National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title	: Development of Process Technology for Efficient Production of Nanocellulose from Jackfruit Peel and its Application in Food Systems
Speaker	: Subhanki Padhi (Rollno : 521fp1004)
Supervisor	: Winny Routray
Venue	: CH-113
Date and Time	: 01 Aug 2025 (17:00)

Abstract :

Lignocellulosic biomass includes wastes from different sources, like agricultural waste, forest remains, industrial waste, and algae waste. Recycling of these wastes by converting them into value-added bio-based products can lead to a reduction in tons of global wastage, and at the same time, will also add to the global economy. Lignocellulosic wastes contain significant quantities of cellulosic materials that are considered as natural polymers. The cellulose can be further reduced to a nanoscale dimension, leading to nanocellulose, through the application of various extraction techniques like physical, biological, and chemical methods. Nanocellulose possesses some extremely significant properties, including biodegradability and biocompatibility, high aspect ratio, better mechanical attributes, easy surface modification, crystallinity, non-toxic nature, and water absorption capacity, making it a perfect material for a wide range of applications. Jackfruit, known as the poor man&rsquos fruit of India, is grown in abundance in different parts of the country. Jackfruit peel constitutes around 60% of the whole fruit. The consumption and processing of jackfruit lead to the production of tons of waste. Thus, jackfruit peel can be utilized for the extraction of cellulose and nanocellulose, which will contribute towards waste valorisation.

The aim of this research was to extract cellulose from jackfruit peel using alkali and bleaching treatments and then utilize this cellulose to produce nanocellulose by various techniques such as acid hydrolysis, oxidation method, and ultrasonication. Further, the nanocellulose having better properties was utilized to develop Pickering emulsions for bioactive compound delivery. During the extraction of cellulose, the maximum yield of cellulose was obtained at 4% NaOH concentration and was 25.65% with a purity of 86.03%. The crystallinity of cellulose was found to be 69.4%. The FTIR analysis confirmed the removal of non-cellulosic materials such as hemicellulose and lignin. The rheological characterization was conducted to understand the flow behaviour, gel-like nature, stability, and recovery of strain and viscosity upon the action of external shear stress. The viscosity was found to be higher for higher concentrations of cellulose, and the cellulose suspension exhibited shear-thinning behaviour, i.e., with an increase in shear rate, the viscosity reduced.

The jackfruit peel cellulose was further acid hydrolysed using different organic and inorganic acids to obtain jackfruit peel nanocellulose. The dissociation potential of different acids to disintegrate the hydrogen bonds of cellulose molecules to form NC was observed. It was found that the inorganic acid hydrolysis, i.e., NC/SA, NC/HA, and NC/PA, had a particle size of 100&ndash160 nm, and the organic acid hydrolysis, i.e., NC/FA, NC/OA, and NC/CA had a particle size in the range of 170&ndash230 nm. The organic acid hydrolyzed NCs had higher crystallinity than the inorganic acid hydrolyzed NCs (NC/CA> NC/OA> NC/FA> NC/PA> NC/HA> NC/SA). The TGA showed good thermal stability of the nanocellulose and cellulose compared to raw JP. The rheological characteristics showed the shear-thinning behaviour of nanocellulose suspension and the gel-forming ability of nanocellulose.

The effect of mechanical treatment method, oxidation method, and a combination of both on the yield and properties of the obtained nanocellulose. It was found that the yield of nanocellulose was higher for the ultrasonication method, followed by the oxidation-ultrasonication combination method and oxidation method, respectively. The carboxyl content and degree of oxidation were found to increase with an increase in NaClO concentration. The FTIR confirmed the presence of functional groups similar to cellulose in case of all the nanocellulose extracted, and TEMPO-oxidized nanocellulose showed a characteristic peak at 1725 cm^{-1}, which confirms the oxidation of nanocellulose. All the nanocellulose suspensions showed shear-thinning behaviour and a gel-forming ability from the rheological characterization. The TEM images showed the formation of fibrils upon the mechanical method of extraction of nanocellulose. The combined TEMPO-oxidization and ultrasonication produced nanocellulose exhibited better thermal stability and possessed good functional properties, making it suitable for applications in food-based emulsions, packaging materials, sensors, and other biotechnological fields.

Furthermore, the combined treatment method, i.e., TEMPO oxidation at 5 mmol NaClO concentration followed by ultrasonication at 60% amplitude and 15 min time, was used as an optimized method to produce nanocellulose with good yield and properties and was used to develop nanocellulose stabilized Pickering emulsion (NPEs). Three different concentrations of nanocellulose and flaxseed oil were used to develop NPEs. The freshly prepared NPEs had well-dispersed particles in them and exhibited a homogeneous and stable emulsion. The particle size of freshly prepared NPEs varied from 237.14 nm to 498.21 nm. With an increase in storage time, the particle size increased. The zeta potential of freshly prepared NPEs varied from -46.698 mV to -35.878 mV. The arrangement of NC particles at the oil-water interface in the NPEs was observed from the CLSM images. Further, the NPEs were encapsulated with &alpha-tocopherol and evaluated for their encapsulation efficiency, changes in emulsion properties, and the release of

&alpha-tocopherol through in vitro digestibility. The particle size increased slightly, and zeta potential values decreased after encapsulation. &alpha-tocopherol added emulsion showed the least production of TBARS, resulting in enhancement of the oxidative stability of the NC stabilized emulsion. The maximum release of &alpha-tocopherol was observed in the case of NC1/FO10 (72.3%) after complete in vitro digestion for 4 h. The FFA release was highest for NPE with 1% NC and 10% oil and 30% oil concentration, and was lower for NPE with 0.25% NC and 50% oil content. The digestibility study of NPEs suggested that for enhanced lipid hydrolysis and delivery of bioactive compounds, a higher NC concentration is required that can surround the oil droplets by forming a stable emulsion. Thus, the NC of optimized concentration can be used to obtain a stabilized Pickering emulsion that can be further used for various functional food applications such as the delivery of bioactive compounds and nutraceuticals.