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Potential and Characteristics of Oil Palm Trunk as Material in Oriented Strand Board for Structural Application

N.I. Ibrahim, M.T.H. Sultan, M. Jawaid, N. Saba, S.S. Azry

Abstract: There are many oil palm trunks (OPT) from the cycle of oil palm plantation cultivation at field, and this can be extended to the production of value-added products, where wood composite products are the earliest and most immediate product. However, the nature of the OPT structure is physicochemical and unique but not competent for use in wood applications. This may be due to the limitation of utilization OPT in composite material. However, in improving the properties of OPT can be done in many studies and one of these studies through the compression process. In this review, the properties of OPT were analyzed to the production of oriented strand board (OSB) process. The rapid development of research in developing and creating OSB with broader applications, higher usability and marketability and is essential to being environmentally friendly. OSB manufacturing can be generated from unused resources such as factory residues or small logs. The production of OSB from the OPT may be helpful in the production of material for structural applications. Malaysia expectations, by converting OPT to the wood-based panel (OSB), together will reduce the OPT waste and cut the timber demand. This review article covers the potential to utilize OPT biomass as OSB as wood composite panel products to replace non-wood panel products for the structural application. The investigation of this study is to find alternative materials to produce OSB from OPT, which is well-thought-out to be a biomass waste product. It also covers anatomical, mechanical and physical characteristics of OPT and how to produce OSB to improve its strength and dimensional stability.

Index Terms: Oil palm trunks (OPT), physical properties, mechanical properties, wood-based panel.

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I. INTRODUCTION

Malaysia has a good position in manufacturing and exporting oil palm waste (*Elaeisguineensis*) in the world. Now, the oil palm industrial process has been characterized by large residual generation in the upstream and downstream sectors. At the beginning of palm oil (*Elaeisguineensis*) has been introduced as an ornamental plant in Malaysia, but around 1960, oil palm plantations have expanded rapidly. In 2014 there were 5.4 million hectares of oil palm cultivation areas, and in the newest estimate in 2017, the figure is larger than the previous to 5.81 million hectares [1]. Oil palm biomass is used as a source of energy to create energy and heat. The only thru energy generated from biomass are power and heat, besides additional products such as fuel, for instance, hydrogen, biogas, biochar, biofuel, briquettes, syngas and pellets and so on [2]. Besides the understandable benefits, oil palm industry as well extremely gives to environmentally friendly issues, at both activities input and output sides [3], [4]. Oil palm industries produce huge amounts of oil palm plantation waste, for example, oil palm empty fruit bunch (EFB), oil palm frond (OPF) and oil palm trunk (OPT) [5], [6]. In addition to human healthinessanxieties and increased environmentally friendly awareness, the high amount of organic biomass was created which led to some environmental issues and ecological problems [7], [8]. Several types of research indicated that after 30 years the efficiency of oil palm categorized as unproductive. The oil palm will be clear-felled and most of them as well as trunk (OPT) are leftward to rot on cultivated area and consider as agricultural waste [9].

Today, the sustainable application of resources was mainly supported by the reusing, recycling or creating techniques of various types of biodegradable wastes [10], [11], [12]. The shortage of timber supply and increasing in timber prices has exaggerated the wood-based industries in the world [13]. Therefore the development of biodegradable wastes can contribute to the enhancement in wood based industry [14]. Wood-based composite products such as medium density fiberboard (MDF), particleboard (Pb), plywood, flakeboard (Fb) and oriented strand board (OSB)) are among the most beautiful and environmentally friendly. Particleboard, MDF, and Flake board are classified of wood-based composites have various advantage and disadvantage which are low strength, low effectively, less flexibility and durability compared to OSB.

OSB is one type of wood composites material or also known as engineered wood

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material and commonly used for structural application. Laterally with the MDF and particleboard, OSB is also posted rapid growth and has slowly replaced the use of sawn timber for furniture and structural application in developed countries [15] OSB has been accepted since the product was marketed in 1970 [16]. OSB has proved to dominate the structural material market in the past two decades [17]. Its use has been extended to replace plywood in structural applications at worldwide. Therefore, the purpose of this study was to clarify proof regarding the potential and characteristics of OPT to be used as material in OSB manufacturing for structural application. In manufacturing, OSB is produced efficiently from a renewable resource. Additionally, the natural nature of the wood panel, combined with highly effective wood-frame structure systems, make it a highest choice in energy conservation. This country, in particular Malaysia, has been the leader in high-quality manufacturer and exporter of this product panels for more than 50 years. Developed for years, wood-based Industrial panels in Malaysia now comprise plywood / veneer mills, and MDF manufacturing plants, particles and OSB. These factories are able to provide supply consistently for timber-based panels for world markets [18].

II. CHARACTERISTIC OF ANATOMICAL PROPERTIES OF PALM STEMS AND ITS CHALLENGES

Oil palm tree or species name *Elaeisguineensis*. Oil palm in the family *Arecaceae*, it is a monocotyledonous plant[19]. Palm do not have cambium, It is contains of vascular bundles and parenchyma cells as shown in Figure 1, in contrast to softwoods and hardwoods for which the cells consists of mostly tracheids,fibers,ray parenchyma, and vessels parenchyma cells [3], [20]. The Figure 1 shows a region with overcrowded vascular bundles and narrow layers of parenchyma, known as periphery, that make available the leading mechanical support for the OPT [20]. In fact, the walls are gradually darker and thicker from the inner to the outer area [21].

