# PRELIMINARY STUDY ON ENHANCED PROPERTIES AND BIOLOGICAL RESISTANCE OF CHEMICALLY MODIFIED *ACACIA* SPP*.*

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A preliminary experimental study was carried out to examine the ability of a chemically modified *Acacia* spp. to resist biodegradation. The modifications of *Acacia mangium* and *Acacia* hybrid were carried out by propionic anhydride and succinic anhydride in the presence of sodium formate as a catalyst. The treated samples were found resistant to microbial attack, while the untreated ones were damaged on 12 months exposure to a soil burial. The appearance grading, mass loss, mechanical properties, and scanning electron microscopy results revealed that chemical modification enhances the resistance of *Acacia mangium* and *Acacia hybrid* wood species to biodegradation.

*Keywords: Physical properties; Mechanical properties; Scanning electron microscopy terms; Esterification of wood; Biodegradation*

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## INTRODUCTION

Among three-dimensional polymeric composites, wood is the most commonly used organic material, consisting of cellulose, hemicelluloses, and lignin (Mohan et al. 2006; Deka et al. 2002). Researchers have focused on the traditional wood preservatives, which are being currently used to improve the durability of wood. While using these methods the impact on the environment is the prime factor to be taken into consideration. Wood technologists have achieved success in improving the durability in terms of dimensional stability or biological resistance of wood by means chemical modification (Timar et al. 1999; Devi et al. 2003; Papadopoulos and Avtzis 2008). Chemical modification of wood leads to covalent bond formation between hydroxyl groups and the chemical reagent used, which reduces availability of hydrophilic groups present in wood polymers, and hence leads to increased dimensional stability. Chemical modification of wood enhances its biological resistance, which has been assumed to be mostly due to crosslinking, bulking, or a combination of both, leading to dimensional stabilization (Papadopoulos and Hill 2002; Papadopoulos et al. 2008; Papadopoulos 2010). Hydroxyl groups in cell wall polymers are the sites not only of water adsorption, but also of biological enzymatic reaction. Wood rotting fungi and termites have a very specific enzyme system capable of degrading wood polymers into digestible units. Therefore, if the substance for these systems is chemically changed, then this enzymatic action cannot take place, because the chemical configuration and molecular conformation of the substrate has been altered (Takahashi 1996). Of these polymers, hemicelluloses are probably attacked first, because they are the most accessible. This then allows the accessible portion of cellulose to be degraded (Youngquist et al. 1986; Rowell et al. 2000; Rowell 2006).

The fibrous nature of wood has made it as one of the most suitable raw material for a variety of applications; however, two properties restrict its much wider use: dimensional changes when subjected to fluctuating humidity and susceptibility to biodegradation by microorganisms (Papadopoulos and Georgia 2010). Chemical modification of wood is applied in order to address these shortcomings and this is well documented in the literature (Risi and Arseneau 1957; Rowell 1983; Kumar 1994; Hill 2006; Rowell et al. 1986, 1987, 2009; Beckers et al. 1994, 1995).

*Acacia* spp. is a fast-growing wood that contains a high proportion of juvenile wood with poorly developed heartwood. The fast growth rate results in wide growth rings and low-density wood, which exhibits low dimensional stability and low durability against biological deterioration (Li 2002). In recent years, large areas of *Acacia* spp. plantation have been established in Malaysia, but because of the inferior qualities of fast-grown wood, for example poor dimensional stability and durability, the wood produced can be made available in market at very low prices. With the advent of the chemical modification the possibility arises of transforming this poor quality wood into a value-added commercial product capable of competing with traditional hardwoods for similar applications.

Juvenile wood has lower strength, higher longitudinal shrinkage, lower specific gravity, more compression wood, thinner cell walls, lower percentage of latewood, lower cellulose content, and higher lignin content as compared to mature wood and degrades more easily when exposed to microbial attack. Hence, this wood needs different treatments, either chemical or physical to enhance these properties. Therefore, we are reporting a study based on enhanced properties of this juvenile wood. Results are reported for the physical, mechanical and morphological properties of chemically modified *Acacia mangium* and *Acacia hybrid* by propionic anhydride and succinic anhydride after they were subjected to soil burial testing.

## EXPERIMENTAL

### Materials and Procedures

The cultivated *Acacia mangium* and *Acacia hybrid* wood was obtained from Forest Research Institute Malaysia (FRIM) plantation and Rantau Panjang, Selangor, respectively. The selection was carried out on random basis. The trees were 12 years old without defects. Wood samples were sawn at FRIM sawmill, and all the samples were subjected to the right cutting pattern in the tangential portion. After the drying process, the moisture content appear 12-15 % from kiln dry and carried out to resizing for lab scale size samples. Both species were prepared for modification and control samples for comparison. Propionic anhydride, succinic anhydride, sodium formate, and *N*,*N*–dimethylformamide were purchased from Sigma-Aldrich (Malaysia).

## Chemical Modification of Wood Samples

The chemical modification was carried out according to our earlier method (Bhat et al. 2010). The chemical modification of *Acacia mangium* and *Acacia hybrid* by propionic anhydride and succinic anhydride was carried out at 100 $^{o}$C for 3 hours. The weight percent gain (WPG) obtained after chemical modification of *Acacia mangium* and *Acacia hybrid* by propionic anhydride and succinic anhydride was 15.06%, 20.2 and 21.1, 22.3%, respectively.

## Soil Burial Test

This test was performed for 12 months, using a procedure adopted from the BS standard EN ISO 846:1997 (Plastic-evaluation of the action of micro-organism). The samples were completely buried in natural soil at 90% water holding capacity (WHC) and a 50% soil moisture content. The samples were in permanent contact with the soil and exposed to a temperature of 29°C ±1°C. Shirley cotton strips were used to determine the biological activity of the soil (cotton material to monitor clearly microorganism attack in soil). The cotton strip retained less than 25% of the original tensile strength at the end of 7 days soil burial. The soil test was set up using a wooden box 100 cm x 60 cm x 55 cm. The samples assemblies are shown in Fig. 1. All the specimens of size 20 mm x 20 mm x 5 mm were vertically buried with sorted distance of about 3 cm from each other. About 50 specimens were prepared for each batch.

