Development of biodegradable bioplastic films from Taro starch reinforced with bentonite

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Abstract: Bioplastics are biodegradable plastics made from renewable natural sources like plants, animals and microbes. The synthetic plastics currently in use possess threat to the environment as it is non-biodegradable and is obtained from petrochemical sources which are non-renewable as well. Out of all the plastics used, the single use plastics are of great concern as they cannot be efficiently recycled. To encounter this problem, synthetic plastics can be replaced with bioplastics. Starch from *Colocasia esculenta* (Taro) is one of the best options available to develop such plastics as the granules sizes of them are smaller compared to *Solanum tuberosum* (potato) starch. The difference in size and shape of the granule will have an influence on the physicochemical properties of the starch and thus on the bioplastic film generated. Suitable fillers such as bentonite clay can be used to improve the mechanical property of the film. Apart from mechanical property, Bentonite was found to reduce starch matrix retrogradation by influencing B-type crystallinity.

In this study, bioplastic films were developed using Taro starch (*Colocasia esculenta*) with glycerol as plasticizer and varying the bentonite concentration (0 to 2.5% w/w) as a filler material. The bioplastic films thus generated was characterised by instrumental techniques such as scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), universal testing machine and differential scanning calorimetry (DSC). The films were also subjected to swelling test, chemical tests, wettability test and soil degradation studies. The SEM and FTIR results showed that the films formed were homogeneous without any agglomeration and ascertains that all the films are solely made from starch as they have similar wave number. The gelation temperature was predicted as 85°C using DSC. The tensile strength was also found to increase with increase in the concentration of bentonite. The swelling and soil degradation tests confirmed that the films formed were biodegradable and the rate of degradation was influenced by the bentonite concentration. The chemical tests show that the bioplastic films with bentonite showed increased resistance to acids and salts. Based on the results obtained, it can be concluded that the bioplastic films generated from taro starch were biodegradable with good mechanical properties which can replace synthetic plastics.

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DEVELOPMENT OF BIODEGRADABLE BIOPLASTIC FILMS FROM TARO STARCH REINFORCED WITH BENTONITE

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Contents of the presentation

- Introduction
- Problem statement
- Methodology
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Introduction

- Bioplastics – **renewable** and **biodegradable** plastic manufactured from natural sources
- Starch
  - Amylose and amylopectin
  - Semicrystalline
  - Abundance
  - Cost effective
  - Thermoplastic behaviour

Introduction

Plastics properties

- High molecular mass
- Mechanical strength
- Thermoplastic/ thermosetting behavior

- High tensile strength
- Toughness
- Inertness
- Toughness
- Chemical and weather resistance

Plastics – ‘White pollution’

Plastic waste disposed in landfills:

- Sequestration of carbon
- 20% of green house gases
- Improper recycling

Plastic wastes affecting ocean

- 60-80 % of marine animals affected
- Polymer pellets ingested by marine organisms
- Biomagnification

FICCI- 9.7 kg plastic/ person in 2014

- Single-use plastic bags and plastics for packaging
- Recycling is inefficient and expensive

Rationale

- Taro starch granules are the smallest of all the tubers known – 1µm to 5µm
- Bentonite reduces starch matrix retrogradation.
- Glycerol decreases cohesive forces, facilitates dispersion of blends and influences the interfacial affinity.

