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ACCELERATED AGEING ASSESSMENT OF BITUMEN AS A PRESERVATIVE FOR THE TREATMENT OF *Gmelina arborea* WOOD

Jacob Mayowa OWOYEMI and Olasunkanmi Joshua OGUNNIYI*

Department of Forestry and Wood Technology, Federal University of Technology Akure, P.M.B. 704, Akure, Ondo State, Nigeria; e-mail: jmowoyemi@futa.edu.ng

*Correspondence: ogunniyiolasunkanmi8@gmail.com

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ABSTRACT. Concerns about the health and environmental risks linked with the use of preservatives, such as chromate copper arsenate (CCA), zinc chloride, mercuric chloride, and the oil-born preservative creosote, prompted the quest for the use of readily available bitumen as a wood preservative. Using samples that had been processed into dimensions of 20 × 20 × 60 mm, the durability and physical characteristics of *Gmelina arborea* wood treated with bitumen were evaluated. The samples were dried for 24 hours in an oven set to 103°C and treated with hot bitumen at a melting point of 270°C to ensure the flow and maximum penetration of the bitumen. The density showed mean values of 504.93 and 498.71 kg/m^3 for the untreated and treated samples, respectively, with the treated samples recording lower values due to the thermal difference in the density distribution between the untreated and treated wood samples. The average weight loss due to leaching of the untreated and treated wood samples after soaking in cold water and hot water was 3.07% and 0.07%, 1.49% and 1.38% respectively for the treatment. The study confirmed the suitability of using bitumen as a preservative for treating *G. arborea* wood in an environment with extreme weather conditions without causing serious leaching, thereby exposing the wood to degrading agents.

Keywords: accelerated ageing; bitumen; *Gmelina arborea*; treated wood; wood preservative.

INTRODUCTION

Wood is a material of biological origin prone to degradation, and it continues to maintain its prime position as a material for building and other construction applications, including bridges, boardwalks and structures, in waterways and wetlands. The sustainable service life of these applications can be accomplished by treating wood with preservatives (Bernhardt, 2017). To ensure that the fixing and retention in place when splits, abrasions and other in-service defects damage the wood, preservatives can be impregnated into the fibre during pressure treatment to protect the timber.

The wood preservation industry has taken large leaps to develop and produce chemicals that protect wood from microorganisms and weathering degradation with no or low environmental impact (Khademibami and Bobadilha, 2022). When deciding which building materials to use, preserved timber has several intrinsic environmental advantages that should be considered (Allan and Phillips, 2021; Morrell, 2011).

The use of bitumen for treating wood, however, has not received much attention. Nigeria's 42 billion barrels of known bitumen reserves are dispersed throughout a 120-kilometre "bitumen belt" that connects the country's middle to its western region (Nigeria First).

Bitumen is a non-crystalline solid or viscous substance with sticky qualities that can be made from petroleum naturally or by refinement. It is a thermoplastic hydrocarbon substance that is either black or dark brown in colour and is produced by processing crude petroleum (Riley, 2004). Bitumen is also used for road building and stone wall waterproofing. Typically, it is heated and kept in a molten condition to make handling easier throughout manufacture, storage, transit and use (Rajib *et al.*, 2021).

The use of wood for different purposes is limited due to its susceptibility to wood-destroying organisms. When in a wet state, wood is easily attacked by biodegrading agents (such as termites, fungi and insects), drastically decreasing its strength properties (Hadi *et al.*, 2021). Testing the durability of wood to be used for different purposes in different intended environments is desirable (McNamara, 1994; Santhakumaran, 1973). Globally, wood users do not appreciate the importance of preservation before utilisation; hence, large quantities of timber are used immediately after conversion from logs, leading to insect attacks and fungal infestation (Dodds *et al.*, 2019). One of the major inhibitions in the processing and utilisation of wood is dimensional instability. Due to the hygroscopic nature of wood, wood in service has the tendency to warp and leach material into the environment. Thus, there is a need to assess *Gmelina arborea* wood treated with bitumen for permanence since this species is now largely used for all forms of construction due to a decline in the supply of durable wood species from the natural forest.

