Received: 12 March 2026 | Revised: 18 June 2026 | Accepted: 27 June 2026

DOI: https://doi.org/10.36481/jaiit.v21ino2.kyvhfc04

RESEARCH ARTICLE

Publisher: Daffodil International University
https://journals.diu.edu.bd/index.php/jaiit

Viability of Panels Processed from *Elaeis guineensis* (Oil Palm) Trunk for Use as Interior Wall Cladding Material

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Abstract: This study assessed the suitability of oil palm (*Elaeis guineensis*) trunks for interior wall cladding, with the aim of developing a new use for oil palm trunks that have outlived their primary purpose of fruit production. Selected physio-mechanical properties of *Elaeis guineensis* were determined on small air-dry wood specimens collected from top, middle, and bottom regions of the trunk. Strips of uniform thickness were laminated, visually graded, and installed for real life evaluation. Analysis of Variance at P = 0.05 revealed a significant difference for samples from the three regions of the tree for all properties evaluated. Physical and mechanical property results fell within C30 to D50 strength class of BS 5268-2, indicating moderate suitability for structural and semi-structural applications. Conversion process revealed the need for machines with stiff blades, high speed and torque for conversion of *Elaesis guineensis* due to the high cutting resistance of the wood, which dulls blades relatively faster. High aesthetic appeal and dimensional stability of *Elaesis guineensis* indicated suitability for wall panels and non-structural applications like woodcraft items production, although real-life assessment indicated moderate susceptibility to powder-post beetle after about 20 months of installation. Therefore, *Elaesis guineensis* wood harvested from replantation operations have relatively high potential of augmenting wood material supply but requires pre-treatment for improved durability.

Keywords: Wall cladding; oil palm wood; physio-mechanical properties; glulam wood; Elaesis guineensis.

1. Introduction

The ever-increasing demand for wood, to support various human activities, has been extensively discussed [1]. This continuous demand for wood has been reported to have a linear relationship with the world's growing population [2]. Nigeria's ever-increasing population has increased pressure on forest estates, resulting in over-exploitation of available forest resources in both natural and plantation forests, which were previously self-sufficient and adequately met demands [3]. This, along with several other factors, has posed a significant threat to forest products, prompting a reconsideration of the need to find suitable substitutes that can supplement major commercial timber species [4].

The exploitation pattern across all timber species have been found to be non-uniform, due to the over-reliance on familiar economic wood species [5]. Most trees grown for fruit and other purposes other than timber production have active productive years, after which they become less productive and eventually non-productive, before they die as a result of old age. According to [6], oil palm (*Elaeis guineensis*) is one of the most important economic crops in this category. This may be due to its widespread availability and numerous applications, such as oil, brooms, etc. Oil palms can live for up to 200 years, but their commercial oil yield drops dramatically after 30 years [7]. Old and dying oil palm trees are common in Nigeria, especially in open fields, plantation and natural forests. A preliminary survey by the authors indicated that substantial quantities of felled or dying palm trees are left to rot away without concern for wastage and have the propensity to pose fire and environmental hazards.

Several studies agree that older trees have better mechanical performance than younger trees because the latter have juvenile wood [8], [9], [10]. The bole of the oil palm tree tends to be cylindrical than several other wood species, which could suffice for higher wood volume recovery [11]. However, the size of the palm trunk is often the great bane for processing it into standard lumber. Perhaps that is why it is only converted to dimension lumber of 2 × 3, 2 × 4 and 2 × 6 inches for structural application such as truss member fabrication in rural house construction [12]. The percentage of use for this purpose is significantly small

compared to the availability of dying and felled oil palm trunk in Nigeria.
However, one promising application for oil palm is in the production of laminated boards using principle of Glue-Laminated (GLULAM) technology. It has been reported that GLULAM has higher utilization potential in terms of dimensional stability, uniformity, desired mechanical properties, availability in larger sizes, improved stress distributing properties, appealing appearances, ease of moulding, and, adaptability to be engineered based on the desired end use. This has promoted it as a successful alternative to solid wood [13]. Therefore, adaptation of GLULAM to utilizing wood from oil palm trunk is capable of enhancing its utilization potential.

