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Comparative Evaluation of Tensile Strength, Young's Modulus and Deformation Behaviour of Selected Nigerian Hardwoods Treated with Used Engine Oil

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Abstract

This investigation compared tensile strength, stiffness and deformation of White Safari, Opeper and Bush Mahogany under untreated and used-engine-oil-treated conditions. Wood obtained in Calabar, Nigeria, was prepared, cleaned and sanded before treatment. The oil was filtered and treated specimens were immersed for six hours. Three specimens were tested for each of nine conditions (27 specimens in total), and the available tensile results are reported as condition means. A universal testing machine operated at 30 mm/min with a 1 N pretension. The highest reported mean peak stress was 64.998 MPa for Bush Mahogany condition MATKD, 16.82% above its untreated reference (55.639 MPa). Untreated White Safari showed the highest reported modulus (2103.601 MPa), while untreated Opeper had the greatest strain at peak (9.067%). Treatment-associated changes differed markedly between species: both treated Opeper conditions showed lower peak stresses than the untreated reference, whereas the White Safari conditions showed higher peak stresses but lower moduli. Strength, stiffness and deformation therefore did not improve simultaneously. Only consolidated means were available, preventing estimation of specimen-level variability or statistical significance. The findings provide a descriptive basis for further replicated investigation with archived specimen-level results, moisture control and measured treatment retention; they do not establish structural suitability or environmental safety.

Keywords: Hardwood, Used Engine Oil, Tensile Strength, Young's Modulus, Mechanical Characterisation, Nigerian Timber, Wood Modification

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1. Introduction

Wood combines relatively low density with useful mechanical performance, yet its anisotropic cellular architecture makes the response to tensile loading sensitive to species, fibre orientation, defects and moisture history. Cellulose-rich microfibrils contribute to longitudinal resistance, while hemicelluloses, lignin and anatomical voids affect deformation and failure. Wood modification is therefore best evaluated through multiple performance measures rather than strength alone (Hill, 2006; Zelinka et al., 2022).

Modification processes can alter moisture interactions and mechanical behaviour, but the direction of the change depends on the treatment medium, processing conditions and substrate. Julian and Fukuda (2024) review how different modification technologies produce distinct physical and mechanical outcomes. Mandraveli et al. (2024) likewise show that oil-heat treatment can change stiffness and strength differently. Those hot-oil processes should not be equated with the six-hour immersion in used engine oil investigated here: temperature, oil composition and treatment mechanisms differ. A Nigerian-focused review by Oyeleye et al. (2024) also underscores the importance of species-specific evaluation.

Used engine oil is not a standardised preservative: its composition varies with service history and it may carry contaminants. Even a favourable mechanical comparison cannot demonstrate suitability for use without environmental and leaching assessment. Recent reviews of wood modification emphasise that changes in physical and mechanical properties must be interpreted together with the underlying treatment chemistry (Jančíková and Jablonský, 2025; Dziurka and Mirski, 2025).

This study compares the available tensile-test means for three Nigerian hardwoods, focusing on peak stress, Young's modulus and strain at peak. It distinguishes observed contrasts from statistically demonstrated effects and examines whether greater measured strength coincides with greater stiffness.

2. Materials and methods

2.1 Wood selection and preparation

White Safari, Opeper and Bush Mahogany wood samples were obtained from the timber market at Effio-Ette, Calabar, Nigeria. Specimens were cleaned and lightly sanded using 120–180 grit abrasive paper to remove surface dirt and contamination, prepared for their respective tests and dried before treatment and characterisation. The original experimental account does not provide a complete numerical record of cross-sectional dimensions, initial moisture contents or drying temperature and duration; these parameters are therefore not assigned values here.

