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EFFECT OF HEAT TREATMENT ON THE DURABILITY OF LAMINATED BAMBOO AGAINST BROWN ROT FUNGUS (*SCLEROTIUM ROLFSII* SACC) ATTACK

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Abstract

Bamboo is a fast-growing woody grass with increasing importance for the sustainable production of materials with many applications. However, due to its susceptibility to fungal and insect attacks, there is need to consider treatment options to enhance its durability in service. One of these is heat. This study therefore investigates the effects of lamination and thermal (heat) treatment on the durability of laminated bamboo against brown-rot fungus attack. Twenty Bamboo culms of 4yrs old were harvested from the plantation in Gbedun, Akanran, Ona-Ara Local Government Area of Oyo State, Nigeria. The production of laminated bamboo board was carried out in the Wood Workshop of the Department of Forest Resources Management, University of Ibadan, Nigeria. Laminate thickness of 4, 6, 8 and 10mm were used to produce boards and were also thermal treated by steaming in an autoclave at 140^{0}C for 4, 6 and 8 hours with un-treated boards serving as control. Durability test was carried out on the laminated samples and data were analysed using descriptive statistics and ANOVA at $P<0.05$. From the results, the weight loss of the laminated boards ranged from 8.11 to 29.24% with increase in laminate thickness and thermal treatment duration resulting in decrease in weight loss of the boards produced. Laminated boards thermal treated for 8hrs were moderately resistant (class III) while, the untreated samples and those treated for 4 to 6hrs belong to susceptible class (class IV). Laminate thickness of 4, 6, 8 and 10mm belongs to class IV decay resistance class with the implication that they are non-resistant to fungus decay.

Keywords: Bamboo, laminate thickness, thermal treatment, durability test, weight loss

1. Introduction

The world is currently facing rapid decrease in forest resources and serious degradation of the environment. The tropical forest is decreasing at an alarming rate today and the demand for wood has continued to increase in proportion to human population. It is expected that there would be increase in the demand for wood due to its versatility and affordability over and above other construction materials. The high demand for wood would result in over-exploitation of both the natural and plantation forest with its attendant environmental consequences (Geomatic, 1998; Youngquist and Hamilton, 1999; Fuwape, 2001; Falemara *et al.*, 2012). The over exploitation of existing forest resources and the disappearance of economic hard wood species are of great concern to wood scientist, technologist and users as well. The supply of quality timber from the natural forest to wood-based industries is no more available in the quantities that can sustain the usual large diameter class logs required by these industries. Therefore, the development and exploitation of bamboo is of considerable importance.

Bamboo is an important forest resource that grows abundantly in many tropical and sub-tropical regions of the world, especially in Asia (FAO, 2007). As a fast-growing material, bamboo has been widely used as a traditional material for making basic tools and furniture as well as a building material, due to its strength, surface hardness and easy machinability.

Despite the many excellent properties of bamboo, the major drawback of this material is its durability against the deteriorating agents due to the high level of starch content and other lignocellulosic material that attracts bio-deteriorating agents to it (Roziela Hanim *et al.*, 2012). Bamboo is susceptible to attack by insects (like powder-post beetles and termites) and decay fungi such as sap-staining fungi and fungi causing brown rot, white rot and soft rot (Liese 1980, Li 2004, Krisdianto 2008). Bamboos, like other lignocellulose materials, are subject to biodegradation by fungi under certain condition which may affect their quality (Hamid *et al.* 2003). Bamboo is attacked by brown rot, white rot and soft rot fungi, above its fibre saturation point (Liese, 1985). Like the decay resistance in wood, the natural durability of bamboo is related to its endurance to attack by destructive organisms like termites, powder-post beetles, marine borers and decay fungi.

The carbohydrate content of bamboo plays an important role in its durability and service life. Durability of bamboo against mold, fungal and borers attack is strongly associated with the chemical composition (Abd.Latif *et al.*, 1991). Bamboo resistance indicates the durability of a bamboo species against destroying organisms. The resistance of bamboo against decay fungi serves as an important parameter in bamboo establishment.

Recently, attempt has been made to subject bamboo to heat treatment (Leithoff and Peek, 2001) to enhance its durability. Heat treatment has been used for various wood products to improve their dimensional stability and durability against biodeterioration (Kamdem *et al*., 2002; Militz, 2002). Heat treatment is environmentally friendly and does not involve toxic chemical.

