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# INCREASING THE MECHANICAL PROPERTIES OF BIODEGRADABLE PLASTIC BASED ON POLY LACTIC ACID (PLA) WITH THE ADDITION OF COCONUT COIL (COIR) AND CHITOSAN

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## ABSTRACT

Petroleum-based plastics that are difficult to decompose have been used for years to become the biggest environmental polluter.The solution is to replace conventional plastics such as bioplastics with the same quality as conventional plastics so that they can replace the existence of petroleum-based plastics.The innovation of combining natural polymers (poly lactic acid) with coir-chitosan fillers is able to make polymers have good mechanical properties. This study aims to see the effect of mixing the natural polymer poly lactic acid (PLA) with coir (coconut coir) and chitosan fillers. With variations in fiber mass fraction3.8 grams; 3.9 grams; 4 grams; 4.1 grams; 4.2 grand mass variation of chitosan 0.36 gr; 0.38 gr; 0.4 gr; 0.42 gr; 0.44 gr. The addition of coir and chitosan fillers affects the mechanical properties and thermal properties of the material.The synthesized composites were tested for their mechanical strength to determine material characteristics and morphological observations. In the tensile test, the highest tensile strength value was produced by a material with a mass fraction of coir 19% (w/w) and 1.8% (w/w) chitosan, which was 44.23 MPa and the lowest tensile strength value was produced by a material with a mass fraction coir 21% (w/w) and chitosan 2.2% (w/w) of 31.48 MPa. Based on test results *Differential Thermal Analysis* sample with coir modification 20% (w/w) chitosan 2% (w/w) has the best thermal stability among other samples where the sample begins to degrade (on set) at 461.77 ($^oC$) and stops experiencing degradation (end set ) at a temperature of 531.48 ($^oC$). The results of the morphological test using the SEM tool show that the surface structure of the PLA79.2% sample is more homogeneous due to coir (coconut coir) and chitosan chains are well dispersed into the poly lacti acid (PLA) interlayer.

**Keywords** : *Bioplastics, Coir, Chitosan, Biodegradation, Natural Polymers.*

## 1. INTRODUCTION

Plastics are polymers of long chains of atoms that bind to one another. These chains form many repeating molecular units (1). The entire polymer chain is composed of hydrogen and carbon atoms, designed to inhibit the entry and exit of oxygen so that the products stored therein do not decompose. The properties of plastics which are corrosion resistant, well insulated and have low conductivity have made plastics widely recognized as playing an important role in all aspects of human existence (2). Over the years plastic is used in almost every sector such as packaging products, electricity and electronics, textiles, transportation and industrial machinery. Conventional plastic made from petroleum is the biggest environmental pollutant because it is difficult to decompose in nature. Experts estimate that 10% of the plastic waste generated will enter the sea and will exceed the number of fish in the oceans by 2050 (3). One example of a biodegradable polymer is poly lactic acid (PLA), this poly lactic acid was chosen as a substitute for petroleum plastic because it has several advantages such as its renewable nature, can be decomposed naturally and can be obtained from agricultural crops such as corn, sweet potatoes and bananas (4).

### Research Urgency

Various studies have been carried out to find a substitute for conventional plastics, in recent years biodegradable polymers are believed to be able to replace petroleum-based plastics. Referring to ISO (International Standardization Organization) biodegradable is a degradation process caused by biological activity such as enzyme activity which causes significant changes in chemical structure and produces carbon dioxide, water and minerals in the degradation process. Biodegradable plastic is defined as plastic that can be decomposed into carbon dioxide gas with the help of microorganisms (5). The advantages of using cellulose fiber include being environmentally friendly and recyclable (6).Currently the utilization of coco fiber waste is still limited and has not been processed into products that have higher economic value. One way to convert coco fiber into products that have higher economic value is to use coco fiber as reinforcement in composite materials (7 ). From this background it is known that PLA also has the weakness of low mechanical properties, moving from these problems, this research will use coconut coir (coir) and chitosan to improve the mechanical properties of PLA.

