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Determining the effect of plant extracts on the development and characterization of biodegradable composite films from Corypha Umbraculifera L. stem starch

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INTRODUCTION

- The use of synthetic polymers causes augmentation in waste generation and environmental pollution due to their non-degradability and generation of harmful components during the disposal [1].

- To combat this problem, the packaging industries have encouraged the development and use of novel environmental friendly non-toxic biodegradable materials

- Starch is a naturally occurring polymer with an extended application in food and non-food industries owing to its abundance, low cost, biodegradability, edibility, and good film-forming properties [2].

TALIPOT PALM

- Talipot starch from talipot palm is a non-conventional and underutilized starch source [3].
- **Scientific name**: *Corypha umbraculifera* L.
- It is a tropical monocarpic palm belonging to the family of ***Aracaceae***.
- **Geography**: inhabit in moist climate and native to semi-wild coastal plains of south western India, Sri Lanka, Malaysia and Myanmar.
- The stem pith of the mature talipot palm is a store house of the abundant amount of light brown coloured starch.
- The talipot starch yielding 76 % starch with an appreciable amylose content of 28 % makes a suitable candidate for preparing biobased starch films.

PLANT EXTRACTS

- Starch-based films started gaining attraction when researchers enriched them with nutrients, antioxidants, antimicrobials, and color change indicators for the development of active and intelligent packaging materials to increase the shelf life of food [4].

- Natural plant extracts are abundant sources of active compounds that mainly exhibit antioxidant and antimicrobial activities [5].

- Among the plant extracts, the extracts from the leaves of curry tree, neem, tulsi, and Mexican mint can be considered for developing active films due to their effectual bioactive characteristics that is expected to exhibit a wide spectrum of biological properties: anti-inflammatory, antioxidant, antimicrobial, anticarcinogenic, and anti-diabetic properties.

OBJECTIVES

- To extract and isolate talipot starch from talipot palm stem.
- To extract plant extracts from the leaves of neem, tulsi, Mexican mint, and curry leaves.
- To fabricate biodegradable composite films by adding plant extracts from the leaves of curry tree, neem, tulsi, and Mexican mint to talipot starch-CMC matrices.
- To characterize crystalline, morphological, barrier, and antimicrobial properties of fabricated biodegradable composite films.

MATERIALS AND METHODS

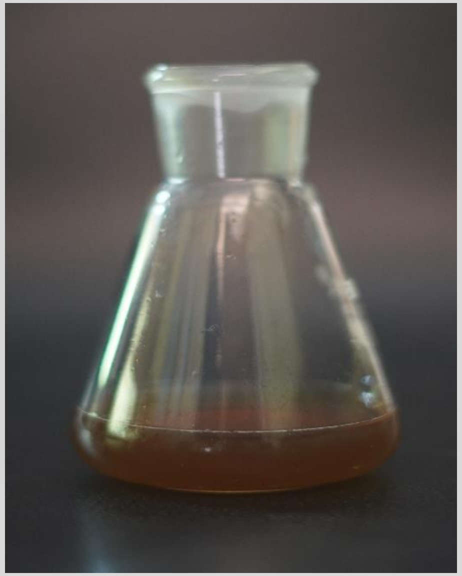
PHASE - 1
- Isolation of talipot starch by Aaliya et al. [6]
- Extraction of plant extracts from neem, tulsi, Mexican mint and curry leaves by Kumar et al. [7]

PHASE - 2
- Development of composite films with talipot starch-CMC-plant extracts by solution casting method Sudheesh et al. [8]

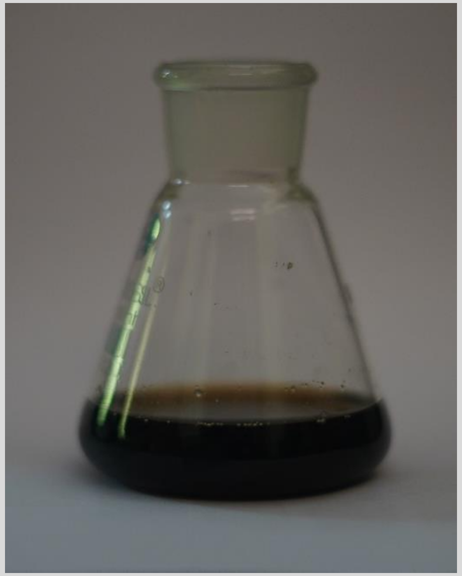
PHASE - 3
- Morphological properties by AFM and SEM
- XRD and relative crystallinity
- Opacity
- Water vapor permeability
- Oxygen permeability
- Antimicrobial activity
- Biodegradation study

