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ASSESSMENT OF THE RESISTANCE OF *Bambusa vulgaris* Schrad TREATED WITH CASHEW NUT SHELL LIQUID AGAINST FUNGI AND TERMITE DETERIORATION

Babajide Charles FALEMARA *
PhD Student - Federal University of Technology, P.M.B. 704, Akure, Ondo State, Nigeria
Department of Forestry and Wood Technology
E-mail: fbabajide@gmail.com

Nike Osekafoire OLATUNBOSUN
MSc Student - Ahmadu Bello University, P.M.B. 1045, Zaria, Kaduna State, Nigeria
Department of Geography
E-mail: osekaola@gmail.com

Habiba Usman LAWAL
Federal College of Forestry, P.M.B. 2019 Jos, Plateau State, Nigeria
Department of Forestry Technology
E-mail: charles_jide@yahoo.com

Abstract:
The study investigated the effect of cashew nut shell liquid on the decay resistance of Bambusa vulgaris against brown rot fungi, white rot fungi and termite attack. The extraction of cashew nut shell liquid (CNSL) was done by using soxhlet extractor method. The treated bamboo samples were subjected to fungi and termite activities for a period of 12 weeks after which percentage preservative absorption and weight loss were assessed. A 3 x 5 factorial experiments in Complete Randomized Design (CRD) was adopted for the study. Data obtained were subjected to Analysis of Variance. The result obtained revealed that undiluted cashew shell nut liquid extract had the highest (22.70%) volume of preservative absorption by the bamboo, while diluted CNSL+kero (1:3) indicated the least quantity (10.95%) of bio preservative absorb by bamboo. The hot treatment technique enhances deep penetration and absorption of the preservative chemicals into the bamboo wood samples. Untreated bamboo wood had the highest weight loss (42.7%), followed by CNLE Extract (Undiluted) bamboo treated wood samples (15.7%) while solignum (undiluted) bamboo treated wood samples had the least weight loss of 13.0%. Bamboo wood treated with undiluted solignum chemical and subjected to brown rot fungi had the least weight loss (7.6%). The undiluted CNLE extract and untreated bamboo wood had a weight loss of 17.0% and 30.6%. The untreated bamboo wood subjected to white rot fungi had the highest weight loss (28.4%) while bamboo wood treated with undiluted solignum had the least weight loss of 12.6%, followed by samples treated with undiluted CNLE (15.6%). The statistical analysis further revealed that the preservative treatments had significant effects (p=0.001) on the weight loss observed on the bamboo wood, while the interaction between the agents of decay and the preservative treatments was not significantly different (p=0.778). The high termite susceptibility and fungal decay as revealed by the control (untreated) in this study showed that the bamboo wood is not durable, consequently, there is need for preservative treatment to extend its service life.

Key words: *Cashew Nut Shell Liquid; bamboo; fungi; termite; deterioration.*

INTRODUCTION

Bamboo is a fast growing woody grass of increasing interest for the sustainable production of materials with many applications for buildings and industrial utilization. However, bamboo has generally a low natural durability and is easily attacked by fungi during storage, transport and final use. Previous research showed that the use of bamboo as an alternative material has the same problem with the wood. Like other lignocellulose materials, bamboos are subject to biodegradation by fungi under particular conditions which affects their quality (Hamid *et al*. 2003). The behaviour of bamboo against decay fungi is an important parameter in bamboo establishment and use. Bamboo is not durable, it means the use of bamboo is often degraded by biotic factors such as fungi and insects, and abiotic factors such as drying stresses and environmental conditions. This causes make the lifetime of bamboo is short (Prinindya and Ardiansyah 2014). Bio-deterioration in bamboo are known to be caused by different types of microbiological destroying organisms (Gunnar *et al*. 2002). Decay is by far the most serious kind of microbiological damage since it can cause structural failure. To prevent or retard the development of decay in bamboo, preservative treatments are normally applied (Wahab *et al*. 2007).

