Wheatgrass Dyed Biopolymer for manufacturing a low-cost Bioplastic

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***Abstract*: On a historical scale, the rapid expansion of plastic production was a 21st-century event. Plastics' low cost and versatility have opened the door to a wide range of uses. Bioplastics were being created because plastics are non-biodegradable and have been discovered to have hazardous impacts on humans, animals, and the environment. Bioplastics are biodegradable and can be made from renewable biological sources. Bioplastics are used in the same ways as plastics. Although there are various sources of bioplastics, such as plants, animals, and microbial sources, they all have drawbacks, such as a lack of high biomass and cultivation challenges. Wheatgrass, in such instances, can serve as one of the dyes in bioplastics alternatives due to its large biomass, ability to grow in a variety of conditions, and cultivation in a natural environment, as opposed to other microbiological sources that require a particular environment for cultivation. Wheatgrass is economically effective, has a low influence on the food chain, and is chemical-free, in addition to the benefits listed above. Dyed biopolymers are frequently costly or need a significant amount of resources to process. The purpose of this research is to see how efficient wheatgrass is as a dye for biodegradable biopolymers (a plant-based bioplastic made from a combination of vinegar and corn starch and animal-based bioplastic made from gelatine). The findings revealed no significant differences, indicating that wheatgrass is an exceptionally efficient dye. A test was undertaken to examine if the dyed biopolymer degrades, and it was discovered that the already existing biopolymer had boosted strength. The biopolymer's tensile strength and biodegradability were tested before and after the dye was added. The bioplastic was also made hydrophobic using an iron chloride composite and results were obtained to see if wheatgrass interfered in this process. Bioplastics are still in their infancy in terms of application, but they hold a lot of promise for the future development of sustainable plastics and the current study focuses on developing a natural, biodegradable dye for these biopolymers and evaluating their efficacy.**

***Index Terms*: Bioplastics, Biopolymer, Wheatgrass, Plastics, Biomass, Iron Chloride, Biodegradable, Hydrophobic**

I. INTRODUCTION

The majority of plastics produced and used today are petrochemical-based plastics. They have good mechanical properties: effective barrier properties, good stiffness and high tensile and tear strength. Major drawbacks to these plastics are the extremely low MVTR, non-biodegradability, etc. which leads to environmental impacts [1]. Even economically, these plastics are low cost, durable, light and easily mouldable so a majority of plastics today are petrochemical-based. Since the 1950s, more than 8.3 billion tonnes of plastic have been produced. Of these only 9% has been recycled and the remaining 91% have been burnt (12%) or ended up in landfills or the natural environment (79%) [2]. Burning plastics causes emissions of toxic gases like dioxins, furans, mercury and polychlorinated biphenyls that pose a threat to vegetation, human and animal health [3]. Plastics also naturally degrade in the presence of UV light in the natural environment at a rate of 253 g CO_2e per kg plastic [4] to be produced. In 2020 alone 367 million plastics were used in the world [5]. Plastic has led to soil pollution, air pollution and water pollution. It is estimated to affect around 700 marine species and yearly causes the death of 100,000 marine animals [6]. Plastics are also made of toxic and carcinogenic components. An average human consumes 250 g of plastic per year which over time will be fatal [7, 8]. They also cause disturbances in thyroid hormone levels. (taken from [1,9]) To reduce these problems recycling of plastics is looked on favourably. Plasticizers are added to a plastic to make it softer and more flexible, to increase its plasticity, to decrease its viscosity, or to decrease friction during its handling in manufacture. Additives such as phthalate plasticizers and brominated flame retardants are used in the production of plastics (taken from [1,10, 11, 12, 13]) so suitable alternatives are required.

Bioplastics are an eco-friendly solution to plastics, specifically biodegradable bioplastics or those that can be thermally degraded with ease. Products obtained from agriculture are used as bioplastics. Life cycle assessment suggests that their overall CO2 emission is much lesser compared to petrochemical plastics. Greenhouse emissions for starch polymer and PLA pellets, the most commonly used bioplastics (18.7% of global bioplastics each [14]) are about 20%-80% and 15-20% less than polyethene respectively [15]. These plastics are also biodegradable and are not made of carcinogenic materials (except some plasticizers). They are usually hydrophilic by nature and have a lot of medical potential uses. They can be decorated or bound with a compound to make them hydrophobic and thus more versatile in their uses compared to petrochemical bioplastics which are just hydrophobic.

Natural dye for bioplastics is something still being looked into properly. This study explores the use of the fast-growing wheatgrass as a natural, biodegradable dye for the plant-based bioplastic made using starch and vinegar and the animal-based bioplastic made using gelatine. Wheatgrass refers to the young grass of the common wheat plant, *Triticum aestivum*. Wheatgrass is readily available, takes less time to grow and requires less processing required. Wheatgrass can grow in 6-10 days. [16] To examine the change in mechanical and chemical properties of the biopolymer on the addition of wheatgrass we collected results from three tests: tensile strength test, biodegradability test and hydrophobic nanocomposite test. A dye that shows no change or shows an increment in the properties compared to the control experiment would be deemed as a successful dye and the opposite would not.

