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EXPLORING STARCH-BASED BIOPLASTICS FOR A SUSTAINABLE FUTURE

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ABSTRACT
The food packaging industry massively relies on petroleum-based plastics for their convenience and appeal in agro, food, and packaging sectors. Challenges include the safe disposal and limited renewability of petroleum-based plastics. The growing interest in bio-plastics as asolution to environmental concerns is becoming more evident. Bio-plastic is derived from renewable resources like starch and cellulose and is known for its safety and eco-friendliness in food applications. The Research aims to improve their mechanical and water barrier. Ongoing research is being conducted on starch-based sustainable packaging materials to develop bio-plastics that meet the specific needs of the food packaging industry.

KEYWORDS: *Petroleum-based industry, Bio-plastics, Starch-based materials, Cellulose, Food packaging industry.*

INTRODUCTION

1.1 Background

Plastic pollution has a huge environmental impact, which causes challenges to environmentalists, governments, and politicians. Globally, 200 million tonnes of plastic are consumed annually. In Africa, plastic waste prompts tariff proposals. This waste threatens marine life and birds. The sustainability of packaging material is questioned. Bioplastic resolve the plastic waste problem that pollutes our earth. They are renewable biodegradable materials. Bioplastic are used in various industries, including healthcare, packaging containers and 3D printing (Tyagi, 2022).

Worldwide, the bioplastic industry is projected to grow from $17 billion to $44 billion by 2022, with PLA and PHA as the main types. PLA, made from maize starch, cassava, or sugarcane, is edible, biodegradable, and carbon neutral, while PHA is produced by microbes from organic resources. Bioplastic help reduce plastic pollution through their renewable sources and lack of hazardous chemicals like phthalates and biphenyl (Tyagi, 2022). However, not all bioplastic fully degrade, Presenting challenges such as contamination of recycled plastics and competition with food production for land. Finding a balance and researching sustainable alternatives is essential to effectively combat plastic pollution.

Problem Statement

Land pollution, predominately from plastics, metal and glass containers, food packaging, rubbish, is a major environmental issue. In the us, 25 billion plastic bottles are made annually, generating 25% of trash volume and persisting in landfills for centuries (YARADODDI ET AL., 2016). Plastics are widely used due to their cost and durability, leading to environmental pollution. Slow plastic deterioration harms land, streams, and seas. Plastic pollution also effects human health by change thyroid hormones levels. Some communities have reduced plastic usage and pollution while boosting recycling.

1. Literature Review:

2.1 Seaweeds: A Potential Solution for Sustainable Bioplastic

Plastic Production Grew Significantly In The 20th Century Due To Its Low Cost And Versatility. However, Non-Biodegradable Plastics Harm the environment, leading to the development of bioplastic. Derived from renewable sources, bioplastic offer similar applications to conventional plastics. Seaweeds are a promising alternative due to their high biomass, diverse growth environments, and natural cultivation (RAJENDRAN ET AL., 2012). They are cost-effective, minimally impact the food chain, and don't rely on chemicals. Seaweed-based bioplastic also resist microwave radiation, are durable, and less brittle. While still in the research phase, advancements in fermentation and genetic engineering could make them viable.

2.2 Optimizing starch extraction from plantain peel waste

At 2 minutes soak in nacio (1% v/v) cleansed the banana peel. Then, it was chopped into 4 mm pieces and soaked in ascorbic acid for 5 minutes. Then it was mashed into a paste, filtered, and washed repeatedly (Hernandez-Carmona et al., 2017). The mixture settled in glass funnels after 24 hours. Vacuum-filtering the mixture reduced water content. The starch was obtained after 10 hours of 40°C drying**.**

2.3 fiber based bioplastic film from morus sp. (mulberry) leaves for medical Purpose

Biodegradable bioplastic films from morus sp. leaves are researched for burn treatment. Currently, fossil oil-based bioplastic are used for severe burns. Morus sp. leaves are traditionally used for skin and inflammation treatments. The study combines morus sp. leaves with pave to create bioplastic. Leaves contain phenolic compounds, flavonoids, antioxidants fir cell growth, prevent bacterial contamination. 2g leaves blended with varying pva (20%, 40%, 60%, 80%, 100%). stirred at 95°C for 1 hour, poured into petri dishes, dried at 50°C for 24 hours. characterized via antimicrobial, tensile, sem, ftir analyses. bioplastic with 80% pva exhibits optimal mechanical, anti-microbial properties. potential as medical alternative highlighted (Aziz, Mohamad & Adollah, 2019).

