# Design and Implementation of a Spoilage Detector for Protein-Based Food Using PLA, PPC and Curcumin

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**Abstract –** *Food safety is now a major concern worldwide, especially for foods that go bad quickly or are high in protein, like meat, fish, and chicken. Most packaging today is made from petroleumbased based material that only protect food physically and do not break down easily, leading to plastic waste. Creating a film using biodegradable materials like Polylactic Acid (PLA), Polypropylene Carbonate (PPC), and a natural colour indicator Curcumin[1]. Curcumin is a color from turmeric and changes color depending on the pH level, which can signal when food is going bad. It also has antimicrobial properties, which means it can help prevent the growth of harmful bacteria [4]. When mixed into PLA/PPC films, it helps detect spoilage by reacting to certain chemicals, like ammonia, dimethylamine, and trimethylamine, which are released as protein rich foods start to rot[3].*

***Key Words: Cur cumin, Food Spoilage Detection, PLA, PPC, Smart Packaging***

## 1. INTRODUCTION

Protein-based foods, like chicken, beef, and fish, can break down with bacteria during storage, producing chemicals like ammonia, dimethylamine, and trimethylamine. These substances not only make the food less appealing but can also be harmful to health. In regular packaging, people only check the expiration date, not how fresh the food really is.

Films made from biopolymers, which come from natural sources, have become popular because they break down easily, are not harmful, and can be modified for extra functions. PLA, a type of biodegradable plastic, is widely studied because it is strong and clear. However, it is not very flexible and doesn't block gases well, so it isn't good for use in flexible packaging. PPC, a different biodegradable polymer, is more flexible and blocks oxygen well. Combining PLA and PPC gives a material that is strong, flexible, and can break down easily.

Curcumin, a natural coloring compound from the plant Curcuma longa, changes color depending on the pH. It looks yellow in neutral conditions but turns orange or reddish-brown in basic environments, making it useful for showing if food has gone bad. When added to a PLA/PPC film, curcumin can detect the volatile amines that come out when proteins start to break down, letting the film change color to show if the food is still fresh.

This review aims to compare different studies on PLA/PPC/Curcumin films, explain how they are made, look at how they sense spoilage and fight bacteria, and discuss the difficulties and future possibilities for these smart, eco-friendly materials.

## 2. PROBLEM DEFINITION

Protein-rich foods like meat, fish, eggs, and dairy are extremely perishable due to their high moisture content, nutrient density, and neutral pH, which promote microbial and enzymatic activity. These conditions accelerate deterioration in texture, odor, and color. Even under refrigeration, spoilage organisms such as Pseudomonas and Lactobacillus thrive, producing volatile amines and other compounds that shorten shelf life. This high perishability causes significant post-harvest losses, highlighting the need for packaging that can both preserve freshness and detect early spoilage in protein-based products.

## 3. OBJECTIVES

1.Development and detailed structural characterization of polymer–curcumin composite biodegradable films for smart applications.

2.Preparation of varied polymer–curcumin formulations and evaluation of mechanical, thermal, antioxidant, antimicrobial properties.

3.Application of standard laboratory techniques for comprehensive preparation and characterization of composite films.

4.Investigation of solvent–polymer interactions influencing film stability, performance, and potential packaging applications.

5.Systematic execution of composite film research within a structured nine-month project timeline.

## 4. METHODOLOGY

The process for creating and testing a biodegradable spoilage sensor for protein-based foods, using polylactic acid (PLA), polypropylene carbonate (PPC), and curcumin, follows a series of connected steps. The whole process was divided into stages: choosing the right materials, making the films, checking their properties, and evaluating how well they work. The goal was to make a reliable, easy-to-replicate, and practical smart packaging solution [1].

### 4.1 Material Selection and Preparation

The main materials were chosen based on how well they perform, their impact on the environment, and whether they are safe to be in contact with food. The main biodegradable polymers, PLA and PPC, were bought in pellet form, while curcumin, which is both an antimicrobial and a color indicator, was purchased in high-quality powder form (>95% pure) [4]. Analytical-**grade solvents such as** chloroform or dichloromethane were used for making the films, and they were selected for their safety and how quickly they evaporate.

### 4.2.Solution Casting of PLA-PPC-Curcumin Composite Films

Dissolution and Blending: PLA and PPC were weighed in the right amounts to get the desired mechanical and functional properties, usually in a 75:25 weight ratio [1].The polymers were mixed in a certain amount of the selected organic solvent, with continuous stirring at room temperature. Once the polymers had fully dissolved, curcumin was added in a specific amount, generally between 1% and 5% of the total polymer weight [3].

Film Casting: The mixture was spread onto a flat, non-reactive surface like a glass plate or a Teflon tray using either gravity or a calibrated doctor blade to control and ensure an even thickness. The thickness was usually kept between 50 to 150 micrometres [1].