## 2. RESEARCH OBJECTIVES, BENEFITS AND LIMITATIONS

*Poly Lactic Acid* (PLA) was discovered in 1932 by Carothers who produced low molecular weight PLA by heating lactic acid under vacuum. PLA is a biopolymer composed of lactic acid monomers resulting from fermentation of agricultural materials such as corn starch (6). Chemical polymerization to produce PLA from lactic acid can be done in 2 ways, namely directly from lactic acid and indirectly through the formation of lactide first and followed by polymerization into PLA or in principle it can be made through two different processes, namely condensation and polymerization. . The most common polymerization technique known as ring opening polymerization is a process that uses a metal catalyst in combination with lactide to make larger PLA molecules. The condensation process is similar in this way, the main differences being the temperature during the procedure and the by-product (condensate) released as a consequence of the reaction (8). Coconut coir plays an important role in various polymer composite applications because of its high strength and modulus and friendly ability to reduce environmental pollution so that this composite is able to overcome environmental problems that may arise from the large amount of coconut fiber that is not utilized. Coconut coir fiber reinforced polymer composites have high resistance to corrosion, impact and stress to weight ratio (9). Chemical treatment of coconut fiber is a process that aims to increase the adhesion between the surface of the fiber and the polymer matrix as well as remove dirt on the fiber surface so that a cleaner and rougher surface is obtained. This process reduces the water absorption capacity of the fiber thereby improving its mechanical properties.

So, the limitation in this study is the treatment of filler, namely coconut coir. Treatment of fiber with alkali is one of the most widely used fiber processing methods. Alkali solution has the effect of removing oil and other impurities on the fiber, decomposition of cellulose which causes short crystallite exposure and increases the surface roughness of the fiber resulting in better mechanical properties.

## 3. RESEARCH METHODS

### Research methodology

The materials used in this study were commercial PLA, coconut fiber, chitosan, NaOH and distilled water.

- The steps are as follows:

1. Raw Material Preparation

The fibers were soaked in 5% NaOH alkaline solution for 5 hours. Then the fiber is filtered. The fiber is dried in an oven with a temperature of 80℃, after drying the coconut fiber is cut into smaller pieces. Then the fiber is crushed using a crusher.

2. PLA – coir - chitosan synthesis

*Poly Lactic Acid*(PLA), coconut coir and chitosan were prepared by weight ratio according to the independent variables. PLA, coconut coir and chitosan are mixed in an extruder at 160℃. After mixing, the material is transferred to the ASTM D-638 standard mold which has been coated with Teflon paper. Pressing was carried out using a hot press at a temperature of 200 ℃. Then the material in the mold is allowed to stand until the mold temperature decreases.

- Trial Treatment

1) Fixed variable
   - Coconut coir soaking time is 5 hours
   - ASTM D-638 standard mold
   - Sample weight 20gr/mold
2) Independent variable
   - Coir weight (coconut coir): 3.8 gr; 3.9 grams; 4 grams; 4.1 grams; and 4.2 gr
   - Chitosan weight: 0.36 gr; 0.38 gr; 0.4 gr; 0.42 gr; 0.44 gr
3) Dependent variable
   - Tensile strength was tested using a tensile tester
   - Morphological test using Scanning Electron Microscope (SEM)
   - Thermal properties tested using Differential Thermal Analysis (DTA)
   - Biodegradability Test

## 4. RESULTS AND DISCUSSION

### 1. Tensile strength

The mechanical characteristics of the PLA/coir/chitosan material were analyzed through a tensile strength test using the UTM (Universal Testing Machine) tool. The dimensions of the specimens used follow the dimensions of the specimens in ASTM D-638. The mechanical properties in the form of tensile strength of bioplastics are important factors that must be studied in depth to determine the extent to which these bioplastics can be applied. Testing the mechanical properties of bioplastics is also very important to determine the homogeneity of a mixture of polymer materials and mixed materials used in the manufacture of bioplastic composites. Increasing the concentration of coir and chitosan has an effect on the tensile strength value of the

PLA/coir/chitosan composite, this is explained through the graph in Figure 4.1.

