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ALLEVIATING CLIMATE CHANGE EFFECT USING ENVIRONMENTALLY FRIENDLY PROCESS TO PRESERVE WOOD AGAINST BIODETERIAORATING AGENT

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ABSTRACT

Human generated climate change caused by deforestation is one of the serious issues' humanity is facing recently. Due to the effect of diminishing forest resources on climate change, it becomes indispensable to preserve the limited wood resources using eco-friendly preservation methods. Thus, this study aimed at modification of *Triplochiton scleroxylon* wood, with a view to increasing its durability. Sixty clear wood blocks, each with dimension of 20x20x60 mm were obtained from *Triplochiton scleroxylon*. After conditioning, the wood blocks were placed in a bioreactor containing acetic anhydride and acetylated at 120 °C for a varying time of 60, 120, 180, 240 and 300 minutes, whereas the unmodified blocks were used as control. The moisture content and weight percent gain (WPG) of the wood blocks were assessed using standard procedures. The acetylated wood was characterised by Fourier Transform-Infrared Spectroscopy. Wood blocks were exposed to termites in termite colony for 12 weeks. Analysis of variance was used to analyse the data at α 0.05. The WPG varied from 10.4% (60 minutes) to 22.7% (300 minutes). The durability of the acetylated wood was enhanced with the percentage weight loss ranging from 30.20±3.20 to 3.46±0.54. However, all treatments proved to be effective over control (44.32±6.3%).

Contribution/Originality: This study is one of very few studies which have investigated the chemical modification of *Triplochiton scleroxylon* to increase its durability against biodeterioration. In order to mitigate the effect of climate change caused by deforestation, limited wood resources must be preserved using environmentally friendly processes.

1. INTRODUCTION

In the 21st century, climate change is one of the serious problems humans and the environment are facing while greenhouse gases cause global warming after being released to and trapped in the atmosphere (IIPCC Climate Change, 2001). Various approaches are been used for climate change alleviation such as reducing the factors that triggers emissions of CO_2 (e.g. enhanced buildings insulation, expanding the use of renewable energy among others). In addition to all these, forest and wood products are known to play a vital role in carbon sequestration (Van der Lugt & Vogtländer, 2014). This is accomplished through the process of photosynthesis in which trees take up CO_2 from the atmosphere, and produces oxygen in return, and carbon are stored in their tissue and soil. After felling the trees, this carbon stored in wood products still remains until when the wood is burnt. This is further proof that forests, in which wood as the forest products play a vital role (both negative and positive) in the global carbon cycle as a result of deforestation, burning of forests for human activities which allows the net flow of carbon from the atmosphere into the forest ends likewise allow the release of the stock of carbon that has accumulated, forest conservation (reuse of wood, wood preservation), afforestation (massive regular tree planting) and increasing application of wood and enhancing its durability being the most important primary materials for construction, furnishing among others (UNECE/FAO, 2003).

In Nigeria like any other part of the world, the high demand with the export rate on tropical hardwood has called for illegal logging and this is because of its choice over softwood due its durability, hardness, and also dimensional stability. Therefore, other renewable solutions such as preserving wood against biodeteriorating agents are needed to reduce burden placed on tropical hardwoods (Van der Lugt & Vogtländer, 2014).

Wood is a chosen building material for many purposes thereby resulting to uncontrolled deforestation. Deforestation is an established universal environmental problem, bringing about prevalent loss of flora and fauna habitat, in addition to obstructing proper functioning of the ecosystem. Brown, Sathaye, Cannell, and Kauppi (1996) estimate that "deforestation contributes to 20-25 % of the current global anthropogenic CO_2 emissions." In the tropics, increasing rate of deforestation is caused majorly by the felling of juvenile's trees for constructions, furniture and other purposes leading to early wood decay. Hence, such wood must be treated to prevent decay and enhance their durability.

Conventional methods for preventing decay in wood are based on treating wood with toxic chemicals (Adegoke, Okanlawon, & Ajala, 2020) thus very efficient in protecting wood against decay but can result in environmental problems (Rowell, 2005). Modified wood could play an essential role in enhancing decay resistance thereby increasing service life of wood resulting in reduced deforestation.

