PLYWOOD FROM OIL PALM TRUNKS

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ABSTRACT

Currently, the annual availability of oil palm trunks (OPT) in Malaysia is estimated at around 13.6 million logs based on 100 000 ha of replanting per year. Under specific controlled processing conditions to manufacture oil palm plywood, the total logs available can be converted into 4.5 million cubic metres of plywood. A number of plywood mills have embarked on the use of OPT in the manufacture of plywood. Nevertheless, because of the weaker and less durable veneers, the application of these materials was only as a core layer. Research and development on OPT has been getting much attention from researchers and members of other wood-based industries for which this material has shown exciting potential as an alternative raw material. However, anatomically, OPT is not truly a woody material and this poses a big challenge in how to turn OPT into what has been achieved with rubber wood or other tropical wood in terms of product quality and market acceptability. This article shows that OPT can be used to produce plywood and that its strength properties meet the minimum requirements of the Japanese Standard Method, JAS 233:2003.

Keywords: oil palm trunks, oil palm veneer, oil palm plywood.

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INTRODUCTION

Currently, the annual availability of oil palm trunks (OPT) is estimated at around 13.6 million logs based on 100 000 ha of replanting per year (Anon., 2005). Under specific controlled processing conditions to manufacture oil palm plywood, the total logs available can be converted into 4.5 million cubic metres of plywood. Plywood, a versatile wood paneling product, is in great demand by building contractors and furniture makers. Hardwood plywood may be pressed into panels or plywood components (*e.g.* curved hardwood plywood, seat backs, chair arms, *etc.*). Generally, hardwood plywood is used for interior applications such as furniture, cabinets, architectural millwork, paneling, flooring and doors. To date, we have successfully manufactured and commercialised oil palm plywood with the technical and collaborative support by the Malaysian government which has facilitated the production and commercialisation of the product. The use of oil palm plywood currently is for non-structural materials used for such products as cabinets and packaging materials.

OPT, one of the potential raw materials for the wood-based industry, has its own imperfections. It is very hygroscopic in nature, shrinking and swelling at a higher rate than wood. Economically, only the outer part of the trunk is suitable for plywood production as the centre part contains only soft parenchyma tissues. Oil palm does not grow much in diameter as it gets older, but will normally grow from 35 to 75 cm in height each year. Oil palm being a monocotyledon, OPT does not possess any vascular cambium, secondary growth, growth rings, ray cells, sapwood and heartwood, branches and knots (Killmann and Lim, 1985). The growth and increment in diameter of the trunk result from cell division and cell enlargement in the parenchyma tissues, along with the enlargement of fibre in the vascular bundles. The amount of vascular bundles per unit area declines gradually towards the inner parts and increases from the butt end to the top of the palm (Lim and Khoo, 1986). The height of the palm can be up to 15 m and the estimated volume of one trunk stands at about 1.6 m^3 (Khali and Wan Razali, 1989). With trunk density ranging widely between 200 and 700 kg m^{-3} and

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moisture content ranging from 100%-500%, OPT poses a big challenge when used in wood-based industries, in particular the saw milling and panel industries.

Oil palm plywood is considered to be lower strength plywood because of the poor strength characteristics of the oil palm itself compared to that of tropical wood. This problem may be associated with the cell wall structure and density variations along and inside the trunk itself, which result in greater density variations after peeling and difficulty in drying. Furthermore, anatomically, OPT is not truly a woody material, and this poses a big challenge to R&D in attempting to turn OPT into what has been achieved with rubber wood or other tropical wood, in terms of the product quality and market acceptance.

With this scenario in mind, a preliminary study was carried out using OPT as a raw material for manufacturing plywood. According to Bakar and Hadi (2001), oil palm wood has at least four weaknesses: it is very low in strength, durability and dimensional stability, and has bad machining properties. Hence, special measures have to be taken to enhance the quality and transform it into useful products that meet market demand. The high density gradient and moisture content that exist along the radial and longitudinal directions of the trunk make drying and machining difficult.