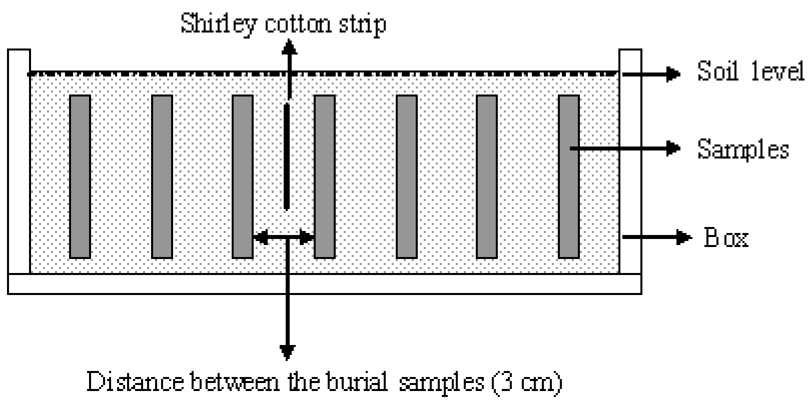


**Figure 1**. Test assemblies of soil burial test

## Assessment Methods

The samples were exposed to the action of micro-organism in compost soil, for a time period of 12 months, under the specific conditions of temperature and humidity (29°C ±1°C/ RH 95). The assessment was carried out at 3, 6, 9, and 12 months of exposure in soil.

## Appearance Grading

This is non-destructive test in which the extent of decay is graded in terms of intensity of fungal growth as shown in Table 1. Stakes were removed at various time intervals and grades. Results are presented on a scale of decay.

**Table 1**. Assessment of Fungal Growth

| Intensity of growth | Evaluation |
| --- | --- |
| 0 | No apparent growth under the microscope |
| 1 | No visible growth to the naked eye, but clearly visible under the microscope. |
| 2 | Visible growth to the naked eye, covering up to 25% of the surface. |
| 3 | Visible growth to the naked eye, covering up to 50% of the test surface. |
| 4 | Considerable growth, covering more than 50% of the test surface. |
| 5 | Heavy growth, covering the entire test surface. |

## Mass Loss

This procedure determines the extent of destructive decay by mass change. There are two methods to determine the rate of decay, such as direct mass loss and relative mass change. Samples were cleaned by wiping off the adherent soil on the surface with a cotton brush. Then samples were placed in an oven at 103 ± 1 °C at 5 hours. The samples were transferred to a dessicator for 10 minutes at 20 °C ± 1°C and 65% RH, before weighing. The percentage of mass loss was calculated by equation 1,

$$\Delta m_l = \frac{m_o - m_a}{m_o} \times 100 \qquad (1)$$

where $m_0$ is dry weight of specimens before and $m_a$ is the dry weight after soil burial tests, as a function of time.

## Flexural Test

Static flexural properties were evaluated on the modified and unmodified wood specimens (after weathering exposure duration) using three-point bending tests by means of an Instron model 5582 tensile / compression machine, according to the ASTM D143 / D 790 standard. The dimensions of wood samples were 5 mm x 20 mm x 120 mm, the support span was 80 mm, and the crosshead speed employed was 5 mm/min. In each test the load was applied perpendicularly to the direction of the wood fibers.

## Tensile Test

Tensile tests were conducted according to ASTM D 3039 using the Instron Testing Machine (Instron model 5582 tensile / compression machine). The tests were performed at a crosshead speed of 1.0 mm/min and at room temperature using the length span (gauge length) of 30mm. The dimension of the specimen was 5 mm x 15 mm x 150 mm.

The bar graphs represent the mean of the obtained values for flexural and tensile tests.

### Scanning Electron Microcopy (SEM)

The wood samples of *Acacia mangium* and *Acacia hybrid* (before and after 12 month soil burial) were prepared for SEM observation of the cell wall structure. The samples were cross cut using a microtome, carefully and securely. A light microscope was used to examine the smoothness and flatness of the end surface cross cut. The samples were mounted on the SEM holder using double sided carbon electrically conducting adhesive tape, to prevent surface charging when exposed to the electron beam. The samples were then coated with gold to a thickness of 20 nm using a so-called ‘sputter coater’ Fison SC 515. Then the samples were observed in a Leica Cambride S-360 SEM.

### Statistical Analysis

Inferential analysis statistics can be defined as those methods that make possible the estimation of characteristics of a population or the making of a decision concerning a population based only on results. This study correlation and Analysis of Variance (ANOVA) were used to determine few factors including samples (control, chemically modified), duration exposure (0-12months), flexural strength (MOR and MOE) and tensile properties. The value of strength loss was analyzed by the SPSS software. The analysis of variance at 95, 99, and 99.9 percent confidence was used to find out the correlation between factors in determining the significant value.

## RESULTS AND DISCUSSION

### Determination of Performance

A preliminary study on samples from the entire batch at the intervals of 3, 6, 9, and 12 months were visually graded, and their mass loss was determined. After 3 months of exposure, a slight variation was observed between chemically modified and unmodified samples.

### Appearance Grading

The progressive deterioration of surfaces by microorganisms of both unmodified and modified samples of *Acacia mangium* and *Acacia hybrid* is shown in Table 1 and 2. After three months burial no visual effects were observed in the modified samples. The fungal growth rings started to appear on the surface of unmodified samples of *Acacia mangium* and *Acacia hybrid* as observed by naked eye and microscope, respectively. The unmodified samples exhibited visible decay with progress in burial time; however, in modified samples only slight discoloration was observed. Both modified species showed the highest degree of protection against the biodegradation after 12 months with a small amount of discoloration and stains on the surface.

