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Studies about Palm Sago Starch as a Filler to Make Biodegradable Packaging Material

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ABSTRACT

The sago starch of oil palm has a big potential to be a filler for biodegradable packaging material. The starch of palm sago starch can be extracted from the trunk of oil palm. The grafting process of polypropylene and maleic anhydride has done by reflux method from 1g maleic anhydride, 0,1 g BPO, and 10 g polypropylene, with xylene as the solvent. The mixing of PP-g-MA and PSS (starch of the palm trunk) has done using the cross clamp method at temperatures 1700C for 20 minutes. The variation of PP-g-MA and PSS were (99,5:0,5), (99:1), (98:2), (97:3), (96:4), (%w/w) while the commercial tapioca is used as a comparison, with variation (99,5:0,5) (99:1), (99:2) (%w/w). The result of this research shows that the most optimum variation of PP-g-MA and PSS for biodegradable packaging characteristic is (97:3), with the tensile strength value 16,010N/m2 and elongation at break value 8,5937%. Whereas, a mixture of PP-g-MA and PSS with variation (98:2), the tensile strength value is 6,9410 N/m2, and the elongation at break value is 3,1875%, which is almost the same with commercial tapioca. According to biodegradable packaging requirement of ISO 7188.7:2011, the mixture containing thermoplastic, and natural starch, elongation at break value is less than 5% can be used as a raw material of biodegradable plastic. The research is also supported by SEM test, DTA test, FTIR test and Biodegradable test.

INTRODUCTION

Nowadays, starch is a popular filler ingredient in the manufacture of packaging plastic materials, especially starch derived from Cassava *(Manihot utilising)*. However, sago palm starch is also potential to be used as a filler of biodegradable packaging plastics material. This is because the oil palm tree is in great quantities in Indonesia. Besides, oil palm trunk used for the manufacture of biodegradable plastic is from 24 or 25-year-old oil palm trees. Therefore, cutting down the trees will not contaminate the environment. Biodegradable packaging plastic is needed in our lives today and is increasing in terms of its use and its production. The packaging plastic we used now is a Synthetic Polymers made of petroleum, which is a non-renewable natural resource. It means that the plastic cannot be degraded by microorganisms in the environment. This condition makes synthetic packaging plastics cannot be used for a long time because it will add the environmental problems in the future. According to literature and the increasing of people's awareness on health and sustainable environment, it is important to research and develop technology to produce biodegradable packaging plastic material (Latief, 2011). The common material of packaging plastic is Propylene because of its good mechanical properties, low density, and affordable price. And the main advantage of Propylene is its resistance at low the temperatures (Ezzatti, 2008).

The possible functionalization of Propylene, either the isotactic or the atactic polymers, by the polar monomers is an effective way to increase the polarity of polypropylene. In fact, various types of grafted polymers have been widely used to improve the surface adhesion between the components and the mixture of polymers. Modification of the isotactic and atactic polypropylene is also used extensively to increase the use of mechanics materials of the composites made from polypropylene as well as to increase the strength of the composites (Collar, 1997).

Biodegradable plastic is a polymer material that can be changed in certain time and circumstances. Its chemical structure can be changed by the effects of microorganism such as bacteria, fungi, algae, etc (Grifftin, 1994). The biodegradable plastic film is a polymer material that turns into low molecular weight compounds, at least one level of its degradation process through the natural metabolism process of organisms. Biodegradable plastics are usually made by combining the nature-based material plastics. One of the natural materials that can be used in manufacturing the biodegradable plastics is starch. Biodegradable plastics that made of starch can be degraded by the *Bacillus Pseudomonas* bacteria and broke the chains of the polymer into monomers (Seal, 1994).

Starch as filler material in the manufacture of biodegradable plastics can be obtained from the oil palm plantations which are in a huge number in Indonesia. According to the data from Agriculture Ministry of Indonesia, in the year 2012, the palm oil plantation area in Indonesia is 9.271.00 Ha. Technically, the useful life of the oil palm is 25 years old. It means that every 4% of the area should be replanted to increase the production of oil palm starch. However, so far the palm trunk utilization for industrial use is still limited (Ginting, 1995).