Taro procured from local market in Orissa

Methodology - Processing of Taro

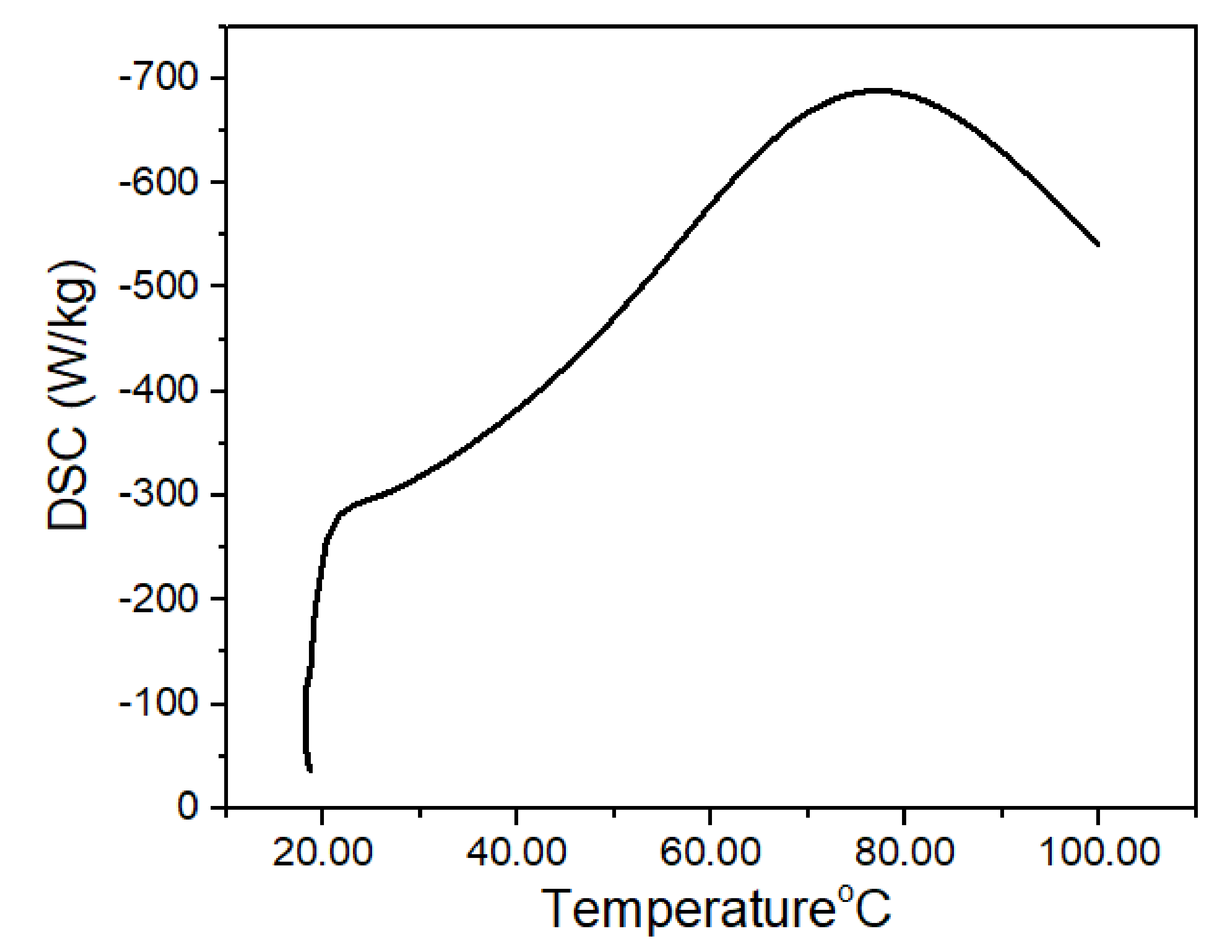
Taro (3kg) was sliced into thin pieces
→
It was grinded with water in a laboratory blender.
→
The paste obtained was made up to 5l with distilled water.
→
It was left undisturbed for 6 hr.
→
It was filtered using a muslin cloth and the residue was collected.
→
The residue was dried at 50ºC.
→
The dried sample was powdered using a laboratory blender.

Casting of films

- Taro starch (x g) and 100 ml of distilled water was stirred for 10 min at 350 rpm.
- Bentonite at concentrations 0.5% (w/w), 1% (w/w) and 1.5% (w/w) was added and stirred at the same condition.
- Glycerol (y ml) was added to it and was stirred at 350 rpm for 10 min.
- It was heated around 80 ^{0}C to 90 ^{0}C for 1.5 h with continuous stirring at 250 rpm.
- The slurry was then casted onto a petri plate and was dried in a hot air oven at 50 ^{0}C.