This paper therefore investigates the effect of thermal treatment on the durability of glue-laminated bamboo against *Sclerotium rolfsii* with a view to maximizing the utilization potential of bamboo as a substitute to other wood species.

2. Materials and Method

2.1. Raw-material source

Twenty bamboo culms of 4yrs old were harvested from the plantation in Gbedun, Akanran, Ona-Ara Local Government Area of Oyo State, Nigeria located on latitude 7^{0}13'60"N and longitude 4^{0}1'60"E. The harvested bamboo culms were taken to the Department of Forest Resources Management Wood Workshop, University of Ibadan, Ibadan, Nigeria for processing and conversion to laminated bamboo board.

2.2. Laminated bamboo board formation

The harvested bamboo culms were cross-cut from the base into 3m long billet using a circular saw. The billets obtained were again cut into three sections of 1m long each to obtain straight pieces and then split in the radial direction using a circular saw. The inner and outer surfaces of the strips obtained were later planed into laminate thickness of 4, 6, 8 and 10mm. The strips were thereafter edged on one end and cut on the other un-edged end to 25mm. The 25mm wide strips obtained were further cut into smaller length of 500mm long, thermal treated at different period intervals of 4hrs, 6hrs, 8hrs and un-treated, dried followed by application of adhesive bond (top bond) on the split faces of the strips. The strips were cold-pressed with a clamp for proper penetration of adhesive at the bond lines to form strong boards.

Thereafter, the boards formed were cured at room temperature for 14 days (2weeks) for proper bonding of the adhesive with the bamboo strips to enhance good machining.

2.3.Thermal treatment of bamboo strips

The 4, 6, 8 and 10mm thick of 500mm long and 25mm wide strips produced were dried at room temperature until moisture content value ranged between 75 to 80% after which they were thermal treated. Thermal (heat) treatment was conducted at Bio-Science Centre of International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria in a Tomy SX-700 Autoclave. Strips were subjected to temperature of 140^0C (Constant) at different period intervals; 4hrs, 6hrs, 8hrs and un-treated.

2.4.Laminated bamboo board testing

At the end of the curing process, the bamboo boards produced were planed, edged and cut to 19mm x 19mm x 19mm for Weight loss determination in accordance with IS. 4873 (IS, 2008). Each treatment combination of thermal treatment and laminate thickness were replicated five times and 80 samples were obtained for the weight loss test. Analysis of variance in 4 x 4 factorial experiments in a completely randomized design (CRD) was carried out to determine if thermal treatment and laminate thickness had significant effects on the durability of the laminated bamboo boards produced.

2.5.Culture medium

The inoculum of *Sclerotium rolfsii* (brown rot fungus) was obtained from the Pathology Section of Forestry Research Institute of Nigeria, Ibadan, Nigeria and the culturing of the inoculum was carried out following the standard IS. 4873 (IS, 2008).

2.6.Infection of test blocks

The bottles containing the test blocks of 19 x 19 x 19mm were incubated at 27 ± 2^0C for 24 weeks. At the end of the incubation period, the blocks were removed from the culture bottles, cleaned of the adhering mycelia, taking care not to remove the splinters of wood and weighed immediately to determine moisture absorbed. The weighed samples were oven-dried at 103^0C to constant dry weight (IS, 2008).

2.7.Determination of durability after incubation

At the end of the incubation period, the wet weights of the test blocks were calculated after which they were oven-dried for 18hours at 103^0C. The test blocks were then allowed to cool and weighed. The durability level of the laminated bamboo samples was determined based on the percentage of weight loss of the laminated bamboo after exposure to brown rot fungus attacks. The Percentage weight loss was determined as shown in equation 1 and used for the analysis of the effect of the fungi on the laminated bamboo samples. The resistance of the bamboo thermal treated samples were determined by categorizing it based on the average weight loss of laminated bamboo samples (Suprapti, 2010) (Table 1).

$$W = \frac{W_1 - W_2}{W_1} X100 \ldots\ldots\ldots\ldots(1)$$

Where: W= Weight loss

W_1=Initial weight before fungi attack

W_2=Final weight after fungi attack (after oven dried)

Table 1: Classification of laminated bamboo resistance based on the weight loss by fungi

Average Weight Loss (%)	Decay Resistance	Resistance Class	The Expectancy of Service Life (years)
None or negligible	Very resistant	I	≥8
Less than 5	Resistant	II	6-7
5 to 10	Moderately resistant	III	4-5
10 to 30	Non-resistant	IV	2-3
More than 30	Perishable	V	<2

Source: Suprapti, (2010).