MATERIALS AND METHODS

Study area

This study was carried out at the Department of Forestry and Wood Technology of the Federal University of Technology Akure, Ondo State, Nigeria. Akure is located at a longitude 5.09°E and latitude of 7.18°N in the southwestern part of Nigeria. Its average annual rainfall is approximately 1524 mm, and its average annual relative humidity is approximately 80%. The temperature ranges from 28°C to 31°C (Ibitolu and Ogunjobi, 2016).

Preparation of wood samples

Gmelina arborea trees were obtained from the Department of Forestry and Wood Technology plantation at the Federal University of Technology Akure. The tree trunk was processed into billets for easy evacuation. At the onset of the study, the processed tree trunk was used for different research, such as drying, termite resistance, ageing test, modification and durability. A total of 20 samples were used for this experiment, and the samples were cut to 20 × 20 × 60 mm for the determination of density, moisture content, leaching and accelerated ageing. All samples were planed to remove rough edges, labelled for easy identification and weighed using a weighing balance. After achieving a steady weight through oven drying at 103°C for 24 hours, the samples were placed in a desiccator to cool to room temperature before being weighed.

Determination of physical properties

The physical properties of *Gmelina arborea* wood species were determined on defect-free wood samples with a measurement of 20 mm × 20 mm × 60 mm. The samples were weighed and measured to obtain their initial weights and dimensions and oven-dried at a steady temperature of 103 ± 2°C until a constant weight was achieved. The following tests were carried out.

Moisture content

The moisture content was determined by selecting five wood samples randomly and was calculated as one of the basic properties of the wood. The wood samples were weighed to obtain the initial weight (Wg) and final weight (Wo) before and after drying. Calculations were made to determine the wood samples' moisture content according to ASTM D442-16 (2016) (*Equation 1*):

$$MC(\%) = \left(\frac{Wg - Wo}{Wo}\right) \times 10 \qquad (1)$$

where MC = moisture content, Wg = weight of green samples (g), and Wo = weight of oven-dried samples (g).

Density

The density of the wood samples was determined according to ASTM D2395-14 (2017) (*Equation 2*):

$$\text{Density} = \left(\frac{M}{V}\right) kg/m^3 \qquad (2)$$

where M = mass of the oven-dried sample (kg) and V = volume of the oven-dried samples (m^3).

Weight loss after cold water leaching

The control and treated samples were immersed in cold water for 72 hours and then oven-dried at a certain temperature. After being dried in the oven, the samples were weighed, and the weight loss was calculated using *Equation (3)*:

$$WL\,\% = \left(\frac{C_3 - C_4}{C_3}\right) \times 100 \qquad (3)$$

where WL = weight loss, C_3 = weight of the sample before soaking (g) and C_4 = weight of the sample after soaking (g).

Weight loss after hot water soaking

The control and treated wood samples were boiled in hot water for 1 hour and then oven-dried at a constant temperature of 103±2°C until a constant weight was achieved. The samples were then weighed, and weight loss due to leaching was calculated using *Equation (4)*:

$$WL\,\% = \left(\frac{B_3 - B_4}{B_3}\right) \times 100 \qquad (4)$$

where WL = weight loss, B_3 = weight of the sample before boiling (g) and B_4 = weight of the sample after boiling (g).

Weight loss due to an accelerated ageing test

An accelerated ageing test was conducted according to Sharman and Vautier (1986). The test samples were soaked in water at room temperature for 48 hours.

The soaked samples were boiled in hot water for 1 hour and force-cooled to a temperature of less than 1°C in the freezer (refrigerator) for 24 hours. The samples were later transferred to an oven and dried at 180°C for 1 hour. The tests were carried out based on standardised procedures, following Falemara *et al.* (2012).

The samples were weighed, and their weight loss was calculated using *Equation (5)*:

$$WL\,\% = \left(\frac{A_1 - A_2}{A_2}\right) \times 100 \qquad (5)$$

where WL = weight loss, A_1 = weight of the sample before the ageing test (g) and A_2 = weight of the sample after the ageing test (g)

Determination of the bitumen boiling point

The boiling point of the bitumen was determined by heating it and measuring the temperature when bubbles formed using a thermometer.

