One Layer Experimental Particleboard from Oil Palm Frond Particles and Empty Fruit Bunch Fibers

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***Abstract*— The aim of this study is to investigate physical and mechanical properties of experimental particleboards manufactured from mixing the oil palm fronds particles with empty fruit bunch fibers. Variables were two blending ratios (100:0 and 70:30), press temperature (160°C and 180°C) and press time (180 and 300 s). Experimental boards with a target density of 750 kg m^{-3} were manufactured from these two particles and fibers blended with urea formaldehyde resin and compressed into targeted thickness. The effect of these manufacturing conditions on bending strength, internal bonding, water absorption and thickness swelling were determined. From this research, it can be concluded that hybridization of fibers with fronds particles improved some properties of particleboard. Empty fruit bunch fibers and fronds particleboard showed better modulus of rupture and internal bonding than fronds particleboards.**

Keywords*— *oil palm fronds; empty fruit bunch; particleboards

I. INTRODUCTION

Particleboard is a composite panel product normally consisting of small pieces of cellulosic materials combined with a synthetic resin and joined together under certain temperature and force per unit area. Particleboards are extensively employed in the manufacturing of furniture, kitchen cabinets, door parts and flooring. Currently, there is renewed interest in the development of abundant, renewable biomass resources for the production of wood composite panels such as particleboards, fiberboards and oriented strand boards. Natural sources have become depleted and any harvesting of wood has to be sustainable to ensure the forests do not suffer. Thus, utilization of agricultural biomass as a raw material in the composite manufacturing is one of the solutions that came to the minds of many researchers. In 2012, Malaysia recorded 5.08 million hectares of oil palm planted area. Thus, massive amounts of oil palm biomass are generated over the year. The sources of lignocellulosic materials from oil palm biomass are fronds (OPF), trunks (OPT) and empty fruit bunch (EFB) could be used as a feedstock in bio-based material production [1,2]. Approximately, total of dry biomass residues generated per hectare of OPF is 9.6; OPT is 3.0 and EFB is 1.4 tons respectively [3]. Utilization of these residues may benefit both the environment and socioeconomic developments since these waste materials are mostly are either burnt or just being left to decay in the field.

Nowadays, the oil palm biomass has extensively been studied as alternative raw material resources for bio-composite manufacturing [4-7]. These studies showed that the fronds have potential to manufacture composite panels [2, 8,9]. Hybridization of two or more different particles and materials have effect on the properties of the particleboards [10, 11]. There were studies on production of hybrid plywood and medium density fiberboards from oil palm biomass [9, 12-14]. Furthermore, there is no information on producing of particleboard from OPF particles and EFB fibers. Therefore, the purpose of this research attempts to fabricate particleboards mixed of OPF particles and EFB fibers and examined the physical and mechanical properties of fabricated boards.

II. Experimental

A. Materials

Fresh OPF were collected from a private plantation and the petiole and leaflets were removed from the fronds. The fronds were rinsed with water in order to get the gum off from the frond's surface and were dried until it achieved moisture content of 6-8% before were grounded into particles using hammer milled producing particle size length ranged from 5 mm – 20 mm. The oil palm empty fruit bunch (EFB) fiber strands was supply by Sabutek Sdn. Bhd. The fibres were ground to an approximate length of 5 -10 mm. The adhesive; a water soluble urea formaldehyde (solid content: 63%, viscosity 0.19 Pa.s at 25°C pH 7.62 and sg 1.281) was obtained from Malaysian Adhesive Sdn. Bhd. As a hardener, 20% solution of ammonium chloride solution was used. Based on oven dry particles and fibers weight, 10% UF and 1% NH_4Cl were applied.