* Corresponding author

In addition, much concerns have been raised on the use of synthetic chemicals in wood preservation due to their unavailability, cost, toxicity and negative environmental impacts (Tiilikkala *et al*. 2010). This has prompted intense research globally into the development of novel efficacious botanicals in controlling the actions of bio-degrading organisms on wood (Thlama *et al*. 2012; Malami *et al*. 2015; Falemara *et al*. 2015). Looking at detrimental effects of these synthetic chemicals available in the market it is imperative to search for alternative. A potential strategy in the search for alternative preservatives against fungal decay is to target the decay process, without causing any detrimental effect to the environment (Salim *et al*. 2009). These have led to recent global increase in the recommendation of more environmental benign, safer and cheaper means of realizing this goal, a very good example of which is the utilization of natural extracts from plants for this purpose (Erakhrumen 2012).

Green plants have been discovered to be reservoirs possessing inexhaustible harmful fungicides/pesticides that are innocuous to man when compared to their synthetic counterparts (Venmalar and Nagaveni 2005). As such, the course of exploring the potentials of plants in the development of wood biocides has been vigorously pursued over the years (Ogunsanwo and Adedeji 2010; Ajala *et al*. 2014). The need thus arises to protect bamboo and bamboo products prior to utilization so as to extend its service life. This therefore necessitated the study to assess the resistance of *Bambusa vulgaris* treated with cashew nut shell liquid against fungi and termite deterioration.

MATERIALS AND METHOD

Preparation of Samples

The experiment was carried out in Federal College of Forestry Jos, Plateau State Nigeria. The bamboo culms was harvested from Shere hills forests, Jos and cut into sample size of 20mmx60mm for fungi decay test (Fig. 1a), and 25mmx600mm for the termite field test (Fig. 1b). The bamboo samples were dried in an oven for 24 hours at 103±2^{0}C. This weight was recorded as T1. Cultured brown rot fungi (*Sclerotium rolfsii*) and white rot fungi (*Pleurotus sajorcaju*) species were procured from the Pathology Department at Forestry Institute of Nigeria, Ibadan, Oyo State. The cashew nut shells were collected, dehulled, air dried and pulverized into powder.

Extraction from cashew nut shell liquid

The extraction of the cashew nut shell liquid was done by using the soxhlet extractor procedure of Gandhi *et al*., (2013). Five hundred milliliters of ethanol solvents was charged into the round bottom flask of soxhlet apparatus. 50g of crushed cashew nut shell was charged in to the thimble and fitted into the soxhlet extractor. The solvent in the set-up was heated to its boiling point and the vapors produced were subsequently condensed by water flowing in and out of the extraction set-up. This process of heating and cooling continued until a sufficient quantity of CNSL was obtained. At the end of the extraction, the thimble was removed while the remaining solvent in the extractor was recharged into the round bottom flask for a repeat of the process. Finally, the set-up was then re-assembled and the solvents were recovered from a simple distillation method. The process was repeated 5 times in which 400g of the Cashew Nut Shell (CNS) was used to produce 40g of the CNSL (Fig. 1c).

Preparation of Preservatives and Treatment of Bamboo Samples

The preservatives were formulated by using the volume-to-volume method employed Owoyemi *et al*. (2011) and Adenaiya *et al*. (2016). The formulation involved the following; T_1: 1:0 (650mls of undiluted CNSL); T_2: 1:1 (650mls of CNSL + 650mls of Kerosene (Diluent)); T_3: 1:3 (650mls of CNSL + 650mls of Kerosene (Diluent)); T_4: Creosote (Solignum (undiluted) and T_5: control (no chemical formulation). All bamboo samples (excluding the control) were hot dipped at 100^{0}C and heating was discontinued after 6 hours, allowing the bamboo samples and the preservative to cool together for 24hours after which they were drained of excess preservatives on a wire mesh and the treated weight was recorded as T2.

a

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b

c

Fig. 1.
a - Bamboo Samples for Fungi Exposure; b - Bamboo Samples for Termite Exposure; c - Extract and Preservative Chemical Formulation.

Experimental Study I: Fungi Exposure

Treated bamboo samples were transferred into sterilized plastic containers containing culture fungi. Additionally, untreated samples were also used in the process to determine the efficacy of treatment. After 12 weeks of exposure to fungi, the adhering mycelium was cleaned softly with a brush, and the samples were weighed, oven dried and weighed till constant weight was obtained (Fig. 2-4). Based on the average percentage weight loss of samples by fungal attack, the decay resistance of bamboo was determined based on class (Martawijaya 1975) and expectancy of service life (Seng 1990) as shown in Table 1.

