International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A REVIEW ON BANANA PSEUDOSTEM DERIVED CELLULOSE EXTRACTION- ITS APPLICATION AND CHALLENGES

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ABSTRACT :

Biopolymers are now widely used in many areas including pharmaceuticals, textiles and as excipient in many drug delivery systems due to its advantages such as stability, biodegradability, and cost effectiveness. Banana is one of the most consumed fruits in the world. The residues from banana plant can be converted into valuable products and there by waste dumbing can be reduced and also it can be converted into useful polymers such as cellulose and can be used commercially in many fields.

Keywords: Banana pseudo stem, Biopolymer, Cellulose

Introduction:

Recently, the extraction of cellulose from agricultural wastes to produce green and clean products has received great attention in the world. Extraction and evaluation of the quality and efficiency of the extraction process from many different materials such as rice straw, corn, sugarcane bagasse, oil palm, starch. Among these raw materials, the banana stem was evaluated as a potential source of cellulose (1).

The banana plant is a large-scale herbaceous plant belonging to the Musaceae family, Zingiberales order, and Musa genus. There are about 70 species of classified banana plants cultivated in more than 130 countries mainly tropical and subtropical regions like India , Malaysia , and japan(1).Banana plant consist of a rhizomatous underground stem, from which the leaves starts, presenting spirally arranged pods that look like a false stem and hence called as pseudo stem (2).

Cellulose is an excipient. Since plant polysaccharides comply with many requirements expected of pharmaceutical excipients such as non-toxicity, stability, availability and renewability they are extensively investigated for use in the development of solid oral dosage forms. Cellulose can be derived from a number of sources using a number of techniques that are considered synthetic and some that might be considered nonsynthetic (natural). It is available in many forms for different function Petitioned uses in food products include as a processing aid for filtration of juices, as an anti-caking agent ingredient for shredded cheese, and as a processing aid in the form of peel able hot dog casings. Various forms of cellulose have many other permitted FDA uses, including as a fat substitute and bulking agent in low calorie foods, as a texturizer, emulsifier, and extender.al purposes in food products& it obtained as a pulp from fibrous materials such as wood or cotton and although it was used in pharmaceutical applications such as a filler in tablets, it is microcrystalline cellulose that represents a novel and more useful cellulose powder, mainly used in the pharmaceutical industry as a diluent/binder in tablets(3).

The primary component of banana stems, accounting for over 50% of the total stem, is cellulose, a naturally occurring, renewable, and biodegradable polymer with a wide range of applications, including paper, insulation, adsorption, construction, and environmental treatment(4). Because each plant only bears fruit once, banana stalks are a waste biomass that is produced in vast quantities after fruit is harvested. The plant's inedible components, which include pseudo-stems and leaves and account for over 88% of its total weight are thrown away as trash (5).

Methods of cellulose extraction

There are several methods are available such as chemical treatment, steam explosion treatment, alkali-acid hydrolysis method, enzymatic hydrolysis, TEMPO- mediated oxidation etc.

- **CHEMICAL TREATMENT**
- Alkali treatment of the fibre: It is an inexpensive surface treatment that successfully alters natural fibres' surface. It entails preparing a solution of caustic soda (NaOH) in concentrations of 1.5%, 2%, 5%, and 7.5% and soaking the sheath fibres in it for six hours at room temperature. In order to ensure that the sheath can be utilized for an extended amount of time, impurities are removed.
- Autoclave process: The process of steam pre-treatment involves the direct insertion of fibres treated with NaOH under high steam pressure into the autoclave. The mercerized sheath fibres were compressed to 103 Pa for 1.5 hours. The fibres were removed and carefully cleaned with distilled water following the steam explosion. After cleaning, the fibres were placed in a hot air oven and dried for four hours at 60°C.