B. Production of particleboards

Particleboards with target dimension 200 x 200 x 6 mm^3 and density of 750 kg m^{-3} were produced using hot press method. Rotary drum blender was used for mixing particles, fibers and adhesive. The resin-hardener mixture was sprayed with a single pneumatic spray gun onto particles and particles-fibers mixture as they rotated in the blender. The materials were then subjected to hot pressing under pressure at 2.7 Nmm^{-2} with three selected factors. In this study, two types of particleboards were produced; 100% OPF and mixing 30% of EFB fibers into fronds particles.

The effects of pressing conditions; press temperature (160 and 180 °C), time (180 and 300 s) on the properties of the particleboard were studied. Table I shows the sampling schedule. Metal stops were used to control targeted thickness of 6 mm particleboards. The experimental design generates 8 types of particleboards and each type was replicated three times. After pressing, particleboards were conditioned at a temperature of 20±2°C and 65±5% relative humidity for a week prior analysis.

TABLE I. SAMPLING SCHEDULE

Sample	**Press temp. (°C)**	**Press time (sec)**	**EFB: OPF ratio**
A	160	180	0:100
B	160	180	30:70
C	160	300	0:100
D	160	300	30:70
E	180	180	0:100
F	180	180	30:70
G	180	300	0:100
H	180	300	30:70

III. MEASUREMENT

The board quality was assessed using parameters on water absorption (WA), thickness swelling (TS), modulus of rupture (MOR) and internal bond (IB). Prior testing, test samples were cut from conditioned particleboards and the following properties determined in accordance with ASTM Standard [15]. The dimension of specimens for WA and TS were 50x50 mm^2. The samples were dried in an oven at 80˚C for 2 hours and then are allowed them to cool to room temperature in desiccators before weighing. The specimens were weighed before and after submersion in water in a horizontal position for 2 and 24 hours at ambient temperature. After immersion, the specimens were taken out from the water and all surface water was removed with tissue paper before weighing. Average thickness was determined by taking several measurements at specific locations. TS was calculated as Equation (1) where T_1 is thickness of the sample before immersion (g) and T_2 is thickness of the sample after immersion (g). While, WA was calculated according to Equation (2) where W_a is weight of the sample before immersion (g) and W_b is weight of the sample after immersion (g).

$$\text{Thickness Swelling (\%)} = T_2\text{-}T_1/T_1 \times 100 \quad (1)$$
$$\text{Water Absorption (\%)} = W_b\text{-}W_a/W_b \times 100 \quad (2)$$

MOR and IB properties were tested by using Shimadzu universal testing machine. The dimension of specimens in bending tests was 144x50x6 mm^3 while, samples panels were cut into 50 × 50 mm^2 pieces in order to determine IB values. The testing method implies to apply a load of approximately 10 mm/min at a mean deformation speed from the surface of the test piece. The MOR and IB values were calculated using the Equation (3) and Equation (4) respectively.

$$\text{Modulus of rupture (MPa)} = 3P_mL/2bt^2 \quad (3)$$
$$\text{Internal Bonding (MPa)} = P'/b \times L \quad (4)$$

Where P_m is the maximum load (N), P′ is rupture load (N), L the length of the test piece (mm), b the width if the test piece (mm) and t is the thickness of the sample (mm).

IV. RESULT AND DICUSSION

The average values of MOR, IB, TS and Wa of the experimental boards are presented in Table II. TS and WA are the keys parameters for dimensional stability of a composite. According to European Standard [16], particleboard should have a maximum TS requirement value of 8 and 15 percent for 2 and 24 hours immersions, respectively. The averages values for TS percentage are out of ranged for all manufactured particleboards. The results showed that OPF particleboard has higher water absorption capacity than OPF mixed EFB particleboard. However, all the particleboards are damaged after two hours immersions time. In general, TS and WA of particleboards produced in this experiments increased with and increasing soaking time (Figure1 and 2). The results are expected because of the hygroscopic characteristic of OPF particles and EFB fibers. Lignocellulosic materials are hygroscopic which contain high number of methoxyl and hydroxyl group (O-H) that could absorb water from surrounding atmosphere easily [17, 18].

