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Keywords: *Plastic pollution, Bioplastic, Starch, Sustainability, Alternative.*

Introduction

Plastic pollution is one of the most critical environmental challenges of the 21st century. Conventional plastics which are derived from petroleum might be durable and widely used but their resistance to decomposition leads to long-term environmental damage. Millions of tons of plastics are thrown in landfills and oceans every year, with microplastics infiltrating ecosystems, harming wildlife and affecting human health. These issues highlight the urgency for a sustainable alternative to common plastic.

Bioplastics are plastic-like materials made from biodegradable natural materials. In this research, bioplastics made from starch are investigated. These bioplastics are biodegradable and easy to produce, while they have similar properties to basic plastic. Starch derived from potatoes, corn and other sources is a polymer. When combined with plasticizers such as glycerol, and heated, it undergoes gelatinization and forms a polymer material similar to plastic in physical properties.

The theoretical background of this process is as follows: Starch is a natural polymer composed of two main polysaccharides, amylose (with linear chains) and amylopectin (with branched chains). When heated in the presence of water, starch absorbs moisture and undergoes the gelatinization process, where hydrogen bonds break allowing the chains to move freely. During this process, the plasticizer is added which inserts between these chains increasing flexibility. During the heating, excess water evaporates and the mix solidifies into a plastic material after it cools down.

Experiment and Results

In this experiment, three different starches were used to make bioplastic: Corn starch, potato starch, and tapioca starch (Figure 1). To prepare the bioplastics, glycerin, water, and white vinegar were all added to a beaker. The starch was added and the mixture was heated at medium temperature while stirring. After some time the mixture gradually thickened and became more transparent, which indicated the gelatinizing of the starch. The beaker was then removed from the heat and the mixture was placed on parchment paper to cool down and dry.

After several days, the bioplastics were fully dried. For each starch type, two bioplastic films were produced, one of approximately 1mm thickness, and one of 5mm. The scope of the experiment is to test different physical and mechanical properties of each sample. For each bioplastic, the following parameters were tested: Cooling time, transparency, water resistance, and stretchability.

Εικόνα 1. Bioplastics from different starches.

Cooling time

After each plastic was left to dry, the plastics were checked on every 6 hours. Expectedly, the thick layers took longer to dry than the thin ones. The cooling time is presented in Table 1. Furthermore, corn starch-based plastic took the shortest amount of time to dry, followed by potato starch-based plastic. The thick layer of the tapioca starch did not completely dry, even after several days.

Thickness (mm)	Corn	Potato	Tapioca
1	30	36	48
5	48	72	–

Πίνακας 1. Drying time of different bioplastics and thicknesses.

Transparency

To test the transparency of the bioplastic films qualitative and quantitative analyses were done. To qualitatively show the transparency, the plastics were placed on a color and a text chart.

To quantitatively test the transparency of each bioplastic, a lux meter app was used to measure the intensity of light that passes through the plastic from a light source (lamp). First, a measurement was taken of the light intensity without the plastic. After, the plastic was held up against the light source, and the intensity was measured again from the same distance.

Using the results the transparency percentage can be calculated using the following formula, where I is the intensity with the bioplastic held up against the light source and I_0 is the initial intensity of the source:

$$T = \frac{I}{I_0} \times 100\%$$

As seen in Table 2, the tapioca bioplastic presented the best transparency percentage (approximately 79%). It is important to note that all three transparency rates are very high, which is also qualitatively shown in the previous tests.

Sample	**Intensity (Lux)**	**Transparency (%)**
Initial	2020	–
Corn	1200	59.41
Potato	1490	73.76
Tapioca	1590	78.71

Πίνακας 2. Intensity and transparency measurements.

Water resistance

To test for water resistance, a sample of all three bioplastics was submerged in water and rubbed for 5 minutes. Afterwards, the thickness of the sample was measured to account for any losses.

As shown in Table 3, the corn and potato bioplastics showed great water resistance, since their thickness was not affected, showing they don't easily break down when in contact with water. The tapioca bioplastic presented a significant loss in thickness and even had some holes in it after the test.

Sample	**Thickness before (mm)**	**Thickness after (mm)**
Corn	1	1
Potato	1	1
Tapioca	1	0.6

Πίνακας 3. Measurement of decomposition in water.

Stretchability

A stretchability test was also conducted to show the durability of each sample. For the test, a line of 1cm was drawn on each sample with a marker. Then, the samples were stretched until tearing. Using video footage, the final length of the line was measured.

Stretchability was quantified as percent elongation at break, calculated from the change in length of a 1cm marker line drawn on each sample, using the following formula:

$$S = \frac{L - L_0}{L_0} \times 100\%$$

The results for the different samples are presented in Table 4. As shown by the experimental process, the potato and tapioca starches presented the best results for stretchability, or durability rates.

Sample	L_0 (cm)	L (cm)	Stretchability (%)
Corn	1	1.2	20
Potato	1	1.7	70
Tapioca	1	1.7	70

Πίνακας 4. Length and stretchability measurements.

Discussion

Out of the three starch-based bioplastics that were tested, the corn bioplastic had the least cooling time, while the tapioca bioplastic presented the best transparency percentage. Both corn and potato-based plastics presented great water resistance. The tapioca bioplastic however was not proven to be water resistant, which is a drawback for industrial use. Lastly, both potato and tapioca-based plastics presented remarkable durability when stretched.

With all the parameters that were tested taken into consideration, it is concluded that potato-based bioplastic is the most fit for consumer or industrial use.

Conclusions

Starch-based bioplastics are a sustainable and environmentally friendly alternative to common plastics. The materials required to produce bioplastics are abundant and affordable, while the production process is simple, quick, and cost-effective.

Most importantly, their durability and physical characteristics tested (stretchability, water resistance, transparency, etc.) combined with their short decomposition time make them accessible and suitable for several applications, from small scale educational purposes to industrial and consumer use. Although further optimization is still required to enhance industry needed qualities, these bioplastics offer a viable and sustainable alternative to common plastics, thus creating a solution to reduce global waste and promote an eco-conscious economy.

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