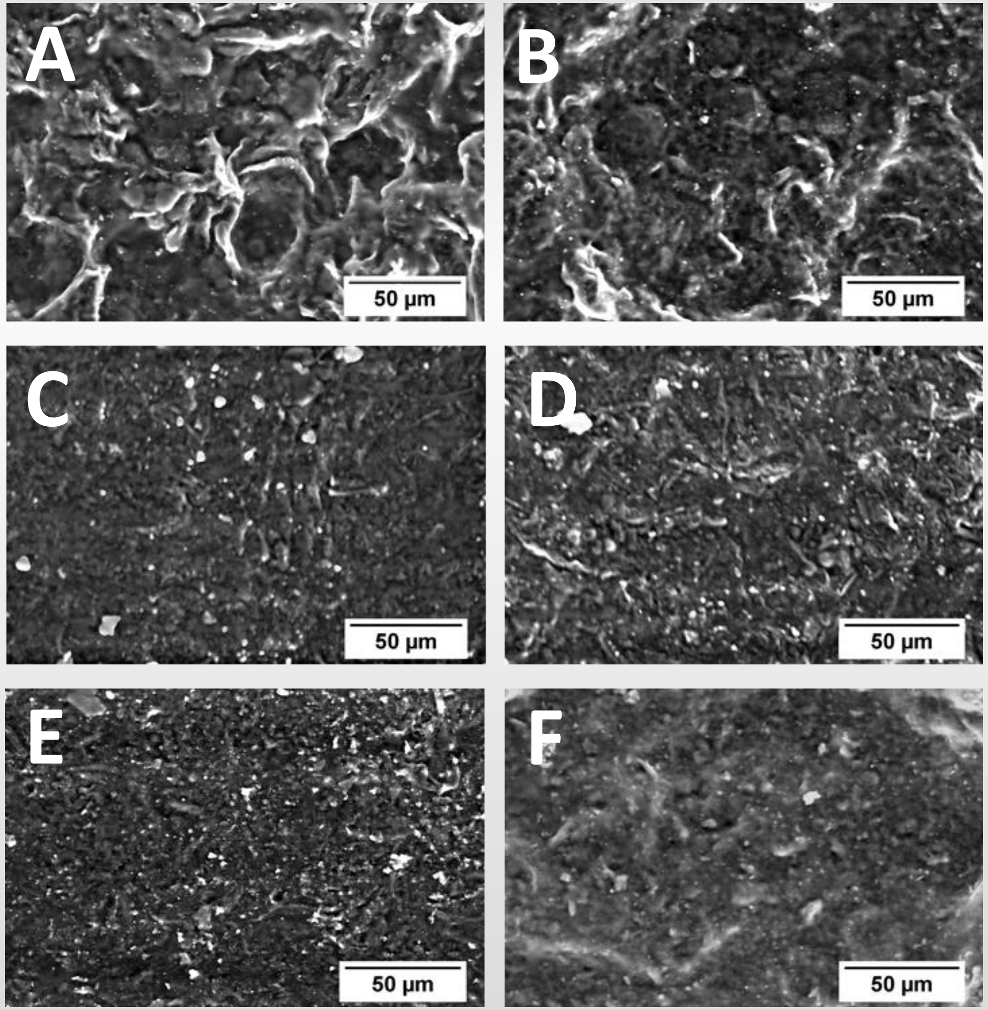
RESULTS AND DISCUSSION

Differential scanning calorimetry



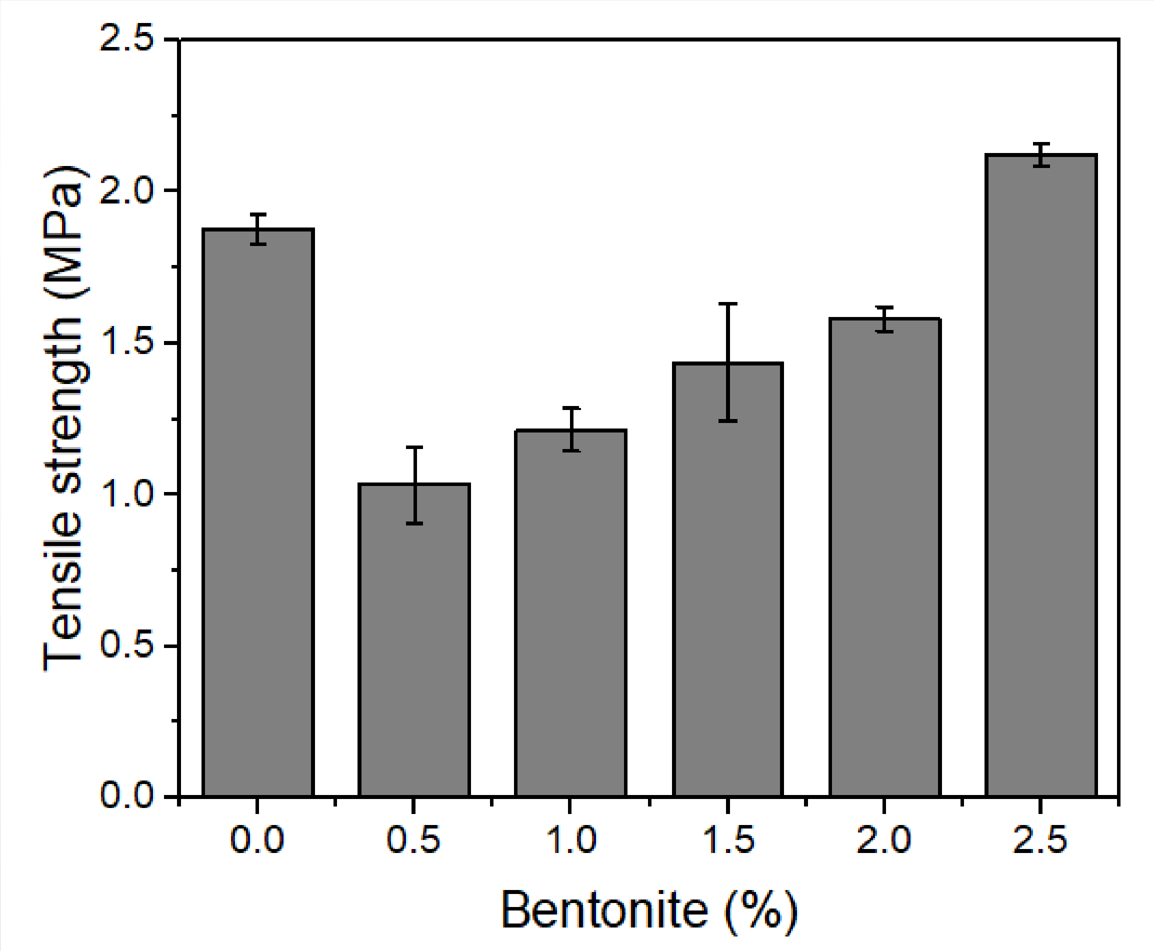
- The glass transition temperature of starch - **80º C**

