Available online at www.equijost.com

Equity Journal of Science and Technology, 2021 8(2): 1 - 6

ISSN 2354-1814; E-ISSN 2683-5961

EQUIJOST

An Official Publication of Kebbi State University of Science and Technology, Aliero, Nigeria

Termite Resistance of Thermally-Modified Wood of *Bambusa vulgaris*

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Received: July 12, 2021: Accepted: October 23, 2021; Published Online: October 23, 2021

Abstract

Preservative treatment of wood is important to extend its service life. Bamboo can serve alternatively as timber in structural applications. However, without preservative treatment, bamboo is not durable due to its lack of natural resistance to the biodegradable agent. This paper reported findings of a study on the durability of thermally modified *Bambusa vulgaris* through Ground Contact Test (GCT) using Timber graveyard. Bamboo strips of 30 cm x 2 cm x 0.5 cm were used. Thermal treatment was conducted in vertical pressure steam sterilizer (Model LS B50L-I® and JSA-100®). A completely randomized factorial design was employed. Bamboo strips were subjected to thermal modification at varying temperature and time durations (untreated, 100, 110, 120, 130 and 140 °C each, for 10, 20 and 30 min) for base, middle and top sampling height, with 3x3x6 experimental design resulting into 54 treatments combination. The weight loss of untreated samples were 15.29 ± 8.60% and 28.2 ± 14.1% for 6 and 12 months, respectively, while weight loss mean of 13.87±2.34 and 25.1±2.9% were reported at the maximum treatment temperature and time (140 °C/30 mins) for 6 and 12 months respectively. Despite the fairly significant effect of thermal modification on thermally modified samples in respect to termite resistibility, thermally modified bamboo is not effectively suitable for ground contact uses except with a concrete basement, notwithstanding thermally modified bamboo-Glulam can be relevant in the structural usage such as flooring, wall paneling, chopping boards, tooth pick and furniture.

Keywords: Termite Resistance, durability, service life, Thermal modification, weight loss, *Bambusa vulgaris*

1. Introduction

Wood biodegradation caused by biodegradable agents is identified as one of the major problems in the wood industries. Insects such as termites and wood-borers affect the wood both in service and in the forest. Although, this phenomenon has been widely addressed by various chemical preservatives, limitations exist on its environmental acceptability.

In recent times, the use of bamboo as a substitute for wood is on the increase; however, bamboo is easily attacked by fungal and insect infestation. The wood properties of bamboo also deteriorate rapidly if the material is not treated with preservatives [1]. Therefore, the use of preservative in bamboo has been recognised as necessary if it has to be considered for utilization in furniture and construction purposes.

However, the use of preservatives is not always effective as bamboo is not easily treated [1]. Bamboo is a natural material of organic origin; without any protective treatment, its durability is less than five years. Unlike other varieties of timber which are naturally durable, bamboo structure is void of toxic deposits. The presence of starch makes it more attractive to microorganism. Thus, biological degradation can affect the usage, strength, utility and value of the bamboo [2,3]. Notwithstanding, bamboo is one of the most important non-timber species which abundantly grows in most tropical and subtropical zones [4]. Since the 20th century, bamboo has received increasing attention for industrial applications, especially as raw material for wood-based composites because of its fast-growing nature, high productivity, quick maturity and high strength with an advance in processing technology and increased market demand [4, 5].

Thermal modification is an environmentally friendly wood treatment and preservative technique. It has an advantage over toxic chemicals that affect human beings and animals; hence, thermal treatment is found to be a reliable alternative wood-preservation technique [6]. Thermal modification improves the durability and dimensional stability of wood [7, 8]. This study was therefore conducted to determine the effect of thermal

https://dx.doi.org/10.4314/equijost.v8i2.1

modification on the termite resistance of *Bambusa vulgaris.*

2. Materials and Methods

2.1 Thermal treatment of bamboo samples

Bamboo strips of 30 cm x 2 cm x 0.5cm cm were produced. They were air-dried at indoor conditions until the moisture content value ranged between 20 to 25%. Thermal treatment was conducted at the Biotechnology Department of National Institute of Horticulture, Ibadan inside a Vertical pressure steam sterilizer (Model LS B50L-I® and JSA-100®). The autoclave is equipped with a close stainless-steel basket (240 x 190 mm in diameter and height, respectively) and a microprocessor, which permitted the programming of various times and temperatures (100 – 140 °C). The maximum capacity of the autoclave was 50 L under constant pressure (220 N/m^2).

