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Original Research Paper

Effect of Plasticizer on Mechanical and Moisture Absorption Properties of Eco-friendly Corn Starch-based Bioplastic

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ABSTRACT

Plastics are extensively used in every facet of our lives. But at the same time, petroleum-based plastics have hazardous effect on the environment. Bioplastics, made from biological materials represent an effective solution to this problem. Starch based bioplastics account for the major portion of the bioplastic market. In the manufacture of starch-based thermoplastics, plasticizers are added to the polymer matrix to enhance its flexibility. This study examined the effect of glycerol as plasticizer on the mechanical and moisture absorption properties of starch-based bioplastics. Varying amount of glycerol was used to produce bioplastics and then their tensile strength, density and moisture content were determined. It was observed that, there is a decreasing trend in tensile strength and moisture content with increase in the amount of glycerol, whereas, this trend gets inverted in case of density.

INTRODUCTION

Plastics are ubiquitous in daily lives and widely used for packaging and other applications because of their several advantages compared to other materials. Over the past two decades, polymers from renewable resources have gained attention due to the environmental concerns that mount over the disposal of synthetic polymers (Zhou 2012). The biopolymer industry is in its early years but is developing rapidly. Bioplastics cover approximately 10-15% of the total plastics market and will increase its market share to 25-30% by 2020 (Helmut Kaiser Consultancy home page).

Bioplastics have two-thirds less harmful greenhouse emissions, including carbon and sulphur oxides, during their production. This means significantly less air pollution and less of an effect on global warming (Reddy et al. 2013). They do not release any toxic chemical and by-product during the breakdown and decay period. Bioplastics degrade and breakdown into CO_2, water and biomass at the same rate as cellulose (paper) and these are absorbed back into the earth.

Starch, which is an inexpensive biodegradable polymer produced in abundance from many renewable sources is one of the most promising candidates for fabrication of bioplastics (Huangu et al. 2004). Starch based bioplastics are developed from wheat, corn, rice, potatoes, barley and sorghum.

Natural starch exhibits a pronounced macromolecular structure which is suitable for bioplastic synthesis (Yunos & Rahman 2011). The native starch can be transformed to TPS by several methods which destroy its semicrystalline granular structure (Saiah et al. 2012). The transformation of granular starch into TPS is influenced by the processing conditions such as temperature and plasticizer content (van Soest et al. 1996). Water is the most commonly used plasticizer in starch processing but it results in poor mechanical strength such as brittleness due to recrystallization. Therefore, other non-volatile plasticizers that are used in synthesis of starch based materials include polyhydric alcohols such as glycerol, glucose, ethylene glycol and amides such as urea formamide, acetamide, etc. (Shogren 1993, Yu et al. 1998).

Plasticizers as polymer additives serve to decrease the intermolecular forces between the polymer chains, resulting in a softened and flexible polymeric matrix. They increase the polymer's elongation and enhance processibility by lowering the melting and softening points and viscosity of the melts (Benaniba & Massardier-Nageotte 2010). The International Union of Pure and Applied Chemistry (IUPAC) defines plasticizer as a "substance or material incorporated in a material (usually a plastic or an elastomer) to increase its flexibility, workability or distensibility" (Vieira et al. 2011). Taking into consideration that effective plasticization is dependent on chemical structure of the plasticizer, its compatibility and miscibility with the polymer, molecular weight and concentration of plasticizer, different polymers require different plasticizers (Sothornvit & Krochta 2005).

In the current study bioplastics were developed from

Fig. 1: Bioplastics containing varying amounts of glycerol.

corn starch using varying amount of glycerol, which works as plasticizer. Further, the mechanical and moisture absorption properties of those bioplastic samples were determined.

MATERIALS AND METHODS

Six bioplastic samples were made using corn starch, acetic acid and varying amount of glycerol.