Scanning Electron Microscopy



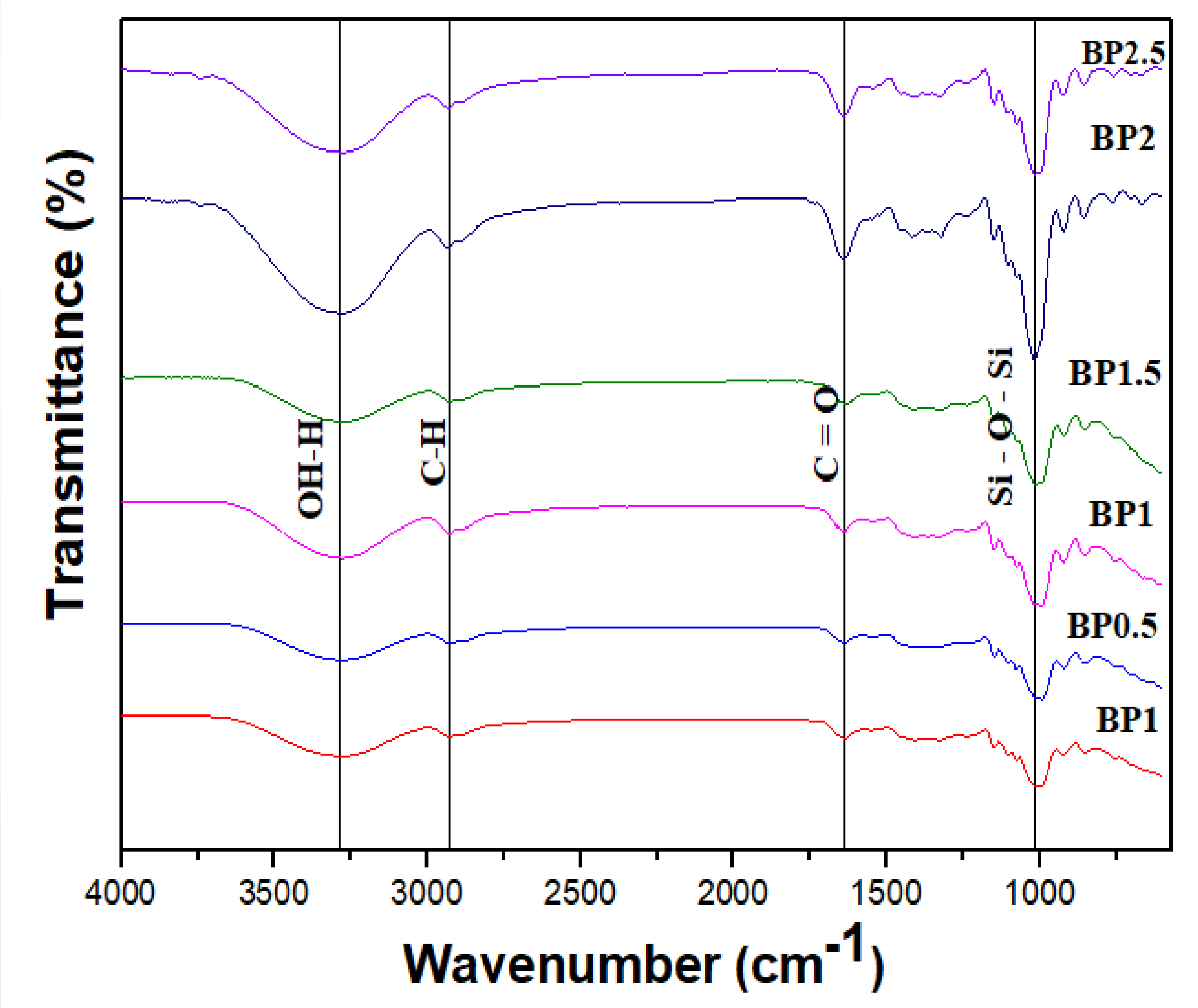
SEM graph of the bioplastic films generated at 2000X magnification (A) Film BP0 (B) Film BP0.5 (C) Film BP1 (D) Film BP1.5 (E) Film BP 2 (F) Film 2.5

Tensile strength of the films



- The tensile strength was found to increase with bentonite concentration
- The initial decrease in the tensile strength is because of **Intercalation** and **exfoliation**.

