Scientific Research Publishing

Materials Sciences and Applications, 2025, 16(7), 367-375
https://www.scirp.org/journal/msa
ISSN Online: 2153-1188
ISSN Print: 2153-117X

# The Thermo-Chemical Modification of Avodire (*Turraeanthus africanus*) to Enhance Its Performance for Interior Applications

**Gladys Ama Quartey, Eric Donkor Marfo, Emmanuel Yaw Wereko, Kezia-Beryl Godwyll**

Department of Interior Design and Technology, Faculty of Built and Natural Environment, Takoradi Technical University, Takoradi, Ghana
Email: glad.quartey@gmail.com

**How to cite this paper:** Quartey, G.A., Marfo, E.D., Wereko, E.Y. and Godwyll, K.-B. (2025) The Thermo-Chemical Modification of Avodire (*Turraeanthus africanus*) to Enhance Its Performance for Interior Applications. *Materials Sciences and Applications*, **16**, 367-375.
https://doi.org/10.4236/msa.2025.167021

**Received:** May 26, 2025
**Accepted:** July 13, 2025
**Published:** July 16, 2025



## Abstract

Lesser-utilised wood species may have the same or even superior performance for certain end-uses compared to the majority of Ghana's most commonly used wood species. Avodire (*Turraeanthus africanus*) is a Lesser-utilised wood species and is found in large quantities in forests of Ghana, but it is a less durable wood. Thermal treatment is a technique that can be used to enhance the durability of wood. The purpose of this research was to chemically and thermally treat Avodire wood samples to investigate the impact of the modification on its durability for interior applications. The wood samples were chemically modified to a weight percentage gain of 7.78 ± 0.48 and thermally modified between temperatures 150˚C and 240˚C. Thermo-chemically modified samples exhibited resistance to decay and termite degradation. According to the study's findings, samples that were not thermally treated and those that were thermally treated but not chemically modified had more weight loss and were less resistant to termite damage. Thermo-chemically modified samples at temperatures between 150˚C and 240˚C were effective for increasing the species' resistance to damage from termites and decay.

## Keywords

Avodire, Durability, Graveyard, Thermal Treatment, Weight Loss

## 1. Introduction

In recent years, chemical and thermal modification of wood has become a well-known method for protecting wood against water absorption [1] and fungal infestations. Thermal modification is a technique that, when carried out at high temperatures in the absence of oxygen to prevent wood combustion, enhances dimensional stability and durability. Thermal treatment has an insignificant negative effect on environmental pollution [2]. Thermal treatment enhances the durability of woods with poor natural durability, making them resistant to decay [3] [4]. The enhanced decay resistance of wood is due to changes in the wood cell wall polymers after heating [5]-[7]. While thermal modification increases the durability of wood, it reduces its strength properties [8]-[10]. In termite-infested regions, thermally treated wood does not provide enough protection against termite damage [11]-[14]. According to Salman [15], samples of thermally modified wood that were impregnated with boron offered complete protection against termite attack and deterioration. Also resistant to termites were wood samples impregnated with polyglycerol methacrylate and modified at 220 degrees Celsius [15]-[17] reports that chemical modification of wood increases its resistance to termite destruction. Polyglycerol methacrylate is a mild chemical that has been used in conjunction with thermal treatment to improve the durability of thermally treated wood [15] [16].

There are around 90 (ninety) wood species in Ghana that are actively harvested and marketed as timber. Some Lesser-known and Lesser-utilised species may have comparable or even superior performance end-uses according to [18], but the durability of some of these species is poor. Durability refers to the capacity of a wood species to withstand the deterioration of degrading organisms [18]. Ghana's natural woodlands contain significant quantities of Avodire [18]. Its hue ranges from creamy-white to pale-yellow to yellow as it darkens. It is a wood species with low-to-medium density between 460 and 660 $kgm^3$. It is non-durable to decay and is susceptible to insect attack (http://www.wood-database.com/avodire/). It is used for furniture, joinery, cabinetry, and paneling [18] which are interior works. The purpose of this study was to chemically and thermally treat Avodire wood samples and assess their resistance to decay and termite damage.