**Table 2.** Intensity of Growth from the Assessment of Fungal Growth of *Acacia sp.* Unmodified and Chemically Modified Wood. (AM= *Acacia mangium*, AH=*Acacia* hybrid)

| Samples | Duration | Unmodified | Propionylated | Succinylated |
|---|---|---|---|---|
| AM | 3 | 2.1 | 0 | 0 |
| | 6 | 3.2 | 0 | 0 |
| | 9 | 4.0 | 1.2 | 1.0 |
| | 12 | 4.5 | 1.3 | 1.2 |
| AH | 3 | 1.2 | 0 | 0 |
| | 6 | 2.2 | 0 | 0 |
| | 9 | 3.3 | 2.0 | 1.1 |
| | 12 | 4.2 | 1.5 | 1.1 |

**Each values from mean of 20 samples.*

*Acacia spp.* treated with succinic anhydride was more resistant to the decay than that treated with the propionic anhydride. Protection of hydroxyl functionalities by substituted anhydrides leads to formation of cross linked adducts, which in turn stops the enzymatic reaction and hence defends the wood from degradation (Kartal et al. 2004).

## Mass Loss

The percent loss of both modified and unmodified *Acacia mangium* and *Acacia hybrid* are shown in Figs. 2 and 3. With increase in exposure time to soil burial the rate of mass loss percentage was also increased. Unmodified samples exhibited more loss in mass percentage as compared to modified ones. It is clear from Fig. 2 that modification by succinic anhydride led to less loss in mass percentage, which can be attributed to the occupation of more hydroxyl groups as compared propionic anhydride. The control samples *Acacia mangium* and *Acacia hybrid* displayed the highest mass loss 17.6% and 14.3% after 12 months of exposure, respectively.

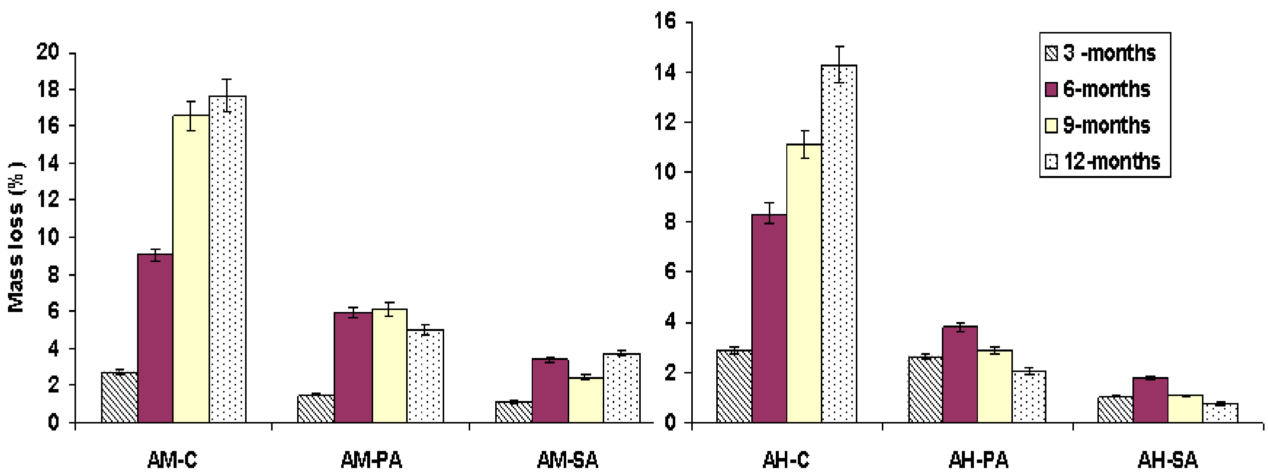


**Figure 2**. Mass loss in terms of percentage of chemically modified *Acacia mangium* (AM), *Acacia hybrid* (AH) by propionic anhydride (PA) and succinic anhydride (SA) after 0-12 month soil burial test

The samples of *Acacia mangium* modified by propionic anhydride and succinic anhydride exhibited the mass loss of 4.9% and 3.7 %, respectively. However propionic anhydride and succinic anhydride modified *Acacia hybrid* showed mass loss of 3.1% and 2.6% over the same period.

The trend in mass loss clearly indicates that the activities of microorganisms in the soil reduced the samples masses. As the moisture was absorbed by the voids in the samples, it also permitted the colonization by microorganisms. The microbes depend on the nutrients provided by the compound materials, resulting in their being more susceptible to degradation. Gu *et al.* have reported that wood structure serve as capillaries assisting the migration of moisture, chemicals, and bacteria to other components of the woods (Gu et al. 1996).

## Flexural Properties

The unmodified samples showed a progressive loss of strength and modulus in relation to time of exposure. The maximum value for strength and modulus losses for unmodified *Acacia mangium* and *Acacia hybrid* after 12 months exposure were found to be 25.6 - 34.6% and 24.3 - 30.6%, respectively (Figs. 3-4). In chemically modified samples, almost no change was observed after 6 months. The percent moisture content of unmodified *Acacia mangium* and *Acacia hybrid* was 10.0% and 10.6%. After modification by propionic anhydride and succinic anhydride the values obtained were 7.7%, 9.3%, and 7.1%, 6.5%, respectively. The less loss in strength of the treated wood samples might have been due to the decrease in the water uptake capacity of the treated wood (Rashimi et al. 2003; Solpan and Guven 1998), since, chemical modification leads to hydrophilic nature of *Acacia* wood therefore, reducing water uptake capacity which is necessary for microbial growth.