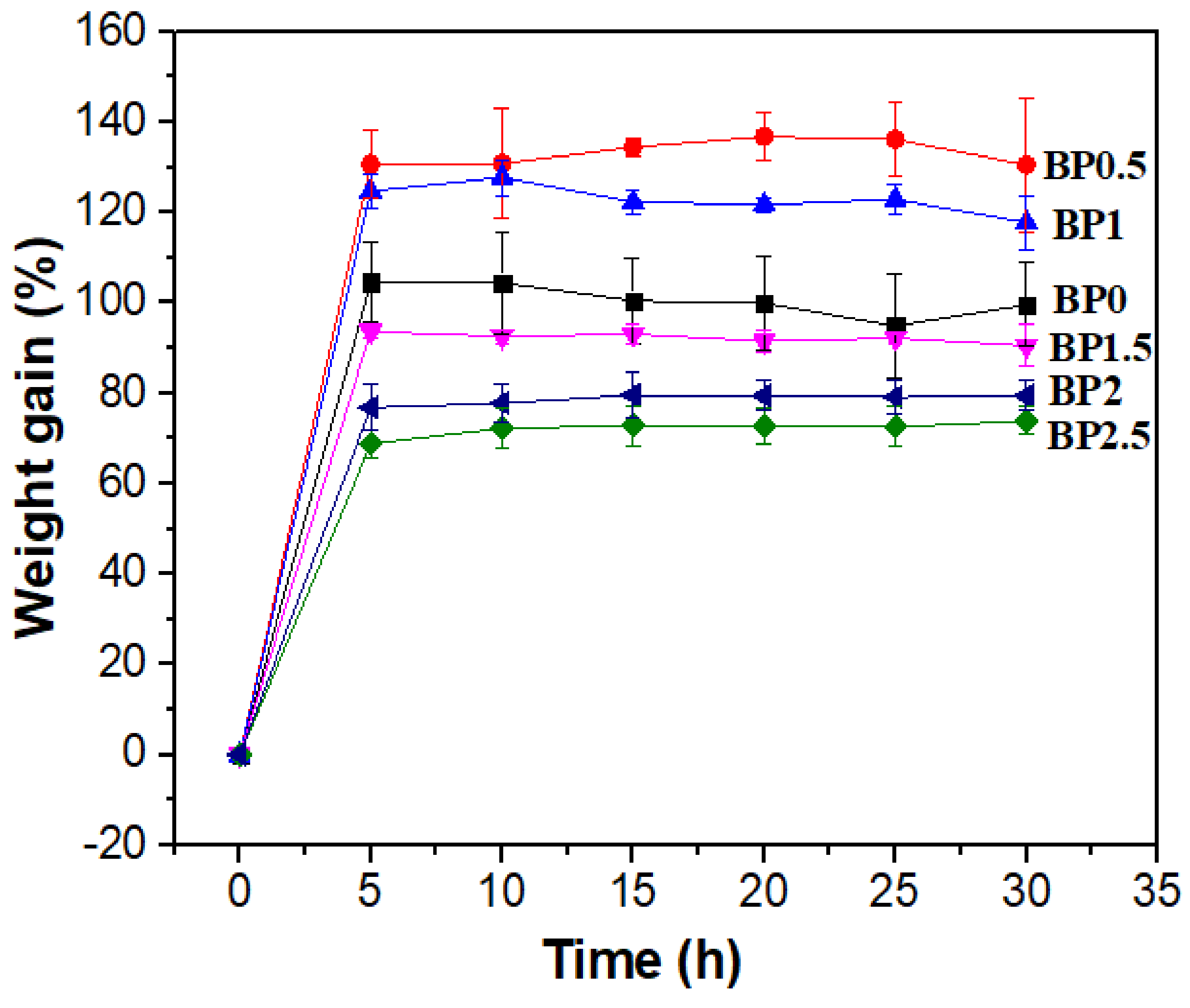
Fourier-transform Infrared Spectroscopy



Characteristic peaks at:

- 3280 cm^{-1} - hydroxy group and H-bonded OH stretching
- 950 cm^{-1} to 800cm^{-1} - vibration of glycosidic linkages
- 2940 cm^{-1} - methyl C-H stretch
- 1210 cm^{-1} and 1055 cm^{-1} - C=O stretch in the primary alcohol
- 1005 cm^{-1} - Si-O-Si

