Chemical Modification of Wood Using Vinegar and Benzoic Acid against Termites Degradation

*Azeh Yakubu1, Yohanna Bello Paiko2, Gimba Alfred3
1,2,3Department of Chemistry, Ibrahim Badamasi Babangida University, P. M. B. 11, Lapai, Niger State, Nigeria

Wood is a free gift of nature used for engineering, construction and in agricultural purposes. However, it has shortcomings when in contact with moisture, sunlight and organisms, which limits longevity in its applications. Chemical modification by acetylation and benzoylation of wood cellulose using vinegar and benzoic acid as modifying agents was carried out in heterogeneous phase. The extent of modification was calculated as weight percent gains. Burial in a termite hill for four months was done in order to investigate its biological resistance to termites as trial organisms. Acetylation or benzoylation of the wood cellulose carried out for 1 h yielded WPGs values in the range of 18-31 % (acetylation) and 11-25 % (benzoylation), while 3 h gave 15-25 % (acetylation) and 16-22 % (benzoylation). The following absorption peaks were indication of acetylation or benzoylation reactions: 3343-3375, 1715-1737, 1689-1658, 1621-1614, 1594-1593 and 1309-1377 cm⁻¹ are due to –OH, C=O, C=C, and –CH₃ as revealed by FT-IR results. The SEM images of the treated samples revealed a clear structural transformation of the native wood as a result of the chemical treatments. The modified wood cellulose was resistant to termite degradation, indicating that longevity can be achieved by the modifying agents.

Keywords: Wood cellulose, Acetylation, Benzoylation, Biodegradation, Termites

INTRODUCTION

Wood has been used as a construction material since ancient times mostly without modification Roger, (2006). Nowadays, impregnation appears to be the most common wood preservation technique. It involves application of suitable impregnating agents as coatings or vanishes on the surface of a wood. Wood is treated with preservatives to increase longevity as it is protected from deterioration caused by insects, and marine wood-boring animals Tacioglu et al. (2012), Pia, (2013). Wood preservatives can be divided into two general classes: the type (creosote) and the water-bone salts for example chromated copper arsenate (CCA) and alkaline copper quaternary ammonium ACQ Pia, (2013) and natural bioactive compounds from termites or insects’ resistance varieties Tacioglu et al. (2012). According to Pia, (2013), chemical coatings on wood surfaces can only prevent moisture sorption by the wood cell wall polymers over a limited period of time and the prevention get lost as time extends. However, wood modification as an alternative to toxic chemical wood preservatives, gives a longer protection through a non-toxic mode of action Sande et al. (2003), Roger, (2006), Pia, (2013). Chemical modification can alter the wood constituents physically and/or the wood structure can be chemically altered to offer durable wood products Sande et al. (2003), Roger, (2006), Pia, (2013). The three major components (cellulose, lignin, and hemicelluloses) that make up the cell wall are responsible for most of the physical and chemical properties of wood and wood products Roger, (1983), Varshney and Sanjay, (2011). It can be possible to change the chemical and properties of wood cell wall polymers through chemical reactions. These are usually carried out to improve the biological resistance, dimensional stability, and weathering performance of woods Sande et al. (2003) Roger, (2006).
Most of the researches conducted in the area of chemical modification involved the use of a mixture of acetic acid and acetic anhydride (Sereshti and Mohammadi-Rovshandeh, 2002), which has limited applications because of its negative effects on the final product and its ban in some countries being a useful starting material for the production of morphine and its derivatives. Delignified and unbleached beech woods have been modified using benzyl chloride and acetic anhydride Sereshti and Mohammadi-Rovshandeh, (2002). The researchers found the chemically modified woods to be soluble in some organic solvents such as chloroform and have lower hydrophilicity and water absorbency relative to native wood. FT-IR spectra have been used to study the structure of chlorite bleached eucalyptus wood Popescu et al. (2007). They found that the structure of the bleached wood was modified due to the removal and/or transformation of the wood components. There was also the increase in the crystallinity data calculated due to chlorite bleaching. This study was aimed at acetylation and benzoylation of wood cellulose using vinegar and benzoic acid, determination of the extent of modification based on weight percent gains, FT-IR characterization of important functionalities and biological resistance of the modified wood cellulose against termites as trial organisms.

MATERIALS AND METHODS

Reagents and Chemicals

The reagents and chemicals used in the experiment were of analytical grade and used as received. These chemicals included benzoic acid, ethanol, potassium hydroxide, acetic acid, hexane and sulphuric acid, all of which were obtained from BDH Laboratory (Poole, England). Commercial vinegar and hypochlorite were purchased from a local market.