MATERIALS AND METHODS

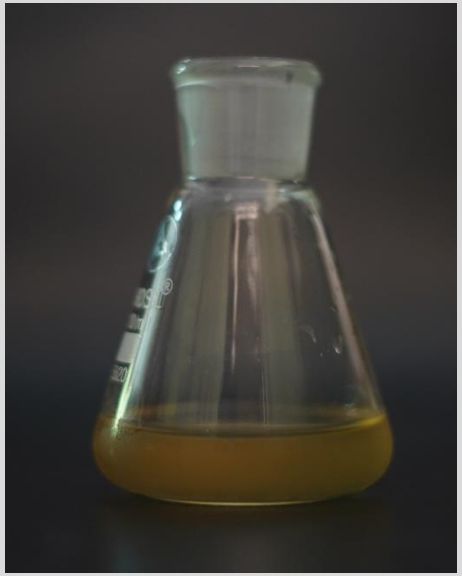
TALIPOT PALM STARCH



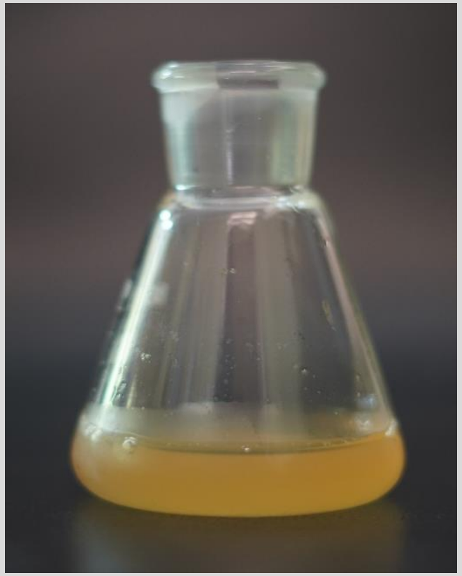
CURRY LEAF EXTRACT



TULSI LEAF EXTRACT



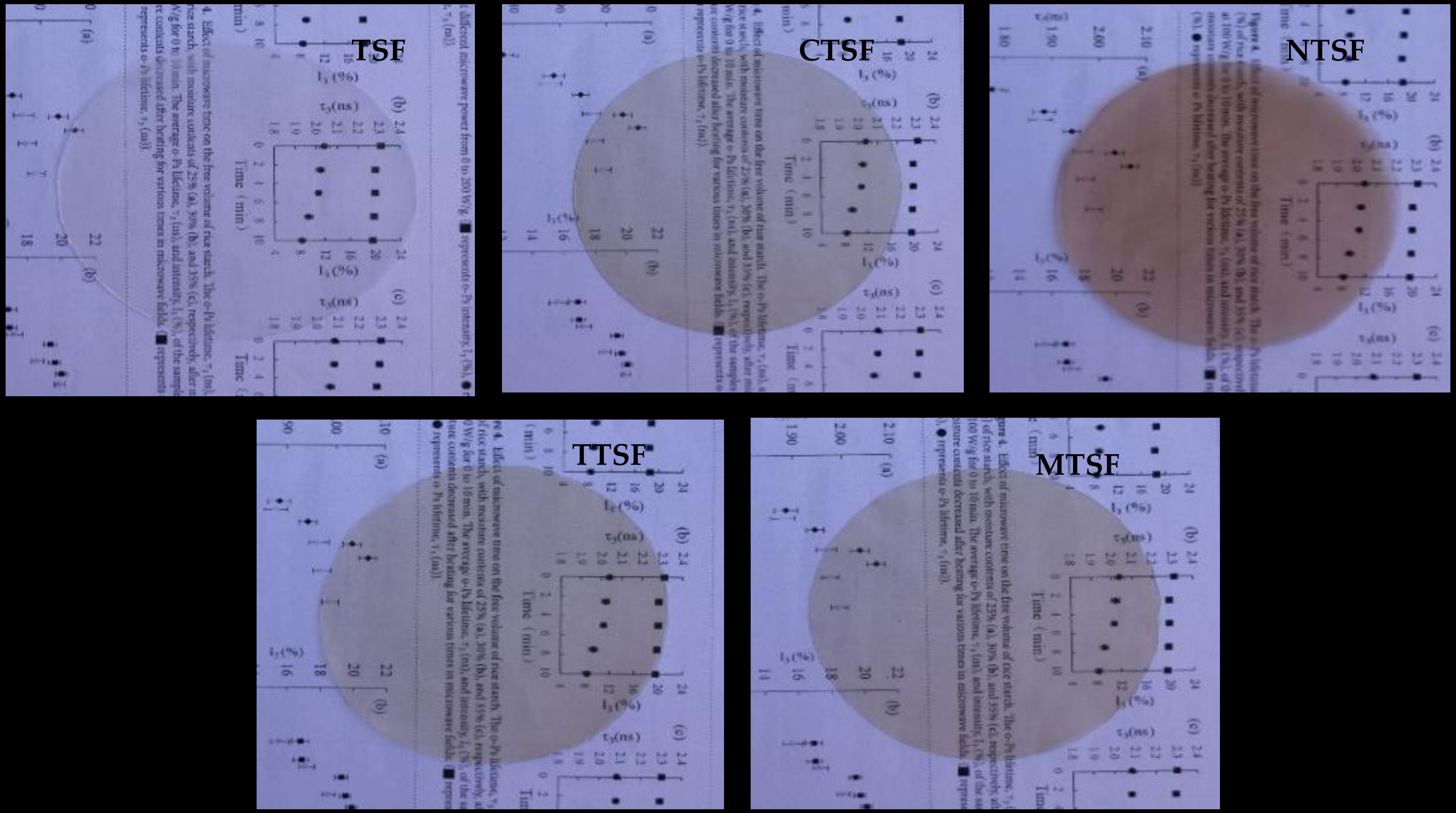
MEXICAN MINT LEAF EXTRACT



NEEM LEAF EXTRACT

RESULTS AND DISCUSSION

MORPHOLOGICAL PROPERTIES



- ✓ **TSF-** Native talipot starch film
- ✓ **CTSF-** curry leaf extract added composite film
- ✓ **NTSF-** neem leaf extract added composite film
- ✓ **TTSF-** tulsi leaf extract added composite film
- ✓ **MTSF-** Mexican mint leaf extract added composite film

Figure 1. (**a**) Digital photographs of biodegradable composite films with and without plant extracts.