It well documented that there is a connection between the moisture content and biodegradability of wood. Chemical modification decreases amount of moisture that is absorbed by wood from its environment and thus effective in preventing the biodeterioration agents. Hence, the reduction in moisture content as a result of after being modified chemically is the reason the modified wood is more decay resistant (Adebawo et al., 2016); (Adebawo., Ogunsanwo, & Olajuyigbe, 2020).

A number of wood modification techniques is available, such as thermal modification (treatment at low oxygen levels and high temperature) and chemical modification (reaction between hydroxyl groups in wood and chemical to change the components permanently). Example of such modification is acetylation, which is the most commonly known method. The wood modification involves changing the structure of the wood at molecular level to enhance wood properties, significantly the durability and dimensional stability (Adebawo et al., 2016; Adegoke et al., 2020; Van der Lugt & Vogtländer, 2014).

Acetylation is a well-known chemical reaction that has been experimented over times. It involves the reaction of wood with acetic anhydride, through which the cell wall's hydroxyl groups are replaced by acetyl groups. The acetyl groups are non-toxic and are inherently present in all woods, but the process of acetylation increases the acetyl content significantly to a higher level thereby enhancing the wood properties (Adebawo. et al., 2020). The coproduct of this reaction is acetic acid, also known as vinegar in its dilute form, which is being used extensively in various industries.

This research work, therefore, considered wood modification by acetylation and test its durability using ground contact test. This is to increase performance of non-durable wood species thus reducing pressure on tropical rainforests woods which in turns mitigating climate change.

2. MATERIALS AND METHODS

2.1. Preparation of Wood and Acetylation Procedures

Wood from a 22-year-old *Triplochiton scleroxylon* tree was used for this study. The wood was converted into

20 mm × 20 mm × 60 mm (radial × tangential × longitudinal) and wood blocks that are free from faults were selected. The moisture content (MC) of the wood blocks was determined by oven drying at 105±2 °C before chemical modification. The chemical modification of the wood specimens was achieved by introducing the wood samples (MC ~ 7%) into a stainless-steel reactor vessel containing the acetylation liquid. The pre-impregnation of the wood with the reagent, was done by setting the temperature at 25 °C and 10 -15 bar for 30 minutes. Then, the temperature of the reaction was set at 120 °C for 0, 60, 120, 180, 240 and 300 minutes according to our previous studies (Adebawo et al., 2016; Adebawo. et al., 2020).

2.2. Weight Percent Gain (WPG)

After acetylation, weight percent gain (WPG) of the wood were determined on the oven dry basis. The wood blocks were weighed, oven-dried at 105±2 °C until a constant weight is reached. Ten (10) replicates of treated and untreated specimens were used to determine the WPG. The average weight percent gain (WPG) was calculated using Equation 1 for each batch.

$$WPG\ (\%) = \frac{W_2 - W_1}{W_1} \times 100 \qquad (1)$$

Where,

W1 = Oven-dry weight of samples before treatment (g).

W2 = Oven-dry weight of samples after treatment (g).

2.3. FT-IR

The infrared spectra of chemically modified and unmodified woods were determined using an ATR with Perkin Elmer FT-IR spectrometer Frontier by accumulation of 64 scans at a resolution of 4 cm^{-1} at 600 - 4000 cm^{-1} according to previous reports (Adebawo et al., 2016).

2.4. Preparation of Test block for Termite Colony

A total of sixty samples with dimension 20 x 20 x 60 mm comprising of 10 replicates for each treatment (60, 120, 180, 240 and 300 minutes) and control samples were exposed to termites at termite colony at 0.5 m apart for three months using ground contact exposure; to evaluate termites degradation resistance (Emerhi, Adedeji, & Ogunsanwo, 2015).

2.5. Moisture Content and Weight Loss Determination

After three months of exposure to termite, the wood blocks were removed, conditioned and their moisture content and weight losses were determined using Equation 2 and 3.

$$\text{Moisture Content}\ (\%) = \frac{W_b - W_a}{W_a} \times 100 \qquad (2)$$

Where,

W_b = Weight of specimen before graveyard test.