2.2 Oil immersion and specimen identification

Condemned (used) engine oil was filtered to remove coarse solid particles. Prepared treated specimens were fully immersed for six hours, removed from the oil and dried before characterisation. Untreated wood served as the within-species reference. The tensile records identify Bush Mahogany as MATK, MATKD and MAUT; Opeper as OPTK, OPTKD and OPUT; and White Safari as WSTK, WSTKD and WSUT. UT identifies the untreated condition. The original analytical records sometimes use the suffix O where the tensile reports use D; those differently labelled conditions are not assumed to be identical. The treatment distinction between the two treated tensile codes is not specified beyond their recorded identifiers, so the results are interpreted by code rather than assigned an unverified chemical mechanism.

2.3 Tensile testing and data reduction

Tensile testing used a universal testing machine at a recorded crosshead speed of 30 mm/min and a pretension of 1 N. The instrument reports identify a sample length of 100 mm. Nominal engineering stress is force divided by original cross-sectional area ($\sigma = F/A_0$); engineering strain is extension divided by

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initial gauge length ($\varepsilon = \Delta L/L_0$); and Young's modulus is the slope of the approximately linear stress–strain interval. The reported output variables were peak force, peak stress, yield stress, modulus, energy to peak and strain at peak. The original cross-sectional dimensions, gauge-length definition and modulus-fitting interval were not preserved in the supplied consolidated record, so instrument-derived values are reproduced rather than independently recalculated.

2.4 Replication and analysis

Three specimens were tested for each of nine experimental conditions (n = 3 per condition; 27 specimens altogether). According to the authors' experimental clarification, the values retained in the results table are arithmetic means of the three specimen measurements. For a property P, the condition mean is $\bar{P} = (P_1 + P_2 + P_3)/3$. Only the consolidated means are available; the three individual values for each condition were not retained in the supplied thesis. Consequently, standard deviations, confidence intervals, error bars and inferential tests cannot be calculated reliably. Within-species percentage differences were calculated as 100 × (treated mean − untreated mean)/untreated mean. These differences describe the available means and do not establish statistical significance.

3. Results

Table 1 summarises the recorded condition means. Peak stresses ranged from 19.128 to 64.998 MPa and Young's moduli from 1353.211 to 2103.601 MPa.

Table 1. Reported mean tensile properties of hardwood specimens (n = 3 per condition).

Code	Peak force (N)	Peak stress (MPa)	Yield stress (MPa)	Modulus (MPa)	Energy to peak (N·m)	Peak strain (%)
MATK	4557.2	42.623	42.623	1997.340	7.080	3.110
MATKD	6686.3	64.998	64.998	1353.211	17.448	5.338
MAUT	6309.5	55.639	55.639	1495.013	19.036	5.278
OPTK	4240.6	37.395	37.395	1950.510	7.607	3.341
OPTKD	4055.0	32.132	32.132	1903.422	11.689	4.732
OPUT	7274.2	64.146	63.088	1501.306	42.723	9.067
WSTK	2819.6	22.487	22.487	1931.537	4.096	2.591
WSTKD	6050.6	56.504	50.651	1457.394	29.594	7.830
WSUT	2240.4	19.128	19.128	2103.601	2.099	1.578

Bush Mahogany MATKD recorded the greatest peak stress (64.998 MPa), closely followed by untreated Opeper (64.146 MPa). Untreated White Safari recorded the lowest peak stress (19.128 MPa) but the highest modulus (2103.601 MPa). Untreated Opeper also had the greatest peak strain (9.067%) and energy to peak (42.723 N·m).

Table 2. Percentage differences in reported means relative to the untreated condition of each species.

Species	Treated code	Peak stress (%)	Modulus (%)	Peak strain (%)

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Bush Mahogany	MATK	-23.39	+33.60	-41.08
Bush Mahogany	MATKD	+16.82	-9.49	+1.14
Opeper	OPTK	-41.70	+29.92	-63.15
Opeper	OPTKD	-49.91	+26.78	-47.81
White Safari	WSTK	+17.56	-8.18	+64.20
White Safari	WSTKD	+195.40	-30.72	+396.20