MORPHOLOGICAL PROPERTIES

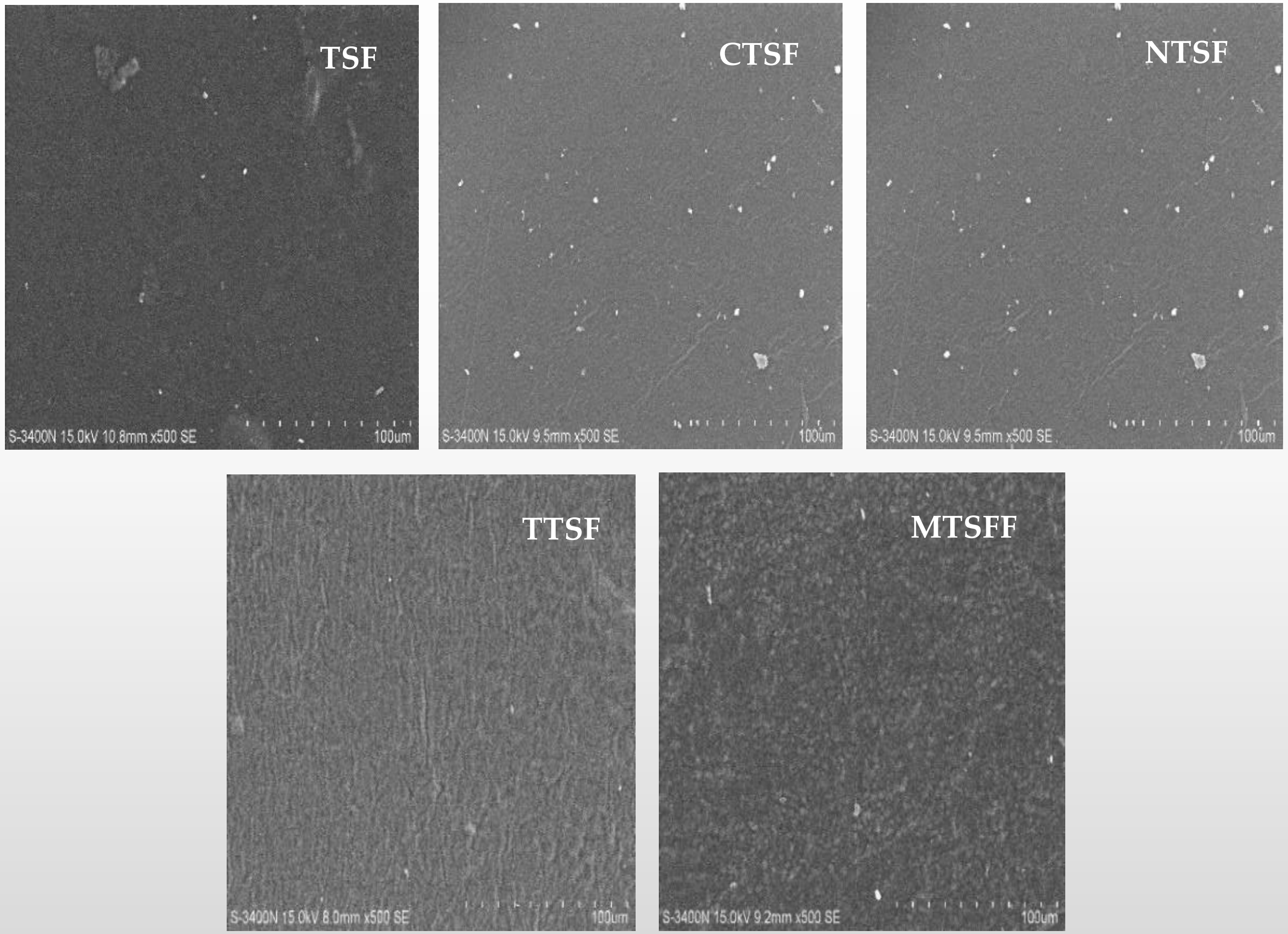


Figure 1. (**b**) Scanning electron monographs of biodegradable composite films with and without plant extracts.

- A few white spots on the SEM images of CTSF, NTSF, TTSF, and MTSF showed homogeneous distribution of plant extracts throughout the film and the surfaces showed slight heterogeneity when extracts were added.
- The roughness of native TSF, CTSF, NTSF, TTSF, and MTSF were 20.32 nm, 28.13 nm, 25.14 nm, 22.99 nm, and 29.13 nm, respectively.
- The incorporation of plant extracts significantly increased ($p \leq 0.05$) the R_a values, possibly because of biopolymer-extract interaction.

