

ANALYSIS OF DENSITY, BIODEGRADATION, AND MORPHOLOGY OF BIOPLASTIC COMPOSITES

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ABSTRACT

The purpose of this study was to analyze the effect of adding polypropylene (PP) to sago starch thermoplastic (TPPS) combination of polypropylene grafting maleic anhydrous (PP-g-MA) on density values, degradation tests, and morphological analysis. The thermoplastic mixture of sago starch/polypropylene/polypropylene maleic anhydrous was carried out using the blending method using an internal mixer. Based on the research results, the addition of polypropylene can reduce the density value, and the rate of degradation in freshwater, seawater, and soil storage media. The surface morphology indicates the presence of the dispersed phase (Polypropylene) which is evenly distributed over the entire surface of the matrix (TPPS). there was a shift in wave number in the O-H and C-O groups on the bioplastic composite in the FTIR test.

Keywords: Grafting, Maleat Anhydrate, Sago Starch Thermoplastic, Polypropylene.

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INTRODUCTION

Data analysis in 2018, shows the global demand for plastic is almost 360 million tons.¹ Meanwhile, the production of bioplastics that year was only able to produce 2.01 million tons or representing 0.56% of the world's plastic production.² A significant portion of the non-biodegradable conventional plastics derived from fossil fuels that have been created and discarded over the past few decades are being replaced by biodegradable plastics made from biopolymers (formed in nature) or bio-based polymers (made in factories).³ Plastic waste when burned produces toxic by-products that are bad for the environment and all living things. Meanwhile, it is difficult to decompose. The method of planting in waste management is currently considered inefficient. The usage of biodegradable polymers is another solution that has been found to the issue of plastic waste. Microorganisms including fungi, algae, and bacteria can break down biodegradable plastics.⁴⁻⁵ Unfortunately, although using biodegradable plastic can help save the environment, it has not been extensively adopted. The benefits of using renewable natural resources to make biodegradable polymers are their abundance, affordability, accessibility, and capacity to be degraded in the environment.⁶⁻⁷ Some of the organic components used to make bioplastics are starch, cellulose, protein, and fat.⁸⁻⁹ However, there are several disadvantages of biodegradable plastics, including poor mechanical qualities, sensitivity to high temperatures, brittleness, very low flow index, and hydrophilicity.¹⁰⁻¹¹ The addition of glycerol can help increase the elasticity of starch.¹²⁻¹³ Meanwhile, the addition of reinforcing agents can improve mechanical properties. There are reinforcing agents made from natural polymers and synthetic polymers.¹⁴⁻¹⁵ High flow index, elasticity, hydrophobicity, heat resistance, and outstanding mechanical qualities are some of this synthetic material's benefits. The difference in polarity between the two components (natural and synthetic ingredients) causes problems when combined. The addition of a compatibilizer which is a substance that can increase the homogeneity of the mixture and increase the adhesion between the various phases can improve the compatibility between the two mixtures.¹⁶⁻¹⁷ The purpose of this study was to examine the density, degradation rate, and morphological analysis of thermoplastic composites of sago starch combined with polypropylene using PP-g-MA. Where polypropylene functions as a reinforcing material and PP-g-MA is a compatibilizer.

EXPERIMENTAL

Materials and Procedure

The materials used and the procedures for making TPPS, compatibilizer, and bioplastics follow previous studies.¹⁸

RESULTS AND DISCUSSION

Density Analysis

In Table-1 it can be analyzed that the density value decreases with increasing polypropylene concentration. The addition of dispersed polypropylene into the sago starch matrix affects the weight and density of the polymer in the bioplastic composite.¹⁹ This is because the density of polypropylene is smaller (not equal to) the density of TPPS so that the addition of PP can reduce the density value of the bioplastic composite. The density value at 10% PP concentration is 1.2905g/cm³ while the 30% polypropylene concentration is 1.2317g/mm³ with an average volume of 8.5139cm³ for each sample.