Previous researches show that sago palm starch has the potential to replace commercial starch both in food and non-food industry (Azemi, 1995). Based on the above descriptions, the researcher wants to do research on the mechanical characterization of Sago Palm Starch as filler to make biodegradable packaging plastic material with maleic anhydride grafted Polypropylene as the polymer material and commercial tapioca as the comparative variation.

MATERIALS AND METHODS

This research uses experimental research in a laboratory (true experimental research). This research has several stages; preparation, grafting, mixing and characterization. First, 25-year-old oil palm trunks are prepared from PT. Buana Estate in Langkat, North Sumatera. The extraction process is done by cutting down the palm trees and taking 1-2 m part from the top of the stem. Palm trunk split and separated from the rough skin. Then, it was shaved to obtain the pitch before changing it into powder. Afterward, added water to the powder, precipitated and filtered it so that starch and drugs are produced. Then the drugs are disposed of while the starch is deposited. Later, starch is heated in the oven at 50^0C temperature. Then, filter it using a 140-mesh sieve to obtain the smooth and dry palm starch. Second, the grafting process of maleic anhydride was conducted by mixing 1 g of maleic anhydride and 90 mL Xylene. Then added to 10 g mixture which is refluxed earlier and continue refluxing it for 10 minutes. The result is poured into a porcelain dish and is evaporated so the compound will obtain dry and smooth grafted maleic anhydride polypropylene. Third, making the process of Polypropylene and sago palm starch mixture and the variation is conducted by using the blender and is pressed by using a film print machine (size 15cm x 15cm, thickness 0.1mm), hot pressed machine, Hydraulic Press. The PP-g-MA and PSKS will be obtained after the cooling process.

The last process is the characterization. In this stage, characterization of the mechanical characteristics is conducted by using the tensile test based on ASTM -1822-L with load type and rate 100kgf, 50 mm/minute thickness 0.1mm. Besides, characterization of the functional group is conducted by FITR test while morphology characteristics by SEM test. In addition, characterization of thermal characteristics is conducted by DTA test and biodegradable test to know the ability to be decomposed in nature.

Equipment

The main raw materials (primary) required in this study is starch extracted from oil palm trunk, which is taken from 25-year-old oil palm trees. The others material (secondary) is Benzoyl peroxide as an initiator, Xylene as a solvent, and maleic anhydride as a starch binder. The main equipment is reflux tools, 1 set of porcelain bowl, Fourier Transform Infra Red (FTIR), SEM (Scanning Electron Microscopy), DTA (Thermal Analyzer DT 30 Shimadzu), thermal analyzer type DT 30 Shimadzu-Japan.

RESULTS AND DISCUSSIONS

From the calculation of tensile strength, yield strength and elongation at break of the grafted PP-g-MA and sago palm starch, the optimum condition is in the ratio (97:3). It has the most mechanical characteristics with yield strength 50,913N/m^2, tensile strength 16,010N/m^2 and elongation at break 8,593%.

Table 1: Mechanical characterization PP-g-MA and Sago Palm starch produced

No	Ratio (composition and mass)	*Yield Strength (N/m^2)*	*Tensile Strength (N/m^2)*	*Elongation at break (%)*
1	Pure Polypropylene	56,848	17,878	10,2969
2	PP-g-MA	55,922	17,586	9,876
3	99,5% PP-g-MA and 0,5% PSKS	7,7499	2,4367	9,25
4	99% PP-g-MA and 1% PSKS	32,765	10,3035	7,625
5	98% PP-g-MA and 2% PSKS	22,072	6,9410	3,1875
6	97% PP-g-MA and 3% PSKS	50,913	16,010	8,59375
7	96% PP-g-MA and 4% PSKS	13,9302	4,3805	6,25
8	99,5% PP-g-MA and 0,5% Commercial tapioca	22.157	7,1878	8
9	99% PP-g-MA and 1% Commercial tapioca	19,914	6,262	3,21
10	98% PP-g-MA and 2% Commercial tapioca	20,993	7,4346	3,847

Based on the data in Table 1, the rate yield strength, tensile strength, and elongation at break of PP-g-MA and sago palm starch are greatly varied according to the characterization of involving materials. Besides, each composition has various characteristics according to the composition of its constituent materials. Besides, the data shows that the mechanical characteristics of sago palm starch are relatively competitive compared to the characteristic value of commercial tapioca.

