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## The Effect of Zephyr Layer Orientation on Zephyrboard Made from Oil Palm Petiole

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### Abstract

It is very important to utilize oil palm petiole for the production of zephyr boards. This study aimed to analyze the effect of layer orientation on zephyr board quality. Zephyr boards were made with three coating patterns (A = cross perpendicular, B= combine A and C, and C= paralell) and five zephyr layers using urea formaldehyde adhesive. They were pressed for 20 min at a pressure of 25 kgf/cm<sup>2</sup> and a temperature 120 °C, to a target density of 0.80 g/cm<sup>3</sup> and a size of 300 mm X 300 mm X 12 mm. Our results showed that the physical and mechanical properties fulfilled the standards of JIS A 5908-2003. The best physical properties were found in the type C layer pattern, which had a density of 0.82 g/cm<sup>3</sup>, Moisture Content of 9.46%, Water Absorption of 16.49%, and Thickness Swelling of 16.49%. The best mechanical properties—Modulus Of Elasticity and Modulus Of Repture —were also found in the type C layer pattern, with values of 35.2 x 10<sup>3</sup> kgf/cm<sup>2</sup> and 603.9 kgf/cm<sup>2</sup>, respectively. However, the best IB and screw holding strength (SW) results were found with the type B layer pattern (Internal bonding B of 38.65 kgf/cm<sup>2</sup>, Screw Withdrawl of 145.11 kgf).

### Abstrak

**Pengaruh Pola Pelapisan Zephyr terhadap Sifat Papan Zephyr dari Pelepah Sawit.** Pelepah sawit sangat menarik untuk dibuat menjadi papan zephyr. Penelitian ini bertujuan untuk menganalisa pengaruh pola/arah pelapisan lembaran zephyr terhadap kualitas papan zephyr. Papan zephyr dibuat dengan 3 model pola pelapisan (A= tegaklurus serat , B= kombinasi A dan C, C = sejajar serat) dari 5 lembaran lapisan zephyr dengan menggunakan perekat urea formaldehida. Papan dibuat berukuran 300 mm x 300 mm x 12 mm, pada suhu kempa 120 °C tekanan kempa 25 kgf/cm<sup>2</sup> selama 20 menit, dengan target kerapatan 0,8 g/cm<sup>3</sup>. Hasil penelitian menunjukkan bahwa sifat fisik dan mekanik papan zephyr dapat memenuhi standard JIS A 5908-2003. Sifat fisik terbaik adalah papan zephyr type C, dengan kerapatan 0,82 g/cm<sup>3</sup>, kadar air 9,46%, penyerapan air 16,49% dengan kembangsusut 16,49 %. Sifat mekanik (MOE dan MOR) menunjukkan bahwa papan zephyr type C adalah yang terbaik dengan nilai rata-rata 35,2 x10<sup>3</sup> kgf/cm<sup>2</sup> dan 603,9 kgf/cm<sup>2</sup>. Pada sifat kekuatan rekat (IB) dan kuat pegang sekrup pola lapisan type B adalah yang terbaik (IB= 38,65 kgf/cm<sup>2</sup> dan SW= 145,11 kgf).

*Keywords: 3-layer orientation, oil palm petiole, zephyr board properties*

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### 1. Introduction

Utilization of oil palm petioles for the creation of biocomposite board is a necessity because oil palm petiole is an organic raw material containing lignocellulose and very potensial resources. According to Rowwel [1], the utilization of lignocellulose-based natural resources is a potential alternative for the developing biocomposite board industry. Rhaman and colleagues [2] claimed that the making of lignocellulose natural materials into composite board products fixed and improved both physical and mechanical properties of raw material.

Zephyr board is a biocomposite board that is obtained from the pressing process, during which it becomes a long, continous fibrous material [3]. Oil palm petiole has an ideal shape for use as a raw material for zephyr board. Nugroho and Ando [4] stated that it was possible to develop bamboo zephyr board as a structural wood. Gopar and Sudyani [5] found that zephyr board could be developed for outdoor use, which would result in only a small reduction of its physical properties.

