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EFFICIENCY OF NATURAL WOOD EXTRACTIVES AS WOOD PRESERVATIVES AGAINST TERMITE ATTACK

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ABSTRACT

Wood extractives play a major role in the protection of wood against termite and fungal attack. Wood extractives from three hard wood species of *Milicia excelsa*, *Albizia coriaria* and *Markhamia lutea* that are known to be very resistant against termite attack and fungal decay were studied to assess their role as wood preservatives in Uganda. Acetone, hexane and distilled water were used in the extraction of these compounds from the outer heartwood of the selected durable species. Extraction was done using a soxhlet extractor. The extractives obtained were used to treat *Pinus caribaea* and *Antiaris toxicaria* species known to be susceptible to termites and fungal attack. Treated blocks were then exposed to *Macrotermes bellicosus* termites in the field. It was observed that wood extracts used as preservatives improved the resistance of less durable samples to termite attack by 50% compared to the controls. It was also observed that removal of extractives decreased resistance of the durable samples. It can be concluded that wood extractives contribute greatly to the protection of less durable wood species against termite attack.

Keywords: Durability, deterioration, preservation, extractives.

INTRODUCTION

Wood being a biological material is readily degraded by bacteria, fungi and termites (Walker 1993, Schultz and Nicholas 2002). However, some wood species are resistant to these degrading agents while others are very susceptible to deterioration (Kityo and Plumptre 1997). Wood preservation is a process of reducing and/or preventing attack by wood deteriorating agents thereby increasing the service life of wood (Barnes 1992).

At present, most wood is treated with synthetic organic and inorganic substances such as Copper Chromium Arsenate (CCA) and creosote. These synthetic chemicals are expensive and often harmful to the workers and the environment (Venmalar and Nagaveni 2005). Worse still, these preservatives are not readily degraded to harmless products and are not easy to detoxify. The copper based preservatives are also poor inhibitors of mould (Arango *et al.* 2005) and are very costly. The dangers posed to wood treatment workers by most of the conventional proprietary wood preservatives, in addition to environmental degradation are becoming a matter of major concern worldwide (Barnes 1992).

There are wood species that are naturally resistant to bio-deterioration agents. The resistance is mainly due to the accumulation of extractives in the heartwood, some of which are decay inhibitors (Kityo and Plumptre 1997). It is these extractives which render the heartwood unpalatable to wood destroying organisms. Hinterstoisser *et al.* (2000) noted that the content of extractives plays a key role in the prediction of the durability of wood. The concentration of extractives varies among species, between individual trees of the same species and within a single tree.

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There are several advantages of using wood extractives as preservatives to enhance the service life of wood. For example, wood extracts have been reported to be relatively safer than synthetic preservatives, but still effective against plant pathogens (Arango *et al.* 2005). Barnes (1992) noted that extractives are organic based preservatives produced by nature and might be easier to detoxify and dispose off without adverse environmental effects. The aim of this study was to assess the use of wood extractives as wood preservatives in increasing the service life of susceptible timber species.

MATERIALS AND METHODS

Selection of sample trees and sample preparation

The outer heartwood of mature trees of *Milicia excelsa* (Welw.) C. Berg, *Markhamia lutea* (Benth.) K.Schum. and *Albizia coriaria* Welw. ex Oliver were selected for the study based on their known natural durability. Two mature defect free trees of each species with diameter of 80cm and above were selected from Mukono District. The trees were converted into timber by pitsawying. The heartwood was selected for the study. The timbers selected for the study were planed and cut into small test specimens of 10 x 5 x 5cm. Each sample set was labeled for ease of future identification.

Pinus caribaea Morelet and *Antiaris toxicaria* Lesch trees have low durability and were selected for the study to test for the effectiveness of the extracts. Two mature trees with diameter above 40cm were obtained from Kifu forest in Mukono district and converted to timber. Only the sapwood from the butt end was selected for the study because it is very susceptible to insect and fungal attack (Kityo and Plumptre 1997). They were planed and cut into small test specimens, with dimensions of 10 x 5 x 5cm.