Table 1

Classification of Bamboo resistance based on the weight loss by the fungal and termite attack

Average weight loss (%)	Decay resistance	Resistance class	The expectancy of service life (years)*
None or negligible	Very resistant	I	≥8
<5	Resistant	II	6-7
5 – 10	Moderately resistant	III	4-5
10 – 30	Non-resistant	IV	2-3
≥30	Perishable	V	<2

Source: Martawijaya, (1975) and *Seng 1990

Experimental Study II: Termite Exposure

The termite exposure was based on the procedure of American Wood Protection Association (AWPA E21-11, 2012). Treated bamboo wood samples were installed in the timber graveyard with spacing of 50 cm in-between stakes. The samples were placed vertically in the soil leaving half of the length exposed for exposure to termite degradation in the ground condition. After 12 weeks period of exposure, the wood samples was removed, thoroughly cleaned with a brush to remove all soil material, oven dried and weighed. The percentage weight loss was calculated and the ratings for classification was confirmed (Table 1; Fig. 5-6).

Fig. 2.
Fully Colonized Brown and White Rot Treated and Untreated Bamboo Wood after 12 weeks of exposure.

Fig. 3.
Brown rot exposed treated and untreated bamboo wood with fungi mycelium after 12 weeks.

Fig. 4.
White rot exposed treated and untreated bamboo wood with fungi mycelium after 12 weeks.

Fig. 5.
Installed Bamboo Samples in Timber Graveyard for Termite Exposure.

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Fig. 6.
Termite Exposed treated Bamboo wood after 12 weeks.

Parameters Assessed
Percentage Preservative Absorption and Weight Loss

The percentage absorption of the preservatives was estimated using equation 1. The extent of fungal attack was determined by weight loss using equation 2. The ratings for classification of wood into various resistance classes from a natural durability standpoint was based on per cent weight loss caused by the test fungi (Table 1).

$$\% \text{ Absorption} = \frac{T_2 - T_1}{T_1} \times 100 \quad (1)$$

$$\% \text{ Weight loss} = \frac{W_i - W_f}{W_i} \times 100 \quad (2)$$

where:
T_1 = Treated weight; T_2 = Oven-dry weight; W_i = Weight of oven dried wood block before fungi/termite exposure; W_f = Weight of oven dried wood block after fungi/termite exposure.

Experimental design and Statistical Analysis

The experiment was 3 x 5 factorial experiments in Complete Randomized Design (CRD) consisting of three agents of bio deterioration (Termite, White rot and Brown Rot fungi) and five preservative treatments (undiluted CNSL, CNSL+kero (1:1), CNSL+kero (1:3), Solignum and Control (untreated)) replicated five times. Data obtained were subjected to analysis of variance for significant differences and where significant differences existed, Duncan Multiple Range Test (DMRTs) was used comparison.

RESULTS AND DISCUSSION
RESULTS
Percentage Preservative Absorption (%)

The result of the effects of the preservatives treatment on preservative absorption (%) as presented in Fig. 7 revealed that undiluted CSNL extract had the highest (22.70%) volume of preservative absorption by the bamboo. This is followed by undiluted solignum and diluted CNSL+Kero (1:1) indicating 16.25% and 12.13% respectively. Diluted CNSL+kero (1:3) indicated the least quantity (10.95%) of bio preservative absorb by bamboo. The statistical analysis revealed that there were significant differences between undiluted CNSL and CNSL+Kero (1:1); undiluted CNSL and CNSL+Kero (1:3); undiluted CNSL and undiluted solignum; CNSL+Kero (1:1) and undiluted solignum; and between CNSL+Kero (1:3) and undiluted solignum on percentage preservative absorption by the bamboo. On the other hand, no significant difference between CNSL+Kero (1:1) and CNSL+Kero (1:3) on percentage preservative absorption by the bamboo (Fig. 7).