The suitability of wood-based panels for interior wall cladding largely depends on their physical and mechanical properties. Previous studies have identified sorption properties like water absorption and thickness swelling as important parameters for assessing the dimensional stability of wood-based products exposed to fluctuating moisture conditions [14], [15]. These sorption properties are important because excessive moisture uptake may cause dimensional changes, delamination and gaps between laminated panels during service. The structure of oil palm has been reported to be highly porous and heterogeneous, which may promote rapid moisture uptake, making the evaluation of these properties essential before the material can be recommended for panel applications [16], [17]. Mechanical properties of wall-cladding materials demonstrate how they can handle installation impact and other service loads. Although wall cladding is generally considered a non-structural or semi-structural element, the material must possess adequate strength and stiffness to maintain its integrity throughout its service life [18]. Studies on oil palm trunks have shown considerable variation in mechanical performance due to differences in density and anatomical structure within the stem, highlighting the need for further evaluation of their suitability for engineered panel products [16], [19], necessitating the assessment of both physical and mechanical properties of oil palm trunks as raw material for interior wall-cladding panels.

Again, the texture and aesthetical features of wood from oil palm are additional features that could makes it suitable for use in interior upgrade especially in form of panel application. Yet there is paucity of information on the suitability of wood from oil palm trunk for semi-structural and non-structural applications. This is why this study was initiated to carry out investigation of the viability of processing the trunk of *Elaeis guineensis* into engineered products in form of panels, for use as construction material in interior wall cladding.

2. Methodology

Senescent *E. guineensis* trunk sourced within the University of Ibadan main campus was felled and cant-sawn. Lumber of 50 x 150 x 1400 mm and discs sawn from three (3) sections of the tree (top, middle and bottom) were sorted and taken to the Department of Wood Products Engineering for further processing. Panels were processed from the senescent *E. guineensis* trunk, following the procedures outlined in Fig. 1. Urea formaldehyde was used as panel's adhesive (Fevicol®).

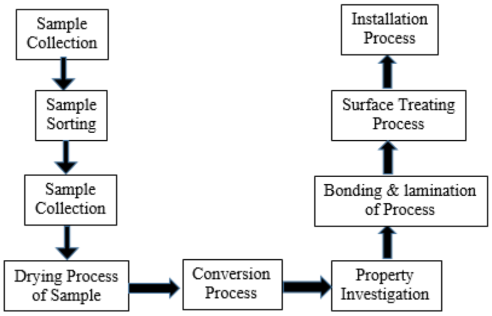


Fig. 1. Production and Study Process

Green samples were obtained for from the bottom, middle and top of the log for shrinkage test. Six replicates were produced from each section of the tree and labelled accordingly.

Plate 1: Conversion and Sorting
(a) sawing process (b) Sorted lumber from the base, middle and top sections

2.1. Material Testin

Their initial moisture content was measured using a moisture meter and they were stacked and air-dried under a shed. Temperature, relative humidity and moisture content were monitored in the space of twelve (12) weeks at intervals until equilibrium moisture content was reached.

Plate 2. Moisture Determination

Plate 3. Stacking and air-drying

Wood materials from the discs were dimensioned to sample sizes of 20 x 20 x 60 mm for the determination of physical properties and 10 x 10 x 300 mm for mechanical property evaluation as per [20]. Five replicates were gotten from each region.