Table-1: Density Test Result

TPPS: PP (%)	Specimen (g)	Thick (cm) 0.32 ± 0,04	Density (g/cm ³)
100:0	11.4256	0.31	1.3392
90:10	11.0105	0.32	1.2905
85:15	10.8894	0.33	1.2763
80:20	10.7601	0.32	1.2612
75:25	10.6318	0.33	1.2461
70:30	10.5087	0.31	1.2317

FTIR Analysis

The addition of PP and PP-g-MA into sago starch thermoplastic resulted in several shifts in wave numbers such as at the peak widened with a wave number of 3265 cm⁻¹ with a transmittance of 47.87% at TPPS to 3287 cm⁻¹ (55.82%) in bioplastics identified as O-H group. This also occurs in the C-O functional group, there is a shift in transmittance from 14.89% to 22.65% at the same wave number of 998cm⁻¹ (Fig.-1). It is suspected that the bond that occurs between TPPS and PP occurs in the O-H (Hydroxyl) group of TPPS with the C-H Stretching group of CH₂ from PP-g-MA. Approaching wavenumbers have been reported by previous studies.²⁰⁻²¹

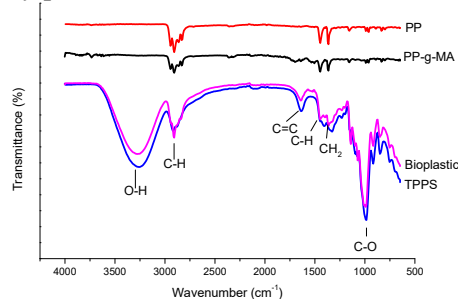


Fig.-1: Spectrum of PP, PP-g-MA, Bioplastic and TPPS

Functional groups detected in sago starch thermoplastic (TPPS) after the addition of PP and PP-g-MA are summarized in Table-2 and Fig.-1.

Table-2: FTIR Analysis of Bioplastics (TPPS/PP/PP-g-MA Blends)

Wavenumber	Functional groups
3287	O-H Stretching
2922	C-H Stretching of CH ₂
1647	C=C Bending
1453	C-H Bending of CH ₂
1367	CH ₂ Vibrational deformation of CH ₂ OH
1148	C-O-C Stretching antisymmetric
998	C-O Stretching

Degradation Analysis

Degradation Analysis on Freshwater Media

The degradation observed was decomposition of sago starch thermoplastic, because polypropylene could not be degraded in the given time period. The graph in Fig.-2 shows that the thermoplastic mixture of sago starch/polypropylene/compatibilizer in fresh water media until day 180 can decompose up to 69% at a concentration of 10% polypropylene, or there are about 31% that have not been decomposed, 21% comes from sago starch. While the bioplastic samples containing a concentration of 30% polypropylene, there was a mass loss of about 58% or 42% had not been decomposed, 12% came from sago starch. If given an extension of the decomposition time it will definitely be completely decomposed by water, similar research results are reported.²² When compared with the rate of thermoplastic degradation, sago starch completely decomposes in about 120 days, meaning that the addition of polypropylene requires an additional 70 days to decompose the starch. The addition of polypropylene into sago starch thermoplastic has a negative effect on the rate of thermoplastic degradation of sago starch. This is due to the bond between sago starch thermoplastic and polypropylene so that the water medium as a decomposing agent takes time to release the bond. The trend of the chart shows no significant mass loss. This means that the thermoplastic which has reacted with polypropylene with the help of a compatibilizer is evenly dispersed (homogeneous) to form a polymer network.²³⁻²⁴

