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FABRICATION OF CELLULOSE-BASED BIOPLASTIC USING SUGARCANE BAGASSE FOR FOOD PACKAGING

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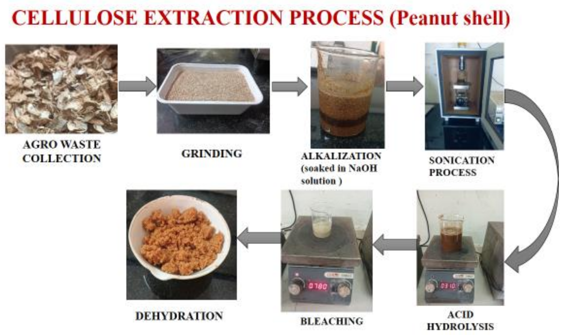
ABSTRACT

Bioplastics are becoming increasingly recognized as environmentally friendly substitutes for traditional polymers derived from petroleum in food packaging. Bioplastics, which are made from renewable biological resources, such as proteins, cellulose, and starch, are intended to be compostable or biodegradable, resolving environmental issues related to conventional plastics.

This research work focuses on developing bioplastic films from natural ingredients such as Cellulose of sugarcane bagasse by involving alkalization, bleaching, acid hydrolysis, and dehydration processes. Cellulose (sugarcane bagasse) characterization was extensively studied using SEM and FTIR, which were used to examine physical characteristics like crystal structure, phase composition, and orientation of cellulose powder.

Casting was carried out by using cellulose (sugarcane bagasse), starch, polyethylene glycol and glycerol by varying different ratios and tests like water absorption, moisture content and water solubility were made. Thus, the bioplastic membranes were prepared from cellulose (sugarcane bagasse), which is considered as ecofriendly.

Keywords: Cellulose, Bioplastic, Properties



INTRODUCTION

The food sectors has recently placed a lot of emphasis on packaging-related issues, which by themselves define an entire industry. This industry continuously adapts to the demands and standards of the food production sector, and its emphasis on creating new biopolymer-based packaging is essential to the sustainability of the food industry as a whole and its quality standards. This results in more sustainable and clean delivery chains from production facilities and their internal storage systems to transportation facilities, market locations, and consumer homes.

Compostable or degradable bioplastics can meet the need for high-quality storage characteristics and packaging that is economical, environmentally friendly, easily customizable, and low encumbrance. Although there are still few effective uses of packaging in the food sector compared to other industries, this needs to change. However, the largest food distribution companies are now aware of the issue and are eager to switch to bioplastics as much as feasible.

When creating this type of material, it's crucial to keep in mind that different food products require distinct packaging features, necessitating the development of several technologies such multi-layer films, modified atmosphere packaging, and smart and active packaging. The ability to protect food packing from air and water is one of the most demanded qualities. Although creating bio-based multicomponent synthetic coatings that function as a barrier is not difficult, this presents a challenge for recycling, provided that recycling is feasible for single-component materials.

BIOPLASTIC

Bioplastic is a mouldable plastic material made from chemical compounds produced by microbes such as bacteria or modified plants. Bioplastics are made from renewable resources, and some of them decompose naturally, in contrast to traditional plastics, which are derived from petroleum. Compostable bioplastics, on the other hand, can decompose spontaneously and turn into soil nutrients. These materials break down more quickly, often in a few months, when exposed to the right composting conditions, such as regulated temperature and humidity. This not only keeps plastic garbage from piling up, but it also helps to enhance soil quality and encourages the circular economy.

MATERIALS AND METHODS

CELLULOSE EXTRACTION PROCESS

COLLECTION OF RAW MATERIALS

The sugarcane bagasse was collected at a juice bar in Tamil Nadu, India's Coimbatore District. The collected samples were cut into 2–4 cm pieces and allowed to dry in the sun for a week. Cellulose was extracted from the dried material using the subsequent methods.

GRINDING

To avoid contamination and moisture contact, the dry materials were ground after a week and kept in a sterile, airtight container.