2.2 Determination of the durability study of thermally modified Bambusa vulgaris

The durability test was carried out at Forestry Research Institute of Nigeria, Ibadan, Oyo State. The bamboo samples for this test were taken from thermally modified bamboo strips described earlier. The laminated boards were converted into 20 mm x 20 mm x 370 mm stakes. This test was conducted based on ASTM- D 1758-74 [9] procedure with some modifications 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 (Plate 2.1). The test stakes were exposed to the decay hazard as well as termites; *Macrotermes spp*, a native of subterranean termites, were identified on the site. The stakes were installed during the raining season in April, 2015. The testing site for the Timber graveyard study was at Forestry Research Institute of Nigeria (FRIN), Ibadan, Oyo State (Plate 2.1). The Institute is located on longitude 3.51°E and 7.23°N. There are two distinct seasons: the raining season from April to October and the dry season from November to March. The dry season is accompanied by the harmattan (dry weather) in December. Based on 2010 weather data issued by the Meteorological Information centre of FRIN, the annual rainfall, mean temperature and relative humidity are 1702.5 mm, 24.8 - 32.2 °C, and 76.4%, respectively.

The first inspection of the stakes was done 6 months (September, 2015) after installation and some replicated treatment samples were exhumed and the weight and percentage weight loss were calculated accordingly (Plate 2.2a). The second set of treated samples were exhumed in March 2016, 12 months after their installation. The samples were examined and recorded (Plate 2.2b). The criteria for testing was based on weight loss experienced by the stakes. The stakes were oven dried before and after the ground contact tests in line with literature [10]. Percentage weight loss of the samples were used to determine the effect of thermal treatment on the durability of the *Bambusa vulgaris.*

2.3 The experimental design and Statistic analysis adopted for the experiment was Completely Randomised Design (CRD) with five replications. The experiment was a factorial experiment with 3x3x6 experimental design resulting into 54 treatments combination. Duncan Multiple Range Test (DMRT) was used to separate the treatment means where significant differences occurred in the ANOVA.

Plate 2.1: Thermally modified and untreated bamboo stakes on the field for Ground contact test in Timber graveyard.

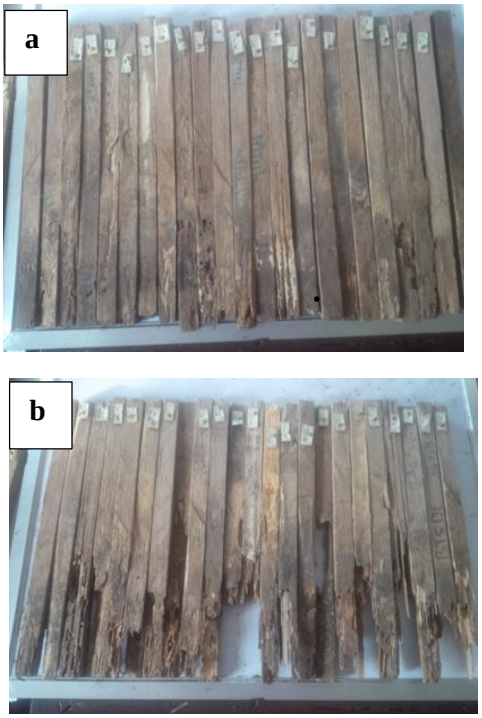

Plate 2.2: (a) Bamboo test samples after six months of Ground contact test in Timber graveyard (b) Bamboo test samples after 12 months of Ground contact test Timber graveyard.