W_a= Weight of specimen after graveyard test.

$$\text{Weight loss}\ (\%) = \frac{Wb - Wa}{Wb} X\ 100 \qquad (3)$$

Where,

W_b= weight of specimen before exposure to termite colony.

W_a= Weight of specimen after exposure to termite colony.

2.6. Statistical Analysis

Analysis of variance (ANOVA) was used to analysed data obtained. Treatment means were separated using the Duncan Multiple Range test at 95 % level of significance.

3. RESULTS AND DISCUSSION

3.1. FTIR

The IR of modified and unmodified *Triplochiton scleroxylon* wood is shown in Figure 1 which has also been reported in our previous work (Adebawo et al., 2016). The three prominent peaks seen in the acetylated wood which were obviously absent in the unmodified wood could be used to confirm the reaction between the acetic anhydride and OH groups in wood. The peaks are carbonyl (C=O) stretch region at (1738–1730 cm^{-1}), carbon–hydrogen (C-H) bond between 1375-1370 cm^{-1}, and carbon-oxygen (C–O) stretch at (1245-1000 cm^{-1}) (Jebrane, Pichavant, & Sèbe, 2011).

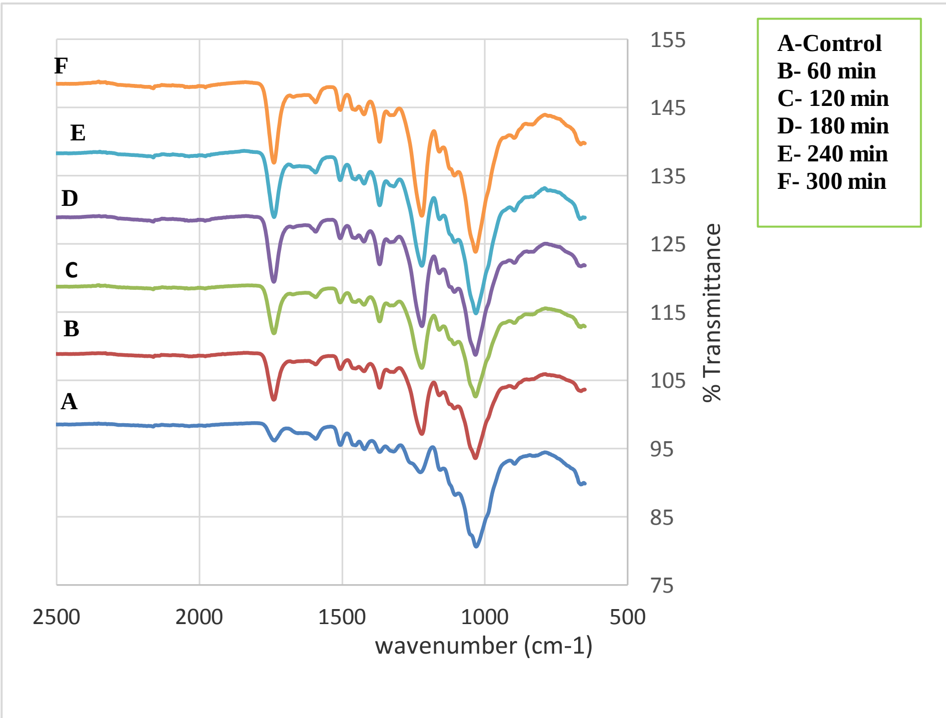

Figure-1. FT-IR (ATR) spectra of acetylated and untreated *Triplochiton scleroxylon* wood.

The stretch at carbonyl region at 1738-1730 cm^{-1} in all the acetylated samples indicates that some of the hydroxyl groups (-OH) in the wood has been changed with the acetyl groups. The intensity of these peaks increase due to increase in the reaction time (Blanco & Alfaro, 2014; Mohebby, 2008). The C-H stretch at 1370 cm^{-1} seen in the modified wood is due to deformation of methyl groups in cellulose and hemicellulose (Evans, Micehll, & Schmalzl, 1992). The C–O stretch region occurring at 1245-1000 cm^{-1} in acetylated samples is due to deformation of carbonyl in the ester bonds in lignin and xylan which also increases as the reaction time increases (Blanco & Alfaro, 2014; Mohebby, 2008). The stretch at this peak when compared to untreated samples confirms the esterification reactions between the acetic anhydride and the hydroxyl groups.