ALKALIZATION

Soaked a dried sample weighing ten grams in 10% NaOH for two days to remove the exterior components. For two hours, the final sample was submerged in 1% NaOH in a water bath set at 60°C. Thus, the lipid and lignin components are removed from the sample. The resulting sample is known as delignified once the NaOH solution has been filtered away. To neutralize the alkaline sample and eliminate the alkali, the delignified sample was repeatedly washed with distilled water until pH 7 was reached.

DELIGNIFIED SAMPLE

BLEACHING

The samples underwent bleaching by soaking in a 4:1 hydrogen peroxide acetic acid solution and then being heated to 60 °C for an hour in a water bath following delignification and neutralization. Bleaching decolorizes the sample by removing all of its pigments. Until pH 7 was reached, the bleached sample was washed many times with distilled water to neutralize it.

BEFORE BLEACHING

SONICATION PROCESS

AFTER BLEACHING

ACID HYDROLYSIS

After bleaching and neutralizing the sample, it was treated with 5M HCl in a water bath for 30 minutes at 60 °C. Acid hydrolysis is the term used to describe the resultant sample. This sample is then regularly washed with distilled water to get its pH down to 7.

ACID HYDROLYSED

SONICATION PROCESS

DEHYDRATION

The cellulose fibers are kept in a desiccator for five to one week in order to remove the moisture content and transform them into powder.

BEFORE DEHYDRATION

AFTER DEHYDRATION

MATERIALS AND THEIR PROPERTIES

CELLULOSE

Sugarcane bagasse is the fibrous residue left after extracting juice from sugarcane stalks. It is primarily composed of cellulose, hemicellulose, lignin, and moisture, making it a valuable byproduct for various industrial uses. Its potential as a raw material in several applications has been explored due to its abundance and renewable nature.

STARCH

The granular form of starch, which is inexpensive and widely available in nature, is composed of the two polysaccharides amylose and amylopectin. These starch-based polymers are thermoplastic and biodegradable. Because starch has several benefits, including improved tensile strength, biodegradability, and simplicity of manufacture, it is used to make bioplastics.

PLASTICIZERS

Plasticizers are crucial additions that improve the flexibility, durability, and processing capabilities of both conventional and bioplastics. They are added to plastic formulations to enhance the material's functionality and increase its suitability for a range of uses. Here, we synthesize the bioplastic membrane using two plasticizers.

GLYCEROL

Glycerol is an odorless, viscous liquid that is utilized as a lubricant and solvent in many different applications. Glycerol provides a stable hydrophilic biopolymer chain.

POLYETHYLENE GYLCOL 400 (PEG 400)

Polyethylene Glycol (PEG) 400 is used as a plasticizer to increase the elasticity of bioplastics. PEG 400 has the advantage of producing bioplastics that are elastic and strong and can increase the value of strain on bioplastics.

FILLERS

Fillers are used in bioplastic production to improve the strength, reduce shrinkage, and lower the cost of the bioplastic and also help to overcome the brittleness of bioplastics. Fillers are additives used in bioplastics to improve certain properties or reduce production costs. These fillers are typically inert, non-toxic materials that are mixed with the biopolymer matrix to achieve specific performance enhancements.

CASTING OF BIOPLASTIC MEMBRANE

- A beaker is filled with 100 ml of water.
- The temperature is maintained at 80°C while the beaker is resting on a heated oven plate.
- To avoid the formation of cellulose powder particles, 15% cellulose powder has been added to the boiling water and properly blended.
- Remove the beaker from the hot plate and place it on a magnetic stirrer with a hot plate after the cellulose has completely dissolved.
- The rotation speed is set to its maximum after the magnetic pellet has been inserted into the beaker.
- The cellulose solution is progressively supplemented with 15% plasticizer. The magnetic stirring is continued while the temperature is kept at 100 °C until the solution takes on the appearance of a gel-like matrix and becomes slightly transparent. The term is called as "**gelatinized state**". The solution is left to cool at room temperature for ten minutes after achieving these qualities.
- The solution poured into the film former at 60 °C.
- Once the bioplastic layer has dried completely, it is carefully peeled off and allowed to dry for another day at room temperature.

