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A STUDY ON THE EFFECT OF ADDING CELLULOSE EXTRACTED FROM WATER HYACINTH (*Eichhorniacrassipes*) IN STARCH-BASED BIODEGRADABLE PLASTIC FILMS FOR PACKAGING APPLICATIONS

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Abstract

Plastics are a menacing threat to the environment. As a substitute for synthetic plastics, biodegradable alternatives can mitigate the pollution problem. Cellulose is one of the natural ingredients in biodegradable plastic production. Water hyacinth (WH), a prolific aquatic weed abundant in cellulose, can be exploited for this purpose. The aim of this study was to extract cellulose from WH, to fabricate biodegradable plastic films using WH cellulose in different proportions with starch and to compare the properties of the samples. To isolate cellulose, sun-dried WH powder was bleached with H_2O_2 and alkalized with NaOH. Cellulose powder thus obtained was used to develop several bioplastic films, by mixing with arrowroot starch in different proportions, as well as acetic acid and glycerol. The mixture was gelatinized and molded into thin films. The plastics possessed satisfactory homogeneity, water absorption capacity, tensile strength, heat-sealability and were biodegradable. It was also observed that incorporation of cellulose powder to a certain extent contributed to improved properties of the bioplastic.

Keywords: Water hyacinth, Cellulose, Biodegradable plastic

1. Introduction

Plastic is a synthetic or semi-synthetic polymer material in which repeating series of monomer units form long, strong chains of molecules. These are usually processed from natural products such as oil, coal, petroleum, and natural gases. Due to their excellent mechanical properties like durability, hardness, strength, heat sealability, water resistance, flexibility and versatility, plastics are extremely popular all over the world. Applications of plastics include packaging, building and construction, textiles, consumer products, automobile parts, electric and electronics, cosmetics, industrial machinery etc.

The extensive availability and inexpensive production of plastics cause them to end up getting disposed after single use. For example, plastic bags, straws, soda and water bottles, one-time-use dinnerware, food packaging etc. This type of plastic is termed as "single-use" plastic (SUP) or disposable plastic. Among the total amount of plastic produced globally each year, almost half of it is disposable. In 2019, the worldwide plastic production was 368 million tonnes [1] compared to 348 million tons in 2017 [2]. Bangladesh was the first country to officially ban SUPs in 2002 (*Plastic Bag Backlash Gains Momentum*, 2013) [3].

After the COVID-19 pandemic outbreak, almost 1.6 million tonnes/day of plastic wastes were globally generated as single-use surgical facemasks, face shields, syringes, latex or nitrile gloves, medical gowns, shoe covers, sanitizer containers [4].

Methods of disposal of plastics include land filling, incineration, dumping in the ocean, rivers, ponds etc and disposing off to local garbage dumps. Petroleum based plastic is resistant to chemical, physical and biological degradation. Most plastic wastes end up in landfills, where they can last for hundreds of years and remain unimpaired without decomposing. Thus, plastic pollution is a threat to terrestrial and aquatic life. Direct incineration of plastic waste emits toxic contaminants e.g. furans, dioxins, polychlorinated biphenyls and mercury [5]. This results in soil, air and water pollution. Recycling and reuse are effective ways to reduce plastic waste in the environment. However, recycling costs can sometimes exceed the cost of production of new plastic [6].

Plastic pollution has raised huge concerns among environmental scientists, leading to the search for sustainable alternatives of synthetic plastics. The use of biodegradable plastics and bioplastics effectively

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resolves this problem to a satisfactory level. Plastics made from renewable raw materials or from non-food source are called bioplastics [7]. Biodegradable plastics are bioplastics capable of decomposing in nature through the enzymatic action of living organisms (bacteria, yeast, fungi), to produce the final products CO_2 and H_2O. Starch-based bioplastics have gained popularity in the past. But due to their lower mechanical strength and poor water resistance, later on cellulose derivatives and their reinforcement in starch-based bioplastics have proved to demonstrate better functionality.

Cellulose extract is easily obtainable from plant sources. One of the natural fibers containing cellulose is water hyacinth (*Eichhorniacrassipes*), the fastest growing aquatic weed on earth. Water hyacinth is an active threat to the environment, causing restrictions of movement on water ways, blocking oxygen dissolution and transportation, irrigation problems, reducing infiltration of sunlight, altering the natural pH of water, destroying habitats of aquatic life forms and reducing water quality through decomposing plants [8]. However, its high cellulose content can be a promising precursor in production of biodegradable plastic. WH contains almost 20% cellulose, 48% hemicellulose and 3.5% lignin [9]. Another study reveals that the content of cellulose, hemicellulose, and lignin in WH is 43%, 29%, and 7%, respectively [10].

