Ecofriendly Polymeric Material: Paving The Way For Circular Bio-Economy

Problem

Today, petroleum-based plastics is a major part of our everyday life. Their chemical and insulating properties complemented by the low cost of manufacturing has made us dependent on them. On the downside, they are resistant to microbial degradation and hence continue to accumulate over a long period. Up to 12 million tons of plastic debris is entering the ocean every year, which calls it a "plastic crisis." In today's world, plastic waste is everywhere, they are in the air, soil, and in the water. It's very important that we find an alternative to conventional plastic that will help maintain our lifestyle while eliminating or reducing the impact on the environment. Plastics made from biomass (organic resources) could be the solution to the issue at hand because of their biodegradability.

Engineering Goal

The goal of the experiment is to enhance biodegradability and water resistance strength of the "bio-fiber plastic" prototype developed in last year's project by adding chitosan, a compound derived from crustacean shell waste.

Materials and Method

The chitosan sources identified for this research are shellfish exoskeleton. Starch based bio-fiber plastic samples from last year's research is used as a control to contrast the performance of the prototype developed in this year's research. Key Materials and their Role:

- Starch: Rice acts as biopolymer. Base ingredient and acts as bio-polymer.
- Fiber: Recycled office paper are used to enhance the tensile strength.
- Chitosan: Chitosan helps to enhance the bio-degradability and water resistance strength. As the Tensile strength of Chitosan reinforced prototype increased, it had a minor reduction in the flexibility of the prototype.

Biodegradability

Biodegradability is calculated by calculating the "loss of weight" of the bioplastic sample over a specific period of time when buried in compost soil at room temperature. Flexibility will be tested by folding the bioplastic samples at 180 degrees and placing a weight (100 grams) repeatedly until it shows signs of a crease.

Starch: Starch is an abundantly available biomass which can be a substitute for synthetic polymers. Starch is the complex carbohydrate that exists in many foods, including grains, vegetables, and fruits. Starch consists of two repeating glucose subunits: amylose [linear] and amylopectin [branched]. The ratio of Amylose and Amylopectin varies in different starch sources resulting in bioplastic of varied mechanical strength. Starch from Rice has the highest amylose content compare to a control starch sample in this research, making it an ideal candidate for starch-based bioplastic. Even though starch-based bioplastic exhibits similar characteristics as conventional plastics, they still lack in tensile strength and water resistance. In order to improve these properties, other biodegradable polymers can be blended to minimize the limitations of pure starch-based plastics.

Project Idea

Cellulose: Cellulose is a complex carbohydrate, which contributes to the basic structural component of plants cell walls. About 33 percent of all vegetable matter is cellulose making it the most abundant of all naturally occurring organic compounds. The chemical links between the individual glucose subunits have a strong tendency to aggregate to highly ordered structural entities resulting in strong mechanical properties. The strong mechanical property of Cellulose makes it a suitable choice as a co-polymer of starch-based bioplastic to improve tensile strength. Paper products manufactured from trees, typically contains 90-95% cellulose fibers. Paper wasteage facts show that 85 million tons of paper waste are created each year.

Chitosan: Chitosan is a derivative of chitin, obtained by deacetylation of chitin. Chitin is the structural material of crustaceans, insects, and fungi, and is the second most abundant biopolymer after cellulose on earth. Deacetylation process improves the reactivity and solubility nature of Chitin. Chitosan is a linear polysaccharide with similar molecular structure as cellulose, however the hydroxyl group in the cellulose is replaced with acetyl amine group resulting in a stronger hydrogen bond making chitin stronger than cellulose. The hydrophobic and biodegradation nature of chitosan makes it a suitable choice as a co-polymer of starch-based bioplastic to improve water resistance and biodegradable properties. The food industry generates 6 million to 8 million metric tons of crab, shrimp and lobster shell waste every year. Depending on the country, those claws and legs largely get dumped back into the ocean or into landfills.

Results & Discussion

The Water absorption test data trend indicates that Chitosan reinforced bioplastic samples had lower water intake capability than the bioplastic without Chitosan. The decrease in water absorption can be attributed to the hydrophilic nature of Chitosan which helps in the hydrophobic nature of the starch molecules. Another factor that has decreased the water intake is due to the hydrogen bonding between the starch and Chitosan which prevents water molecules from penetrating through the prototype.

The biodegradability test data trend indicates that addition of Chitosan reduced the biodegradability as compared to the control prototype. The decrease in the biodegradability can be attributed to the fact that biodegradability of any material decreases with decrease in water intake capability. Anti-microbial nature of chitosan could be an equally contributing factor to the decrease in the biodegradability rate.

The Tensile strength test data trend indicates that with the addition of Chitosan tensile strength has improved as compared to the bioplastic without Chitosan. The increase in the tensile strength can be attributed to the stronger hydrogen bond between the bordering polymers.

The flexibility test data indicates that Chitosan reinforced bioplastic prototype reduced the flexibility as compared to the control prototype. The decrease in the flexibility can be attributed to the fact that flexibility of any material decreases with increase in their tensile strength. As the Tensile strength of Chitosan reinforced prototype increased, it had a minor reduction in the flexibility of the prototype.

Conclusion

The engineering goal was fairly achieved. The Chitosan upycycled from the ocean or into landfills improved the Tensile strength (~50%) while diminishing the flexibility by a moderate amount. Chitosan infusion to the bioplastic improved the water resistance (~40%) capability with a minor impact on the bio-degradation rate. It is also observed that the amount of Chitosan has a positive correlation to the change in Tensile strength and water resistance. Based on the above, it can be concluded that by varying the ratio of Chitosan, bioplastic of different water resistance, biodegradation rate, tensile strength and flexibility can be produced to meet the different needs. In addition, the project paves the way for a circular economy by recycling waste and extending its useful life as new products. This transition of treating waste as a untapped resource is an important step towards achieving long-term sustainability and conserving resources.

Future Enhancements

For bioplastics to be a true eco-friendly alternative to conventional plastics, production must not be dependent on potential food sources. Further research can be conducted to reduce the use of potential food sources (starch) by identifying non-food sources to produce second-generation bioplastics.

Bibliography