FILM FORMER

RESULTS AND DISCUSSION

GENERAL

This chapter describes the characterization of a bioplastic membrane by extracting the cellulose from sugarcane bagasse.

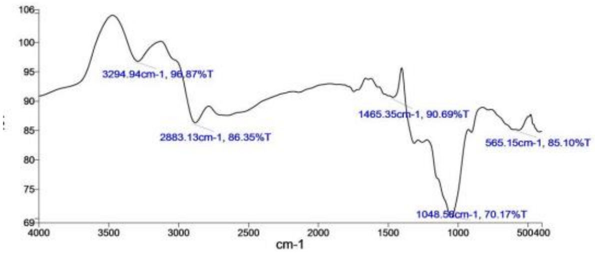
CHARACTERIZATION OF ACTIVATED CARBON

The activated carbon were characterized by various methods such as,

- ✓ Fourier Transform Infra-Red spectroscopy (FTIR)
- ✓ Scanning Electron Microscopy (SEM)

FOURIER TRANSFORM INFRARED SPECTROSCOPY

An interferogram that has been Fourier converted yields a function that plots the infrared intensity against wavenumber.



FTIR IMAGE FOR CELLULOSE

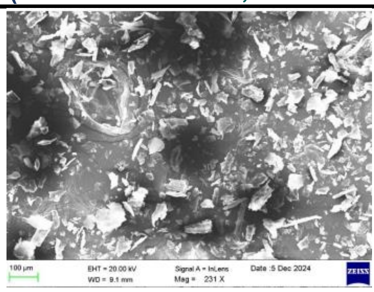
A broad peak at 3294.12 cm-1 corresponds to carboxylic O-H (Acids) stretching which is strong bond. The adsorption peak at around 565.33 cm−1 corresponds to the stretching vibration of Strong intensity. C-Br on the cellulose which is Strong intensity. The wavenumber 1048 cm−1 indicates the C-F stretching which is strong bond. The wavenumber 1465.03cm−1 belongs to the aromatic bond which is Medium.

ABSORPTION INTENSITY OF CELLULOSE POWDER

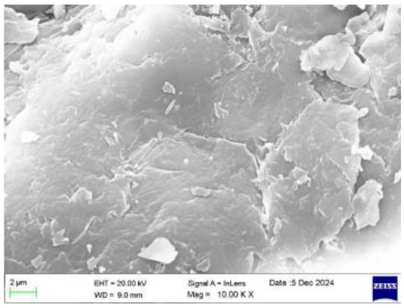
Wave Number (cm^{-1})	Functional groups	Absorption Intensity
3294	O-H	Strong
565	C-Br	Strong
1048	C-F	Strong
1465	CH3	Medium
2883	C-H	Weak

SCANNING ELECTRON MICROSCOPY (SEM)

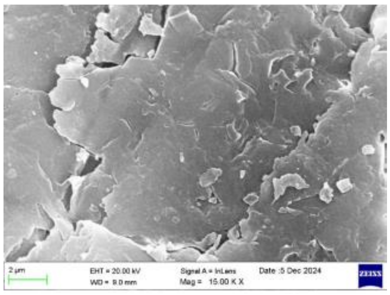
Analyzing Scanning Electron Microscopy (SEM) results for sugarcane bagasse powder involves a careful assessment of various structural and morphological characteristics. The SEM images of sugarcane bagasse cellulose powder made of lignocellulosic material reveal a rough, fibrous, irregular morphological structure that typically appears as small particles or fine powders with irregular shapes since plant-based powders are not perfectly spherical. At higher magnifications, individual cellulose fibers appear rough and fibrillated, indicating a high degree of surface area and a heterogeneous size distribution ranging from 1 µm to 10 µm. The presence of large pores within the fibers suggests a high surface area.