3. Results and Discussion

Table 3.1: Mean value of Ground Contact Test using Timber graveyard weight loss for 6 months for untreated and thermal modified *Bambusa vulgaris*

Treatment temperature (℃)	Treatment time (min)	Sampling Base	Height Middle	Top	Pooled Mean
0 (Untreated)	Untreated	20.59±11.98	18.53±10.94	6.75±2.89	15.29±8.60ab
100	10	26.49±2.24	33.59±8.94	43.45±3.24	34.51±4.81b
	20	22.17±2.04	22.48±1.48	36.59±2.80	27.08±2.11a
	30	20.91±6.51	26.02±8.68	31.42±0.97	26.11±5.39a
	Mean	23.19±3.60	27.36±6.37	37.15±2.34	29.23±4.10e
110	10	20.06±3.34	22.36±5.44	28.64±0.80	23.69±3.19b
	20	18.71±3.49	21.36±5.31	25.91±1.38	21.99±3.39a
	30	15.61±2.38	16.25±2.84	23.22±0.49	18.36±1.90a
	Mean	18.13±3.07	19.99±4.53	25.92±0.89	21.35±2.83d
120	10	26.81±16.39	19.33±6.53	21.59±0.42	22.58±7.78b
	20	19.80±15.15	17.62±6.12	20.97±0.35	19.46±7.21a
	30	16.24±3.53	16.67±3.15	19.97±0.36	17.63±2.35a
	Mean	20.95±11.69	17.87±5.27	20.84±0.38	19.89±5.78cd
130	10	16.38±2.18	19.78±2.49	18.85±0.49	18.33±1.72b
	20	22.10±6.37	17.62±1.26	17.71±0.20	19.15±2.61a
	30	18.66±6.00	16.83±0.98	17.19±0.28	17.56±2.42a
	Mean	19.04±4.85	18.08±1.58	17.92±0.33	18.35±2.25bc
140	10	13.04±2.15	13.38±1.72	15.85±0.26	14.09±1.37b
	20	16.01±11.39	18.66±10.55	15.32±0.48	16.66±7.47a
	30	12.72±3.13	14.59±3.70	14.31±0.18	13.87±2.34a
	Mean	13.92±5.56	15.54±5.32	15.16±0.31	14.88±3.73a
	Pooled mean	19.30±8.59a	19.56±7.70ab	21.27±9.02c	20.05±8.47

Mean with same superscript in the column are not significantly different (P<0.05)

3.1 Six months in Ground Contact Test in Timber graveyard *percentage weight loss*

The mean values of the percentage weight loss for six (6) months ground contact test in Timber graveyard are presented in Table 3.1. The average mean values of weight loss for 6 months of thermally modified *Bambusa vulgaris* range at base from 23.19 to 13.92%, from 27.36 to 15.54% for middle and from 37.15 to 15.16% for top, at temperature level treatments; 100, 110, 120, 130 and 140°C with respect to time 10, 20 and 30 min respectively. The result of analysis of variance indicated that there were significant differences in the temperature variation (°C) and treatment time (min) except in sampling height.

Also, there was no significant difference among the interactions effect except between sampling height and temperature variation (°C), as shown in Table 2.1.

Table 3.2: Analysis of Variance (ANOVA) of percentage Ground Contact Test weight loss for 6months for thermal modified and untreated *Bambusa vulgaris* samples

Source of variation	Df	Sum of square	Mean of square	F-cal	P-value
Sampling height	2.00	205.19	102.59	2.70^{ns}	0.07
Temperature variation (°C)	5.00	5749.44	1149.89	30.23^{*}	0.00
Treatment time (min)	2.00	660.71	330.36	8.69^{*}	0.00
Sampling height * Temperature variation (°C)	10.00	2787.66	278.77	7.33^{*}	0.00
Sampling height * Treatment time(min)	4.00	99.73	24.93	0.66^{ns}	0.62
Temperature variation (°C) * Treatment time (min)	10.00	678.34	67.83	1.78^{ns}	0.07
Sampling height * Temperature variation (°C) * Treatment time (min)	20.00	890.67	44.53	1.17^{ns}	0.28
Error	216.00	8215.83	38.04		
Total	270.00	127783.80			

*=Significant at P<0.05

ns= not significant at P>0.05

The result of this study revealed the increasing percentage mass loss values in the timber Ground Contact Test for six months of thermal modified *Bambusa vulgaris*. The highest mean value (20.59%) was recorded at the untreated base samples, while the least values (13.92%) was also recorded at thermal modified

base samples at 140 °C/30 min. This result is in accordance with the reports of Kaul *et al* [11] and Ashaari & Mamat [12].

