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CHARACTERIZATION OF BIOPLASTIC PREPARED FROM COMPOSITES OF FOOD WASTE

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Abstract

This research project investigates the use of food waste as a source material for producing bioplastics. Food waste is processed to extract starch, which is then transformed into bioplastics through various chemical and enzymatic processes. The resulting bioplastics are characterized for their physical, mechanical, chemical, and thermal properties. Tests such as solubility, elongation at break, water absorption, and thermal stability are carried out, along with evaluations of biodegradability and compostability. The findings demonstrate that bioplastics derived from food waste have comparable properties to traditional plastics, while also exhibiting significant biodegradability. This study offers a novel approach for waste management and emphasizes the importance of sustainable practices in addressing plastic pollution.

Keywords: Single resource, Combined resource, yam peel starch,potato peel starch, characterization

1.Introduction

Plastic pollution is a serious global issue, with over 300 million tonnes of plastic waste generated annually and only 9% being recycled. This waste accumulates in landfills and the environment, harming ecosystems and marine life. Microplastics are ingested by humans and sea creatures, while harmful chemicals from landfills contaminate water sources. Bioplastics, made from sources like food waste, offer a more eco-friendly alternative. They can reduce waste, conserve resources, and decrease greenhouse gas emissions. Biodegradable polymers like PLA and PHAs can be extracted from food waste to create bioplastics. By using food waste as a resource, bioplastics can mitigate the environmental effects of plastic production and disposal, contributing to a circular economy approach to waste management. Effective food waste management is vital for sustainable development and minimizing pollution. Wasted food depletes resources and releases methane, contributing to global warming. Using food waste for bioplastics reduces reliance on non-renewable resources and tackles plastic waste. Proper food waste management is crucial for reducing pollution, conserving resources, and promoting a circular economy. It's essential for sustainable growth. There are several types of biodegradable polymers used in various products. PLA is made from agricultural waste and used in fabrics, cups, cutlery, and packaging. PHA is produced by microorganisms and used in disposable items. PBAT is a synthetic biodegradable polymer commonly found in flexible films for bags, diapers, and food packaging. Starch-based polymers are derived from plants like corn and used in food packaging and single-use dishes. Cellulose-based polymers are made from plant cell walls and used in films, coatings, and textiles. PGA is a biodegradable polymer made from renewable resources and used in medical applications such as sutures, implants, and drug delivery devices. To change the properties of polymers, additives are chemicals that are added to the polymer. They consist of fillers, stabilisers, colourants, processing aids, and plasticizers. Depending on the desired qualities of the finished product, different additives are employed in the creation of bioplastics. Glycerol is an excellent plasticizer that enhances the flexibility and mechanical properties of bioplastics. Sorbitol is a widely utilized sugar alcohol that is renowned for a variety of qualities, including its adaptability and superior moisture retention.Bagasse is the fibrous byproduct that remains after sugarcane juice is extracted.

2.Materials And Methodology

2.1 Materials: In this project work, Yam peels and Potato peels was selected as valuable raw material in the preparation of bioplastic film. They were collected from local Hotchips store from Mysuru Region. The required chemicals such as glycerol, Sorbitol and distilled water were at the college water analysis laboratory, Dept. of Environmental Engineering, JSS Science and Technology, Mysuru

2.2 Methodology:

Here is a methodology for preparing bioplastics using yam peel starch, potato peel starch, bagasse powder, sorbitol, and glycerol:

2.2.1. **Collection and preparation of raw materials:** Collect fresh yam peels, potato peels, and bagasse (sugarcane waste),Thoroughly wash and clean the yam peels and potato peels to remove any dirt or impurities and then Grind the dried yam peels and potato peels separately to obtain fine powder.Collect dried bagasse powder (from sugarcane waste) from a sugar mill or obtain it commercially.

2.2.2. **Preparation of starch suspension:** Take separate containers and add water to the yam peel starch, potato peel starch, and bagasse powder. Stir the mixtures well to obtain a starch suspension with a smooth consistency.