SEM IMAGE FOR MAGNITUDE OF 231 X



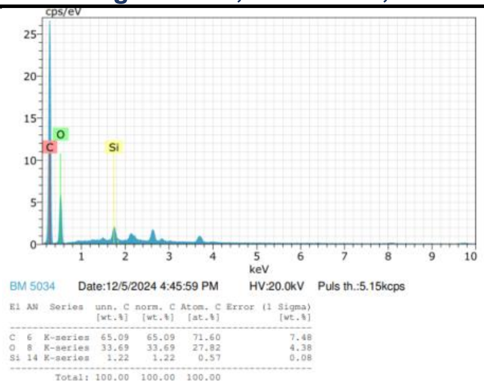
SEM IMAGE FOR MAGNITUDE OF 10 KX



SEM IMAGE FOR MAGNITUDE OF 15 KX

ENERGY-DISPERSIVE X-RAY ANALYSIS (EDAX)

Energy-Dispersive X-ray Analysis (EDAX), also known as EDS, is a nondestructive technique that identifies and quantifies the elemental composition of a material. It is performed along with the SEM, you can assess the elemental composition of the sugarcane bagasse powder. The primary elements will likely include carbon (C) (from cellulose and lignin), oxygen (O), and small amounts of sodium (Na), potassium (K), and calcium (Ca) from ash content. The elemental distribution might provide insights into the inorganic content, which could affect properties such as combustion or material strength. The observed porosity and fibrillation suggest a material with potential for high adsorption and mechanical reinforcement



ELEMENTAL COMPOSITION OF CELLULOSE

There are 65.09 percent of carbon, 33.69 percent of oxygen, and 1.22 percent of silicon in this, which encompasses 100%. EDAX analysis of a cellulose-based bioplastic provides a detailed elemental composition that can confirm the presence of cellulose, any additives (such as plasticizers or stabilizers), and potential inorganic fillers. The bioplastic's strength, flexibility, biodegradability, and any alterations made to enhance its performance may all be deduced by looking at the relative intensity of the peaks and their constituent composition.

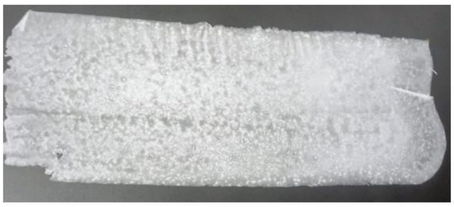
CASTING AND TESTING OF BIOPLASTIC FILM

CASTING OF BIOPLASTIC FILM

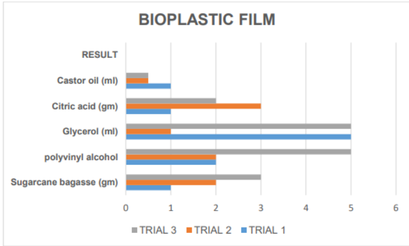
Casting of bioplastic was done by adopting the procedure mentioned in the previous chapter.

TRIALS FOR CASTING OF BIOPLASTIC FILM

CONTENT	TRIAL 1	TRIAL 2	TRIAL 3
Sugarcane bagasse (gm)	1	2	3
polyvinyl alcohol (PVA) (gm)	2	2	5
Glycerol (ml)	5	1	5
Citric acid (gm)	1	3	2
Castor oil (ml)	1	0.5	0.5
RESULT	Imperfect film	Thick film	Perfect film



BIOPLASTIC FILM



COMPARATIVE CHART FOR BIOPLASTIC FILM

QUALITATIVE TESTS FOR THE PRESENCE OF CELLULOSE

To verify that cellulose was present, a number of qualitative tests were conducted.

QUALITATIVE TESTS FOR THE PRESENCE OF CELLULOSE

TEST	OBSERVATION	INFERENCE
Solubility test	Water does not dissolve cellulose.	The obtained powder compound is cellulose
Iodine potassium iodide test	No change in colour was observed.	When iodine potassium iodide solution is added to cellulose,no color is produced.
Iodine test	Cellulose disintegrated in sulfuric acid and turned blue.	Cellulose is present

WATER SOLUBILITY TEST

The film samples were divided into square pieces of 2.0 cm2, and their masses were carefully measured and recorded. For six hours at 25 °C, static agitation at 180 rpm was carried out while the samples were still immersed in 100 cc of distilled water. The remaining film was filtered six hours later. The samples were dried in a hot air oven at 110 °C until a final fixed weight was established. The fraction of all soluble materials, or solubility, was calculated as

$$W_s = \frac{W_i - W_f}{W_f} \; X\ 100$$

Where,

W_s _ Solubility in water

W_i – Initial weight of the bioplastics

W_f – Final weight of the bioplastics.

