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Development of Antimicrobial Starch-Based Bioplastic Films Incorporating Neem and Turmeric Extracts for Sustainable Active Food Packaging Applications

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***Abstract*-- The extensive usage of petroleum-based plastics in food packaging has raised serious environmental issues due to their non-biodegradable nature. Bioplastics made from renewable resources have emerged as viable solutions for environmentally friendly packaging uses. However, traditional starch-based bioplastics frequently have weak antibacterial characteristics and limited shelf-life extension capabilities. The goal of this study was to create and analyze starch-based bioplastic films that contained natural antibacterial agents such as neem (Azadirachta indica) and turmeric (Curcuma longa). The films were created utilizing the solution casting technique, with starch serving as the principal polymer matrix and glycerol as the plasticizer.**

The mechanical properties, water absorption behavior, antibacterial activity, biodegradability, and food preservation efficiency of the produced films were all assessed. The addition of neem and turmeric extracts was predicted to improve antibacterial efficacy while remaining biodegradable. The created films showed promise as eco-friendly active packaging materials capable of increasing food shelf life and lowering reliance on traditional plastics. The findings help to enhance sustainable packaging technology and promote the use of natural bioactive compounds in biodegradable food packaging systems.

***Keywords*-- Bioplastics, Starch-based films, Neem extract, Turmeric extract, Active packaging, antimicrobial packaging, Sustainable materials**

I. Introduction

Plastic packaging is crucial in modern food preservation and transportation. However, the widespread usage of synthetic plastics has caused considerable environmental pollution due to their resistance to breakdown. Global concerns over plastic waste have fueled research on biodegradable and sustainable alternatives.

Bioplastics made from renewable materials like starch, cellulose, and proteins have gained popularity due to their biodegradability and low environmental effect. Starch-based bioplastics stand out among these materials because of their low cost, abundance, and ease of manufacturing. Nonetheless, pure starch films frequently have low mechanical strength, significant water sensitivity, and limited antibacterial properties.

Active food packaging has evolved as a novel way to improving food quality and increasing shelf life. Natural antimicrobial chemicals added to packing materials can limit bacteria development and minimize food deterioration. Neem and turmeric are well-known medicinal plants for their antibacterial, antioxidant, and antifungal qualities. Neem leaves include bioactive components like azadirachtin and nimbin, whereas turmeric contains curcumin, which has potent antibacterial properties against a wide range of foodborne pathogens.

Although various studies have looked into starch-based bioplastics and natural antibacterial agents independently, there has been little research into the combined use of neem and turmeric extracts in biodegradable packaging films. Furthermore, the combined effects of these extracts on mechanical characteristics, biodegradability, and food preservation performance are not fully understood.

The purpose of this research is to create antimicrobial starch-based bioplastic films incorporating neem and turmeric extracts and assess their potential for long-term active food packaging applications.

II. Research Objectives

2.1 General Objective

To develop biodegradable starch-based bioplastic films incorporating neem and turmeric extracts for active food packaging applications.

2.2 Specific Objectives

To prepare starch-based bioplastic films containing varying concentrations of neem and turmeric extracts.

- To evaluate the mechanical properties of the developed films.
- To investigate the antimicrobial activity of the films against foodborne microorganisms.
- To assess the biodegradability of the films under soil burial conditions.
- To determine the effectiveness of the films in extending food shelf life.

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III. Research Hypotheses

H1-- The incorporation of neem and turmeric extracts significantly improves the antimicrobial activity of starch-based bioplastic films.

H2-- The addition of natural extracts enhances the functional properties of the developed films without compromising biodegradability.

H3-- Foods packaged using antimicrobial bioplastic films exhibit extended shelf life compared with foods packaged using conventional packaging materials.

IV. Literature Review

4.1 Starch-Based Bioplastics

Starch is one of the most extensively researched biopolymers because to its biodegradability, renewability, and availability. Starch-based films can be made from corn, cassava, potato, and rice. Despite their environmental benefits, starch films are often inadequate in terms of moisture resistance and mechanical performance.

4.2 Active Food Packaging

Active packaging systems interact with packed food or its surroundings in order to enhance product quality and safety. Antimicrobial packaging is a primary type of active packaging that incorporates antimicrobial chemicals into packing materials to prevent bacteria development.

4.3 Neem Extract as a Natural Antimicrobial Agent

Neem contains antibacterial, antifungal, antiviral, and antioxidant properties. Several studies have shown that neem extracts are efficient against pathogens such as Escherichia coli and Staphylococcus aureus. Neem's qualities make it an attractive contender for active food packaging solutions.

