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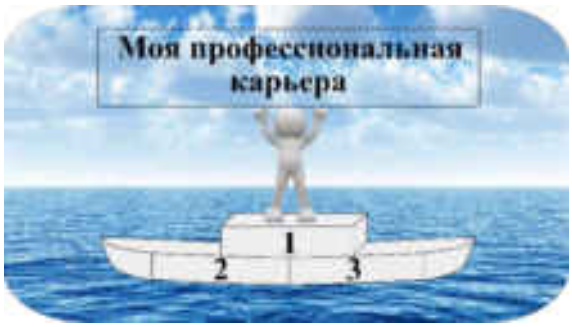

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Introduction

The increasing environmental problems caused by petroleum-based plastics have encouraged scientists and industries to develop biodegradable and sustainable alternatives. Conventional plastics require hundreds of years to decompose and contribute significantly to environmental pollution, marine contamination, and ecosystem damage. As a result, bioplastics have emerged as an environmentally friendly solution for reducing plastic waste.

Bioplastics are biodegradable polymer materials produced from renewable biological resources such as starch, cellulose, proteins, and agricultural waste. Among various agricultural residues, banana peels have attracted considerable scientific interest because they contain large amounts of starch, cellulose, hemicellulose, pectin, and natural fibers that can be converted into biodegradable plastic materials.

Banana is one of the most consumed fruits worldwide, generating significant quantities of peel waste. Approximately 30–40% of the banana fruit mass consists of peel material. Utilizing banana peel extract for bioplastic production not only reduces organic waste but also supports sustainable material engineering and circular economy principles.

Composition of Banana Peel

Banana peels contain several important biopolymer components:

- Starch
- Cellulose
- Hemicellulose

- Pectin
- Lignin
- Natural sugars

The approximate chemical composition can vary depending on banana species and maturity stage.

The moisture content relationship may be expressed as:

M(%)=Wi−WfWi×100M(\%) = \frac{W_i - W_f}{W_i} \times 100M(%)=Wi Wi−Wf×100

Where:

- MMM = moisture percentage
- WiW_iWi = initial mass
- WfW_fWf = final dry mass

Reducing moisture is an important step during raw material preparation for bioplastic synthesis.

Principle of Bioplastic Production

Bioplastics from banana peel are generally produced by extracting starch and polysaccharides, followed by gelatinization and polymer film formation.

The process involves:

1. Raw material preparation
2. Drying and grinding
3. Extraction of starch and cellulose
4. Mixing with plasticizers
5. Heating and gelatinization
6. Casting and drying

The polymer chains interact through hydrogen bonding to form flexible biodegradable films.

Raw Material Preparation

Collection and Cleaning

Fresh banana peels are collected and washed thoroughly to remove:

- Dust
- Dirt
- Sugars
- Microbial contaminants

Clean raw material improves the quality and stability of the final bioplastic.

Drying Process

The peels are dried using:

- Sun drying
- Oven drying
- Vacuum drying

Drying temperatures are usually maintained between:

50∘C≤T≤70∘C50^\circ C \leq T \leq 70^\circ C50∘C≤T≤70∘C

Proper drying reduces moisture content and prevents microbial growth.

Grinding and Powder Formation

After drying, banana peels are ground into fine powder to increase surface area and improve extraction efficiency.

Smaller particle sizes allow better interaction between solvents and biomolecules during extraction.

Extraction Technology

Starch Extraction

Banana peel powder is mixed with water and heated to extract starch and polysaccharides.

The gelatinization process occurs when starch granules absorb water and swell under heat.

The general gelatinization temperature range is:

60∘C≤Tg≤80∘C60^\circ C \leq T_g \leq 80^\circ C60∘C≤Tg≤80∘C

Where:

- TgT_gTg = gelatinization temperature

During heating, intermolecular bonds break, allowing polymer chains to form viscous solutions.