Selection of Wood Samples

Beech wood (Gmelina arborea), counter wood (Afzelia africana), Shea butter wood (Vitellaria paradoxa), African rosewood (Pterocarpus erinaceus), Madubiya (Andira enermis) and Ankpa (Afzelia africana) were selected to obtain cellulose. These species can be commonly grown in the guinea savanna part of Nigeria and are commonly used for decking, furniture and for the construction of roofing rafters in their native state. These wood species were collected from a local sawmill located in Lapai, Nigeria.

Sample Preparation

Each sample of the solid wood collected was sawn into a 2 x 2 x 2 cm by dimension and oven-dried at 105 °C for 3h.

Removal of the Wood Extractives

Ten grams (10 g) of wood (solid wood) were extracted using a mixture of hexane-ethanol (2:1) for 3 h Azeh et al. (2013).

Sample Mercerization

Two grams (2 g) of oven-dried extracted solid wood tablet were mercurized using 17 % KOH (20 mL) and were heated for 1 h on a hot plate. The sample was washed with distilled water until the wash water was neutral. This procedure was repeated for each wood tablet Azeh et al. (2013). After this, the sample was then oven-dried at 105 °C for 3 h which was followed by the addition of hypochlorite solution (100 mL) to the extracted wood in a 500 mL beaker. This was followed by the drop-wise addition of 10 mL of acetic acid and heating for 3 h. The procedure was repeated six times to remove the lignin and residual extractives Kumar et al. (2013).

CHEMICAL MODIFICATION OF WOOD CELLULOSE

Benzoylation of Wood Cellulose

Benzoylation of the wood cellulose was carried out using benzoic acid (2.3 g) dissolved in 17 % KOH (20 mL). Ethanol (40 mL) alongside pyridine (5 mL) that was used as a catalyst was added to the benzoic acid solution.

To this mixture, the mercerized wood (1 g) was introduced and the mixture was heated for 1 to 3 h Sereshti and Mohammadi, (2002). After modification, the product was washed with distilled water until the wash water was neutral, and then oven-dried at 105 °C for 3 h until constant weight. The extent of benzoylation was calculated as the weight percent gain (WPG) based on the differences in the oven-dried weight of the samples before and after modification using equation (1) Azeh et al. (2013):

\[
\text{Weight Percent Gain (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \text{ % Equation (1)}
\]

Where \( W_1 \) is the initial weight (g) of the wood before modification and \( W_2 \) is the final weight (g) of the wood after modification.

Acetylation of the Wood Cellulose

Acetylation of the four wood species was done using the method described by Azeh et al. (2013). The wood species were acetylated using commercial vinegar (100 mL), which was heated for 1 to 3 h. The modified products were then washed with distilled water until a neutral pH was obtained, and the WPGs were calculated using equation Equation (1) above.

Burial Experiment

In the burial experiment, a termite nest was opened, where treated and untreated wood samples were placed inside the opened vent and allowed to stay for a period of four months during the rainy season. After four months, the termites nest was opened, and the samples were collected and examined by visual changes. This was done in order to investigate the biological resistance to termite attacks.
SCANNING ELECTRON MICROSCOPY

The surface morphology of the samples was analyzed with scanning electron microscopy (SEM) using a PhenomWorld ProX desktop scanning electron microscope (Eindhoven, Netherlands) with a fully integrated and specifically designed energy-dispersive detector. The modified wood tablets were crushed and coated with gold using an ion sputter coater and were observed under an electron microscope at NARICT Ahmadu Bello University (Zaria, Nigeria). The scanning electron electron microscope was operated at 15 kV.

FT-IR Spectroscopy

The structural changes for both the unmodified and modified wood samples were recorded at Ahmadu Bello University using Fourier transform infrared (FT-IR) spectroscopy. The samples were run as KBr pellet disks on a Cary 630 by Agilent Technologies, Fourier transform infrared spectrophotometer (USA) in the range 500 to 4000 cm⁻¹.

RESULTS AND DISCUSSION

Weight Percent Gains (WPGs)

The WPGs of each sample modified was quantitatively determined using Equation 1 and the results are shown in Table 1.

