Palms - An Alternative Raw Material for Structural Application

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Abstract

The three main species of palms are oil palm, coconut palm and date palm. Their total plantation area is close to 30 million ha. Oil palm is the most important one with a sustainable production of more than 150 million m³ of trunks per year. The main goal of this research was to produce and test strand board made of oil palm trunk (OPT) as well as in mixture with poplar and coconut palm wood. The produced boards were 13 mm thick, 550 kg/m^3 in density, press time 320s, using 5% pMDI. 100% OP strands or a mix of OP with poplar or light Coconut wood. The results showed that panels with 100% oil palm had higher properties compared with EN300 standard but panels made with poplar as face and oil palm as core had the highest MOR and MOE. A mixture of coconut and oil palm showed the best internal bond (IB). No significant IB difference observed between panels made with a mixture of poplar/oil palm and poplar as face/oil palm as core. Highest and lowest thickness swelling was found with 100% oil palm and a mixture of coconut and oil palm, respectively. The paper analyses the structural and mechanical properties of oil palm wood in relation to the strand board properties and gives a brief recommendation of further studies and for commercial production of OSB/CSL.

Keywords: Oil palm, poplar, coconut palm, oriented strand board, physical and mechanical properties, area of wood utilization

Introduction

Wood based composites are widely used for various applications in the building and furniture sector. The demand for wood composites is growing continuously. One aspect of present and future research is focused on new product design and uses for load bearing and non-load bearing constructions in both residential and commercial buildings. Oriented Strand Board (OSB), Oriented Strand Lumber (OSL) and Parallam are some examples for load bearing composites. The shortage of current raw material and increasing costs requires new raw materials for these products. Due to this challenge, finding suitable wood and/or non-wood raw material is one of the serious challenges for the future. One strategy is the use of non-commercial fiber materials as an alternative for OSB, OSL, and Glued Laminated Timber (GLT) or Cross Laminated Timber (CLT). The most available materials of this type are bamboo and palms. Also a combined use of these materials with traditional timbers is a promising option. Malanit (2009) has already shown the potential of bamboo for OSB with excellent product properties.

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Palms have similar physical, mechanical and chemical properties like wood (Killmann & Lim 1985). Palms are found naturally or planted on large areas throughout the world but mainly in Asia and West Africa. Generally, palms are cultivated to provide oil and fats (oil and coconut palm) or fruits (date palm). When the fruit production declines the old palms are replaced and the trunks of the palms (OPT) have a potential for product use or energy purposes. The highest potential has oil palm and coconut palm which are planted on 20 million ha and 5 million ha, respectively. The single plots planted with coconut are small which creates huge logistic and supply problems. Oil palm is often planted on large and very large sites. The life time of an oil palm tree is 25 years before replanting and the available volume per ha at the time of replanting is 150-200 m³. Considering the existing 20 million ha (mainly in SEA) 800.000 ha have to be replanted every year which give a theoretical volume of 120-160 million m³ OPT per year. At least 75% are located in Indonesia, Malaysia and Thailand where the harvest of traditional timber for the industry from natural forest will fall below 50 million m³ together in the three countries. OPT is a lignocellulosic material which is sustainable available, and cheap, has no harvesting or trade restrictions and is therefore a raw material with a good potential to reduce the pressure on softwood/hardwood forests (Sulaiman *et al*. 2009).

Objectives

The objectives of a recently performed research project were a) to produce and test oil palm based OSB with 100% strands from Oil Palm Trunks (OPT) and b) to test a mixture of OPT strands with strands from low density coconut wood and poplar as low density hardwood.

Material and methods

Strand preparation

Small diameter poplar trees were harvested near Reinbek, Germany. After debarking manually, the logs were converted into strands at PALLMANN (Zweibrücken). A knife ring flaker produced poplar strands in dimension of 12.5 cm in length, 0.7 mm in thickness and 20-40 mm in width. The wet strands were collected in plastic bags and transported to Hamburg and immediately dried in a kiln.

The oil palm (OP) material used in the tests came from Southern Malaysia Peninsular and was originally used as core layer in 30 mm thick block board. From the block boards which were tested in Hamburg, the core material was removed and used to produce strands. In order to increase the moisture content before the stranding process the boards were put in water for half an hour. The strands were produced by sawing using a circular saw (Fig.1). Due to low density of the used oil palm wood (0.30 g/cm^3), it was not possible to produce thinner strands than 1.0 mm. This is due to the very low density and therefore low splitting properties of the parenchyma and the high cutting forces during circular sawing. The strands produced had overall dimensions of 1 mm thick, 20 mm width and 125 mm length (same as poplar).