In ratio (97:3), the mixture of PP-g-MA and the starch shows the typical functional group value at 1165.00 cm^{-1}, which shows the bending C-O of starch and PP-g-MA. It is reinforced by the other compounds value 1103.28cm^{-1} and ketones value 1720.50 cm^{-1} formed by the interaction between PP-g-MA and the starch. In addition, value 3433.29 shows the functional group of typical O-H stretching to demonstrate the starch. Meanwhile, commercial tapioca as the comparison, almost all of the values in the ratio (98:2) is same as the ratio (97:3). However, there is a value 1296.16 cm^{-1} from the commercial tapioca that shows a functional group of C-O stretching and value 1851 cm^{-1} that is the stretching functional groups. This can occur because of the low-purity of commercial tapioca due to the addition of other substances when manufacturing process was conducting.

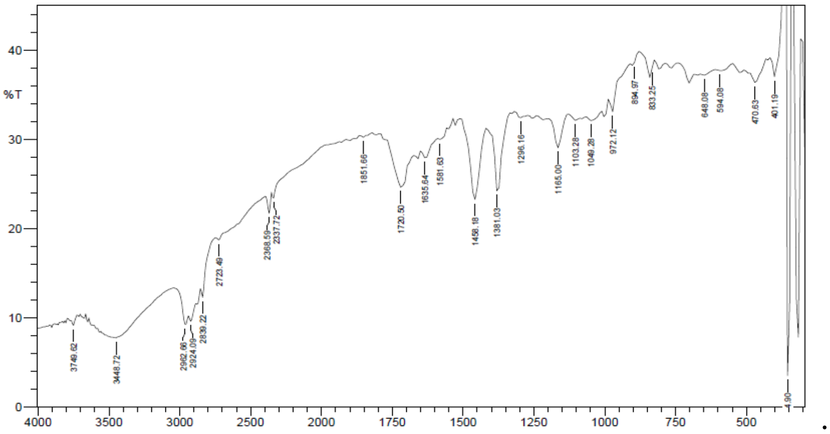

Figure 1: FTIR spectrum specimen 97% PP-g-MA and 3% PSKS

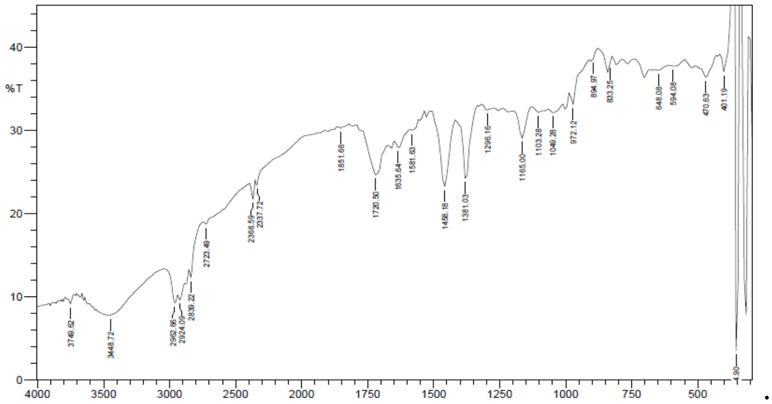

Figure 2: FTIR spectrum specimen 98% PP-g-MA and 2% commercial starch

ANALYSIS OF MORPHOLOGY BY SEM TEST

SEM test analysis provides information about the shape and change of the tested material. Basically, the material experiences the change of fragments, curves, structures, and energy. The energy change can be emitted, reflected and absorbed then converted to electron waves. The results can be captured and be read on the SEM photograph.