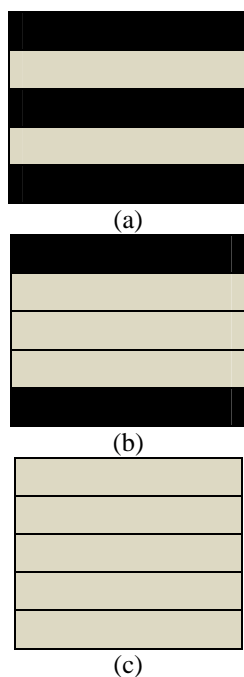
Previous research by Lusita *et al.* [6] indicated that zephyr board made from the base part of the oil palm petiole had wider, thicker, and harder sizes than that

made from the tip of the petiole. Zephyr board made from the petiole base also had lower density and higher water absorption than board made from the tip of the petiole; this is because the sheath structure at the base oil palm petiole is harder and does not break when crushed. In fact, five pressings are required in order to obtain better physical properties. Research on orientation differences in zephyr board layers, by random mixing of oil palm petiole parts. Currently this states that the research will improve the board properties.

## 2. Methods

Materials used in this study were oil palm (*Elaeis guineensis* Jacq) petiole wastes collected from the gardens around the Institute Pertanian Bogor campus, Dramaga. The oil palm petioles were cut into 1 m lengths and compressed 5 times in order to obtain homogeneous fibers.. Zephyr sheets were cut into 300 mm lengths, and then dried in an oven until the moisture content reached <10%. Urea formaldehyde was used as an adhesive material. The size of zephyr board was 300 mm X 300 mm X 12 mm. The target density of zephyr board was 0.80 g/cm<sup>3</sup> with a thickness of 12 mm. Adhesive, at 10% of oven dry weight, was applied by spraying. The layers of the 5-layer zephyr board were prepared in the following directions (Figure 1): type A (cross perpendicular orientation layer), type B (surface and back cross perpendicular orientation of core layer), and type C (parallel orientation layer).

After the zephyr layers were sprayed with adhesive, they were manually arranged into the experimental layer



Note: Layers with the same color have the same orientation.

Figure 1. Patterns of Zephyr Board Layers

orientations. Both surfaces (top and bottom layer) were coated with teflon paper and then compressed at a pressure of 25 kgf/cm<sup>2</sup> and temperature of 120 °C for 20 minutes. The tests of physical and mechanical properties were conducted in accordance with standards JIS A 5908-2003 [7]. The tests of modulus of elasticity (MOE) and modulus of rupture (MOR) were carried out based on the direction of cutting (parallel or cross).

## 3. Results and Discussion

**Physical properties of zephyr board made from oil palm petiole.** Evaluation of the zephyr boards' physical properties included moisture content (MC), density, water absorption for 2 hours and 24 hours (WA2 and WA24), and thickness swelling for 2 hours and for 24 hours (TS2 and TS 24). The processed zephyr boards were tested to determine their quality. The results of physical property tests to determine the quality of the board are presented in Table 1.

**Density and moisture content.** Moisture content of the zephyr boards ranged from 9.34% to 9.45%. The lowest density was 0.77 g/cm<sup>3</sup>, which was found in the type B layer pattern. The type A and type C patterns had equal density (0.82 g/cm<sup>3</sup>). Zephyr board of oil palm petiole has a special character, especially if the sheet of zephyr constituent was derived from the base of the petiole. It is possible that the preparation of the panel-coating layer on pattern type B was derived from the base of the petiole. Lusita *et al.* [6] stated that zephyr boards from the base of the oil palm petiole had lower density because the fiber sheets were less homogeneous and harder, especially if they were from the base edge.

Zephyr board of the type B layer pattern likely also contained blisters, which would cause it to have a relatively smaller density than the other layer types. In contrast, the type C layer pattern contained the original material of zephyr and a parallel fiber direction. The parallel direction of the type C pattern made the zephyr board more dense and more rigid than types A and B, and the thickness of the board was thinner. Lee *et al.* [8] suggested that different layer patterns produced physical and mechanical properties that were not the same; the best properties were generally obtained in cross patterns. Subiyanto *et al.* [9] stated that the compression process, with a three-step pressing method, could prevent the occurrence of blisters, while zephyr that did not have homogeneous form and that received only one-step processing could result in the occurrence of blisters. Board density was calculated based on the ratio of weight to volume; if the board volume was larger due to blisters, the density of the board became lower.