- Bleaching of fibre: After that, the fibres were treated with an HCl solution with a pH of 2.3 that contained 5% sodium chlorite (NaClO2). An inorganic sodium salt called NaClO2 is used as bleach. The solution was applied to the fibres and heated to 50 °C using a magnetic heater for one hour. In essence, the bleaching procedure removes any remaining lignin.
- Treatment of bleached fibres with acid: The fibre is lightly acid treated with (2%, 5%, 7.5%, and 10%) oxalic acid for acid hydrolysis after the bleaching treatment. Fibres were submerged in a solution of oxalic acid for one and a half hours. Water was used to completely rinse the fibres in order to eliminate any remaining acid (6).

➢ **ALKALINE-ACID HYDROLYSIS METHOD**

This method uses combination of alkali, bleaching and acid hydrolysis (9).

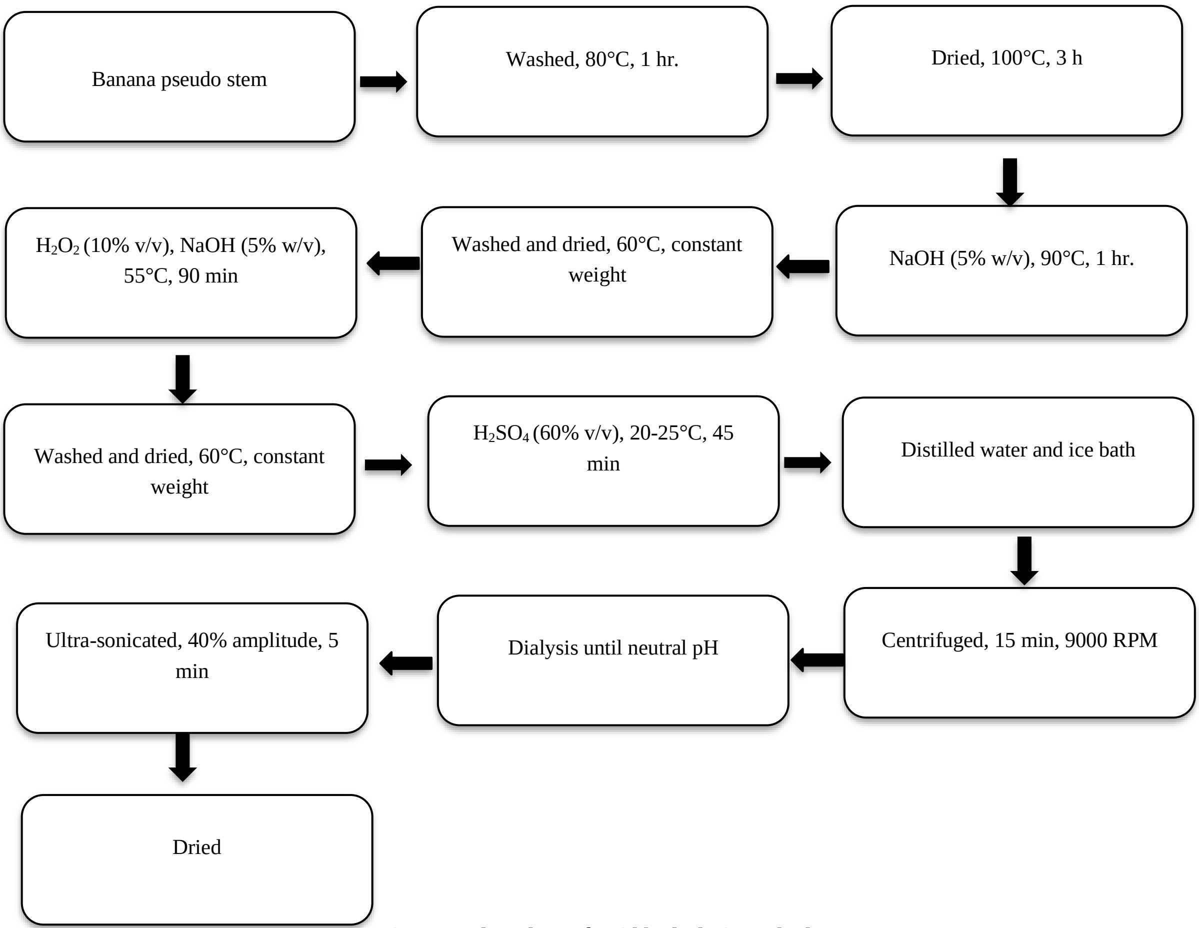

Figure 1: Flow chart of Acid hydrolysis method

➢ **STEAM EXPLOSION TREATMENT**

- The biomass was steamed at high pressures and temperatures between 13, 15 and 17 bar and 192, 200 and 205 °C respectively for 5 to10 min residence time in a reactor during the steam explosion pre-treatment with (citric acid, NaOH, and water) and without the addition of catalysts.
- The cellulose bundles are defibrillated by the abrupt pressure release, resulting in enhanced cellulose accessibility for enzymatic hydrolysis and fermentation. The fibres were discharged via a connecting pipe and gathered in a collection bin after being steam-exploded. The outcome was sludge, and the fibres were dried in an oven at 100 °C for 8 hours (7).

➢ **ENZYMATIC HYDROLYSIS.**

This method uses and enzymatic process for cellulose extraction (10).