Extraction of durable species

Two hundred grams of the samples of each durable wood species were placed in the soxhlet extractor at a time and extracted with 150ml of hexane, acetone and distilled water respectively according to ASTM D1413 (2003) standards. During extraction, one solvent was used at a time and later replaced with another after washing the apparatus to avoid contamination. A total of nine wood extracts were obtained. Each extract was kept separately in the dark under refrigeration at 10-15^{o}C.

Treatment of samples with extracts

Ten test specimens of each of the two less durable timber species in the study were randomly selected from the samples and treated with hexane, acetone and distilled water extracts from *M. excelsa, M. lutea* and *A. coriaria.* As a control, ten specimens of each less durable species were exposed to the termites without any treatment. A total of 100 samples of each less durable species were treated. Treatment involved total immersion of the specimens in a bath of extracts for 5 days until a constant weight was achieved. This method compares to the results got with pressure impregnation of chemicals during wood preservation (Ibach 1999, Roll 2003). Four percent Copper Chromium Arsenate (CCA) a known preservative was also used as a control to compare the level of efficiency with extracts.

After treatment, the test specimens were air dried, then oven dried at 60^{o}C for 10 hours, until a constant weight was achieved. A lower temperature was used so that extractive compounds were not lost through evaporation, degradation or by high temperatures. The specimens were then relabeled, conditioned to equilibrium moisture content and weighed to determine their initial weight $W_{1.}$

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Field trials

The test specimens were then end painted with different colors for easy identification (Bultman and Southwell 1976) labeled and then exposed to termites in the field. Field trials were preferred to laboratory studies because they allow the collective and cumulative effects of all kinds of abiotic and biotic deterioration factors to be evaluated (Peralta *et al.* 2003). They also give reliable data regarding natural resistance of wood (Bultman and Southwell 1976).

The effect of extractives on natural durability was also tested by exposing hardwoods whose extracts had been removed to termite attack. Ten specimens of the studied hardwood species that had been extracted with water, hexane or acetone were exposed to the same termites that were exposed to the less durable species. The total number of hardwood samples was ninety with a 3 x 3 x 10 treatment structure. Ten specimens of each species that was not extracted were also exposed to these termites as control.

Study area description and arrangement of samples in the field

The field site was in Kilungu village, Nama sub county in Mukono district, Uganda where large infestation of *Macrotermes bellicosus* (Smeathman) termites had been detected earlier during preliminary studies. Samples were arranged randomly in the field (Figure 1).The experiment was carried out in an enclosed farm with a fence that helped keep away grazing animals. The samples were then covered with grass, and tree branches to attract termites and prevent grazing animals from disturbing them. Samples were exposed during the dry season, a period when termite infestation is high.

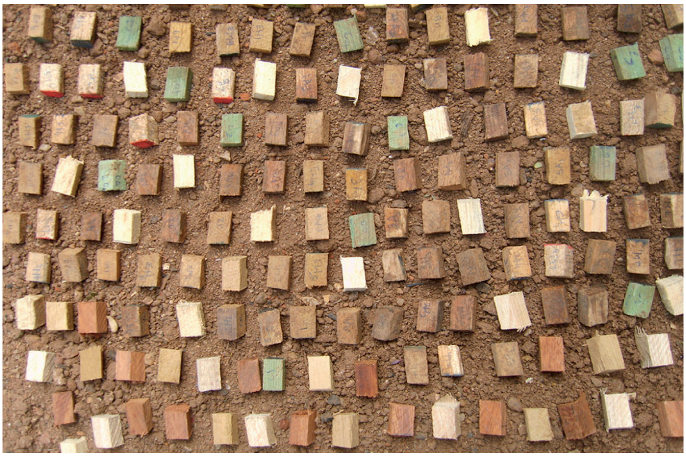


Figure 1. Arrangement of samples in the field.