**Water absorption and thickness swelling.** The Japanese Standard Association [7] did not set standards for water absorption; however, it was necessary for us to

test the water absorption in order to determine the particle board's resistance to water when used in exterior locations or in areas often exposed to the effects of weather, such as humidity and rain. Considerable water absorption in zephyr board could be caused by several factors, such as the empty volume of zephyr fiber, zephyr fiber surface area that was not covered by adhesive, and the depth of adhesive penetration. The 24-hour water absorption for each type was A (22.46%), B (19.57%), and C (16.49%). Our results were lower than those of previous researchers, who found that the water absorption of zephyr boards made from petiole sections (base, middle, and tip) was 32.7–38.2% after 24-hour immersion [10]. It is possible that mixing patterns, without randomly distinguishing parts of zephyr sheet in the arrangement of zephyr layers, could fix the water absorption properties. Lusita *et al.* [10] concluded that the base of the palm frond absorb more water than the middle and end. This study did not separate the base, middle and end of the stem so as to improve the water absorption properties of zephyr board.

The increased thickness (TS) of zephyr board correlated to water absorption in the 24-hour test. The water absorption of each layer pattern was: A (24.06%), B (19.27%), and C (16.49%). Zephyr boards with the pattern of parallel layers (type C) had the smallest thickness swelling and water absorption properties compared to those of the other types. It was obvious that the entry of water into the pores of zephyr board only happened in voids formed from zephyr sheets. In the parallel direction (type C) the void was relatively close and small (Figure 3). In general, zephyr boards made from oil palm petiole with urea formaldehyde adhesive have better physical properties than particle boards made from oil palm petiole with 10% urea formaldehyde adhesive, which researchers found to have an average of moisture content of 12.6%, thickness swelling of 21.2% and density board of 0.52 g/cm<sup>3</sup> [11]. Sukma *et al.* [12]

reported that zephyr board from sago (*Metroxylon sago* Rottb) petioles made with polyurethane and phenol formaldehyde adhesives, with a resin content of 10% and a density of 0.5 g/cm<sup>3</sup>, had a moisture content of 11.38% and 10.04%; thickness swelling of 18.17% and 23.93%, and water absorption of 64.85% and 78.42%, respectively.

The size or geometry of zephyr fibers that are longer could possibly be responsible for the better quality of physical properties, compared to the zephyr fibers made from the shorter oil palm petiole. Moreover, the lignin attached to the zephyr fiber could possibly make the zephyr board of palm petiole chemically more resistant on hygroscopic effects.

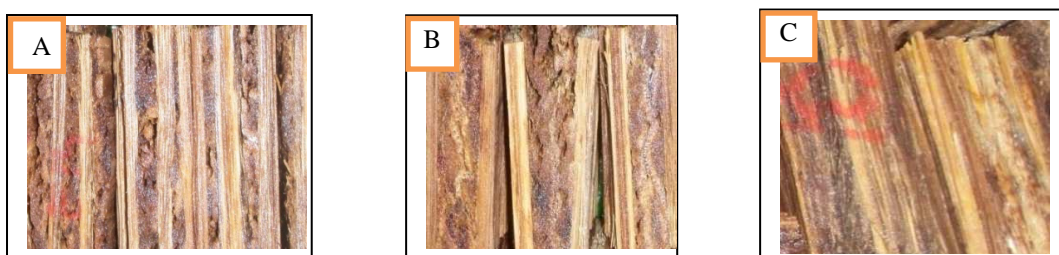
Figure 3 shows photographs with microscopic of zephyr fiber sheets from oil palm petioles for each of the test layer patterns. The cross-sliced layers in pattern types A and B showed the parenchyma of the oil palm petiole, but the parenchyma of type C were on a different side. The oil palm petiole parenchyma looked empty and there was no line of adhesive filling in the type A pattern; the zephyr fibers of the type B pattern, on cross direction, did not look unified because there was an empty space. Here, the water could enter easily so that thickness swelling and water absorption would be higher.

**Mechanical properties of zephyr board of oil palm petioles.** Evaluation of zephyr board's mechanical properties included modulus of elasticity, modulus of rupture, and internal bond (IB). Results are shown in Table 2.