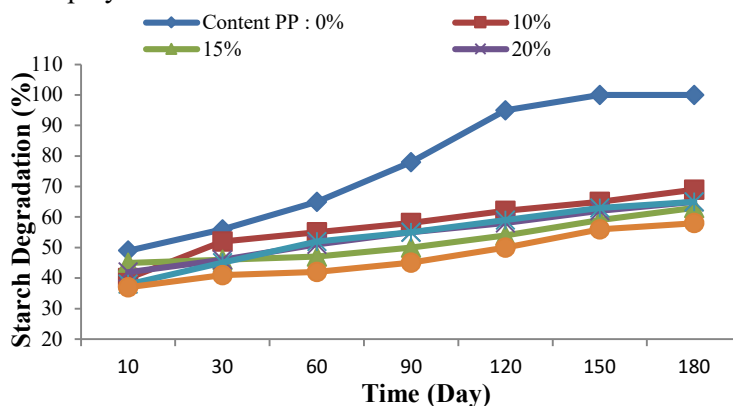


Fig.-2: The Effect of Time on the Starch Degradation in Freshwater

Degradation in Seawater Media

The graph in Fig.-3, it can be analyzed that the degradation rate of seawater media in the thermoplastic mixture of sago starch/polypropylene/compatibilizer until the 180th day was 72% at a concentration of 10% PP. This means that there is about 28% has not been degraded, and 18% comes from sago starch. Meanwhile, at a concentration of 30% polypropylene, 64% had been degraded or 36% had not been degraded, and 6% came from starch. When compared with the time required to decompose sago starch thermoplastic, the addition of polypropylene to sago starch thermoplastic requires more time to decompose all sago starch bound to polypropylene with the help of a compatibilizer. Judging by the trend on the chart, there is no significant mass loss. This means that polypropylene can react with TPPS with the help of a compatibilizer to form a polymer network that is spread evenly into the matrix. Closer results reported before.^{23,25}

Degradation in Soil Media

The degradation test by planting the sample in the soil can be analyzed through the graph in Fig.-4. The speed of the degradation rate until day 180 reaches 81% at a concentration of 10% polypropylene, or about 19% that has not been degraded, 9% of which comes from starch and 10% comes from of polypropylene. Meanwhile, at a concentration of 30% polypropylene, the degradation rate reached 69%, or about 31% which had not been decomposed, of which 1% came from sago starch (almost completely decomposed). When compared with the rate of degradation of sago starch thermoplastic in about 80 days, it can be completely decomposed, meaning that the addition of polypropylene into sago starch thermoplastic requires an additional 100 days. The addition of polypropylene into sago starch

thermoplastic has a negative effect on the rate of degradation of the composite. Microorganisms from soil media require more time to break the relationship between sago starch thermoplastic and polypropylene. When viewed from the trend on the graph, there is no significant mass loss (linear graph). This means that polypropylene reacts with sago starch thermoplastic with the help of a compatibilizer to form a polymer network that is evenly distributed (homogeneous). Closer results reported before.²⁵⁻²⁶