The physical, sorption and mechanical properties determined were moisture content, specific gravity, density, shrinkage and swelling, Moduli of Elasticity and Rupture (MOE and MOR). Moisture content was determined in accordance with [21]. The sample sizes were 50 x 50 x 50 mm. The samples were weighed and then dried in an oven at a temperature of 103 ± 2 °C (217 ± 4 °F) until the weight is constant. The moisture content of the test piece was determined by the weight loss expressed as a percentage of the final oven dry weight. Percentage Moisture content (M.C) is expressed as:

$$M.C = \frac{W_g - W_o}{W_o} \qquad (1)$$

Where: Wg = Air-dried weight of sample at test in grams, W_o = Oven-dried weight of sample in grams.

The densities of oven dry samples of dimensions 20 x 20 x 60 mm were computed using the formula:

$$P = \frac{M_o}{V_w} \qquad (2)$$

Where, P = Density; W_0 = Mass of oven dry wood (kg); V_w = Volume of wood (m^3)

Specific gravity was determined in accordance with [21] by dividing the dry density of the specimen by the density of water at 4^0 C (999.997 kg m^{-3}). The test specimens were of dimensions 20 x 20 x 60 mm.

In accordance with [21] Test specimens of 25.4 mm × 25.4 mm × 101.6mm, collected at green state were first weighed, then air-dried to equilibrium moisture content. The radial and tangential shrinkages were computed using Equation 3 and then summed to give the volumetric shrinkage.

$$S = \frac{L_g - L_a}{L_g} \times 100 \qquad (3)$$

Where, S = Percentage shrinkage; L_g = Green width (Inches); L_a = Air-dried width (Inches)

Swelling, the volume of dry wood of 20 x 20 x 60 mm was first calculated, and the test specimens were then soaked in water for 48 hours (2 days) to condition to moisture above fibre saturation point (FSP). Specimens were removed, and their wet-state dimensions were measured with a digital Vernier calliper and recorded to the nearest millimetre. The following formula was used to calculate volumetric swelling:

$$S = \frac{V_2 - V_1}{V_1} \times 100 \qquad (4)$$

Where S is the volumetric swelling coefficient, V_2 is the wood volume after humidity conditioning or wetting with water, and V_1 is the oven-dried sample's wood volume before wetting.

Flexural test was conducted on a 50 KN Jinan Hensgrand® Universal testing machine in accordance with [21], at a loading rate of 2mm/m from which the Moduli of Rupture (MOR) and elasticity (MOE) were evaluated (Plate 3.2). The flexural properties were computed as follows:

$$MOE = \frac{P'L^3}{4\Delta' b d^3} \qquad (5)$$

$$MOR = \frac{3PL}{2bd^2} \qquad (6)$$

Where MOE is the Modulus of Elasticity (N/mm^2) ; P' is the load at the proportionality limit (N); P is the static bending maximum load; L is the length of the span (mm); Δ' is the centre deflection at the proportionality limit load (mm); b is the width of the sample (mm), and, d is the thickness (depth) of the sample (mm).