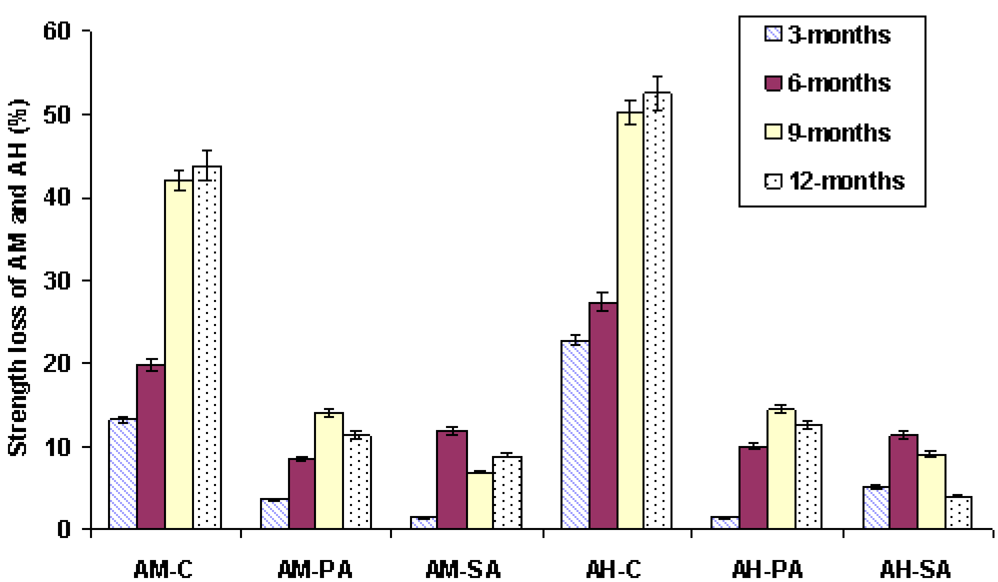


**Figure 3**. Flexural strength loss in terms of percentage of chemically modified *Acacia mangium* (AM), *Acacia hybrid* (AH) by propionic anhydride (PA) and succinic anhydride (SA) after 0-12 month soil burial test

The maximum values, observed at 12 months burial in the case of propionylated and succinylated modified samples with both of the wood species, were determined to be 3.2 to 3.5% and 4.7 to 6.7% with respect of strength and modulus losses. It is apparent that the maximum changes with propionylated and succinylated samples were significantly lower than those of unmodified samples. The loss in flexural properties of unmodified *Acacia mangium and Acacia hybrid* increased with 12 months of soil burial. The chemically modified wood is believed to decrease moisture absorption in the cell wall due to substitution of hydroxyl groups of the cell wall polymers by esterification (Militz et al. 1997; Hill 2006)

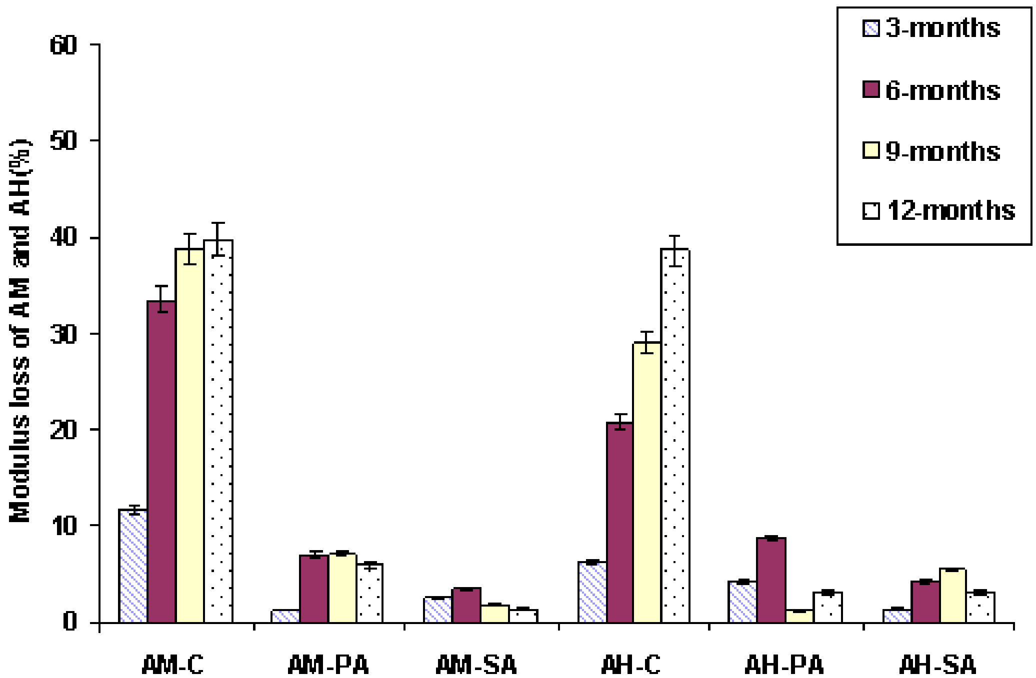


**Figure 4**. Flexural modulus loss in terms of percentage of chemically modified *Acacia mangium* (AM), *Acacia hybrid* (AH) by propionic anhydride (PA) and succinic anhydride (SA) after 0-12 month soil burial test

Some modified wood can cause strength losses due to acidic and thermal degradation of cell wall polymers during treatment or in other words the production of acid by-products during esterification with some anhydrides.

The modulus of rapture and modulus of elasticity of unmodified and modified samples is given in Tables 3 and 4. Based on Analysis of Variance (ANOVA), the non-significant values for unmodified samples were obtained. It is clear from the table that less loss in MOR and MOE was obtained after modifying the samples. These results are in accordance with findings of chemically modified wood in soil burial degradation (Eaten et al. 1993).