## 2. Materials and Methods

### 2.1. Sample Preparation

The Avodire log was obtained from the Suhuma forest in Sefwi Wiawso located in the Western region of Ghana. The log was sawn to 12 mm × 25 mm × 120 mm (radial tangential longitudinal) sample sizes at Samartex sawmill in Ghana. The sawn samples were dried for two weeks to a moisture content of 20˚C in a kiln. Six sets of samples were produced for decay test and another six sets for termite test. Each sample set had thirty replicates. Wood samples were oven-dried at 103˚C for 12 hours and weighed. For the decay test, one set received no treatment and acted as the control. A second set was treated at 240˚C for eight hours in an oven under a limited oxygen environment using nitrogen as inert gas to prevent combustion. The remaining four sets of samples were impregnated with polyglycerol methacrylate, and subsequently thermally treated at varied temperatures of 150˚C, 180˚C, 210˚C, and 240˚C under a limited oxygen environment for four hours. Samples treated for termite deterioration test followed the same process as that for the decay test.

## 2.2. Impregnation

The 10% (m/m) polyglycerol methacrylate was prepared at the laboratory via hydrolysis of glycidyl methacrylate in aqueous solution [19]. The molecular mass of the glycidyl methacrylate was 142.1546 g/mol with a density of 1.07 g/cm$^3$.

The wood samples were vacuum-impregnated with a Polyglycerol methacrylate solution in a tank equipped with a vacuum pump for eight hours, then oven-dried at 102˚C for 8 hours, dried over silica gel in a desiccator, and weighed. As stated in Equation (1), the percentage of weight increase due to modification was computed.

$$\text{WPG } (\%) = 100 \times (M_o - M_w)/M_w \quad (1)$$

where:

WPG% = percentage weight gain.

$M_w$ = oven-dry mass of unmodified samples.

$M_o$ = oven-dry mass of modified wood samples.

The WPG% computed in equation 1 gave 17.78.

## 2.3. Graveyard Test

The American Society for Testing and Materials [20] method of assessing wood treatment using a graveyard test with stakes was used to record and assess the weight loss and visual changes caused by termite attack and decay. According to [21], the termites found around the site where the test was conducted are the *Cryptotermes havilandi* which are the most common dry wood species in Ghana and occur mainly along the coast but have also been reported to be found in the Ashanti Region. The [20] standards propose a variety of methods for assessing the results of a durability test, including the evaluation of termite destruction and decay based on weight loss.

Samples for the test were exposed to the ground, wood-deteriorating fungus and termite.

Fertile, flat, moist and well-drained land was chosen. There was a 300 cm by 600 cm interval between specimens. The area was not treated with any fertilizers or other chemicals, and the vegetation was managed manually. Every month for six months, five replicates from each of the six sets for the decay test and five replicates from each of the six sets for the termite deterioration test were retrieved from the ground using a straight upward pull, cleaned and oven dried at 103˚C for 12 hours. The weight loss was determined as in Equation (2).

$$(\%\text{DP}) = 100 \times (M_1 - M_2)/M_1 \quad (2)$$

where:

%DP—Percentage weight loss.

$M_1$ = original oven-dry mass of samples before planting in-ground

$M_2$ = oven-d mass of the wood sample after time t, where t = month 1, 2, 3, 4, 5, or 6.

*Resistance to deterioration using weight reduction* (*percent*) *by* [20]

0 to 10: very resistant

11 - 24: resistant;

25 to 44: resistant to some degree;

45 or higher: low resistant or non-resistant.

According to [20] standard, grading termite destructions and decay by visual evaluation is by using grade numbers 10 > 9 > 8 > 7 > 6 > 4 > 0 indicating increasing order of degradation from zero degradation, degradation to 3%, degradation from 3% to 10%, degradation from 10% to 30%, degradation from 30% to 50%, degradation from 50% to 75%, and fail, respectively.

### 2.4. Statistical Analysis

The study used Genstart, version 12. Analysis of Variance (ANOVA) was used to assess the differences in the results from the test.

## 3. Results and Discussion

### 3.1. Durability Evaluation Based on Weight Loss

The percentage weight loss of samples after six months on the ground is shown in **Table 1**.

**Table 1.** Average percentage weight Loss for samples of avodire not polyglycerol methacrylate modified and not thermally treated (nMPMnT), samples thermally and chemically modified with polyglycerol methacrylate (MPMT), and samples not polyglycerol methacrylate modified but thermally treated at 240˚C (nMPMT) after six months of contact with the ground.