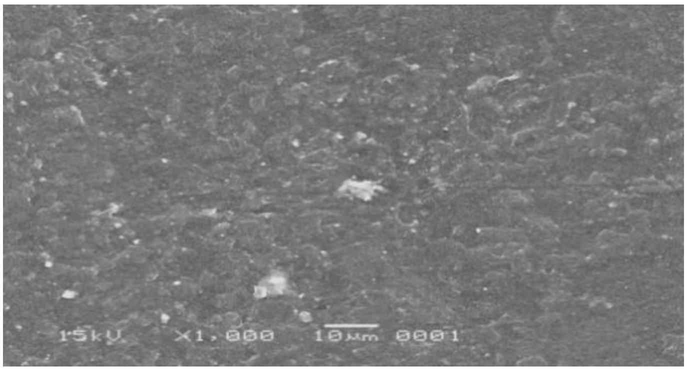

Figure 3: SEM test of Pure Polypropylene magnification 1000 times

Figure 3 is the SEM test result of pure Polypropylene. It shows a flat surface without visible pores.

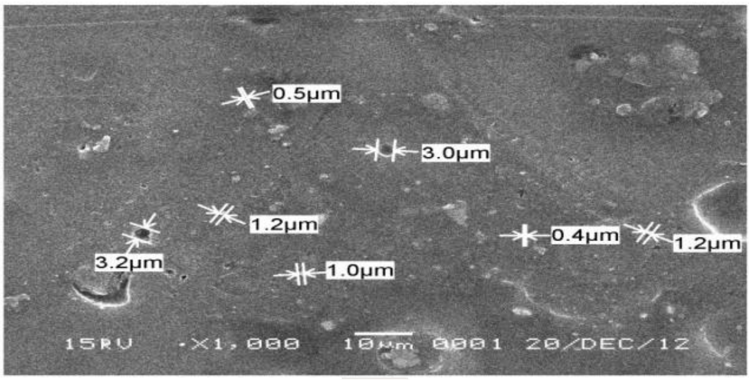

Figure 4: SEM test of PP-g-MA and sago palm starch (97% : 3%) magnification 1000 times

Figure 4 surface shows grains on the surface which indicate that the starch does not perfectly interact with maleic anhydride grafted Polypropylene. However, the grains are in micron size, which is very small so that it can be said as the flat surface. It indicates that interaction between maleic anhydride grafted Polypropylene and sago palm starch is progressing well.

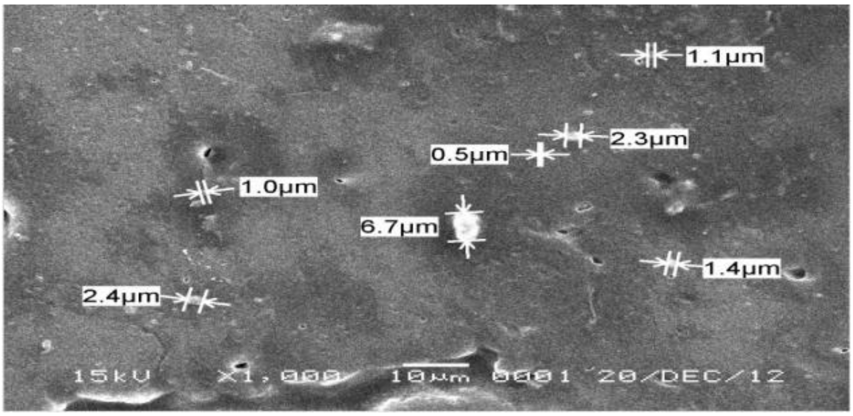

Figure 5 : SEM test (98% : 2%) commercial tapioca magnification 1000 times

Figure 5 shows grains on the surface which indicate that the starch does not interact well with maleic anhydride grafted Polypropylene. The size of starch grains that do not react or mixed perfectly with maleic anhydride grafted Polypropylene is greater. This may be influenced by the reduced purity of commercial tapioca due to the process of production and packaging. Therefore, the result of the mixing process is unfavorable.