**Table 3**. ANOVA for Flexural Test of *Acacia mangium* Modified Wood (AMPA= *Acacia mangium* modified by propionic anhydride, AMSA= *Acacia mangium* modified by succinic anhydride)

| Source | MOR | | MOE | |
|---|---|---|---|---|
| | MS | F-value | MS | F-value |
| Unmodified | 143.66 | 7.23ns | 11127.29 | 1.14ns |
| AMPA | 125.5 | 2.19** | 13426.27 | 11.9** |
| AMSA | 155.5 | 1.81ns | 15400.76 | 0.65ns |
| $R^2$(%) | 87.64 | | 76.34 | |
| CV | 11.73 | | 16.41 | |

*MS-means square, n.s- not significant **- significant (at p< 0.01) * - significant (at p<0.05).*

**Table 4.** ANOVA for Flexural Test of *Acacia hybrid* Modified Wood. (AHPA= *Acacia hybrid* modified by propionic anhydride, AHSA= *Acacia hybrid* modified by succinic anhydride)

| Source | MOR | | MOE | |
|---|---|---|---|---|
| | MS | F-value | MS | F-value |
| unmodified | 109.51 | 9.39ns | 10540.71 | 1.14ns |
| AHPA | 112.23 | 2.31* | 6711.29 | 11.9** |
| AHSA | 116.58 | 1.61ns | 5558.35 | 0.65ns |
| $R^2$(%) | 86.32 | | 89.59 | |
| CV | 15.27 | | 23.40 | |

*MS-means square, n.s- not significant **- significant (at p< 0.01) * - significant (at p<0.05).*

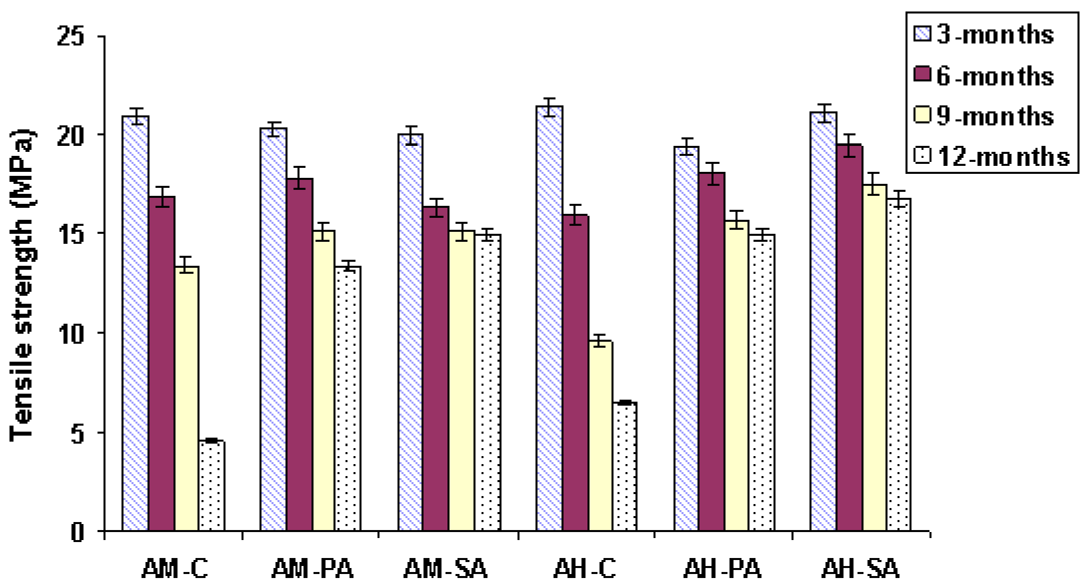


**Figure 5.** Tensile strength of chemically modified *Acacia mangium* (AM), *Acacia hybrid* (AH) by propionic anhydride (PA) and succinic anhydride (SA) after 0-12 month soil burial test

## Tensile Properties

The biodegradation increased with increase in burial period, i.e. from 0 to 12 months. The tensile strength, tensile modulus, elongation at breakage and toughness of modified *Acacia mangium* and *Acacia hybrid* decreased by about 20.4 - 34.0%, 38.5 - 46.7%, and 51.5 - 55.6%, respectively (Figs. 5-7).

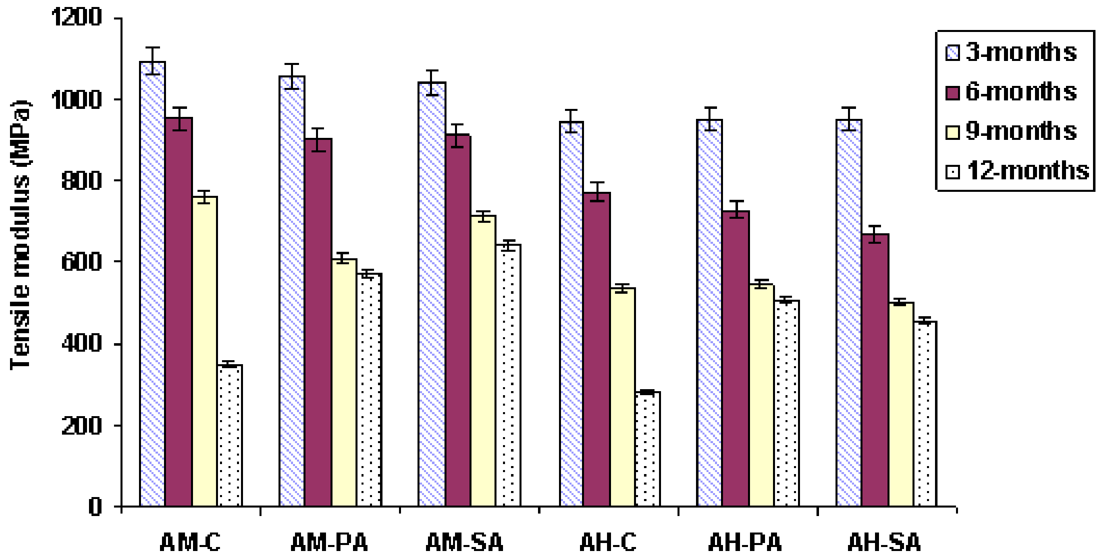


**Figure 6.** Tensile modulus of chemically modified *Acacia mangium* (AM), *Acacia hybrid* (AH) by propionic anhydride (PA) and succinic anhydride (SA) after 0-12 month soil burial test