2.2.3. **Mixing the starch suspensions:**Take a clean container and combine the yam peel starch suspension, potato peel starch suspension, and bagasse powder suspension in predetermined ratios. The exact ratios may vary depending on the desired properties of the bioplastic.Stir the mixture thoroughly until a homogeneous mixture is obtained.

2.2.4. **Addition of plasticizers:**Add sorbitol and glycerol to the starch mixture as plasticizers. These plasticizers help to improve the flexibility and reduce the brittleness of the bioplastic.The recommended ratio of sorbitol and glycerol to the starch mixture is typically 15-30% (w/w) of the total dry weight of the starch.

2.2.5. **Heating and stirring:** Transfer the starch mixture containing plasticizers to a heat-resistant container. Heat the mixture using a hot plate or a temperature-controlled water bath. Stir the mixture continuously to prevent the formation of lumps and ensure even distribution of heat.Heat the mixture at a moderate temperature of around 70-80°C until the bioplastic mixture thickens and forms a gel-like consistency.

2.2.6. **Casting and drying:**Pour the heated bioplastic mixture onto flat, non-stick surfaces like glass or metal sheetsor petriplate.Spread the mixture evenly on the surface to form a thin film.Allow the bioplastic film to air dry at room temperature for several hours until it becomes solid and rigid.

2.2.7. **Bioplastic film properties and testing:** Once the bioplastic film is completely dry, carefully peel it off from the casting surface.Test the physical and mechanical properties of the bioplastic film, such as tensile strength, solubility test, water absorption, and biodegradability, using standard testing methods.

3.Composition Of Bioplastic Samples

3.1 Single resource bioplastic preparation: Peels from 12 g of dry yam tuber starch were carefully combined with 100 ml of distilled water, 10 ml of glycerol, and 5 ml of vinegar. The mixture was poured into a 100 ml beaker and placed on a hotplate, where it was heated while being constantly stirred until it reached the desired level of gelatinization. The gelatinized bioplastic paste was then transferred to a Petri plate to give it a proper shape and kept in a hot air oven at 40 °C for hours to thicken the biofilm. For characterisation, the bioplastic film was removed.

3.2 Combined resource bioplastic preparation: In order to adequately combine the dry starch from 5 g of potato peels, 5 g of yam tuber peels, and 2 g of baggase powder, 100 ml of distilled water, 10 ml of glycerol, and 5 ml of vinegar were added. The mixture was put into a 100 ml beaker and heated on a hotplate while being constantly stirred until the desired level of gelatinization was achieved. The gelatinized bioplastic paste was then put into a Petri dish to give it a proper shape and kept in a hot air oven at 40 °C for hours to thicken the biofilm. The bioplastic film was removed so that it could be examined.

4.Characterization of bioplastic samples

4.1 Solubility test: Solubility tests on bioplastics assess their chemical properties and suitability for specific applications. By measuring how much a bioplastic dissolves in various solvents, these tests determine its susceptibility to deterioration. Small bioplastic pieces were immersed in solvents like ammonia, acetic acid, acetone, sulfuric acid, and ethyl alcohol for 24 hours. Solvent selection considered factors such as weak acidity, polarity, and type to evaluate the bioplastic's activity.

4.2 Swelling test: Swelling tests assess how well bioplastics absorb moisture, oils, and other liquids. These tests also reveal the internal structure and potential weaknesses or strengths of the bioplastics. The test involves immersing a bioplastic sample in a liquid and tracking its dimensions over time. The difference in measurements determines the level of swelling. Morphological changes were observed using a pre-weighed portion of the material, which was submerged in solvents like water, chloroform, and methanol for approximately 24 hours. Results were recorded based on these observations.

Biodegradability Test: Biodegradability tests evaluate how easily bioplastics break down in the environment. These tests assess the speed of degradation and ecological integration to determine the environmental impact and sustainability of bioplastics. They also provide insights into the mechanisms of deterioration and help determine their suitability for specific applications. The soil burial degradation test, involving burying bioplastics in soil to assess their complete decomposition, is commonly used. By measuring the reduction in mass of the buried samples, these tests quantify the degree of damage to the bioplastics.

