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Research Article

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Evaluation of Starch Bioplastic Films with Dialdehyde Starch and with Reinforcement of Graphene Oxide Nanoparticles

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Abstract

The necessity of bioplastic is very important in reducing plastic pollution. Researchers are interested in making starch-based bioplastic. However, the properties of starch are very low in nature. So, the improvement on properties of starch-based bioplastic is very essential. In this study, films were made using the sol-gel method—starch with dialdehyde starch solution and reinforced with graphene oxide by various weight ratios. The film was immersed in deionized water for 6 h to analyze the solubility. From this test, SRGO0.75 film had a solubility of 21.73%. One of the mechanical properties of the tensile test was recorded. The tensile strength and elongation of bioplastic is 4.31 MPa, 11.25% obtained for SRGO0.75 film. From the above results, X-ray diffraction (XRD) spectroscopy and Fourier transform infrared (FTIR) spectroscopy showed that the SRGO0.75 film had the best properties of bioplastic.

Keywords

Nanocomposite, Bioplastic, Dialdehyde starch, Graphene oxide, Nanoparticles

Introduction

Nowadays, the usage of nonbiodegradable synthetic plastics is increasing. It creates heavy land pollution by using packaging products [1-5]. To clean the nonbiodegradable plastics from the earth is very important. Due to this reason, many researchers from various countries are doing research to develop starch-based bioplastics. Starch is the most affordable, easy to film, and it takes less effort to process polymer to make biodegradable bioplastic [6, 7]. Modified starch enhanced the mechanical property and biodegradability of bioplastic. The addition of dialdehyde starch has improved the hydrophobicity. Starch-based bioplastics are mostly made from edible cassava starch. It creates a lacking in the food chain.

Starch is one of the abundantly available natural polymers and is easily extracted from plant sources. Starch-based bioplastics are easily biodegradable and blended with chemicals. Generally, repairing of physical flaws and removal of functional groups are done by graphene oxide. Compared to starch-based bioplastic, starch with graphene oxide bioplastic had the best water barrier property. Graphene oxide had good dispersibility in water and contained starch. This research used starch with dialdehyde starch solution and reinforced with graphene oxide with various quantities (0.25, .050, 0.75, and 1%). The tensile strength, XRD, FTIR, and water solubility were analyzed.

Materials and Method

Materials

Starch of corn was bought in the local market, and the preparation of dialdehyde starch was established on the stated work. Graphene oxide, acetic acid, glycerol, and deionized water were purchased from SRL Chemicals, Chennai. The samples code is mentioned in table 1.

Bioplastic production

Bioplastic was prepared by the sol-gel method. The bioplastic was prepared by as following method: 10 g of starch was taken in a beaker, already prepared dialdehyde starch solution was added to the beaker, graphene oxide (wt.% of starch mentioned in table 1) was added to the starch, 8 g of glycerol added to the solution, 200 ml of deionized water was added in the beaker, The method is presented in the figure 1.

Table 1: Sample code for the composition.

Sample code	Starch (g)	Glycerol (g)	Acetic acid (g)	Graphene oxide (wt.% of starch)	Dialdehyde starch solution
Starch	10	8	14	0	10
SRGO0.25	10	8	14	0.25	10
SRGO0.50	10	8	14	0.50	10
SRGO0.75	10	8	14	0.75	10
SRGO1	10	8	14	1	10

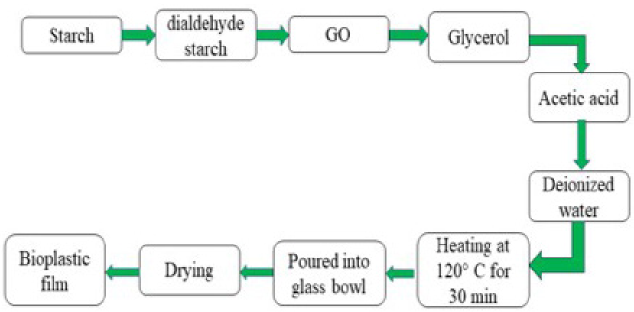

Figure 1: Preparation of bioplastic using starch and graphene oxide.

Methodology

Tensile test

The specimen for tensile test was prepared by length and width as 100 mm x 15 mm. It was tested by a universal micro-tensile testing machine (Instron Machine-Series 3369). The loading fixture was manufactured separately according to the machine's specifications. ASTM D882-02 successfully did the test.

XRD

The prepared starch and graphene-reinforced bioplastics were investigated through XRD at the angle 2θ = 10° - 45° using an X-ray diffractometer.

FTIR

FTIR of starch, SRGO0.25, SRGO0.50, and SRGO0.75 biobased films were investigated by the infrared spectrometer in the 4000 cm^{-1} to 500 cm^{-1} range.

