

# Characterization of Physical, Machining and Finishing Properties of Oil Palm Lumber: An Emerging Non-Timber Forest Product in Sub-Saharan Africa

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**Abstract--** Environmental problems associated with the rapid depletion of the tropical forest have necessitated the need to look for alternative sources of timber supply. Compression parallel to grain tests, three-point static bending tests, machining tests and finishing characteristics of oil palm lumber, a non-timber forest product were conducted to determine its suitability for furniture production. A compression parallel to the grain of 13 N/mm<sup>2</sup>, a modulus of elasticity of 2924 N/mm<sup>2</sup>, and a modulus of rupture of 25 N/mm<sup>2</sup> at 12% moisture content were obtained.

The lower strength properties of oil palm lumber compared to conventional lumber suggest that oil palm lumber could be used for light load bearing products such as coffee tables, center tables, ceilings and wall panels. Planing and sanding operations produced rough surfaces with sharp raised grains which had piercing effect on the fingers. However, application of sanding sealer followed by sanding operations removed all the sharp raised grains, thereby resulting in production of smooth surfaces. Application of synthetic clear varnish at the final phase of the finishing process produced a very bright surface with a protective plastic-like film. It could therefore be concluded that oil palm lumber could be used for the production of light load bearing furniture products.

**Keywords--** Compressive strength, Furniture production, Oil palm lumber, Sanding operations, Static bending,

## I. INTRODUCTION

The forest cover of Ghana which contains over 300 species of trees capable of growing to timber size has reduced from 8.2 million hectares in the 1980s to the current forest cover area of 1.3 million hectares. The reduction of the forest cover is partly due to illegal logging and over dependence on traditional timber species including Odum (*Milicia excelsa*), Wawa (*Triplochiton scleroxylon*) and Mahogany (*Khaya ivorensis*). Environmental problems associated with the depletion of the forest cover include soil erosion, high sedimentation in river systems which reduce water quality, the spread of water borne diseases, drought due to poor rainfall pattern, desertification, and destruction of properties due to the absence of trees to act as wind breaks.

In the quest to arrest the depletion of the tropical rain forest, institutions mandated to conduct forestry and forest products research are looking for alternative raw materials for the timber industry as substitutes to the traditional timber species which are fast dwindling [1,2,4 and 5].

Species whose machining properties are not well known and which have the potential of being utilized by the timber industry include the oil palm tree which is a non-timber forest product and commonly referred to as the tree of life because of its numerous applications in daily life. The oil palm tree which is a species native to West Africa where it grows in abundance has been introduced to various parts of the tropics including Central and East Africa; South America, and some parts of Asia, notably, Malaysia and Indonesia. Products which can be obtained from the oil palm tree include broom for sweeping, palm oil from its fruit, and palm wine, a delicacy drink for the people of Sub-Saharan Africa.

In spite of the numerous uses of the oil palm tree in West Africa, the felled trees are sometimes burnt to pave way for replanting or mixed farming after extracting the palm wine. Thus, enormous quantities of oil palm trees are allowed to go waste, while the destruction of the rain forest has been continuing in the same tropical areas through excess felling of trees. A research problem which is worth mentioning and which needs to be addressed urgently to help halt the depletion of the forest is the huge volume of oil palm trunks which are left in the forest to rot after being felled either to make way for farming activities or for tapping the wine from them.

There are few reports on industrial utilization of the oil palm trunk. It has been reported that difficulties in utilizing oil palm trunk stem from its extremely tough outer bark and high content of decayable parenchyma cells [6, 7]. Trunks of the oil palm trees have also been found to contain mineral salts, notably, silica and this calls for the use of specialized tools when machining wood samples of the oil palm [1, 6]. High cutting tool edge recession or faster rate of tool wear when machining wood samples from the oil palm have also been reported [1].

This study aims at determining the suitability or otherwise of the oil palm trunk as alternative species for furniture production by considering its physical, machining and finishing characteristics and making appropriate recommendation to the forest industry on effective use of the oil palm trunk for sustainable forest management.