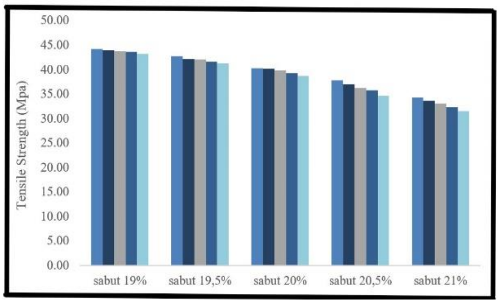


Figure 4.1 Graph of the tensile strength of PLA/coir/chitosan

Based on the graph above, it can be seen that the tensile strength value produced by the PLA/coir/chitosan composite decreases with the increase in the value of the coconut coir content in the composite, one of the causes of the decrease in the tensile strength value is the large interface bond between the fiber and the PLA matrix. The presence of fibers partially blocks the chain bonds of PLA thereby making the distance between the molecules larger and forcing the PLA bonds to weaken.

This coincides with the results observed by Marwanto (6) where in his research the composite with the highest fiber content produced the lowest tensile strength, this was due to the weak interaction between the fiber and the PLA matrix in holding the applied load. If the fiber content increases, the bond between PLA and fiber will weaken and the compatibility between fiber and PLA will decrease. The decrease in the value of the tensile strength of the composite is also caused by agglomeration or clumping (10). Agglomeration can be caused by differences in decomposition temperature between the amorphous PLA matrix and coco fiber. This phenomenon resulted in reduced dispersity of the mixture between the PLA matrix and coconut coir.

**2. Differential Thermal Analysis (DTA)**

The characteristic feature of polymeric materials is that they are highly susceptible to changes in temperature. This is because when the temperature changes, the movement of molecules due to thermal changes will change the molecule group or change the structure (especially structures with large dimensions). Thermal analysis is a technique that studies the physical properties of materials that change with temperature. One method that can be used to analyze the properties of materials thermally is differential thermal analysis (DTA) in which the changes that occur between the sample and the reference material (inert) will be seen and measured. Characterization of thermal properties is used to determine the amount of heat energy used and to determine what temperature should be used for the synthesis process (10).

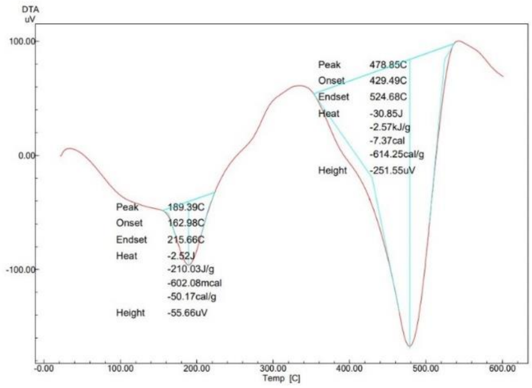


Figure 4.2 Thermogram PLA 78.8%, coir (coir) 19%, chitosan 2.2%

Figure 4.2 shows the thermal properties of the bioplastic composite which is heated from 100 °C to 600 °C and undergoes double decomposition. It can be seen from the thermogram that shows on set and end set occurring 2 times, namely in the temperature range of 200 °C and 500 °C. On set is the temperature at which the sample begins to degrade thermally and end set is the temperature at which the sample retains its mass from the combustion reaction or end set is the end of the decomposition reaction. The bioplastic composite PLA 78.8%, coir

(coir) 19%, chitosan 2.2% melted at a temperature of 162.98℃ which was characterized by the formation of an endothermic reaction with the required enthalpy of 210.03 J/g.

**3. Analisa Struktur Morfologi**

The surface structure of a material, a Scanning Electron Microscope (SEM) can be used. This microscope is a type of electron microscope that depicts the surface of a sample through a scanning process using high energy emission electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample to generate signals and provide information about the sample's surface topography, composition and other properties such as electrical conductivity (7).

In principle, if there is a change, for example a fracture, indentation and differences in material structure, the energy tends to change. These energy changes can be emitted, reflected, absorbed, and converted into electron wavefunctions that can be captured and read on SEM photos. In addition, SEM can analyze morphology or identify the surface of a material with a higher resolution than conventional optical microscopes (Rihayat, 2019). SEM testing as an additional test in this study aims to support the best sample results taken from the main test, namely the tensile strength test. In this study SEM analysis was carried out on samples with a fiber composition of 19% and 20% with the aim of seeing the effect arising from differences in the percentage of fiber, PLA and chitosan contained in the samples. The following is a picture of the test results at a magnification treatment distance of 100x and 1000x of the PLA-coir-chitosan composite.

