ISETC2025

2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM

THE POWER OF SCIENTIFIC INNOVATION

INTELLIGENT SOLUTIONS FOR A SUSTAINABLE WORLD

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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
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ISETC 2025 Proceedings Editors

BANANA PEEL-BASED BIOPLASTIC FOR ECO-FRIENDLY FOOD PACKAGING

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Abstract: Banana peels, an abundant form of agricultural waste, offer significant potential as raw material for biodegradable packaging. This study focuses on the development and comparative analysis of three banana peel-based bioplastic films: a plain formulation, one infused with natural pH indicators (anthocyanins from red cabbage), and another coated with agarose hydrogel. Starch was extracted from boiled banana peels and blended with glycerol to form the base bioplastic. For the pH-sensitive variant, anthocyanins were incorporated, while the hydrogel-coated films were treated with agarose solution to enhance barrier properties. All films were subjected to mechanical testing, water vapor permeability analysis, pH sensitivity observation, and biodegradability assessment. The plain film served as the control. The hydrogel-coated film demonstrated superior mechanical durability and moisture resistance. The anthocyanin-infused film successfully changed color under acidic and alkaline conditions, highlighting its potential for intelligent food packaging. All films exhibited biodegradability to varying extents. This study demonstrates the feasibility of utilizing banana peel waste to produce multifunctional, eco-friendly bioplastics through a low-cost, small-scale process, making it especially beneficial for rural industries and sustainable packaging innovations.

Keywords*: *Banana peel, bioplastic, pH indicator, hydrogel, food packaging

INTRODUCTION

Plastic pollution is one of the most pressing environmental challenges globally, with millions of tons of plastic waste generated annually. Single-use plastic packaging, particularly from the food industry, contributes significantly to landfill overflows and marine pollution. Conventional plastics are petroleum-based and can take centuries to degrade, releasing harmful microplastics and toxic chemicals into ecosystems. According to the United Nations Environment Programme (UNEP), more than 400 million tons of plastic are produced globally each year, with over 50% being single-use plastics. These plastics contribute to an estimated 8 million tons entering the oceans annually, harming marine life and entering the food chain through microplastic pollution.

Bioplastics have emerged as a potential solution, offering degradability, reduced environmental impact, and the ability to use renewable sources. However, commercial bioplastics often face limitations such as high production costs, limited mechanical strength, and lack of intelligent features like spoilage detection. One such alternative is bioplastics derived from agricultural by-products like banana peels. These peels contain valuable compounds such as starch, pectin, and cellulose, which are well-suited for creating biodegradable polymer films (Aneeshia et al., 2022). To boost the effectiveness of these bioplastics, various enhancements can be applied. For example, incorporating natural pH-sensitive pigments such as anthocyanins extracted from red cabbage allows the packaging to visually indicate food spoilage through color changes (Razavi et al., 2023). Another method involves applying hydrogel coatings like agarose to strengthen the film and reduce moisture permeability (Nair et al., 2022). However, the integration of all banana peel-based bioplastics, natural pH indicators, and hydrogel coatings into a single multifunctional packaging system has not been widely studied.

This study aimed to (i) formulate and characterize three types of bioplastics using banana peels, including plain bioplastic (control), pH-sensitive bioplastic (with anthocyanins), and hydrogel bioplastic (with agarose), (ii) investigate the physical and chemical properties of the bioplastics, including tensile strength, water vapor permeability (WVP), pH sensitivity, and biodegradability, and (iii) determine the most suitable type of banana peel-based bioplastic for potential use in eco-friendly food packaging.

LITERATURE REVIEW

Banana peel, a major agro-industrial waste, is rich in starch, cellulose, hemicellulose, and lignin, making it suitable for bioplastic production (Aneeshia et al., 2022). The utilization of banana peel for bioplastic synthesis have been widely studied, with researchers demonstrating that films produced from banana peel exhibit good flexibility and biodegradability (Suhardi et al., 2021). The blending of banana peel with polylactic acid has been shown to improve tensile strength and water resistance, making it more suitable for food packaging applications (Jumaidin et al., 2020; Sani et al., 2021). The addition of plasticizers such as glycerol can further improve the mechanical properties and processability of these films. However, unmodified banana peel-based bioplastics often suffer from high water sensitivity and limited barrier properties, restricting their application in food packaging (Aneeshia et al., 2022).