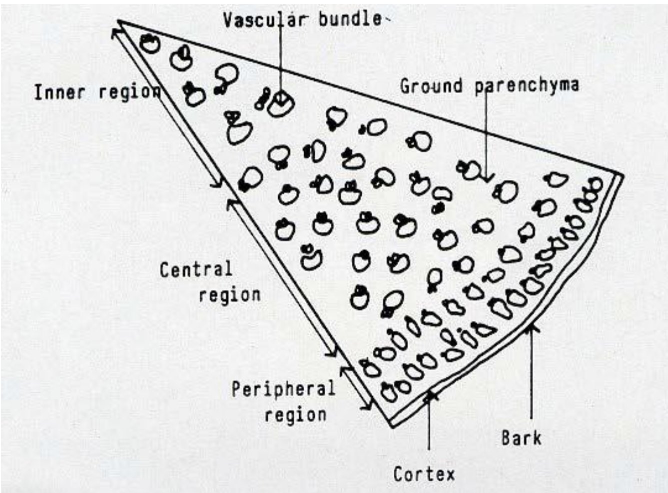

Fig 1. Cross-section of OPT [21], [22]

According to [23]–[25] the OPT materials have various of imperfections, mainly in their durability, strength, dimensional stability, and machining behavior and these probably true that only 1/3 to 3/4 of the outside part of the bottom of the OPT has good physical and mechanical properties, and that is applicable for use as a lightweight structural material and the remaining is not suitable because it is too soft [9]. Indeed, the bottommost portions of the trunk, being older usually have well developed secondary walls than do the topmost portions [26].

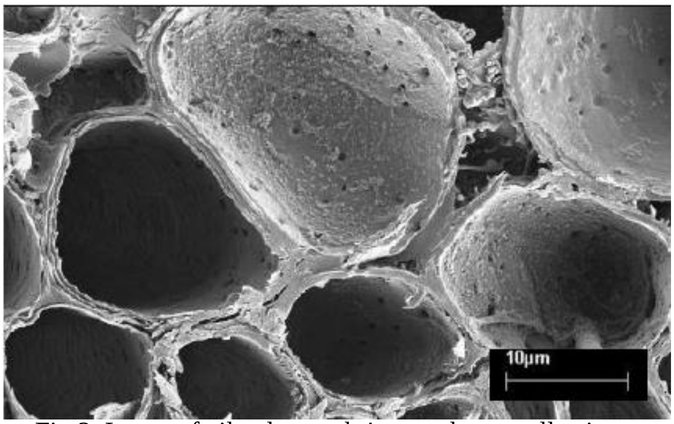

Fig 2. Image of oil palm trunks' parenchyma cell using Scanning Electron Microscopy (SEM)[27]

There are three main part of trunk that be made up of fibers, vascular bundles and parenchyma cells as shown in Figure 2. Parenchyma tissues are looks like bowl-shaped and make accessibleplaces for resin, which increases the physical characteristics of OPT bio-composites [20]. Besides, parenchyma also has high starch content where, starch gives to interfacial adhesion when producing binderless panels [3], [22]. At the same time, it helps to solve the biggest challenge of OPT is not truly a woodland material and improved mechanical properties in line for to the variance in density and stability of OPT.

III. PHYSICAL AND MECHANICAL PROPERTIES OF OIL PALM BIOMASS AS WOOD BASED PANEL PRODUCT

Numerous experimental studies of wood based panel product that have been produce from oil palm trunk (OPT), such as, particleboard (Pb),plywood,medium density fiberboard (MDF), parallel strand lumber (PSL), laminated veneer lumber (LVL), and others compressed wood. According to [8], [28], the upgrading of the physical and mechanical properties of wood based panel product is influenced by few aspects, including the types of adhesive. Veneer's moisture content and amount of resin penetrate into cells contribute to affecting the physical properties of palm trunk plywood whereas the pressing time also gives influence in increasing the bonding performance and mechanical properties of the pre-impregnated [29]. Besides adhesive, density also contributed to affecting most physical and mechanical properties and showed linear correlations with various properties of Pb[30].

In fact, based on [9], the density of PSL was greater compared than the solid oil palm trunk and hot pressing treatment improved remarkably the density of PSL. Besides, [3] indicated that by increasing the press temperature also take part in improving the characteristics of binderless Pb from fine oil palm particles. However, the water uptake resistant of such oil palm trunk binderlessPb from [3], [22], [31] still not meet the several international standard requirements. According to [32], [33] particle size is a significant factor in controlling a boards' response to strength, water absorption and thickness swelling. Where, the larger particles size contributes surface area better distributing the stress and the ability to resists the uptake of water since the surface is better covered with resin.

[34] stated that the improvement in board strength and Internal Bond (IB) significantly caused by increased pressing temperature, duration, pressure and adhesive ratio. It's showed in Figure 3 when an internal board value is more than 0.45Nmm^{-2} when the temperature augmented from 160◦C to 180◦C. This is probably because the relationship with resin curing, the limitation of diffusion, the reduced wettability of the particle surface or the dispersion of the resin within the particles and over the particles' surface [34]–[36]. Studies carried out by [35] record that the thickness swelling of Core-Board improved when the hot pressing temperature increase. Figure 4 below showed the acceptable temperature range for Core-Board is from 160◦C to 170◦C. Oil palm Trunk (OPT) material is highly hygroscopic and can absorb higher moisture from surrounding and affected thickness swelling [34]–[36].