4.3 Water absorption: The water absorption test evaluates the durability and suitability of bioplastics for moisture or water-related applications. Bioplastic samples are immersed in water or exposed to high humidity for 24 hours, and their weight is measured afterwards to determine the amount of water absorbed. This test provides insights into the material's resistance to water infiltration and its dimensional changes or expansion when exposed to moisture.

4.4 FTIR Analysis: FTIR analysis is used to gain insight into the chemical composition and molecular structure of bioplastics. It helps identify and analyze the functional groups present in the material, providing crucial information about its characteristics and functionality. This analysis is essential for quality control and ensuring compliance with regulations. Additionally, FTIR can be used to monitor the degradation or aging of bioplastics. FTIR was done by the model named FT/IR-4100type A, Start 397.264

cm-1,End 4003.5 cm-1,Data interval 3.85693 cm-1.According to the analysis's findings, the sample's FTIR spectrum was recorded at a wavelength between 400 and 4000 cm^{-1}.

4.5 SEM Analysis: Bioplastics are subjected to SEM (Scanning Electron Microscopy) study to look at their surface appearance and structure at a microscale level. We can also see the microstructure of bioplastics via SEM examination, including how polymer chains, filler particles, and other components are organised and distributed. SEM analysis can also shed light on how the bioplastic material is affected by the production environment.

4.6 Organoleptic properties:

Organoleptic features describe a substance's sensory qualities, specifically those that can be detected by the senses of humans. The evaluation of organoleptic qualities is crucial when analyzing bioplastics for a report in order to analyze their sensory components and potential influence on consumer acceptability.some of the factors assessed are odour, colour, durability etc.

5. Results And Discussion

5.1 Solubility test:

The solubility test results showed that the single resource sample and combined resource sample (with or without sorbitol) of bioplastics had similar solubility behavior. Both samples were insoluble in water and acetone, partially soluble in ammonia, ethyl alcohol, and acetic acid, and completely soluble in sulfuric acid.

Adding a plasticizer, such as glycerol, increased solubility values. The crystalline structure of starch granules explained their insolubility in cold water. Glycerol enhanced solubility in acid compared to sorbitol, while the combination of glycerol and sorbitol showed intermediate solubility. Solubility properties are crucial when selecting sustainable biomaterials for bioplastics. The tested material's insolubility in water and organic solvents makes it suitable for bioplastic production at an affordable cost.

5.2 Swelling test: The results represents the observation of the swelling test conducted on bioplastics. The sample without sorbitol showed minimal weight changes when immersed in chloroform and methanol, while a slight increase was observed when placed in a water medium. Similar findings were observed for biofilm samples using both single and combined resources with sorbitol.These results suggest that bioplastic materials with low water absorption or engorgement levels are more desirable.

5.3 Biodegradability test: The biodegradability test was conducted only on samples containing sorbitol due to their favorable performance in previous parameters. 1.5 cm bioplastic samples were initially weighed (W1) and placed in cups with damp garden soil for 5 days at room temperature. After keeping the samples moist, the remaining bioplastic residue was removed, washed, dried in an oven, and weighed again (W2). Biodegradability was calculated using a specific formula, and the results were recorded in Table 5.3.

$$\text{Biodegradability (\%)} = \left(\frac{W1-W2}{W1}\right) \times 100$$

SL NO.	TIME	Sample	INITIAL (gm)	FINAL (gm)	WEIGHT LOSS PERCENTAGE (%)
1.	One Weeks	C1	3.0	2.7	10.0
		C2	3.8	3.4	10.5
2.	Two Weeks	C1	3.0	2.1	30.0
		C2	3.8	3.0	21.0
3.	Three Weeks	C1	3.0	1.2	60.0
		C2	3.8	2.8	26.5
4.	Four Weeks	C1	3.0	0.9	70.1
		C2	3.8	2.0	48.0

Table 5.3 Biodegradability Property of Prepared Bioplastic Film

5.4 Organoleptic properties: Table 5.4 displays the developed bioplastic film's organoleptic characteristics. It is evident that the potato starch-based bioplastic sheet had a light yellow colour, no odour, was smooth and translucent but opaque, and was just slightly stretchy.