TABLE II. Mechanical and physical properties of produced particleboard

Sample	MOR (MPa)	IB (MPa)	WA, 2 hr (%)	WA, 24 hr (%)	TS, 2 hr (%)	TS, 24 hr (%)
A	9.17	0.29	83	88	27	29
B	11.47	0.25	86	86	24	28
C	11.02	0.35	76	83	21	25
D	13.4	0.51	74	87	23	26
E	10.55	0.37	75	83	19	23
F	12.35	0.47	72	76	21	24
G	11.19	0.42	61	67	16	24
H	15.48	0.64	68	70	19	22

For 2 and 24 hours immersions time, all the particleboards compressed at 160°C had higher TS and WA values in comparison to the boards compressed at 180°C. The TS and WA values had slightly decreased with increasing temperature as illustrated in Figure 1 and 2. This is due to the hardening of the resin efficiency during pressing stage [19, 20]. Increasing the press temperature and time caused interference in the curing of the adhesive, reduced wettability of the particle surface or limitation of diffusion and/or spreading of the adhesive within the particles and over the particle surface [21]. Comparing the physical properties with the oil palm fronds particleboards in previous research using board density of 500, 700 and 900 kgm^{-3}, obtained TS values in this experiment are slightly higher than the published value [9]. It is expected due to absence of wax paraffin emulsion. Thus, application of hydrophobic chemicals and paraffin may reduce the TS and WA values of particleboards [22]. Besides, the dimensional and structural changes due to atmospheric moisture can be minimized by cross linking the cellulose chain of the component trough chemical treatment of the particle and fibers.

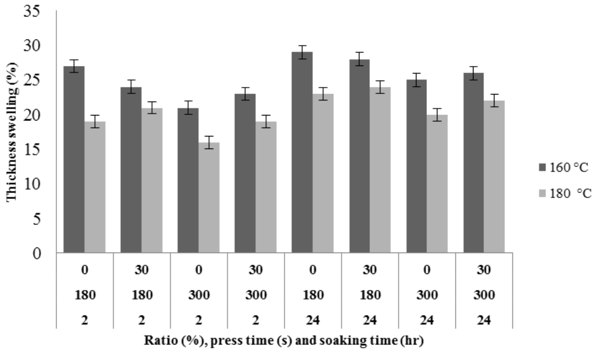

Fig. I. Thickness swelling against ratio, press time and temperature

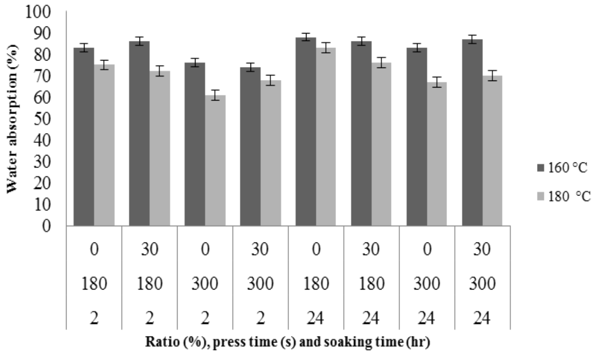

Fig. II. Water absorption against ratio, press time and temperature

As shown in Table II, MOR mean values for the manufactured boards ranged from 9.17 to 15.48 MPa. According to American National Standards Institute, A2081.1 [23], the minimum values for MOR requirement for Type M1 and Type MS particleboard for commercial application is 11 and 12.5 MPa, respectively. Based on this standard, the manufactured boards pressed at 160°C and 180°C passed the minimum requirement for MOR properties except for Type A and E boards which recorded 9.17 and 10.09MPa, respectively. At both press temperature and press time, it indicates that, the mixture of OPF particle with 30% EFB resulting in increment of MOR of particleboards. IB average values are presented in Table II and as shown Figure 2 ranged from 0.25 to 0.64 MPa. The minimal requirement of IB for ANSI A.208.1 [23] and European Standard [24] are 0.40 and 0.24 MPa, respectively. According to these standard, all the IB mean values of the particleboards produced were achieved the minimal requirements.