Materials: Biopolymer (corn starch), glycerol (glycerin), de-ionized water, 5% acetic acid solution (vinegar)

Synthesis of bioplastic: 5g of corn starch was thoroughly mixed with 30 mL of distilled water, 2mL of acetic acid and varying amounts of glycerol (1mL, 2mL, 3mL, 4mL, 5mL, 6mL). The mixture was heated to paste-like form on hot plate at a temperature of 150°C for 15 minutes with continuous stirring resulting in a viscous mixture. After the mixture turned clear again, it was spread uniformly with the help of glass rod on an aluminium sheet and was allowed to dry at room temperature for few days. After drying, each of the bioplastic samples was cut in strips of size (6 cm × 1.5 cm) and their average thickness was determined. Further, the samples were tested for different properties like tensile strength, hardness and moisture absorption capacity.

Tensile test: The average thickness of all the samples was measured using micrometer. Further, tensile testing of the samples was performed by using a Tinius Olsen tensiometer with following specifications: a static load cell of 500 N, 1.5 mm/min crosshead speed and a gauge length of 30mm. The results are given in Table 1.

Density: Each of the prepared sample strips was weighed on an electronic balance and respective density of the samples were calculated as given in Table 2.

Weight change and moisture content analysis: Dry weight of all the samples was determined using an electronic balance. The bioplastic samples were then immersed in water for an interval of 10 minutes and were weighed again. The equation used to determine the moisture content was as follows:

$$\text{Moisture content} = \{(W_f - W_i) / W_i\} \times 100$$

Where, W_i = Initial weight of sample, W_f = Final weight of sample

RESULTS AND DISCUSSION

Tensile strength: The effect of adding glycerol on the tensile strength of bioplastic samples is shown in Fig. 2. Bioplastic containing 1mL glycerol has the maximum tensile strength of 14.561 kg/cm^2 (Table 1) and as the amount of glycerol is increased, the tensile strength goes on decreasing. The tensile strength of the samples decreased up to 87% approximately as the amount of glycerol increased from 1mL to 6mL. Thus, the addition of glycerol results in increased flexibility of bioplastics.

Density: The trend in variation of density of bioplastics containing different amount of glycerol is plotted in Fig. 3. As the amount of glycerol increased from 1mL to 3mL, the density decreased. With further addition of glycerol, there is a steep increase in density up to 5mL (0.1959 g/cm^3) beyond which, it decreases again. The trendline shows that there is a net increase in the density with increase in amount of glycerol.

Moisture content analysis: Fig. 4 indicates that bioplastics

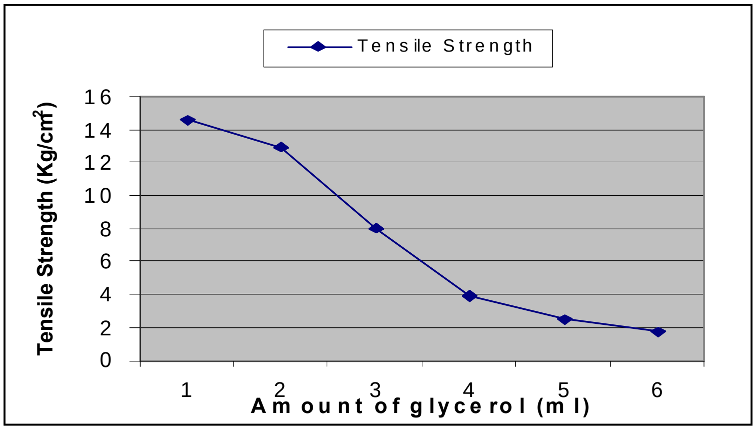

Fig. 2. Tensile strength of bioplastic samples having different amounts of glycerol.

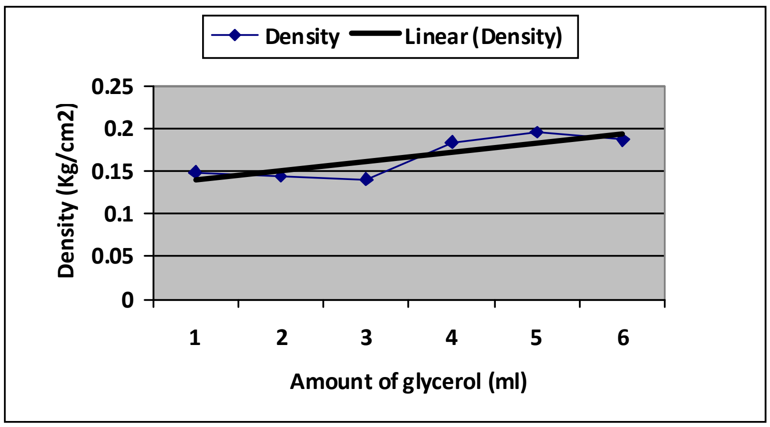

Fig. 3: Density of bioplastic samples having different amounts of glycerol.