**Modulus of elasticity and modulus of rupture.** Evaluations of MOE and MOR properties were based on the different board surface conditions when samples were parallel and perpendicular (Figure 3) at the time of cutting. This is to show that the direction/orientation

**Table 1. The average Value of Physical Properties of Zephyr Board Made from Oil Palm Petiole**

Layer type	MC (%)	Density (g/cm <sup>3</sup> )	WA 2H (%)	TS 2H (%)	WA24H (%)	TS24H (%)
A	9.34	0.82	15.60	3.29	22.46	24.06
B	9.59	0.77	14.29	2.84	19.57	19.27
C	9.41	0.82	11.90	5.76	16.49	16.49



**Figure 2. The Appearance of Zephyr Boards After They Have been Immersed in Water for 2 Hours**

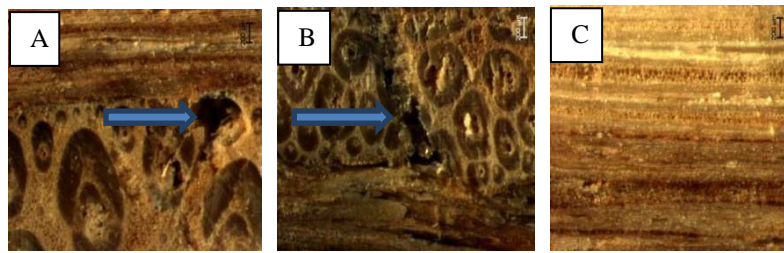


Figure 3. The Appearance of Cross-sliced Layers of Pattern Types A, B, and C in Photographs by Microscope

Table 2. The Average Value of Mechanical Properties Zephyr Board Made from Oil Palm Petiole

Layer type	MOE (x 10 <sup>3</sup> kgf/cm <sup>2</sup> )		MOR (kgf/cm <sup>2</sup> )		IB (kgf/cm <sup>2</sup> )	SW (kgf)
	Parallel	Crossing	Parallel	Crossing		
A	12.52	31.6	157.3	515.4	3.08	100.04
B	22.83	22.3	156.6	279.4	3.86	145.11
C	7.42	35.2	47.8	603.9	3.04	84.01
JISA5908-2003	30		180		3.0	50

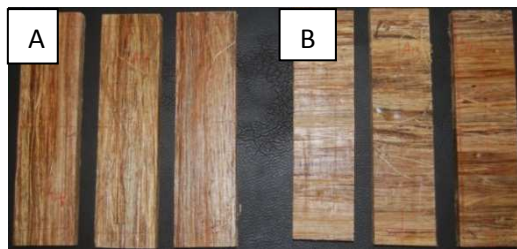


Figure 4. The Pattern of MOE and MOR Tests of Palm Petiole Zephyr Board

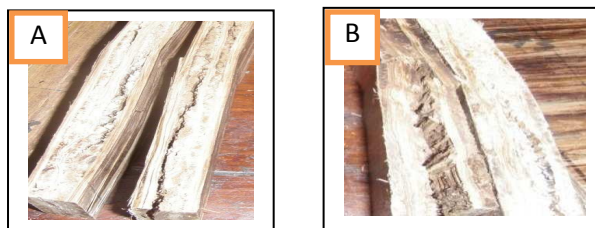


Figure 5. The Pattern of Testing Damage of MOE/MOR in Cross Position (A) and Parallell Position (B)

of the layers can provide different strengths. The results show that layer orientation affected the flexural strength, or MOE, of zephyr board. The test evaluations were carried out in two directions: parallel and crossperpendicular. The MOE value of perpendicular zephyr boards tested at a perpendicular position (type A) was better than that of boards tested in a parallel position (type B).

