# Tensile, Flow and Thermal Properties of Biodegradable PLA/Pineapple Fiber Composite

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*Abstract*— Human activities and food need to be pack than be transported to the worldwide especially in import export business. The materials that use was very important and had their own shelf-life to deliver most products in its required condition a specification. In reinforcement the strength of various regulations that used to aim at reducing the wastes generated, packaging waste forms main municipal solid waste and this will cause increasing in environmental problems. With regard to environment aspects, it would be beneficial if natural fibers could be used instead of synthetic fibers as reinforcement in some structural and food packaging applications. There were many things need to be consider during fibers selection such as length, strength, and purpose of usage. Raw material for production of PHA is us a pineapple leaf fibers (PALF). Different composition that used in fabrication of PLA and PALF which were 50% PLA - 50%PALF, 60% PLA – 40% PALF and 100% PLA – 0% PALF for controlled. There were four testing need to be done which were melt flow tester, tensile tester, Fourier Transform Infrared (FTIR) and Differential Scanning Calorimetry (DSC).

***Keywords— PLA, PALF, Melt flow tester, Tensile tester, Fourier Transform Infrared (FTIR), Differential Scanning Calorimetry (DSC).***

## I. INTRODUCTION

Nowadays, packaging industries was very widely used in daily life. Human activities and food need to be pack than be transported to the worldwide especially in import export business. The materials that used was very important and had their own shelf-life to deliver most products in its required condition a specification. Different materials were used for packaging including metals, glass, wood, paper, polymers or combinations such as composites. All of these types of materials enter municipal waste streams at the end of their service life. In reinforcement the strength of various regulations that used to aim at reducing the wastes generated, packaging waste forms main municipal solid waste and this will cause increasing in environmental problems.

In reinforcement the strength of various regulations that used to aim at reducing the wastes generated, packaging waste forms main municipal solid waste and this will cause increasing in environmental problems. Fossil fuel polymers was currently used in packaging applications namely polyethylene (PE), polypropylene (PP) and Nylon PET etc. The polymers are mostly non-biodegradable, and some were really difficult to recycle or reuse due to their complex composites as different blends and contamination level exists. In previous years, the packaging materials already be recycling and become increased but the recycling rates for most plastic packaging remain low (Davis & Song, 2006). There was large number of different types of polymers, each of this types of polymer may contain different processing additives such as fillers, colorants and plasticizers. All were used for packaging applications (Andrady & Neal, 2009). At a recent time, significant progress had been made in the development of biodegradable plastics and largely from renewable natural resources to produce biodegradable materials with similar function as non-biodegradable polymers such as PLA, PHA and PHBV PCL. The development in these bio-based materials has several potential benefits which were in greenhouse gas balances and other environmental impacts over whole life cycles and in the use of renewable rather than limited resources. Sustainability in the environmental effected to prevent huge destruction of oil-based polymers can be solved using biodegradable polymers.

Some products had tried to be made by using biodegradable polymers but they were expensive, lack of strength and thermal properties. Hence these biodegradable polymers will have high price in the market and consumers cannot afford to buy these products. Even huge supermarket also did not provide biodegradable bags to replace the conventional polyethylene (PE) and polypropylene (PP) bags. Actually, biodegradable items had reached some packaging market sectors in many countries like Europe, Australia and USA. They produce bags from some manufacturers of PLA, PHBV resin namely from manufacturers like Dow Inc. and Nature Works do produce PLA resins. However, the used was still growing and people awareness and policies need to be strengthened towards the used of biodegradable plastics (Song, Murphy, Narayan, & Davies, 2009).

In Malaysia, policies had been implemented to change the law of using biodegradable straw for restaurant premises. In The Star newspaper, Sept 2018 mentioned that plastic straws will be banned in all the Federal Territories of Kuala Lumpur, Putrajaya and Labuan from 1 Jan 2019. Ministry secretary-general Datuk Seri Adnan Mohd Ikhsan already issued a statement whose businesses which were still found to be using plastic straws in 2019, their business licenses will terminate. The business owners may also be penalized, lose their deposits and had their trading items confiscated or even be imprisoned. Business owners need to cooperate and strictly attach to requirements to protect the environment (“Ban on plastic straws in KL, Putrajaya and Labuan from Jan 1, 2019 - Nation | The Star Online,” n.d.).

Waste management were having problems in tackling the plastic issues as most packaging products for food and consumer were from non-biodegradable plastics used in the industries. Industrialization and urbanization had severe pollutions to the environment (Thompson, Moore, vom Saal, & Swan, 2009). Wastes from agro industries also need to be revolutionized to produce alternative products made from natural fibers and particulates being left abandon in huge amount after processing into relevant food items such as from rice field and oil palm plantation. The wastes such as rice husks, pineapple fibers and oil palm fibers all can be used as composite for further applications. From rice husks, composite products for food packaging had been produced recently and composite panels and decking had been converted to furniture and decorative panels, doors and window frames.