This paper aims to extract cellulose from WH fiber, to develop and examine several biodegradable plastic films using cellulose extracted from WH stem in different proportions with arrowroot starch and to compare their properties. It is noted that the addition of WH cellulose to the bioplastic matrix affected the water absorption, heat sealability, tensile strength and biodegradability of the resulting plastic film.

2. Materials

The materials used were water hyacinth (*Eichhorniacrassipes*), 11% H_2O_2 solution (w/v), 10% NaOH solution (w/v), 1% acetic acid solution (v/v), arrowroot starch and glycerol. Instruments used in the experiment were oven dryer, hot plate, electric balance, magnetic stirrer, shaking incubator, optical microscope, impulse sealer and universal testing machine (Hounsfield).

3. Methodology

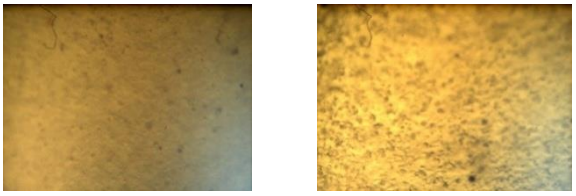
WH plants were collected from a local pond, washed, cut and sun-dried for 4 days before grinding into fine powder. 20g dried WH powder was first bleached with H_2O_2solution (11%, 450mL) at 50°C, 150 rpm for 1 hr in a shaking incubator. The bleached sample was neutralized and filtered with distilled water. Then, alkylation was done using NaOH solution (10%, 300mL) for 2hrs, followed by neutralization and filtration. The product was bleached again with 300mL H_2O_2 for 1hr under the same conditions as the first bleaching. Then it was filtered again, yielding a white colored filter cake which was dried and grinded to obtain WH cellulose powder.

Several bioplastic samples were prepared with different weight ratios of starch: cellulose (sample 1 (5:0), sample 2 (9:1), sample 3 (4:1) and sample 4 (1:1)) in the matrix. 30mL of 1% acetic acid and 1mL glycerol (plasticizer) were added to each 5g formulation and mixed using a magnetic stirrer. All the homogenous mixtures were heated till gelatinization. Then each gelatinous mix was spread separately on a smooth mould and left to dry at room temperature for 24-48hrs. Plain transparent plastic films were obtained after demolding.

4. Results and Discussion

4.1 Homogeneity

The surface texture of plastic films was observed under an optical microscope at 10X magnification.



(a) (b)

Fig. 1 Structure of (a) sample 1 and (b) sample 2

Fig. 1 (a) shows that sample 1 (5:0) had smoother surface characteristics compared to others. In Fig. 1 (b), sample 2 (9:1) exhibits a slightly coarse structure. Isroi et al. conducted similar tests and found that starch bioplastic is transparent and no fiber could be seen under the microscope. Addition of cellulose increased the density of the fiber inside the bioplastic composite, due to the lower starch content in the latter. Evidently, the plasticizer (glycerol) reacts better with the mix in the presence of starch, giving the final product a more homogeneous texture [11].

4.2 Heat sealability

The sealability of the samples was determined by sealing with an impulse sealer. The films were sealed from three sides to form pouches of the same size.

20g, 50g and 100g weights were placed into each of the heat-sealed pouches one by one to observe their seal strength.

All the samples were found to be heat sealable and were able to hold 20g and 50g weights efficiently. On placement of a weight of 100g, the seal on the pouch made from sample 1 fell apart, whereas those made from sample 2, 3 and 4 were able to hold the weight without collapsing, and they offered similar strength and durability of seals despite having slight difference in cellulose content. This implies that the strength and stability of plastic pouches were enhanced due to the addition of WH cellulose.

4.3 Water Absorption Capacity

Water absorption test of each sample was conducted by calculating the weight before and after immersing under water for 1hr. From Fig. 2 it is apparent that WAC decreases appreciably with the increasing proportion of cellulose in the bioplastic samples. However, the water absorption suddenly increased on addition of 50% cellulose (sample 4), breaking the descending trend. Abral et al. and Marichelvam et al. found that lower moisture absorption was found in WH cellulose-reinforced samples, meanwhile starch bioplastic displayed higher moisture absorption [12].