3.2. Moisture Content after Exposure to Termite

The moisture content of wood blocks after being exposed to termite colony is given on Figure 2. As observed in the graph, the untreated samples had the highest MC of 110.53 % while the acetylated samples ranged from 10.31 – 21.48 %. A reduced moisture content has been reported to enhance resistance of wood against decay in modified wood by inhibiting the diffusion of oxidative fungal metabolites. A moisture content below 23 – 25 % has been reported to inhibit decay in wood which also relates to the level of weight percent gain reported to protect modified wood from decay (Ringman, Beck, & Pilgård, 2019). According to Popescu, Hill, and Popescu (2016) during acetylation, the accessible OH-groups on the polysaccharides are replaced by acetyl groups, thereby reducing the number of OH-groups that are accessible at different sorption points. Recent studies revealed that there is a negative relationship between WPG and MC of modified wood which was authenticated by Passarini, Zelinka, Glass, and Hunt (2017) using differential calorimetry and low-field nuclear magnetic resonance.

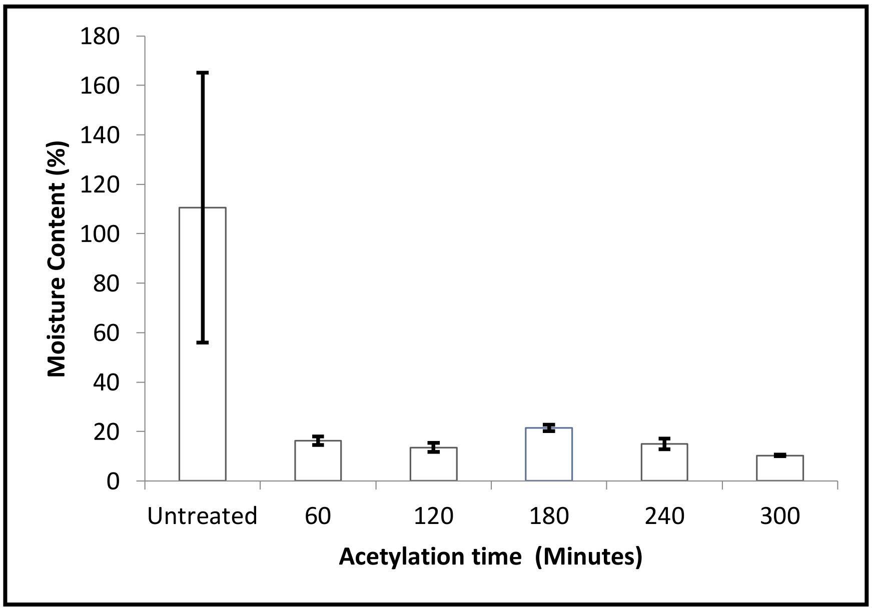

Figure-2. Moisture content of acetylated and unmodified *Triplochiton scleroxylon*

Precisely, it has been reported that there was a decrease in water, inside the cell wall of modified wood with increasing WPG (Beck, Thybring, Thygesen, & Hill, 2018). The reduction in level of water uptake of modified wood compared to untreated wood shown in Figure 2 could be due to substitution of hydroxyl groups with acetyl groups thereby reducing its affinity for water absorption. This has further been confirmed by Beck et al. (2018) who showed that acetylation reduces OH accessibility than what was expected if OH substitution was merely for accessibility reduction. This indicates that there is also reduction in the accessibility of water molecules to unmodified OH groups in acetylated wood due to stearic hindrance by acetyl groups.

3.3. Weight Percent Gain and Weight Loss

3.3.1. Weight Percent Gain (WPG)

WPG of *Triplichiton scleroxylon* wood blocks after acetylation with varying reaction time is presented in Table 1. Expectedly, the WGP increased with increasing reaction time as reported in our previous work (Adebawo et al., 2016).