| Weight loss (%) | | | | | | |
|---|---|---|---|---|---|---|
| | nMPMnT | nMPMT | MPMT | | | |
| Month | | | 150˚C | 180˚C | 210˚C | 240˚C |
| 1 | $18.86^{a1}$ | $17.26^{a1}$ | $1.42^{b1}$ | $1.22^{c1}$ | $1.10^{c1}$ | $1.10^{c1}$ |
| 2 | $28.61^{a2}$ | $24.38^{a2}$ | $2.06^{b2}$ | $1.80^{c2}$ | $1.54^{c1}$ | $1.40^{c1}$ |
| 3 | $49.93^{a3}$ | $44.22^{a3}$ | $3.50^{b3}$ | $1.88^{c2}$ | $1.76^{c1}$ | $1.24^{d1}$ |
| 4 | $56.78^{a4}$ | $60.14^{a4}$ | $3.74^{b3}$ | $2.83^{c3}$ | $2.60^{d2}$ | $2.06^{e2}$ |
| 5 | $66.88^{a5}$ | $70.00^{a5}$ | $3.93^{b3}$ | $3.50^{c3}$ | $2.84^{d2}$ | $2.60^{d2}$ |
| 6 | $78.92^{a6}$ | $82.04^{a6}$ | $4.51^{b4}$ | $4.00^{c4}$ | $3.60^{d3}$ | $3.20^{e3}$ |

*Superscript with the same letters on a row are not significantly different at $P < 0.05$; *Subscript with the same numbers on a column are not significantly different at $P < 0.05$.

**Table 1** demonstrates that the resistance of polyglycerol methacrylate-thermally treated samples (MPMT) to termite destruction was superior to that of samples not modified with polyglycerol methacrylate and not thermally treated (nMPMnT), and samples not modified with polyglycerol methacrylate but thermally treated at

240˚C (nMPMT). As the temperature increases, the weight loss for MPMT samples was low compared to the weight loss of nMPMnT and nMPMT samples. In termite-infested locations, thermally treated wood alone without chemical modification does not provide enough protection against termite damage [11]-[14]. For samples not treated with polyglycerol methacrylate and not thermally treated (nMPMnT) there was a significant weight loss. Weight loss rose from 18.86% after the first month to 78.92% after six months. Weight loss rose for (nMPMT) from 17.26% to 82.04%, suggesting poor performance against deterioration for both nMPMnT and nMPMT after six months of in-ground testing. After the first month, both nMPMnT and nMPMT began to lose weight in accordance with [20] criteria, with the samples failing after six months. The samples were resistant in the first month, moderately resistant in the second month, and failed in the sixth month after resistance decreased from less resistant in the third month to failure. However, the performance of the MPMT under different thermal treatments was superior. This indicates that the polyglycerol methacrylate contributed to the improvement of resistance of MPMT samples to termite destruction. As the temperature of the MPMT rose from 150˚C to 180˚C, 210˚C, and 240˚C, the weight loss reduced, showing greater resistance to degradation. According to [22] and [23], there is a correlation between mass loss issues from wood thermal degradation, treatment intensity (time and temperature) and weight loss of heat-treated wood due to decay. From the findings at temperatures below 210˚C, degradation of only hemicellulose might have started, hence a lower absorption of water and a decrease in the activities of the termite. Cellulose and hemicellulose degrade at higher temperatures above 180˚C leading to lower absorption of water molecules and reducing activities of termite resulting in lower weight loss.

## 3.2. Durability Evaluation Using Visible Termite Damage

After six months of in-ground planting in soil, the visible termite damage to wood samples is shown in **Table 2**.

**Table 2.** Average visual termite destruction in 6 months for nMPMnT, nMPMT, and MPMT samples of avodire.

| Visual Termite Grade | | | | | | |
|---|---|---|---|---|---|---|
| | nMPMnT | nMPMT | MPMT | | | |
| Month | | | 150˚C | 180˚C | 210˚C | 240˚C |
| 1 | $6.86^{a1}$ | $6.87^{a1}$ | $9.90^{b1}$ | $9.92^{b1}$ | $9.96^{c1}$ | $10.00^{c1}$ |
| 2 | $5.99^{a2}$ | $5.43^{a2}$ | $9.88^{b1}$ | $9.91^{b1}$ | $9.96^{b1}$ | $10.00^{c1}$ |
| 3 | $4.82^{a3}$ | $4.86^{a3}$ | $9.88^{b1}$ | $9.90^{b1}$ | $9.94^{b1}$ | $9.99^{c1}$ |
| 4 | $2.76^{a4}$ | $3.00^{a4}$ | $9.86^{b1}$ | $9.86^{b1}$ | $9.93^{c1}$ | $9.98^{c1}$ |
| 5 | $1.20^{a5}$ | $1.06^{b5}$ | $8.96^{c1}$ | $9.80^{c1}$ | $9.93^{c1}$ | $9.96^{d1}$ |
| 6 | $0.00^{a6}$ | $1.00^{b5}$ | $8.96^{c1}$ | $8.98^{c2}$ | $9.92^{d1}$ | $9.95^{d1}$ |

*Superscript with the same letters on a row are not significantly different at $P < 0.05$; *Subscript with the same numbers on a column are not significantly different at $P < 0.05$.

