Production of palm frond based wood plastic composite by using twin screw extruder

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Abstract. Wood plastic composite (WPC) is the blending product from wood as filler and polymer thermoplastic as matrix. Palm frond waste is a material with cellulose about 68%, so it has potential to be developed as raw material for WPC. The purpose of this research was to learn how to produce WPC based on palm frond use twin screw extruder. It used polypropilen as matrix. As for aditif, it used Maleated Polypropilene (MAPP) as compatibilizer and paraffin as plasticizer. The size of palm frond is 40 – 80 mesh. WPC is made from blending polipropylene, palm frond, MAPP and paraffin with dry mixing method in room temperature. Then, PP, Palm frond and additive from dry mixing is fed into twin screw extruder at 190°C and 60 rpm. It use palm frond/polypropylene 60/40, MAPP 5% w/w and paraffin 2% w/w. From the result, it shown that WPC based on palm frond met the standards for commercial WPC. It has tensile strength up to 19.2 MPa, bending strength 43.6 MPa and water adsorption 0.32% w/w. So, WPC based on palm frond has perspective to be developed for commercial WPC.

1. Introduction
Wood plastic composite is composite product from blending wood and thermoplastic. The development of WPC is driven by the need for solid wood materials that are durable but still environmentally friendly. So far, preserved wood using chomated copper arsenate (CCA) is widely used for a variety of exterior needs, such as docks, wood fence, playgrounds and others, especially in America and Europe. However, since 2003, CCA for exterior is prohibited by the world [1]. So that the alternative wood are required for durable and environmentally friendly. Wolcott and Englund, 1999 [2] finally get WPC as an alternative material to replace the use of wood that is durable and can be recycled so that more environmentally friendly.

WPC consists of thermoplastic polymer as matrix and wood fibers as fillers. Basically, all high cellulose-containing biomass can be used as a filler on WPC manufacturing. Wood is used as filler because it has the highest cellulose composition than other biomass. Palm frond has cellulose just like wood, about 68.3% [3]. Now, palm frond is waste without further processing. Waste of palm frond reaches 6.3 ton/ha/day [4]. Large amount and high cellulose provide large potential for palm frond waste to be developed as filler for WPC.

WPC production used pellet thermoplastic that has density 500 kg/m³. Instrumentation for plastic production has problem about wood fiber, because wood fiber has low density. The next problem is temperature process. Plastic has high melting points, but wood fiber will be degraded although it used the lowest melting point of plastic.

High water content in wood or other natural fibers is also a problem for plastic industry. Usually, instrumentation of plastic industry used material with 1 – 2% water content. Althought some instruments be equipped with equipment, it can remove water vapor, it can not remove water vapor from wood fiber that has 5 – 7% water content. The resin dryer for plastic is not suitable for wood fiber and it has risk of fire.
Some problems begin to be solved with the development of technology and additives. So, it produces WPC that has high resistance, durable and can be recycled. Currently, WPC is experiencing significant growth. Since its introduction in the American market in 1990s, WPC production has increased 300% in a decade [5].

Some of WPC research that has been done, such as Chen et al, 2006 [6] has made WPC from recycled wood waste and HDPE with soybean oil as plasticizer. Nzokou et al, 2006 [7] has made WPC from oak particle and PP with additive carbon nanofibers and maleated polypropylene (MAPP). Jarusombuti and Ayrlmils, 2011 [9] also made WPC from rubber wood powder and PP with MAPP as additive. Bahruddin et al. 2013 [10] also made WPC from palm rod particle and polypropylene. The results of these research show that the content and size of biomass particle affects of characteristic of WPC.

WPC that have been commercially developed are generally based on pine wood and other types of fibrous one. Palm frond as material for WPC has not been developed because of relatively low quality of wood. Usually, palm frond waste will be burned to produce ash for plant fertilizer or just stacked among palm tree, so it is not economically profitable. Based on competition, palm frond waste has considerable potential for further processing, especially for WPC [3].

