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Original Research Article

Microcrystalline Cellulose from Jute Fiber: A Bright Prospect for Pharmaceutical Industry

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Abstract

Synthesis of microcrystalline cellulose (MCC) from jute sticks has been studied and reported in this work. The successful removal of lignin and hemi-cellulose has been confirmed through Fourier Transform Infrared (FTIR) spectroscopic technique. X-ray Diffraction (XRD) technique has been used to measure the crystal size and crystallinity index. The FTIR analysis revealed that the acid hydrolysis had an effect on the crystalline of the fibre; however it did not influence the chemical components of the fibres. Pharmaceutical standard tests were done. Higher concentration of sodium chlorite produces minimum particle size and the effective thermal degradation occurs at 340 °C.

Keywords: jute, fiber, MCC, pharmaceutical, Avicel pH-101.

1. INTRODUCTION

South Asian countries like Bangladesh economy largely influenced by jute. In last fiscal year Bangladesh earns more than 1 billion USD from jute sectors. But researchers think this income can be multiplied. The traditional use of jute as sacks, bags, jute hessian cloth, jute quality sacks, jute quality bags, jute yarn, woven bags, carpet backing etc. So along with these traditional usage sophisticated product from jute like MCC, CMC, charcoal, pulp, paper, viscose, blended yarn, activated carbon, and composites are now prepared. Jute fiber is a good source to prepare MCC. Usages of MCC are wide. MCC has recently gained more interest owing to its renewability, non-toxicity, economic value, biodegradability, high mechanical properties, high surface area and biocompatibility [1]. It can be used in pharmaceutical industry, food industry, textile industry etc. Among them pharmaceutical and food industry usages are most vital and crucial. MCC mostly used filler-binders in direct tablet compression. Its popularity in direct compression is due to its excellent binding properties when used as a dry binder. It also works as a disintegrant, lubricant and has a high dilution potential in direct compression formulations. In addition to its use in direct compression formulations, MCC is used as diluents in tablets prepared by wet granulation as well as filler for capsules and spheres [2]. The food industry is the second biggest user of MCC after the pharmaceutical sector. MCC has nutraceutical functions and impact positively on the gastrointestinal physiology as well weight management. MCC is a good candidate for emulsion stabilization and fat replacer in many food systems [3].

The physicochemical properties and functions of MCC are influenced by its source and preparation methods. As source is very important factor, Jute fiber here has taken source of preparation of MCC. Jute is a bast fiber containing cellulose (60-62 %), hemi-cellulose (22-24%), lignin(12-14%), wax(0.8-1%), pectin(0.1-0.4%), protein(0.8-2.5%), mineral matter (0.6 -1.2%), tanin and other coloring matters. The researchers have investigated alternative value-added application of jute sticks in different fields, viz. pulp and paper industries, bio-fuel production [4] composite making [5] activated carbon and microcrystalline cellulose [6] in order to uplift the socio-economic status of the jute cultivators and also to commercialize jute sticks in diversified fields. Keeping this in mind, the objective of the present study is to synthesize

microcrystalline cellulose from jute stick through mechanical and chemical pre-treatment process. The synthesized MCC is also characterized through various instrumental techniques, viz. FTIR, and XRD techniques after those pharmaceutical standard tests were done.The objective of this article is to evaluate the possibility, scope, advantages and drawback of jute fiber MCC in pharmaceutical industries.

MCC was first commercialized in 1962 under the name Avicel®, which is marketed by FMC Corporation. Since then, an exponential number of researchers have focused their work on such material. Industrial scale MCC is manufactured through hydrolysis of cotton and wood cellulose using dilute mineral acids. MCC is characterized by a high degree of crystallinity, and the values typically range between 55% and 80% [7].

2. MATERIALS AND METHODS

The study was carried out from 1st July 2021 to 30 June 2022 in Chemistry Division, Bangladesh Jute Research Institute, Dhaka.