2.4 Alternative packaging: corn and rice starch-based bioplastic

This study examined corn and rice starch-based bioplastic for packaging to reduce the environmental impact of synthetic plastics (Marichelvam et al., 2019). Samples were made with maize and rice starch, glycerol, citric acid, and gelatin. Adding rice starch improved tensile characteristics while reducing water absorption and solubility. The most promising sample was tested for thickness, biodegradability, seem, hydrophobicity, thermo gravimetric analysis, and sealing.

2.5 Development of nanostructured bioplastic material for wound healing

The goal of this study was to create a bioplastic material by using collagen, elastin, and hyaluronic acid that mimic the properties of human tissues. Researchers mixed these with distilled water, used photochemical crosslinking for stabilization and form nanostructured scaffold. They tested it with human skin fibroblasts. The material was non-toxic, biocompatible, and showed excellent elasticity and porosity under electron microscopy. Furthermore, when human fibroblasts were co-cultured with the bioplastic material, no harmful effects on the cultured cells were observed. This indicates that the biomaterial is non-toxic tocells and holds potential for various applications. It maintains physical properties in the culture medium for over 10 days but deteriorated after 3-4 weeks' incubation (Gilmutdinova et al., 2021). The biomaterial promoted cell proliferation, potential for wound healing application.

2.6 Waste to wealth: bioplastics promotes sustainability

Naturally biodegradable bioplastic address the depletion of fossil fuels and rising environmental contamination. There is demand for affordable and durable bio-based polymers, but their agricultural origins pose food security issues. Utilizing organic waste from food andagriculture can reduce dependence on crops and manage solid waste, potentially lowering production costs. This paper explores bio-based plastics and the potential of biological wastein their production. Innovation and research are essential to advance bio-based plastic technologies, offering an eco-friendly alternative to fossil-based polymers for a sustainable future (George et al., 2021).

2.7 Algal Bioplastic: Current Market Trends and Technical Aspects

Plastics Have A Significant Environmental Impact, Worsened By Covid-19. Interest In Sustainable Bioplastic From Renewable Sources Is Growing. Replacing One Ton Of Synthetic plastics with bio-based ones reduces co2 emissions by 1.8 tons (Nanda & Bharadvaja, 2022). Microalgae are ideal due to their fast growth, non-competition with food sources, and wastewater treatment benefits. Theyalso need fewer nutrients and are less climate-dependent. Although the algal bioplastic market is expanding, costs must become competitive with petroleum-based plastics. Market researchassessed the global status and future potential of algal bioplastic, proposing solutions for industry scale-up. Various production technologies and optimization strategies were discussed, emphasizing a multi-dimensional approach, like algal bio-refinery. Comprehensive comparisons and life cycle assessments are crucial for commercialization and integration intoa circular economy (Nanda & Bharadvaja, 2022).

3. Materials and Methodology:

3.1 Materials

S/No	Materials	Functions
1	Potato Starch Or Corn Starch	Function As The Polymer So It Becomes A Solid
2	Liquid Glycerin	Function As The Plasticizer So It Become Flexible
3	Water	For Dissolving And Mix The Polymer And Plasticizer And Also Dissolving For Potato Starch
4	Vinegar	When Making Starch-Based Biopolymers, Vinegar Is Commonly Used To Modify The Starch's Molecular Structure, and Enhancing Its Strength And Workability. Adding Vinegar Helps Break Down The Starch Molecules Even More, Resulting In A Smooth And Consistent Bioplastic
5	Food Color	For Coloring

3.2 Methodology

3.2.1 Extraction of Starch from Potatoes

There are various methods of starch extraction among which the following three areused that are explained below.

3.2.1.1 Extraction of starch using 30°C water

Cleaned and cut potatoes were mixed with one litter of 30°C water for there to four minute. The mixture was sifted through muslin cloth, and the residue was repeatedly washed until the water was clear. The liquid was collected in a glass jar and left undisturbed for two hours to allow starch to settle. **[10]** The starch was washed with distilled water, sieved through a 120-mesh sieve, and dried overnight at 40±5°C. Finally, it was ground and sieved through a 150-mesh sieve.