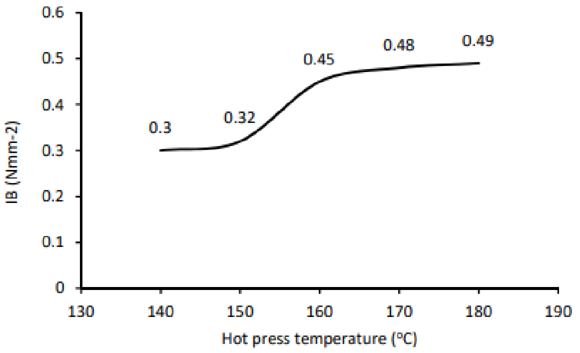

Fig 3. Effect hot-press temperature on an internal bond of CB. [Resin content: 12%, urea- formaldehyde; board density, 700 kg/m^3, board thickness, 12 mm] [35]

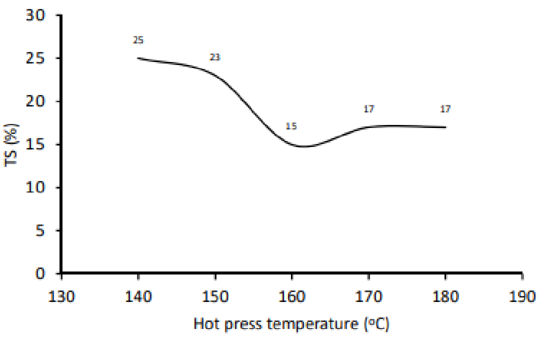

Fig 4. Effect hot-press temperature on swelling in the thickness of CB. [Resin content: 12%, urea-formaldehyde, board density, 700 kg/m^3, board thickness, 12 mm] [35]

According to [37]showing that the Pb made from oil palm with 700kg/m^3 density with 12% of Urea Formaldehyde (UF) and have the highest values of Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) compared with boards produced 500kg/m^3 density with 8% of UF. The study showed that the mechanical properties of Pb were improved with cumulative board density [38]. Density for OSB can differ between 0.5 and 0.7 g/cm3 in marketable manufacture but bigger densities are potential. Main effects for densities are the density of wood particles composite with resin used and the compression in hot pressing.Increasing board density has a good performance influence on mechanical properties for OSB panels [39]–[41].

IV. COMMERCIAL USES OF OIL PALM TRUNK

Oil palm trunk (OPT) remains obtainable only when the economic life expectancy of the palm tree is get hold of at the time of planting.Oil palm has a productive life is up to 25 - 30 an age, after that, its classified as unproductive [42]. In terms of economic aspects of oil palm clear-felling, the height of trunks should reach up to 13 m and above, and the diameter of the felled trunks is average 45 cm to 65 cm, measured at the breast height[3]. Based on the Malaysian Palm Oil Board (MPOB) statement, by the end of 2015, there were 5.64 million hectares of oil palm plantations throughout the country, which is about 23% of the total land area of Malaysia. The Table 1 below shows Oil Palm Biomass-based Products and their Commercialization Stage in Malaysia.

Table 1: Oil Palm Biomass-Based Products and Their Commercialization stage in Malaysia [43]

	PELLETS	BIOFUELS	BIOGAS	GREEN CHEMICAL	BIOFERTILISERS	BIOCHAR	BIOCOMPOSITES	OTHERS
EFB	EFB Pellets	Bioalcohol	Syngas	Industrial Sugars/ Chemical	Organic Compost	Carbon Fibers	Fibreboard	Pulp Fibremat
PKS	Coal substitute					Activated Carbon		
OPT	OPT Pellets	Bioalcohols	Syngas	Industrial Sugars/ Chemical	Organic Compost	Biochar	Engineered lumber	
OPF	OPF Pellets	Bioalcohols	Syngas	Industrial Sugars/ Chemical	Organic Compost	Biochar		Phytochemicals
PKC	PKC Pellets			Biopolymers				Animal Feed
POME		Bioalcohols	Methane	Biopolymers	Organic Compost			
SAW DUST	Wood Pellets	Bioalcohols	Syngas	Industrial Sugars/ Chemical	Mushroom Cultivation	Biochar	Fiberboard	
RICE HUSK								Silica Aerogel
PADDY STRAW	Straw Pellets							
KENAF							Biocomposites	
SAGO WASTE	Fuel Pellets	Bioalcohols	Methane	Biopolymers				Animal Feed
MSW	RDF Pellets		Methane		Organic Compost			
SEWAGE								Phosphate Recovery

LEGEND Commercialised Development Stage Potential

Palm oil industry contributes to the major part of biomass available in Malaysia and is responsible for stable biomass growth in recent years. Different components of oil palm biomass have different potential uses, including oil palm trunk (OPT) for organic compost, biochemical products, and engineered lumber. The wood from the OPT cannot be used directly as sawn timber such as other timber species; it is used as material in manufacture of wood bio- composites in a structural application, and furniture [38]. However, in wood industry emphasis, especially for veneer and plywood manufacturers have deeply focus on the use of OPT as a raw material in a various application such as for both exterior and interior plywood and laminated veneer lumber (LVL) [26], [32].

Several kinds of wood such as plywood or lumber had been produced from oil palm trunk. The strong point of the plywood made from OPT was as good with the existing and marketable plywood in the industry [22], [44]. However, according to [45], it showed the low performance of

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mechanical properties are based on density variation and instability of the OPT.Therefore, it's the main challenge in changing OPT into products have a marketplace suitability and good value-added, as has been attained by the others tropical timber like rubberwood[34]. Table 2 shows the current utilization of oil palm biomass for wood-based panel industry as well as the number of companies involves. In addition, table 3 shows that are many research studies in products that produce from OPT and others oil palm biomass.

Table 2: Current Utilization of Biomass for Wood Based Industry [46]

Oil palm biomass	Number of companies
Plywood (trunk)	5
Medium density board (EFB)	3
Oil palm lumber (trunk)	2
Particleboard (EFB)	1
Fiber plastic composite (EFB)	1

As is known, there are many uses of bio-composite materials obtained from OPT such as particleboard, laminate board, plywood, fiberboard and others. The OPT bio-composite, as non-wood based material, could have appropriatedesignate used in the structural application. In addition, it also plays a role as a control measure of erosion, contributes to the cycle of soil nutrients in the plantation, and as an animal feed. [47]. According to [48], there are Innovative investigation with combining both empty fruit bunch (EFB) and OPT wastes to produce a good value-added of plywood with superior quality comparativefor the most part regarding screw withdrawal, flexural and shear strength properties. This shows that the reuse of palm wastes for example OPT in the manufacture of engineered lumber has begun to grow. The development of value-added products or now known as engineered lumber has increased since 1990 [49].