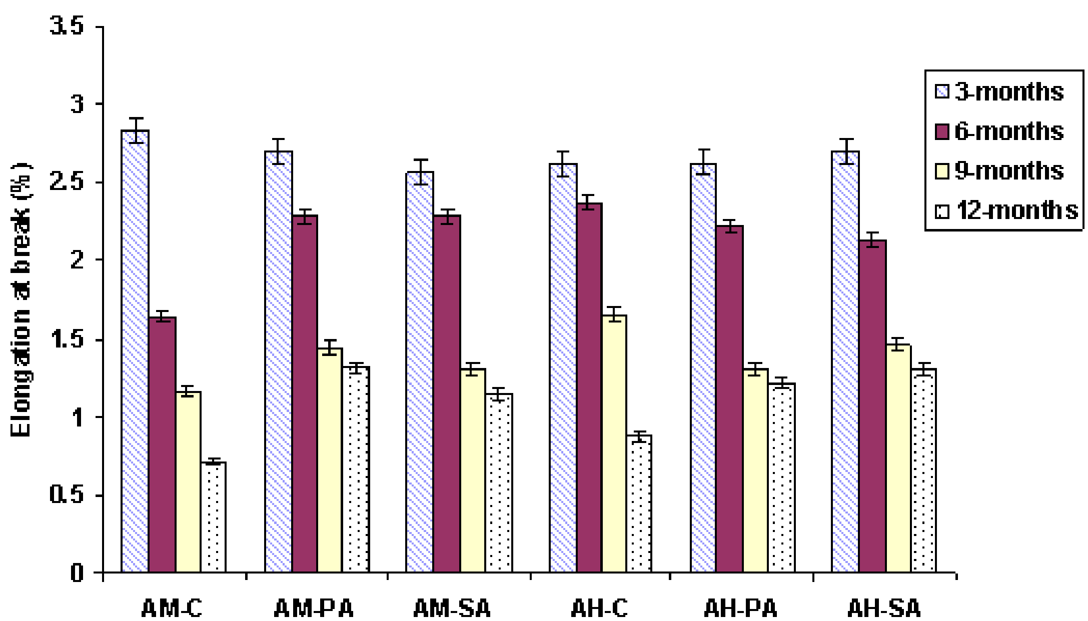


**Figure 7.** Elongation at break of chemically modified *Acacia mangium* (AM), *Acacia hybrid* (AH) by propionic anhydride (PA) and succinic anhydride (SA) after 0-12 month soil burial test

In unmodified *Acacia mangium* and *Acacia hybrid* the losses in tensile strength, tensile modulus, and elongation at breakage indicated that there was a high degree of biodegradation. The entire ANOVA results for *Acacia mangium* and *Acacia hybrid* are given in Tables 5 and 6. Similar observations have been reported by Khalil *et al*. (2009), where tensile properties, flexural properties, and impact strength decreased by about 38-47%, 37-50%, and 47%, respectively, as compared to the value before the biological test.

Rowell and Banks (1987) showed that the structure of modified wood was affected by the bulking by the acetyl groups within cell wall (Rowell and Banks 1987), although some of the strength loss may also be polymer hydrolysis due to the strong acid catalyst (Rowell 2005).

**Table 5**. ANOVA for Tensile Test of *Acacia mangium* Modified Wood (AMPA= *Acacia mangium* modified by propionic anhydride, AMSA= *Acacia mangium* modified by succinic anhydride)

| Source | Tensile test | | | | | |
|---|---|---|---|---|---|---|
| | Tensile strength | | Tensile modulus | | Elongation at break | |
| | MS | F-value | MS | F-value | MS | F-value |
| unmodified | 54.170 | 5.87** | 272324.6 | 34.35 | 2.004 | 17.36* |
| AMPA | 523.8 | 6.92** | 7928.15 | 1.710* | 7.430 | 4.84** |
| AMSA | 186.979 | 2.32* | 10486.23 | 132.27ns | 7.734 | 2.63** |
| $R^2$(%) | 84.65 | | 75.54 | | 83.68 | |
| CV | 12.65 | | 27.25 | | 25.01 | |

MS-means square, *n.s- not significant **- significant (at p< 0.01) * - significant (at p<0.05).*

**Table 6**. ANOVA for Tensile and Fexural Tests of *Acacia hybrid* Modified Wood (AHPA= *Acacia hybrid* modified by propionic anhydride, AHSA= *Acacia mangium* modified by succinic anhydride)

| Source | Tensile test | | | | | |
|---|---|---|---|---|---|---|
| | Tensile strength | | Tensile modulus | | Elongation at break | |
| | MS | F-value | MS | F-value | MS | F-value |
| unmodified | 18.08 | 11.6ns | 10407 | 2.14ns | 9.09 | 9.35ns |
| AHPA | 15.68 | 1.75* | 8910.11 | 0.55* | 2.63 | 2.32* |
| AHSA | 14.94 | 1.36** | 135710.6 | 1.78ns | 2.22 | 1.55* |
| $R^2$(%) | 84.36 | | 74.25 | | 82.56 | |
| CV | 19.43 | | 16.86 | | 29.04 | |

MS-means square, *n.s- not significant **- significant (at p< 0.01) * - significant (at p<0.05).*

Analysis of Variance (ANOVA) and Ducan's multiple range tests indicated the there were highly significant differences between control and chemically modified wood in tensile properties (strength, modulus, and elongation at breakage). According to Rowell (2005), chemical modification alters the chemical structure of the wood component by reducing the biodegradability of wood, as well as increasing its dimensional stability when it contact with moisture. Therefore, the mechanical properties of chemically modified wood performed well during the soil burial exposure. Tensile strength loss with small decrease in strength properties resulting from acetylation may be attributed to the hydrophobic nature of the acetylated furnish (Youngquist et al.1986).