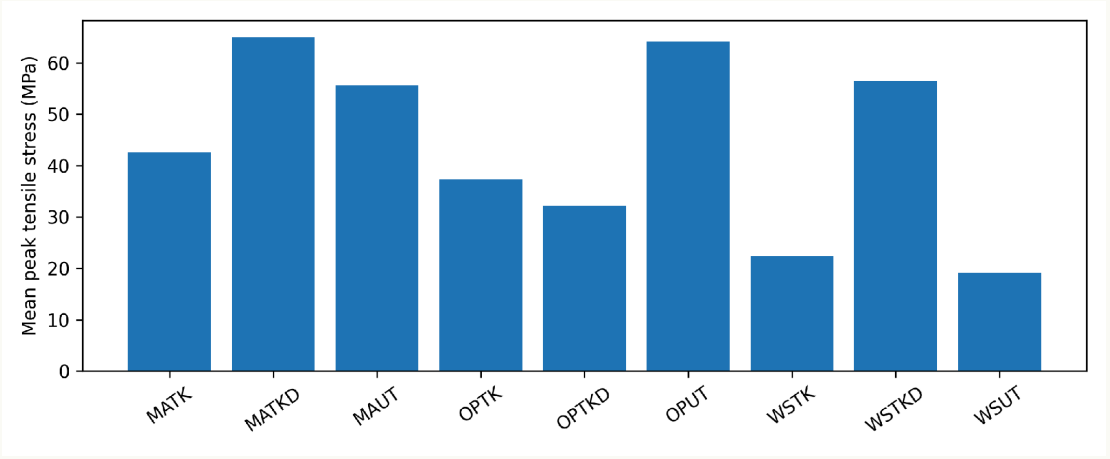


Figure 1. Mean peak tensile stress by specimen condition. Bars represent retained condition means (n = 3); variability estimates were unavailable.

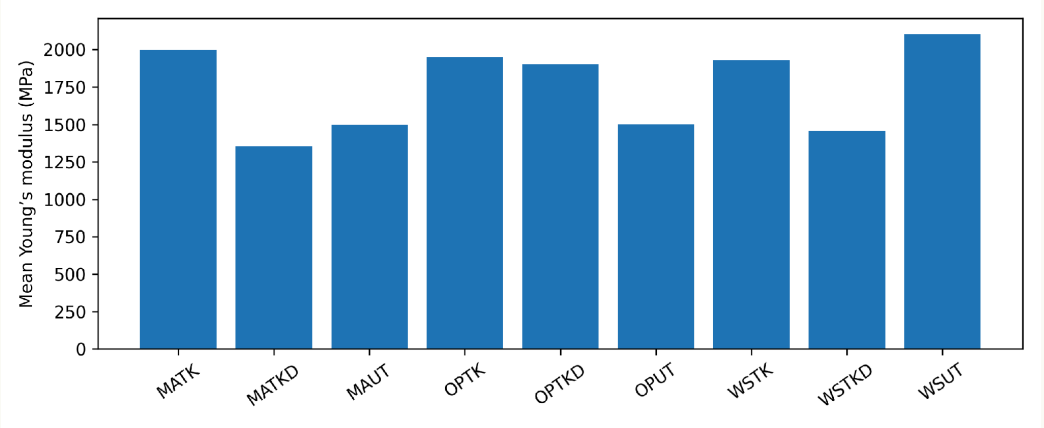
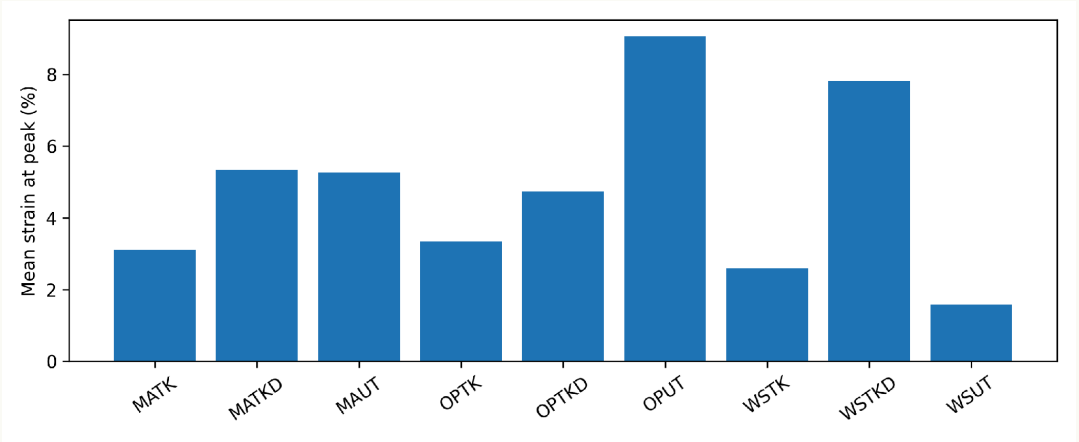