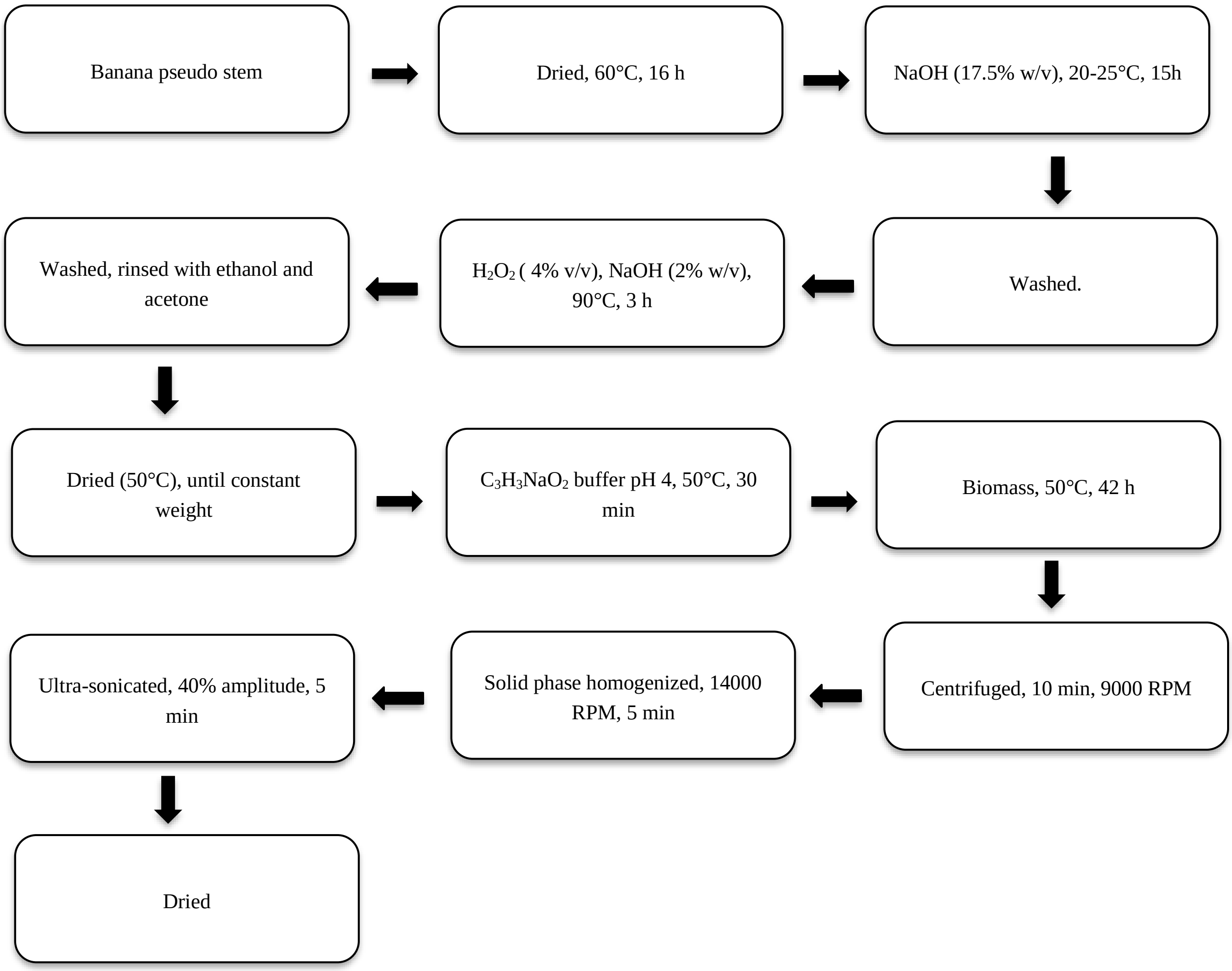

Figure 2: Flow chart of enzymatic hydrolysis

➢ **DELIGNIFICATION OF BANANA STEM**

- The banana stem fibres were soaked in H_2SO_4 solution (2 g/L) at 50°C for 2 h without agitation at a solid loading of 5% (w/v) to remove pectin and free sugars. The solid residue was separated by filtration and washed thoroughly with DI water until the pH value of the filtrate is neutral.
- The washed solid residue was then soaked in NaOH solution (200 g/L) at 30°C for 30 min to remove lignin. The delignified residue was thoroughly washed with DI water, squeezed to remove excess water and dried in an oven. The cellulose, hemicellulose and lignin contents were measured according to detergent fibre method.
- Followed by the extraction with the Van Soest acid detergent, the acid detergent fibre residue (ADF) was obtained. By extracting the ADF by sulphuric acid, the acid detergent lignin residue (ADL) was obtained.
- The cellulose, hemicelluloses and lignin contents are calculated as ADF–ADL, NDF–ADF, and ADL, respectively. The raw banana stem fibre contains 48.0% of cellulose, 21.1% of hemicellulose and 15.7% of lignin and the delignified residue 79.1% of cellulose, 7.6% of hemicellulose and 3.2% of lignin (8).

