IMPROVING MECHANICAL AND PHYSICAL PROPERTIES ON THERMOPLASTIC SAGO STARCH BLENDS WITH THE ADDITION OF POLYPROPYLENE

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ABSTRACT

This study aims to improve the mechanical and physical properties of the thermoplastic sago starch blends with the addition of polypropylene (PP). PP concentrations were given starting from 10, 15, 20, 25, and 30 percent (%), with the addition of a PP-g-MA compatibilizer as a coupling agent. From the mechanical properties, it is known that the tensile strength and elongation at break increase with increasing PP concentration, whereas Young's modulus decreases with increasing PP concentration. The Thermogravimetry Analysis (TGA) did not show a significant reduction in degradation on each temperature increase. From the morphological results, it could be seen that the PP is dispersed into the TPSS matrix with the help of this compatibilizer, evidenced by the absence of flocculants on the surface. The rate of degradation indicates that the addition of PP to the sago starch matrix could still be degraded by environmental elements such as freshwater, seawater, and soil burial.

Keywords: Bioplastic, Compatibilizer, Coupling Agent, Polypropylene

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INTRODUCTION

Plastic is a raw material that we often encounter around us. It's strong, light, durable and cheap, making this material widely applied to products such as packaging, household appliances, electronics, and others.¹ In the last half-century, plastic production has continued to increase with the increase in population from the estimated plastic production in 2018 to reach 360 million metric tons and about 18.5% market share in Europe.² Increasing plastic production must pay attention to the availability of fossil raw materials both today and in the future because the material is sourced from the earth's crust which cannot be renewed. and must also consider the effect of the waste generated on living things and the environment. Plastic waste in soil, marine and freshwater ecosystems causes severe problems for living things and can endanger human health.³⁻⁸ The current management of plastic waste is not perfect and there are around 5–13 million tons of plastic ending up in the oceans every year.⁹

Handling plastic waste for recycling requires special treatment such as separation, transportation, processing and remanufacturing.⁸ Usually, plastic waste that is burned emits carbon dioxide (CO₂) and other irritating gases into the atmosphere. However, if thrown in a landfill, it has a long decomposition time in the environment, even more than a century.³

To reduce plastic waste resulting from the use of products from synthetic polymers, researchers began to look for alternative materials to replace synthetic polymers with natural polymers such as cellulose, starch, lignin, and many others.¹⁰⁻¹³ The advantages of natural polymers are that they are inexpensive, widely available in nature, lighter, impact-resistant, and easy to implement. Besides, the most important thing is that it is biodegradable.¹⁴ to reduce the buildup in landfills. With the help of microorganisms, plastic molecules are broken down into simpler ones and finally converted into H₂O, CO₂, CH₄, and/or into new biomass substances that are non-toxic to humans and the environment.

The development of global bioplastic production has shown increasing growth over the last few years. However, bioplastics still represent a small market share.¹⁵ The development of starch-based bioplastics has drawbacks such as low tensile strength, stiffness, and high water absorption. Plasticization of starch is an effort to modify the structure of starch compounds to be more elastic by adding plasticizers such as glycerol, glycol, sorbitol, urea, formaldehyde, and sugar.¹⁶⁻²⁰ Some researchers report that the addition of a strength agent from synthetic polymers (plastics) can increase the tensile strength and make it more elastic.²¹⁻²⁵ However, to increase the interfacial adhesion between the two components of different polarities, it is necessary to add a compatibilizer to act as a liaison between hydrophilic starch and hydrophobic plastics.²⁶⁻³³

In this study, researchers added a thermoplastic polymer (PP) into thermoplastic starch (sago starch). The difference in polarity between hydrophilic and hydrophobic by adding PP-g-MA compatibilizer as a coupling agent.

EXPERIMENTAL

Material and Method

Sago starch was gained from Warna Jaya company, Parang brand, and water content, 14%. The Density of Polypropylene Pellet: 0.895gr/m³, Melt Flow rate 27gr / 10 minutes, Melt Point 130-157°C gained from PT. Chandra Asri, Indonesia.

TPSS Preparation

TPSS was processed by blending sago starch with a plasticizer (glycerol), added with water as solvent, as reported by R. Abdul Majid²⁶. Water content was less than 5%.