Table-1. Weight Percent Gain (WPG) and weight loss of acetylated *Triplochiton scleroxylon*

Reaction time (Minutes)	WPG (%)	Weight loss (%)
Untreated	-	44.32 (6.3) [a]
60	10.37(0.9) [a]	30.20(3.2) [b]
120	14.09(1.27) [b]	21.00(2.7) [c]
180	18.37(0.52) [c]	15.849(3.3) [c]
240	19.06(0.85) [c]	6.49(1.2) [d]
300	22.74(1.42) [d]	3.46(0.5) [d]

Note: Means with the same superscript letters in the same column are not significantly different from each other at $\alpha = 0.05$ Standard deviations are in parenthesis.

The highest WGP was 22.74 % which was reached when the samples were left in the reaction mixture for 300 minutes while the lowest was found to be 10.37 % at 60 minutes reaction time. The WPG of other acetylated woods were found to be 14.09, 18.37 and 19.06 % at 120, 180, and 240 minutes respectively.

3.3.2. Weight Loss

The result for the weight loss after 12 weeks of exposure to termite by ground contact method is presented in Table 1. The highest weight loss was observed in untreated samples having 44.32 % while weight loss for the acetylated samples ranged from 3.46-30.20 %. The untreated blocks were attacked sternly, modified blocks at the lowest reaction time showed substantial attack, whereas modified blocks at higher WPGs exhibited gentle attack. There is a decrease in weight loss as the WPG increases. The time of reaction used has a great influence on the level of attack by the termite. The highest resistance to termite attack was observed in wood treated at 300 minutes with WPG of 22.74 % having weight loss of 3.4 %. In all acetylated wood blocks, the amount of wood loss was considerably lesser when measure up with unmodified wood blocks. At higher WPG, the termite degraded less wood. This result suggested that acetylated wood has low susceptibility to attack by termite. This is very close to the report of Papadopoulos, Avtzis, and Avtzis (2008) who reported highest resistance to termite at WPG of 24.1 %. They reported that termite could hardly attack acetylated wood leaving only marks of nibbling.

Termites have complex digestive system which modifies them to feeding on wood and to consume cellulosic substances (Watanabe & Tokuda, 2010). The ability of natural wood to resist termite attack differs as a result of varieties of extraneous compounds, hardness of the wood species and termite genera (Ewart & Cookson, 2014). In addition to wide range of properties of wood which might affect their resistance to termite, acetylated wood in this study, however, has a reduced moisture content when compared to untreated wood blocks. As suggested by (Rowell. & Dickerson, 2014) the resistance of acetylated wood to termites may be due factors such as reduced equilibrium moisture content, and increased hardness.

It is well established that wood decay hardly occurs by fungi, if such acetylated wood has achieved WPG of 20 % and above Adebawo. et al. (2020). Subterranean termites have the ability to transport water to wood being attacked, but only little water could be absorbed by acetylated wood and is believed to be tougher for biting than their unmodified counterparts. Termite species display different preferences for specific wood and in some cases prefer wood infected by specific fungi due to certain odours and reduced hardness. Due to exposure of the wood to organisms in the soil, they might as well be affected by fungi. Wood density differences could also be a factor why termites attack some wood species and leave others without attack.

The level of acetylation needed to prevent termite attack might also vary between the termite species. Yusuf (1996) found that lower acetylation levels were needed to prevent attack by *R. speratus* compared to *C. formosanus*. Other factors such as wood smell, may also contribute to lower rate of attack of acetylated wood by termites in test conditions.

4. CONCLUSION

The results from this study have shown that climate change could be mitigated by reducing deforestation using acetylation, an environmentally friendly process to preserve wood against biodeterioration. All the wood treated at higher reaction time had higher weight percent gain and lower moisture content, hence, resistant against termite attack. Thus, it could be concluded that acetylation modified the wood structure such that moisture absorption rate was reduced such that it prevented the wood from termite attack.

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