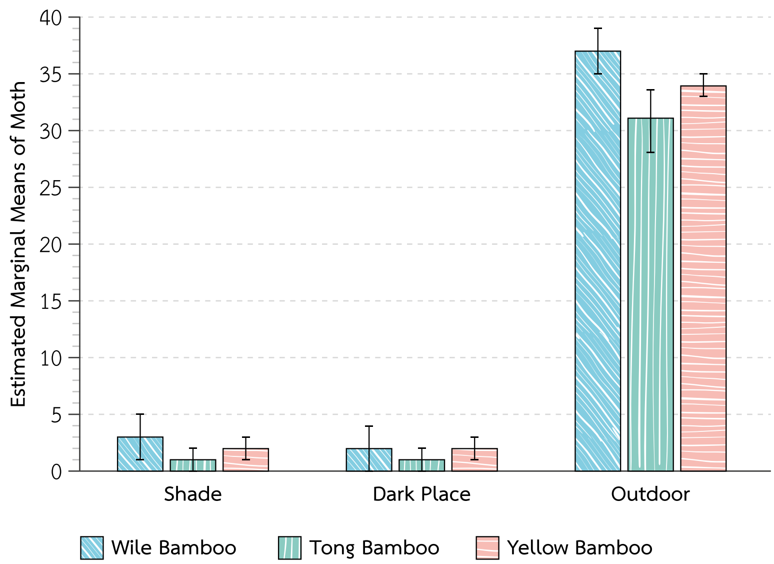

Figure 8 Incidence of termites for each bamboo species soaked in wood vinegar

Conclusions and future research

Based on the obtained results, the following conclusions are presented:

Bamboo fungi are naturally mold-free (very good), bamboo grove and Bambusa vulgaris, dark-room design. Fungal incidence was 0.6% (very good). In the bamboo room design at 13.19% (moderate) of indoor bamboo had fungi at 23.15% were fungi (moderate). It indoor Bambusa vulgaris. 33.1% were fungi (poor). Fungi made up 42.45% (poor) of bamboo forest outdoor design 52.18% were fungi (unusable level).

Bamboo mold, drying, bringing. No fungi were found (very good level). Bambusa vulgaris and bamboo woodland. Darkroom indoor design of 18.9% was fungi (moderate level) at 21.73% were fungi (moderate level). Yellow outdoor bamboo of 25.07% was fungi (moderate level).

Bamboo moths are natural. Moth-born bamboo forest indoor design was 0.06% (excellent), 0.07% was moth-born (very good), and 0.10% was moth-born (very good) of 0.11% was moths (very good). Bamboo forest darkroom Moth caused 0.13 (very good) Outdoor bamboo design of 0.17% were moths (very good) Darkroom Bamboo Tong room at 0.5% of moths hatched (very good). Bamboo indoor, yellow at 0.52% of moths marked (very good).

The bamboo heat treatment is well-developed, although several areas need further studies: (1) Conducting heat treatment on more bamboo species used for different goods. There are many bamboo species, but most heat treatments have been done on moso bamboo (Phyllostachys pubescens). (2) Designing economical heat treatment equipment. (3) Optimizing heat treatment parameters and balancing dimensional stability and mechanical qualities for final applications. Exploring innovative heat transfer media with high thermal stability, low cost, and low energy consumption. (5) Standardizing bamboo heat treatment and the market. (6) Developing non-destructive and fast heat-treated bamboo product quality testing technique. These issues demand researcher-entrepreneur collaboration. Bamboo heat treatment technologies allow it to be employed in more valuable industries.

Acknowledgments

This research was supported by funding from the Phranakhon Rajabhat University research grant #2565.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships with any influence on the work reported in this paper.

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