**Table 2** shows that the nMPMnT and nMPMT samples fared less well than the MPMT. After the first month, 30% to 50% of nMPMnT and nMPMT samples exhibited visible termite damage. Visual grading of termite destruction rose from 50% to 75% beginning in the second month, and by the sixth month, samples of nMPMnT and nMPMT lacked termite resistance. According to [11]-[14], thermal modification alone does not increase resistance against termite destruction. Therefore, neither the nMPMnT nor the nMPMT was resistant to termite destruction.

The MPMT samples exposed to temperatures between 150˚C and 180˚C degraded by 3% in the first month and 10% in the sixth. MPMT treated at 210˚C was damaged by 3% during the sixth-month trials, but at 240˚C experienced no destruction during the first month and 3% destruction during the sixth month. This indicates that as the temperature used to treat MPMT increased, so did their resistance to decay, termites and destruction. As the temperature for the treatment increases, the wood polymers are degraded and OH groups decrease, leading to less hygroscopicity and less fungi activity. The impact resistant to decay of the thermally treated material is its low moisture content which is not enough for fungal growth [3].

### 3.3. Estimation of Durability Using Visual Deterioration Grade

After six months of in-ground planting of specimens in soil, the degrees of decay seen on wood samples are shown in **Table 3**.

**Table 3.** Average visual deterioration grade for nMPMnT, nMPMT, and MPMT of avodire samples after six months in-ground.

| Visual Decay Grade | | | | | | |
|---|---|---|---|---|---|---|
| | nMPMnT | nMPMT | MPMT | | | |
| Month | | | 150˚C | 180˚C | 210˚C | 240˚C |
| 1 | $6.82^{a1}$ | $9.10^{b1}$ | $9.28^{b1}$ | $9.94^{b1}$ | $9.98^{c1}$ | $9.98^{c1}$ |
| 2 | $5.91^{a2}$ | $9.00^{b1}$ | $9.28^{b1}$ | $9.94^{c1}$ | $9.95^{c1}$ | $9.98^{c1}$ |
| 3 | $4.68^{a3}$ | $8.84^{b1}$ | $9.18^{c1}$ | $9.93^{d1}$ | $9.94^{d1}$ | $9.97^{d1}$ |
| 4 | $2.24^{a4}$ | $8.82^{b1}$ | 9.17c1 | $9.86^{d1}$ | $9.93^{e1}$ | $9.97^{e1}$ |
| 5 | 1.00a5 | $8.12^{b2}$ | $8.16^{c2}$ | $9.84^{d1}$ | $9\ .90^{d1}$ | $9.96^{e1}$ |
| 6 | $0.00^{a6}$ | $8.00^{b2}$ | $8.15^{b2}$ | $8.83^{c2}$ | $9.82^{d1}$ | $9.99^{e1}$ |

*Superscript with the same letters on a row are not significantly different at $P < 0.05$; *Subscript with the same numbers on a column are not significantly different at $P < 0.05$.

The results for nMPMnT, nMPMT, and MPMT samples are shown in **Table 3**. The visual decay grading reveals that samples of nMPMT and MPMT were more resistant to deterioration than nMPMTnT. The finding was consistent with publications by [3] and [4] which indicated that heat treatment increases the decay resistance of low durability. When wood is thermally treated, it causes a reduction of accessible OH groups. Reduction of accessible OH groups leads to less absorption of water molecules and therefore fungi activity is reduced [4]. Fungi mobilise substrate that has moisture content above a certain threshold [24]. Chemical modification involves a reaction between the reagent and the hydrophilic hydroxyl groups in the cell wall polymers thereby reducing absorption of moisture into the cell wall. The adduct formed due to the formation of a covalent bond between the reagent and the hydroxyl groups in the cell wall polymers also reduces the volume of space to accommodate moisture in the cell wall [25]. Since chemical modification of wood tends to reduce absorption of moisture into the cell wall, deterioration by fungi is reduced. In addition, the enzymes for metabolising the cell wall polymers are not able to recognise the substrate once the hydroxyl groups are covalently bonded [25]. After one month, the decay rate of the nMPMnT rose from 10% to 30%, and by the sixth month, they had failed. Nevertheless, all nMPMT and MPMT samples subjected to varying thermal treatments performed better than nMPMTnT. As the treatment temperature of nMPMT and MPMT rises, so does their resistance to deterioration. After six months, the decay of nMPMT and MPMT at 150˚C, 180˚C, and 210˚C rose from 3% to 10%; however, at 240˚C, the rise was limited to 3%. At a higher temperature of 240˚C, the wood cell polymer cellulose and lignin that degrade at higher temperatures are degraded causing higher reduction of accessible OH groups and leading to reduction of water molecules into the wood decreasing activities of fungi.