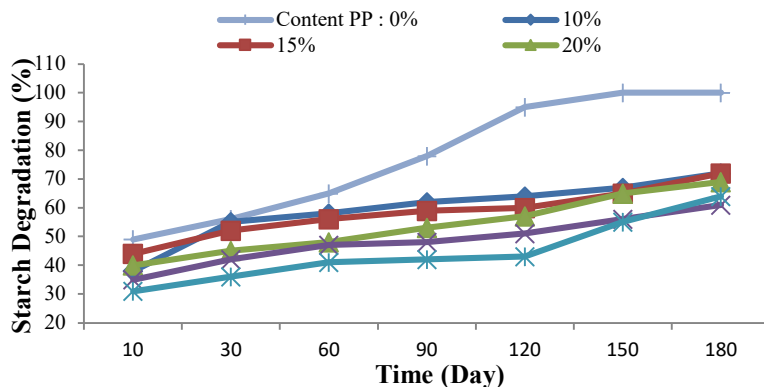


Fig.-3: The Effect of Time on the Starch Degradation in Seawater Media

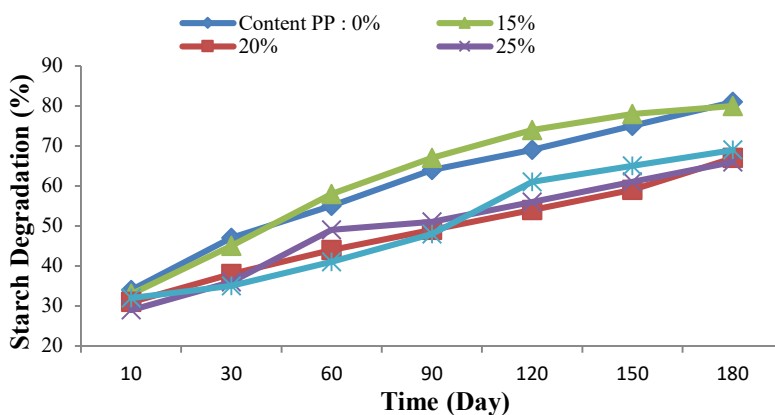


Fig.-4: The Effect of Time on the Starch Degradation in Soil Media

In general, samples are biodegradable in all three media. The effect of the concentration of polypropylene on the speed of degradation is that the higher the concentration of polypropylene, the faster the degradation process, this is because polypropylene cannot be degraded in a short time so only thermoplastic starch can degrade sago starch.

Morphology Analysis

Figure-5a, shows the bioplastic morphological with 250x magnification. Morphological characteristics showed that the surface of the bioplastic composition of sago starch and glycerol looked uniformly black, the addition of polypropylene with the help of a compatibilizer caused a large amount of white tissue, which was suspected to be polypropylene, to be spread evenly in the TPPS matrix (Fig.-5b). This even distribution demonstrates that the interfacial tension has decreased. when a compatibilizer is added, improving the interfacial adhesion. The findings of these observations can be used to confirm the findings of tests on the mechanical properties, which show that as polypropylene concentration increases, so does the tensile strength.^{18,27-28}

CONCLUSION

The addition of polypropylene to sago starch thermoplastic had a negative effect on the rate of degradation in fresh water, sea water, and soil media. This is due to the occurrence of thermoplastic bonds between sago starch and polypropylene with the help of a compatibilizer so that the media as a decomposer takes longer to release the bond when compared to the decomposition time of TPPS. The

surface morphology study of the samples, which demonstrated that polypropylene was uniformly dispersed in the sago starch thermoplastic, confirmed this. In addition, there is a shift in wave number which proves that there has been a reaction between polypropylene and sago starch thermoplastic.

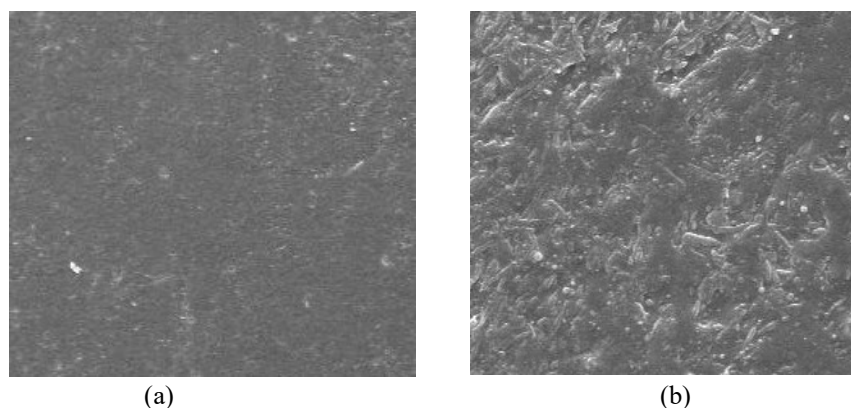


Fig.-5: Morphological Characteristics of (a). TPPS, (b). Bioplastic Composition 80% TPPS, 20% PP, and 10% PP-g-MA (based on TPPS Weight)

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CONFLICT OF INTERESTS

The author (s) declares that there is no conflict of interest in this research and manuscript.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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