Water solubility

The bioplastic films were prepared in 3 cm x 3 cm for solubility. The films were immersed in deionized water for 6 h. The initial weight was measured after drying, and the final weight was measured after solubility. The solubility was measured by equation 1.

$$\text{Solubility of bioplastic film } (\%) = \frac{W_o - W_i}{W_o} \text{ x } 100 \qquad (1)$$

Results and Discussion

Tensile strength

The prepared bioplastic of starch with dialdehyde starch solution based and the addition of graphene oxide with the same solution has the ultimate tensile strength between 1.54 MPa to 3.53 MPa. The tensile strength increased while adding the graphene oxide and the starch solution. The tensile strength of bioplastics is recorded as 1.54 MPa, 2.63 MPa, 3.01 MPa, 4.31 MPa, and 2.15 MPa for starch, SRGO0.25, SRGO0.50, SRGO0.75, and SRGO1, respectively. The mechanical properties gradually increased while increasing the percentage of graphene oxide. The ultimate tensile strength increased up to adding the 0.75 wt.% of graphene oxide in starch solution. The tensile strength was decreased when adding 1% of graphene oxide to the starch solution. The bioplastic film of 0.75 wt.% graphene oxide in SRGO0.75 nanocomposite film recorded the best tensile strength.

The elongation of bioplastics is recorded as 54.61%, 20.31%, 18.62%, 23.14%, and 11.25% for starch, SRGO0.25, SRGO0.50, SRGO0.75, and SRGO1, respectively. Among these, the maximum elongation was monitored for the starch (Pure starch with dialdehyde starch solution) based bioplastic. While adding the graphene oxide to the starch solution, the elongation varied. The maximum elongation is 54.61% has been recorded. The tensile strength and elongation chart is shown in figure 2.

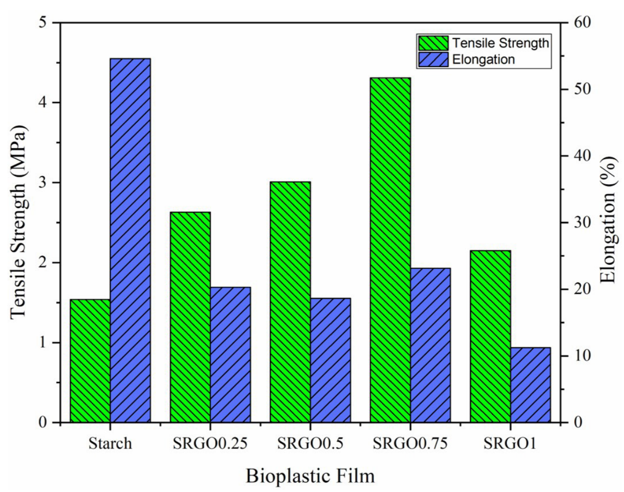

Figure 2: Tensile strength of starch, SRGO0.25, SRGO0.50, SRGO0.75, and SRGO1.

XRD

XRD pattern of starch, SRGO0.25, SRGO0.50, and SRGO0.75 is shown in figure 3. Starch displays three distinct peaks in its XRD pattern. The initial peak, observed at 22.98°, is a recognizing feature of the B-type polymorphs typically found in tuber starch. The second peak at 15.0° correlates with A-type polymorphs, mainly correlated with cereal starch. Lastly, the third peak, at 17.47°, is an attribute of polymorphs of A- and B-type [8]. The recognition XRD broad diffraction peaks of the graphene oxide were located at 2θ = 12.98° and 12.44°. The existence of oxygen functional groups and water molecules in the structure of carbon layer raises the distance between fields in graphene oxide.

FTIR

FTIR of starch, SRGO0.25, SRGO0.50, and SRGO0.75 are shown in figure 4. Starch has a broad peak observed at 3387.22 $cm^{-1,}$ related to O-H groups. The absorption peak observed at 1643.17 cm^{-1} is related to the C-O group. The C-H stretching is observed at 2901.34 cm^{-1}. The peaks of SRGO0.75 is observed at 2921.05 cm^{-1}, which is attributed to stretching vibrations of C-H. The next peak was observed at 1673.85 cm^{-1}, attributed to carboxyl groups. The C-O-H group was identified at 1397.67 cm^{-1}, and the stretching vibrations of C-O were identified at 1049.88 cm^{-1}. This confirms that constant and strong correlations were observed in the system. It confirms that the matrix and reinforcement phases are formed by hydrogen bonds by earlier studies.

Water solubility

The presence of hydrophilic compounds in bioplastic films is indicated by water solubility. Starch-based bioplastic films had a high-water solubility in nature.

Films containing glycerol are less soluble due to the higher degree of intercalation attractions and crosslinks in the matrix leading to a lower ability to interact with water. From this experiment, SRGO0.75 had less solubility (21.73%) in water due to the graphene oxide. Starch, SRGO0.25, and SRGO0.50 films had a solubility of (50%), 33.33%, and 48.38%, respectively. The water solubility of starch, SRGO0.25, SRGO0.50, and SRGO0.75 are shown in the figure 5.