Table 3: Products Manufactured from Oil Palm Biomass [20], [50]

Products	Research studies (References)
Fiber reinforced concrete	[51]
Medium density fiberboard	[52], [53]
Particleboard	[22], [26], [31], [40], [54]
Laminated veneer lumber	[2], [44]
Blackboard	[55]
Compressed wood	[26]
Plywood	[45], [52], [56]–[58]
Parallel strand Lumber	[9], [59]
Oriented Strand Board	[30], [60]
Hardboard	[61]
Wood Plastic Composite	[62]
Agro-Lumber	[63]

In the production of bio-composite materials whether MDF and plywood for different sectors, different molding methods are also used. The main advantages of bio-composite materials are lightweight, relative stiffness and strength properties. Therefore, physical properties, material properties, tools, designs, inspections, and fixes are the key concepts that are often emphasized in bio-composite production. Particleboard has been widely used in the production of furniture and construction industry due to its low cost [64]. This particleboard has been used for structural industry where most of these products are used for interior applications [65]. Each production of particleboard industries will produce different grades where it depends on its use, however for structural industry use, high grade panels are used where mechanical strength is the most important part as it exposes the product to a high load. In the late 1960s, a medium density fiberboard (MDF) was commercially produced in competing with particleboard [66], [67]. This is because these products are able to provide good dimensional stability and surface properties. MDF also competes with solid wood and solid wood composite materials. MDF is also used mainly in furniture manufacturing [68]–[71] Normally the MDF will be covered with wood veneer or plastic laminate to give a surface look of quality products [67]. In 1797 a patent was introduced by Samuel Bentham in the production of wood veneer in which the concept of laminating several layers of veneer with glue to form thick pieces and it was called as plywood [23]. This product complying presented good performance in physical and mechanical behavior equated with those of particleboard. As well, wood veneer has good rigidity and strength properties.

Previous research, showed that OPT has the possible as bio-composite board material [9], [59], [72] Adhering to bio-composite panel products comprising veneers, particles and strands, in particular as wood component layers tied with adhesive thermosetting show an improvement in physical and mechanical properties significantly such as OSB [73], [74]. MacMillan Boedel stated that in the production of strand lumber products the properties to be controlled are varying strand length and thickness and the product density [75]. Nevertheless, the problem of developing strand lumber products to commercially viable manufacturing facilities is huge. This is because the manufacturing method should be consistent whereas the strands should be coated with resin and then reorganized in a consisted and uniform manner before conveyed to the press curing. Wood-based composite performance is mainly related to the properties of adhesive used, its compatibility with the strands and properties of the strands itself.

V. POTENTIAL ORIENTED STRAND BOARD (OSB) MADE FROM OIL PALM AND CHALLENGES

The process of manufacture OSB could also be applied by using OPT as a bio-material, even though this has not yet been stated or reported in any literature. Its use has been extended to replace plywood in structural applications at worldwide. However, the studies from [32] focused on the effect of particle geometry on the properties of OPT the research indicated that the panel made from particles size in strands shape showed better strength properties more than fine particles size. In fact, the strength properties of particles sizes in strand from such panel success met the JIS standard. This statement shows the

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initial potential in the manufacture of OSB from OPT. However, Slenderness ratio, a ratio of strand length to thickness, has been bring into being to have an influence on board properties. According to [68] stated that strand geometry as important in obtaining optimum OSB properties. Past research decided that strands slenderness ratio was a good measurement in the influence of strand's geometry on the OSB behavior, where, if the average length of overlap is increased, the strands length-to thickness ratio is also increased. Longer strands at a certain thickness did give greater strength.

Besides that, Innovative studies have been successfully proving that the OPT strand has a good prospect designate used for OSB and might be innovative renewable resources as wood strands. However, the density and the anatomical structure of OPT are two constraint for this material resources to be used in structural application, so the mixture of OPT for core layer with other tree species such as fast growing species could improve the properties of OSB [76]. The development of an economical and efficient means to transform the trunk material into high quality fiber strands is highly desirable because it's can have significant influence on OSB quality. The most challenging one would be, perhaps, the development of an efficient technique to manufactured OSB from OPT because oil palm tree show a very dissimilar density difference in the interior the trunk with 2/3 of an outer part trunk is not feasible because it is too soft. The strength of OSB is mainly derived from undisturbed fiber wood, long stripping of the strands or wafer, and strand level orientation on the surface of the layers. Table 4 below showed the all panel including the panel with 100% oil palm fulfilled the standard EN 300, in fact the result showed higher properties compared with the standard. OSB is a solid wood-based panel product, where most of the wood-based panels are heavily linked to panel specific gravity.