## II. MATERIALS AND METHODS

### A. Harvesting of oil palm trunk

Trunks of oil palm trees were extracted at Norpalm Limited at Aboadze near Takoradi in the wet semi-deciduous forest zone of Ghana using a chain saw machine. The average age of the palm trees shown in figure 1 was 40 years.



**Fig. 1** Oil palm tree plantation at Norpalm Limited

### B. Processing of oil palm trunk into dried lumber

Oil palm trunks of moisture content ranging from 100% to 120% were sawn in the forest into beams of thickness 50mm and lengths 1.8m and 2.4m using a chainsaw machine. The beams were immediately transported to the workshop of the Department of Construction and Wood Technology Education of the University of Education, Winneba for further processing. In order to protect the beams from insects attack, they were immersed into a preservative for three (3) days. The preservative was made up of 2 litres of Dursban 4E and 504 litres of water. Beams being treated with preservative are shown in figure 2. The preservative-treated boards were kiln dried to moisture content between 8% and 10%.



**Fig. 2** Oil palm lumber being treated with preservative

The kiln dried oil palm lumber was re-sawn into specific dimensions using an electric powered horizontal mobile bandmill (model LT 25). The saw blade has a thickness of 0.8mm and width of 31.25mm. The specific dimensions of boards re-sawn were 30mm × 300mm × 2400mm, 25mm × 250mm × 1800mm and 30mm × 200mm × 1800mm.

### C. Mechanical properties of oil palm lumber

Compression parallel to grain tests and static bending tests, namely modulus of rupture (MOR) and modulus of elasticity (MOE) were conducted using the Instron strength testing machine (Model 4482). Thirty (30) wood samples each for compression parallel to grain tests and static bending tests were prepared in conformity with British Standard Institution (BS 373:1957) of testing small clear specimen [8]. The straining rates or the cross head speed for static bending and compression parallel to grain tests at full scale load range of 100 kN were 2.54 mm/min and 0.6350 mm/min respectively. The following readings were recorded: displacement at maximum load, load at maximum load, stress at maximum load, and strain at maximum load in units of mm, kN, MPa, and mm/min, respectively.

After each test, the samples were immediately kept in desiccators to prevent moisture content changes. Small wood samples were taken from areas near to the portion of rupture under static bending, kept in the desiccators, and subsequently used for the determination of the moisture content of the samples tested. In the case of compression parallel to the grain, the moisture was determined from the entire wood sample.

The moisture content of each wood sample of a particular test was determined using the British standard for the determination of moisture content of wood by oven-dry method [3]. Thereafter, standard equations were used to convert the strength values at the measured moisture content to that at 12% moisture content [4].

#### *D. Surface and thickness planing of oil palm lumber*

Wood samples of oil palm lumber dried to a moisture content of 10% were planed to different nominal sizes (table 1 to 4) using a combined thicknesser/surface planer that has four blades or knives. The spindle speed of the machine was 9000 revolution per minute (rpm).

#### *E. Sanding of oil palm lumber*

A drum sander (model 3000) (figure 3) was used to perform the sanding operation. It has an adjustable table to pick any thickness of wood samples and sand to predetermined thickness.



**Fig. 3 The drum sander (model 3000) used**

Abrasives used for sanding were 60 and 80 grit for initial sanding and 120 grit for light sanding. Finally, the disc orbital sander (figure 4) with abrasive grit of 180 was used for smooth sanding and also for removal of the raised edges after using the drum sander.



**Fig. 4 Disc orbit sander for sanding oil palm lumber**

#### *F. Turning of flower pots and legs of coffee tables*

Wood samples were laminated by pressing them at a pressure of 310 MPa for 45 minutes using polyvinyl acetate glue. It was then planed to a dimension of 100mm × 100mm × 300mm and lathed to a flower pot. Sanding operation took place in the lathe as the flower pot revolved using sand paper of grit 60 for initial sanding and grit 120 and 180 for the finished work. A 100mm square × 300mm length scantling of the oil palm was also turned for coffee table leg. A heavy floor standing lathe was used to lathe the samples. This lathe uses a belt drive to transmit power from (1hp) electric motor to the headstock spindle. It has a maximum speed of 2000 rpm which is varied with the aid of stepped pulleys.