ANALYSIS OF THERMAL CHARACTERISTICS BY DTA TEST

Differential thermal analysis (DTA) is one of the ways to determine thermal characteristics of a sample by measuring the temperature difference between samples and the comparisons. In this study is Al_2O_3 is used for the test. This analysis provides information about the changes of physical characteristics of the sample, such as melting point and evaporation. It also includes the process of polymerization, degradation, and decomposition (Wirjosentono, 1995).

Table 2: DTA test results of pure polypropylene, PP-g-MA, and sago palm starch

No	Sample	Melting point (^oC)	Decomposite point (^oC)
1	Pure Polypropylene	165	350
2	PP –g-MA	160	390
3	PP-g-MA and PSKS (98:2)	160	370
4	PP-g-MA and PSKS (97:3)	150	370
5	PP-g-MA and Commercial Tapioca (98:2)	160	370

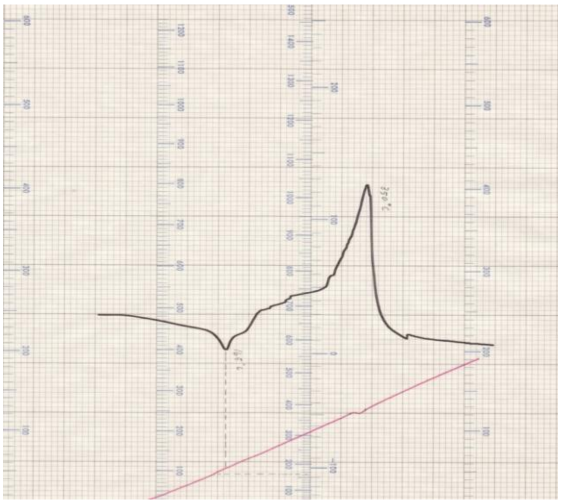

Figure 6: DTA graphic of pure Polypropylene

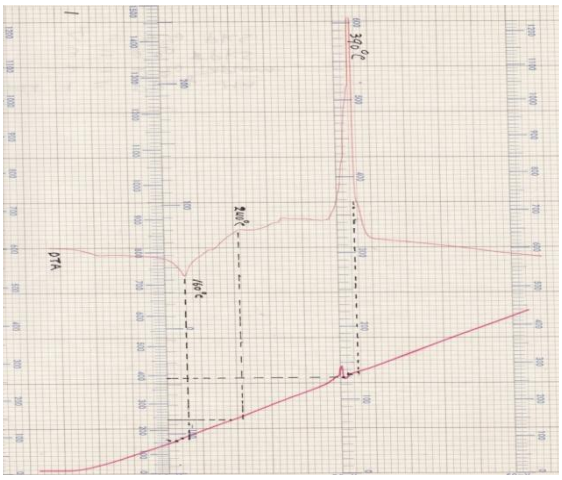

Figure 7: DTA graphic for PP-g-MA

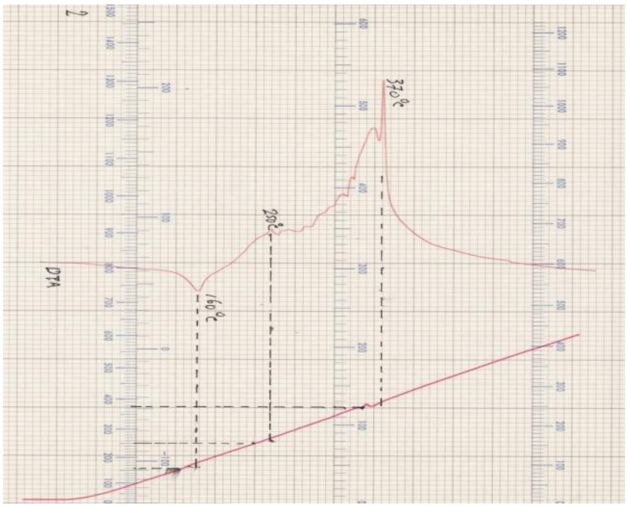

Figure 8: Chromatogram for DTA test of PP-g-MA and sago palm starch (98:2)