With regard to environment aspects, it would be beneficial if natural fibers could be used instead of synthetic fibers as reinforcement in some structural and food packaging applications. This was because the natural fibers can be used as fillers, other than biodegradable, they can be source of cheap fibers for composite with biodegradable resin which was of high price. Besides that, usually plastic drinking straw was made from polypropylene (PP) or polystyrene (PS) and its had contributed to plastic pollution and this can be replacing with biodegradable materials. Polyethylene and polypropylene for straw was not environmental friendly as it creates pollute and harm human or marine life. Many NGOS were making various pickets and protests about endangering life of marines which in the long run affecting human.

Normal fibers had deliberate inner cell divider structure which was isolated into three structural parts (Madsen & Danmarks Tekniske Universitet. BYG. DTU, 2004). Cell wall fundamentally comprises of two cell wall, primary cell wall (S1) and secondary wall (S2). Primary cell walls spreads at the season of plant growth. Secondary cell wall is produce by three layers and each layer conveys long chain of micro fibril (John & Anandjiwala, 2008). There are many things need to be consider during fibers selection such as length, strength, and purpose of usage. Raw material for production of PHA was used a pineapple leaf fibers (PALF). In pineapple fruit there consist same number of hexagonal areas on external shell and not rely upon the size or on the other hand shape. Malaysia also one of large producer in Asia as much as Hawaii. It produces large number of waste substance, around 384,673 metric tons in year 2008 (Fao, n.d.).

## II. METHODOLOGY

### *A. Crusher*

Function of crusher was to reduce the size of pineapple leaf fibre (PALF) and simply or make next method much easier. Pineapple fibre will be break or compress by metal surface.

### *B. Sieve Shaker*

This machine used to reduce the size of pineapple leaf fibre (PALF) and the structure of the fibre change in powder form. Sieve size that used for this method was 30 µm.

### *C. Extrusion Machinery*

Pineapple leaves fibres (PALF) will mixed with poly (lactic acid) (PLA) resin and compounded following the formulate of extrusion process. After that, the compound which already mixed was melted at process temperature range within 170˚C and 180˚C using twin screw extruder PRISM/Haake with length to diameter ratio of 16:1. The screw speed keep constant at 50 rpm.

### *D. Testing Equipment*

There are several testing need to be done on PLA composites properties after extrusion process. The equipment that used for the testing process is listed in Table 1 below:

| Properties | Description | Equipment |
|---|---|---|
| Melt Flow Index (MFI) | The melt flow of the PLA composite was tested to confirm the suitability for extrusion process. | Melt Flow Tester |
| Mechanical | The tensile strength of the PLA composite was tested to determine its toughness. | Tensile Tester |
| Thermal | The thermal properties of the PLA composite was tested to ensure its stability. | Differential Scanning Calorimetry (DSC) |

Table 1: Equipment for testing characterization of PLA composite.

### *E. Specific Formulation*

Different composition that use in fabrication of PLA and PALF are listed on the Table 2 below:

| Composition (%) | |
|---|---|
| PALF | PLA |
| 15 | 85 |
| 30 | 70 |
| 0 | 100 |

Table 2: Formulation of PLA/PALF composites.

### *F. Testing*

There is several equipment that was provided to run the testing are listed in the Table 3 below:

| **Equipment** | **Faculty** |
|---|---|
| Melt Flow Tester | Applied Science, Polymer Lab |
| Tensile Tester | Applied Science, Polymer Lab |
| Fourier Transform Infrared (FTIR) | Applied Science, Polymer Lab |
| Differential Scanning Calorimetry (DSC) | Applied Science/Chemical Engineering/ Mechanical Engineering Lab |

Table 3: List of testing equipment provided by faculty

## III. RESULTS AND DISCUSSION

### *A. Melt Flow Index (MFI)*

Melt flow Index (MFI) properties testing was conduct by used temperature at 190°C. Next, ASTM D 1238 was used as a common standard for melt flow test. MFI machine model was Model 2 Digit Melt Flow Indexer (RAY-RAN). The extrudes were obtain every 10s by cutting it close to the orifice. Result for three specimens were tabulated in Table 3 below:

| **Type of Specimens** | **Weight of Specimens (gm)** | | | | **Time range (s)** | **MFI (g/10min)** |
|---|---|---|---|---|---|---|
| | **W1** | **W2** | **W3** | **Average** | | |
| PLA Virgin | 0.3655 | 0.3065 | 0.3702 | 0.3474 | 30 | 6.948 |
| PLA+ 15% PALF | 0.3691 | 0.4412 | 0.4563 | 0.4222 | 10 | 25.34 |
| PLA+ 30% PALF | 0.2843 | 0.3534 | 0.6727 | 0.4368 | 10 | 26.20 |