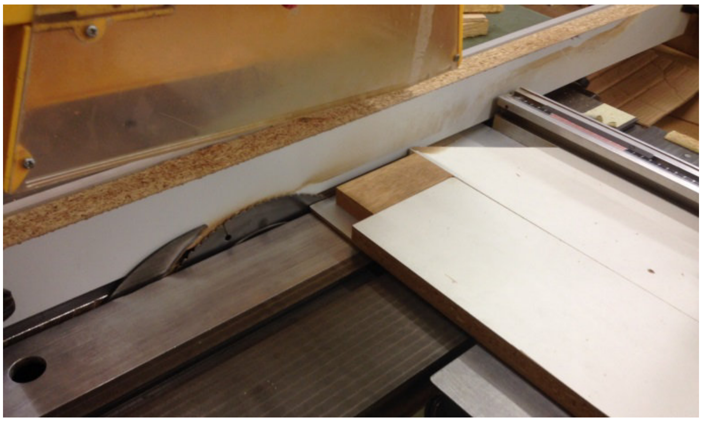


Figure 1. Producing strands with circular saw in the lab

Coconut timber *(Cocos nucifera)* was obtained from a plantation in Northern Sulawesi, Indonesia. The density ranged from high (600-900 kg/m^3) to low density (200-400 kg/m^3). For the OSB the lower density timber was selected (300-450 kg/m3) to be comparable to the Oil Palm material.

Figure 2. Strands from poplar (left), coconut palm (middle), and oil palm (right)

Panel manufacturing

Four different types of panels were produced for this study. A) pure (100%) oil palm OSB, B) mixture of oil palm and poplar with 50/50 % ratio, C) poplar as face and oil palm as core layer, and D) mixture of oil palm and poplar with 50/50 % ratio. Table 1 shows the material combinations and design of OSB panels.

Table 1: Characterization of OSB panel

Samples	Panel type	Ratio by mass (%)	Target Density (kg/m³)	Target Board Thickness (mm)
A	oil palm	100	550	13
B	mix of poplar/oil palm	50/50		
C	poplar /oil palm/ poplar	20/60/20		
D	mix of coconut/oil palm	50/50		

The moisture content of the strands after storage and conditioning was 10% for face and 5% for core strands. These strands were separately blended with 5% polymethylene diisocyanate (pMDI) as adhesive in a drum blender. No wax or other additives were applied. A wooden frame (40*40 cm^2) was applied to form the mat. For each panel type A-D two panels were produced. The forming of the tree layer panel (with the core running perpendicular to the faces) was done by hand. This certainly is not comparable to an industrial process. Pressing parameters were 180°C, press time 320s, final thickness 13 mm and target density after pressing 550 kg/m^3. Before testing, all the test specimens were conditioned at 65% RH and 20°C for 1 week. Modulus of elasticity (MOE), modulus of rupture (MOR), internal bond (IB), thickness swelling after 24h (TS24h), and vertical density profile (VDP) of the boards were measured and compared with EN300 standards. Samples for testing MOR and MOE (3 samples), VDP (1), IB (6) and TS (6) were cut from each panel to determine properties. For the measurement of MOR and MOE according to EN 310, a Zwick/Roell Z050 universal test device was used. The internal bond strength test was performed with a universal testing machine as well (Losenhausenwerk). Samples for thickness swell were prepared and tested according to EN 317. Average thickness was measured in the center of each sample. The samples were submerged in water at 20°C for 24h. Then the specimens were dripped and wiped clean of any surface water. The thickness of specimens was measured with digital caliper of 0.01 mm precision. Determination of the cross sectional density profile was conducted using gamma-ray densitometry.

Results

The average values of modulus of rupture (MOR) and modulus of elasticity (MOE) for the main board axis (parallel to face strands), internal bond, and thickness swelling of all panels are presented in Table 2 and Figures 3 through 7. The average oven dried density for all panels after pressing was around 0.60 g/cm^3.