The importance of the nanocomposite hydrophobic test is that a very crucial advantage of bioplastics is its versatility: it can be both hydrophilic and made hydrophobic. By making the wheatgrass bioplastic hydrophobic we can confirm that wheatgrass is not affecting the chemical properties of the biopolymer, and thus the bioplastic is retaining its versatility.

II. Materials and Methods

Wheatgrass

Wheatgrass was grown from wheat seeds purchased from nurserylive. The seeds were soaked for 8-12 hrs. Post soaking, the sprouting of seeds started. The seeds were watered regularly 2 times a day and excess water was drained to ensure proper sprouting. Within 6 to 10 days the seeds sprouted into plants. When the grass grew 1-2 inches tall it was moved to a well-lit condition. When the grass reached a height of 4-12 inches it was harvested by cutting them just above the medium with the help of scissors.

All the reagents used were of analytical grade and were used without further purification. Iron (III) chloride (96.0%), Iron (II) chloride (96.0%), Starch, Acetic acid and Ammonia solution (30wt %), were purchased from Merck. Standard solutions of dye were prepared in double-distilled water. Distilled water was used throughout the experiments.

Plant-based bioplastic

Wheatgrass was thoroughly mixed with 10 ml of water to create a saturated solution. This solution was filtered and mixed with 50 ml of water. 10g of corn-starch, 4 ml of acetic acid and 4g of glycerine was mixed in the solution. The weights were measured using a gms scale and liquid readings were measured using a burette. In the control experiment, 10g of glycerine, 4 ml of acetic acid and 4g of glycerine was mixed in 60 ml of water. The resulting mixture in both cases was heated to a paste-like form on a hot plate at a temperature of 150ºC for 15 mins with continuous stirring, leading to the formation of a viscous mixture. The quantities used have been mentioned clearly in Table 1. After the mixture turned clear again, it was spread uniformly with the help of a glass rod on an aluminium sheet and was allowed to dry at room temperature for 3 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. The experiment was repeated to form 5 samples each of the control and wheatgrass dyed bioplastic. Further, the samples were tested for different properties like tensile strength and biodegradability. [17, 18]

Acetic Acid (ml)	Cornstarch (g)	Glycerine (g)	Wheatgrass liquid (ml)	Water (ml)	Total liquid (ml)
4	10.0	4.0	10	50	60
4	10.0	4.0	0	60	60

Table 1

Animal-based bioplastic

Wheatgrass was thoroughly mixed with 10 ml of water to create a saturated solution. This solution was filtered and mixed with 50 ml of water. 12g of gelatine and 3g of glycerine was mixed in the solution. The weights were measured using a gms scale and liquid readings were measured using a burette. In the control experiment, 12g of gelatine and 3g of glycerine was mixed in 60 ml of water. The resulting mixture in both cases was heated to a paste-like form on a hot plate at a temperature of 95ºC for 15 mins with continuous stirring, leading to the formation of a viscous mixture. The quantities used have been mentioned clearly in Table 2. After the mixture turned clear again, it was spread uniformly with the help of a glass rod on an aluminium sheet and was allowed to dry at room temperature for 3 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. The experiment was repeated to form 5 samples each of the control and wheatgrass dyed bioplastic. Further, the samples were tested for different properties like tensile strength and biodegradability. [19]

Gelatine (g)	Glycerine (g)	Wheatgrass liquid (ml)	Water (ml)	Total liquid (ml)
12.0	3.0	10	50	60
12.0	3.0	0	60	60

Table 2

Tensile strength measurement

The tensile strength measurements were done using the formula stress/strain.

$$\frac{FL}{A\Delta L}$$

The thickness was calculated for the samples and multiplied by the width to give the cross-sectional area used in the calculation. A clamp that was connected to weight was strongly attached to one end of the bioplastic sample of size (6 cm × 1.5 cm). The other end of the bioplastic was attached to another clamp that was connected to a digital newton meter. The Newton meter was pulled to different force measurements: 1, 2, 3, 4 and 5 Newtons and the final length at each force was calculated. The calculations were repeated 5 times for the 5 different force values and with the 10 samples created.

Soil Burial Test for Biodegradability Comparison

Bioplastic samples prepared as mentioned above (1x1 cm) were taken. Their thickness was calculated using a micrometer screw gauge. The samples were then buried in compost soil at 7.5 cm depth (measured using a measuring scale) in a box. The entire setup was then incubated at room temperature for 10 days. After 10 days the sample was then taken out and thickness was measured.