CRYSTALLINE PROPERTIES

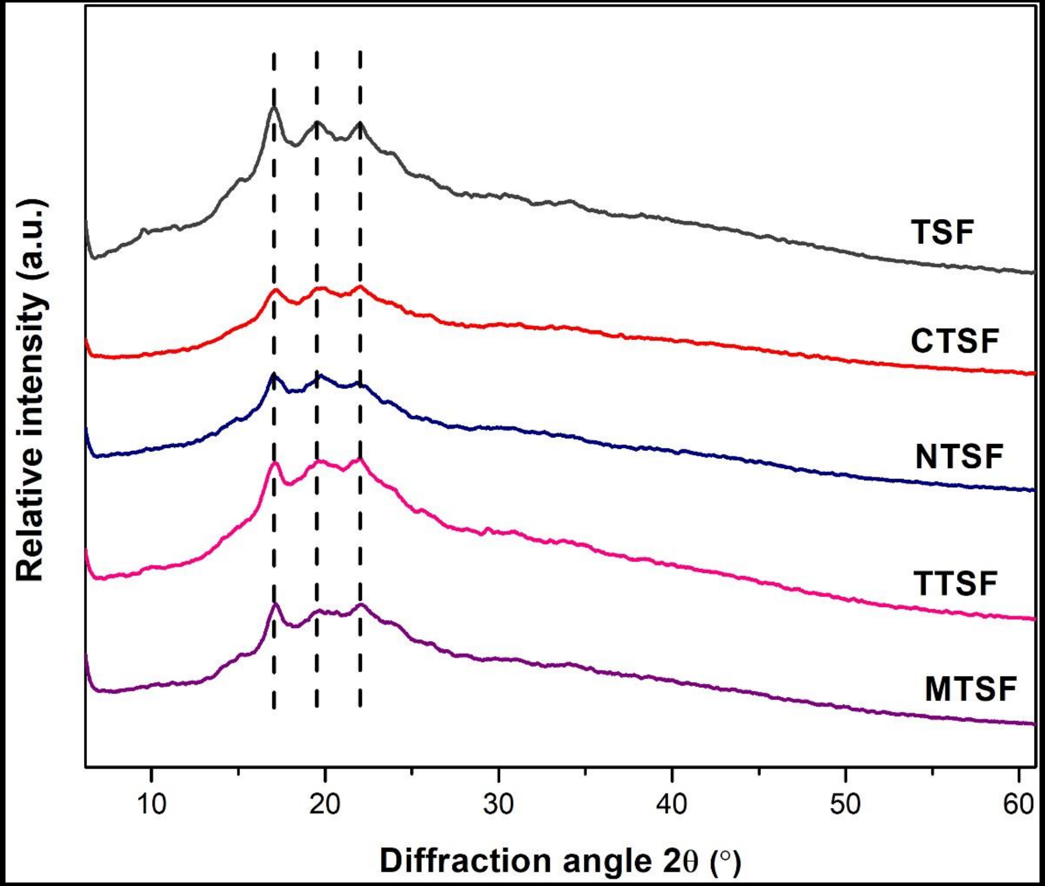


Figure 2. XRD of biodegradable composite films with and without plant extracts.

- Native talipot starch film showed crystalline peaks at 17.09°, 19.52°, and 21.99° indicating a V-type crystalline pattern that can be ascribed to the starch's plasticization effect [9].
- The addition of plant extracts reduced the intensity of peaks at 17.09- 21.99°.
- The native TSF showed a RC of 2.03 %. XRD patterns of films incorporated with plant extracts exhibited decreased crystallinity fraction compared with native TSF.
- This leads to an increase in the amorphism of the film structures and implies that plant extracts had hindered the phenomenon of retrogradation [22]. This result can be due to the development of intermolecular hydrogen bonds between amylose/amylopectin chains and polyphenols that potentially averts the reassociation of starch to a more ordered structure.

OPACITY

- The opacity of native TSF was 1.55 AU/mm and significantly increased ($p \leq 0.05$) to 3.63 AU/mm, 5.21 AU/mm, 4.04 AU/mm, and 4.61 AU/mm in CTSF, NTSF, TTSF, and MTSF, respectively.

- In general, the inclusion of plant extracts enhanced the UV-blocking ability of the talipot starch films [5].

- The increase in opacity relates to the irreversible phase partition to polymer-rich and polymer-deficient regions, and it can be associated with the observation here that plant extracts slowed down the retrogradation process.

Table 1. Roughness (R_a), relative crystallinity (RC), and opacity of biodegradable composite films with and without plant extracts.