Table 2: *Average physical and mechanical properties of OSB*

Panel	Density (g/cm³)	MOR (N/mm²)	MOE (N/mm²)	IB (N/mm²)	TS (%)
A	0.61 (0.02)	23.4 (5.1)	3846 (555)	0.57 (0.03)	30 (4)
B	0.62 (0.04)	47.3 (7.0)	6071 (737)	0.64 (0.06)	17 (2)
C	0.61 (0.03)	51.2 (6.8)	6767 (829)	0.65 (0.05)	14 (2)
D	0.63 (0.03)	30.5 (7.0)	4565 (579)	0.8 (0.08)	13 (3)

MOR: modulus of rupture MOE: modulus of elasticity, IB: internal bond, TS: thickness swelling after 24h, Standard deviation in parentheses

Vertical density profile (VDP)

Figure 3 shows the average vertical density (density along board thickness) among different panels. As shown in figure 3, panels made with a mixture of coconut and oil palm strands showed the highest density compared with panels made with a mixture of poplar/oil palm or pure oil palm. In addition, panels made with 100% oil palm and oil palm in core layer showed the same vertical density profile. In general, high density face and low density core layer are the main characteristic of oriented strand board. The result with all board types is a mean density between 0.61 and 0.63 g/cm^3 regardless of the combination of the three material types. This leads to the assumption that the densification of the strands of poplar (350 kg/m^3), coconut palm (400 kg/m^3), and oil palm (300 kg/m^3), after board pressing results at the same density of some 600-650 kg/m^3. This means that densification ratio for poplar strands is 1.7, for coconut strands 1.5 and for oil palm strands 2.0.

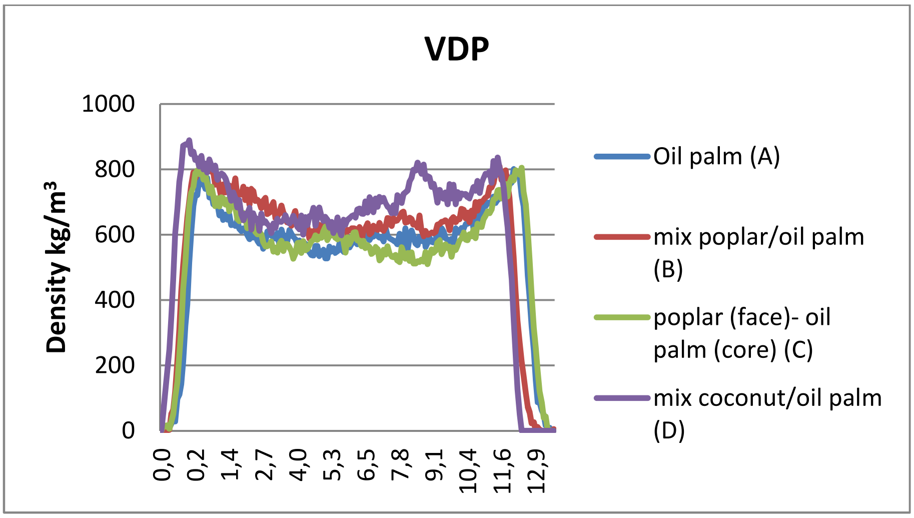
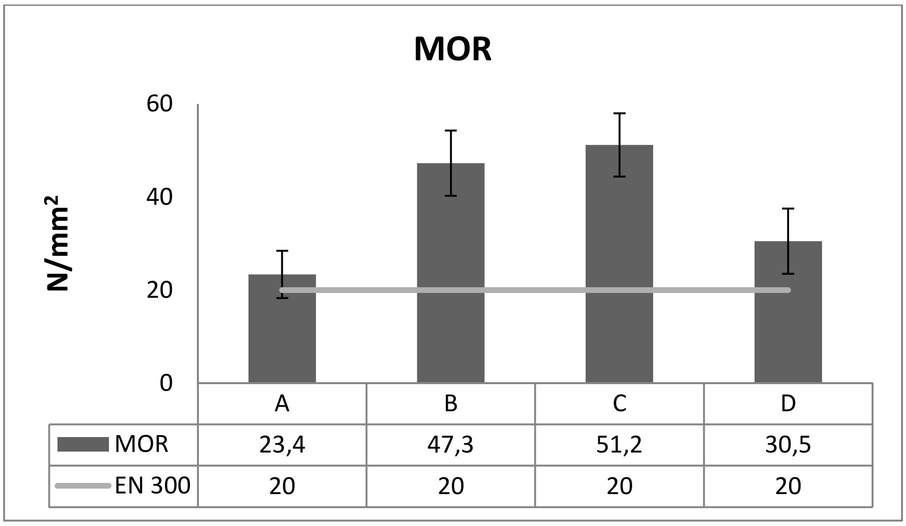