Materials

Raw jute yarn and fabrics were collected from Mechanical processing division of Bangladesh Jute Research Institute (BJRI). Most of the experimental works had been carried out in the Industrial Chemistry Laboratory, Chemistry Division, Bangladesh Jute Research Institute (BJRI), Dhaka and Applied Chemistry& Chemical Engineering Department of Dhaka University. All the chemicals are reagent grade (Merck), such as sodium hydroxide (NaOH), glacial acetic acid (CH_3COOH), sodium chlorite ($NaClO_2$), sulfuric acid (H_2SO_4).

MCC Preparation

White jute was taken for the preparation of microcrystalline cellulose. The long jute fibre was cut into small pieces. Then 50 gm jute fibre was treated for delignification by bleaching with 34 gm Sodium Chlorite ($NaClO_2$) at pH 4.5. Then hemi-cellulose was removed by keeping overnight in 96 gm Sodium hydroxide at 8:1 liquor ratio. The prepared cellulose was washed thoroughly. Then the cellulose was hydrolyzed by 5% H_2SO_4 solution for 3 hours to get fine powder of microcrystalline cellulose. The prepared MCC was washed thoroughly to get neutral pH.

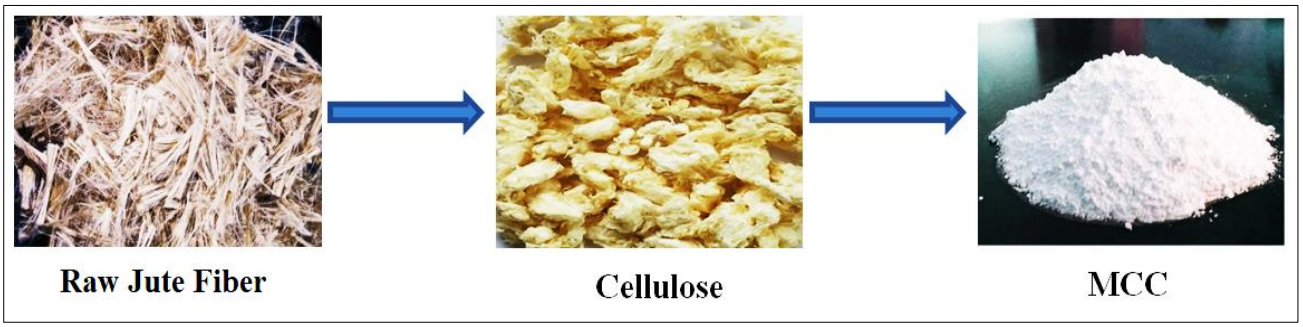


Fig 1: process flow chart for MCC preparation

Drying

The white paste of microcrystalline cellulose was dried at 40°C for 20 h in a hot air oven and finally crushed into powder form for further characterization.

3. RESULT AND DISCUSSION

The microcrystalline cellulose (MCC) was obtained from alpha cellulose which was isolated from the jute fiber of variety of CVL-1. MCC was prepared by acid hydrolysis using sulphuric acid.

3.1 Fourier Transform Infrared (FTIR)

Infrared spectroscopy is a particularly powerful and reliable technique which is sensitive and rapid as well as inexpensive that is used to study polymers [8]. Fourier transform infrared spectroscopy is a measurement of the intensity and wavelength of the absorption of IR radiation by a sample. In this modern era, Fourier transform infrared spectroscopy has been used more in depth by monitoring the chemical structure and functional groups of lignocellulosic compounds [9-11]. For instance, various applications for biological, biochemical, and food industries are widely used in the mid-region at 4000–400 cm^{-1} where the band absorption involves transitions between vibrational energy states and rotational substrates of the molecule [12].