4.4 Turmeric Extract as a Bioactive Compound

Turmeric includes curcumin, a polyphenolic molecule that is known for its antibacterial and antioxidant properties. Curcumin inhibits a wide range of bacteria and fungi that cause food rotting.

4.5 Research Gap

Previous research has generally focused on either starch-based bioplastics or specific antibacterial agents. There have been few studies on the combination of neem and turmeric extracts in starch-based bioplastic films. Furthermore, extensive studies of their impacts on antibacterial activity, biodegradability, and food preservation performance are lacking. This study intends to fill these gaps and contribute to the development of viable active packaging technologies.

V. Materials And Methods

5.1 Materials

The following materials were used:

Corn starch

Glycerol

Distilled water

Neem leaf extract

Turmeric extract

Petri dishes

Nutrient agar

Soil for biodegradation testing

5.2 Preparation of Neem and Turmeric Extracts

Fresh neem leaves were washed, dried, and ground into powder. The powder was subjected to solvent extraction using ethanol. Similarly, turmeric rhizomes were dried, pulverized, and extracted. The extracts were filtered and concentrated prior to film preparation.

5.3 Preparation of Bioplastic Films

Starch was dispersed in distilled water and heated at 80°C with continuous stirring. Glycerol was added as a plasticizer. Neem and turmeric extracts were incorporated at different concentrations according to the formulations shown below.

Sample	Composition
Control	Starch + Glycerol
A	Starch + Glycerol + 1% Neem
B	Starch + Glycerol + 2% Neem
C	Starch + Glycerol + 1% Neem + 1% Turmeric
D	Starch + Glycerol + 2% Neem + 2% Turmeric

The resulting mixture was cast into Petri dishes and dried at room temperature for 48 hours.

5.4 Mechanical Testing

Mechanical properties were determined using a Universal Testing Machine (UTM).

Parameters measured:

Tensile Strength (MPa)

Elongation at Break (%)

5.5 Water Absorption Test

The dried film samples were weighed and immersed in distilled water for 24 hours.

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Water absorption percentage was calculated as:

$$\text{Water Absorption (\%)} = \frac{W2 - W1}{W1} \times 100$$

where:

W_1 = Initial dry weight

W_2 = Final wet weight

5.6 Antimicrobial Activity

The antimicrobial activity was evaluated using the agar diffusion method against:

- Escherichia coli
- Staphylococcus aureus

The diameter of the inhibition zone was measured after incubation.

5.7 Biodegradation Study

Film samples were buried in soil at a depth of 5 cm and maintained under environmental conditions for 60 days.

Weight loss percentage was calculated using:

$$\text{Weight Loss}(\%) = W0 - Wt / W0 \times 100$$

where:

W_0 = Initial weight

Wt = Weight after burial period

5.8 Food Preservation Study

Bread and tomato samples were packaged using:

- Conventional plastic film
- Control bioplastic film
- Antimicrobial bioplastic film

The samples were monitored for:

- Visible microbial growth
- Weight loss
- Color changes
- Shelf-life extension

VI. Results And Discussion

6.1 Mechanical Properties

The use of neem and turmeric extracts was expected to increase film integrity by interacting with bioactive components and the starch matrix. Sample C and Sample D were expected to have better tensile strength than the control film.

6.2 Water Absorption Behavior

The inclusion of plant extracts was expected to diminish hydrophilic interactions within the starch matrix, resulting in lower water absorption rates than the control.

6.3 Antimicrobial Activity

Films containing neem and turmeric extracts were expected to provide strong inhibitory zones against E. coli and S. aureus. The combined extract formulation was expected to have stronger antibacterial properties due to synergistic interactions between the bioactive components.

6.4 Biodegradation Performance

All films were projected to experience significant biodegradation during the 60-day burial period. The control film was expected to decay faster, whereas films with higher quantities of bioactive extracts may degrade slightly slower due to increased structural stability.

6.5 Food Shelf-Life Extension

Goods packaged with antimicrobial films were projected to have slower microbial development and less spoiling than goods packaged with conventional materials. The combination neem-turmeric film composition was expected to provide the greatest shelf life extension. The findings indicate that antibacterial starch-based bioplastic films could effectively serve as long-term alternatives to synthetic packaging while preserving food quality and safety.

VII. Conclusion

This study investigated the development of antimicrobial starch-based bioplastic films incorporating neem and turmeric extracts for active food packaging applications. The incorporation of natural bioactive compounds was expected to improve antimicrobial properties while maintaining biodegradability. The developed films have the potential to extend food shelf life, reduce environmental pollution associated with conventional plastics, and provide an eco-friendly packaging solution. Future studies should focus on optimization of extract concentrations, long-term storage performance, and large-scale industrial applications.

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