Figure 3. Vertical density distribution

MOR & MOE

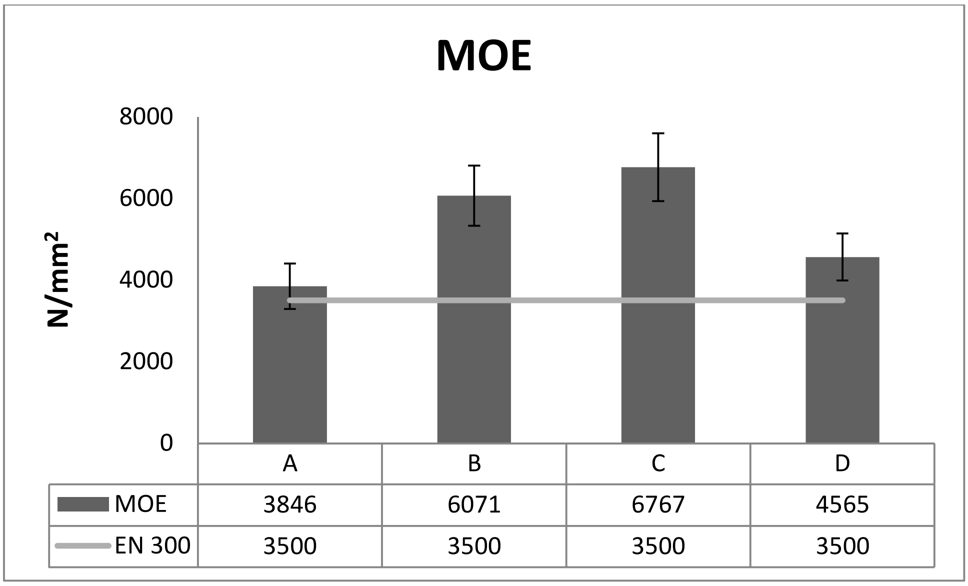
The results of MOR and MOE for the different panels are illustrated in Figure 4 and 5. The same trend was observed for MOR and MOE among the panels. Panels made with poplar strands in face layer showed 51.2 and 6767 N/mm^2 as MOR and MOE, respectively. It is well known, bending strength and MOE of wood based composites relates to face layer properties and thickness. Because of higher MOR/MOE properties of poplar compared to coconut and oil palm considering the same density after compressing of the boards, the panels with poplar in face either 100% (C) or 50% (B) have the better bending properties.



A: Pure oil palm, B: mixture of poplar and oil palm,

C: poplar (face) + oil palm (core), D: mixture of coconut and oil palm

Fig 4. Average MOR of 13 mm OSB



A: Pure oil palm, B: mixture of poplar and oil palm,

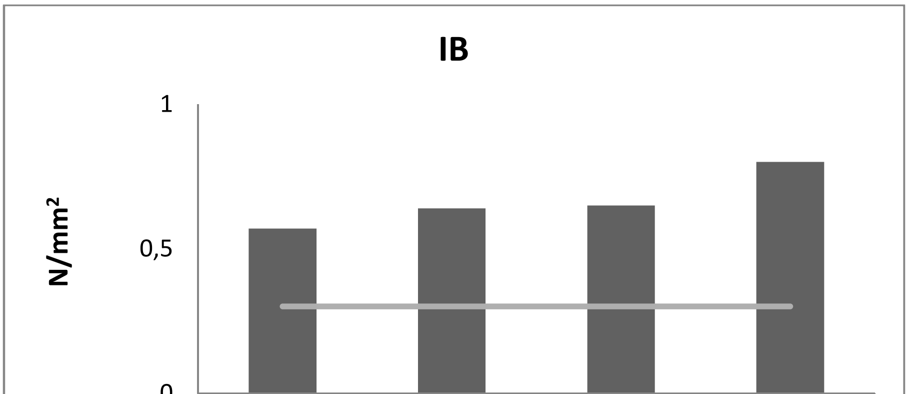
C: poplar (face) + oil palm (core), D: mixture of coconut and oil palm

Fig 5. Average MOE of 13 mm OSB

Internal bond (IB)

The results showed that the internal bond values of the test samples vary between 0.57 and 0.8 N/mm^2. Mean IB of all boards was considerably higher than the minimum requirement for

OSB type 2 which is 0.3 N/mm^2 (EN300). The results show that panels made of type A (100% oil palm) and type B (poplar as face and OP in core) has no big influence on the IB. It means that the glue line properties are sufficient and shows the good bonding between oil palm strands and pMDI. Panels made with a mixture of 50-50% coconut and oil palm showed the highest IB among the different combinations. It may be related to the role of oil palm as filler in core layer because of lower original density compared with coconut and most likely higher flexibility across grain.