Samples	R_a (nm)	RC (%)	Opacity (AU/mm)
TSF	20.32 ± 0.07^a	2.03 ± 0.02^a	1.55 ± 0.03^a
CTSF	28.13 ± 0.17^d	2.45 ± 0.02^b	3.63 ± 0.02^c
NTSF	25.14 ± 0.28^c	2.89 ± 0.13^c	5.21 ± 0.10^b
TTSF	22.99 ± 0.12^b	3.52 ± 0.07^e	4.04 ± 0.06^c
MTSF	29.13 ± 0.21^e	3.10 ± 0.22^d	4.61 ± 0.04^d

Values articulated are the mean of triplicate measurements ± SD. The values within the same column having different superscript alphabets indicate a significant difference at $p \leq 0.05$.

WATER VAPOUR PERMEABILITY (WVP)

- WVP of native TSF (3.67 g $Pa^{-1}h^{-1}m^{-1}x10^{-6}$) is greater than that of plant extract added talipot starch films.
- The inclusion of plant extract decreased the WVP compared to the native TSF, which is desirable, suggesting that plant extract incorporated films have a more effectual moisture barrier than native TSF.
- The plant extracts' compounds might have occupied the empty spaces of the polymer matrices, slowering the water vapor diffusion through the film [4]. The tortuous path hence developed reduces the rate of water molecule diffusion through the film that leads to the reduction in WVP.

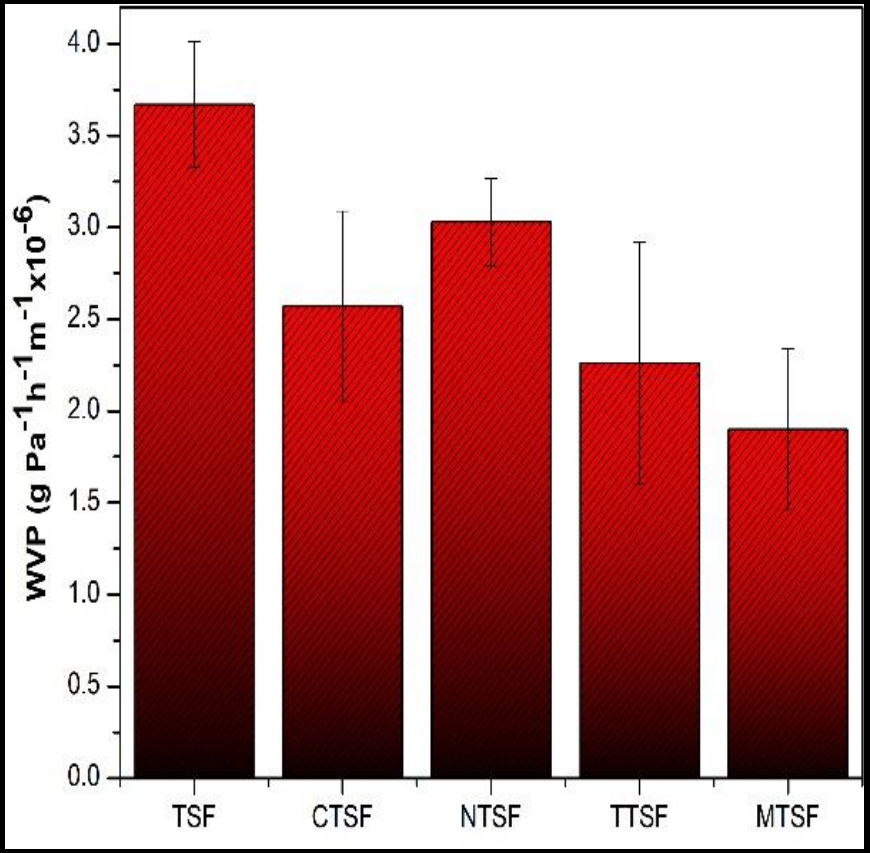


Figure 3. (**a**) WVP of biodegradable compostite films with and without plant extracts.

OXYGEN PERMEABILITY (OP)

- The OP of talipot starch films was found by measuring the peroxide value (POV) of oil covered by the developed starch films.
- The POV of soybean oil covered by native TSF, CTSF, NTSF, TTSF, and MTSF is 8.97 meq/kg, 7.02 meq/kg, 7.54 meq/kg, 6.29 meq/kg, and 6.08 meq/kg, respectively.
- The extract-starch-CMC matrices increased the compactness of the film surface and resulted in higher oxygen barrier properties [10].