#### *G. Preparation of template and members for furniture production*

A compressed paper board was used to cut the templates which were used for preparing the individual parts of the members to their respective sizes. The artifacts prepared were coffee table, centre table and a bed. The cutting lists are shown in tables 1 to 4. The template was used to cut the members to their specific sizes and shapes using a band saw machine.

Having sawn the various parts to size, the spindle moulder was used to machine the curved areas. Cutting across the grains of the oil palm lumber was done with the radial-arm saw of thickness 3 mm. It is fitted with an induction motor rated at 1.1KW. This was powerful enough to generate adequate saw-blade speeds of nearly 3000 rpm.

*H. Assembling members*

*i) Coffee table and center table*

In this study, widening joint was used to join members of dimensions 300mm x 300mm x 20mm to obtain a wider board for centre table and coffee table tops. The bases of these tables were also joined using dowels. Framing joints used were all dowelled. Drilling bit of diameter 10mm to depth of 40mm was used. The joints were pressed very hard for forty five (45) minutes at a pressure of 310 MPa.

**Table 1**  
**Cutting list for center table**

Part #	Description	Quantity	Nominal Dimension (mm)	Actual dimension (mm)	Material
1	Top	1	900×700×25	850×650×20	Oil Palm Lumber
2	Legs	4	500×80×25	450×75×20	Oil Palm Lumber
3	Bottom/Base	1	450×450×25	400×400×20	Oil Palm Lumber

**Table 2**  
**Cutting list for coffee table**

Part #	Description	Quantity	Nominal Dimension (mm)	Actual dimension (mm)	Material
1	Top	1	450×450×25	400×400×20	Oil Palm Lumber
2	Legs	1	500×80×25	450×75×20	Oil Palm Lumber
3	Bottom/Base	1	350×350×25	290×290×20	Oil Palm Lumber

**Table 3**  
**Cutting list for bed**

Part #	Description	Quantity	Nominal Dimension (mm)	Actual dimension (mm)	Material
1	Head	1	1500×600×40	1440×500×30	Oil Palm Lumber
2	Tail	1	1500×500×40	1440×400×30	Oil Palm Lumber
3	Sides	2	2000×260×40	1920×240×30	Oil Palm Lumber

**Table 4**  
**Cutting list for bed side cabinet**

Part #	Description	Quantity	Nominal Dimension (mm)	Actual dimension (mm)	Material
1	Side	2	550×300×30	550×250×20	Oil Palm Lumber
2	Top	1	400×300×30	350×250×20	Oil Palm Lumber
3	Bottom	1	400×300×30	350×250×20	Oil Palm Lumber
4	Shelve	2	350×300×30	310×250×20	Oil Palm Lumber
5	Door	1	350×500×30	310×400×20	Oil Palm Lumber

ii) *Bed*

The widening joints used were grooved and tongued. Angle joints used were mortise and tenon. The designed bed went through the above discussed processes. The platform or support for the foam mattress is not dependent on the side members of the bed because the strength of oil palm lumber is not as great as other woods species to withstand heavy load. Thus, the bed designed was such that the weight of the user and the foam mattress would not have any effect on the side rail of the bed.

### III. RESULTS AND DISCUSSION

#### A. *Sawing of oil palm trunk into lumber*

It was extremely difficult to convert oil palm trunk into lumber using the chainsaw machine. Additionally, it was difficult to re-saw boards of oil palm lumber into smaller dimensions using the horizontal mobile bandmill known as the “woodmizer”. The conversion process was characterized by frequent wearing or dulling of the saw teeth which had no tippings. The saw blades had to be sharpened or replaced in less than every ten minutes during operation.