Swelling test

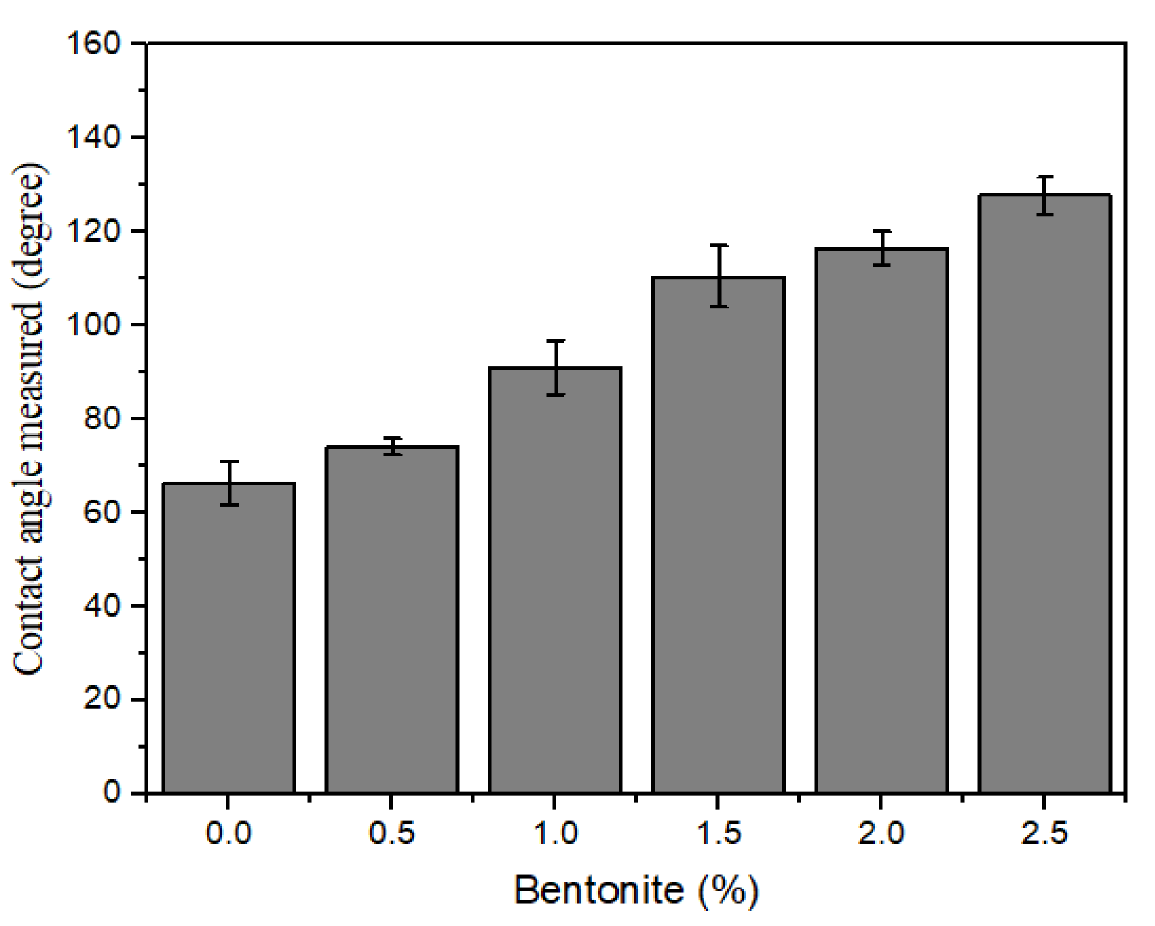


Swelling was found to be high for films with low concentration of bentonite.

- Increase in swelling – phenomenon of **Diffused double layer (DDL)**.