METHODOLOGY

Raw Material Preparation

Oil palm trunk selection. OPT used to manufacture plywood is normally collected during replanting. In order to produce good quality veneers from OPT, selection of the logs is very important (*Figure 1*).

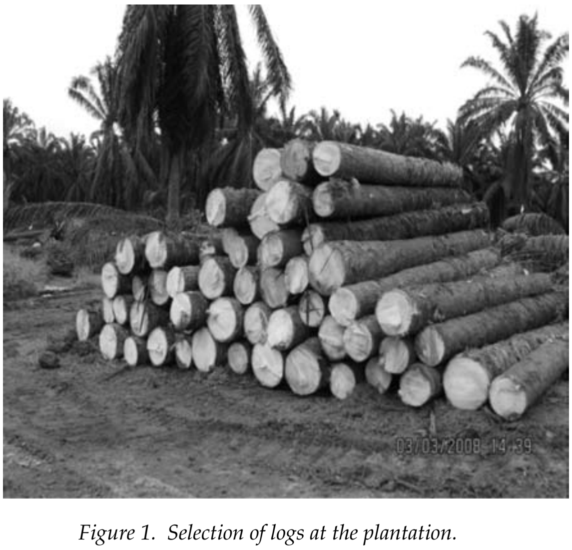


Figure 1. Selection of logs at the plantation.

Figure 2. Loading of felled oil palm trunks (OPT) onto the lorry.

The logs were selected based on their straightness and uniformity in their top and bottom diameters.

Log Handling/Log Yard

The methods of storing and handling logs at a mill site do not differ greatly from those employed at sawmills as can be seen in *Figures 2*, *3a* and *3b*. Generally, logs represent a high-cost raw material and additional precautions are usually taken against degradation or deterioration. The most common symptoms of deterioration are stains and moulds (black and white in colour). OPT can be stored up to three or four weeks under shade prior to further processing. Storage of OPT in the open is estimated at about two to three weeks, depending on the weather on site. The storage life of OPT can be prolonged by end-coating both ends of the logs with bitumen or black paint.

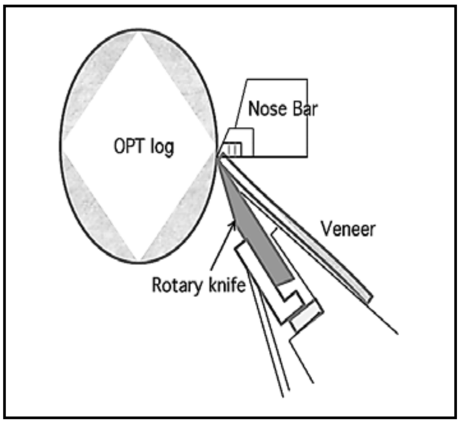
At the mill, chain saws with hydraulic tilting and height adjustment are used to cut OPT to the required length before processing. These save labour and time, and also ensure straighter end cuts. OPT are cut into 270 cm lengths, and this cross-cutting process can produce about 34 logs per hour. The logs are then ready for the debarking process and for making veneers.

PEELING OF VENEER

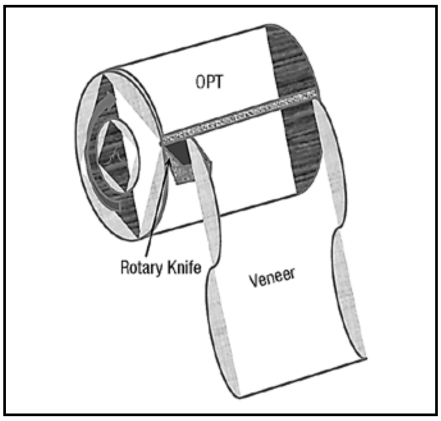
Normally, OPT are supplied to the factory in 540 cm or 600 cm lengths. The logs are then cross-cut into two lengths of 270 cm each and grouped together based on whether they are from the bottom or top part before peeling. In this study, peeling was done using two different machines that is a rotary lathe to first remove the bark (round-up) before proceeding to the second peeling using a spindle

Figure 3a. Logs in the storage yard.

