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Synthesis of Nano-Cellulose from Argo Wastes and Making a Fibre Film as an Alternative of Plastic Film and its Characterization

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ABSTRACT

With the rapid increase in the consumption of plastic films for different purposes it becomes crucial to develop films that are made from agro-waste materials like rice husk and wheat straw so that it can be helpful for sustainable development. As cellulose is the most abundant polymer, we can easily extract it from different resources like rice husk. So, firstly we extract cellulose naturally, and then using different mechanical and chemical treatment methods we will obtain film. The research has been focused on isolating Nano cellulose from rice husk. For characterization of film, we will use FTIR, SEM, and XRD techniques. These techniques are used to determine surface morphology, size, and characteristics of Nano cellulose. The main objective of the following research is focused on obtaining valuable products from agro waste and one such product is Nano cellulose.

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Introduction

The surge in global plastic waste has sparked an urgent quest for sustainable alternatives, with the amplified production and consumption of plastics magnifying environmental concerns and greenhouse gas emissions. This surge in plastic waste, predominantly from short-lived plastics like packaging, textiles, and consumer goods, has disrupted ecosystems and raised apprehensions about long-term sustainability. Plastic waste management is a complex challenge, with a significant portion incinerated or left in landfills, and a concerning percentage seeping into uncontrolled dumpsites or natural environments, particularly impacting economically vulnerable regions.

In response to this global crisis, the demand for biodegradable options is on the rise. One promising avenue involves harnessing nano-cellulose from Agro-wastes, such as rice husk, and employing it to create fibre films, presenting an innovative and sustainable solution to plastic waste. This initiative embodies a proactive strategy toward a more environmentally responsible future, where the impact of plastic pollution is minimized.

India, as a significant player in global rice production, generates a substantial quantity of rice husk. Given the estimated 35% to 40% rice husk generated per metric ton of rice, the potential for repurposing this byproduct is immense. By utilizing rice husk to synthesize nano-cellulose and produce biodegradable fibre films, India can significantly contribute to global efforts in reducing plastic pollution and fostering a more sustainable future. This initiative underscores the nation's commitment to sustainable development and its proactive stance in addressing pressing environmental challenges. The synthesis process of nano cellulose undergoes mechanical and chemical treatments such as size reduction, screening, alkali treatment, bleaching process and acid hydrolysis.

Materials and Methods

Ricehusk Chemicals

NaOH (Sodium hydroxide), $NaClO_2$(Sodium hypochlorite), H_2SO_4(Sulphuric acid).

MechanicalTreatment

The process begins by washing the unpurified rice husk, followed by drying it in an oven for 24 hours to eliminate moisture. Subsequently, the size of the rice husk is reduced.

Chemical Treatment

Alkali treatment: Alkali treatment is a crucial procedure that involves submerging natural fibre in a potent aqueous solution containing NaOH or KOH, aimed at eliminating lignin, hemicellulose, and oils. To execute this treatment, a 1:20 weight/volume solution of husk and NaOH is utilized. In this process, rice husk is combined with a 5 wt. % of NaOH solution. The resulting mixture is then subjected to continuous heating at 45 degrees Celsius for a duration of 7 hours, while ensuring consistent stirring at 300 revolutions per minute. Following the treatment, the solution is allowed to cool down, and multiple rinses with distilled water are carried out until the pH level reaches 7. Subsequently, the solution is filtered using filter paper, facilitating the removal of lignin and hemicellulose from the pulp fibre. The pulp fibre is then dried for 24 hours.