WATER SOLUBILITY TEST

TRIAL	Initial weight (g)	Final weight (g)	Water solubility (%)
Trial 1	0.501	0.450	11.33
Trial 2	0.497	0.374	32.88
Trial 3	0.516	0.432	19.44

WATER ABSORPTION TEST

The sample was split into tiny pieces, each measuring 1 cm by 2 cm. The sample's original weight was noted. After that, the sample was kept at room temperature for a whole day in a beaker with 60 mL of water. After that, the sample was removed from the water and cleaned. The final weight was noted. The following formula was used to determine the quantity of water absorption.

$$WA\ (\%) = \frac{final\ weight\ (g) - initial\ weight\ (g)}{initial\ weight\ (g)}\ x\ 100$$

WATER ABSORPTION TEST

TRIAL	Initial weight (g)	Final weight (g)	Water absorption (%)
Trial 1	0.505	0.416	21.39
Trial 2	0.457	0.384	19.01
Trial 3	0.550	0.451	21.91

MOISTURE CONTENT TEST

The weight loss of the films was used to assess the moisture content. The samples of bioplastics were precisely weighed after being cut into 2.0 cm2 square pieces. After drying at 110 °C in an oven until a static dry weight was reached, the dry film mass was recorded. Five iterations of each film treatment were used to measure the moisture content.

$$\text{Moisture content (\%)} = \frac{W_i - W_f}{W_i} \text{ x } 100$$

Where,

W_i - Initial weight in gm

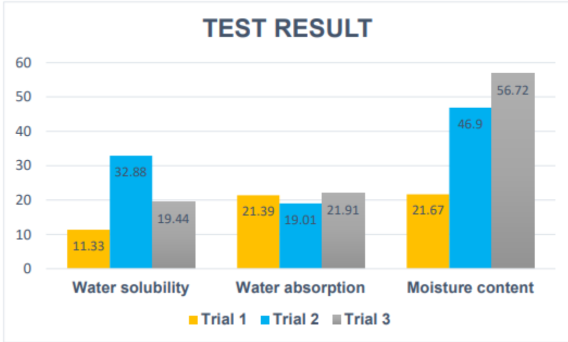
W_f - Final weight in gm

MOISTURE CONTENT TEST

TRIAL	Initial weight (g)	Final weight (g)	Moisture content (%)
Trial 1	0.320	0.263	21.67
Trial 2	0.451	0.307	46.90
Trial 3	0.373	0.238	56.72

THICKNESS TEST

The thickness of each bioplastics produced was 2 cm x 2 cm measured using Screw gauge. The thickness of the bioplastic was measured six times throughout the sample length and the average thickness was recorded as **0.5 mm**.



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CONCLUSION

SUMMARY

The study was carried out to prepare and characterize cellulose using sugarcane bagasse and the casting of bioplastic film was done by taking various trials of sugarcane bagasse cellulose, polyvinyl alcohol, glycerol, etc., and the various tests were conducted.

CONCLUSION

The following conclusions were drawn from the study,

- ✓ In this study, the cellulose were extracted from sugarcane bagasse and characterized.
- ✓ FTIR analysis for the cellulose has shown that the spectral peak at 565.33 cm−1 indicates the stretching C-Br which is Strong intensity.
- ✓ The SEM images of sugarcane bagasse cellulose powder made of lignocellulosic material reveal a **rough, fibrous**, irregular morphological structure that typically appears as small particles or fine powders with irregular shapes since plant-based powders are not perfectly spherical.
- ✓ In EDAX analysis of a cellulose, there are 65.09 percent carbon, 33.69 percent oxygen, and 1.22 percent silicon in this, which encompasses 100%.
- ✓ Water solubility= 21.21 %
- ✓ Water absorption = 20.77 %
- ✓ Moisture content = 41.76 %
- ✓ Thickness = 0.5 mm.

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