Table 1: WPGs by the modified samples based on time and the method used for modification

<table>
<thead>
<tr>
<th>Sample</th>
<th>Method</th>
<th>Time (h)</th>
<th>WPG (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shea butter</td>
<td>Acetylation</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>Gmelina</td>
<td>Acetylation</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Shea butter</td>
<td>Benzoylation</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Gmelina</td>
<td>Benzoylation</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Rosewood</td>
<td>Benzoylation</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Ankpa</td>
<td>Benzoylation</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Ankpa</td>
<td>Acetylation</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Rosewood</td>
<td>Acetylation</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Ankpa</td>
<td>Benzoylation</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>Rosewood</td>
<td>Benzoylation</td>
<td>3</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 1 shows the WPGs results after acetylation and benzoylation. The 1 h reaction time for the modification of the wood tablets showed favorable results for acetylation and benzoylation, as the treatments resulted in 31 % and 25 % WPGs, for the Shea butter wood tablets respectively. Benzoylation of the African rosewood for 1 and 3 h resulted in 25 % and 16 % WPGs respectively. Low WPGs of the acetyl and benzoyl groups may have been caused by the removal of the attached acetyl and benzoyl groups as a consequence of deacetylation or de-benzoylation due to equilibrium attainment as a result of extended reaction time being esterification reactions. Generally, weight gains because of modification reflect the success of the reaction and successful replacement of the accessible –OH group in a wood biopolymer.

FT-IR of the Acetylated Wood Cellulose (Tablets)

There were strong absorption bands of hydroxyl stretching vibration of the acetylated wood samples at 3928, 3888, 3756, 3699, 3591, 3343 and 3180 cm⁻¹ (Table 3). These were reflected separately in the acetylated wood tablet and attributed to –OH stretching vibration similar to the reports by Adebajo and Frost, (2004); Azeh et al. (2013). The –OH absorption bands in the untreated samples were located at 3897, 3799, 3673, 3585, 3390 and 3176 cm⁻¹ (Table 2).

Table 2: Bands Assignment for the Untreated Samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Wave Number (cm⁻¹)</th>
<th>Band Assignment (Functional Group)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosewood</td>
<td>3878 – 3500</td>
<td>-OH bond stretching vibration</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td>Untreated</td>
<td>3390 – 3176</td>
<td>-OH intramolecular hydrogen bonds in cellulose</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>2923 – 2724</td>
<td>C-H methyl and methylene groups</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>1747 – 1703</td>
<td>C=O stretching in conjugated ketones</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1694 – 1651</td>
<td>C=O in aromatic ring of syringyl in lignin</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>1645 – 1614</td>
<td>-OH absorbed water</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>1538 – 1505</td>
<td>C=O aromatic skeletal absorption caused by lignin</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>1494 – 1455</td>
<td>C-H asymmetric stretching in OCH₃</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1377</td>
<td>C-H bending</td>
<td>Francesca et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>1311 – 1033</td>
<td>C-H deformation</td>
<td>Francesca et al. (2012)</td>
</tr>
</tbody>
</table>

The observed decrease in the –OH group of the acetylated wood cellulose samples showed that the hydroxyl group contents in the wood were reduced because of acetylation. This decrease in the –OH groups of the acetylated wood samples was an evidence of acetylation Sassi et al. (2000); Adebajo and Frost, (2004). It was also observed that the –OH peak for the intramolecular hydrogen bonds in the acetylated samples decreased from 3390 cm⁻¹ to 3350 cm⁻¹ and 3343 cm⁻¹, which indicated that some of the –OH groups were blocked by the modifying reagent. The presence of –OH absorption in the acetylated wood samples was attributed to hydroxyl functionalities that are not accessible to the modifying reagent (Hill, 2002). The absorption at 2923 cm⁻¹ and 2853 cm⁻¹ in both the untreated and acetylated wood samples was because of asymmetric and symmetric stretches of methyl and methylene groups in the wood. This band also decreased to 2671 cm⁻¹ in the acetylated wood samples, which is an
An important indication for acetylation by the –C–O linkage in the guaiacyl aromatic methoxyl group Popescu et al. (2007). The absence of absorption at 1840 cm\(^{-1}\) to 1750 cm\(^{-1}\) in the vinegar-acetylated wood samples revealed that the acetylated products were free of unreacted vinegar Azeh et al. (2013). However, there was a slight increase in the intensity of the –OH stretching band of the acetylated wood samples at 3928 cm\(^{-1}\) and 3888 cm\(^{-1}\), which indicated a gradual decrease in the extent of acetylation because of a longer reaction time. Since the acetylation of cellulose is a reversible process like any other esterification reaction, deacetylation may begin to occur under appropriate reaction conditions, as reported by Klemm et al. (1998). Therefore, it is possible that deacetylation led to the reformation of free hydroxyl groups because of the long reaction time. The presence of bands at 1655, 1644, 1619 and 1614 cm\(^{-1}\) in both the treated and untreated wood samples can be attributed to absorbed water and \(\beta\)-glycosidic linkages (ether –C–O–C–), as reported by Azeh et al. (2013). However, this absorption band decreased in the treated wood samples to 1594 cm\(^{-1}\) and 1593 cm\(^{-1}\), which indicated a replacement of this group with C=C stretching of the aromatic ring and C=O stretching as revealed in a study by Adapa et al. (2009) on spectromicroscopy of agricultural biomass, which was an evidence of acetylation. The bands at 1667 cm\(^{-1}\) and 1686 cm\(^{-1}\) can be linked to –OH out-of-plane bending or atmospheric CO\(_2\) (deformation vibration) contamination according to Gunzler and Gremlich, (2002). An important band indicating that some level of acetylation was achieved was observed at 1309 cm\(^{-1}\) and 1307 cm\(^{-1}\). This is attributed to aliphatic C–H deformation/bending vibration of –CH\(_2\) in the acetyl groups, which is an evidence for the establishment of ester bonds as a result of acetylation of cellulose and hemicelluloses in wood.