Table 4: MFI result for all samples

The main purpose of this test is to measure the ease flow of the melt of thermoplastic polymer because different composition had different melt flow. From the results above, it shows that the higher the concentration of fiber, the higher reading for melt flow. Besides that, if melt flow reading increase, the lower the viscosity and molecular weight supposed to be. PLA with 30% PALF was much better to use because it's had high reading for melt flow. Composition for fiber used also much higher and indirectly help to cut cost for PLA used.

### *B. Fourier Transform Infrared (FTIR)*

FTIR purposed was to determine the organic, polymeric and inorganic materials. This test was run by infrared light to scan chemical properties for each sample that used in this research project. FTIR spectra for all the samples were acquired within the wavelength of 4000-600 $cm^{-1}$. Resolution was setting 4 $cm^{-1}$ and scan speed was 16 spectra per second. Below was the result for each sample that conduct by this testing:

1. PLA + 15% PALF

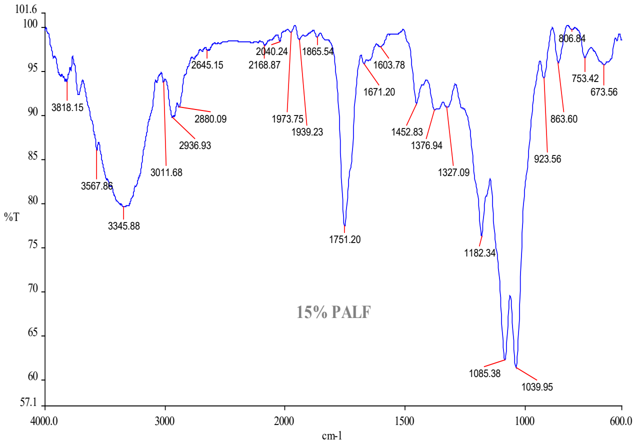



Figure 1: FTIR result for PLA + 15% PALF

2. PLA + 30% PALF

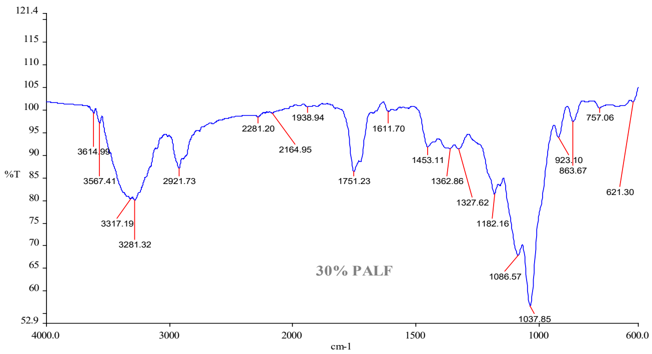



Figure 2: FTIR result for PLA + 30% PALF

Based on the graph, peak at 3567.86 $cm^{-1}$ and 3567.41 $cm^{-1}$ which represent intermolecular H bonds of O-H stretching. This shows that the appearance peak for PLA + 30% PALF sample had strong stretch. From Figure 1 and 2 also displays a C-H stretching peak at 2936.93 $cm^{-1}$ and 2921.73 $cm^{-1}$. This peak shows mainly in cellulose and major component of the lignocellulose fibers (Prado & Spinacé, 2015). As well as a peak at 1751.20 $cm^{-1}$ and 1751.23 $cm^{-1}$ which represents C-H bending vibrations aromatic esters (Lim, Srinivasakannan, & Al Shoaibi, 2015).

Noticeably, a new peak emerged at 1452.83 $cm^{-1}$ and 1453.11 $cm^{-1}$, which near with 1450 $cm^{-1}$ shows C-H bending. This was cause the amount of PLA present in the PALF (Izwan Abd Razak, Fadzliana Ahmad Sharif, Hasraf Mat Nayan, Idayu Muhamad, & Yazid Yahya, 2015). Next the peak at 1085.38 $cm^{-1}$ and 1086.57 $cm^{-1}$ shows that functional group of C-O stretching vibration in the aliphatic ether.