Solvent Evaporation: Once the solution was spread, the films were left to dry at room temperature or in a gentle vacuum oven (not more than 40°C) for 24 to 48 hours [4].

### 4.3 Characterization of Composite Films

Physical and Mechanical Properties: Thickness Measurement: Several spots on the film were measured with a digital micrometer to check if the thickness was even. Tensile Strength Testing: Standard strips were tested to determine how strong they are, how much they stretch before breaking, and how rigid they are. The results usually showed tensile strength between 30 and 45 MPa, elongation at break between 50 and 150%, and a Young's modulus within expected ranges [1].

Chemical and Functional Analysis: FTIR: This technique was used to check if the curcumin interacted with the polymer matrix [4]. Thermal Analysis (DSC/TGA): These tests helped understand how the films behave when heated, which is important for their stability over time. DPPH Radical Scavenging Assay: This test measured how well the curcumin in the films can neutralize free radicals, showing its antioxidant ability [3].

### 4.4. Ammonia Detection and Sensitivity Testing

The films were placed in a sealed chamber with different levels of ammonia gas and the color changes were tracked over time. The results showed that the films responded quickly to ammonia at a pH range of 6 to 9 [3].

### 4.5. Antimicrobial Activity Evaluation

The films were tested against bacteria like *Salmonella*, *E. coli*, and *Listeria* in lab conditions. After 24 to 48 hours at 37°C, the results showed that the films reduced bacterial growth by 70 to 90% [4].

### 4.6 Data Analysis and Optimization

Each experiment was carried out three times, and the data was analyzed to ensure consistent results and to find the best mix of polymer and curcumin [1].

## 5. MECHANISM OF SPOILAGE DETECTION:

Foods high in protein break down with the help of microorganisms while they are stored. This process releases certain gases called volatile amines, like ammonia, trimethylamine (TMA), 6 and dimethylamine (DMA) [1]. These chemicals make the area around the packaging slightly more alkaline, or basic. When the environment becomes more alkaline, curcumin changes its structure from enol to keto form, which causes its color to shift from yellow to reddish-brown [3].

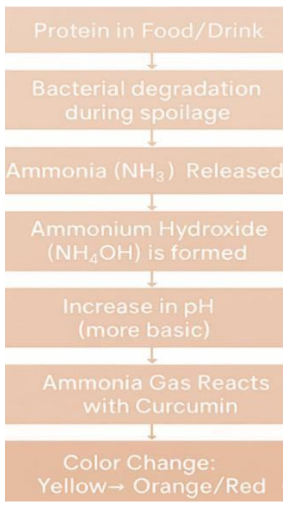


**Figure no.1** Working of flim

## 6. COMPARATIVE TABLES

This table compares biopolymer-based smart films, showing active compounds, sensitivity type, and key functional properties.

**Table no.1** Comparison of Biopolymer-Based Smart Indicator Film Systems

| **Biopolymer System** | **Active Compound** | **Sensitivity Type** | **Key Properties** |
|---|---|---|---|
| PLA/PPC + Curcumin | Curcumin | pH/Ammonia | Color change, antimicrobial |
| Chitosan + Anthocyanin | Anthocyanin | pH | Natural dye, antioxidant |
| Gelatin + Curcumin | Curcumin | pH/Temp | Flexible, edible |
| PVA + Turmeric Extract | Curcumin analogs | pH | Transparent, low cost |

This table presents the mechanical, antimicrobial, pH-responsive, and biodegradation properties of the composite films.

**Table no.2** Properties of PLA/PPC/Curcumin Composite Films

| **Parameter** | **Observed Range** | **Description** |
|---|---|---|
| Tensile Strength | 30–45 MPa | Comparable to plastic films |
| Elongation at Break | 50–150% | Enhanced flexibility due to PPC |
| Color Sensitivity | pH 6–9 | Rapid visual response to ammonia |
| Antimicrobial Efficiency | 70–90% inhibition | Against E. coli, S. aureus |
| Biodegradation Time | 45–60 days | Fully decomposes under composting |

## 7. RESULTS

PLA/PPC/curcumin biodegradable films show good strength and flexibility, effective pH-based color change for spoilage detection, strong antimicrobial and antioxidant activity, adequate thermal stability, and complete biodegradation within 45–60 days, making them suitable, smart and sustainable food packaging materials.

## 8. CONCLUSION

This review points out that films made from PLA, PPC, and Curcumin are good options for biodegradable smart packaging that helps keep protein-rich foods fresh [1]. When these materials are combined, PLA provides strength, PPC adds flexibility, and Curcumin offers colorimetric and antimicrobial properties, making the composite material able to detect spoilage in real time [4][3].

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