Some researchers are specifically discussing WPC using palm fiber such as Fadly et al, 2015 [11] that made from palm frond and polypropylene with MAPP as compatibilizer. Parsaulian et al. 2015 [12] made WPC from palm frond with pretreatment oxalic acid solvent and polypropylene.

For this research, it will study the production process of WPC based on palm frond and polypropylene. For additive, it uses MAPP as compatibilizer and paraffin as plasticizer.

2. Research methodology

2.1 Material

Material for this research are palm frond as filler from local plantations; Polypropylene (PP) HE 2.0 TF produced by PT Chandra Asri Petrochemical Tbk as matrix; MAPP produced by Aldrich Chemistry, USA as compatibilizer; and paraffin wax as plasticizer. It used pretreatment for Palm frond particle use oxalic acid as solvent.

2.2 Filler preparation

The palm frond cleaned from leaf, crushed using sawmill to produce particle. Particle of palm frond macerated by 0.01 M oxalic acid in autoclave at 120 °C for 15 minutes. Particle from mazerate process strained and dried at sunlight for about 24 hours. Particle palm frond is dried again with oven at 105 °C for 2 hours for maximum drying, so water content no more than 5% w/w. The dry palm frond is crushed again and stir so it get palm frond powder size 40 – 80 mesh.

2.3 WPC blending

WPC blending needed four steps, dry mixing, blending at twin screw extruder, pelleting and pressing.

The first step, palm frond powder and polypropylene ratio 60/40 mixed with MAPP 5% w/w and paraffin 2% w/w with dry mixing method at room temperature. The second step, the result from dry mixing was fed on twin screw extruder at 190 °C and 60 rpm motor speed. The result of this process was a long cylindrical WPC. WPC ferom extruder need cooling water because hot WPC has low tensile strenght. The next step, WPC from cooling water was cut into pallet shape using pelleting unit. Water content of WPC from cooling water caused low tensile strength of WPC. So, it needed to be dried at 60 °C for one night. Pallet WPC from this process can be molded or pressed to become final product.

The last step for WPC production was pressing process. Pressing process for WPC used hot press at 190 °C for 5 – 10 min with 5 bar pressure. WPC from hot press can be cut for tenting. For this process, it used weather test, QUV for 108 hours.
3. Results and discussion

3.1 Mechanical properties

WPC produced in this research is a mixture of palm frond and polypropylene as matrix of palm frond as filler and polypropylene as matrix ratio 60/40 with MAPP 5% w/w as compatibilizer and paraffin 2% w/w as plasticizer.

Technically, all types of wood can be used as raw material for WPC, but wood from hardwood trees are better than softwood trees. Palm frond is one of softwood, so the fiber from palm frond is random fiber.

60% w/w palm frond particle gave 3x volume than 40% w/w polypropylene. This made problem for mixing process. Polypropylene as matrix has too small volume compared to palm frond as filler. So, some of the palm frond particle can not be mixed perfectly with polypropylene. This caused mixed compatibility to be weak.

The problem of mixing plastics and wood are the consistency of wood that has low density into the small pore of plastics at extrusion process. Another problem is plastic’s melting point is too high for wood fiber. Wood fiber will be degraded at high temperature. Usually, the water content of wood particle is high, more than 1 – 2%.

Wood particle should be dried before use for WPC, and water content will evaporate at high temperature and put pressure on. Bubbles will also provide an empty space that will reduce mechanical strength. Wood particle could be dried in various ways such as rotary drum drier. Water content may also remove when extruding with venting. WPC is thermoplastic composit from wood particle or fiber from other sources. Usually, USA used wood material, europe used natural fiber such as jute, hemp and kenaf, and Asia used rice husks and bamboo fiber. Wood mixing can be expressed in low aspect ratio such as wood flour also high ratio such as wood fiber. Although wood fiber have problem in process, but it better tensile proprietise.