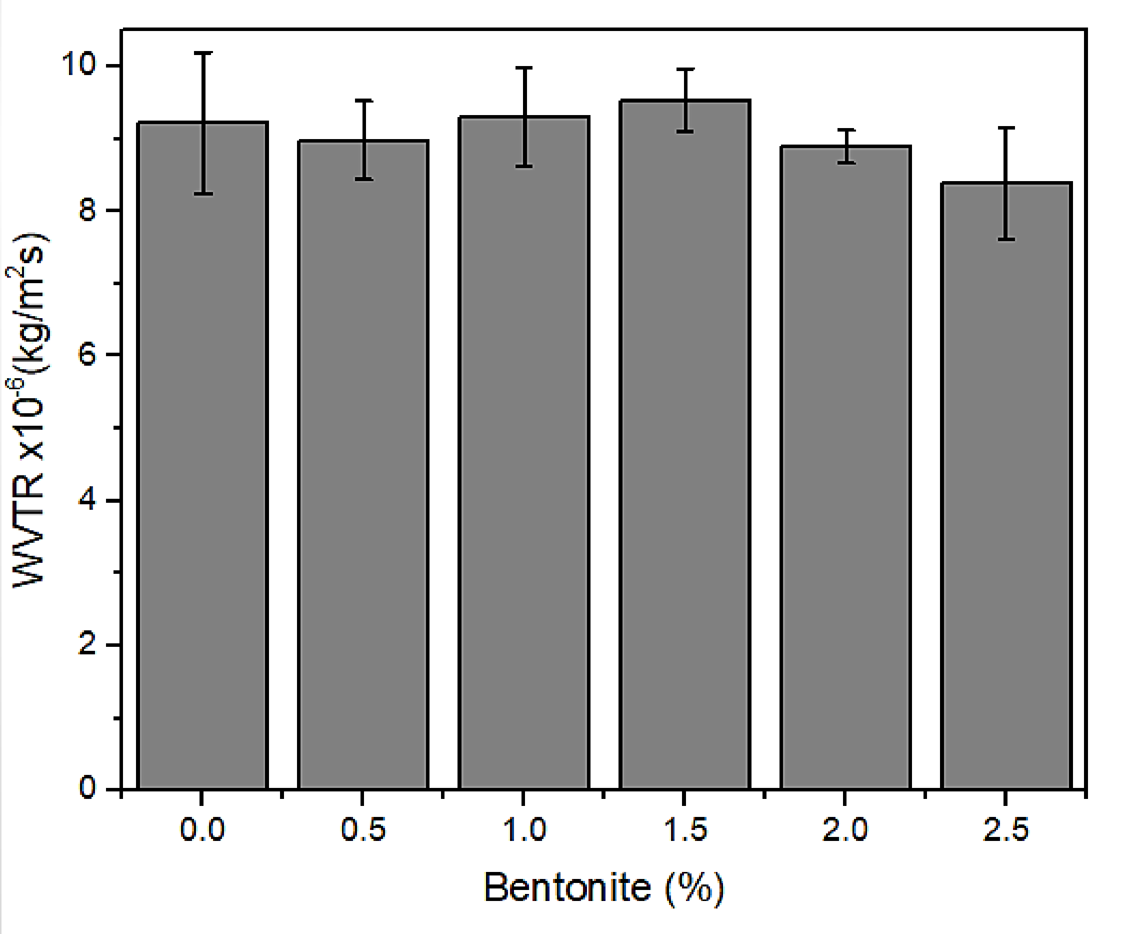
- Decrease in swelling – Bentonite being a layered filler, facilitates **solvation of Sodium ions.**

Wettability test



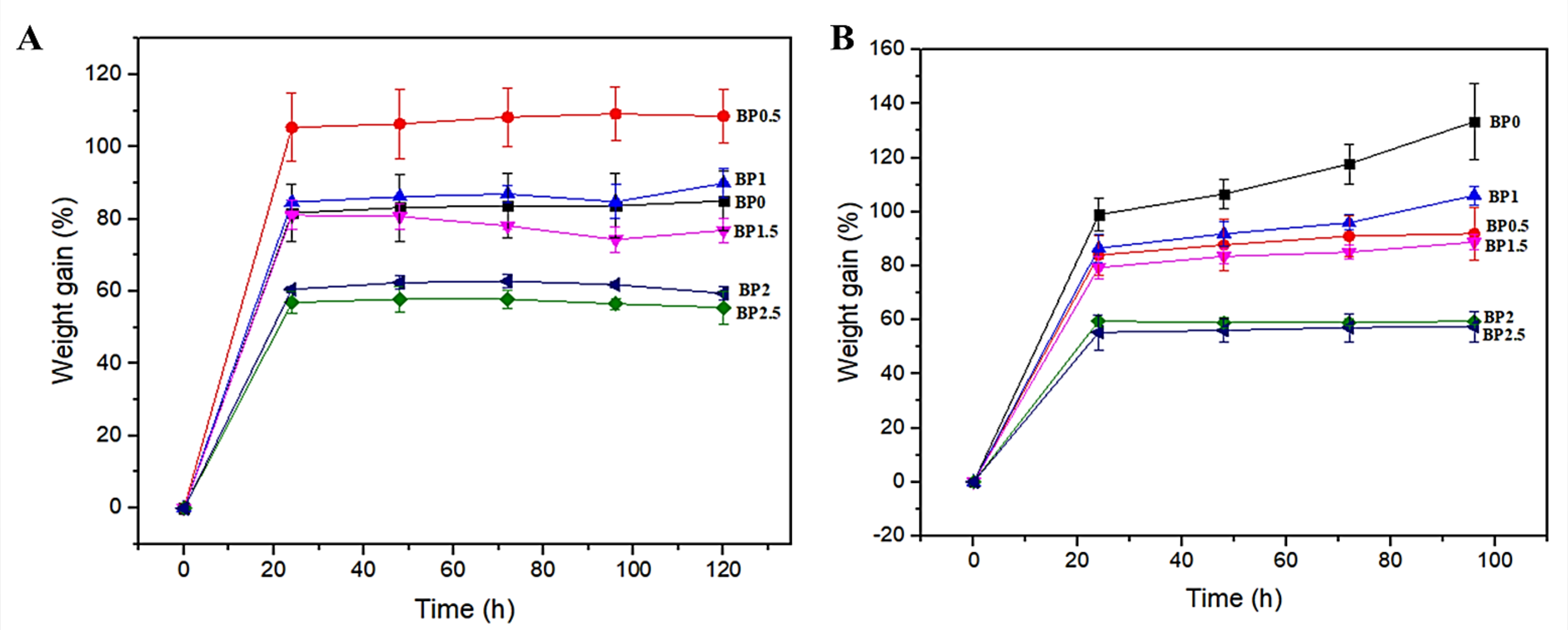
- Increasing hydrophobicity.
- **Convoluted path** formed by bentonite.