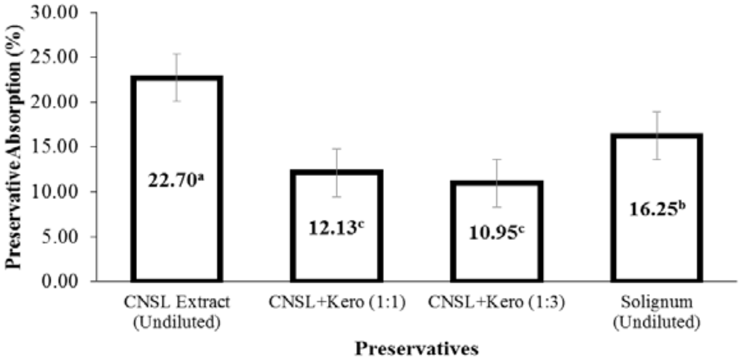

Fig.7.
Effects of the Preservatives Treatment on Preservative Absorption (%) of the Bamboo
Means in the same bars having the same superscripts are not significantly different (p≤0.05).

Percentage Weight Loss (%)

Mean effects of agents of decay on weight loss of the bamboo wood after 12 weeks of exposure (Fig. 8) revealed that bamboo wood samples exposed to termite deterioration that the highest weight loss of 23.53%, followed by bamboo wood subjected to brown rot decay fungi (20.40%) and white rot decay fungi (20.28%). The result of the mean effects of preservative treatments on weight loss of the bamboo (Fig. 9) showed that the untreated bamboo wood had the highest weight loss (33.89%) as attacked by the bio deteriorating agents. Bamboo wood treated with undiluted solignum had the lowest percentage weight loss (11.07%). The statistical analysis revealed there were no significant differences (p≥0.05) between the undiluted CNLE extract and CNLE+Kero (1:1); undiluted CNLE extract and CNLE+Kero (1:3); undiluted CNLE extract and undiluted solignum; and CNLE+Kero (1:1) and CNLE+Kero (1:3) treatments on weight reduction of the bamboo wood. Conversely, there were significant differences (p≤0.05) between CNLE+Kero (1:1) and undiluted solignum; CNLE+Kero (1:5) and undiluted solignum; and undiluted solignum and untreated bamboo wood treatments on weight reduction of the bamboo wood.

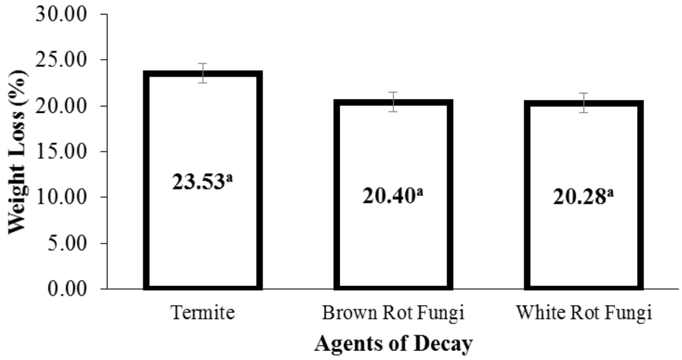

Fig. 8.
Mean Effects of Agents of decay on Weight Loss of the Bamboo Wood
Means in the same bars having the same superscripts are not significantly different (p≤0.05).

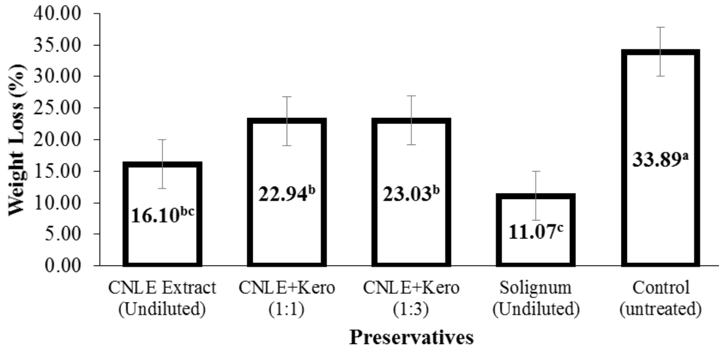

Fig. 9.
Mean Effects of Preservative Treatments on Weight Loss of the Bamboo Wood
Means in the same bars having the same superscripts are not significantly different (p≤0.05).