Figure 3b. Logs before processing.



a. Knife cutting angle



b. Peeling of OPT logs

Figure 4. Knife cutting angle for peeling oil palm trunks (OPT) logs.

less lathe to get veneers. The round-up process involved centreing the log onto the lathe chuck. The log was slowly rotated as the knife carriage moved into the log. The knife then converted the bole into a cylinder. The settings of the knife and nose bar pressure during peeling are important in reducing the formation of checks, and also in controlling veneer thickness. Generally, from the round-up process, about 90 boles (of 270 cm length) could be peeled within 1 hr.

First Peeling

The purpose of this operation was to remove the outer bark of the log without substantially damaging the logs. Positioning the veneer knife correctly played an important role in producing quality veneers. The angle of the lathe knife also determined the uniformity of the veneer thickness during peeling (*Figures 4a* and *4b*). In this study, the angle of the knife was adjusted to peel the bark and to round the outer layer of the OPT logs.

The chuck with a diameter of 20 cm clamped the bole before peeling. The 270 cm rotary lathe machines used for this process could peel OPT logs until they reached 25 cm in diameter (*Figure 5*). Centreing of the logs must be conducted before peeling, and adjustments were done manually by using the i-centreing (infra-red light) method. Peeling speeds of considerably more than 300 per min and spindle speeds at 200 rpm have been used. During the operation, the knife speeds were controlled to reduce the formation of checks and to control the veneer thickness. At lower speeds, vibrations were likely to affect the quality of the veneer, giving rise to a rough and corrugated surface. The 25-cm diameter log core was then transferred to the second peeling machine.

Second Peeling

The 25-cm diameter log core was loaded onto the spindle less lathe machine for the second peeling operation. A roller system was applied in

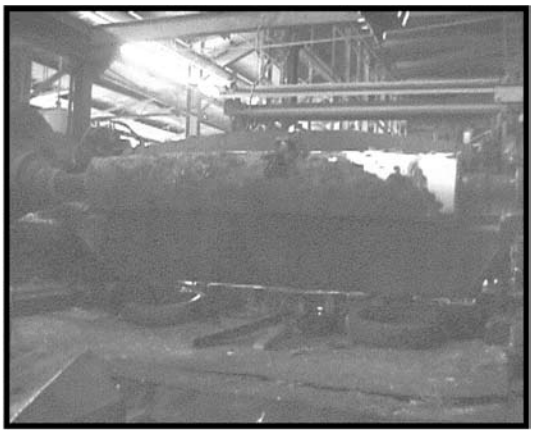


Figure 5. Rotary lathe machine.

this machine to spin the log for peeling purposes, and the knife angle was adjusted to the most suitable angle for OPT. The peeling process took about 25 s per bole, and the final diameter of the log core was 11 cm. The veneers were then cut into sections which were 60 cm wide by 240 cm long at the sizing machine before drying.

DRYING OF VENEERS

A typical dryer consisting of heated zones and a cooling section was used to dry the oil palm veneers. Each heated zone had a hot air source, fans to move the warm air, and an exhaust vent or stack. The efficiency of the drying operation was fully controlled by the temperature and the conveyer speed of the dryer. Steam was supplied from a boiler (at a pressure of about 10 kg cm^{-2}) and the temperature was controlled (at around 130°C to 150°C) for drying the veneers down to about 2%-5% moisture content. Generally, it took about 40-45 min to dry the veneers. The cooling section circulated ambient air over the veneers to reduce the veneer temperature just before they exited the dryer.

GLUING OF VENEER

In general, veneers are brought to the lay-up process where resin is applied on both sides of the veneer, which is then placed between two plies of the veneer that are not spread with resin. The resins are applied by a glue spreader using spray systems. Spreaders have a series of rubber-covered grooved application rolls that apply the resin to the sheets of veneers. Normally, two types of resin are used, namely:

- urea-formaldehyde glues, which are used to glue interior grades of hardwood plywood; and
- phenol-formaldehyde glues, which are used for softwood plywood and exterior grades of hardwood plywood.