**FT-IR of the Benzoylated Wood Cellulose (Tablets)**

The wood tablets were successfully modified in the aqueous alkaline solution of KOH, as shown by the reaction below Equation (2).

\[
\text{R-OH} + \text{KOH} \rightarrow \text{R-O-K}^+ + \text{H}_2\text{O} \quad (2)
\]

The FT-IR absorption bands of hydroxyl vibration in the benzoylated wood spectra were at 3888-3570 cm\(^{-1}\) (Table 4) were in agreement with the findings of Marino et al. (2015) on nanocellulose from citrus waste while the bands due to \(-\text{OH}\) vibration in the untreated samples were observed at 3878-3500 and 3390 cm\(^{-1}\). It was evident from these absorption bands that the chemical structure of the benzoylated wood cellulose (solid wood tablets) was remarkably different from the structure of the native wood.
This was because of the decrease in the intensity of the –OH absorption caused by benzoylation which was in agreement with the work on acetylation of cotton by Adegbuyi and Frost (2004). Furthermore, the presence of benzyols in the wood structure was confirmed by the absorption bands at 770 cm\(^{-1}\) and 769 cm\(^{-1}\) as reported by Li et al. (2012) on benzylation of pre-swelled bamboo fibres. After modification, it was observed that the –OH peaks due to intermolecular hydrogen bonds in modified samples decreased. This is an evidence that some of the free and accessible –OH functional groups on the polymer chain were blocked by the modifying reagent. The presence of the absorption band at 1305 cm\(^{-1}\) is attributed to aliphatic C=H deformation/bending vibration of –CH\(_3\) in the acetyl groups, which is likely an indication of ester bonds caused by acetylation Popescu et al. (2007). 

**Table 4: Bands Assignment of the Benzoylated Samples**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Band Position (cm(^{-1}))</th>
<th>Band Assignment (Functional Group)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzoylated</td>
<td>3901 – 3564</td>
<td>–OH bond stretching vibrations</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td>Ankpa</td>
<td>3353 – 3168</td>
<td>–OH intramolecular hydrogen bonds in cellulose</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>2922 – 2724</td>
<td>C-H methyl and methylene groups</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>2671</td>
<td>Guaiacyl ring breathing C-O linkage in guaiacyl</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1715</td>
<td>Stretching in conjugated ketones</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1621</td>
<td>C=O stretching</td>
<td>Lani et al. (1997)</td>
</tr>
<tr>
<td></td>
<td>1377</td>
<td>C-H bending</td>
<td>Francesca et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>1305</td>
<td>CH(_2) wagging in cellulose</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>970</td>
<td>–OCH(_3) stretching</td>
<td>Adapa et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>770</td>
<td>C-H stretching from benzoyl group</td>
<td>Li et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>722</td>
<td>OH out-of-plane bending</td>
<td>Li et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>3611 – 3507</td>
<td>OH bonded stretching</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>3334 – 3175</td>
<td>OH intramolecular hydrogen bonds in cellulose</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>2922 – 2724</td>
<td>C-H methyl and methylene groups</td>
<td>Azeh et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>2671</td>
<td>Guaiacyl ring breathing C-O linkage in guaiacyl</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1737 – 1715</td>
<td>C=O stretching</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1689 – 1659</td>
<td>C=O stretching</td>
<td>Azeh et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>1621 – 1614</td>
<td>Aromatic skeletal vibration plus C=O stretching</td>
<td>Ilharco et al. (1997)</td>
</tr>
<tr>
<td></td>
<td>1593</td>
<td>C-H bending</td>
<td>Adapa et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>1377</td>
<td>CH(_2) wagging in cellulose</td>
<td>Francesca et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>1306</td>
<td>C-O-C stretching in cellulose</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1155</td>
<td>C-O vibration mainly from C(_3)-O(_3)</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>1031</td>
<td>–OCH(_3) stretching</td>
<td>Popescu et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>971</td>
<td>Aromatic C-H out-of-plane bending</td>
<td>Adapa, et al. (2009); Li et al. (2012)</td>
</tr>
</tbody>
</table>