3.2.1.2 Extraction of starch using hot 60°C water

Potatoes were sliced, soaked in 60°C water, and blended into a slurry. The mixture was filtered through muslin cloth, and the liquid was separated. After settling, clear liquid was removed, and fresh water was added to the starch residue several times until clear. The starch was dried at 40±5°C overnight, then ground and sieved through a 150-mesh sieve.

3.2.1.3 Extraction of starch using cold 10°C water

Prepare and shred potatoes. Soak in 10°C water for an hour, stirring occasionally. Blend, strain through cloth, and filter with a 250-mesh sieve. Let starch settle, remove clear liquid. Wash and settle starch multiple times. Dry at 40±5°C overnight. Grind and sieve to achieve smooth starch (Neeraj et al., 2021).

3.2.2 Method for making of bioplastic

There are specific steps involved in the production of bioplastic (Bogers, 2020).

3.2.2.1 Preparation

Measure ingredients accurately. Prepare the mold. Choose a suitable undisturbed spot, ideally near an open window for airflow.

Figure 1: Measuring Ingredients

3.2.2.2 Dissolving the Ingredients

Figure 2: Mixing Ingredients

Heat Water until Boiling. Optionally Add Natural Dye For Color. Add Glycerin While Stirring. Maintain Temperature Below 80℃. Stir Slowly With A Regular Spoon To Prevent Bubbles.

3.2.2.3 Cook The Ingredients

Figure 3: Dissolving the Starch To Other Ingredients

Use a separate bowl. Dissolve starch with a few tablespoons of hot water. Combine dissolved starch with the mixture. Stir for 5-10 minutes at 80 degrees. Result should be a thick paste with liquid consistency.

3.2.2.4 Casting

Figure 4: Casting Of Starch

Spread thick paste onto mild quickly with spatula. Place mild in cool, well- ventilated area. Avoid warm areas to prevent rapid drying and microbial growth. Slab shrinks quickly, remove from mild and air dry. Alternate air drying with applying pressure. Use roller for simultaneous drying and pressing.

3.2.2.5 Shrinkage And Deformation Control

Figure 5: Starch Based Bioplastic

Dry Slab for About A Week Until It Reaches Final Form. Initially Flexible, It Will Become Rigid Over Time. Watch Drying Process, Trim Curled Edges Before Fully Hard. Periodically Flatten Under Stack Of Books For A Few Hours

Time of Releasing From Mold

As For The Minimum Wait For Time Before Releasing It From The Mold, It CanTypically Do So After 1-2 Hours.

3.2.2.6 Processing

Trim and Cut Slab Into Desired Shape before Fully Dry. Store in Dry, Well-VentilatedRoom. Keep Pressed Until Fully Dry.

Figure 6: Bioplastic Final Samples Obtained

(a)

(B)

4. Characterization:

4.1 Introduction

Surface characterization studies material properties and structure, crucial in materials science and for understanding engineered materials. Biomedical materials present challenges. Various methods, including ftir, sem, fesem, xrd, eds, mechanical analysis, astm d5034, and soil burial test (sbt), are used for studying surface morphology and properties.The project focused on specific Techniques for detailed analysis.

4.2 Sbt (soil burial test)

Sbt method standard for quantitatively assessing bioplastic degradation. Evaluate starch- based bioplastic biodegradability. Observe physical change such as color, weight loss over 10 - day period.

4.2.1 Procedure

Bury 1x1 cm bioplastic samples in compost soil at 7.5 cm depth. Incubate at room temperature for 10 days, sampling every two days. Clean and weigh samples afterward. Use an equation to calculate bioplastic weight-loss.

$$\%weight\ loss = \frac{\omega 0-\omega j}{\omega 0} x100\%$$

4.3 Ftir (Fourier Transform Infrared Spectroscopy)

Figure 7: Fourier Transform Infrared Spectroscopy (Ftir) Equipment Setup

Ftir spectroscopy identifies and characterizes microorganisms in biofilms, complementing genetic methods. Ftir-atr observes biofilm formation on surfaces like germanium crystalsnon-destructively, useful in water systems. It discriminates between microorganisms, inorganic materials, and contaminants. Drift investigates surface coating and contaminants, highlighting ftir's versatility in biofilm and surface analysis across applications

Working principal of ftir machine

Ftir generates an infrared absorption spectrum to identify chemical bonds and functional groups in molecules, creating a profile of the sample's molecular structure. It is useful for analysing and identifying elements based on unique molecular characteristics, often used with other spectroscopy techniques to gather comprehensive molecular data.