Intelligent packaging refers to materials that can monitor the condition of packaged food, often by indicating spoilage or changes in freshness. Natural pH indicators, particularly anthocyanins extracted from red cabbage, have been incorporated into bioplastic films to develop smart packaging solutions (Li et al., 2022). These indicators change color in response to pH variations, allowing visual detection of food spoilage, which is often accompanied by pH changes due to microbial activity. Studies have shown that anthocyanin-infused bioplastics can provide clear and reversible color transitions, making them suitable for real-time monitoring of food freshness (Razavi et al., 2023). Other natural colorants, such as curcumin and betalains, have also been explored for intelligent packaging, broadening the scope of freshness monitoring solutions (Wang et al., 2022). Although there is extensive research on banana peel-based bioplastics, natural pH indicators, and hydrogel coatings individually, comparative studies evaluating all three approaches under identical conditions are limited. There is a need to systematically compare plain banana peel bioplastic, pH indicator-infused bioplastic, and hydrogel-coated bioplastic to determine the optimal formulation for intelligent and sustainable food packaging. Furthermore, there is a growing interest in evaluating the synergistic effects of combining multiple functional modifications, such as natural indicators and hydrogel coatings on the overall performance of biodegradable films (Mansur et al., 2021).

MATERIALS AND METHODS

This study employed a quantitative experimental method to create and evaluate three different types of banana peel-based bioplastics designed for eco-friendly and intelligent food packaging. The entire project was carried out over five weeks, from June to July 2025, at the Faculty of Applied Sciences laboratories, Universiti Teknologi MARA (UiTM), Tapah campus. The three formulations developed included (i) plain bioplastic (Sample C), (ii) bioplastic infused with pH-sensitive anthocyanins (Sample A), and (iii) bioplastic coated with an agarose-based hydrogel (Sample B). The materials used consisted of ripe banana peels, red cabbage, agar powder, glycerol, vinegar, baking soda, and distilled water. A variety of standard lab equipment was used during preparation and testing, including beakers, measuring cylinders, glass rods, hot plates, blenders, sieves, Petri dishes, plastic wrap, digital weighing scales, and thermometers.

The basic bioplastic film was made by combining 30 grams of banana starch with 9 mL of glycerol and heating the mixture for 15 to 20 minutes with constant stirring until a thick, even consistency was reached. For Sample A, 15 mL of anthocyanin extract was added to the mixture before it was cast. Each mixture was poured onto plastic wrap and spread into a thin film to dry at room temperature over several days. For Sample B, the plain film (Sample C) was coated with a hydrogel solution made by dissolving 1 gram of agar powder in 100 mL of distilled water and adding 1 mL of vinegar. This solution was brushed onto the surface of the film and left to dry completely.

Once dried, the films were subjected to mechanical testing through basic tear resistance experiments. Water vapor permeability (WVP) was measured by placing the films in a high-humidity environment (such as a bathroom) for four days, with daily weight recordings. For pH sensitivity, the films were submerged in vinegar (acidic) and baking soda solution (alkaline) to observe and document any visible color changes over a span of 1 to 3 hours. Biodegradability was tested by burying the film samples about 2 cm deep in soil and tracking their weight changes on Day 0, Day 7, and Day 14. The percentage of weight loss was used to evaluate how well the films degraded in a composting environment. Additional control factors such as ambient room temperature (27–30 °C), humidity levels, and natural lighting were monitored during drying and testing to minimize environmental variability. Observations were recorded daily using digital cameras and lab notebooks to ensure accurate visual documentation of physical changes during pH testing and biodegradation. All tests were performed in triplicate to enhance reliability, and the final results were analyzed by calculating the average values, allowing for a clear comparison between the three bioplastic samples.

RESULTS AND DISCUSSION

In this study, three types of bioplastics derived from banana peel starch were developed and analyzed: Sample A (bioplastic with anthocyanin extract), Sample B (film coated with agarose hydrogel), and Sample C (unmodified plain film). Each sample was evaluated based on mechanical performance, moisture barrier capacity, pH responsiveness, and rate of biodegradation.

For the mechanical strength, Sample B recorded the highest tensile strength, averaging 1.02 MPa, followed by Sample A with 0.78 MPa, and Sample C with the lowest at 0.24 MPa. The enhanced strength of Sample B is largely due to the agarose hydrogel layer, which reinforces the film structure by creating a tighter molecular network. This type of reinforcement aligns with earlier research indicating that agarose contributes to improved intermolecular bonding and elasticity. In contrast, Sample A's moderate strength is linked to anthocyanins, which form hydrogen bonds with starch molecules but do not offer the same degree of mechanical support. The unmodified Sample C was more fragile and prone to breakage due to the absence of any structural additives. When tested for water vapor permeability (WVP), Sample B again outperformed the others, with an average WVP value of 75 g/m²/day, showing strong resistance to moisture absorption. On the other hand, Sample A had the highest WVP at 255 g/m²/day, most likely because anthocyanins are hydrophilic and tend to attract moisture from the surrounding environment. Sample C measured at 210 g/m²/day, consistent with the characteristics of starch films, which are naturally porous and absorbent. A lower WVP is generally preferred for packaging applications to extend food shelf life by minimizing moisture exposure. The results for pH sensitivity showed a clear distinction among the samples. Only Sample A responded to changes in pH by displaying a noticeable color shift. When exposed to acidic vinegar, the film changed from brown to reddish-brown. In a basic environment created using baking soda solution, the color turned to a muddy olive shade within an hour. These reactions occur due to the nature of anthocyanins, which are known to undergo visible color shifts depending on pH levels. This property is valuable for smart packaging that aims to signal food spoilage through color indicators. Samples B and C showed no such color response, as they lacked pH-reactive compounds.