- **TEMPO-MEDIATED OXIDATION**

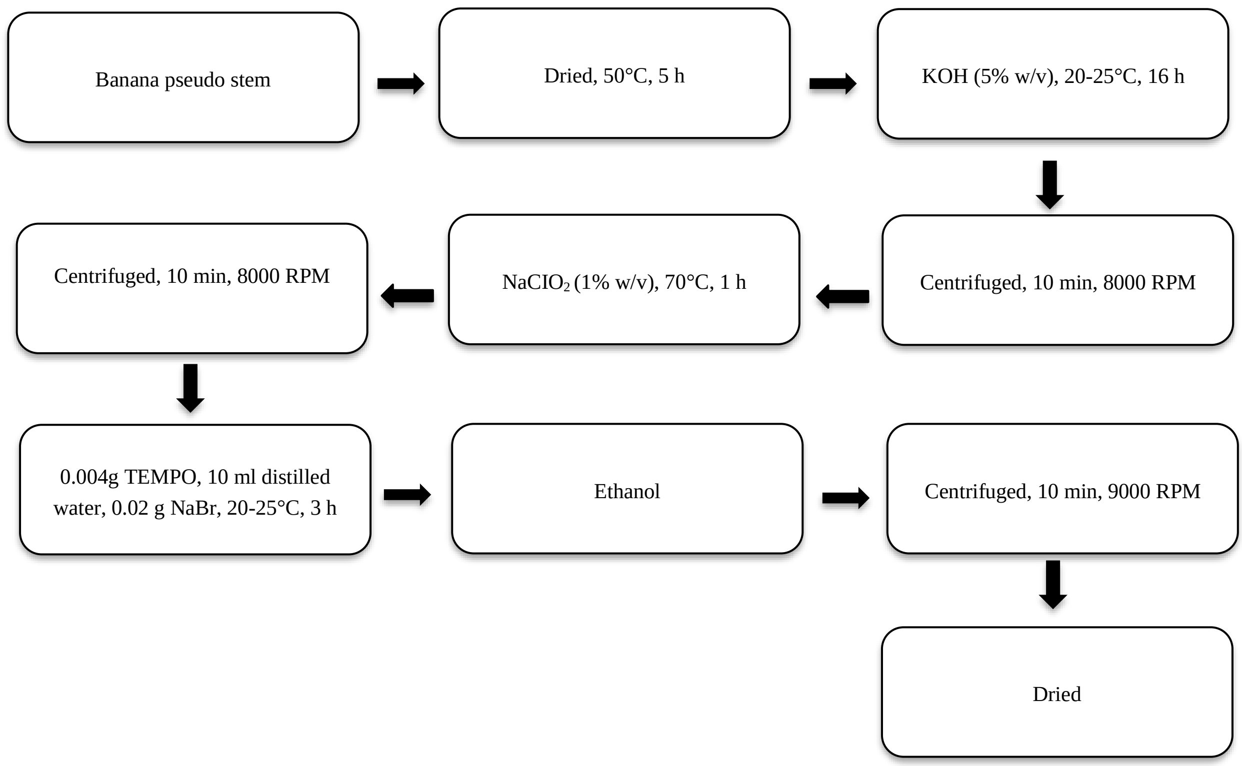

Figure 3: Flow chart of TEMPO Oxidation (11)

Nanomaterials from banana cellulose and Nano cellulose

1. **Cellulose nanocrystals**

Three main steps have been found to be necessary to extract CNC from the inner core of the banana pseudo stem which has a really high content of NC. These include pre-treatment of the pseudo stem, hydrolysis with 63 % Sulphuric acid and defibrillation aided by enzymes, steam, ultrasonic sound or mechanical mills.

2. **Cellulose Nano fibrils**

Microwave assisted and ball milling-assisted ultra-sonication methods were used for extracting cellulose Nano fibrils from the bracts and peels of banana which were later subjected to acetyl and lauryl modification methods for biopolymer synthesis.

3. **Cellulose Nano platelets**

Nano platelets, a recently discovered morphological form of Nano cellulose, could be produced easily and can be detected using an optical microscope.

Extract characterization

1. Sugar quantification
2. Chemical composition identification
3. Crystallinity determination
4. Thermal stability analysis (12).

Chemical modification of cellulose

- **Oxy-cellulose**

It is soluble in diluted alkalis but insoluble in water and acids.It expands, turns translucent, and becomes gelatinous in weakly alkaline solutions. It becomes quite sticky and swells when blood is added, generating a dark brown gelatinous substance (13).

Application:

- With the exception of homeostasis, it is applied directly to the leaking surface during a variety of surgical operations.
- It is employed in the creation of numerous consumer, pharmaceutical, agricultural, and cosmetic goods.

Topical formulations (cream, lotion, or spray) made with oxidized cellulose are bio adhesive, suitable for human skin or hair application, and can be incorporated into cosmetic products.

- Oxidized cellulose dispersion uses in anti-acne cream, anti-acne lotion, sunscreen sprays, anti-fungal cream also (14).

➢ **Microcrystalline cellulose (MCC)**

It is fine, white or almost white, odourless, free flowing crystalline powder. It is Insoluble in water, ethanol, ether and dilute mineral acids. Slightly soluble in sodium hydroxide solution.