Table 5.4 Organoleptic properties of Sample 2 with sorbitol,C1- single resource, C2- combined resource

Sl No.	PROPERTIES	SAMPLE	OBSERVATION
1.	Colour	C1	Pale Brownish
		C2	Light Brown
2.	Odour	C1	Nil
		C2	Nil
3.	Texture	C1	Smooth
		C2	Hard
4.	Transperency	C1	Opaque
		C2	Slightly Opaque
5.	Extensibility	C1	Stretchable
		C2	Stretchable

5.5 FTIR Analysis: From the results obtained Fig and Table 5.5 , it showed the presence of various functional groups in the bioplastics, including Amines, Carboxylic Acid, Alkenes, and Alcohol. These functional groups indicate that bioplastics are safe for human use and the environment. The presence of carboxylic acid is important for enhancing the mechanical and chemical properties of bioplastics, making them a viable alternative to petroleum-based plastics. Amines contribute to the flexibility, strength, and thermal degradation resistance of bioplastics, thus aiding in their biodegradability.

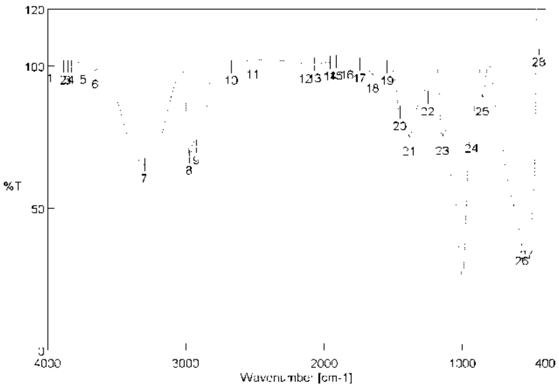

Fig 5.5: Results of combined resource sample with sorbitol

Sl No.	PEAK NO.	OBSERVED FREQUENCY cm^{-1}	REFERENCE SPECTRUM FREQUENCIES cm^{-1}	BAND ASSIGNMENT	REMARK
1.	6	3656.37	3700-3584	O-H Stretching	Alcohol
2.	12	2136.74	2140-2100	CΞC Stretching	carboxylic acid
3.	18	1650.77	1815-1785	C=N Stretching	Acid halide
4	22	1249.65	1275-1200	C-O Stretching	Alkyl aryl ether
5.	26	570.856	690-515	C-Br Stretching	Halo compound

Table 5.5: Observations of the FTIR analysis of combined resource sample with sorbitol

5.6 SEM analysis: The sample with a single source containing sorbitol produced the desired results, while the sample with combined sources had some moisture content, preventing SEM analysis. It displayed a continuous phase structure, indicating successful incorporation of glycerol and sorbitol into the polysaccharide chains and disruption of intramolecular hydrogen bonds. It showed the morphology of the sample at different resolutions. At resolutions of 100 and 500, air bubbles were observed, potentially leading to weaker mechanical properties.

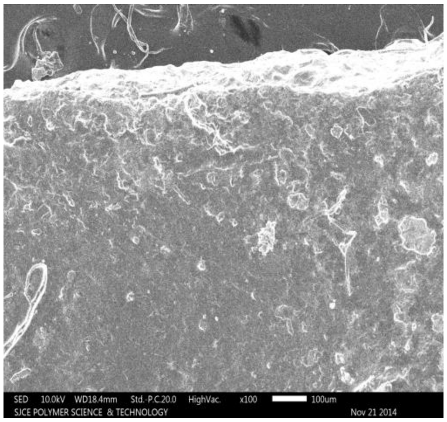

Fig 5.6 Single resource bioplastic film SEM image in ×1oo resolution

5.7 Other physical and chemical properties: Table 5.7 includes parameters such as water absorption, composition, durability, and moisture content. The composition of the samples was categorized as C1 and C2. For the sample without sorbitol, the composition was C1: Yamstarch, glycerol, additive, and water. The composition for C2 was Yamstarch, potato starch, bagasse powder, glycerol, additive, and water. The sample with sorbitol had the composition C1: Yamstarch, sorbitol, glycerol, additive, and water, while C2 consisted of Yamstarch, potato starch, bagasse powder, sorbitol, glycerol, additive, and water.