IB shows the tensile strength between the particles and adhesive. Curing process of the resin had affected the IB properties of the boards. Besides, the bonding between the particles and fibers during the pressing stage is enhanced due to the hemicellulose content in the fronds. It is reported that hemicellulose content in palm fronds is1.5 to 3 times higher than typical hardwood species [9]. In recent study, the binderless particleboards from oil palm fronds also showed better mechanical and physical properties than particleboards produced from oil palms bark, leaves and mid-term trunk [25]. The fronds strands also have better characteristic compare to trunk and EFB since it does not contain unwanted elements such as parenchyma and residual oil that will affect the strength properties of the boards produced [9].

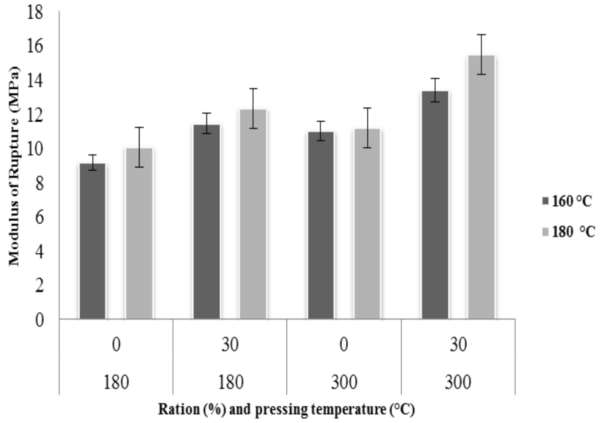

Fig. III. Modulus of rupture against ratio, press time and temperature

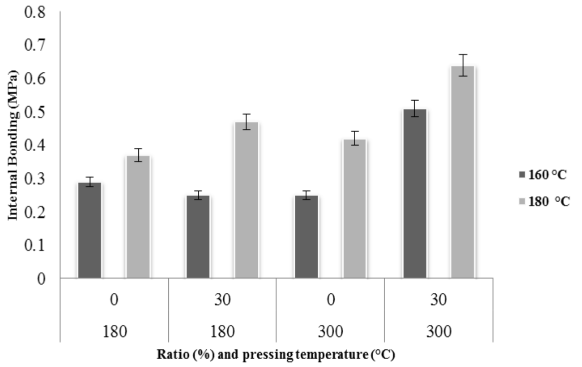

Fig. IV. Internal bonding against ratio, press time and temperature

Nevertheless, the presence of empty fruit bunch fibers improved the MOR and IB strength of the panels. Fiber to fiber bond was formed which lead to better adhesion resulting higher bonding strength. A study on production of hybrid plywood from OPT and EFB showed improvement on bending strength, screw withdrawal and shear strength than OPT plywood [13]. A novel research on hybrid particleboard showed that addition of coir fibers into rice straw particleboard improved the IB of the panels [26]. But adverse observation of IB result is obtained in the study of wood particleboard mixed with 0, 5, 10 and 15% regenerated cellulose fiber. It was revealed that the fibers were partly curled up and had a tendency to stick to adjacent fibers [27]. It is might due to different in length of cellulose fibers (50mm) and wood particle (>0.5 mm and <4 mm) used in the study. The fibers were not mixed homogeneously with the particles. It is important to ensure the particles and fibers were mixed and dispersed homogeneously to form a hybrid structure in which the bonds of particle to particle, fiber to particle, fiber to particle.

V. CONCLUSION

This study investigated the possibility of using OPF particles and EFB fibres in the manufacture of particleboards. Physical and mechanical properties of particleboards produced were evaluated. The results indicated that a of 30:70 mixture of EFB and OPF (180 °C, 300 s) produced the highest values in terms of mechanical properties of the particleboards. The properties of most of the produced particleboard complied with the minimum requirements in standards for general grade particleboards with the exception of TS and WA.

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