Zephyr board from oil palm petioles with a type A layer pattern in crossperpendicular-direction orientation had an average MOE value of 31.6 x 10<sup>3</sup> kgf/cm<sup>2</sup>, while type B had an average value of 22.3 x 10<sup>3</sup> kgf/cm<sup>2</sup>. The highest MOE average was found in pattern type C (35.2 x 10<sup>3</sup> kgf/cm<sup>2</sup>). However, in tests of parallel-direction

orientation, the highest average value of MOE was found in the type B pattern (22.83 x 10<sup>3</sup> kgf/cm<sup>2</sup>) and the lowest was found in the type C pattern (7.42 x 10<sup>3</sup> kgf/cm<sup>2</sup>). In the perpendicular direction, zephyr board MORs were: type A (515.4 kgf/cm<sup>2</sup>), type B (279.4 kgf/cm<sup>2</sup>), and type C (603.9 kgf/cm<sup>2</sup>).

According to Ismardi *et al.* [13], the factors affecting the MOR value were density of wood particle board, particle geometry, particle orientation, grade adhesive resin content, moisture content, pressing condition, and procedures. MOR value results for boards in parallel position were: type A (157.3 kgf/cm<sup>2</sup>), type B (156.6 kgf/cm<sup>2</sup>), and type C (47.8 kgf/cm<sup>2</sup>). It could be that the geometry and orientation pattern of the material greatly

influenced the flexural strength (MOE) and fracture (MOR) properties of zephyr board. Nugroho and Ando [3] reported that 3-layer zephyr made from bamboo reinforced with wood had an MOE value of  $107 \times 10^3$  kgf/cm<sup>2</sup> and a MOR value of 1253 kgf/cm<sup>2</sup>.

Previous research conducted by Sukma *et al.* [12] showed that zephyr board using phenol formaldehyde adhesive, with a density of 0.5 g/cm<sup>3</sup>, resulted in a MOE value of 6250 kgf/cm<sup>2</sup> and a MOR of value 100 kgf/cm<sup>2</sup> only. Aini *et al.* [11] reported that the results of a study of particle board made from palm petiole using 10% urea formaldehyde adhesive resin, with a density of 0.5 g/cm<sup>3</sup>, had a MOR value of 24.2 kgf/cm<sup>2</sup> and a MOE value of 5041 kgf/cm<sup>2</sup>. Nugroho and Ando [3] reported that 3-layer zephyr made from bamboo reinforced with wood had a MOE value of  $107 \times 10^3$  kgf/cm<sup>2</sup> and a MOR value of 1253 kgf/cm<sup>2</sup>. Zephyr board of oil palm petiole had long zephyr fiber geometry with various widths and thicknesses. Lusita *et al.* [10,14] obtained zephyr fiber dimensions of 0.1–7.57 mm. The length of zephyr strands from oil palm petioles affected the elastic and strength properties of weight-bearing in zephyr board compared to those of particle board made of oil palm petiole. Zephyr board was better than particle board from oil palm petiole. Suppleness and firmness of zephyr boards proved to be better. The strength properties of zephyr board are also better than those of particle board. Due to layer orientation, zephyr board with type C and type A patterns have stonger physical properties.

#### Internal bonding and screw holding strength (SW).

The results of tests of zephyr board strength, due to different orientation treatments, also meet the test standards [7]. The best average IB value was obtained in the type B pattern (3.86 kgf/cm<sup>2</sup>), while the type A and type C layer patterns had relatively equal average values. In SW testing, the best value was obtained in the type B layer pattern (145.11 kgf), and the lowest value was found in the type C layer pattern (84.01 kgf). Rhaman *et al.* [2] stated that the water content, fiber and part orientation, SW procedure, and dimension and smoothness of the surface affected the results of the screw test. It was also affected by the resin, type of adhesive, and fiber layer thickness. Zephyr boards made from oil palm petiole in the type C layer pattern were slightly thinner than that of the type A and type B layer patterns, because parallel zephyr sheet orientation results in a higher density board, which makes the board denser and closer.

#### 4. Conclusions

The results of our study of the pattern of coating layers in zephyr board made from oil palm petioles can be

concluded as follows: layers in parallel direction (type C) and cross direction (type A) in 5-layer zephyr board improve the physical and mechanical properties (MOE and MOR) of zephyr board. The best results of IB and SW tests were found in the type B layer pattern. MOE and MOR are affected by cutting either parallel or perpendicular to the surface of the board. The best MOE and MOR results were found in the type C and type A layer patterns. Generally, high quality zephyr boards that meet the standard of JIS A 5908-2003 type 18 were obtained.

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