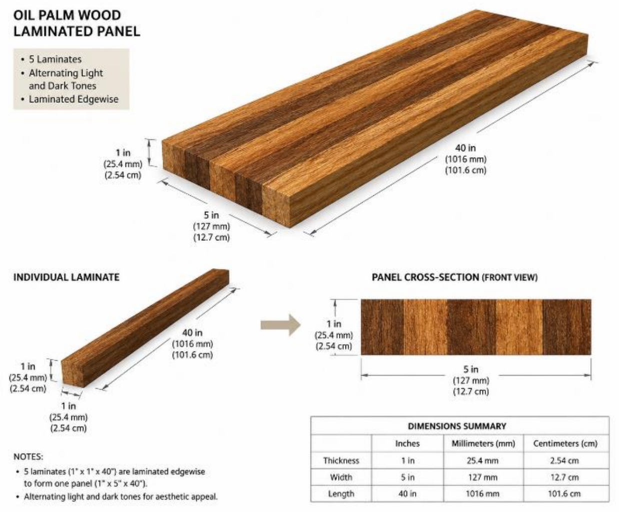
2.2. Panel production and Evaluation

Air-dried planks were processed using a thicknesser and were then converted into strips of 35 × 55 × 1005 mm. The machining characteristics were observed during the conversion process. Sorting was done by visual grading to separate strips of better grades. The strips were laminated flatwise using a synthetic adhesive with trade name Fevicol® which was applied using brush on well dried and clean surfaces. Immediately after adhesive application, the strips were firmly clamped using F-clamps, and allowed to cure for a period of about 24 hours (Plate. 4). Edge trimming and sanding ensued to form laminate panels of dimensions 32.5 x 50 x 100 mm. The surfaces were treated and finished using a mixture of sanding sealer and saw dust to fill voids.

Then sanding again was done before finishing using vanish (Plate 4).

Prior to installation, panels were weighed, the walls were cleaned and the wall dimensions were taken. Installation was done by nailing panels to the wall until intended area was covered. After that, evaluation of the wall panels, at 3 months intervals, within the space of three years ensued.

Plate 4. **Panel** Production and Installation Processes (a) Clamping (b) Sanding (c) Finishing (d) Installation



NOTES:

- 5 laminates (1" x 1" x 40") are laminated edgewise to form one panel (1" x 5" x 40").
- Alternating light and dark tones for aesthetic appeal.

DIMENSIONS SUMMARY

	Inches	Millimeters (mm)	Centimeters (cm)
Thickness	1 in	25.4 mm	2.54 cm
Width	5 in	127 mm	12.7 cm
Length	40 in	1016 mm	101.6 cm

Fig. 2: Detail of Manufacturing Parameters of panels

3. Results and Discussion

The characteristics of *Elaeis guineensis* tree are presented in the Table 1. The height of the tree was about 9 m; the girth was between 30 cm and the moisture content value ranged from 28 % to 65 %. Much waste was generated during the conversion process which can be attributed to wide kerf of the blade of the chain saw and irregularities such as knots.

Table 1: Characteristics of the Harvested Oil Palm Tree

Parameter	Value
Age	43 years
Height	9 meters
Girth/diameter	30 cm
Moisture content	28-70%

3.1. Moisture Content

The result of moisture contents of wood from the three distinct regions are presented in Table 2. The average moisture content of freshly cut bamboo was 70 %. After processing into strips, it dropped to 29 %, and air drying further reduced the moisture content below 18 %. It took about 12 weeks of air drying for the lumber to attain equilibrium moisture content.

Table 2: Mean Values Result for Moisture Content Test

Groups	Count	Sum	Average	Variance
Base	5	85.17	17.04	26.72
Middle	5	82.73	16.55	3.14
Top	5	70.28	14.06	11.00

Analysis of variance of moisture contents from the three regions presented in Table 3 revealed a significant difference in moisture content across the three regions at P = 0.05. This is attributable to the influence of density on the drying rate of wood.

Table 3: Analysis of Variance Results for Moisture Content Test

Variation Source	SS	Df	MS	F	P-value	F crit.
Between Groups	25.55	2	12.77	0.94	0.42	3.89
Within Groups	163.45	12	13.63			
Total	188.99	14				

***(Note:** SS = Sum of Squares; Df = Degrees of Freedom; MS = Mean Square; F = F-statistic (calculated F-value); F crit. = Critical F-value at the 5% significance level (α = 0.05). A significant difference exists when F > F crit.)*

3.2. Specific Gravity

The mean value of specific gravity of *Elaeis guineensis* wood samples are presented in Table 4. It was observed that samples obtained from the top portion of the tree had the lowest value (0.83), while samples obtained from the base gave the highest value of 0.94. The values obtained in this study were in accordance with the results of [22] who reported specific gravity range of oil palm wood as 0.35 to 0.98. The values also compare closely with other materials usable for wall cladding reported by [23] like MDF (Medium-Density Fiberboard), OSB (Oriented Strand Board) and plywood. This indicates potential of its applicability for wall cladding.