## 4. Conclusion

The weight loss and the visual evaluation of decay and termite destruction suggested that the termite and decay resistance for the MPMT samples improved between 150˚C and 240˚C. In field studies, MPMT samples demonstrated outstanding resistance to termite destruction as measured by weight loss, as well as visible resistance to termite and decay. nMPMT samples exhibited decay resistance but not to termite infestation. During the six-month test period, the nMPMTnT samples saw a greater weight loss and performed the least resistance against decay and termite damage. The modification of Avodire with polyglycerol methacrylate and subsequent heat treatment between 150˚C and 240˚C increases the species' resistance to termite and decay damage.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] Pétrissans, M., Pétrissans, A. and Gérardin, P. (2003) Pore Size Diameter, Shrinkage and Specific Gravity Evolution during the Heat Treatment of Wood. *Journal of Innovation in Forest Industry and Engineering Design*, **1**, 18-24.

[2] Pétrissans, M., Pétrissans, A. and Gérardin, P. (2007) Check the Durability of Heat-Treated Beech Wood. *Tracés*, *Bulletin Technique Technologie du bois de la Suisse Romande*, **17**, 12-16.

[3] Allegretti, O., Brunetti, M., Cuccui, I., Ferrari, S., Nocetti, M. and Terziev, N. (2012) Thermo-vacuum Modification of Spruce (*Picea abies* Karst.) and Fir (*Abies alba*

Mill.) Wood. *BioResources*, **7**, 3656-3669.
https://doi.org/10.15376/biores.7.3.3656-3669

[4] Kamdem, D.P., Pizzi, A. and Jermannaud, A. (2002) Durability of Heat-Treated Wood. *Holz als Roh- und Werkstoff*, **60**, 1-6. https://doi.org/10.1007/s00107-001-0261-1

[5] Tjeerdsma, B.F. and Militz, H. (2005) Chemical Changes in Hydrothermal Treated Wood: FTIR Analysis of Combined Hydrothermal and Dry Heat-Treated Wood. *Holz als Roh- und Werkstoff*, **63**, 102-111.
https://doi.org/10.1007/s00107-004-0532-8

[6] Yildiz, S., Gezer, E.D. and Yildiz, U.C. (2006) Mechanical and Chemical Behavior of Spruce Wood Modified by Heat. *Building and Environment*, **41**, 1762-1766.
https://doi.org/10.1016/j.buildenv.2005.07.017

[7] Nguila Inari, G., Petrissans, M. and Gerardin, P. (2006) Chemical Reactivity of Heat-Treated Wood. *Wood Science and Technology*, **41**, 157-168.
https://doi.org/10.1007/s00226-006-0092-7

[8] Gunduz, G., Aydemir, D. and Karakas, G. (2009) The Effects of Thermal Treatment on the Mechanical Properties of Wild Pear (*Pyrus elaeagnifolia* Pall.) Wood and Changes in Physical Properties. *Materials & Design*, **30**, 4391-4395.
https://doi.org/10.1016/j.matdes.2009.04.005

[9] Andersons, B., Chirkova, J., Andersone, I. and Irbe, I. (2012) Prediction of the Properties of Soft Deciduous Wood in Thermal Modification. *Proceedings of the 2nd Workshop Cost Action FP0904*, Nancy, 96-97.