Table 4: Average physical and mechanical properties of OSB [76]

Panel	**Density (g/cm3)**	**MOR (N/mm2)**	**EN 300 (MOR)**	**MOE (N/mm2)**	**EN 300 (MOE)**	**IB (N/mm2)**	**EN 300 (IB)**	**TS (%)**	**EN 300 (TS)**
Oil palm 100 %	0.61	23.4	20	3846	3500	0.57	0.3	30	20
Mix of poplar /oil palm	0.62	47.3	20	6071	3500	0.64	0.3	17	20
Poplar/oil palm/poplar	0.61	51.2	20	6767	3500	0.65	0.3	14	20
Mix of coconut/oil palm	0.63	30.5	20	4565	3500	0.8	0.3	13	20

MOR: Modulus of rupture, MOE: modulus of elasticity, IB: Internal bond, TS: thickness swelling after 24h

The EN 300 standard requires special gravity in panel or horizontal density distribution (HDD) in ±10% [77]. Horizontal density distribution (HDD) very important in to improving the mechanical properties of board, the HDD function is the geometry and particle form.It is the result of the variation in some particles that overlap in the mat which is pressed to a fixed thickness. The HDD leads to the thickness of the swelling variation between the areas of variable density which results in damaging pressure in the panel[55], [78]. Most of the researchers agree that the strength of boards mainly be influenced by on the mechanical properties of individual strands [13], [40], [79]. Table 5 shows the effect of strand size on bulk density, there is a significant difference between all sizes of timber stands in two different age types. The results in the table show that there is a correlation with the decrease in the size of the strands from S0 to S3 against bulk density. However, bigger bulk density will be adding the use of resins. Previous research revealed that the lengthening of the strands affects the resulting increase in OSB product strength.

Table 5*:* Mean effects of strand size on bulk density and strand parameter [13]

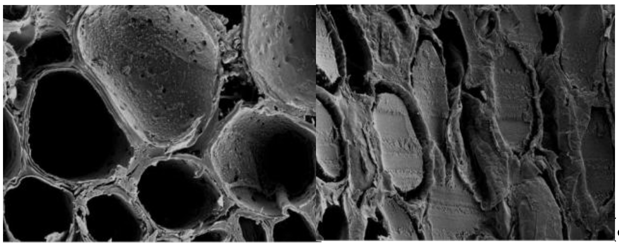
Parameter	**Age**		**Strand size (mm)**			
	8	**16**	**S0 (25.0-3.2)**	**S1(19.0-12.7)**	**S2 (12.7-6.3)**	**S3(6.3-3.2)**
Bulk density	326.27^a	374.43^b	339.67^a	332.56^c	340.46^b	384.26^a
Rectangularity			797.41^b	1117.55^a	625.07^c	325.74^d
Area			0.18^c	0.31^a	0.12^b	0.04^d
Slenderness ratio			114.03^a	80.81^b	70.46^b	75.07^b
Aspect ratio			6.93^b	4.15^c	7.13^b	15.02^a

Means with the same letter down the column are not significantly different at $p \leq 0.05$

Besides that, OPT has potential as an alternative material for manufacturing structural material such as OSB because of the impressive performance of physical and mechanical behavior, thermal stability properties, and high resistance to pests[50]. The type and amount of adhesive used will affect the quality of OSB production. For exterior OSB generally uses a waterproof adhesive such as phenol formaldehyde (PF), melamine formaldehyde (MF) and, methylene diphenyl diisocyanate (MDI). However, PF and MDI are the most commonly used in OSB production recently [80].

Past research stated that

through scanning electron microscopic (SEM) showed the mechanism of resin into OPT. Based on the studies, SEM image can be visualized in the view of the structure of the wood palm wood where resin penetration occurs into parenchyma [81], [82]. Figure 5 showed parenchyma cells completely covered by resins. Abdullah et al. report that the resin is located in the parenchyma tissue [27]. According to [83], the OPT blend with resin using heat techniques showed a 20% increase in mechanical strength compared to solid wood. [84] also stated the bending strength of the OPT will increase after impregnated resin. However, OPT with high resin content cannot withstand greater loads, indicating that composite's flexure modulus such as OSB had decreased. This is because the tensile and flexural strength increase with the upsurge of the amount resin content up to 15% but it will decrease where the resin load increases by more than 15% [82].



a)

(b)

Fig 5. Scanning electron microscopy of oil palm trunk impregnation with resin: (a) before impregnation, (b) after impregnation and curing processes [82], [84]

Based on the previous research, in the production of composite products such as OSB, the impact strength of OPT with PF resin is better than OPT with UF resins. PF resin acts as a good stress-transferring intermediate than UF resins in a production of OSB [82]. Therefore, in the potential of OSB manufacturing from oil palm, resin selection is a major challenge to be emphasized because each type of resins will have a different reaction to the strands.

In addition, in term of machining properties, according to [85] stated that wood from the oil palm trunk has no good machining properties. However, products from a treated OPT or bio-composite panel like OSB that have been blended with a resin have a better of planning quality. The treated OPT parenchyma tissue, resulting in penetration of the resin, becomes compact and denser, which makes it cleanly cut by the knives in the dustless cutting head. Additionally, [39] reports that OPT blend with resin improves the quality of OPT as well as manufactures OSB panels. Regarding external activities by biodegradation agents such as termites, insects, and fungi can weaken the performance of OPT or OSB panels. Previous research showed the impregnated OPT showed high resistance to termites. Resin plays an important role in termites' test which is the result showed the higher resin penetration, the best resistance to termites' attack, and its comparable to commercial preservatives [84].

The use of OPT in the production of bio-composite products has become more widely accepted and established as an alternative source of wood. However, there are still many challenges and limitations in the use of OPT in the manufacture of OSB especially in physical and mechanical behavior such as dimensional stability, strength and durability. In addition, the modification of the materials used in the manufacture of OSB has been enhanced according to the material requirements for obtaining high quality products in term of aesthetic texture, dimension stability, insect resistance and termites, water resistance, hardness, stiffness, and more. In addition, the study by [86] stated that the use of modified and improve OPT can enhances characteristics and decomposition, compared to ordinary timber, thus providing a great opportunity to manufacture OSB commercially from the OPT.