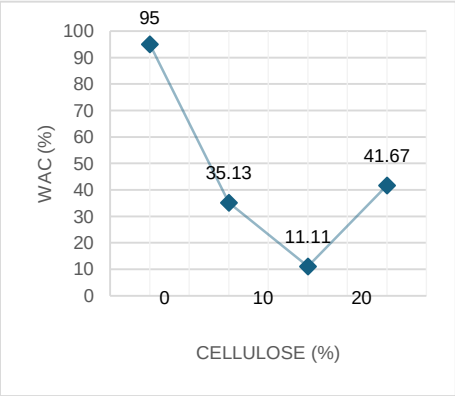


Fig. 2 Water absorption capacity (%) of bioplastic film samples

4.4 Tensile strength

Fig. 3 demonstrates the results of tensile strength test of samples 2, 3 and 4 measured by a universal testing machine (Hounsfield). Sample 3 had the highest tensile strength, 13.33 MPa, followed by sample 2 (10 MPa) and sample 1 (8.67 MPa). This implies that the bioplastic film reinforced with 10% WH cellulose (starch: cellulose ratio of 9:1) shows the best results in terms of tensile strength.

4.5 Soil degradability

Biodegradability of the test samples was determined by soil burial method. The bioplastic samples were

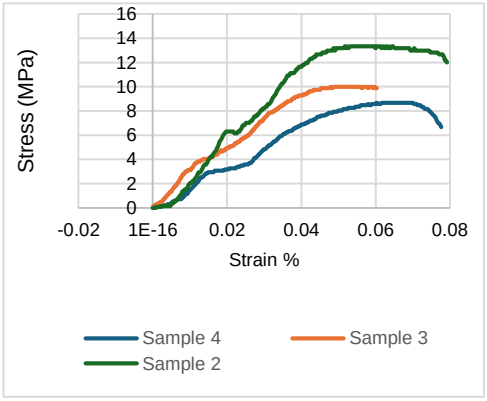


Fig. 3 Tensile strength test of bioplastic samples

buried under soil and the reduction in weight was measured at regular intervals.

On day 7, several cracks and holes were found on the films. At the end of 14 days, the holes were enlarged and cracks became deeper, resulting in further weight loss. Sample 3 was almost degraded and covered in mud on day 28. Hence the weight could not be measured on a balance. Overall, sample 3 degraded faster than any of the others (Fig. 4).

Pratama et al. declares that bioplastics made from a mixture of starch and cellulose have better degradability than starch bioplastic because the biodegradation process of cellulose biopolymers is relatively faster [13]. Cellulosic materials are degraded by an enzyme called cellulase. Examples of bacteria capable of producing cellulase are *Pseudomonasflurescens*, *Bacillussubtilis*, *Escherichiacoli* and *Serratiamarcens* [14]. As these bacteria are naturally present in soil, air and water, degradation of any cellulosic material is faster in these environments. On the other hand, degradation of starch is mostly aided by bacteria like *Microbacteriumaurum*, through a complex metabolic pathway [15]. Hence, sample containing only starch (sample 1) showed a slower rate of degradation in the soil.

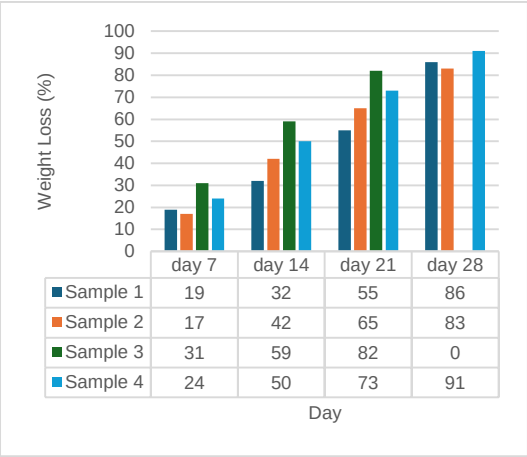


Fig. 4 Biodegradability test of bioplastic film samples by soil burial method

5. Conclusions

This study was focused on the isolation of cellulose from WH, incorporation of the WH cellulose powder into different starch-based biodegradable plastic formula and comparing their properties. Cellulose extraction process was performed successfully. The addition of cellulose to the plastic formula showed improved strength and better degradability but it reduced the elasticity and flexibility of the resulting film. It also reduced water absorption compared to starch-based biodegradable plastics, which is desirable for food packaging applications.

Further studies regarding the improvement of these properties should be conducted, with a focus on the improvement of air and moisture barrier properties and mechanical strength, so that biodegradable plastics from WH cellulose can be used commercially as an alternative to the environmentally detrimental traditional plastics in the packaging industry.

Acknowledgement

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