PRESSING

Cold and Hot Pressing

Cold and hot pressing was applied in OPT plywood manufacture, similar to what is carried out in existing tropical plywood lines. The only difference was in the operating parameters (time and temperature) when hot pressing OPT plywood. For cold pressing, a single-opening hydraulic cold press was used at room temperature. A complete bundle of uncured plywood panels was held together by clamps between top and bottom retainer boards and pressed. As pressure was applied, the retainer clamps were moved up until full pressure was attained. The press was then opened and the entire bundle or package, held together under pressure by the clamps, was removed. In this process, full control of the assembly time was required in order to prevent the formation of defective glue joints, due either to: (a) procuring or hardening of the glues before adequate pressure was applied; or (b) excessive squeeze-out of the thin glue (starve joint) when pressure was applied too quickly.

Hot pressing was then carried out in a hydraulic press incorporated with multiple heated platens between which each individual panel assembly was subjected to heat and pressure. The press heated the plywood up to the required temperature, at different pressures and for different durations according to the different thicknesses of the oil palm plywood.

FINISHING

After pressing, the plywood was taken through a finishing process by which the edges were trimmed, and sanding of the face and back was optional to achieve a smooth surface.

STRENGTH PROPERTIES

In the study, strength properties were determined by using a Zwick testing machine (Model Z010). Testing was carried out in a laboratory at a temperature of 20°C ± 5°C and relative humidity of 65% ± 3% as specified in ISO 3133:1975.

RESULTS AND DISCUSSION

Peelable Logs from Oil Palm Trunks

Normally, the oil palm bole length is about 5.5-6.0 m with an average diameter of 39 cm in the middle and 40 cm at the bottom of the bole. The volume of an oil palm bole (540 cm long) is about 0.71 cm^3. After selection, the logs were divided into two parts (middle and bottom) of 6-m length each, and loaded into a lorry. A lorry of 6 t capacity can transport about 20-22 logs to the factory.

Veneer Recovery

The thickness of the veneer produced will depend on the needs of the final use of the veneer – either for 3-, 5- or 7-ply plywood. In the study, it was peeled to a thickness of 3.7 mm for preparing 5- and 7-ply plywood. The veneer pieces were then clipped to a usable size (60 × 240 cm feet), to allow for shrinkage and trim. Average diameter of OPT logs after debarking and after first peeling and the diameter of the peeler core were about 35 cm (*Figure 6*), 25 cm and 11 cm, respectively (*Figure 7*). From the peeling process, about 20 pieces of veneer could be produced from one bole (of 270 cm length); therefore, in 1 hr when about 90 boles could be peeled, about 1800 pieces of veneer were produced. The average numbers of 60 × 240 cm veneers that were obtained from logs with different diameters are shown in *Table 1*. The veneers were only peeled from the bottom and middle portions of the logs, while the top portions were not used because they were quite soft and difficult to peel.

As expected, the bottom part of the trunk produced a higher number of veneers due to its larger diameter compared to the middle part of the trunk.

Drying of Veneer

Drying of the veneers took a long time because of the high initial moisture content (400%-500%) as well as the variation in density throughout the radial and longitudinal axes of the OPT. In this study, the temperature range used was from 130°C-150°C and the steam pressure was 150 psi. For OPT veneers, a typical drying time for a 4-mm veneer was between 35 and 45 min as opposed to about 20 min for wood veneer. About 288 pieces of veneers could be dried by using the roller type of dryer with the final moisture content at about 5%-10%. Veneer shrinkage occurred during this process: in width (6.96%), length (0.22%) and thickness (18.28%). Attempts to reduce the drying time have

Figure 6. Oil palm trunks (OPT) logs after debarking.

Figure 7. Peeler core (11 cm diameter).

TABLE 1. NUMBER OF VENEERS (pieces) FROM OIL PALM TRUNKS (OPT) LOGS

Number of logs	Middle portion		Bottom portion		Total number of veneers
	Diameter (cm)	Number of veneers	Diameter (cm)	Number of veneers	
1	38	19	40	21	40
2	39	20	42	22	42
3	40	21	42	22	43
4	42	22	44	23	45

been carried out by many researchers, *e.g*. by a pre-pressing stage to squeeze out the excess water prior to normal drying. This will definitely reduce the energy and time for drying.