Treatment of wood samples

Gmelina arborea wood samples were processed into 20 mm × 20 mm × 60 mm pieces. The treated samples were treated with bitumen, while the untreated samples were used as a control. The bitumen was heated in a metallic pot until it completely melted and flowed easily.

Treatment was performed by dipping the wood samples into a container filled with hot bitumen and leaving them for 24 hours to cool. The solidified bitumen was reheated after 24 hours to ensure easy removal of the wood samples. After treatment, the samples were allowed to drain. The treated samples were weighed, and their percentage of absorption was calculated using *Equation (6)*:

$$Absorption\,(\%) = \left(\frac{T_3 - T_2}{T_2}\right) \times 100 \qquad (6)$$

where T3 = weight of the sample after treatment (g) and T2 = weight of the sample before treatment (g).

The visual observation of the cross-section of the treated samples, however, showed that there was maximum penetration of bitumen through colour change (*Figure 1*).

Statistical analysis

The data obtained were analysed using descriptive statistics with the aid of the Statistical Package for Science (SPSS), and analysis of variance (ANOVA) was carried out to test for significant differences.

The graphical representation was carried out using Microsoft Excel.

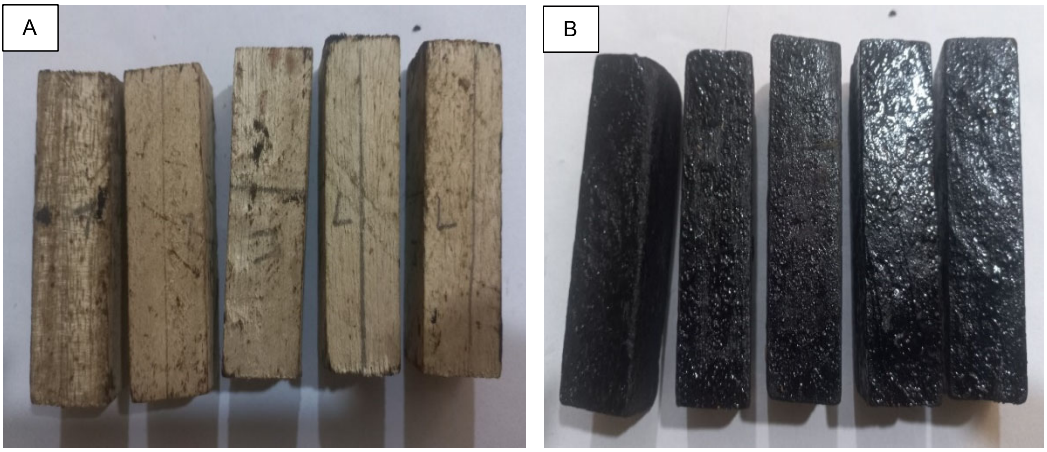

Figure 1 – A: control *Gmelina arborea* wood Samples;
B: treated *Gmelina arborea* wood samples

RESULTS AND DISCUSSION

Percentage moisture content of *Gmelina arborea*

The results in *Figure 1* show the percentage moisture content of the selected *G. arborea* wood samples, which ranged from 44.96 to 92.99%.

When dealing with wood in applications, the moisture content of the wood can have an enormous impact on its quality. Typically, newly sawn wood has moisture levels between 40 and 200%.

According to the relative humidity of the air, the moisture content of wood in typical use ranges from 8 to 25% by weight (Tom, 2018). The existing literature also reports that, through modification involving either chemical treatment or reaction through heat treatment, the dimensional stability of wood can be improved (Owoyemi *et al.*, 2015).

Density

The mean densities of the untreated and treated samples of the *Gmelina* wood species obtained from this study are summarised in *Table 1*. The treated wood samples had a density value of 498.71±41.10 kg/m^3, which was lower than that obtained for the control wood samples, with a value of 504.93±18.57 kg/m^3. Density is a very important variable, with a key influence on every other wood property.

The results of this study revealed that oven-dried *G. arborea* wood was of low density based on the classification method employed by Falemara *et al.* (2012).

Wood absorbs moisture faster due to its large pores. This led to the use of bitumen as a preservative for the treatment of *G. arborea* wood for more stability and resistance against deterioration.