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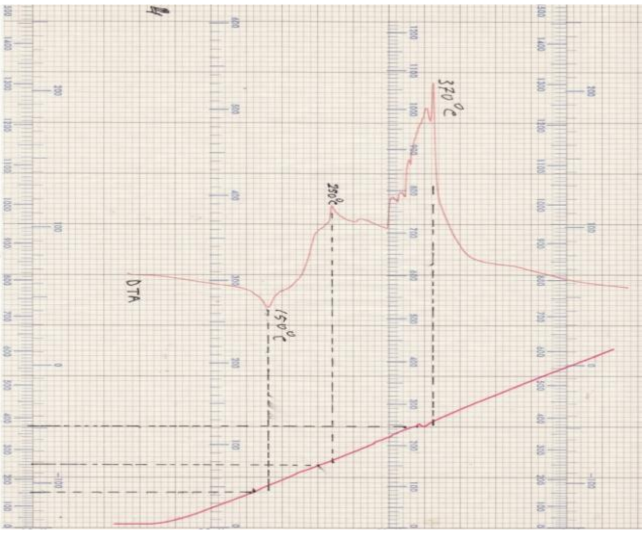

Figure 9: Chromatogram DTA test PP-g-MA and commercial tapioca (97:3)

DTA thermogram of pure Polypropylene shows an endothermic peak at 160^0C which is identified as the melting temperature and exothermic peak at 350^0C as the burning temperature. In this case, the change of melting point is modified (the mixed result) allegedly due to the weakening of the end cluster characteristics of polypropylene so that lower temperature is needed to melt the material. However, at a decomposition temperature, the data shows the rising temperatures which allegedly due to the stronger interaction of mixed materials so that the results are more difficult to be burned. Besides, there is a declining of a melting point after the addition of sago palm starch 3% but the decomposition point remains stable. This is because the starch derived from nature can stabilize the decomposition point of PP-g-MA.

ANALYSIS OF ABILITY TO BE DECOMPOSED IN NATURE BY BIODEGRADABLE TEST

Planting the specimen of packaging materials in various types of soil (e.g: litter soil, garden soil, sandy soil) aims to look at the rate of biodegradability. This is because one of the final packaging materials is returned to the ground. Therefore, it is necessary to test degradation characteristics by conducting in vivo (composting).

Specimen planting is done for 60 days with observations once every 20 days. After planting, it shows the sizeable reduction of mass in the burnt land, which is in the value of 48.7053%. This is probably because a number of nutrients in the burnt soil are greater than other soil so that the number and types of microbes are also greater. The microbes that help the degradation process in the soil are pseudonymous and Bacillus which break the polymer chain into monomers. Therefore, there is a synergistic performance between the activities of some microbes (Wirjosentono, 1998).

Based on the results of FTIR, the intensity of absorption C=O was decreasing that indicates the occurrence of the biodegradation process. The changes in wave number of functional groups O-H stretching and increasing in absorption intensity also indicates microorganism is involved in the degradation process. The first stage of degradation process is the termination of the main chain to form fragments with low molecular weight (oligomers) that can be assimilated by microbes.

Based on these descriptions, we can see that the degradation by planting is more quickly because all the factors that lead to the degradation can be found in the environment. Molecular weight reduction is mainly because of the chain termination of the chain in hydrolysis or oxidative way. Hydrolysis is using aquatic environment with the addition of the enzyme or the non-enzymatic conditions. In this case, autocatalysis, heat or metal catalysts also cause hydrolysis. Oxidative termination is mainly because of the presence of oxygen, metal catalysts, UV rays, and enzymes.

Figure 10: Before and after results of specimen planting of PP-g-MA and PSKS at ratio (97 : 3) and PP-g-MA and commercial tapioca (98: 2) on burnt soil

CONCLUSION

The mixed of maleic anhydride grafted Polypropylene and sago palm starch ratio (97:3) is the most optimum where the tensile strength is in 16.010N/m^2, yield strength in 50,913N/m^2 and elongation at break 8,593 %. It has good mechanical characteristics and has the best morphological characteristics. In this condition, the mixed can be used as the filler material in the manufacturing of biodegradable packaging plastic.

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