4.4 Mechanical analysis

To describe a material's qualities as a function of temperature, time, frequency, stress, environment, or a combination of these factors, mechanical analysis is frequently utilized.

4.4.1 Test for tensile strength

Bioplastic are configured as thin films. Our goal provide mechanical description Of Auxetic Bioplastic. Using Re-Entrant structure mats. Methodology aims to assess mechanical characteristics. Focus on tensile test method insights such as tensile strength, elastic modulus, and strain at break.

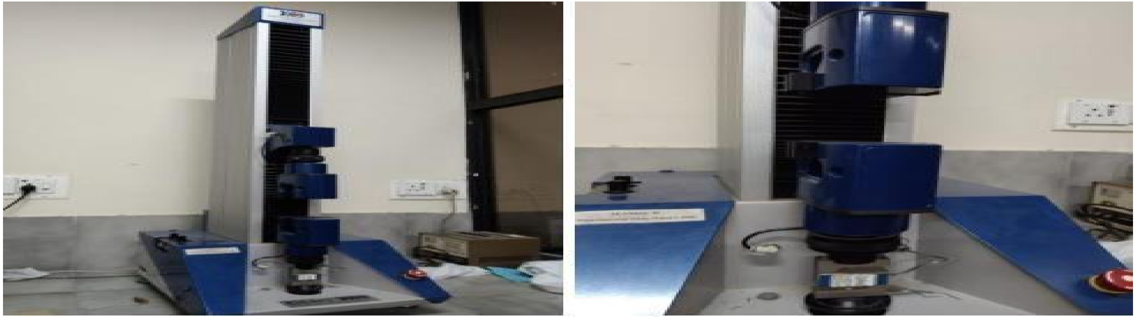


FIGURE 8: TEST FOR TENSILE STRENGTH EQUIPMENT SETUP

4.4.2 Procedure

Material held at both ends for testing. Gradually stretched until it breaks. Load represents stretching force, plotted against material displacement. Load translates to stress value. Displacement translates to strain value.

5.1 Results obtained from tensile testing for bioplastic

Bioplastic tensile strength was verified via ASTM d5034 testing. A 100-mm wide sample was tested in a machine, measuring breaking force and elongation to confirm mechanical characteristics. Results were used to plot the stress-strain curve.