The result of the ANOVA at $\alpha = 0.05$ presented in *Table 2* shows that there was no significant difference in the density distribution between the untreated and treated wood samples, with $F_{(1, 8)} = 0.095$ and $P = 0.766$.

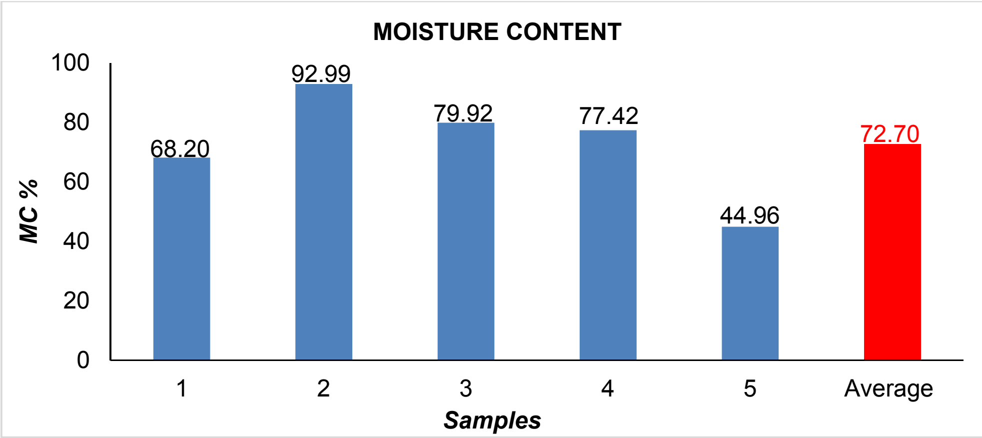

Figure 2 – Percentage moisture content of selected *Gmelina arborea* wood samples before treatment

Table 1 – Density distribution of *Gmelina arborea* wood treated with bitumen

Samples	Density (kg/m^3)
Control	504.93±18.57
Treated	498.71±41.10

Values are means±SD

Table 2 – Analysis of variance for the density of *Gmelina arborea* treated with bitumen

Source of Variation	Sum of Squares	df	Mean Square	F	P-value	Sign
Samples	96.597	1	96.597	0.095	0.766	ns
Error	8134.605	8	1016.826			
Total	8231.202	9				

df = degrees of freedom; F = F-value; ns = Values greater than 0.05 are not significant

Weight loss after cold water leaching

The findings in *Table 3* summarise the results of the weight loss due to the leaching of treated wood samples with bitumen obtained from the study.

The control had a percentage weight loss due to leaching after 72 hours of soaking, with a value of 3.07±0.94%, which was higher than that obtained for the treated wood samples, with a value of 0.07±1.25%.

The ANOVA at α = 0.05 recorded for the cold water leaching of the control and treated wood samples is presented in *Table 4*, showing a significant difference in the cold water leaching of the control and treated wood samples. From this study, the weight loss due to cold water leaching indicates that wood samples treated with bitumen have a lower rate of leaching, while untreated wood samples have the highest rate of leaching.

Weight loss after hot water leaching

Table 5 presents a summary of the weight loss due to hot water leaching of the control and treated wood samples obtained from the study. The control had a higher average weight loss due to leaching after 1 hour of boiling (1.49±0.69%) than the treated wood samples (1.38±0.56%). There were no significant differences (i.e., $P > 0.05$) in the mean of the control and hot water treated samples of the *Gmelina* wood.

The ANOVA at α = 0.05 for hot water leaching of the control and treated wood samples is presented in *Table 6*, showing no significant difference in the hot water leaching of the control and treated wood samples, with $F_{(1,8)} = 0.077$ and $P = 0.789$.

Weight loss after accelerated ageing

The weight loss due to the accelerated ageing test of *Gmelina arborea* wood samples treated with bitumen is presented in *Table 7*.

The control wood samples had a higher weight loss due to the ageing test (4.86±0.83%) than the treated wood samples (2.99±0.80%).