Table 4. Mean Value Results for Specific Gravity Test

Groups	Count	Sum	Average	Variance
Base	5	4.69	0.94	0.00044
Middle	5	4.48	0.90	0.00549
Top	5	4.15	0.83	0.00053

Analysis of variance of specific gravities of *Elaeis guineensis* samples from the three regions presented in Table 5, revealed a significant difference at P = 0.05. This intra-species variability in specific gravity may be influenced by growth conditions as well as variability in anatomical and chemical composition along the stem [25].

Table 5. Analysis of Variance for Specific Gravity Test

Variation Source	SS	Df	MS	F	P-value	F crit
Between Groups	0.03	2	0.01	6.81	0.01	3.89
Within Groups	0.03	12	0.002			
Total	0.06	14				

3.3. Density

The mean value of density result conducted on *Elaeis guineensis* were presented in Table 6. Samples gotten from the base had the highest value of 409.58kg/m^3 followed by the middle sample which had 404.66 kg/m^3 while the top sample recorded the least value of 337.47 kg/m^3. This is in accordance with the work of [26] that reported density values of oil palm wood species to be between the range of 300g/m^3 to 480g/m^3 which falls within the grade of C30 as per [27], which suggests suitability in areas where high strength is not required such as semi-structural and non-structural applications.

Table 6. Mean Values of Density Test

Groups	Count	Sum	Average	Variance
Base	5	2047.92	409.58	4875.85
Middle	5	2023.32	404.66	1761.69
Top	5	1687.37	337.47	919.74

Analysis of variance of densities of *Elaeis guineensis* samples from the three regions is presented in Table 7. There is significant difference between the means of densities of samples from the three regions (Fcal (3.22) < Fcrit 3.89) at 0.05 level of probability.

Table 7. Analysis of Variance for Density

Variation Source	SS	Df	MS	F	P-value	F crit
Between Groups	16231.03	2	8115.51	3.22	0.08	3.89
Within Groups	30229.13	12	2519.09			
Total	46460.17	14				

3.4. Percentage Volumetric Shrinkage

Table 8 shows the mean value of percentage volumetric shrinkage conducted on *Elaeis guineensis* wood samples. The samples obtained from the top portion had the highest percentage value of 3.25 while the samples obtained from the base portion of the tree had the lowest percentage value of 1.81. The results of significance between groups and within groups for percentage volumetric shrinkage of *Elaeis guineensis* samples were presented in Table 9. The Analysis of Variance result showed that *Elaeis guineensis* wood samples were found insignificant with values obtained from Table 9 result Fcal 5.03 > Fcrit 3.89 at 0.05 level of probability. This indicate that there is insignificant difference between the wood samples used for percentage volumetric shrinkage evaluation as this can be attributed to appropriate drying of the samples.

Table 8. Mean Values of Percentage Volumetric Shrinkage

Groups	Count	Sum	Average	Variance
Base	5	9.07	1.81	0.30
Middle	5	14.01	2.80	0.17
Top	5	16.24	3.25	1.15

Table 9. Analysis of Variance for Percentage Volumetric Shrinkage Test

Variation Source	SS	Df	MS	F	P-value	F crit
Between	5.40	2	2.70	5.0	0.03	3.89
Within	6.44	12	0.54			
Total	11.8	14				

3.5. *Volumetric Swelling*

The mean value of percentage volumetric swelling conducted on *Elaeis guineensis* samples are presented in Table 10. The samples obtained from the top portion of the tree had the highest value of 3.37, followed by the samples obtained from the middle portion with the value of 2.88 while the base samples recorded the least value of 1.81.

However, the results of significance between groups and within groups for percentage volumetric swelling of *Elaeis guineensis* samples are presented in Table 11. The Analysis of Variance result showed that *Elaeis guineensis* wood samples were found insignificant with values obtained from Table 11 result Fcal 5.03 > Fcrit 3.89 at 0.05 level of probability. Appropriate drying of the samples could have accounted for this.