Okai et al. [1] conducted studies on tool wear of High-Speed Steels (HSS) and Stellite-Tipped Tools (STT) when machining wood samples of the oil palm (*Elais guineensis*), Afina (*Strombosia glaucescens*) and Sugi (*Cryptomeria japonica*). It was observed that the highest cutting tool edge recession when machining with High Speed Steel of designation SUS420J2 (HV676) and TiN coated SKH 51 (HV2161) according to the Japan Industrial Standards (JIS) were recorded in wood samples of the oil palm in spite of the fact that wood samples of Afina are twice denser than wood samples of the oil palm.

It must be noted that the density of the oil palm lumber is 400kg/m<sup>3</sup> and the density of Afina is 800kg/m<sup>3</sup>. On the contrary, it was observed that stellite-tipped tools in spite of possessing the least hardness (HV580) among all the tested cutting tools recorded the least cutting edge recession when machining wood samples of the oil palm. Okai et al. [1] attributed the presence of mineral salts notably silica in oil palm lumber as the major reason for the high cutting tool edge recession recorded in the wood samples of the oil palm.

The present results have confirmed that stellite-tipped tools should be used for conversion of oil palm trunk into lumber.

#### B. *Mechanical properties of oil palm lumber*

Table 5 shows the compression parallel to grain (13 N/mm<sup>2</sup>), modulus of elasticity (2924 N/mm<sup>2</sup>), and modulus of rupture (25 N/mm<sup>2</sup>) of oil palm lumber at 12% moisture content. The strength of a species can be determined by various criteria including stiffness, compression parallel to grain, resistance to impact and bending strength. A species can be described as possessing a lower strength if its modulus of elasticity is less than 9000N/mm<sup>2</sup>. It is obvious from table 5 that wood samples of the oil palm have lower strength because a modulus of elasticity of 2924 N/mm<sup>2</sup> was recorded.

**Table 5**  
**Mechanical properties of oil palm lumber at 12% moisture content**

MOR (N/mm <sup>2</sup> )	MOE (N/mm <sup>2</sup> )	Compression parallel to grain (N/mm <sup>2</sup> )
25 (9)	2924 (887)	13 (1.5)

*Note: Values in bracket are standard deviation*

The use of wood species depends to a large extent on its strength properties. The lower strength properties of the oil palm lumber clearly suggest that it may not have a wide range of application in the construction industry. For example, oil palm lumber is not suitable for structures which carry heavy loads. In furniture work which sometimes requires less load resistance, the oil palm may be suitable. Artifacts suitable to be manufactured from oil palm lumber may include flooring, flower pot, coffee table, center table, bed side cabinet, ceiling, wardrobe and other light weight bearing structures.

#### C. *Surface and thickness planing of boards from oil palm lumber*

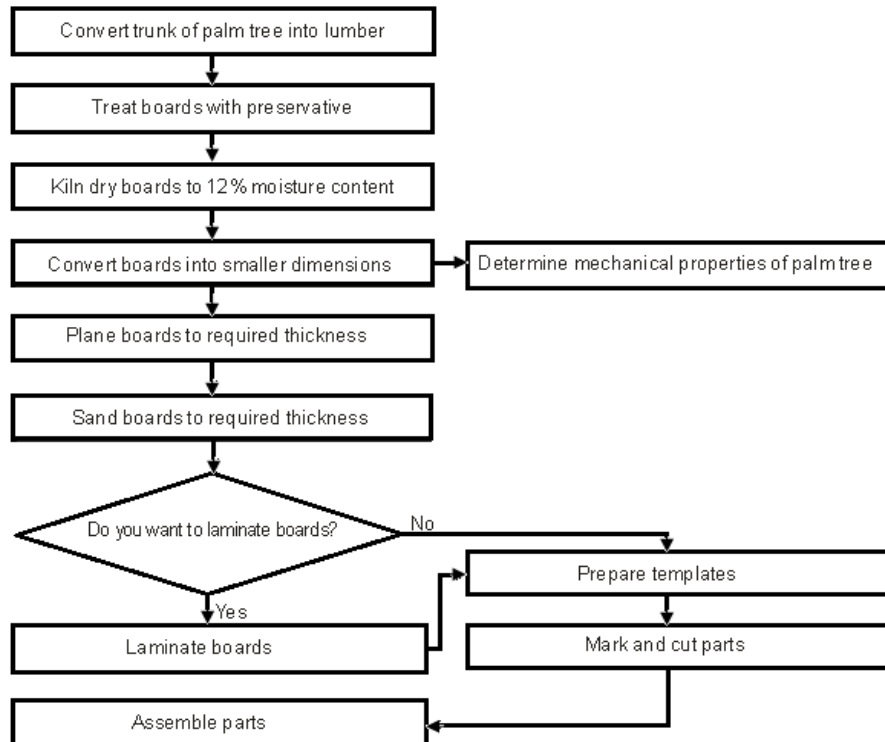
It was realized that contrary to expectation, the four-knife surface planer or four-cutter surface planer revolving at a speed of 9000 rpm which was used for the planing operation produced rough surfaces with raised grains which are sharp in nature. The sharp raised grains had piercing effect on the fingers if care was not taken in handling the planed surfaces. Thus, unlike species such as *milicia excelsa* and *khaya ivorensis* which may not require sanding operation because a planing operation may produce smooth surfaces, oil palm lumber would not under any circumstances undergo planing operation alone without sanding to produce smooth surfaces.