	A	B	C	D
IB	0,57	0,64	0,65	0,8
EN 300	0,3	0,3	0,3	0,3

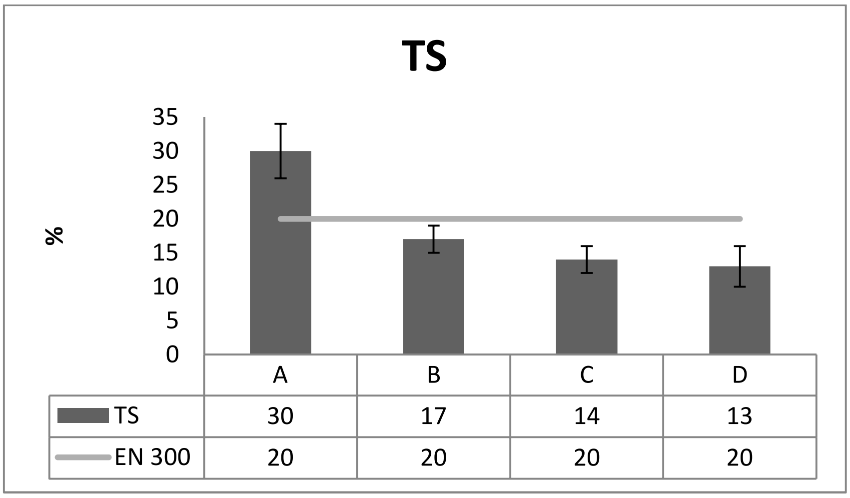
A: Pure oil palm, B: mixture of poplar and oil palm,

C: poplar (face) + oil palm (core), D: mixture of coconut and oil palm

Fig 6. Average IB of 13 mm OSB

Thickness swell 24h

The lowest and highest values of TS were observed with the panels consisting of 100% oil palm and panels made with a mixture of coconut/ oil palm, respectively (Fig. 7). EN 319 defines the maximum TS level for OSB type 2 to 20%. Even having used pMDI the test results show that thickness swelling remains as big disadvantage. One strategy to reduce the thickness swelling could be use of wax or paraffin. This problem could be also solved by treating strands with water repellent before panel manufacturing (Yalinkilic *et al.* 1998) or heat treatment in order to reduce water uptake. As shown in Fig.7 oil palm panels had the lowest TS which might be related to different structure of the wood (vascular bundles and parenchyma) especially the influence of high densification rate on the parenchyma. Physical properties of oil palm trunks differ significantly, as vascular bundles are dense and fibrous, while parenchyma tissue is sparse and spongy (Lim& Khoon 1986, Lim & Fujii 1997, Baker *et al.* 2008). In panels C and D, lower thickness swelling might be related to lower thickness swelling of poplar and coconut strands. Oil palm has more pores compared to poplar and coconut that would be more void spaces for water uptake and storage.



A: Pure oil palm, B: mixture of poplar and oil palm,

C: poplar (face) + oil palm (core), D: mixture of coconut and oil palm

Fig 7. Average TS of 13 mm OSB

Discussion

Akrami *et al*. 2013 used beech and poplar as two potentially important wood species for oriented strand boards in Europe. The panels produced had 16 mm thickness at 650 and 720 kg/m^3 with 180° C and 240s, using 5% pMDI. A comparison between this current research and beech and poplar based OSB showed: Oil palm boards showing the same MOR as panels made with 100% poplar at 650 kg/m^3 but MOE of OPboards are about 25% lower. The IB was comparable to panels made with 50% poplar as core and 50% beech as faces (0.53 N/mm^2). The maximum TS were found 25% for panels made with 75% poplar as core/ 25% beech as face layer , and also pure poplar panels at 720 kg/m^3 (23%) but for OPboard is around 30% (only 610 kg/m^3) . The mixture of coconut and oil palm has the same TS like panels with 50% beech in core and 50% poplar in face at 650 kg/m^3.

The materials from oil palm (OP) and coconut palm (CP) were from the very light weight part of trunks. All palms show a very distinct density variation within the trunk (Shaari *et al*. 1991, Frühwald *et al*. 1992)ranging between 0.2 to 0.8 g/cm^3 dry density (OP) and 0.3 to 1.1 g/cm^3 (CP). The idea of this research was to use the lower density parts of the trunks as the high density parts could achieve revenues as solid wood products in the market. If processing, logistics, and costs are taken into account, it is recommended to use the whole OP-trunk or the upper 2/3 of the trunk (with varying densities) for OSB.

CONCLUSIONS

In this research the typical properties of strand board from 100% oil palm wood and also in a mixture with poplar and coconut wood were determined. The results showed that the oil palm strands have a good potential to be used for OSB and could be a new alternative bio-based material for wood strands. Although the density of oil palm and the anatomical structure are two limitations of this material for some applications like building sector the results of this research show that a mixture of oil palm material for core layer with other tree species (i.e

Acacia mangium or Rubber wood) as face layer could increase the properties of structural oriented strand board or continuous strand board (CSL).

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