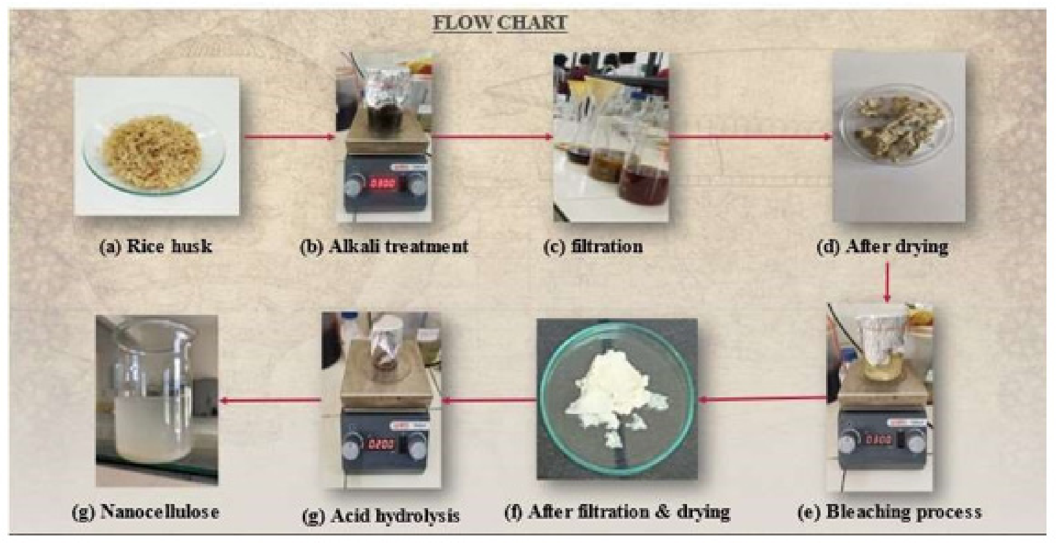
Bleaching

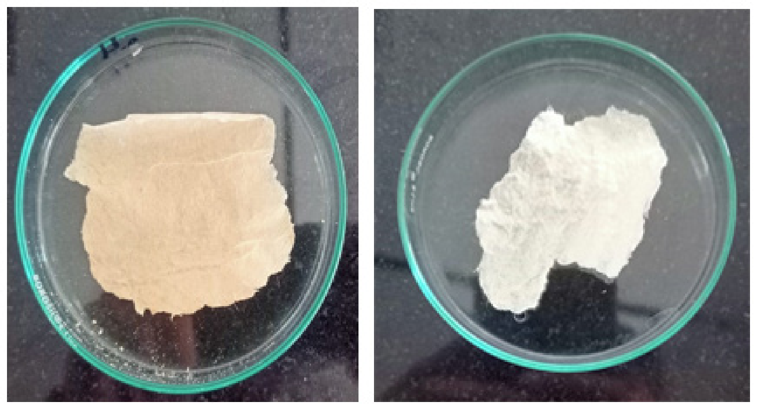
The bleaching process involved the utilization of $NaClO2$ to eliminate natural impurities. A 2% solution of sodium hypochlorite was combined with dry pulp. The process was executed at a temperature of 60°C for a duration of 4 hours, accompanied by stirring at a speed of 300 revolutions per minute.

Acid Hydrolysis

The extraction of CNCs from the pretreated fibres is achieved through the application of acid hydrolysis techniques. This method involves the use of acid $H2SO4$.In this specific case, with bleached fibre combined with 64 wt. % of $H2SO4$.

The solution is heated to 45°C for a duration of 30 minutes while maintaining a rotation speed of 200 revolutions per minute. Post-treatment, the solution is thoroughly washed with cold water to neutralize it.





Fibre Film from Cellulose

Calculation

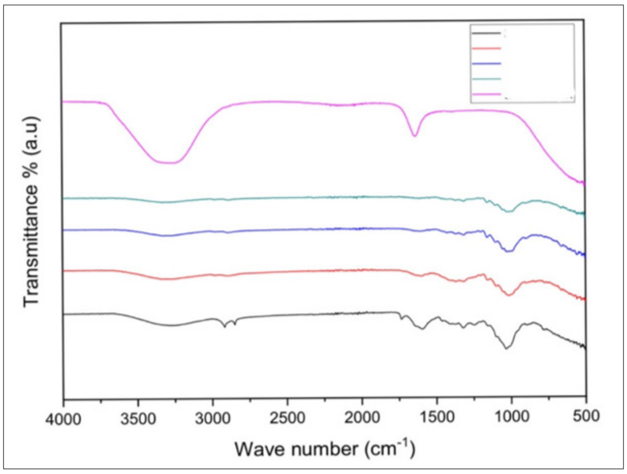
Yield = Final/initial *100
Yield of cellulose after alkali treatment = approx. 50 %
Yield of cellulose after bleaching = 78.4%

Discussion and Result

After acid hydrolysis nanocellulose undergoes various tests which include FTIR, SEM and XRD for characterization.

FTIR

This image is a Fourier Transform Infrared (FTIR) spectroscopy graph of a nanofiber film. FTIR spectroscopy is a technique that uses infrared radiation to identify and analyze the chemical bonds and functional groups in a sample.



The graph shows the transmittance percentage against the wave number. Transmittance is the ratio of the transmitted light to the incident light, and wave number is inversely related to the wavelength. Different peaks and troughs in the graph represent various vibrational modes associated with specific chemical bonds. The graph has five lines of different colours, each representing a different sample or condition of the nanofiber film. The colour codes indicate different sources, treatments, or compositions of the nanofiber film.

The graph can be used to compare and contrast the properties and structures of the nanofiber film samples. For example, some of the common features and differences that can be observed from the graph are:

All the lines have a broad peak around 3400 cm^-1, which corresponds to the O–H stretching vibration of water molecules. This indicates that all the samples have some degree of water absorption, which is expected for hydrophilic nanocellulose materials.

All the lines have a sharp peak around 2900 cm^-1, which corresponds to the C–H stretching vibration of aliphatic groups. This indicates that all the samples have some degree of aliphatic substitution, which may be due to the presence of lignin or other impurities in the nanocellulose.

All the lines have a peak around 1640 cm^-1, which corresponds to the C=O stretching vibration of carbonyl groups. This indicates that all the samples have some degree of oxidation, which may be due to the use of chemical treatments, such as acid hydrolysis or TEMPO oxidation, to reduce the size and increase the crystallinity of the nanocellulose.