3. Results and Discussion

Table 2: The Mean Weight Loss of Laminated Bamboo Board samples and its Resistance Class

		Laminate Thickness				
Durability Test	**Thermal Treatment**	**4mm**	**6mm**	**8mm**	**10mm**	**Mean**
WL (%)	**Untreated**	29.24(IV)	22.07(IV)	21.88(IV)	20.34(IV)	23.38±5.03(IV)^{a}
	4hrs	18.80(IV)	18.24(IV)	17.77(IV)	16.64(IV)	17.86±2.98(IV)^{b}
	6hrs	16.19(IV)	15.71(IV)	14.88(IV)	14.84(IV)	15.41±3.16(IV)^{c}
	8hrs	12.35(IV)	9.49(III)	8.50(III)	8.11(III)	9.62±1.94(III)^{d}
Mean		19.15± 7.20(IV)^{a}	16.38± 5.54(IV)^{b}	15.76± 5.41(IV)^{b}	14.98± 5.35(IV)^{b}	**16.57±6.02**

Means ± Standard Deviation and Resistance class of five replicate samples

The mean value for Weight Loss (WL) was 16.57% ranging from 8.11% to 29.24% (Table 2). It was observed that WL decreased with increase in laminate thickness of the bamboo boards. The lowest WL values were obtained at the laminate thickness of 10mm from each of the 4, 6 and 8hrs thermal treated and untreated boards. The relatively high resistance of 10mm laminate board to brown-rot fungus is an indication that it could be more durable than other laminate thickness.

Meanwhile, weight loss decreased with increase in thermal treatment duration. The untreated LBBs had the highest WL averaged, 23.38% while the least, 9.62% was obtained in 8hrs thermal treated LBBs. The implication of this is that, high temperature is effective in improving the durability of wood. High temperature treatment contributed to durability of material. According to Zaidon and Nazri (2000), the reduction in fungus deterioration is as a result of the reduction of starch content in the bamboo.

The result of analysis of variance for WL presented in Table 3 shows that the differences in thermal treatment and laminate thickness had significant effect on WL while their levels of interaction had no significant effect (P<0.05). The follow up test (Table 2) revealed that 10mm laminated boards treated for 8 hours were more durable than 8mm, 6mm and 4mm boards thermal treated for 6hrs, 4hrs and those untreated.

Based on resistance or durability rating against fungi (Table 2), boards treated at 140^{0}C for 8hrs were considered moderately resistant (class III). However, those treated at 140^{0}C for 4 and 6hrs and, untreated samples belonged to susceptible class (class IV). According to Seng (1990), wood in class III is expected to have a service life of three years, while that of class IV is very short. In this study, resistance of laminated bamboo to destroying fungi varied depending on thermal treatment and laminate thickness. According to Liese (1980), bamboo resistance or its service life is usually shorter than that of wood, from one to three years. Table 2 further showed that fungus decay of laminate thickness of 4, 6, 8 and 10mm belongs to class IV and therefore, expected to have short service life. According to Kumar *et al*. (1994), they stated that under durability classification, bamboo belong to non-durable category with little variation between different species.

Table 3: Result of the Analysis of Variance for Weight Loss of Laminated Bamboo Board Samples

Source of variation	Df	WL Sig.	WL
Thermal Treatment	3	0.000	69.873*
Laminate Thickness	3	0.000	7.039*
Thermal Treatment * Laminate thickness	9	0.221	1.369^{ns}
Error	64		
Total	79		

***** Significant at P= 0.05, **ns** not significant at P=0.05

4. Conclusion

The study showed that durability was influenced by laminate thickness and thermal treatment. The study revealed that as laminate thickness increased with thermal treatment, weight loss decreased.

The study showed that thermal treatment of laminated bamboo boards will enhanced bamboo board durability against fungi. Also, using higher laminate thickness in producing boards will make the boards more durable.

The study further showed that the durability test of the laminated bamboo samples thermal treated at 140^{0}C (constant) for 8hrs were moderately resistant (class III) while those treated for 4hrs, 6hrs and untreated fell into the susceptible class (class IV). The laminate thickness of 4mm, 6mm, 8mm and 10mm belongs to class IV decay resistance class.

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