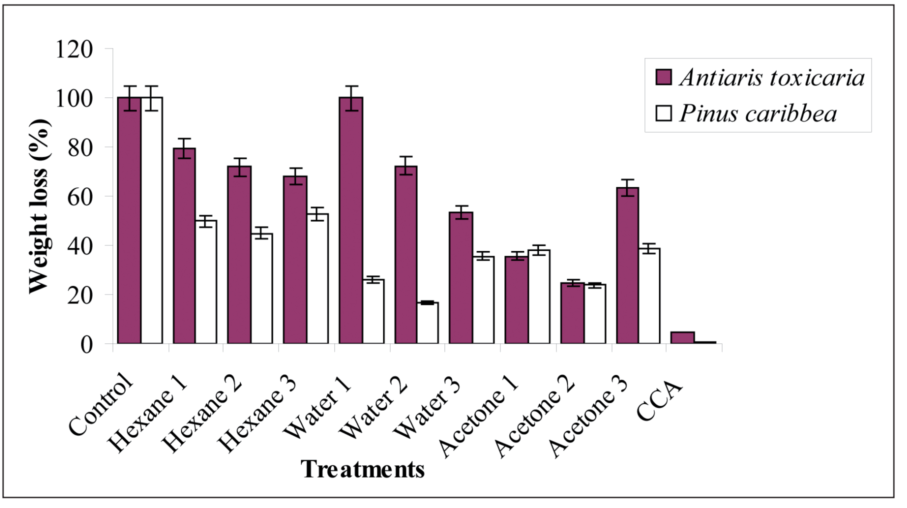
Data collection procedures and Analysis

Inspection of samples was done daily to monitor the level of termite attack. After 7 days of exposure, remaining samples were removed, cleaned, air dried and oven dried for 14 hours at 60°C to obtain a constant weight. After conditioning to equilibrium moisture content (EMC), samples were again cleaned of all soil and weighed to determine their final weight W_2. The percentage weight loss for individual test pieces was determined according to D1413 American standards (2003). Data was analyzed using two way ANOVA and Least Square Difference.

RESULTS AND DISCUSSION

Effect of treatment of less durable species with wood extractives

Average weight loss for *A. toxicaria* and *P. caribaea* treated with CCA (a well known effective wood preservative) was 4.35 and 0.94 percent respectively after exposure to termite attack. On the other hand, the untreated control samples were completely destroyed in the same period of exposure (Figure 2). This indicates that these two species are very susceptible to attack by termites. However their resistance to termite attack significantly improved after treatment with CCA preservative.



Key: 1 = *M. excelsa*; 2 = *A. coriaria*; 3 = *M. lutea*

Figure 2. Effectiveness of the various wood extractives on *P. caribaea* and *A. toxicaria.*

Average weight loss for *A. toxicaria* and *P. caribaea* treated with wood extractives was 57.3 and 40.2 percent respectively after five days of exposure to termite attack (Figure 2). Analysis of variance (Table 1) shows that the resistance to termite attack of *A. toxicaria* and *P. caribaea* increased significantly after treatment with wood extractives (F value of 9.78 and P < 001).

However, the increase in resistance to termite attack was less effective than in CCA treatment. A two way analysis of variance also showed that the extraction method significantly affected the effectiveness of the extracts (P < 0.05) while the species from which the extract was obtained had no significant effect at 5% level of significance (P = 0.695) as shown in table 1. This may be attributed to the fact that different solvents remove different combinations of chemicals from the wood.

Table 1. Analysis of Variance for weight loss of less durable species.

Source of variation	DF	SS	MS	F	P
Treatment	10	15.1518	1.5152	9.78	<.001*
Species	1	0.0238	0.0238	0.15	0.695
Treatment. Species	10	4.8975	0.4897	3.16	<.001*
Residual	198	30.6688	0.1549		
Total	**219**	**50.7419**			

* Significant at 5% level

The interaction between species and treatments was also found to be significant (P<0.01) F=3.16. This is probably because different solvents extracted different compounds from the durable woods that later improved the less durable wood species. This interaction could also be attributed to differences in permeability of the less durable tree species. There could have been better penetration in samples that showed a higher level of protection.

A pair wise comparison of means using the Least Significant Difference (LSD) statistical test shows that the most effective chemicals were those extracted using acetone from *M. excelsa* and *A. coriaria* (Table 2). The samples treated with these extracts showed significant less weight loss compared to water and hexane.

Table 2. LSD between means.

Experimental group	1	2	3	4	5	6	7	8	9
1	0.000			0.109			0.300*		
2		0.000			0.210			0.353*	
3			0.000			0.175			0.112
4				0.000			0.189		
5					0.000			0.143	
6						0.000			0.063
7							0.000		
8								0.000	
9									0.000

Differences larger than 0.255 are significant at α = 0.05 level and are indicated with *

Wood extractives were found to increase resistance to termite attack in both *P. caribaea* and *A. toxicaria* by 50%. Similar results were reported by Goktas *et al.* (2007) who evaluated the wood preservative potentials of *Sternbergia candidum* Mathew Et T. Baytop extracts. Weight losses for all treated samples decreased significantly confirming the effectiveness of extract solution in enhancing decay resistance.

