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by Mr Adnan

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Research Proposal

On

Development of Biodegradable Smart Packaging Films from Banana Peel Starch and Hibiscus Anthocyanins with Natural Antimicrobial Agents for Real-Time Freshness Monitoring of Perishable Foods in Bangladesh

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Introduction: Bangladesh faces mounting environmental and food security challenges due to excessive plastic waste and high post-harvest losses, estimated between 20% and 50% for perishable commodities such as fish, fruits, and vegetables.[1][2]Conventional plastic packaging, while providing physical protection, contributes to long-lasting environmental pollution owing to its non-biodegradable nature and lacks active food quality monitoring features.[3] The global push towards sustainable development goals now prioritizes eco-friendly packaging with smart functionalities to simultaneously address waste management and food preservation.[4]Agricultural wastes such as banana peels, which constitute a substantial portion of banana fruit weight, remain underutilized yet are rich in starch and cellulose suitable for biodegradable polymer development. [5][6] Utilizing banana peel starch aligns with circular economy principles by valorizing local agro-waste and reducing dependence on petrochemical-based plastics. [7]Natural dyes like anthocyanins extracted from Hibiscus sabdariffa provide intrinsic pH-sensitive colorimetric properties capable of reflecting the freshness condition of packaged food via reversible color changes, avoiding the need for electronic sensors.[8] These pigments are abundant, cost-effective, and non-toxic, offering an ideal natural sensor for freshness-indicating smart packaging systems. [9]Incorporating natural antimicrobial agents such as cinnamon and clove essential oils into biopolymer films enhances food safety by inhibiting microbial growth, thereby extending shelf life while maintaining consumer health benefits. [10]

Research Questions:

- How can banana peel starch and hibiscus anthocyanins be efficiently extracted and leveraged for biodegradable smart film fabrication?
- What film compositions optimize mechanical integrity, barrier performance, antimicrobial efficacy, and pH-responsive freshness indication?
- How accurately do anthocyanin-based colorimetric changes in films correlate with biochemical and microbial spoilage markers of local perishables?
- Can the films extend the shelf life of perishable food under typical Bangladesh storage conditions?

Literature Review:

Biodegradable films have emerged as promising alternatives to synthetic packaging, with starch-based polymers from agro-waste demonstrating mechanical and environmental advantages. [5][6] Banana peel starch presents a renewable resource with high film-forming capacity and biodegradability confirmed in recent studies.[13][7] Hibiscus anthocyanins, especially from Hibiscus sabdariffa (roselle), are widely documented for their stable, reversible pH-sensitive color changes usable as freshness indicators in packaging.[8][10] Antimicrobial essential oils such as cinnamon and clove oils exhibit broad-spectrum antimicrobial activity and have been successfully incorporated into starch-based films to improve food safety.[11][12]Global research on smart packaging has increasingly integrated these natural components, yet there is a lack of region-specific innovations adapting to Bangladesh's humid climate and local food items.[3][14] Furthermore, the synergistic application of banana peel starch and hibiscus anthocyanins with antimicrobial natural agents in a smart packaging platform presents a unique research niche with high societal impact potential, blending environmental sustainability with food technology.[4][7]

Proposed Methodology:

1.Materials: Banana peels from local fruit markets, Hibiscus sabdariffa calyces sourced from Rajshahi farms, Food-grade cinnamon and clove essential oils.

2.Extraction: Alkaline extraction for banana peel starch optimized for maximum yield and purity[5]Acidified methanol extraction for hibiscus anthocyanins standardized for concentration and stability.[8]

3.Film Fabrication: Casting films of banana peel starch (6–10% w/v), plasticized with glycerol (2–8% w/w), loaded with hibiscus anthocyanins (2.5–10% v/v) and essential oils (0.5–1.5% v/v). Drying and conditioning under controlled temperature and humidity.

4.Characterization: FTIR and XRD for chemical and crystalline structure analysis. [10]SEM for surface morphology. [16]Mechanical testing (tensile strength and elongation) as per ASTM D882. [17] Barrier properties (water vapor permeability and solubility).Colorimetric pH sensitivity assessment in buffer solutions. Thermal properties analyzed by TGA/DSC.

5.Functional Testing: Antimicrobial activity evaluated against foodborne pathogens via disc diffusion and MIC assays. [18]Real-time freshness monitoring tested on packaged fish and vegetables with microbial and chemical spoilage correlation. [19]

6.Biodegradability Studies: Soil burial and composting tests over 60 days measuring weight loss and physical degradation.[20]

7. Data Analysis: Statistical optimization via Design of Experiments (DOE).Significance analyses using ANOVA ($p < 0.05$).Correlation analysis between film color change and spoilage markers.

Expected Outcomes:

- Fully optimized extraction protocols for banana peel starch and hibiscus anthocyanins adapted for local raw materials. .
- Biodegradable smart films exhibiting balanced mechanical strength, barrier functions, antibacterial activity, and reliable freshness indication via color changes.
- Demonstrated shelf-life extension and spoilage reduction in real food packaging trials.
- Feasibility and groundwork for scalable, low-cost, sustainable packaging solutions customized for Bangladesh.

Impact and Significance:

This research supports Bangladesh's environmental sustainability and food security goals by providing biodegradable packaging alternatives that reduce plastic pollution and food waste. Utilizing agricultural waste enhances circular economy principles. The smart freshness monitoring improves food safety and consumer confidence while promoting green technology innovation and rural economic development through value addition of local raw materials.

Potential Limitations:

- Variability in raw material composition and availability.
- Stability constraints of natural anthocyanins and essential oils under different storage conditions.
- Technical challenges in scaling laboratory-developed films to industrial production.

Though, these will be mitigated by rigorous quality control, protective formulation strategies, pilot-scale trials, and early engagement with regulatory bodies.

Conclusion: By integrating banana peel starch and hibiscus anthocyanins with natural antimicrobials into biodegradable smart packaging films, this research aims to deliver an innovative, environment-friendly solution that enhances food freshness monitoring and preservation tailored to Bangladesh's needs, yielding substantial socio-economic and environmental benefits.

Project practicalities:

Duration: 18 months with phases for extraction optimization, film development and characterization, functional and biodegradation testing, and final evaluation.

Facilities: Collaborations with different governmental organizations like BCSIR, BSTI along with other reputed universities like University of Dhaka, Bangladesh University of Engineering and Technology and University of Rajshahi.

Team: Principal Investigator, Research Associate, 2 or 3 graduate, undergraduate students.

Budget: Cost-efficient leveraging local sourcing and shared instrumentation facilities

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Moreover, Dissemination through scientific conferences, patents, workshops, and community engagement.

Post Program Plans:

- Intellectual property protection and technology transfer to packaging industries.
- Capacity building through academic courses and workshops.
- Scaling studies for commercial production.
- Policy advocacy to support biodegradable smart packaging adoption.

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