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Development and Characterization of Cellulose Bioplastic Films using Wheat Straw as Raw Material

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ABSTRACT

Wheat straw is a versatile and abundant agricultural by-product that holds significant importance in various industries and environmental contexts. In this study, wheat straw collected from farmers was used for the development of biofilm. The best condition of film was obtained at 2.5% wheat straw concentration, concentration of 30 % sorbitol, and 1.5% gelatin. With a maximum tensile strength of 25.6% and an elongation break of 18.3%, thickness of 0.22 mm, solubility of 20%, and swelling index of 25%, the maximum strength of the film was 25.6 pa. Solubility values were 40% and 12%, respectively. Soil burial degradation studies were carried out to evaluate the biodegradability of the material under natural environmental conditions. The weight loss of the composite films during 15 days soil burial study was above 85%.

Key words : *Bioplastic films, Wheat, Raw material*

Introduction

Wheat straw is a versatile and abundant agricultural by-product that holds significant importance in various industries and environmental contexts. It is the residue left behind after wheat grains have been harvested from the wheat plant (*Triticum aestivum*) during the threshing process. Wheat, one of the most widely cultivated cereal crops globally, serves as a staple food source for millions of people. As a result, the large-scale cultivation of wheat generates substantial quantities of wheat straw as a natural by-product. Gelatin is a translucent, colorless, flavorless food ingredient, commonly derived from collagen taken from animal body parts. It is brittle when dry and rubbery when moist. It had emerged as an effective alternative to conventional packaging materials due to their biocompatibility good film-forming properties, abundance in nature, effective absorption of UV light due to the presence of aromatic amino acids in their structures, and good mechanical properties (Sunderman *et al*., 2018). Sorbitol is a kind of polyol. It is an effective plasticizer due to it has an active hydroxyl group i.e., some -OH or -NH rich polymers. It is good enough to reduce internal hydrogen bonds that will improve the intermolecular distance. As sorbitol is a nontoxic, it can be used in some food contacting materials and makeas a good choice food packaging material (Maulida and tarigan, 2016)

Materials and Methods

The experimental setup and techniques used to develop biodegradable films from wheat straw and, the methods for determining physico-chemical, mechanical, biodegradable properties of biopolymer film as a food packaging material was mentioned. Raw materials like wheat straw were purchased from the local farmers. All the chemicals used like hexane, sodium hydroxide, sodium hypochlorite, sulfuric acid, hydrogen chloride, glycerol, sorbitol was procured from the Tharun laboratories.

Extraction of cellulose from wheat straw and film formation

Wheat straw was washed, sun dried and powdered, then treated with 15% Hcl (v/v) at 90 ^{0}C for 2h followed by washing with distilled water. Using NaoH an alkaline solution of 20% (w/v) for 2h at 90 ^{0}C in hot air oven followed by washing with distilled water. Using 15% Naclo (v/v) for bleaching at 90 ^{0}C for 2h and then filtered with sieve and washed with distilled water followed by drying (Olt *et al*., 2020). The process was given in the below flow chart.

Wheat straw 1g/10 ml mixed with 15 Hcl (v/v) at 90 ^{0}C for 2h
↓
Sample boiled in alkaline solution with 20% (w/v) NaoHfo 2h at 90 ^{0}C
↓
Washing
↓
Bleached with 15% Naclo (v/v) at 2h at 90pc
↓
Filtered
↓
Washed
↓
Dried
↓
Degraded wheat straw suspended in 10ml of distilled water
↓
Stirred continuously for 1h on hot plate
↓
Added (10 -30%) sorbitol +(1.5%) gelatin
↓
Stirred continuously for 10 min on hot plate
↓
Add 1ml of oil
↓
Casting on polypropylene plates
↓
Drying at ambient temperature for 24h

Determination of Physico-chemical and Mechanical Properties of the Developed Cellulose Based Biopolymeric Film

Thickness

The micrometre (Mitutoyo, Japan) was used to measure the thickness of thedeveloped film with an accuracy of ± 0.001 mm. Ten different points (Randomly...) of measurements were carried out on individual films. The film's average thickness and mean values were calculated as per the procedure reported by Sani (2019).