DISCUSSION

Percentage Preservative Absorption

The result of the study revealed that the percentage preservative absorption of the bamboo significantly ranged between 10.95% and 22.70% (Fig. 7). The maximum percentage preservative absorption indicated in this study is far less than maximum preservative absorption reported by previous researchers. Falemara *et al*. (2015) in their evaluation of the different treatment techniques on preservative absorption of obeche wood against fungi attack reported a maximum percentage preservative absorption of 97.29%, while Faruwa *et al*. (2015) reported a value of 113% for *Ceiba pentandra* and 128% for obeche when treated with tar oil, *Tridax procumbens* and *Parkia biglobosa* extracts. This occurrence can be attributed to the fact that outer skin of bamboo is composed of high amount of silica. This restricts the flow of preservative into the culm and makes it difficult to penetrate inside the waxy layer of bamboo (Janssen 2000). In addition, the absence of ray cells in bamboo restrain the flow of preservative to only the longitudinal direction. The radial flow of the preservative is hindered due to the refractory nature of bamboo culms. (Liese and Kumar 2003; Kaur *et al*. 2016). Owoyemi (2010) on the other hand attributed the wide contrast to the viscosity of the preservative. As posited by Adetogun (1998), the oily and viscous nature of CNSL requires the use of organic solvents for dilution to enhance absorption and penetration by wood. Conversely, the undiluted CNSL and creosote preservatives exhibited higher percentage preservative absorption than the kerosene solvent diluted CNSL bio preservative as similarly observed by Owoyemi *et al*. (2011). This trend reduces as the concentration of the active CNLS reduces because further dilution affected viscosity which in turn affected weight intake of the active ingredients. Consequently, the essence of the kerosene solvent is that it creates an hydrophobic environment inside and on the surface of the bamboo as well as prevents the leaching of preservatives by moisture penetration (Runumee *et al*. 2014) but not to aid absorption of preservative. The significant difference observed between CNSL and Creosote (Fig. 7) contradicts the findings of Owoyemi *et al*. (2011) who reported that there was no significant difference (p>0.05) between the absorption of both Creosote and CNSL despite the dilution with kerosene.

Percentage Weight Loss

The mean weight loss of the preservative treated bamboo wood ranged between 13.0% and 23.4% for termites, 7.6% and 24.8% for brown rot fungi and 12.6% and 23.4% for white rot fungi decayed bamboo wood (Fig. 8). The result of this findings laid credence to the observations of Wahab *et al*. (2007) who similarly reported mean weight losses of bamboo blocks ranging between 27.8% and 31.9%. Razak (1998) in his study on termite infested wood confirmed that termite attack on treated samples was low compared to untreated samples. He reported that the attack on untreated wood samples was considerably high as indicated by 64.52% weight loss compared to samples soaked in neem oil extract having a weight loss of 24.22%.

The observed low effect of kerosene diluted CNLE preservative is in line with the findings of Adenaiya *et al*. (2016) who reported that the kerosene diluent preservative was able to impart some form of inhibition to decay by the fungus. Its high weight loss compared to the other preservative treatments indicated that it was only able to impart a temporary fungal resistance on the wood samples. The effectiveness of the undiluted CNLE extract compared to the kerosene diluted CNLE extracts can be attributed to higher concentration of anacardic acid in the undiluted extract. As posited by Asogwa *et al*. (2007) cashew nut shell liquid is a complex mixture composed of anacardic acid constituted of cardanol (which has only one hydroxyl group attached to the meta-position of the ring) and larger percentage of cardol embedded with two hydroxyl functional groups. The additive functional groups, carboxylic and hydroxyl groups thus confer added functionality to this complex monomer. The reactive nature of CNSL constituents makes it an important material for insecticide formulation. Thus the effectiveness of the liquid extract against bio deteriorating agents.

The effectiveness of solignum treated wood compared to the undiluted and diluted CNLE extract against the bio deteriorating agents as reported in this study collaborate with the study of Owoyemi *et al*. (2011). They reported that the mean weight loss of CREO treated samples ranged between 54.2% and 76.0% compared to the 86.7% weight loss indicated by the control (untreated) sample. The weight loss of CNSL treated samples on the other hand ranged between 80.0% and 85.0% compared with the 86.7% of control. They concluded that CREO treated samples provided a better protection against subterranean termites compared with CNSL treated samples. Furthermore, Owoyemi *et al*. (2011) asserted that *Gmelina arborea* treated with CNSL at three levels (undiluted; 1:1 kerosene and 1:3 kerosene) provided a minimal protection against termite attack as similarly observed in this study.