Compatibilizer Preparation

Compatibility was examined by reacting PP with Maleate Anhydride and Benzoyl Peroxide (BPO) as an initiator with the comparison of 88:9:3 (W / W) used internal mixer instrument at the temperature of 150°C and speed 100 rpm. The entire mixing process lasted 13 minutes.

TPSS / PP Blends Preparation

The mixing of TPSS with PP was the aim of this research. The process was conducted in the internal mixer as the following compositions:

Table -1: The Composition of TPSS-PP-Compatibilizer.

Sample	TPSS %	PP %	Compatibilizer based on TPSS %
1	100	0	0
2	90	10	9
3	85	15	8.5
4	80	20	8
5	75	25	7.5
6	70	30	7

Compression Molding

The sample was printed using manual hydraulic pressure compression at 150°C lasted for 15 minutes. All printed specimens were by ASTM D638 Type 1.

Tensile Strength

Tensile Strength was examined using Universal Brand Tensilon machine. The Chamber temperature was 25°C with a speed of 10mm/minute.

Spectroscopy of Fourier Transform Infrared

Infrared Spectroscopy of Fourier transformation at Micro Lab University of Lampung. Background scanning= 32, resolution=16, interval= 4000-650 cm⁻¹

Thermogravimetric Analysis (TGA)

The used Thermogravimetric Analysis was STA module, TGDTA channel 7300. Measurement committed at 7.73mg with heat rate $10^{\circ}\text{C} / \text{minute}$. The heating started at 30°C to 650°C . The Nitrogen rate was 50 ml/minute.

Morphology Test

Morphology test was examined to observe PP dispersion into TPSS matrix as interfacial adhesion tension, using Election Microscopy Scanning device (SEM) at UPTLTSIT Universitas Lampung with Mag=150x, WD=9.0mm, signal A= SE1, EHT = 15.0 kV.

Water absorption Test

The sample sheet with a dimension of 20mm x 20mm, thickness 3mm. The sample was then in distillation and dried up at 80% temperature for 12 hours, and then it was cooled down in a desiccator and weighed as initial weight. The sample was soaked in distilled water for 10 (ten) days at room temperature and reweighed to obtain post-soaking weight.

Biodegradability Test

The sample was tested for its biodegradability performance with the difference of condition control. Each sample was soaked in fresh water, seawater, and soil-burial, every 10, 20, and 30 days to be in observation.

RESULTS AND DISCUSSION

Mechanical and Physical Properties

Figure-1 Shows the continuous increase with the increasing PP concentration at tensile strength and Elongation at Break. This showed that the addition of PP has increased the mechanical nature of blended sago starch thermoplastic with the help of a compatibilizer. It is proven that the tensile strength and elongation at break of TPSS / PP blends, each increased from 1,73 N / mm² to be 5,51 N /mm² and 0.32% to be 1,05%. The observed increase was due to the good interfacial adhesion between two polymers and different polarity resulted in good tension transfer between matrix (TPSS) and dispersed phase (PP) evenly. In contrast, (young's modulus) decreased with the increasing PP concentration from 1321 to be 524 N/mm^{2,26}. Detailed data can be viewed in Table-2.

Fig.-1: Tensile Strength (TS), Elongation at Break (EB) and Young's Modulus (YM) for loading PP on Thermoplastic of Sago Starch

Table-2: Density, Tensile Strength (TS), Elongation at Break (EB) and Young's Modulus (YM) for loading PP on Thermoplastic of Sago Starch.

PP Loading (%)	Density	Tensile Strength	Elongation at Break	Young's Modulus
	gr/cm ³	(N/mm ²)	%	(N/mm ²)
0	1,17	1,73	0,00	0

10	1,34	3,89	0,32	1231
15	1,32	4,20	0,46	920
20	1,31	4,65	0,72	646
25	1,29	5,11	0,79	647
30	1,28	5,51	1,05	524

Fourier Transform Infrared (FTIR)

In the PP-g-MA spectrum, the characteristic peak was seen from Alkane (C-H) and Carbonyl (C=O) at wavenumbers of 2914 cm^{-1} and 1707 cm^{-1} . The addition of PP and PP-g-MA into the TPSS blend resulted in value change of wavenumbers from 3265 to 3287 cm^{-1} , this is the hydroxyl groups (OH) in the present together with peak 998 cm^{-1} as peak characteristic (C-O). In the spectrum of TPSS/PP compatibilized blends, The peak was formed at wavenumbers of 1695 cm^{-1} , identified as Esther groups formation resulted from the reaction of hydroxyl groups of TPSS and Anhydride groups of PP-g-MA. It can be observed in Fig.-2.