VI. CONCLUSION

This paper study on the potential of this new renewable resource and look how it is being used nowadays in wood-based panel products or bio-composite material. The discussion also considers the characteristics regarding the increased or improve use OPT in the future focusing on oriented strand board (OSB) manufacture. This study also reviews on the use of fine core material and its effect on physical and mechanical properties of OPT OSB. From this study, it is proven that the parenchyma content and the board density have a great effect on OSB properties as compared to the effect of resin level. As discussed, earlier, the fiber strands from OPT are good source of alternative raw material for the production of OSB. Resin impregnation or penetration can upgrade the physical and mechanical properties of strands palm trunk OSB. Many studies have been carry out previously on other wood-based panel products, but there is no information yet on how to make OSB from OPT. Therefore, a study is needed to examine the potential for making OSB from OPT in structural application. However, an economical and effective technique of produce high quality strand is needed to produce the desirable and good quality of OSB. In reality, the high quality of products and the environmental health concern are interconnected and should be taken into consideration in future planning and development of the industry. The results of this study can contribute to the viability of using non-wood strands of OPT tree species for OSB manufacturing, it is important to meet the requirementssuitable raw material supply for the board industry.

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REFERENCES

[1] MPOB, "Oil Palm planted area as of 2013," 2014.

[2] M. R. Hani, M. Mahidin, H. Husin, H. Hamdani, and K. Khairil, "Oil palm biomass utilization as an energy source and its possibility use for polygeneration scenarios in Langsa City, Aceh Province, Indonesia," IOP