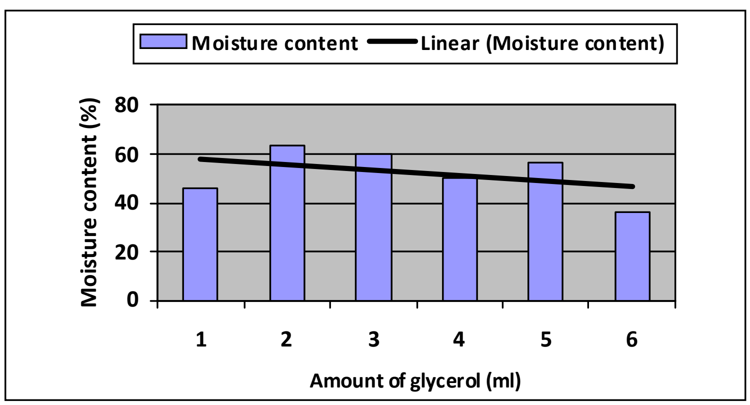

Fig. 4: Moisture content of bioplastic samples having different amounts of glycerol.

containing glycerol absorb moisture over time which is likely due to the hydrophilic nature of glycerol. The bioplastic sample containing 2mL of glycerol shows maximum gain in the absorption content of 63.15% in the same interval of time. This could render this plastic unsuitable for most applications as the resulting water absorption would alter the properties of the plastic, reducing its tensile strength. However, the trendline indicates that with addition of glycerol, moisture absorption capacity of bioplastic decreases.

Table 1: Average thickness and tensile strength of different bioplastic samples.

S. No.	Sample	Glycerol (mL)	Average thickness (mm)	Tensile strength (kg/cm^2)
1	BP 1	1	0.800	14.561
2	BP 2	2	0.617	12.950
3	BP 3	3	0.508	7.984
4	BP 4	4	0.744	3.874
5	BP 5	5	0.694	2.447
6	BP 6	6	0.965	1.753

Table 2: Density of different bioplastic samples.

S. No.	Sample	Weight (g)	Mass (g)	Thickness (cm)	Volume (cm^3)	Density (g/cm^3)
1	BP 1	1.067	0.1097	0.0817	0.7353	0.1491
2	BP 2	0.785	0.0801	0.0617	0.5553	0.1442
3	BP 3	0.713	0.0727	0.0575	0.5175	0.1404
4	BP 4	1.208	0.1232	0.0744	0.6696	0.1839
5	BP 5	1.200	0.1224	0.0694	0.6246	0.1959
6	BP 6	1.170	0.1193	0.0965	0.8685	0.1373

Table 3: Moisture absorbed by different bioplastic samples.

S. No.	Sample	Initial weight (g)	Final weight (g)	Moisture absorbed (%)
1	BP 1	0.24	0.35	45.83
2	BP 2	0.19	0.31	63.15
3	BP 3	0.15	0.24	60.00
4	BP 4	0.26	0.39	50.00
5	BP 5	0.23	0.36	56.52
6	BP 6	0.25	0.34	36.00

CONCLUSIONS

When comparing the amounts of plasticizer used in fabricating bioplastics from starch, it was found that the sample containing 2mL glycerol provided the best mechanical properties like low density and high tensile strength. However, it demonstrated the maximum moisture absorption capacity among all the samples which makes it unsuitable for many applications. One area of interest that requires further research is the continued modification of the starch based biopastics by altering the percentages of each component used as well as using different materials to make bioplastics in order to reach the optimum properties for other applications. As for the aspect of moisture content, it would be beneficial to examine the possible uses of other materials that would limit the amount of moisture content change that would occur with starch based plastics as it has been demonstrated that this area has a significant effect on the overall properties of the plastic.

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