Glue Formulation

The glue recipes for making 1 m^3 of plywood for indoor and outdoor use are shown in *Table 2*. The resin coverage or adhesive spread rate used for OPT veneers was the range of 300-400 g m^{-2}, about 20%-30% higher than that used for wood veneers. Currently, only urea-formaldehyde (UF) resin is used because the end-products are meant for short period applications such as for concrete formworks at construction sites.

Hot Pressing

Table 3 shows the differences in pressure and time for hot pressing OPT plywood. Results show that a longer time (13-15 min) and higher pressure (125-135 kg m^{-2}) were needed to cure the glue for manufacturing thicker (18 mm) OPT plywood.

RECOVERY OF MANUFACTURING OIL PALM TRUNKS PLYWOOD

The recovery rates of plywood from OPT based on per cubic metre are shown in *Table 4*. The amount of wastage seems to be high in the peeling section due to debarking, clipping and also trimming processes. From the second peeling process, the wastage was from the clipping and trimming processes, while the remaining log core of 11 cm in diameter was considered a waste.

PROPERTIES OF OIL PALM TRUNKS PLYWOOD

For decorative applications, both the appearance and dimensional stability of plywood are important, while the strength and stiffness of the plywood are important for construction uses. The tendency of plywood panels to warp is affected by changes in moisture content as a result of changes in atmospheric moisture conditions or actual wetting of the surface by water. The dimensional stability of plywood, associated with moisture and thermal changes, involves not only cupping, twisting and bowing but includes also expansion or contraction. The usual swelling and shrinking of the plywood is effectively reduced because grain directions of adjacent layers are placed at right angles. The strength properties (modulus of rupture) of plywood from OPT are shown in *Table 5*. All the tests were carried out according to the method stipulated in the Japanese Standard Method, JAS 233:2003 (Anon., 2003).

From the results, it may be seen that the modulus of rupture of OPT plywood exceeded the minimum

TABLE 2. GLUE FORMULATION TO MAKE 1 m^3 OF OIL PALM TRUNKS (OPT) PLYWOOD

Plywood for indoors	Percentage (%)	Amount (kg)
Urea-formaldehyde glue	77.6	99.3
Wheat flour	15.5	19.8
Hardener (HP-200)	0.6	0.8
Water	6.3	8.1
Total mix ratio	100	128.0
Plywood for outdoors		
Phenol-formaldehyde glue	76	92.7
Filler	24	29.28
Total mix ratio	100	122.0

TABLE 3. HOT-PRESSING PARAMETERS FOR DIFFERENT THICKNESSES OF OIL PALM TRUNKS (OPT) PLYWOOD

Base board thickness (mm)	Temperature (°C)	Pressure (kg m^{-2})	Time
9	105	40 125	30 s 9 min
12	105	40 125	30 s 10 min
18	105	40 135	30 s 14 min

TABLE 4. RECOVERY RATE PER m^3 OF OIL PALM TRUNKS (OPT)

Processing stage, section	Amount of wastage, % (based on volume)	Recovery rate, % (based on volume)
Storage yard		100
Peeling		
1st peeling	25	75
2nd peeling	7	68
Peeler core	7	61
Drying	2	59
Gluing and pressing	6	53
Finishing	6	47

Note: for every 1 m^3 of OPT, approximately 47% can be used for making plywood.

TABLE 5. STRENGTH PROPERTIES OF OIL PALM TRUNKS (OPT) PLYWOOD

JAS 233:2003 (minimum requirement)		Modulus of rupture (MPa)	
		Parallel to the face grain	Perpendicular to the face grain
3 mm thick	8.0	10.6	30.8
9 mm thick	12.0	20.8	33.5
12 mm thick	20.0	25.2	37.0

requirement as stipulated in the Japanese Standard Method, JAS 233:2003.

CONCLUSION

OPT can be used to manufacture plywood of acceptable quality when certain processing measures are taken into consideration. Based on the OPT properties, certain parameters such as the peeling operations and variables, drying parameters, resin treatments and pressing variables have to be modified from the current wood-based plywood processing practices.

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