1. PLA + 15% PALF (Table 5)

| Test No | Width (mm) | Thickness (mm) | Force @ Peak (N) | Stress @ Peak (MPa) | Strain @ Peak (%) | Stress @ Break (MPa) | Strain @ Break (%) | Youngs Modulus (N/mm$^2$ | Elong @ Break (mm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 20.740 | 2.780 | 65.900 | 1.143 | 0.188 | 0.000 | 1.438 | 540.233 | 1.150 |
| 2 | 20.450 | 2.890 | 93.900 | 1.589 | 0.175 | 1.579 | 0.188 | 736.003 | 0.150 |
| 3 | 20.160 | 2.940 | 41.600 | 0.702 | 0.063 | 0.378 | 0.075 | 318.147 | 0.060 |
| Mean | 20.450 | 2.870 | 67.133 | 1.145 | 0.142 | 0.978 | 0.567 | 531.461 | 0.453 |

2. PLA + 30% PALF (Table 6)

| Test No | Width (mm) | Thickness (mm) | Force @ Peak (N) | Stress @ Peak (MPa) | Strain @ Peak (%) | Stress @ Break (Mpa) | Strain @ Break (%) | Youngs Modulus (N/mm$^2$ | Elong @ Break (mm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 22.560 | 2.960 | 30.400 | 0.455 | 0.213 | 0.000 | 0.675 | 157.433 | 0.540 |
| 2 | 21.250 | 3.010 | 37.700 | 0.589 | 0.325 | 0.030 | 0.613 | 223.847 | 0.490 |
| 3 | 22.130 | 3.080 | 30.500 | 0.447 | 0.150 | -0.015 | 0.588 | 255.822 | 0.470 |
| Mean | 21.850 | 3.053 | 33.775 | 0.508 | 0.219 | 0.181 | 0.519 | 226.050 | 0.415 |

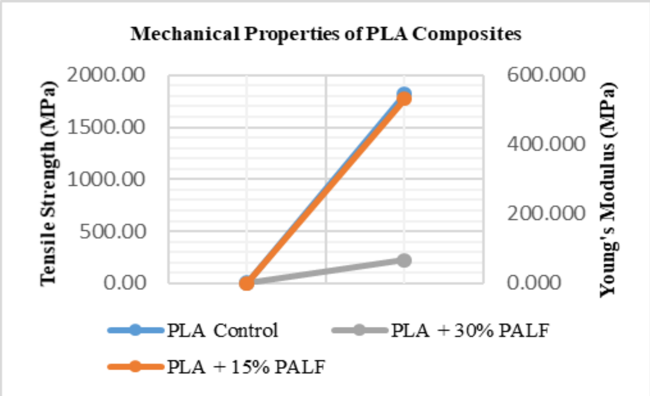
### *C. Tensile Practice*

Tensile tester was conducted at test speed only 5 mm/min and test was conducted by used Testometric materials testing machines. Two types of sample which PLA + 15% PALF and PLA + 30% PALF. Three specimens were tested for each sample and presented as an average of tested specimens.

Based on the result from table 5 and 6, shows the effect of different fiber contain and PLA on the tensile properties. For specimen 15% PALF, it shows that mean value for stress peak was 1.145 MPa but the mean result of stress peak for specimen 30% PALF was about 0.508 MPa. Tensile strength was decreasing when the contain of fiber increased in overall. It resulted from fiber agglomeration and occurred by increasing in fiber interaction. Next, poor fiber dispersion also may act as a defect of stress transfer between the composites (Panyasart, Chaiyut, Amornsakchai, & Santawitee, 2014).

Furthermore, stress break also decreases when amount of fiber increased because the interfacial adhesion between pineapple leaf fiber (PALF) and poly lactic acid (PLA) was not good (Panyasart et al., 2014). Stress break for specimen 15% PALF shows 0.978 MPa but for 30% PALF 0.181 MPa, this results shows that increasing of fiber contain also made the sample cannot stand with high pressure and easy to break.

Stiffness and strength can be increase by some treatment which alkali treatment and consecutive silane treatment. Alkali treatment will help to remove natural impurities in fiber and for consecutive silane treatment will fix fiber-matrix chemical bonding (Panyasart et al., 2014).




## IV. Conclusion

Research project already done with successful and all the objectives achieved. PALF incorporation in the PLA matrix creates better surface interaction and the medium become stronger. The tensile properties reduce when the PALF contain increased from 15% to 30%. FTIR showed that fiber existence and interact with functional groups from cellulose. For the Melt Flow Index (MFI) shows that the higher of fiber contain, the higher of reading of the melt flow. This project which was helped reduce the cost and find use in food packaging industry. The addition of PALF helped to reduce the use of plastic to save an environment but too many addition of fiber contain also can reduce the strength of the product. Strength of fiber can be improving if put some addition treatment so that the properties will mixed well with PLA.

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