Kaul *et al* [11] reported on the decay resistance of bamboo modified with plant extracts and oil cakes. A weight loss of 65% was observed in the untreated blocks of the bamboo, which is higher than that observed for all samples treated with either plant extracts or oil cakes.

Moreso, Ashaari and Mama [12] reported their work on the resistance towards white rot fungus and durability of two Malaysian bamboo species (*Dendrocalamus asper* and *Bambusa vulgaris)*. They reported 35-53% mass loss at the end of 6-months Ground Contact Test in the untreated both species samples while 14-20% weight loss was recorded at treated of both species' samples. This is as a result that those termites depend merely on cellulose rather than starch for source of food [13]

3.2 Twelve months Ground Contact Test in graveyard percentage weight loss

The average mean value of the percentage weight loss for 12 months graveyard test is presented in Table 3.3.

Table 3.3: Mean value of Ground contact test with Timber graveyard weight loss for 12 months for untreated and thermal modified *Bambusa vulgaris*

Temperature variation (ºC)	Treatment time (min)	Sampling Base	Height Middle	Top	Pooled Mean
0	Untreated	37.33±22.12	31.67±13.97	15.65±6.02	28.21±14.04a
100	10	60.74±20.11	62.07±16.91	85.60±5.86	69.47±14.30c
	20	42.74±3.95	48.34±11.15	71.95±4.82	54.34±6.64b
	30	43.61±7.42	52.38±11.67	60.87±2.28	52.28±7.12a
	Mean	49.03±10.49	54.26±13.24	72.81±4.32	58.70±9.35d
110	10	35.16±9.74	35.44±6.41	55.54±1.63	42.05±5.93c
	20	37.00±5.67	45.99±12.21	50.58±1.87	44.52±6.58b
	30	27.99±0.81	29.56±2.84	44.61±0.87	34.05±1.51a
	Mean	33.39±5.41	37.00±7.15	50.24±1.46	40.21±4.67c
120	10	41.58±24.94	37.89±12.37	41.55±1.12	40.34±12.81c
	20	49.60±34.01	34.04±11.55	40.16±0.37	41.27±15.31b
	30	30.23±7.21	32.35±5.62	38.28±0.58	33.62±4.47a
	Mean	40.47±22.05	34.76±9.85	40.00±0.69	38.41±10.86bc
130	10	31.17±4.08	35.18±6.17	36.28±0.88	34.21±3.71c
	20	36.50±10.95	34.89±3.60	33.94±0.58	35.11±5.05b
	30	39.93±14.04	32.57±1.39	32.94±0.42	35.15±5.28a
	Mean	35.87±9.69	34.21±3.72	34.39±0.63	34.82±4.68a
140	10	26.19±5.37	25.40±3.22	30.55±0.89	27.38±3.16b
	20	31.32±21.24	35.67±19.95	29.55±0.23	32.18±13.81
	30	21.92±3.96	25.87±4.32	27.35±0.26	25.05±2.85
	Mean	26.48±10.19	28.98±9.16	29.15±0.46	28.20±6.61
	Pooled mean	37.09±17.34a	36.81±13.65a	41.34±17.61c	38.41±16.37

Mean with same Superscript in the same column is not significantly different (P<0.05)

The average mean values of weight loss for 12 months of thermal modified *Bambusa vulgaris* range at base from 49.03 to 26.48%, from 54.26 to 28.98% for middle and from 72.81 to 29.15% for top, at temperature level treatments; 100, 110, 120, 130 and 140°C with respect to time 10, 20 and 30 minutes, respectively. The results of the analysis of variance indicated that there were significant differences in all the factors considered; also there were significant differences among interaction effect except between sampling height and treatment time (min) and among sampling height, temperature variation(°C) and treatment time (min) .(Table 3.4)

Table 3.4: Analysis of Variance (ANOVA) of percentage Ground contact test with Timber graveyard weight loss for 12 months for thermal modified and untreated samples