In terms of biodegradability, all films showed significant degradation over a two-week period. Sample C degraded the fastest, losing about 67% of its original weight, followed by Sample A with 61%, and Sample B with 54%. The relatively slower decomposition of Sample B is likely due to the presence of the hydrogel layer, which creates a denser barrier that slows microbial breakdown. Nevertheless, all three samples are considered biodegradable, making them more environmentally responsible than petroleum-based plastics. To supplement these findings, visual documentation and graphs (Figures 1–3) were created to depict mechanical performance, permeability, and degradation rate, reinforcing the trends observed.

In summary, each formulation had specific advantages. Sample A demonstrated potential for smart packaging, capable of signaling spoilage via color changes. Sample B proved most suitable for moisture-sensitive or heavier packaging applications due to its superior strength and barrier properties. Sample C, although basic, was helpful for comparison and confirmed the benefits of the enhancements made in the other two samples. These findings support the broader use of banana peel-based bioplastics as functional, customizable materials for sustainable food packaging solutions.

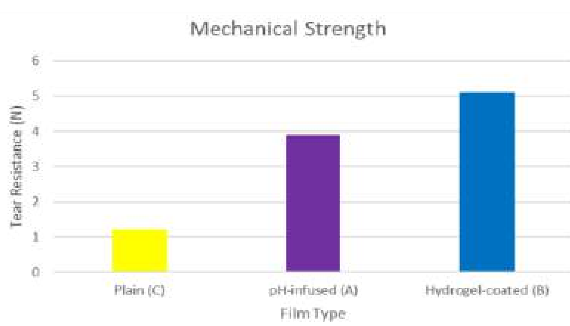

Figure 1. Tear Resistance Bioplastic Film

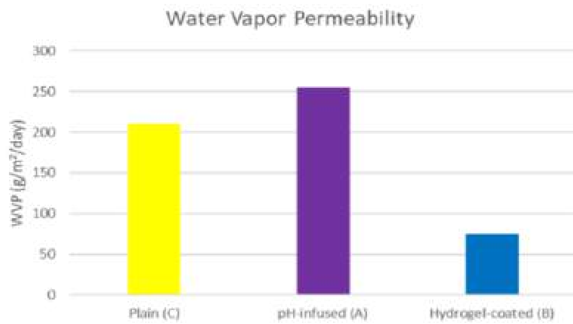

Figure 2. Water Vapor Permeability Rate for Each Bioplastic Film

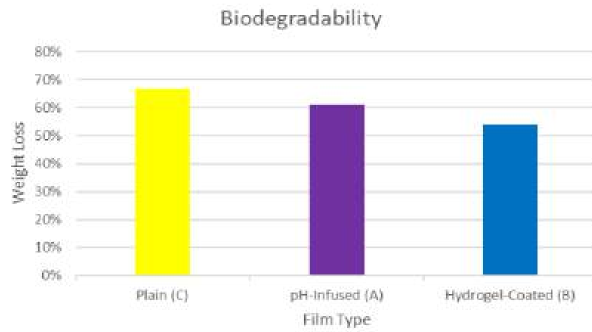

Figure 3. Biodegradability Rate for Each Bioplastic Film

CONCLUSIONS

This study demonstrated the potential of banana peel starch as a renewable and biodegradable material for bioplastic development. Three formulations were produced and assessed: a plain starch-based film, a pH-responsive film incorporating anthocyanins, and a hydrogel-coated film enhanced with agarose. Each variation displayed distinct strengths, indicating their suitability for different roles in sustainable food packaging. The anthocyanin-infused film (Sample A) responded visibly to acidic and alkaline conditions, showing its promise for use in smart packaging capable of indicating food spoilage. The agarose-coated film (Sample B) outperformed the others in terms of mechanical strength and moisture resistance, suggesting its suitability for packaging applications requiring durability and protection against humidity. The plain film (Sample C), though the least robust, provided a valuable control for comparison. Among the three, the hydrogel-coated sample offered the most well-rounded performance, effectively balancing strength, barrier properties, and biodegradability. However, the pH-sensitive film's ability to detect changes in food freshness makes it particularly useful for intelligent packaging solutions. These findings highlight the adaptability of banana peel-based bioplastics when formulated for specific functional needs. For future improvements, adjustments to the drying process such as using controlled heating could reduce waiting times and improve consistency. Additionally, using natural stabilizers could enhance the light and heat stability of anthocyanin-based indicators, extending the lifespan and reliability of the smart films.

Overall, the project supports the use of banana peel waste in creating cost-effective, environmentally friendly bioplastics. With further optimization, these materials have real potential to replace conventional plastics in the packaging industry, especially in applications requiring biodegradability, moisture protection, or freshness detection.

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