Fig.-2: The Spectrum of TPSS, PP-g-MA and TPSS/PP Compatibilized Blends

Thermogravimetric Analysis (TGA)

The first phase of degradation occurred at $200,3^{\circ}\text{C}$ with a mass loss of $11,8\%$. This was shown by water molecules evaporation together with a plasticizer (glycerol). In the second phase, degradation occurred at $350,8^{\circ}\text{C}$ with a mass loss of $60,7\%$. In the final phase, degradation occurred at $501,4^{\circ}\text{C}$ with a mass loss of $87,4\%$. From The TGA curve, clearly seen that degradation of TPSS / PP compatibilized blends does not show a significant reduction in each phase. This can be observed in Fig.-3.

Fig.-3: The Spectrum of Thermogravimetry Analysis TPSS/PE Compatibilized Blends

Morphology Test

In this study, an SEM test was committed to observing PP dispersion into the TPSS blend. In fig.4, TPSS/PP with the absence of compatibilizer showed the occurrence of flocculent (black circle) on the surface. In the concentration of 20 wt. %, PP was clearly seen, attempted to coagulate somewhere resulted from bad interfacial adhesion between TPSS and PP. This was due to the different polarities of the blends. Meanwhile, fig.5 is TPSS / PP compatibilized blends of SEM micrograph, showing us an even PP dispersion on the surface or a good occurrence of interfacial adhesion between TPSS and PP, with the help of PP-g-MA as compatibilizer. This observation supports the resulting test of the previous elongation at the break, where the presence of PP-g-MA could help the interaction of the two materials with different polarity increase.

Fig.-4: TPSS/PP Un-compatibilized Blends

Fig.-5: TPSS/PP Compatibilized Blends

Water Absorption Test

The water absorption index of various PP concentrations is presented in Fig.-6. The figure showed the water absorption toward TPSS and TPSS/PP compatibilized blends. In the TPSS blend, water absorption was bigger than TPSS /PP compatibilized blends of 121,3%, resulting from the hydrophilic property of starch which was responsible for water absorption in the blend. Meanwhile, the ability of water absorption in TPSS / PP compatibilized blends decreased to the increasing content of PP. There has already been a reaction between hydroxyl groups from sago starch and anhydride groups from PP-g-MA, as it decreased the water molecule interaction with hydroxyl starch groups.

Biodegradation Test

Characteristic of bioplastic is degradable. The decomposer, namely microorganism, environment, and time affected degradation rate ability. In this study, speed and decomposition were observed based on the environment (freshwater soaking, seawater, soil burial), and length of degradation. From fig. 7,8, and 9, it can generally be concluded that the percentage of sample weight reduction increased to the increasing time of degradation. The degraded material reported was starch, while PP was not degradable within a

short time. If sorted based on the degradability speed of the three environments, namely; first freshwater, seawater, and soil burial.

Fig.-6: Water Absorption Test

If the remaining freshwater soaked sample, be in observation until the 30th day which was not degraded yet in each PP concentration (10,15,20,25, and 30%) were 62,56,52,45 and 41%. Soaked in the seawater were 55,52,47,42, and 38% in the soil burial were 53,45, 38, 32, and 25%. Detailed data can be viewed in Table-3.

Fig.-7: Degradation in Freshwater

Fig.-8: Degradation in Sea Water

Fig.-9: Degradation in Soil burial

CONCLUSION

From the explanations above, it can be concluded that the addition of Polypropylene (PP) to Thermoplastic Sago Starch (TPSS) could increase the mechanical property, like tensile strength and elongation at break. Compatibilizer (PP-g-MA) as the coupling agent could help to react TPSS with PP. The spectrum of FTIR showed that hydroxyl groups from TPSS have been in reaction with anhydride groups, forming Esther groups. TPSS / PP compatibilized blends can be degradable in the three environments, namely freshwater, seawater, and soil burial. The figure of SEM TPSS/PP/Compatibilized blends, showing that PP dispersed evenly in the whole surface with the help of compatibility.

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