Table 10. Mean Value Result for Percentage Volumetric Swelling Test

Groups	Cou	Sum	Avera	Varianc
Base sample	5	9.25	1.85	0.32
Middle	5	14.4	2.88	0.19
Top sample	5	16.8	3.37	1.29

Table 11. Analysis of Variance for Percentage Volumetric Swelling Test

Variation Source	SS	Df	MS	F	P-value	F crit
Between Groups	6.02	2	3.01	5.02	0.03	3.89
Within Groups	7.18	12	0.59			
Total	13.20	14				

3.6. *Flexural Properties*

The Moduli of Elasticity and Rupture are depicted in Fig. 3 and 4. It was observed that the base samples had the highest MOE value of 13,656 N/mm^2 followed by the top samples which recorded MOE value of 12,713.96 N/mm^2. The top middle had the lowest MOE value of 12,351.68 N/mm^2.

The MOE values found in this study are very similar to those values reported by [23 & 27], who found that MOE values of selected oil palm wood produced from three portions of the tree at different moisture contents. The MOE values fall within grade D50 of BS 5268-2:2002 [28], suggesting suitability for structural and semi-structural applications like furniture, craft/novel items. Preliminary studies in Oyo State show that the *Elaeis guineensis* wood is currently in use for roof trusses. Samples obtained from the top portion recorded the highest value of Modulus of Rupture of 290.72 N/mm^2 followed by middle samples portion with the MOR value of 290.03 N/mm^2 and the base samples had the lowest MOR value of 276.55 N/mm^2. It is also important to note that the test samples were not very strong in bending, probably due to the presence of high silica content found in *Elaeis guineensis* wood as against other non-wood species such as bamboo that demonstrated infinitesimal rupture behaviour as observed by [29]. Comparing *Elaeis guineensis* bending properties with that of other wood-based composite materials applicable for wall cladding, reported by [24], the MOE values *Elaeis guineensis* were substantially higher than all engineered wood-based panels, including particleboard (2,760–4,140 N/mm²), MDF (3,590 N/mm²), OSB (4,410–6,280 N/mm²), and plywood (6,960–8,550 N/mm²). Similarly, the MOR values (276.55–290.72 N/mm²) greatly exceed those reported for particleboard (15.17–24.13 N/mm²), OSB (21.80–34.70 N/mm²), hardboard (31.02–56.54 N/mm²), and plywood (33.72–42.61 N/mm²), indicating markedly superior stiffness and bending strength relative to conventional panel products. This may be because most of these cladding materials are reconstituted wood products, not engineered like *Elaeis guineensis.*

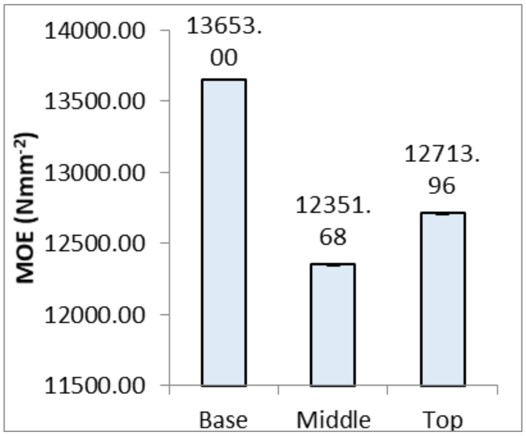


Fig. 3. MOE of *Elaeis guineensis* from the three regions of the trunk

3.7. Machining Characteristics of Oil Palm Wood

The inherent fluctuating density of oil palm timber makes machining this material difficult [30]. High cutting speeds, on the other hand, resulted in better sawing and edge profiling characteristics, with an average defect-free surface of about 85%. Chip out and tear out were the most prevalent flaws discovered while machining the oil palm lumber utilized in this study, which was most likely owing to the lumber's varied density and the presence of a significant number of vascular bundles and parenchyma cells. Consequently, while machining the oil palm timber, the increased tool wear rate was substantial, as the tool was totally worn out within 50 minutes of cutting. The oil palm lumber's high silica content (6%) generates a high degree of abrasiveness to the boards, which increases tool wear. Because of the high cutting speeds, the strong oil palm fibers were split effectively, resulting in a better machined surface quality.