Figure 2. Mean Young's modulus by specimen condition. Bars represent retained condition means (n = 3); variability estimates were unavailable.



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Figure 3. Mean strain at peak by specimen condition. Bars represent retained condition means (n = 3); variability estimates were unavailable.

4. Discussion

4.1 Differences between strength and stiffness

The specimen conditions with the greatest strength and stiffness were different. MATKD had the highest peak stress but the lowest modulus in the dataset; WSUT had the highest modulus but the lowest peak stress. These contrasting rankings show why a single tensile descriptor cannot adequately characterise engineering performance. Differences in grain orientation, defects, anatomical structure and moisture may influence stiffness and failure stress differently (Zelinka et al., 2022; Dziurka and Mirski, 2025). The present measurements do not isolate these causes.

4.2 Species-specific comparisons

Relative to untreated Bush Mahogany, MATKD was 16.82% higher in peak stress, whereas MATK was 23.39% lower. For Opeper, both treated conditions had lower peak stresses than the untreated reference (−41.70% and −49.91%) but higher moduli. For White Safari, WSTKD was 195.40% higher in peak stress than WSUT, with a 30.72% lower modulus. The large White Safari contrast should not be interpreted as a confirmed treatment benefit without access to specimen-level variation, moisture data and treatment retention. This species-dependent pattern is broadly consistent with the wider observation that wood modification effects are contingent on material and process conditions (Julian and Fukuda, 2024; Mandraveli et al., 2024).

4.3 Deformation, limitations and implications

Untreated Opeper had the greatest strain at peak and the greatest instrument-reported energy to peak. The latter describes work accumulated to the peak load and should not be interpreted as intrinsic fracture toughness without the relevant geometry and integration procedure. Peak strain likewise does not necessarily equal total elongation at rupture.

The three-specimen design is acknowledged, but the absence of individual replicate values prevents evaluation of experimental scatter. The treatment codes also lack complete differentiation, and measured moisture content, oil retention and contaminant composition are unavailable. Oil immersion should not be equated with reactive chemical modification or oil-heat treatment. The results are therefore a descriptive comparison of reported means, not evidence of statistically significant strengthening or of qualification for structural use. Environmental suitability of used-engine-oil-treated wood additionally requires contaminant, leaching and exposure assessment.

5. Conclusion

The reported tensile means demonstrate distinct strength–stiffness–deformation profiles among the three hardwoods. MATKD recorded the highest peak stress (64.998 MPa), WSUT the highest modulus (2103.601 MPa) and OPUT the greatest strain at peak (9.067%). Relative to untreated references, treated conditions did not show a consistent direction of change across species or mechanical properties. Three specimens were tested per condition, but only the mean values are available, limiting analysis to descriptive comparisons. Future work should retain specimen-level observations, document dimensions

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and grain orientation, control moisture content and quantify treatment retention and environmental risks before application recommendations are made.

Declarations

Data availability: The consolidated mean tensile results are presented in Table 1 and originate from the underlying doctoral experimental record. Individual specimen measurements are not available in the supplied record.

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Competing interests: No competing interests are reported in the available manuscript record.

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