Onuorah (2000) also found out that heartwood extract of *Erythrophleum suaveolens* (Guill. & Perr.) Brenan and *Milicia excelsa* when applied to less durable sapwoods were effective in suppressing attack of either *Lenzites trabea* or *Polyporous vericolour* fungal species. In their study on the effect of wood extracts on growth and cellulase production of strains of *Bacillus subtilis*, addition of wood extract significantly inhibited the growth of *Bacillus* strains (Femi-ola and Aderibigbe 2008) confirming their effectiveness.

Resistance of these woods to termites after preservation could be due to the extractives repellent characteristics. The repellent characteristics could be due to the toxic chemical composition of the various wood extractives and the durability of the heartwood of the tree species from which they were extracted. This is in support with Taylor *et al*. (2006) who in their study suggested that the methanol-soluble extractives of *Thuja plicata* and *Chamaecyparis nootkatensis* play an important role in heartwood resistance to attack by *Coptotermes formosanus* and *Postia placenta*. They further noted that methanol soluble extractives of the heartwood of those tree species were positively correlated with both termite and decay resistance.

Chemical combinations of the several wood extractive components could probably be the reason for the improvement of resistance to termites by the less durable sapwoods. This is because different compounds obtained by the different extracting solvents show different efficacy towards termite resistance. Since there are many different compounds present in wood extractives, it was not possible to determine the active chemicals that are toxic to termites. Taylor *et al.* (2006) also concluded that it was not possible to focus on a single heartwood extractive measurement in order to understand the natural durability but on their combination.

Resistance of *P. caribaea* to termite attack after treatment with wood extracts was significantly higher than in *A. toxicaria* treated with same extracts. *Pinus caribaea* had better protection than *A. toxicaria* probably due to better penetration of extracts during immersion. This could be due to the fact that *P. caribaea* is more porous than *A. toxicaria* hence was able to take in more extractives than *A. toxicaria.*

Extractives with which susceptible timbers were treated would not offer a practical alternative to CCA treatment. The extractives did not render the susceptible timbers resistant enough to termite attack to offer a reliable alternative to standard wood preservatives. This resistance could be achieved by using different durable timbers as a source of extractives than the ones chosen for this study or a combination of different extractives from various durable woods. The critical components in the extracts will need to be chemically identified and synthesized for use as preservatives. This can be very practical if some of the synthetic preservatives are banned from Uganda.

Effect of removing wood extractives from durable species

Removing combined extractives of durable hardwoods reduced their resistance to termite attack. Average weight loss of the hardwoods after extraction is shown in figure 3.

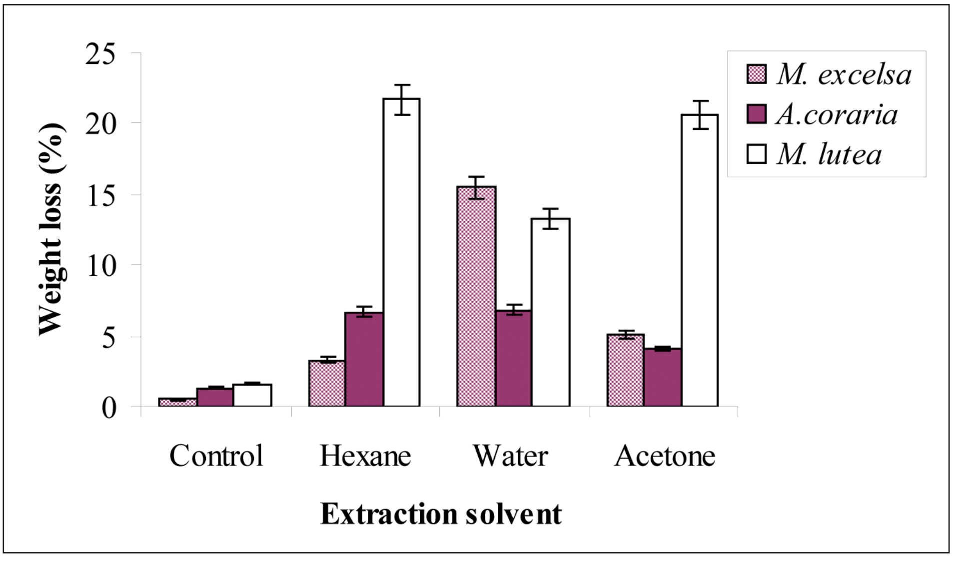


Figure 3. Comparison of percentage weight loss of the durable tree species with extraction solvent used.

