Study on processability and mechanical properties of parawood-powder filled PLA for 3D printing material

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Abstract. Recently, there has been an increasing interest in the development of 3-Dimensional (3D) printing technologies. Among those, material development play an important role in helping the growth of 3D printing technique, which led to more supporting of wide range of applications and user requirements. In that regards, advanced materials are continually developed, i.e. filament filled reinforcing fiber and plastic containing metal granulate or wood powder. Special material supporting 3D printer normally showed an expensive cost. On the other hand, it is well known that the processes involving natural rubber from Para rubber trees produced a large amount of wood a year, which resulted in releasing of an abundant waste from wood processing. Therefore, this work focused on the utilization of parawood powder derived from the furniture industry. The processability of polylactic acid (PLA) filament containing wood powder was investigated. Twin and single-screw extrusion machines were used to produce the composite filaments. Coupling agent and treated method were also studied. The results of this work showed that the maleic anhydride (MAH) and sodium hydroxide (NaOH) did not have significantly effects in improving the compatibility and processability. In addition, wood contents were found to influence the quality of filament and mechanical properties. Moreover, it was also found that parawood powder can be filled into PLA with approximately 10 wt%.

1. Introduction

3-Dimensional (3D) printer is gaining popularity in conventional customer due to the lower machine cost, easy to use and various types of material selection. Moreover, it can quickly respond and adapt to the changing needs of consumers. Definitely, the special materials are enhancing considerable attention in terms of reinforcing material, biomaterial [1-3], renewable or degradable material [4,5]. Thermoplastic composites play an important role 3D printing material, i.e. acrylonitrile butadiene styrene (ABS), polypropylene (PP) [6] polyethylene terephthalate (PET) and polylactic acid (PLA) etc. Conventional material using for 3D printer is distributed as a roll of filament, which passed extrusion machine. A price of plastic roll is normally higher than a granulate material. Moreover, special roll supporting 3D printed material is more expensive, about 30 times than that of pellet thermoplastic. Further problem of wood by-product, the waste from parawood industrial was produced a large amount such as sawdust, polishing wood powder in any stage of processing. Therefore, the utilization of residue material in manufacturing of 3D printing technique can lead to the value added of filament and also eliminated the environmental concern. Hence, the objective of this works was to investigate the possibility of producing the parawood filled into PLA. Processability by twin and single screw extruder
was also tested. Processability of wood filament by 3D printer was compared to commercial filament and imported wood powder.

2. Experimental

Different wood powders were used in this study, i.e. commercial grad of wood powder, and blasting powder and residue wood from the furniture industry as shown in Table 1. In Fig x(a)-(b), the degradable polymer, (Poly lactic acid, PLA) was blended with wood powder by twin and single screw extruders, respectively. PLA and wood powder were mixed using the twin-screw extruder at the temperature of 200°C with the rotational speed of 140 rev/min. Each batch of composite was rolled to produce a filament of approximately 1.50 mm in diameter. The powder content in ranges of 5-20 wt% was varying to analysis the processability. For the comparison of mechanical strength, a material test piece in accordance with the standard tensile test ASTM D638 was formed by the 3D printer as illustrated in Fig x. The tensile strength was characterized by using the Universal Testing Machine (UTM, COMETECH Model LRK-20) at a crosshead speed of 500 mm/min.

| Table 1. Formulas of wood composites in percentage by weight. |
|---------------------|---------------------|---------------------|
| Mixture | Wood powder | Content (wt%) | Maleic anhydride (MAH) |
| CW#1 | 5 | 95 | - |
| CW#2 | 10 | 90 | - |
| CW#3 | 15 | 85 | - |
| CW#4 | 20 | 80 | - |
| CW#5 | 5 | 90 | 5 |
| CW#6 | 10 | 85 | 5 |
| CW#7 | 15 | 80 | 5 |
| CW#8 | 20 | 75 | 5 |
| PW#1 | 5 | 95 | - |
| PW#2 | 10 | 90 | - |
| PW#3 | 15 | 85 | - |
| PW#4 | 20 | 80 | - |
| RW#1 | 5 | 95 | - |
| RW#2 | 7.5 | 92.5 | - |
| RW#3 | 10 | 90 | - |
| RW#5 | 15 | 85 | - |
| RW#4 | 20 | 80 | - |

3. Results and discussions

3.1 Effect of wood powder content on the processability by screw extruder

Commercial grade of wood powder (CW) was mixed together with PLA in content of 0-20 wt% as illustrated in Table 1 (CW#1- CW#4). It was found that all formulation varying CW content was able to compound by twin screw machine. The primary mixtures were then dumped to single screw extruder in order to produce a filament. Figure 1 depicts the effect of wood content on the appearance of the composites. A perfectly smooth surface of extrudate was presented in the neat PLA. This was due to a mobility of polymer molecules without any obstacle from wood element. Further increasing the wood content, slight irregularities were observed on the surface of composite extrudate. This result presented that highest contents of filling wood power was 10 wt%.
3.2. Effect of maleic anhydride (MAH) on the compatibility of composite

In order to improve the compatibility of composite, the filling of coupling agent was investigated. This study used MAH as a coupling agent in a content of 5 wt%. It was found that all ingredients are able to blend by using screw extruder. However, the primary mixtures could not be made a filament when it applied to single screw extruder. Figure 2 shows the low viscosity of composites. The result was expected from the decomposition of MAH during the extruding process. MAH at the high processing temperature was transformed into gas, which are released from die as in Figure 1. Other gases were still composed in the mixture, which made compound lower viscosity and aggregated at external machine.

3.3. Effect type of preparing process of natural rubber wood.

Former testing indicated that MAH did not attribute the enhancing incorporation of wood content. In this case, wood powder prepared by sand paper polishing (PW) was compound without coupling agent (PW#1-PW#4, RW#1-RW#5). In the Figure 3, PW could not be prepared an accepted extrudate, which presented the non-uniform distribution of particle. This observation was due to the large differential density of mixing composition, which derived from particle size of wood powder. Residue wood powder (RW) introduced the good filament in ranges of 5-15 wt%. They can be printed by conventional 3D printer.

3.4. Effect of wood powder types on the mechanical properties
In this work, the different types of wood filler were loaded into the PLA passing screw extruder. The highest mechanical strength of neat PLA was found. Two types of commercial filament were used to compare with prepared composites. Figure 4 indicated that the tensile strength of commercial filament were lower than those of producing extrudates. This observation was due to the higher content of wood particle in commercial product. When considering the properties of two types of wood powder, natural rubber wood from grinding process was not much different from the imported wood powder.

![Figure 4](image-url)  
**Figure 4.** Mechanical properties of wood filament (a) maximum tensile strength (b) elongation at break

4. Conclusions
The study result was found that all formulations can compounded in the twin screw extruder. While, the maximum loading of wood powder producing with single screw was 15 wt% (CW#1-CW#3, RW#1-RW#5). Composites containing wood content of 10 wt% can be printed by the 3D printer (CW#1, CW#2, RW#1-RW#4). In the results of preparing filament, the commercial powder and residue wood from furniture industry showed non-significant difference in mechanical strength. From the corresponding result, it should be concluded that the parawood filament is able to produce the product as a filament type for 3D printer. However, an adding more content of powder will be continually investigated in the further work.

5. References
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