MAPP as compatibilizer and paraffin as plasticizer help to overcome mixed deficiency of polypropylene and palm frond. Paraffin serves as lubricant that facilitates the mixing process. MAPP works to modify polypropylene surfaces to provides radical surfaces. So, palm frond particle can be more easily mixed with polypropylene. So, the mixture becomes more compatible.

WPC with MAPP will provides better physical properties than WPC without MAPP. MAPP for WPC increased the WPC mechanical properties. This is confirmed that the increasing of the compatibilizer strength of the interface bonds with chemically modified. One of compatibilizer is MAPP [13]. However, excessive use of MAPP will reduce the mechanical properties of WPC [14]. This is due to the lack interactions of OH from MAPP with palm frond particle and more likely to interact with PP [15]. This is consistent that excessive additive may decrease the mechanical properties of the composite [16].

WPC production used twin screw extruder for blending process at 190°C and 60 rpm rotor speed. Melting point of polypropylene is about 170 °C, so it needed high temperature. However, at 150°C, palm frond particle as filler will be burn. This caused the WPC blend from this process to be black. \( \text{Fe}_2\text{O}_3 \) as color for WPC also not work because the burning black color of palm front particle defeats the yellow color of \( \text{Fe}_2\text{O}_3 \). So, it is prefer to make WPC without using dyes. Although the palm frond particle is burnt, but the result of this process is WPC with excellent properties, exceeding the minimum standard of WPC properties for commercial. Table 1 is shown the a comparison of results test from WPC generated to standart of commercial WPC based on Kronotex, 2017 [17].

| Test          | WPC SPS/PP | WPC Standards |
|---------------|------------|---------------|
| Tensile Strength | 19.2 Mpa   | ≥ 15 Mpa      |
| Bending Strength | 43.6       | ≥ 30 Mpa      |
| Water absorption  | 0.32 %     | ≤ 2%          |
3.2 Weather resistance
Weather testing use QUV for WPC at 60°C for 8 hours and condensate at 50°C for 4 hours. Testing have done for 108 hours or 9 cycle.

![Figure 1. WPC Sample, (a) before, and (b) after weather test (UV-Resistance).](image)

Figure 1 shown the color changed of WPC sample. Irradiance at 340 nm is 0.76 W/m². Changed color of WPC shown that mechanical properties of WPC have been decrease for weathering test 108 hours and 9 cycle.

The fast deterioration of weather is loss of wood. For outdoor application, the change of color and texture will increase. It made tensile strength of wood decrease. Usually, the cause of wood damage is weather (sun light and rain), dust, temperature and air humidity, and organism (fungi or microba). Sunlight with UV is dominant factor for depolimerization process of lignin and rain is perfect process [18].

Fotodegradation for sintetic polymer of polyolefin such as polypropylene get stimulation from polymer-oxgen complex, expecially because of catalyst, hydroperoxide, carboxylyle, and double bond of polymer formation[19; 20]. Polymer degradation of fotooxidation will decrease mechanical propriety of WPC such as tensile strength and bending strength.

The same thing happened to the wood that will be degraded because of fotochemical at outdoor. The research shown that the weather damage to wood is a process at surface wood, involve photoinduced that damage lignin into product that can react with water (loss lignin) [20]. This caused functional group generation of chomophores such as carbonyl, carboxylic acid, quinone and radical hydroperoxide.

Johnson at al,1999 [21] found that if WPC was used for outdoors, it would be open to UV radiation, air humidity and microorganism. Simonsen, 1996 [22] found that WPC or other biofillers with thermoplastics can not withstand the effects of outdoor exposure, decline in properties is particularly noticeable in stiffness and the influence of summer and cold on the composite mechanical properties. Some examples studied were cracked and bent.

The influence of tropical weather in Indonesia on wood-plastic composites has been done [23]. After removal of discoloration on the composite surface directly exposed to UV and decreased the mechanical properties of the composite.

4. Conclusion
From the result of the reseach, it can be concluded that WPC production based on palm frond waste with matrix polypropylene has potential to be developed as commercial WPC, but it need MAAP as compatibilizer and paraffin as plasticizer to get excelent WPC.

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