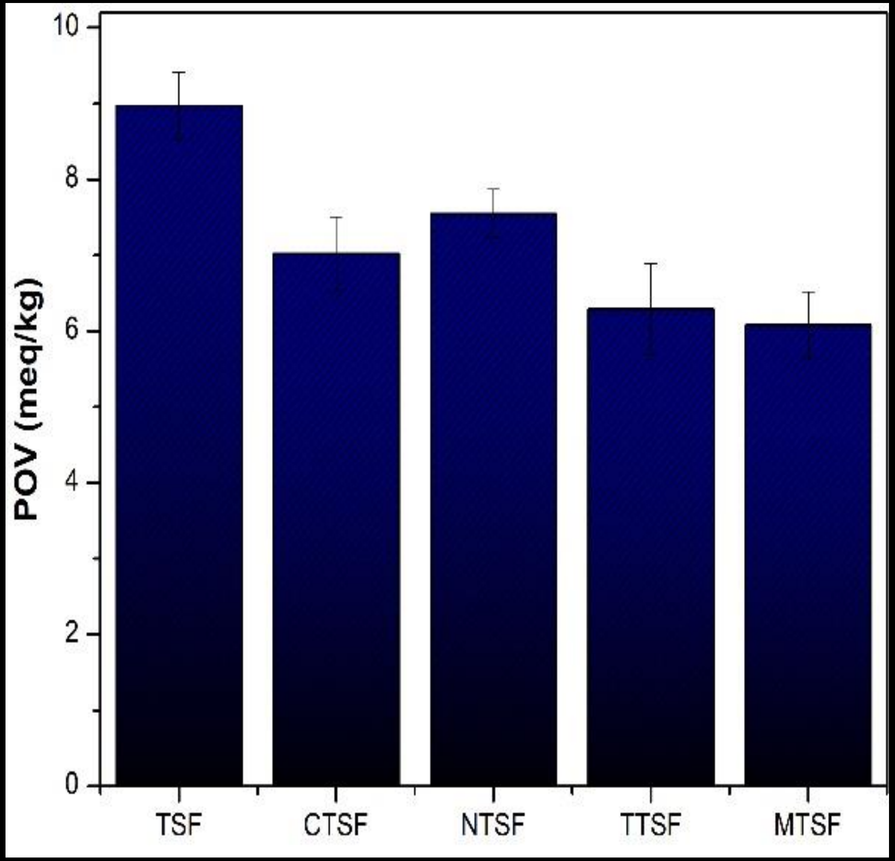


Figure 3. (**b**) OP of biodegradable compostite films with and without plant extracts.

ANTIMICROBIAL ACTIVITY

- No inhibition zone was observed for the native TSF against both *S. aureus* and *E. coli* and the test microorganisms were grown homogeneously in all regions of petri dishes.

- However, the addition of plant extracts from the leaves of curry tree, neem, tulsi, and Mexican mint showed a significant antibacterial effect against the bacterial pathogens.

- The development of the inhibition zone might be due to the leaching of antibacterial bioactive constituents from the talipot films that are incorporated with neem, tulsi, Mexican mint, and curry leaves extracts.

Table 2. Antibacterial activity of biodegradable composite films with and without plant extracts against *S. aureus and E. coli*.

Samples	Inhibition zone diameter (mm)	
	S. aureus	E. coli
TSF	-	-
CTSF	20.01 ± 0.27[b]	22.13 ± 0.13[c]
NTSF	18.14 ± 0.18[a]	17.16 ± 0.31[a]
TTSF	20.97 ± 0.22[c]	19.71 ± 0.07[b]
MTSF	22.13 ± 0.11[d]	24.83 ± 0.12[d]

BIODEGRADATION STUDY

- All the talipot starch films exhibited a continuous reduction in weight as the storage period increased.
- The films began to change their integrity after the fourth day of the experiment indicating the initiation of degradation.
- However, it is noticed that on the seventh day, the films with plant extracts exhibited a significant reduced degradation rate when compared to the native TSF, and after the tenth day of experiment, the films started to degrade into smaller pieces.
- The incorporation of plant extracts to talipot starch films augmented CTSF, NTSF, TTSF, and MTSF stability against the biodegradation process compared to native TSF because of the antimicrobial agents present in the extract.