3.8. Strips Recovery from Oil Palm Wood

The total *Elaeis guineensis* boards obtained were 20 with the dimension of (50 x 150 x 1400 mm) and were crosscut into dimension of (40 x 140 x 1000 mm). Each board was converted into 6 strips with an average of 40mm width before planing, due to some characteristics of the strips such as presence of stains, irregularities etc. the planning process caused a large quantity reduction in strip thickness and length. Also, machining effect caused by factors such as the machine's dull blade and thick kerf contributed to the percentage loss of the strips, thereby lessening the quality of the strips. Table 12 shows the recovery rate and also the percentage of the waste generated after planning and surfacing activities were carried out on each strip.

Table 12. Strip Recovery Rate

Parameters	Values
Number of boards	20
Number of expected strips	120
Number of strips obtained	108
% recovered	92%
% wasted	8%

3.9. Strip Size Converted

Strip size of 32.5 x 50 x 100mm was recovered from each board converted and approximately 108 strips were obtained from the boards gotten from the three portions of the *Elaeis guineensis*.

3.10. Cost of Production

A summary of the production cost is presented in Table 13.

Table 13. Production of Prototype Cost Analysis

Serial Number	Material	Cost (₦)
1	Harvesting of Oil palm tree	12,000
2	Adhesive	8,500
3	Machining Operations	15,000
4	Fasteners	1,500
5	Chemicals	4,000
6	Transportation	7,000
7	Installation	3,000
8	Total	51,000

3.11. Surface Finish Performance Behaviour of Elaeis guineensis

As a result of stains caused by stickers, moulds found on the surfaces of the boards and environmental condition such as temperature and relative humidity as well as drying for a long period of time, the colour of the wood samples changed from light brown to dark brown and the wood finished well (Plates 5 &6). However, surface treatments on laminated panels improved the aesthetic appeal of *Elaesis guineensis* wood samples for interior wall cladding.

3.12. Quality of Installed Panels of Elaeis guineensis Laminates

Panels were installed on the second-floor veranda of the Wood Products Engineering Departmental building. The veranda has a shed. The panels were arranged and installed in a way that enables the colour to alternate, thereby improving the aesthetic appeal of the installed wall panels (Plate 7).

Plate 6. Installed *Elaeies guineensis* Panels

It was observed that the panels were able to withstand environmental factors such as relative humidity and temperature without delamination or any noticeable dimensional changes after subjecting them to visual inspection for months after installation through two seasons. The panels show no traceable changes in terms of swelling and shrinkage, no temperature effect on adhesive used, surface finishing was uniform. Results reveal that the material will be useful for wall cladding, light furniture and other non-structural areas of application.

4. Concluding Remarks

This study has been able to evaluate relevant sorption and physio-mechanical properties of *Elaesis guineensis* in relation to its utilization for wall panel production. The outcomes of this research demonstrate the suitability of *Elaesis guineensis* for utilization in the production of GLULAM panels for interior wall cladding. However, wood gotten from the base region of the trunk will give the best performance in semi-structural applications. This infers that old oil palm trees should not be left to pose fire hazards because they are utilizable. Old oil palm trees from replantation operations have a relatively high potential of augmenting wood material supply and balancing the utilization pattern across timber species. Stiff blades and a high speed and torque are recommended for machines for the conversion of *Elaesis guineensis*. Further studies should evaluate the utility of oil palm for the production of furniture members.

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