Filtration and Separation

The extracted mixture is filtered to remove:

- Fibers
- Insoluble particles
- Residual impurities

The resulting filtrate contains starch-rich biopolymer solution suitable for film production.

Addition of Plasticizers

Pure starch-based plastics are brittle; therefore, plasticizers are added to improve flexibility.

Common plasticizers include:

- Glycerol
- Sorbitol
- Polyethylene glycol

Plasticizers reduce intermolecular forces between polymer chains and increase elasticity.

The flexibility behavior may be associated with stress-strain relationships:

σ=Eε\sigma = E\varepsilonσ=Eε

Where:

- σ\sigmaσ = stress
- EEE = Young’s modulus
- ε\varepsilonε = strain

The addition of glycerol lowers stiffness and improves mechanical performance.

Film Formation Process

Heating and Mixing

The starch solution and plasticizer are heated while stirring continuously. Uniform mixing ensures:

- Homogeneous polymer distribution
- Improved texture
- Stable film formation

Casting Method

The viscous solution is poured into molds or flat trays to form thin films.

The film thickness strongly affects:

- Mechanical strength
- Water resistance
- Flexibility

Drying and Solidification

The cast films are dried under controlled temperature and humidity conditions until water evaporates completely.

The evaporation rate can be associated with mass transfer principles:

m=ktm = ktm=kt

Where:

- mmm = evaporated mass
- kkk = evaporation constant
- ttt = time

After drying, flexible biodegradable plastic sheets are obtained.

Properties of Banana Peel Bioplastics

Bioplastics produced from banana peel exhibit several useful properties:

- Biodegradability
- Renewability
- Low toxicity
- Flexibility
- Low production cost

However, they may also show:

- Lower thermal resistance
- Higher moisture sensitivity
- Reduced mechanical strength compared to petroleum plastics

Researchers improve performance using:

- Nanoparticles
- Fiber reinforcement
- Crosslinking agents

Biodegradation Mechanism

Bioplastics decompose naturally through microbial activity.

The biodegradation reaction may be simplified as:

(C6H10O5)n+O2→CO2+H2O(C_6H_{10}O_5)_n + O_2 \rightarrow CO_2 + H_2O(C6H10O5)n+O2→CO2+H2O

Microorganisms break polymer chains into smaller molecules, reducing environmental pollution.

Unlike petroleum plastics, bioplastics can decompose within months under suitable environmental conditions.

Industrial Applications

Banana peel bioplastics can be used in:

- Food packaging
- Disposable containers
- Agricultural mulch films
- Biomedical materials

- Eco-friendly bags

These materials are especially valuable in sustainable packaging industries.

Advantages of Banana Peel Bioplastics

Environmental Benefits

- Reduced plastic pollution
- Lower carbon emissions
- Renewable raw materials
- Waste utilization

Economic Benefits

- Low-cost raw materials
- Agricultural waste recycling
- Reduced dependency on petroleum resources

Sustainability

The technology supports circular economy systems by converting food waste into valuable industrial products.

Challenges and Limitations

Despite their advantages, banana peel bioplastics face several challenges:

- Limited water resistance
- Lower mechanical durability
- Shorter lifespan
- Sensitivity to humidity

Modern research focuses on improving:

- Thermal stability
- Mechanical strength
- Barrier properties
- Industrial scalability

Conclusion

Technology of bioplastic production from banana peel extract represents an innovative and environmentally sustainable approach for reducing plastic pollution and agricultural waste. Banana peels contain valuable biopolymers such as starch and cellulose that can be transformed into biodegradable plastic materials through extraction, gelatinization, plasticization, and film formation processes.

The resulting bioplastics possess biodegradability, renewability, and low environmental impact, making them promising alternatives to conventional plastics. Although challenges related to moisture sensitivity and mechanical strength still exist, ongoing scientific research continues to improve material performance.

As global demand for sustainable materials increases, banana peel bioplastic technology may play an important role in future green manufacturing systems and environmentally friendly packaging industries.

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