Application:

- It is used as a texturizer, anti-caking agent, a fat substitute, an emulsifier, an extender, and a bulking agent in foods.
- The most common form is used in vitamin pills or tablets.
- It is also used in plaque assays for counting viruses, as an alternative to carboxymethylcellulose (15).

➢ **Hydroxy propyl cellulose(HPC)**

It is non-ionic water-soluble and pH insensitive cellulose ether. HPC has a combination of hydrophobic and hydrophilic groups, so it has a lower critical solution temperature (LCST) at 45 °C.

Application:

- HPC is used as a lubricant for artificial eyes.
- Used as a food additive.
- HPC is used as a thickener, a low level binder and as an emulsion stabiliser. In pharmaceuticals it is used as a disintegrant and a binder in tablets.
- HPC is used as a sieving matrix for DNA separations by capillary and microchip electrophoresis.

➢ **Methyl cellulose(MC)**

Methyl cellulose (or methylcellulose) is a chemical compound derived from cellulose. It is a hydrophilic white powder in pure form and dissolves in cold (but not in hot) water, forming a clear viscous solution or gel. Like cellulose, it is not digestible, not toxic, and not allergenic.

Application:

- It is used as thickener and emulsifier.
- It is used in treatment of constipation.
- Methyl cellulose is used as variable viscosity personal lubricants.
- Solutions containing methyl cellulose or similar cellulose derivatives are used as substitute for tears or saliva.
- Methyl cellulose is used in the manufacture of capsules in nutritional supplements; its edible and nontoxic properties provide a vegetarian alternative to the use of gelatin (13).

CHALLENGES IN COMMERCIAL BANANA WASTE CONVERSION

1. Heterogeneous nature of banana waste

The nutritive characteristics of banana waste also vary greatly with the ripening stage, seasonal variations and geographical area of their cultivation. All these factors can have an impact on the quality and quantity of the cellulose derived from the banana waste. Another major issue is associated with the cost involved in the waste collection, segregation and transport. Since banana peel is highly rich in sugars and moisture content, their storage is impossible as it undergoes autolysis leading to offensive order generation and acts as breeding ground for pathogenic microorganisms and vectors (16).

2. Pre-treatment method and economics

Pre-treatment methods employed in banana based bio refinery approach for biodegradable polymer production are aimed at removing the unwanted compounds like lignin and hemicellulose that are often present with cellulose and thereby affect the quality and quantity of the biopolymer extracted. Although a wide array of methods are available for banana waste pre-treatment like thermochemical, biochemical, catalytic chemistry approaches and enzymatic methods. In spite of their potential benefits each of these methods has limitations especially with their practical applicability in a commercial scale majorly due to the economics associated with these processes. The usage of ripening agents and chemical pesticides during the ripening stages of banana can have an impact on the success of the pre-treatment method in a negative way. The presence of high amounts of moisture in banana peels makes it inevitable to use a drying process prior to pre-treatment steps that requires huge energy investment (17). Traditional method of sun drying often is unsuccessful to yield a steady outcome majorly due to seasonal variation in light intensity and influence of other physicochemical factors. The usage of a hot air oven in any other drying process is often hampered by the requirement of high energy for operation resulting in a huge spike in the overall cost of the production process. The usage of biochemical conversion involving chemicals with or without combining with physical methods results in generation of chemical waste that can be a serious concern for the environment. Lastly, employing an enzymatic process for banana waste valorisation may not be feasible taking into consideration the amount of waste generated on a daily basis. This method, although eco-friendly, cannot be sustainable and affordable even for high income countries (18).