5. Results and discussion:

5.1.1 Specifications and Placement Process

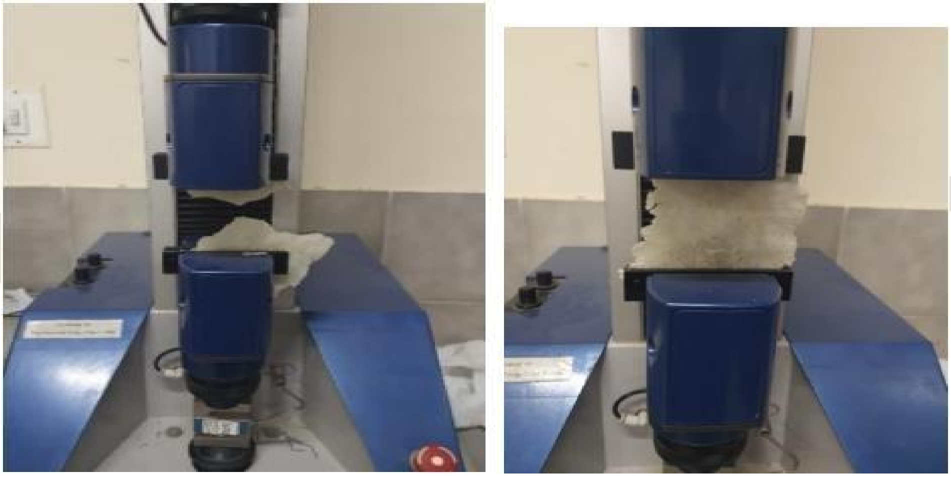
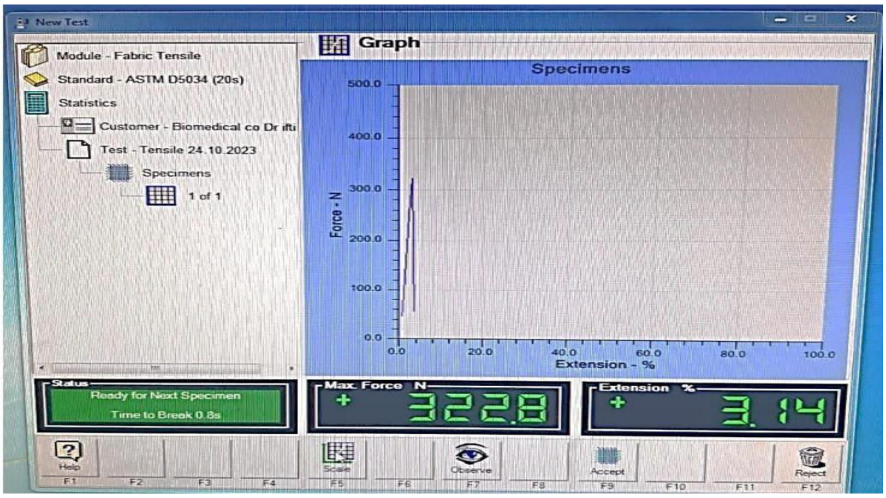


Figure 9: Tensile Testing On Bioplastic Sample Fig (A) Shows Bioplastic Sample And (B) ShowsAfter Breaking Of Bioplastic Sample

The main idea of a tensile test is to clamp a 30x60mm bioplastic sample between two grips. The cross-sectional area and length of the sample are known. One end of the sample is secured while force is applied to the other end. The sample's Length Is measured as the Force Increases Steadily. The Test Results Are Displayed On A Graph OfLoad Versus Displacement.

(A)

(B)



New Test

Module - Fabric Tensile
Standard - ASTM D5034 (20s)
Statistics
Customer - Biomedical co Dr ifti
Test - Tensile 24.10.2023
Specimens
1 of 1

Status: Ready for Next Specimen
Time to Break 0.8s

Max Force N: + 322.8

Extension %: + 3.14

Figure 10: Results Obtained From The Tensile Testing Of The Bioplastic

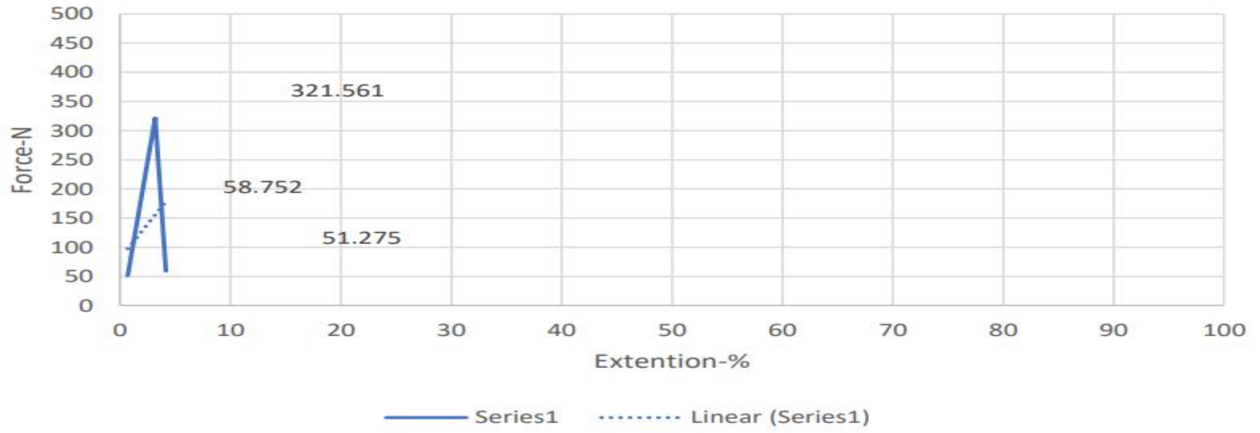


Figure 11: Uniaxial Tensile Testing, the Mechanical Characteristics of the Bioplastic Sample