**D. Sanding operation**

The sanding operation using the drum sander was difficult because the sanding belt got worn out or got torn within two or three cycles of operation. High friction was generated as the raised grains were ground by the drum sander causing burns on the surfaces of the wood samples. The fibres were raised and were sharp enough to wear out the sharpness of the grit. The disc orbit sanding operation was performed after drum sanding in order to ensure that all raised grains that could not be eliminated during the drum sanding operations were successfully removed.

**E. Flow chart for the manufacturing of palm products from oil palm trunk**

Figure 5 shows a flow chart which summarises the manufacturing processes for converting the trunk of oil palm tree into useful products up to the assembling stage in sequential order. The order of operation consists of the conversion of the trunk of the oil palm tree into lumber, preservative treatment of the boards, and kiln drying of the boards to 12% moisture content. After kiln drying, the boards are sawn into smaller dimension when the need arises. Planing, sanding, lamination, preparation of templates, cutting of parts and assembling of parts for final finishing are also presented in figure 5.



**Fig. 5 Flow chart for manufacturing of artifacts or furniture products from oil palm trunk**

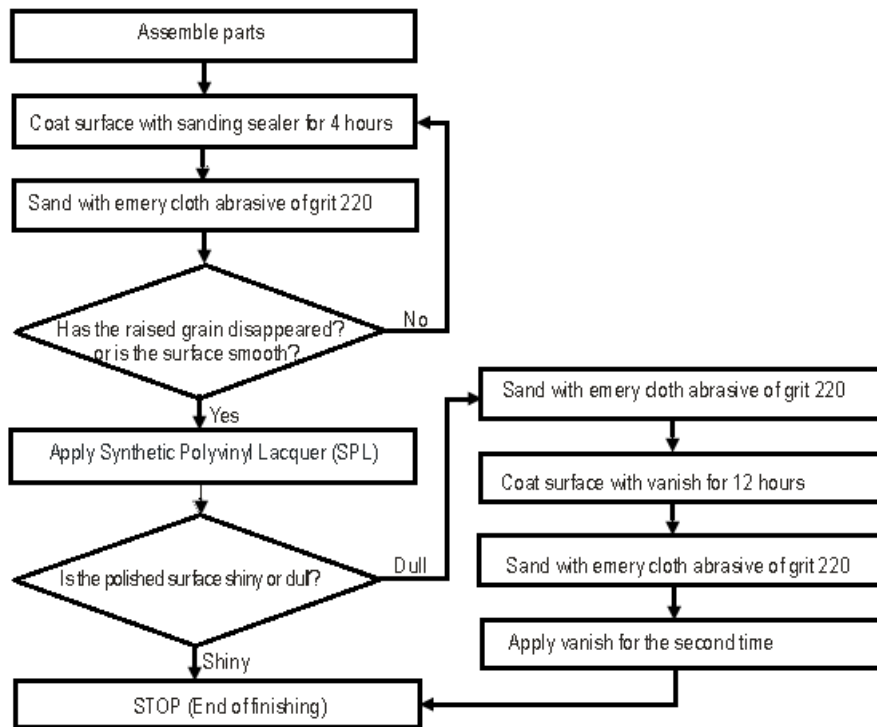
**F. Finishing of artifacts**

It was observed from this study that after sanding wood samples of the oil palm with the disc orbital sander using abrasive grit of 180, the surface of the artifact was not smooth to handle. The grains were raised and very sharp thereby having the tendency to pierce the bare hand if care was not taken in handling the artifacts. The surfaces of the artifacts were coated with sanding sealer with the aim of sealing all the pores on them.

After coating with the sanding sealer for 4 hours under normal room temperature, the artifacts were sanded with emery cloth abrasive of grit 220. The emery cloth abrasive is usually used for finishing metal artifacts but because of the piercing effect of the grains of the oil palm lumber it was employed for the sanding. It was observed that all the raised grains which had the tendency to pierce disappeared after sanding with either the emery cloth abrasive or abrasive of grit 220.

The next phase of the finishing was the application of Synthetic Polyvinyl Lacquer (SPL). Unlike species such as Odum (*Milicia excelsa*), Mahogany (*Khaya ivorensis*) and Asanfena (*Aningeria robusta*) which take SPL easily for final finishing, the oil palm lumber absorbed the SPL very fast regardless of the earlier application of sanding sealer to seal the pores on the surfaces of the artifacts. Thus, the surfaces of the oil palm lumber appeared unpolished and dull. However, a new technique was developed. The surfaces of the artifacts were sanded to remove the SPL using the emery cloth abrasive of grit 220. Synthetic clear wood vanish which is less expensive as compared to the SPL lacquer was used to coat the surfaces of the artifacts using hand brush in the direction of the grains and allowed to dry for 12 hours.