## Scanning Electron Microcopy (SEM)

SEM studies were conducted to assess the degree of fungal attack inside the unmodified and modified samples after 12 months of soil burial. The samples were observed before (a) and after (b) soil burial, as selected from SEM micrographs. In chemically modified *Acacia mangium* and *Acacia hybrid*, no heavy growth of microorganisms on the surfaces was observed after exposure, as shown in Figs. 8-13, which indicates effective protection against biological degradation *Acacia mangium* and *Acacia hybrid*.

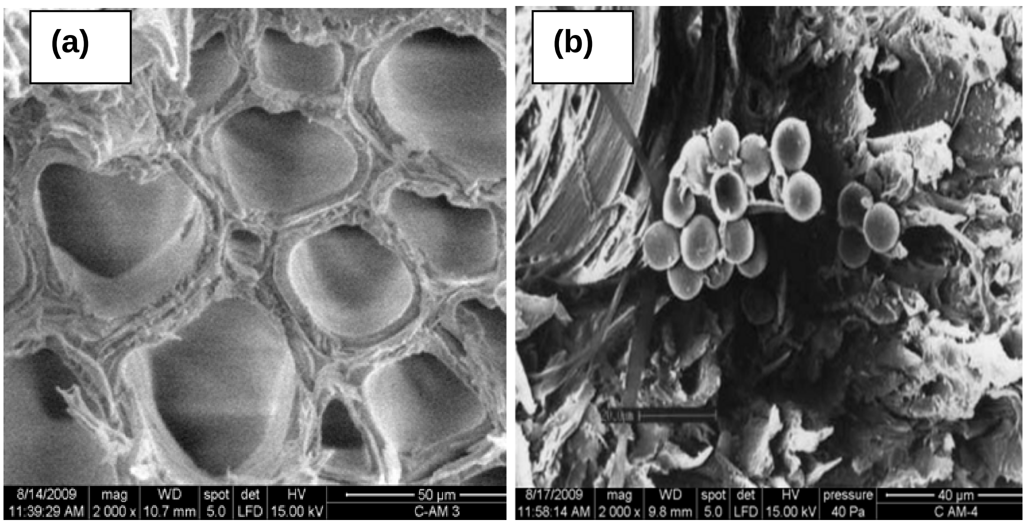


**Figure 8.** (a) SEM micrograph of unmodified *Acacia mangium* before soil burial test **(b)** SEM micrograph of unmodified *Acacia mangium* after soil burial test

The decreased moisture absorption in the cell wall and substitution of hydroxyl groups of the cell wall polymers leads to this protection. According the SEM images, modified samples *Acacia mangium* and *Acacia hybrid* by propionic anhydride were almost similar to *Acacia mangium* and *Acacia hybrid* samples modified by succinic acid. The physical blockage of the cell wall polymers due to the large side groups of anhydrides attached to holocellulose and lignin can be responsible for the less fungal growth in modified samples.

Some study to show improved durability due to chemical modification was reported by Beckers et al. (1998), where acetylated wood exhibited good resistance to brown rot, white rot, and soft rot fungi but was found to give no protection against attack of lower fungi such as mold and stain fungi, even at a weight gain 20% (Wekeling et al. 1991). Chemical modified wood also resisted marine borer attack, but the efficacy did not match that samples treated with CCA or creosote (Johnson and Rowell 1988). Chen and Rowell (1989) also observed that oxidized wood was very resistant to attack by fungi and termites on laboratory scale. Similar testing with oxidated wood by Geothals and Stevens (1994) showed that full protection of beech and good decay resistance of pine were achieved after a decay test with white rot (*Coriolus versicolor*) and brown rot (*Coniophora puteana*).

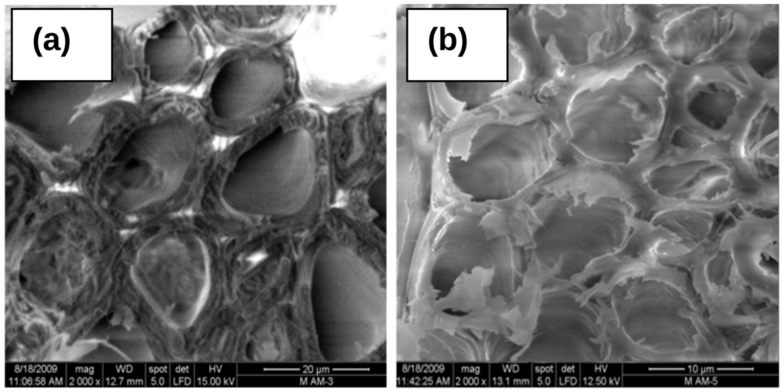


**Figure 9. (a)** SEM micrograph of chemically modified *Acacia mangium* by propionic anhydride before soil burial test, **(b)** SEM micrograph of chemically modified *Acacia mangium* by propionic anhydride after soil burial test (12 months)

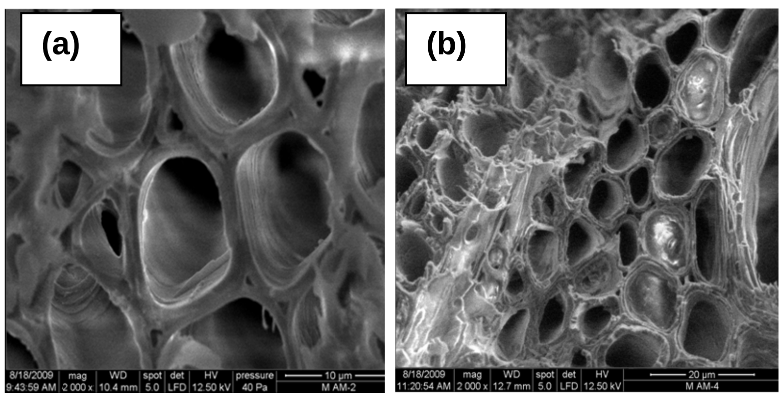


**Figure 10. (a)** SEM micrograph of chemically modified *Acacia mangium* by succinic anhydride before soil burial test (12 months), **(b)** SEM micrograph of chemically modified *Acacia mangium* by succinic anhydride after soil burial test (12 months)