Average weight loss of the control samples of *M. excelsa*, *A. coriaria* and *M. lutea* were 0.9%, 2.1% and 2.4% respectively. *Markhamia lutea* samples were less resistant to termites after removal of extractives followed by *A. coriaria* and lastly *M. excelsa.* This may be attributed to the extractive composition of these woods and the solvents that were used to extract them. One solvent could have failed to extract some components compared to another.

Average weight loss for *M. excelsa* samples was 6%, 26.2% and 8.3% (Figure 2) after extraction with hexane, distilled water and acetone respectively. *Milicia excelsa*, extractives were more soluble in water followed by acetone and lastly hexane. Removal of water extracts from *M. excelsa* affected those specimens negatively. Average weight loss for *A. coriaria* samples was 6.5%, 6.8% and 4.1% after extraction with hexane, distilled water and acetone respectively. *Albizia coriaria* extracts were most soluble in water and hexane. Average weight loss for *M. lutea* was 21.7%, 13.3% and 20.6% (Figure 2) after removal of extractives with hexane, distilled water and acetone respectively. *Markhamia lutea* extracts were most soluble in acetone and hexane than in water.

Resistance of durable tree species against termite attack is significantly different with or without extractives (Table 3). Treatment of durable tree species by removal of their extractives reduced their resistance to termites significantly ($P < 0.05$). In other words, removal of extractives increased susceptibility of durable species to termite attack. The null hypothesis is rejected since removal of wood extractives from durables species reduced their durability to termite attack.

Table 3. Analysis of Variance of Weight loss for durable species.

Source of variation	DF	SS	MS	F	P
Treatment	3	0.58994	0.19665	3.17	0.027*
Species	2	0.54009	0.27005	4.35	0.015*
Treatment. Species	6	0.54499	0.09083	1.46	0.198
Residual	108	6.70287	0.06206		
Total	**119**	**8.37789**			

*Significant at 5% level

The control samples of hardwoods exposed to termites without extraction were not significantly attacked by the termites. *Milicia excelsa* was the most resistant followed by *A. coriaria* and lastly *M. lutea*. However, after extraction, there was a decrease in level of resistance to termites as the durable wood was still relatively resistant. It could be due to the fact that extracts embedded in the cell wall could not be removed. This resistance could also be attributed to their high densities that they are able to remain durable even after extractive removal. Wood density affects the permeability of wood hence solvents used could not be able to remove all the extractives. This is in support with Peralta *et al.* (2003) who deduced that wood density is a determining factor of natural resistance of wood to termites.

Solubility of extractives in polar solvents reduced the resistance of durable species to termites in this study. Taylor *et al.* (2006) observed that most extractives in the heartwood of *T. plicata* and *C. nootkatensis* were methanol soluble and their removal reduced the durability of those wood pieces to fungal decay and termite attack. The resistance of the durable wood samples reduced with extraction which confirms that most of their heartwood extractives responsible for termite resistance were removed. It is not solely the amount and toxicity of extractives in the heartwood that gives heartwood termite resistance, but the extractives combined toxicity and antioxidant properties (Schultz *et al.* 2008, Ragon *et al.* 2008, Pereira *et al.* 2009)

CONCLUSIONS AND RECOMMENDATIONS

The study showed that resistance of perishable tree species significantly increased after treatment with extracts from durable tree species. Toxicity of the chemicals depended on the tree species from which the extract was obtained and the solvent used for extraction. It also showed that durability of *M. excelsa*, *A. coriaria* and *M. lutea* reduced after removal of their extractives but not significantly possibly because extractives embedded in the cell walls were not readily removed by extraction. It is recommended that a similar study be carried out to determine the effectiveness of the extracts to fungi.

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