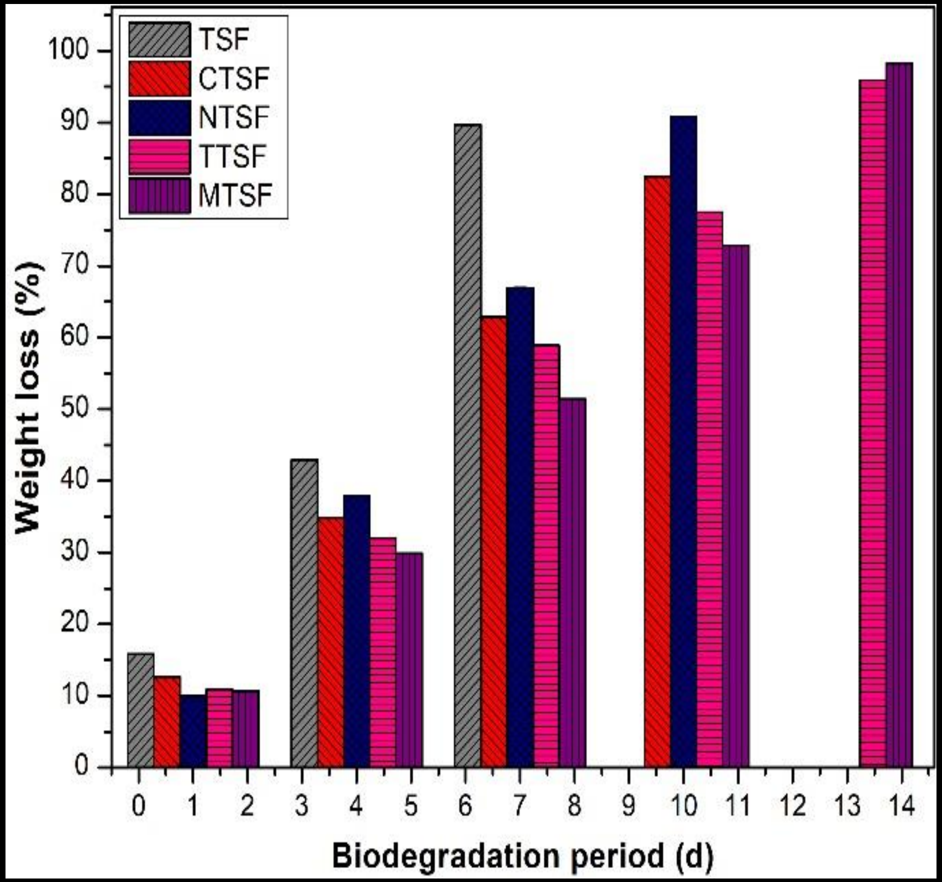


Figure 4. Biodegradability study on soil of biodegradable composite films with and without plant extracts.

CONCLUSION

- A few white spots on the SEM images of CTSF, NTSF, TTSF, and MTSF showed homogeneous distribution of plant extracts throughout the film and the surfaces showed slight heterogeneity when extracts were added.
- Increased surface roughness attributes to the improved opacity and hydrophobic properties of the film.
- The reduced crystallinity of plant extract added films suggests that plant extracts reduce the retrogradation tendency of starch.
- The higher opacity of plant extract added films is potentially beneficial for packaging photocatalytic reaction susceptible food products.
- Lower WVP and OP of developed talipot starch films thus decreases or deprives the transfer of moisture and oxygen between the food products and packages.
- Antimicrobial activity assessed by the inhibition zone method showed that composite films exhibited excellent antimicrobial activity against *Staphylococcus aureus* and *Escherichia coli*.
- The incorporation of plant extracts to talipot starch films augmented CTSF, NTSF, TTSF, and MTSF stability against the biodegradation process compared to native TSF because of the antimicrobial agents present in the extract.

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THANK YOU…