Development of Bio-Based Smart Packaging Materials from Waste Biomass for Sustainable Food Preservation

The increasing consumer dependence on packaged foods, groceries, and ready-to-eat items particularly with the surge in home delivery services—has significantly intensified the use of conventional plastic packaging materials. While such packaging offers convenience and cost-effectiveness, it poses serious environmental concerns due to poor biodegradability and contributes to plastic pollution. Moreover, conventional packaging fails to indicate the freshness or spoilage level of food products, especially liquid foods, making it difficult for consumers to assess food safety before consumption. This creates an urgent need for innovative, eco-friendly packaging materials that are not only biodegradable but also capable of communicating the condition of the packaged food.

The proposed research aims to develop a **biodegradable, smart food packaging material** using natural, sustainable resources. The study focuses on fabricating films from **biopolymers such as starch and guar gum**, incorporating **nanoparticles derived from lignocellulosic biomass** to enhance barrier and mechanical properties. These nanoparticles will be synthesized using **green solvents** assisted by **microwave and ultrasound techniques**, ensuring an energy-efficient and environmentally safe process. Surface modification of the nanoparticles will be carried out to improve their compatibility with the polymer matrix, imparting **antimicrobial and antioxidant properties** that actively prevent food spoilage.

In addition, the research proposes to integrate **pH-responsive natural indicators** into the films, allowing them to change color in response to spoilage-related pH variations in food. This feature transforms the material into an **intelligent packaging system**, offering real-time visual cues to consumers about product freshness. The developed films will undergo comprehensive testing for **mechanical strength, barrier efficiency, biodegradability, and migration safety** under various storage and soil conditions.

Overall, this research aims to create an **eco-sustainable, smart packaging solution** that reduces plastic waste, extends food shelf life, and enhances consumer awareness, offering a promising alternative for modern food packaging industries.