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Conf. Ser. Mater. Sci. Eng., 2018.
[3] R. Hashim et al., “Influence of press temperature on the properties of binderless particleboard made from oil palm trunk,” Mater. Des., 2011.
[4] M. Husin, A. H. Hassan, and R. Ramli, “Blockboard from OPT,” MPOB Inf. Ser., 2001.
[5] S. D. Salman, Z. Leman, M. T. H. Sultan, M. R. Ishak, and F. Cardona, “Effect of kenaf fibers on trauma penetration depth and ballistic impact resistance for laminated composites,” Text. Res. J., vol. 87, 2017.
[6] M. J. Sharba, Z. Leman, M. T. H. Sultan, M. R. Ishak, and M. A. Azmah Hanim, “Partial replacement of glass fiber by woven kenaf in hybrid composites and its effect on monotonic and fatigue properties,” BioResources, 2016.
[7] S. D. Salman, Z. Leman, M. T. H. Sultan, M. R. Ishak, and F. Cardona, “Ballistic impact resistance of plain woven kenaf/aramid reinforced polyvinyl butyral laminated hybrid composite,” BioResources, 2016.
[8] A. U. M. Shah, M. T. H. Sultan, F. Cardona, M. Jawaid, A. R. A. Talib, and N. Yidris, “Thermal analysis of bamboo fibre and its composites,” BioResources, 2017.
[9] I. Fridiyanti and M. Y. Massijaya, “Physical and mechanical properties of parallel strand lumber made from hot pre-pressed long strand oil palm trunk waste,” IOP Conf. Ser. Earth Environ. Sci., 2018.
[10] M. T. H. Sultan, K. Worden, W. J. Staszewski, S. G. Pierce, J. M. Dulieu-Barton, and A. Hodzic, “Impact damage detection and quantification in CFRP laminates; a precursor to machine learning,” System, 2009.
[11] N. H. Mostafa, Z. N. Ismarrubie, S. M. Sapuan, and M. T. H. Sultan, “Effect of equi-biaxially fabric prestressing on the tensile performance of woven E-glass/polyester reinforced composites,” J. Compos. Mater., 2016.
[12] P. Zakikhani, R. Zahari, M. T. H. Sultan, and D. L. Majid, “Thermal degradation of four bamboo species,” BioResources, 2016.
[13] B. Uysal, “Bonding strength and dimentional stability of laminated veneer lumbers manufactured by using different adhesives after the steam test,” Int. J. Adhes. Adhes., 2005.
[14] K.I. Ismail, M.T.H. Sultan, A.U.M. Shah, M. Jawaid, S.N.A. Safri, “Low velocity impact and compression after impact properties of hybrid bio-composites modified with multi-walled carbon nanotubes,” Compos. Part B Eng., 2019.
[15] L. Bufalino, A. A. Ribeiro Corrêa, V. A. de Sá, L. Marin Mendes, N. Amarante Almeida, and V. Dordenoni Pizzol, “Alternative compositions of oriented strand boards (OSB) made with commercial woods produced in Brazil,” Maderas. Cienc. y Tecnol., 2014.
[16] J. A. Youngquist, “Wood-based Composites and Panel Products,” Wood Handbook—Wood as an Eng. Mater., 1999.
[17] “Developments of wood markets—resizing of timber industry.”
[18] “Malaysia’s wood-based panel industry strives for quality, Malaysia Timber Council.”
[19] O. T. Faulkner, J. R. Mackie, O. T. Faulkner, and J. R. Mackie, “The Oil Palm,” West African Agric., 2016.
[20] F. Rosli, C. M. R. Ghazali, M. M. Al Bakri Abdullah, and K. Hussin, “A review: Characteristics of oil palm trunk (OPT) and quality improvement of palm trunk plywood by resin impregnation,” BioResources, 2016.
[21] L. S. Killmann, W., and Choon, “Anatomy and properties of oil palm stem,” Porim, 1985.
[22] R. Hashim, S. N. Sarmin, O. Sulaiman, and L. H. M. Yusof, “Effects of cold setting adhesives on properties of laminated veneer lumber from oil palm trunks in comparison with rubberwood,” Eur. J. Wood Wood Prod., 2011.
[23] E. S. Bakar, O. Rachman, D. Hermawan, L. Karlinasari, and N. Rosdiana, “Pemanfaatan Batang Kelapa Sawit (Elaeis guineesis Jacq.) Sebagai Bahan Bangunan dan Furniture (I): Sifat Fisis, Kimia dan Keawetan Alami Kayu Kelapa Sawit.,” J. Teknol. Has. Hutan, 1998.
[24] E. S. Bakar, O. Rachman, W. Darmawan, and I. Hidayat, “Pemanfaatan Batang Kelapa Sawit (Elaeis guineesis Jacq.) Sebagai Bahan Bangunan dan Furniture (II): Sifat Mekanis Kayu Kelapa Sawit,” J. Teknol. Has. Hutan, 1999.
[25] “Pemanfaatan Batang Kelapa Sawit (Elaeis guineensis Jacq.) Sebagai Bahan Bangunan dan Meubel (III): Sifat Keterawetan Kayu Sawit dengan Basilit-CFK dan Impralit-BI.”
[26] N. Saari, R. Hashim, O. Sulaiman, S. Hiziroglu, M. Sato, and T. Sugimoto, “Properties of steam treated binderless particleboard made from oil palm trunks,” Compos. Part B Eng., 2014.
[27] C. K. Abdullah, M. Jawaid, H. P. S. Abdul Khalil, A. Zaidon, and A. Hadiyane, “Oil palm trunk polymer composite: Morphology, water absorption, and thickness swelling behaviours,” BioResources, 2012.
[28] P. Zakikhani, R. Zahari, M. T. H. Sultan, and D. L. Majid, “Morphological, mechanical, and physical properties of four bamboo species,” BioResources, 2017.
[29] Nor, A. F. M., Sultan, M. T. H., Jawaid, M., Azmi, A. M. R., & Shah, A. U. M, “Analysing impact properties of CNT filled bamboo/glass hybrid nanocomposites through drop-weight impact testing, UWPI and compression-after-impact behaviour,” Compos. Part B Eng., 2019.
[30] Z. Cai and J. E. Winandy, “Opportunity and Development of Bio-Based Composites,”.
[31] N. Jumhuri et al., “Effect of treated particles on the properties of particleboard made from oil palm trunk,” Mater. Des., 2014.
[32] K. Nordin, M. A. Jamaludin, M. Ahmad, H. W. Samsi, A. H. Salleh, and Z. Jalaludin, “Minimizing the environmental burden of oil palm trunk residues through the development of laminated veneer lumber products,” Manag. Environ. Qual. An Int. J.,2004.
[33] “Plywood,” The Gale Group Inc. .
[34] A. Mokhtar, K. Hassan, A. A. Aziz, and M. B. Wahid, “Plywood from oil palm trunks,” J. Oil Palm Res.,2011.
[35] M. Anis, A. Mohd Shamim, H. Kamarudin, A. H. Fazliana, and A. A. Astimar, “Effect of Hot Pressing Temperature and Varying Veneer Density on the Properties of Oil Palm Sandwich Board,” J. Adv. Res. Fluid Mech. Therm. Sci., 2018.
[36] “One-layer experimental particleboard from oil palm frond particles and empty fruit bunches fibers.”
[37] J. Kasim et al., “Effects of Particle Sizes, Resin Content and Board Densities on the Properties of Phenol Formaldehyde Particleboard from Oil Palm Trunk Particles,” Sci. Res. J., 2019.
[38] “Properties of Particleboard manufactured from less-used species: Mollotus Macrostachys (Balek Angin).”
[39] I. Sumardi, “Compregnation phenol formaldehyde as effort quality enhancement oil palm(Elaeis guineensis Jacq),” 2000.
[40] G. P. Han, Q. L. Wu, and J. Z. Lu, “Selected properties of wood strand and oriented strandboard from small-diameter southern pine trees,” Wood Fiber Sci., 2006.
[41] S. Chen, C. Du, and R. Wellwood, “Effect of panel density on major properties of oriented strandboard,” Wood Fiber Sci., 2010.
[42] A. Darwis, M. Massijaya, N. Nugroho, and E. Alamsyah, “No Title,” J. Ilmu Teknol. Kayu Lapis, 2014.
[43] “Malaysian Biomass Industry Action Plan 2020.”
[44] A. Nurhayati and S. Fauziah, “The oil palm wastes in Malaysia,” Biomass Now - Sustain. Growth Use, pp. 76–100, 2013.
[45] L. Y. Feng, P. Tahir, and Y. B. Hoong, “Density distribution of oil palm stem veneer and its influence on plywood mechanical properties,” J. Appl. Sci., 2011.
[46] N. Hashim, “Sustainability of Resources For Wood-Based Industry,” Malaysia Timber Industry Board, 2011.
[47] O. Sulaiman, N. Salim, N. A. Nordin, R. Hashim, M. Ibrahim, and M. Sato, “The potential of oil palm trunk biomass as an alternative source for compressed wood,” BioResources, 2012.
[48] A. H. Saleh, I. Kamal, N. A. A. Rashid, H. P. S. Abdul Khalil, A. S. Bin Mat Seman, and S. Z. Mahmud, “Preliminary study of moulded laminated veneer oil palm (MLVOP),” Mod. Appl. Sci., 2011.
[49] D. L. Singh, G., Huan, L.K., Leng, T., Kow, “Oil palm and the environment: a Malaysian perspective,” Oil palm Environ. a Malaysian Perspect., 1999.
[50] S. S. Suhaily, M. Jawaid, H. P. S. Abdul Khalil, and F. Ibrahim, “A review of oil palm biocomposites for furniture design and applications: Potential and challenges,” BioResources, 2012.
[51] N. Ahmad, J. Kasim, S. Z. Mahmud, S. A. K. Yamani, A. Mokhtar, and N. Y. M. Yunus, “Manufacture and properties of oil palm particleboard,” 3rd ISESEE 2011 - Int. Symp. Exhib. Sustain. Energy Environ., 2011.
[52] Z. Ibrahim, A. A. Aziz, R. Ramli, A. Mokhtar, R. Omar, and S. Lee, “Production of Medium Density Fibreboard (MDF) from Oil Palm Trunk (OPT),” J. Appl. Sci., 2014.
[53] H. P. S. A. Khalil* and A. H. Bhat, “Oil Palm Biomass: Fibre Cultivation, Production and Its Varied Applications,” Oil Palm Cultiv. Prod. Diet. Components, 2011.
[54] J. Lamaming, O. Sulaiman, T. Sugimoto, R. Hashim, N. Said, and M. Sato, “Influence of chemical components of oil palm on properties of binderless particleboard,” BioResources, 2013.