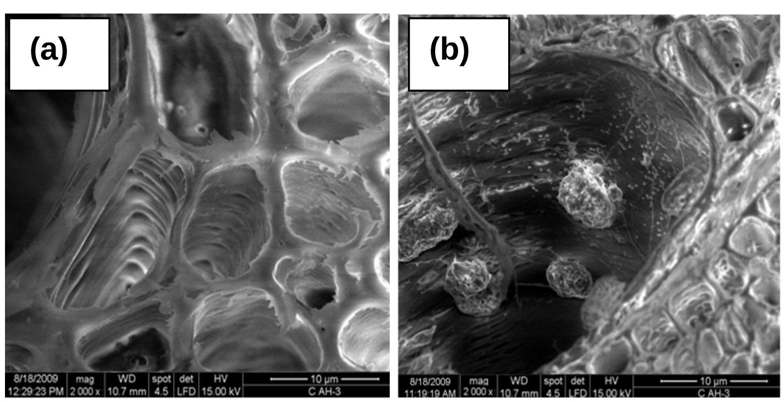


**Figure 11. (a)** SEM micrograph of unmodified *Acacia hybrid* before soil burial test, **(b)** SEM micrograph of unmodified *Acacia hybrid* after soil burial test

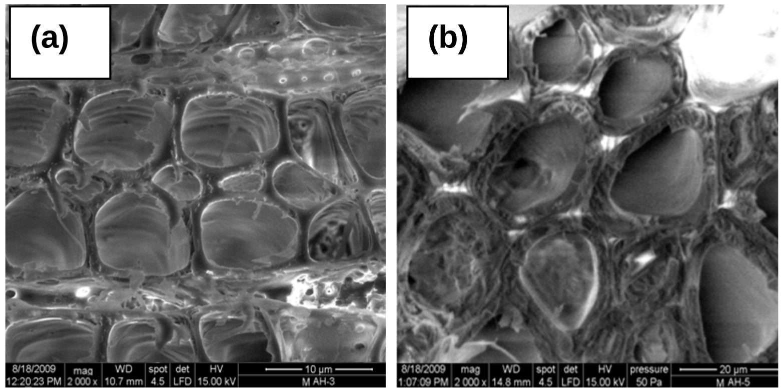


**Figure 12. (a)** SEM micrograph of chemically modified *Acacia hybrid* by propionic anhydride before soil burial test, **(b)** SEM micrograph of chemically modified *Acacia hybrid* by propionic anhydride after soil burial test (12 months)

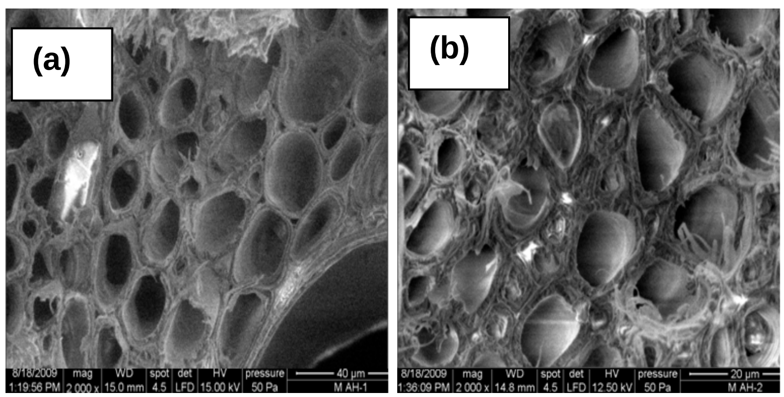


**Figure 13. (a)** SEM micrograph of chemically modified *Acacia hybrid* by succinic anhydride before soil burial test, **(b)**. SEM micrograph of chemically modified *Acacia hybrid* by succinic anhydride after soil burial test

## Discussion of Test Methodology

The rapid change in the wood preserving industry towards the use of non-toxic chemical wood preservatives has increased the need for rapid test methods to evaluate new preservative systems. A key element in accelerated test methodology is the use of accurate, quantitative methods for measuring the extent of decay; therefore mechanical tests developed for small test specimens show promises. Progress has also been made in developing accelerated soil contact and above-ground decay test methodology. The design and development of new eco-friendly wood preservatives are paralyzed by the extended time period required to carry out the evaluation needed to establish assurance in the long term performance of new preservative systems. Reports have shown that using both physical and mechanical properties loss as a measure of the extent of wood decay makes it possible to detect the early stages of decay that results from non-enzymatic reactions (Morton and French 1966; Wilcox 1978; Janzen 2001). Nicholas and Crawford (2003) have designed methods that have applications for both above-ground and soil contact preservative systems. The evaluation techniques provide a better understanding of moisture control, microbial succession, soil chemistry, and soil microbial dynamics; therefore, it is possible to develop improved test methods that can greatly reduce the time required to evaluate wood preservative systems.

## CONCLUSIONS

- In this study a preliminary investigation of degradation of unmodified and modified samples of *Acacia mangium* and *Acacia hybrid* by propionic anhydride and succinic anhydride was carried out. Results revealed that unmodified samples show lower resistance to microbial attack in terms of discoloration, stains on the surface, and mass loss.
- Decrease in mechanical properties (strength and modulus) in relation to time exposure was observed; however less loss in these properties was observed in modified samples.
- SEM studies were conducted to access microbial attack, and the results were consistent with those of the other tests.
- As a general conclusion, chemical modification can provide better physical, mechanical properties and resistance to microbial attack when subjected to soil burial, leading to enhanced stability of *Acacia* wood.

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