Table 3 – Weight loss due to leaching of control and treated wood samples obtained after 1 hour of water soaking

Samples	Weight loss (%)
Control	3.07±0.94
Treated	−0.87±1.25

Values are mean±SD

Table 4 – ANOVA for the weight loss due to leaching of control and treated wood samples obtained after 72 hours of repeated cycles of water soaking

Source of Variation	Sum of Squares	df	Mean Square	F	P value	Sig.
Samples	38.888	1	38.888	31.951	0.000	*
Error	9.737	8	1.217			
Total	48.625	9				

df = degrees of freedom; F = F-value; * = Values less than 0.05 are significant

Table 5 – Weight loss due to leaching of control and treated wood samples obtained after 1 hour of water soaking

Sample	Weight loss (g)
Control	1.49±0.69
Treated	1.38±0.56

Values are mean±SD

Table 6 – ANOVA for the weight loss due to hot water leaching of the control and treated wood samples obtained after 1 hour of boiling

	Sum of Squares	df	Mean Square	F	P value	Sig.
Samples	0.030	1	0.030	0.077	0.789	ns
Error	3.145	8	0.393			
Total	3.176	9				

df = degrees of freedom; F = F-value; ns = Values greater than 0.05 are not significant

There were no significant differences (i.e., $P > 0.05$) in the mean accelerated ageing between the untreated and treated samples of the wood species, as presented in *Table 8*.

The accelerated ageing treatment given to the *G. arborea* wood samples resulted in a significant decrease in the weight of the wood samples. The untreated wood samples had a higher weight loss than the treated wood samples. Accelerated ageing is used to assess the *Gmelina arborea* wood's long-term performance, serviceability and durability.

These three phrases all suggest that a design criterion is met or surpassed for a predetermined amount of time in a specific service environment.

Therefore, accelerated ageing has become a method for gathering data on durability, which is the capacity to preserve the use of a product, component, assembly or building over a predetermined period of time (ASTM E 632.0, 1978).

Properties of bitumen and wood species

The boiling point for the bitumen, as shown in *Table 9*, was 270°C.

Weight loss due to thermal treatment of *G. arborea* wood

The average weight loss of *G. arborea* wood due to thermal treatment was 11.48%. The weight of the wood samples that had been preserved revealed a reduction compared to the normal trend associated with other preservative methods. This decrease could be attributed to reactions during the thermal treatment process with bitumen, as the temperature required to heat the bitumen to a flowing consistency necessary for its flow into the wood rose to 270°C, resulting in weight loss. This agrees with the findings of Juanito *et al.* (2011), who showed that subjecting wood pieces to temperatures between 180 and 260°C for several hours brings about thermal modification of the wood, resulting in weight loss and reduction of strength properties.

Table 7 – Weight loss due to accelerated ageing of the control and treated wood samples

Samples	Weight loss (g)
Control	4.86±0.83
Treated	2.99±0.80

Values are mean±SD

Table 8 – ANOVA table of the weight loss due to accelerated ageing of the control and treated wood samples

Source of Variation	Sum of Squares	Df	Mean Square	F	P value	Sig.
Samples	8.761	1	8.761	13.123	0.007	ns
Error	5.341	8	0.668			
Total	14.102	9				

df = degrees of freedom; F = F-value; ns = Values greater than 0.05 are not significant

Table 9 – Properties of bitumen

Properties	Value
Boiling Point	270°C

Additionally, Niemz *et al.* (2010) revealed that high temperatures initiate chemical reactions in the cell walls, which result in the degradation of cellulose and hemicellulose and the modification of lignin, and that equilibrium moisture content is lowered by this type of treatment.

CONCLUSIONS

Wood protection is a major step towards ensuring longevity and sustainability in service. Bitumen has proven potent as a preservative for treating timber used for external applications, such as transmission poles, fence posts, and wharf jetties. For the effective utilisation of wood, this study revealed that bitumen can be employed in the preservation of *G. arborea* wood.

Therefore, the efficacy of this treatment in improving the commonly available, less durable plantation wood species is a crucial way to lessen the heavy burden placed on forest vegetation. Consequently, a lot of bitumen is available, which should further encourage the use of this preservative to enhance the inherent properties of wood for different construction applications, especially where it will be exposed to extreme weather conditions.

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