[55] "The Influence of a horizontal density distribution on moisture-related mechanical degradation of oriented strand composites,", 2000.
[56] O. Palm et al., "Chapter 9 Oil Palm Biomass Fibres and Recent Advancement in Oil Palm Biomass Fibres Based Hybrid Biocomposites," 2017.
[57] N. Mahat et al., "Comparison Study On Oil Palm Trunk And Oil Palm Fruit Bunch Fibre Reinforced Laterite Bricks," Mod. Appl. Sci.,2014.
[58] H. K. Okoro, O. S. Fatoki, F. a Adekola, B. J. Ximba, R. G. Snyman, and B. Opeolu, "Oil Palm biomass as an adsorbent for heavy metals," Rev. Environ. Contam. Toxicol., 2011.
[59] I. Hermanto and M. Y. Massijaya, "Performance of composite boards from long strand oil palm trunk bonded by isocyanate and urea formaldehyde adhesives," IOP Conf. Ser. Earth Environ. Sci.,2018.
[60] S. Shi and J. C. F. Walker, "Wood-based composites: Plywood and veneer-based products," Prim. Wood Process. Princ. Pract., 2006.
[61] "Which hardboard Is best?"
[62] G. Pritchard, "Two technologies merge: Wood plastic composites," Reinf. Plast., 2004.
[63] H. P. S. A. Khalil et al., "New approach to oil palm trunk core lumber material properties enhancement via resin impregnation," J. Biobased Mater. Bioenergy, 2012.
[64] R. H. D. Abdul Khalil Shawkhataly, "'Gentian dan Komposit Lignoselulosik'.," 2004.
[65] APA, "Structural Composite Lumber," APA -The Eng. Wood Assoc., 2018.
[66] "Panel products: past, present and future developments."
[67] K. Szwajka and T. Trzepieciński, "Effect of tool material on tool wear and delamination during machining of particleboard," J. Wood Sci., 2016.
[68] "Manufacture and use of HAIX.pdf."
[69] K. M. Chapman, "Composite panels in Australia and New Zealand: A focus on MDF," 32nd Int. Part. Mater. Symp. Proc.,1998.
[70] X. F. Sun and A. L. Hammett, "Chinese furniture industry: Its development and wood use," For. Prod. J. 1999.
[71] K. Szwajka and T. Trzepieciński, "An examination of the tool life and surface quality during drilling melamine faced chipboard," Wood Res., 2017.
[72] S. U. N. M. Mangurai, M. Y. Massijaya, Y. S. Hadi, and D. Hermawan, "The physical characteristics of oil palm trunk and fast growing species veneer for composite-plywood," IOP Conf. Ser. Earth Environ. Sci., 2018.
[73] "Flexural properties of veneer overlaid OSB composite panels from southern yellow pine."
[74] P. Král, P. Klímek, P. K. Mishra, P. Rademacher, and R. Wimmer, "Preparation and characterization of cork layered composite plywood boards," BioResources, 2014.
[75] "Engineered Wood: Manufacturing Processes Optimize Fiber Utilization and Engineering Properties."
[76] W. Science, "Palms - an alternative raw material for structural application," 2009.
[77] K. Kruse, C. Dai, and A. Pielasch, "An analysis of strand and horizontal density distributions in oriented strand board (OSB)," Holz als Roh - und Werkst., 2000.
[78] "The density distribution in flakeboard."
[79] R. C. Moody and R. Hernandez, "Engineered wood products-A guide for specifiers, designers and users," Smulsky, Stephen (ed),1997.
[80] W. Hidayat, "Preparation and Properties Enhancement of Oriented Strand Board Made from from Tropical Fast Growing Tree Species," 2009.
[81] A. Abdullah et al., "Study on the Properties of Oil Palm Trunk Fiber (OPTF) in Cement Composite," Appl. Mech. Mater., 2013.
[82] R. Dungani et al., "A review on quality enhancement of oil palm trunk waste by resin impregnation: Future materials," BioResources, 2013.
[83] Erwinsyah, "Improvement of Oil Palm Wood Properties Using Bioresin," Tech. Univ. Dresden, 2008.
[84] I. Ul Haq Bhat, C. K. Abdullah, H. P. S. Abdul Khalil, M. Hakimi Ibrahim, and M. R. Nurul Fazita, "Properties enhancement of resin impregnated agro waste: Oil palm trunk lumber," J. Reinf. Plast. Compos., 2010.
[85] K. . Ho, C. K.T, and L. . Hong, "Processing, Seasoning and Protection of Oil palm lumber," Process. Natl. Symp. Oil pam By-Products Agro-based Ind., 1985.
[86] H. P. S. Abdul Khalil, A. H. Bhat, M. Jawaid, P. Amouzgar, R. Ridzuan, and M. R. Said, "Agro-Wastes: Mechanical and physical properties of resin impregnated oil palm trunk core lumber," Polym. Compos., 2010.

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