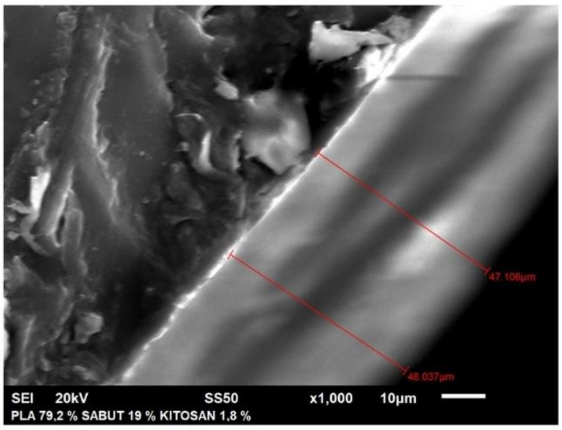


Figure 4.3 Morphological Characteristics of PLA 79.2% : Coir 19% : Chitosan 1.8%

The appearance of cracks at the interface between the fibers and the polymer matrix confirms the low affinity of the material or poor interfacial adhesion between the coir mixture and PLA (12). Based on the morphological characterization results above, the surface of the PLA79.2% sample is more homogeneous because it contains less coir mixture and there is no porous surface and no voids are visible inside. Thus the adhesion of the matrix and filler arranged therein binds and mixes well. If it is related to the tensile test, the results of the SEM test also correlate where the surface structure of the PLA/coir/chitosan composite with the addition of 19% coir and 1.8% chitosan is the best because it produces good tensile strength as well.

**4. Biodegradasi**

The biodegradation test was carried out using soil media. The sample is buried in the ground and the degradation process will be observed for a certain time.

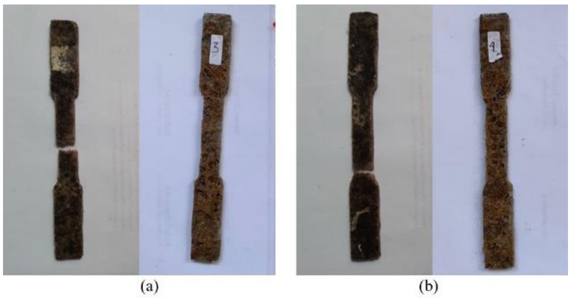


Figure 4.4 Sample after undergoing biodegradation process (a) 19% fiber percentage and (b) 19.5% fiber percentage

The analysis results obtained through observation for 12 days showed little change experienced by the polymer and the changes experienced in terms of weight loss percentage could not be seen clearly. The only obvious change is the color change of the polymer being tested. More significant color changes occurred in samples with a percentage of 19.5% coconut coir. Coconut coir as a filler has hydrophilic properties so that with the addition of this material the level of water absorption is higher and can also provide space for the development of microorganisms. Farida et al (2019) in his article explained thatBioplastics are easily degraded because they contain hydroxyl, carbonyl and carboxyl ester functional groups, these groups have hydrophilic properties so that water molecules can cause microorganisms in the environment to enter the plastic matrix.

**CONCLUSION**

1. The concentration of coir (coconut coir) affects the tensile strength value of the composite, the higher the concentration value of the coconut coir makes the composite have a decreased tensile strength value. The composite with 19% coir content has a tensile strength value of 44.23 Mpa while the composite with 21% coir content has a lower tensile strength value of 31.48 Mpa. The addition of coconut coir as a filler gives good thermal properties to the composite
2. The composite with 2% chitosan content showed that the interaction between PLA, coir, and chitosan had a good level of homogeneity compared to the composite with 1.8% chitosan content.