[10] Dilik, T. and Hiziroglu, S. (2012) Bonding Strength of Heat Treated Compressed Eastern Redcedar Wood. *Materials & Design*, **42**, 317-320.
https://doi.org/10.1016/j.matdes.2012.05.050

[11] Mburu, F., Dumarcay, S., Huber, F., Petrissans, M. and Gerardin, P. (2007) Evaluation of Thermally Modified Grevillea Robusta Heartwood as an Alternative to Shortage of Wood Resource in Kenya: Characterisation of Physicochemical Properties and Improvement of Bio-Resistance. *Bioresource Technology*, **98**, 3478-3486.
https://doi.org/10.1016/j.biortech.2006.11.006

[12] Shi, J.L., Kocaefe, D., Amburgey, T. and Zhang, J. (2007) A Comparative Study on Brown-Rot Fungus Decay and Subterranean Termite Resistance of Thermally-Modified and ACQ-C-Treated Wood. *Holz als Roh-und Werkstoff*, **65**, 353-358.
https://doi.org/10.1007/s00107-007-0178-4

[13] Surini, T., Charrier, F., Malvestio, J., Charrier, B., Moubarik, A., Castéra, P., *et al.* (2011) Physical Properties and Termite Durability of Maritime Pine *Pinus pinaster* Ait., Heat-Treated under Vacuum Pressure. *Wood Science and Technology*, **46**, 487-501.
https://doi.org/10.1007/s00226-011-0421-3

[14] Sivrikaya, H., Can, A., de Troya, T. and Conde, M. (2015) Comparative Biological Resistance of Differently Thermal Modified Wood Species against Decay Fungi, *Reticulitermes grassei* and *Hylotrupes bajulus*. *Maderas. Ciencia y tecnología*, **17**, 559-570.
https://doi.org/10.4067/s0718-221x2015005000050

[15] Salman, S., Pétrissans, A., Thévenon, M.F., Dumarçay, S., Perrin, D., Pollier, B., *et al.* (2014) Development of New Wood Treatments Combining Boron Impregnation and Thermo Modification: Effect of Additives on Boron Leachability. *European Journal of Wood and Wood Products*, **72**, 355-365.
https://doi.org/10.1007/s00107-014-0787-7

[16] Salman, S., Pétrissans, A., Thévenon, M.F., Dumarçay, S. and Gérardin, P. (2015) Decay and Termite Resistance of Pine Blocks Impregnated with Different Additives and

Subjected to Heat Treatment. *European Journal of Wood and Wood Products*, **74**, 37-42. https://doi.org/10.1007/s00107-015-0972-3

[17] Marfo, E.D., Wereko, E.Y. and Larbi, K.O. (2017) Chemical Modification of the Tropical Hardwood Species, *Celtis mildbraedii* (ESA FUFUO), to Improve Its Durability. *Journal of Wood Chemistry and Technology*, **38**, 51-56. https://doi.org/10.1080/02773813.2017.1372476

[18] Blackham, G., Prado, N., Parke, J. and Bastos, C.T. (2020) Lesser-Known and Less-er-Used Timber Species: Utilising Ghana's Sustainable Timber Resources. BVRIO, Forestry Commission.

[19] Ratcliffe, L.P.D., Ryan, A.J. and Armes, S.P. (2013) From a Water-Immiscible Monomer to Block Copolymer Nano-Objects via a One-Pot RAFT Aqueous Dispersion Polymerization Formulation. *Macromolecules*, **46**, 769-777. https://doi.org/10.1021/ma301909w

[20] American Society for Testing and Materials (ASTM) D1758 (2006) Standard Test Method of Evaluating Wood Preservatives by Field Stakes. American Society for Testing and Materials, 220-226.

[21] Quartey, G.A., Zuercher, E. and Frimpong Mensah, K. (2014) Durability Investigations of Lesser-Known Ghanaian Wood Species. *Journal of Technology*, *Takoradi Polytechnic*, **3**, 24-30.

[22] Hakkou, M., Pétrissans, M., Gérardin, P. and Zoulalian, A. (2006) Investigations of the Reasons for Fungal Durability of Heat-Treated Beech Wood. *Polymer Degradation and Stability*, **91**, 393-397. https://doi.org/10.1016/j.polymdegradstab.2005.04.042

[23] Chaouch, M., Dumarçay, S., Pétrissans, A., Pétrissans, M. and Gérardin, P. (2013) Effect of Heat Treatment Intensity on Some Conferred Properties of Different European Softwood and Hardwood Species. *Wood Science and Technology*, **47**, 663-673. https://doi.org/10.1007/s00226-013-0533-z

[24] Eaton, R.R. and Hall, M.D.C. (1993) Wood, Decay, Pest and Protection. Chapman and Hall.

[25] Hill, C.A.S. (2002) How Does the Chemical Modification of Wood Provide Protection Against Decay Fungi? School of Agricultural Sciences, University of Wales, Bangor. Presentation for COST E22.