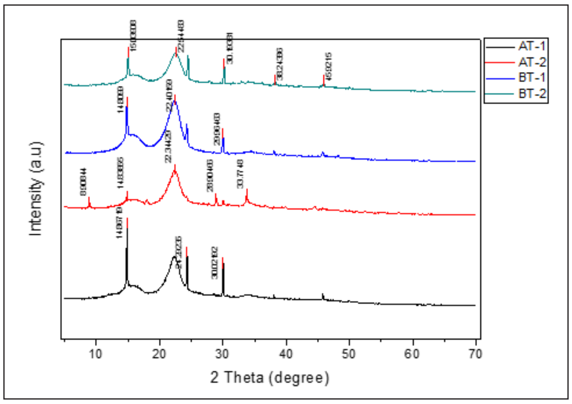
The pink and blue lines have a peak around 1420 cm^-1, which corresponds to the C–O–C stretching vibration of acetal groups. This indicates that these samples have a higher degree of crystallinity than the other samples, as acetal groups are characteristic of the crystalline regions of cellulose.

The green and red lines have a peak around 1370 cm^-1, which corresponds to the C–H bending vibration of methyl groups. This indicates that these samples have a higher degree of methylation than the other samples, which may be due to the use of methyl cellulose as a binder or a modifier for the nanofiber film.

The black line has a peak around 1240 cm^-1, which corresponds to the C–O stretching vibration of ether groups. This indicates that this sample has a higher degree of etherification than the other samples, which may be due to the use of ethyl cellulose or other ethers as a binder or a modifier for the nanofiber film.

XRD

The image is a graphical representation of X-Ray Diffraction (XRD) results used to analyse the structure of Nano cellulose extracted from Agro-waste materials like rice husk.



The image is a graphical representation of X-ray diffraction (XRD) results used to analyse the structure of Nano cellulose extracted from Agro-waste materials like rice husk. XRD is a technique that uses X-rays to determine the atomic and molecular structure of a sample. The graph plots intensity against 2 Theta degrees, showing peaks that represent the typical cellulose I structure. Different lines on the graph correspond to different samples, and their respective peaks are labelled with the angles at which they were observed.

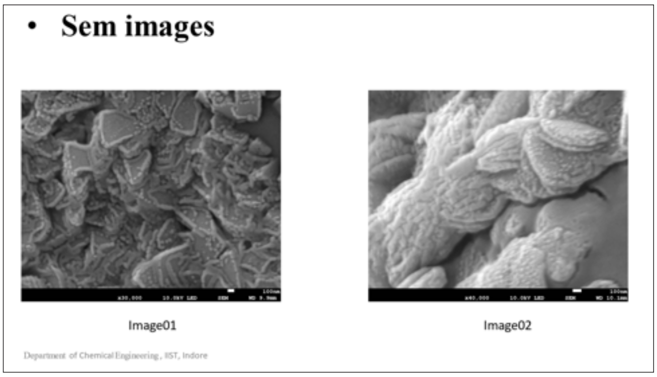
The graph can be used to compare and contrast the properties and structures of the nanocellulose samples. For example, some of the common features and differences that can be observed from the graph are:

All the lines have a peak around 14.7°, which corresponds to the 110 planes of cellulose I. This indicates that all the samples have a high degree of crystallinity, which is desirable for film applications.

The AT-1 and AT-2 samples have higher intensity peaks than the BT-1 and BT-2 samples, which suggests that they have higher purity and lower defects in their structure.

The BT-1 and BT-2 samples have additional peaks around 22.6° and 34.4°, which correspond to the 200 and 004 planes of cellulose I, respectively. This indicates that they have a different orientation or alignment of the Nano cellulose fibres than the AT-1 and AT-2 samples.

SEM



- **Sem images**

Image01

Image02

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This image shows two SEM (Scanning Electron Microscope) images of a nanofiber film that is used to replace or as an alternative of plastic film. SEM is a technique that uses electrons to create high-resolution images of the surface morphology and texture of a sample. The image on the left is labelled as "Image01" and shows a network of intertwined fibres with varying thicknesses and lengths, creating a dense mat-like structure. The image on the right is labelled as "Image02" and shows a closer view of the individual fibres, which appear to have textured surfaces and are bundled together. The scale bars and magnification levels are indicated below each image, providing context for the size of the structures being observed.

The SEM images can be used to analyse the properties and performance of the nanofiber film, such as its surface area, porosity, mechanical strength, and optical transparency. Nanofiber films have many advantages over traditional plastic films, such as being biodegradable, biocompatible, lightweight, and flexible.

Conclusion

In this research, we have extracted Nano cellulose from agro-waste materials like rice husk and used it to produce Nano fibrous films that have potential applications in packaging industries. We have characterized the films using SEM and FTIR techniques to analyze their surface morphology, structure, and composition. The SEM images revealed the intricate network of intertwined fibers with varying thicknesses and lengths, creating a dense mat-like structure. The FTIR spectra showed the presence of various functional groups and bonding vibrations that indicate the purity, crystallinity, oxidation, and modification of the Nano cellulose. These nanofiber films have many advantages over traditional plastic films, such as being biodegradable, biocompatible, lightweight, and flexible. With further optimization and treatment, these films can be a viable alternative to plastic films that hurt the environment [1-22].

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