SwellingIndex

The film sample of 2.5 cm × 2.5 cm was cut into pieces and weighed (W1). The sample film was then dipped in deionized water (25 ^{o}C) for 24 h. The wet sample was sponged with filter paper to remove additional surface water and swelled film was weighed (W2) as per the procedure adopted by Cao *et al*., (2007). It was expressed in percentage. The experiments were carried out in triplicates and mean values were recorded. The quantity of water absorbed from the film was calculated by using the standard equation:

$$\text{Swelling Index (\%)} = \frac{W1-W2}{W1} \times 100$$

Where,
W1 = Initial weight of the sample, g
W2=Final weight of the sample, g

Tensile Strength

Rectangular-shaped film specimens of 2 cm wide and 8 cm long were cut from film sheets and used for the tensile tests. The tensile strength of the films was determined using a tensile testing machine (Model: GP-10-DX) as per the ASTM-D882 standard method. Tensile tests were performed at room temperature with a crosshead speed of 10 mm/min. At least three samples were tested for each film and the average values are reported. The tensile strength of the biopolymeric films was calculated by using the following formula.

$$TS = \frac{F}{L \times W \times T}$$

Where,
TS = Tensile strength, Pa; F = Tension at break, N; L = Length of film, mm; W= Width of film, mm; T= Thickness, mm

Elongation at Break

Elongation at break of developed biopolymeric film was determined by using similar procedure explained under Section 3.5.4. A film sample of size 8 cm x 2 cm was used for the experiment. Elongation at break (Eb) of biopolymeric films was calculated by Faramaraz *et al.,* 2019 using the following formula.

$Eb = L_b/L_0 \times 100$

Where,

Eb = Elongation at break (%)

Lb = Length of film at break, mm Lo = Original length of film, mm

Biodegradability Test

The biodegradability of the film was determined based on the film weight loss after burying the film in soil. A 5×5 cm^2 square film was taken and weighed (W1). The samples were placed in an open field. The film was buried inside the soil for two months. After two months, the film was removed from the soil, cleaned and weighed (W2). Weight loss of film was determined by using the following formula (Xu *et al.,* 1996). The measurement was repeated three times for each film, and an average value was calculated and expressed in percentage.

$$\text{Weight loss (\%)} = \frac{W1-W2}{W1} \times 100$$

W1 = Initial weight of the sample, g

W2 = Final weight of the sample, g

Results and Discussion

Thickness

Thickness of the film is affected by the factors like composition, amount of film forming solutions, and processing conditions. The maximum and minimum thickness obtained respectively was 0.22 and 0.12 mm.

Tensile Strength and Elongation break

The material made from wheat straw by adding different concentrations of sorbitol and gelatin as mentioned above were tested for tensile strength. It was found that all maximum tensile strength of 25.56 pa was observed at 30% sorbitol and 1.5% gelatin. And minimum tensile strength of 16.16mpa was observed at 20% sorbitol and 1.1% gelatin. The destruction of original hydrogen bonding by sorbitol addition would improve the mobility of the macromolecular segments, resulting in the highly enhanced flexibility of the films. The weakening of intermolecular interactions between adjacent chains causes a decrease in tensile strength, increasing the free volume and lowering the mechanical strength. As the concentration of sorbitol increases, tensile strength increases, and elongation at break decreases. The maximum and minimum elongation break values are 29.1 and 18.3 %.

Swelling index and Solubility

Regarding swelling index, minimum was observed at 30% sorbitol and 1.5% gelatin due to according to Lubis M, macromolecules. The maximum swelling index was observed at 40% sorbitol and 1.1% gelatin and minimum at 12%. With the increase of sorbitol, the water content at equilibrium increased. There were six -OH groups per sorbitol molecule, which could form hydrogen bonding interactions with wheat straw and water, thus increased the quantity of bonded water and depressed the water release during drying. Water uptake of straw based films with sorbitol was ten times lower than that of non-plasticized films, according to Lavorgna *et al.* (2010). The maximum, minimum solubility values are 40% and 12% respectively.

Biodegradability

Soil burial degradation studies were carried out to evaluate the biodegradability of the material under natural environmental conditions. After the burial of the films in the soil for 180 days, the percentage weight loss was recorded. The buried material exhibited reduced size. The degradation rate 30% sorbitol and 1.5% gelatin were much faster. The presence of starch increases the microbial attack and the biodegradation rates by stimulating biofouling and the adhesion of microorganisms to the surface leading to roughness and formation of crevices. The weight loss of the composite films during 15 days soil burial study was above 85%.

Conclusion

In this study, wheat straw collected from the farmers were used for development of biofilm. Besides, sorbitol, gelatin used as a source of increasing the strength and flexibility. The best condition of biofilm was obtained at 2.5% wheat straw concentration, concentration of 30 % sorbitol, and 1.5% gelatin. with a maximum tensile strength of 25.6% and an elongation break of 18.3%, thickness of 0.22mm, solubility of 20% and swelling index of 25%.The film was degraded 85% for 15 days.

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