The surfaces of the artifacts were brighter than they were earlier when the SPL lacquer was first applied. After the first layer of vanish was applied using the hand brush, the artifacts were sanded again using the emery cloth abrasive of grit 220. Thereafter, synthetic clear vanish was applied for the second time on the surfaces of the artifacts. A very bright surface with a protective plastic-like film was observed on the surfaces of the artifacts. Figure 6 shows the flow chart for the finishing of palm products from the assembling stage to the final stage.



**Fig. 6 Flow chart for finishing of products developed from oil palm lumber**

### G. Products developed from oil palm lumber

Figure 7 shows flower pot, center tables, bedside cabinet, coffee tables, and a bed produced from oil palm lumber.

The oil palm lumber has a lower strength as compared to conventional lumber.



**Fig. 7 Products manufactured from oil palm lumber**

Therefore, in an attempt to produce a bed from oil palm lumber, care was taken to ensure that the support for the foam mattress rest on the floor instead of the side rail. Any force exerted on the support for the foam mattress is transmitted to the floor instead of the side rail. It is expected that in the design of wood products using oil palm lumber, manufacturers will take into consideration the maximum force acting on the members in order to prevent failure of the members due to excessive load.

#### IV. CONCLUSION

The increase in demand for wood products coupled with the rapid depletion of the tropical rain forest calls for the search for non-timber forest products as alternative materials for furniture production. In this paper, experimental results on furniture production using oil palm lumber (*Elais guineensis*), a non-timber forest product have been presented. Compression parallel to grain tests and three-point static bending tests have been conducted to determine the suitability of the oil palm trunk for furniture production. The strength of oil palm lumber suggests that it could be used for light or low load bearing products. The machined surfaces of oil palm lumber were characterized by sharp raised grains which could pierce the fingers if care was not taken in handling the machined surfaces.

Application of sanding sealer followed by sanding operations removed all the sharp raised grains, and therefore smooth surfaces were produced. Application of synthetic clear vanish in the final phase of the finishing process produced a very bright surface with a protective plastic-like film. Experimental results suggest that several wood products can be manufactured from oil palm lumber.

Thus, the use of oil palm lumber as a suitable alternative material for furniture products with the objective of reducing the pressure on the forest has been established.

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