**REFERENCE**

1. Nugraha Gusniar, I. (2018). Metode Pembuatan Paving Block Segi Enam Berbahan Sampah Plastik Dengan Mesin Injection Molding. *Jurnal Teknik Mesin*, 3(2), 130 – 133.
2. Moshood, T., Nawanir, G., Mahmud, Fatimah., Mohammad, Fazeeda., Hanafiah Ahmad, Mohd., & Abdulghani, Airin. (2022). Biodegradable Plastic Applications Towards Sustainability: A Recent Innovations In The Green Product. *Jurnal Teknik Lingkungan*, 6(1), 1-14.
3. Schmaltz, E., Melvina, E., Diana, Z. (2020). Plastic Pollution Solutions: Emerging Technologies to Prevent and Collect Marine Plastic Pollution. *Environment International*, 144(1), 1-17.
4. Rajeshkumar, G., Arvindh Seshadri, S., Devnani, G.L. (2021). Environment Friendly, Renewable And Sustainable Poly Lactic Acid (PLA) Based Natural Fiber Reinforced Composites - Comprehensive Review. *Journal of Cleaner Production, 310(127483),* 1-26.
5. Flury, M., Narayan, R. (2021). Biodegradable Plastic As An Integral Part Of The Solution To Plastic Waste Pollution Of The Environment. *Current Opinion in Green and Sustainable Chemistry*, 30(100490), 1-7.
6. Marwanto. (2017). Sifat Mekanik Komposit Berbasis Poli Asam Laktat (PLA) dan Serat Selulosa Tandan Kosong Kelapa Sawit. *Jurnal Hutan Lestari*, 5(2), 412-417.
7. Ridwan., Rihayat, T., Ilmi, A., Aidy, N. (2021). Biokomposit Poly Lactid Acid (PLA) Berpenguat dengan *Coir* (Sabut Kelapa) : Evaluasi Kinerja Mekanik dan Sifat Multifungsi**.** *Jurnal Teknik Kimia*, 9(11), 97-108.
8. Subbhash, T., Shelare, S., Aglawe, K. (2015). A Mini Review On Fibre Reinforced Polymer Composites. *Environment International*, 6(54), 682-689.
9. Joshua, P., Aladin. (2013). Analisis Pengaruh Penggunaan Naoh 5% Pada Serat Pelepah Pisang dengan Fraksi

Volume 40%, 50% dan 60% Terhadap Kekuatan Mekanis. 3(2). 2615-0867.

10. Priyono, S., Prihandoko, B. (2015). Pengaruh Penambahan Serbuk Al2o3 Dan Na2co3 Pada Karakter Termal Prekusor Li4ti5o12. *Jurnal Fisika*, 4, 2339-0654.
11. Rihayat, T., (2019). Poli Asam Laktat Nanokomposit, Biodegradable Polimer : Sintesa Karakterisasi dan Aplikasi. Aceh : Yayasan Puga Aceh Riset.
12. Chotiprayon, P., Chaisawad, B., Yoksan, R. (2020). Thermoplastic Cassava Starch/Poly (Lactic Acid) Blend Reinforced With Coir Fibres. *International Journal of Biological Macromolecules*, 156, 960-968.
13. Farida, S., Hartiati, A., Admadi Harsojuwono, B. (2021). Pengaruh Konsentrasi Pati Ubi Talas (Colocasia Esculenta) Dan Jenis Plasticizer Terhadap Karakteristik Bioplastik. *Jurnal Rekayasa dan Manajemen Agroindustri*, 7(3), 457-467.
14. Rafli., Damayanti, W. (2015). Pembuatan Bioplastik dengan variasi Kitosan dan Stabilizer Gliserol. *Jurnal Teknik Kimia*, 1, 39-42.
15. Awan., Sembiring Anwar, D., Iskandar, M. (2018). Pembuatan Dan Karakterisasi Genteng Komposit Polimer Berbasis Limbah Abu Boiler Kelapa Sawit Dan Serat Benang Karet Ban Bekas Yang Diperkuat Oleh Aspal. *Jurnal Ilmu Fisika dan Teknologi*, 2, 8-14.
16. B Waltea, Abhilash., Bholeb, K., Gholave, J. (2020). Mechanical Characterization Of Coir Fiber Reinforced Composite. *Materials Today : Proceedings*, 24, 557-566.