3. Extraction process and environmental concerns

Cellulose extraction majorly involves three major stages namely dewaxing, alkali treatment and bleaching. In the dewaxing step, organic solvents like toluene or ethanol are used to extract the cuticular and epicuticular wax present in the banana peels without disturbing the cellulose network. This is essential as banana peels depending on their varieties have different concentrations of waxy components that interfere with cellulose extraction. In the second step the dewaxed peels were treated using alkali like NaOH and KOH that breaks the glyosidic bonds and thereby helps in removal of hemi cellulosic biomass. In the final bleaching steps involving either chlorine based methods or non-chlorine based methods, the phenolic present in the banana cellulose is removed, resulting in the whitening of the cellulose fibres extracted from banana peels. As these three stages are inevitable components of any cellulose extraction procedure, complete replacement of chemical based processes for cellulose recovery from banana waste is not yet possible commercially (19). The use of huge amounts of alkalis in cellulose recovery calls for the need for an enormous amount of water to neutralize the treated fibres prior to the next step. This water originating from treatment sites with alkaline pH when mixed with river water can prove lethal to aquatic plants and animals. The usage of toluene and ethanol for initial dewaxing of the banana peels may not be a sustainable method, taking into consideration the huge amount of the banana peel waste used for cellulose extraction (20). Moreover, the high cost resulting from the usage of organic solvents for extraction cannot be compromised with the market price of the extracted cellulose thereby making this strategy non commercially attractive. The final bleaching step also generates a huge volume of coloured wastewater that can affect the integrity of the aquatic environment when mixed with it. In short, the chemical extraction method for cellulose recovery from banana waste was evaluated to be non-eco-friendly and non-commercially viable (21).

4. Scale up of production process

The major factors that hinders the commercial scale up of cellulose extraction from banana waste include lack of proper optimized strategy for industrial scale extraction of cellulose from banana waste. The difficulty in optimization primarily arises from the differences in the quantity and quality of the banana waste generated globally. The limitation in designing a bioreactor to carry out alkali treatment at a specific controlled temperature for huge amounts of banana waste is a laborious, time consuming and capital intensive process. Removal of alkali components from the waste water coming from the extraction units is a laborious process. Designing a bioreactor to bring about precise process control, especially the temperature and treatment time which are crucial for cellulose extraction often ends up in accelerating the overall production cost to several folds. Another major drawback in industrial scale up of banana waste based cellulose production is the lack of reproducibility in the results and inconsistency in the overall extraction process when migrating from a laboratory scale to an industrial scale. These hurdles make the scale up of cellulose production from banana waste limited (22).

5. Safety issues and risks associated with modified cellulose derivatives

Although cellulose is classified under the category of Generally Recognized as Safe (GRAS) by the Food and Drug Administration (FDA), the concern about the safety issues and risks originating from the use of Nano cellulose is still a matter of debate globally thereby restricting its commercialization. Modified cellulose derivatives, especially due to their small size, are observed to be highly reactive causing adverse health effects through immunomodulatory effects. Lack of proper information regarding the toxicity of cellulose derivatives and absence of proper legal framework stating its application in food and other sectors inhibits their widespread application in these areas (20). Cellulose nanofiber (CNF) obtained from banana waste was observed to be nontoxic to Caco-2 cell (human small intestinal epithelial layer) at low concentration below 1000 μg/mL in MTT (methylthiazolyldiphenyl-tetrazolium bromide) assay whereas the cell viability is significantly decreased as the concentration increases above 1000 μg/mL. Thus more studies to ensure the non-toxicity of cellulose and its derivatives is inevitable to promote its commercialization and industrial applications in future (23).

Conclusion

Cellulose is the main component of the banana stem, it takes about more than 50% of the total banana stem, and this is a natural, renewable, and biodegradable polymer that can be used in many fields. Cellulose can be extracted from banana waste using various methods, including conventional methods that use synthetic chemicals. However, these methods can be harmful to the environment. The inherent drawback of banana fibre is its poor quality and higher irregularity, owing to the multi-cellular nature of the fibres. The individual cells are cemented with lignin and hemi-cellulose and thus form a composite fibre.

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