Moisture Content: The pre-made bioplastic film was desiccated until its weight (W1) remained consistent. After then, the films were exposed to regular air for 24 hours. The films were then once more weighted (W2) after that. The results of the following calculation for the percentage of moisture absorption are shown in the table below.

$$\text{Moisture Absorption (\%)} = (W1 - W2) \div W1 \times 100$$

Water absorption: The prepared bioplastic film was weighed after being dried with cotton pieces and soaked in water at room temperature for 60 minutes. The findings of the following calculation of the percentage of water absorption are provided.

Water absorption (%): (wet weight-dry weight÷wet weight) ×100

Sl No.	PARAMETERS	TYPE	SAMPLE 1	SAMPLE 2
1.	Composition	C1	10:15:10:70 20:10:2:30:25:80	10:5:10:10:70 5:5:2:10:10:10:80
		C2		
2.	Durability	C1	NIL NIL	+ +
		C2		
3.	Moisture Contennt %	C1	50 65	10 -
		C2		
4.	Water absorption %	C1	63 18.87	80 60
		C2		

Table 5.7: Other physical and chemical parameters

5.7 Possible applications

Yam bioplastic films are gaining recognition as an environmentally-friendly alternative to traditional fossil fuel-based plastics. They have various applications, particularly in the food industry, where they provide moisture and gas barriers, extending product shelf life. Yam bioplastics are also suitable for agricultural uses such as biodegradable nets, grow bags, mulch films, greenhouse covers, and soil stabilization. These applications offer benefits like biodegradability, non-toxicity, and reduced plastic waste. Additionally, yam bioplastics can be utilized in 3D printing and hold potential for further research and development in expanding their applications.

5.8 LCA study of bioplastic film

Life Cycle Assessment (LCA) is used to evaluate the environmental impacts of a product or process from extraction to disposal. It involves defining the assessment's goal and scope, conducting a life cycle inventory analysis, performing a life cycle impact assessment, and interpreting the results. Transparent and objective LCA studies provide evidence for the comparative sustainability of bioplastics. Yam starch is a renewable resource used in the production of yam bioplastics, offering ac (4.2.6b) educed carbon footprint and lower resource depletion. The manufacturing process can be optimized for energy efficiency and utilize renewable energy sources. During the use phase, yam bioplastics can perform similar tasks to traditional plastics, and their compostability helps in reducing environmental pollution and plastic waste. Proper handling and composting after use complete the nutrient cycle. Yam bioplastics contribute to lower greenhouse gas emissions and reduced reliance on non-renewable resources. LCA evaluates factors such as energy consumption, waste generation, water usage, and potential ecotoxicity and human health impacts. Effective waste management and water conservation techniques are crucial for minimizing environmental impact.

6.Discussion

The analysis and characterization of the bioplastic film showed desirable properties, including solubility, stability, solvent resistance, water resistance, and biodegradability. The film exhibited a pale yellow color, smooth appearance, and no distinct odor or taste. FT-IR analysis confirmed the presence of functional groups associated with biodegradability. However, the sample containing combined resources had moisture and showed instability during analysis. The presence of air bubbles and low heat resistance were observed in the SEM and TGA analysis, respectively. Conducting a comprehensive life cycle assessment can provide insights into the environmental performance of the yam bioplastic film and drive improvements in production methods for more sustainable alternatives to conventional plastics.

6.1 Conclusion

Bioplastics were successfully produced using potato and yam peel starch with glycerol and sorbitol as plasticizers and water as the solvent. The raw materials, tubers and potato peels, were abundant, cost-effective, and easily accessible. SEM analysis confirmed the absence of hazardous substances in the manufactured starch, making it suitable for food packaging. The resulting bioplastic film exhibited good texture and flexibility. It demonstrated desirable mechanical, chemical, and biodegradable properties, being resistant to chemicals and degrading rapidly in soil. FTIR spectroscopy confirmed the presence of functional groups associated with starch-based bioplastics, aligning with previous research findings. These findings suggest that the starch-based bioplastic film is suitable for food packaging applications and contributes to reducing environmental pollution.

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