Water Vapour Transmission Rate



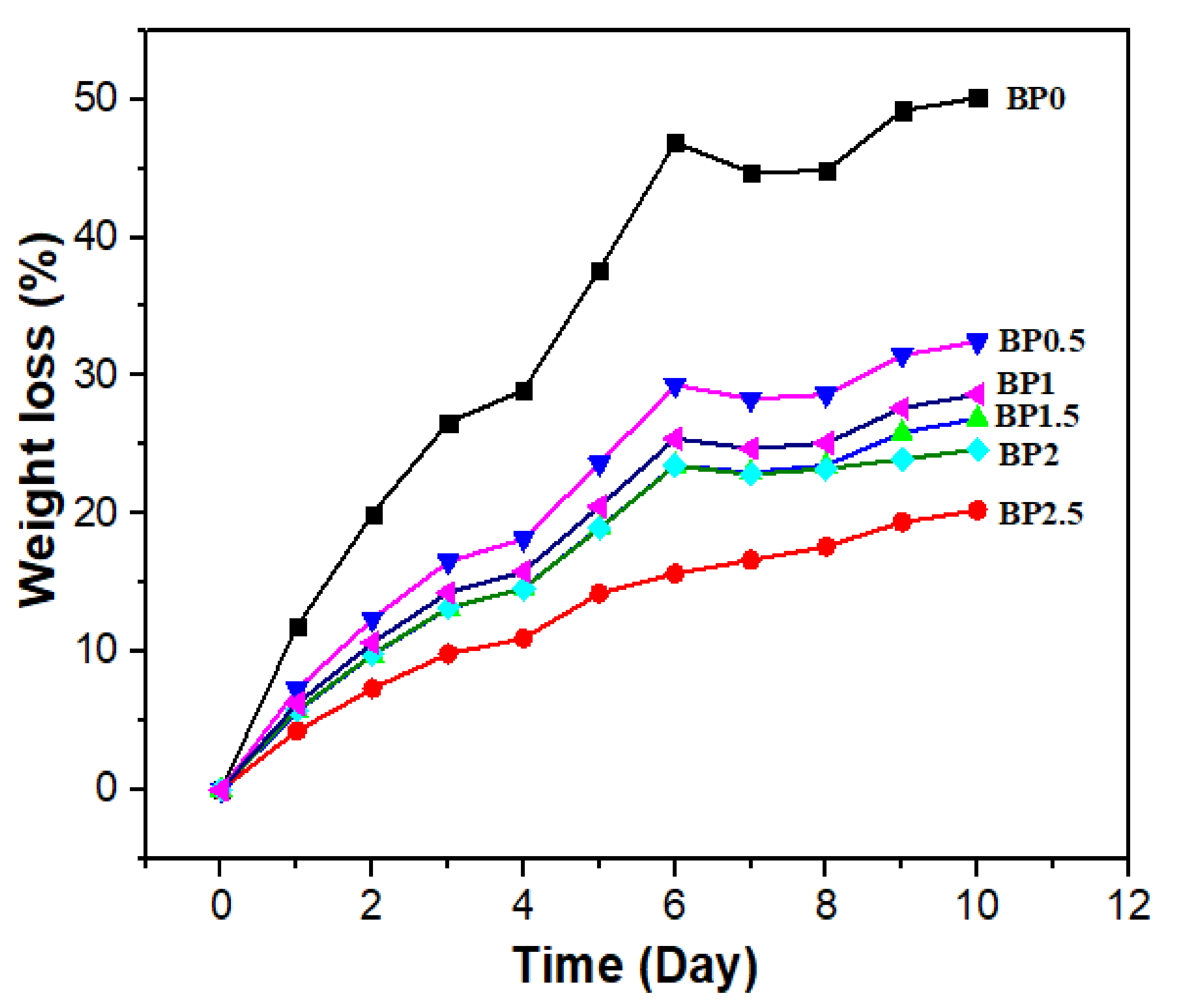
- Gradual decrease in WVTR.
- Convoluted path formed by uniformly distributed bentonite.

Effect of Alkali, Acid and Salt



(A) Effect of 10% Glacial acetic acid (B) Effect of 10% NaCl

Soil biodegradation test



- The films generated are biodegradable.
- Bentonite reduces degradation rate.

Conclusion

BP2.5 could be potentially used for packaging application for the following reasons:

- Swelling of the film was lower
- Resistant to salts and weak acids
- Slower degradation rate in soil
- Tensile strength was considerably good when compared with the other films.

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