Falemara *et al.* (2015) reported a higher mean weight loss which ranged between 19.42% and 97.29% for Obeche wood after 12 weeks' fungal infestation. Chemical preservatives are greatly toxic to the environment (Nurudeen *et al*. 2012) as such plant extracts such as CNSL extract reported in this study are environmentally friendly bio preservatives coupled with their characterized low cost, low mammalian toxicity, ease of handling and treatment.

Bamboo wood samples exposed to termite deterioration that the highest weight loss of 23.53%, followed by bamboo wood subjected to brown rot wood decay fungi (20.40%) and white rot wood decay fungi (20.28%). These slight variations were not significantly different (p≥0.05) from each other (Fig. 8). Notwithstanding, the level of decay caused by termites were more than the decay caused by brown rot fungi, while white rot fungi had the lowest effect on weight loss. In addition, comparisons of the weight losses caused by the two fungi species revealed that the brown rot fungus (*Sclerotium rolfsii*) was more destructive than the white rot fungus (*Pleurotus sajorcaju*) though slightly variable. This observed occurrence corroborate divergent report findings on the virulence of brown rotters and white rotters. Adetogun *et al.* (2006), Goktas *et al*. (2007), Emerhi *et al*. (2008), Ogunsanwo and Adedeji (2010), Hamid *et al*. (2012), Falemara *et al*. (2015), Adenaiya *et al*. (2016) all reported higher virulence by brown rot fungi on wood than white rot fungi. This may be attributed to the fact that brown rotters degrade cellulose and hemicellulose in wood which are the major constituents of wood by proportion, compared to white rot fungi which degrade mainly lignin (Adenaiya *et al*. 2016). This observed variability of decay resistance can also be attributed to diversity of bamboo species and fungus origin as opined by Hamid *et al*. (2012). Li (2004) stated that the durability of bamboo against fungal attack was strongly associated with chemical composition, among others cellulose, lignin and pentosan. However, Venmalar and Nagaveni (2005) and Ajala *et al*. (2014) in their studies have contrary reports as they observed that white rot fungi were more virulent than brown rot fungi. In the study of Falemara *et al.* (2015), white rot fungi (*Pleurotus sajorcaju*) wreck more havoc than brown rot fungi (*Sclerotium rolfsii*) when subjected to obeche (*Triplochiton scleroxylon*) wood decay for twelve weeks though their level of decay were statistically not significantly different ($p \geq 0.05$). The mean weight loss of the control (Fig. 9) in this study for the termites (42.7%), brown rot fungi (30.6%) and white rot fungi (28.4) falls within the range of weight loss for perishable species (≥30%) to last for less than two years (except for value observed for white rot fungi) under the classification of wood resistance to bio deterioration (Table 1) as tabulated by Martawijaya (1975) and Seng (1990). This is contrary to the maximum of 3 years' service life of bamboo reported by Hamid *et al*. (2003) when in soil contact and Kaur *et al*. (2016) who found that untreated bamboo has a service life of only two to five years.

CONCLUSIONS

The study investigated and ascertains the level of percentage preservative absorption of the bio preservative by bamboo. In order for a preservative treatment to be effective three factors must be considered. The proper amount of preservative must be absorbed or forced into the wood to provide adequate toxicity, the quantity of preservative retained or present after treatment and deep penetration of the preservative in the wood. The hot treatment technique increased the penetration and absorption of the preservative chemicals into the bamboo wood samples.

The high termite vulnerability and fungal decay as revealed by the control (untreated) in this research study indicated that the bamboo wood is not durable, and as such requires preservative treatment to prolong its serviceable life or longevity. The findings of this study showed that bamboo species differ in their susceptibility to agents of bio deterioration. Termite caused more deterioration followed by brown rot fungi, while white rot fungi imparted the least level of deterioration on the bamboo wood.

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