**Morphological Study of the Benzoylated and Acetylated Woods**

The SEM images of the benzoylated and acetylated wood tablets are shown in Figures 1, 2 and 3. The images show the presence of individual fibre bundles, which appear detached. The chemical treatments resulted in a loss of the native structural morphology Gwon et al. (2010). The modified fibres were defibrillated because of treatment with hypochlorite and sodium hydroxide. After treatment with the modifying agents, the fibre surface has swollen due to replacement of the accessible –OH groups with larger acetyl or benzoyl groups (Figures 1, 2, and 3). The results agreed with the findings by Sander et al. (2003) on analysis of acetylated wood using SEM. The swelling of wood because of chemical treatment has been reported to be equal to swelling caused by water Sander et al. (2003). The modified fibres appeared white because of the removal of wax, pectin, lignin, and hemicelluloses from the wood structure by the hypochlorite, NaOH, vinegar, and benzoic acid. These treatments led to structural changes of the native wood networks in the treated samples when compared with the structure of the untreated wood (Figure 4). However, prior to pre-treatments and modification, the presence of voids was clearly seen and the lumen of the cell wall was observed to possess some undetached fibre bundles bound by lignin lignin (Figure 4; Ioelovich, 2008). The morphology of the isolated cellulose, as seen under SEM, displayed a web-like structural network, in which the cellulose fibres were seen as entangled filaments (Figure 4) as shown by the findings of He et al. (2013) on the analysis of cellulose nanofibres from Bambusa rigida. Fibre bundles of isolated cellulose were observed with individual bonds, fibre bundles, and clustering because of intra and intermolecular hydrogen bonding networks. This was because of the removal of hemicelluloses and lignin from the wood Li et al. (2012).
Chemical Modification of Wood Using Vinegar and Benzoic Acid against Termites Degradation

Fig. 1: SEM images of the benzoylated Ankpa wood cellulose (Solid wood) at magnifications of 1000x (a) and 4500x (b)

Fig. 2: SEM images of the benzoylated African rosewood cellulose (Solid wood) at magnifications of 1000x (a) and 4500x (b)

Fig. 3: SEM images of the acetylated African rosewood cellulose (Solid) at magnifications of 330x (a) and 1000x (b)

Fig. 4: SEM images of the unmodified wood cellulose (Solid wood) at magnifications of 500x (a) and 1000x (b)
**Effect of the Termite Hill Burial Experiment**

Treated and untreated wood tablets were buried in an anthill for a period of four months to investigate their biological degradation by termites. Afterwards, it was observed that the untreated wood tablets were consumed by the termites and the treated wood tablets were less affected (Figure 5). The inability of the termites to consume the chemically treated wood tablets was a consequence of the successful replacement of accessible –OH groups in the wood biopolymers with acetyl or benzoyl groups. Perhaps the structural transformations made the wood unrecognizable as a food substrate by the termites or the transformed wood could not be softened by secretions from the termites, who were unable to consume the wood cellulose and let alone cause their biodegradation. The absence of the hemicelluloses in the wood structure, because of pretreatments using NaOH and NaOCl confirmed the transformation of the wood structure similar to the findings by (Tasciglu et al. 2012) on beech wood changes in structure due to chlorite treatment, also found was the difficulty for the termites to feed on the modified wood samples. The untreated wood tablets were consumed because of the recognition of cellulose and other biopolymers as food substrates by the termites. This process was enhanced by the presence of hemicelluloses in the wood because of their sugary taste. The acetylated and benzoylated wood is therefore durable, and can be used in construction, roofing, decking, furniture, and other applications because of their ability to survive attacks from termites and other wood-degrading organisms.

**CONCLUSION**

Chemical modification of wood cellulose (Solid wood) through acetylation and benzoylation using vinegar and benzoic acid was successful as quantitatively evidenced by the weight percent gain in acetyl and benzyol groups. The FT-IR spectroscopic analyses confirmed the formation of new functionalities due to modification while morphological examination using SEM revealed the structural differences and similarities in the modified and the native wood samples. The modified wood showed resistance against termites‘ attack during the four months of field exposure. This implied that the level of modification was high enough to protect the modified wood from termite attack.

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