Source of variation	Df	Sum of square	Mean of square	F-cal.	P-value
Sampling height	2.00	1156.01	578.00	4.79*	0.01
Temperature variation(ºC)	5.00	27014.82	5402.96	44.78*	0.00
Treatment time(mins)	2.00	2758.21	1379.11	11.43*	0.00
Sampling height * Temperature variation(ºC)	10.00	8232.01	823.20	6.82*	0.00

Table 3.4: *Cont.*

Source of variation	Df	Sum of square	Mean of square	F-cal.	P-value
Sampling height * Treatment time (min)	4.00	312.90	78.23	0.65^{ns}	0.63
Temperature variation (℃) * Treatment time (min)	10.00	3644.19	364.42	3.02*	0.00
Sampling height * Temperature variation (℃)	20.00	2919.74	145.99	1.21^{ns}	0.25
Error	216.00	26062.42	120.66		
Total	270.00	470528.20			

*=Significant at P<0.05
ns= not significant at P>0.05

This result revealed a decreasing pattern of the thermally modified *Bambusa vulgaris* from top to base, although least percentage weight loss values were recorded at base samples, which were treated at a temperature of 140°C for 30min (25.05±2.85%). According to the results in this study, the treated samples between temperatures of 100 and 120°C had higher values of percentage mass loss due to termite infestation compared with the control samples. This report is in contrary to the report of [12]

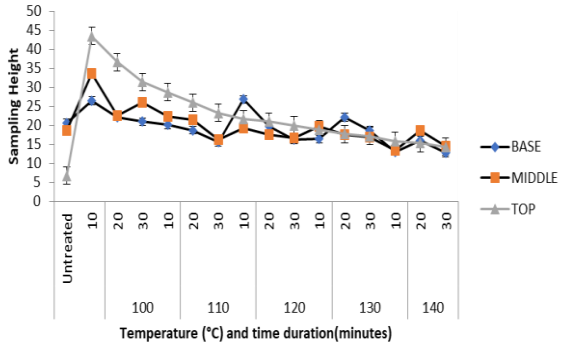

Figure 3.1: Thermal modified and untreated samples under Timber Ground Contact Test for 6 months

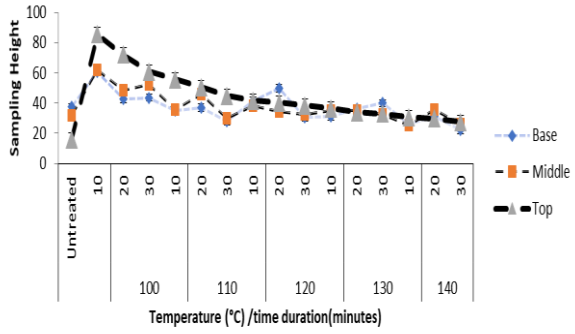

Figure 3.2: Thermal modified and untreated samples under Timber Ground Contact Test for 12 months

Figures 3.1 and 3.2 above showed the pattern of mass loss in Ground contact test with Timber graveyard for 6 and 12 months of thermal modified *Bambusa vulgaris*, respectively. The weight percentage reduced consistently along the bamboo culm from base to top in untreated samples while the highest weight loss in the thermal modified samples was recorded in the middle, followed by top and base samples for 6-months GCT. The highest weight loss in the thermal modified samples was recorded at the top, followed by middle and base samples for 12 months GCT, respectively. It seems that steam-modified bamboo does not have enough resistance for ground-contact uses. According to the result in this experiment, thermal modified base samples of *Bambusa vulgaris* was most resistant to termite attack although not promising for ground-contact uses. Visual observation revealed that the samples of 12-months GCT were more degraded than the samples of 6 months (see Plate 2a&b).

4. Conclusion

The results indicated that the high-temperature thermal modification has the potential to improve termite resistance. Long heating time and high temperatures increase significantly the cost of the process. Any reduction in the duration of the thermal process without any deterioration of bamboo quality saves energy and increases productivity. Further studies should be encouraged to determine the effect of weathering on thermal modified *Bambusa vulgaris*. It is not advisable to use thermal modified bamboo for prolong exterior usage as it has poor resistance to termite attack, and should be discouraged in the application in load bearing construction.

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