5.2 Result Obtained From Sbt (Soil Burial Test)

Figure shows bioplastic weight loss increasing with burial time. Daily weight loss peaked at 29.89% by day ten. ASTM requires pla and pcl films to degrade in 60 days. Chemical degradation reduces polymer molecular weight. Rapid breakdown of starch acetyl connections noted. Bio plastic's significant decrease due to bacterial digestibility. Microbial degradation facilitated by hydroxyl groups

Factors affecting biodegradation include temperature, oxygen, humidity, and microbial activity. Starch's hydroxyl group initiates polymer hydrolysis, aided by glycerol. Glycerol disrupts internal polymer hydrogen bonding. Sample showed surface cracks by day four, deteriorating by day ten. Dimensions shrank, becoming hard and fragile after 90 days. Soil nutrients likely contributed to macrostructure damage by bacteria and fungi.

Figure 12: First Day Bioplastic Sample

Figure 13: After Four Days

Figure 14: After 10th Days

5.3 Result Obtained From Ftir (Fourier Transform Infrared Spectroscopy)

Chemical Composition Analysis Using Ftir Confirmed The Presence Of (Pva). Specific Characteristic Peaks Of Materials Are Observed For Main Four Elements: O, C, H and N at Wavenumbers 3280 cm^{-1} (Hydroxyl Group of Pva) and 1740 cm^{-1} (Carbonyl Group).

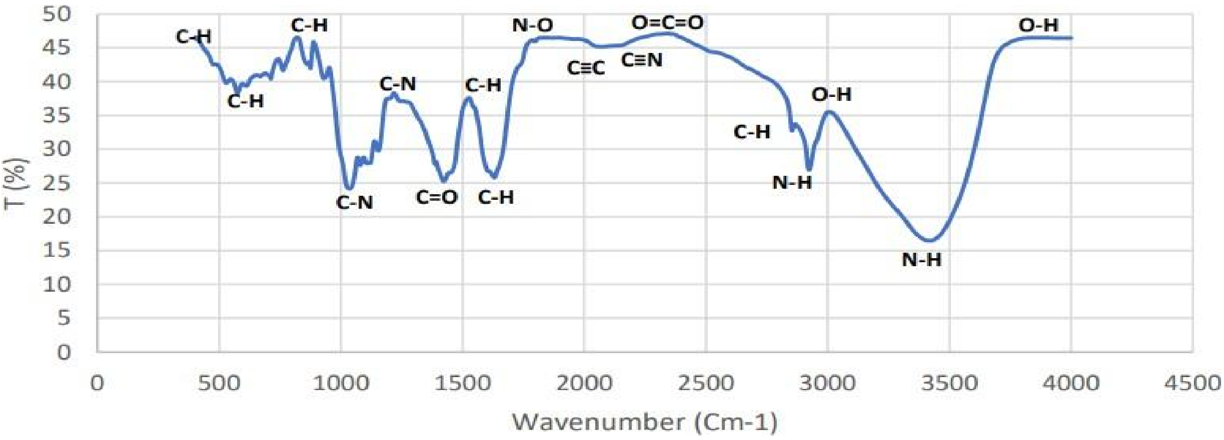


Figure 15: Ftir Spectra of Bioplastic

4. Conclusion:

Many traditional daily items are made of non-biodegradable, which can harm the environment. Biodegradable alternatives from different sources are adopted to mitigate these issues. Bioplastic degradation in soil depends on ph, temperature, humidity, and microbial diversity. Methods of evaluation include mass loss measurement and SEM imaging. Bioplastic like cellulose and starch are preferred for their biodegradability. Starch-based bioplastic degrade faster than cellulose-based due to higher hygroscopicity. Landfilled bioplastic can emit methane, a potent greenhouse gas. Challenges with microorganism-derived bioplastic include scalability and cost. Bioplastic are used in scientific devices, packaging, and other applications. Shifting from non-biodegradable plastics is crucial in sectors like food, medical, and health.

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