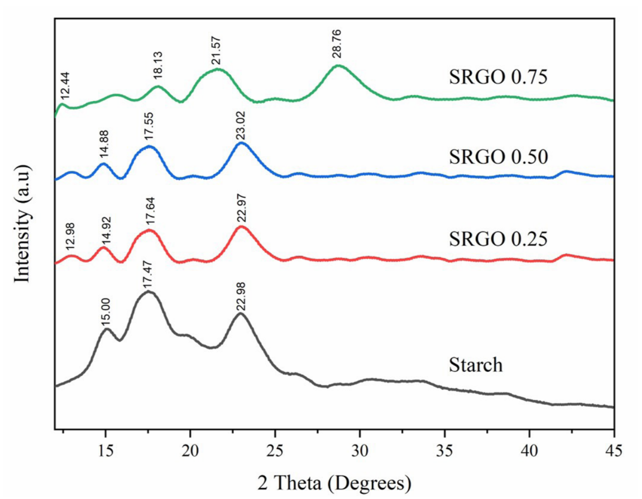

Figure 3: XRD of starch, SRGO0.25, SRGO0.50, and SRGO0.75.

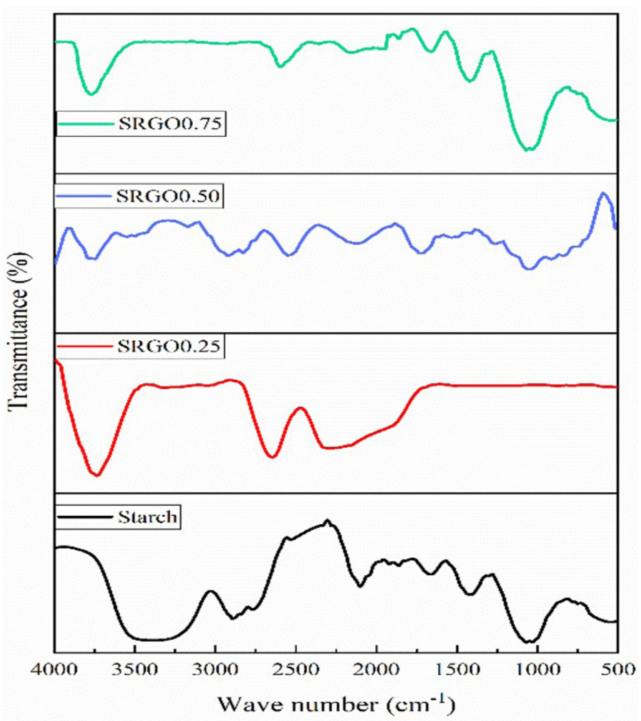

Figure 4: FTIR of starch, SRGO0.25, SRGO0.50, and SRGO0.75.

Conclusion

This study used the sol-gel method to prepare starch with dialdehyde starch solution-based bioplastic film reinforced by graphene oxide. FTIR confirmed that the reinforcement (graphene oxide) was successfully blended with the matrix (starch) through the hydrogen bond collaborations, which confirmed the creation of a consistent combination matrix. The SRGO0.75 nanocomposite bioplastic film had a tensile strength of 4.31 MPa and elongation of 23.14%, which was the best result compared to other films. But elongation was decreased compared to starch with dialdehyde starch solution-based bioplastic film. The water solubility of the nanocomposite films was improved. From these results, our research confirmed that these bioplastic fills with improved properties are suitable for packaging industries.

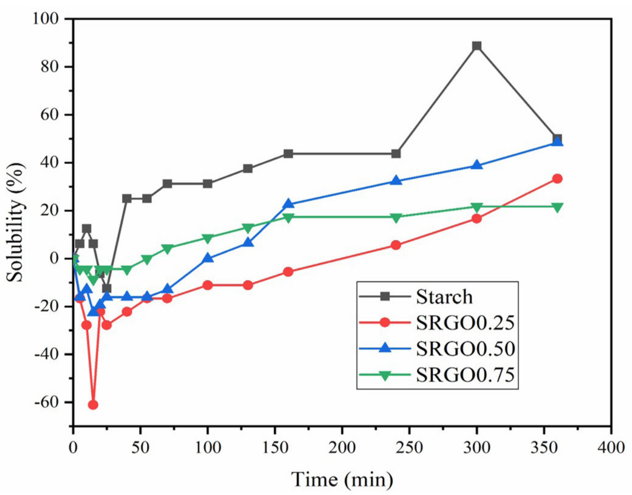

Figure 5: Water solubility of starch, SRGO0.25, SRGO0.50, and SRGO0.75.

Acknowledgements

None.

Conflict of Interest

None.

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