Preparation of Hydrophobic Wheatgrass nanomaterial

The well-known co-precipitation method was used for the preparation of Wheatgrass bioplastic nanomaterial [20]. Iron (III) chloride (1M, 2 ml) and Iron (II) chloride (0.5 M, 2 ml) solution were added in a volumetric flask, and the mixture was stirred at room temperature for 20 min to completely dissolve the iron salt. After that wheatgrass dyed bioplastic was added and the mixture was stirred for another 20 min. Subsequently, 30% ammonia solution was added into the flask and the yellow colour solution immediately changed into black colour precipitates. The black precipitates were washed several times with deionized water and dried in the oven at 50 °C for 12 h after separation from water through an external permanent magnet.

Graphs

All graphs depicting the results obtained for various tests were plotted using GraphPad Prism 9.0.

III. Results and Discussions

To examine the change in mechanical and chemical properties of the biopolymer on the addition of wheatgrass we collected results from three tests: tensile strength test, biodegradability test and hydrophobic nanocomposite test. A dye that shows no change or an increment in the properties compared to the control experiment would be deemed as a successful dye and the opposite would not.

Tensile Strength Comparison

After the experiment for tensile strength was conducted (5 times with control and 5 times with wheatgrass biopolymer), the results were plotted in the form of a graph. As seen above the wheatgrass biopolymer shows no conclusive increment or decrease in tensile strength and can be considered to be approximately equal within the margin of error. The means for the tensile strength of the tested biopolymers are stated below and represented in Figure 1

Plant-Based: 1.292 MPa
With Dye: 1.264 MPa
Animal-Based: 4.286 MPa
With dye: 4.338 MPa

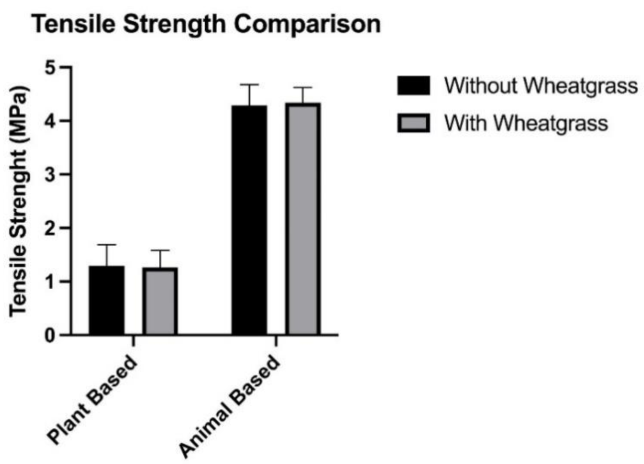

Figure 1

Biodegradability comparison

After the experiment for biodegradability was conducted (5 times with control and 5 times with wheatgrass biopolymer), the results were plotted in the form of a graph as shown in Figure 2. As seen above the wheatgrass biopolymer shows an increment in the change in thickness of the biopolymer, 10 days after burying it in soil. The means for change in thickness of the tested biopolymers are stated below.

Plant-Based: 0.03 mm
With Dye: 0.032 mm
Animal-Based: 0.012 mm
With dye: 0.018 mm

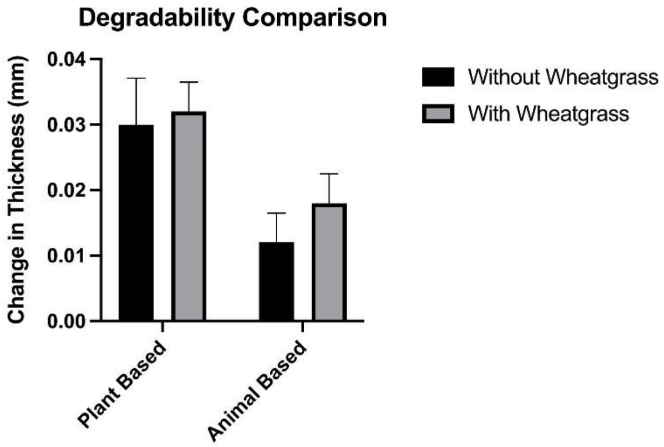

Figure 2

Magnetism Test

After the preparation for hydrophobic wheatgrass nanomaterial, magnetic analysis was conducted (3 times with control and 3 times with wheatgrass biopolymer), the results were observed by checking if the resulting solution is magnetic. This was done using a neodymium magnet. We observed all 6 samples were being attracted by a neodymium magnet after washing.

IV. Conclusions

The wheatgrass biopolymer showed no conclusive increment or decrease in the tensile strength and is approximately the same within the margin of error. The wheatgrass biopolymer shows an increment in the change in thickness of the biopolymer, 10 days after burying it in soil. This may be due to the fact that the extra wheatgrass added degraded leading to a greater decrease in thickness. All 6 samples during the hydrophobic nanocomposite turned out to be magnetic. Being magnetic on the test is a positive result and the biopolymer can be said to be hydrophobic with 99% certainty. Combining all these factors we can safely conclude the wheatgrass is a reliable and successful dye that does not alter the mechanical and chemical properties of the biopolymer it is added to.

V. Acknowledgment

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