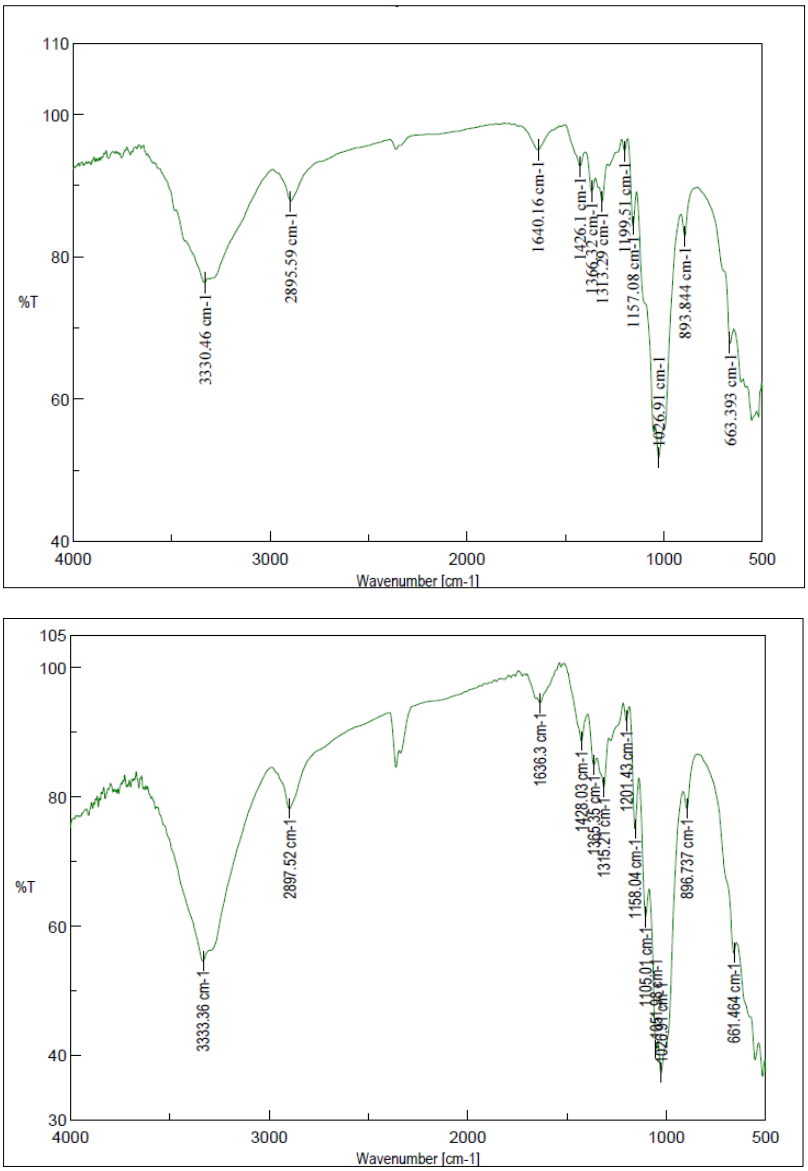


Fig 2: FTIR spectra of a) MCC and b) Avicel pH 101 produced from jute

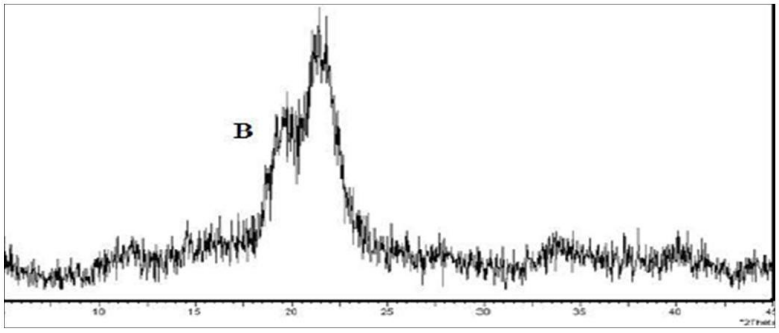
The C-H stretching vibration absorbance intensity in MCC (2893.66 cm^{-1}) upon acid hydrolysis of alpha- cellulose (2893.66); this is due to the presence of $–CH_2$ moieties in the samples. The peaks related to C-H or C-O bending vibrations for alpha cellulose (1317.14 cm^{-1}) in the polysaccharide aromatic rings is same in the spectrum of MCC. The band at 1024.98 cm^{-1} in jute MCC corresponds with 1024.02 cm^{-1} in Avicel MCC are due to $–CH_2$-O-CH_2- pyrans ring stretching vibration. In comparison, the jute MCC spectrum is very much similar with the Avicel 101 MCC. Moreover, the characteristic points of lignin in 1000cm^{-1} to 1700 cm^{-1} is lower in jute MCC than Avicel 101MCC.

3.2 X-ray Diffraction

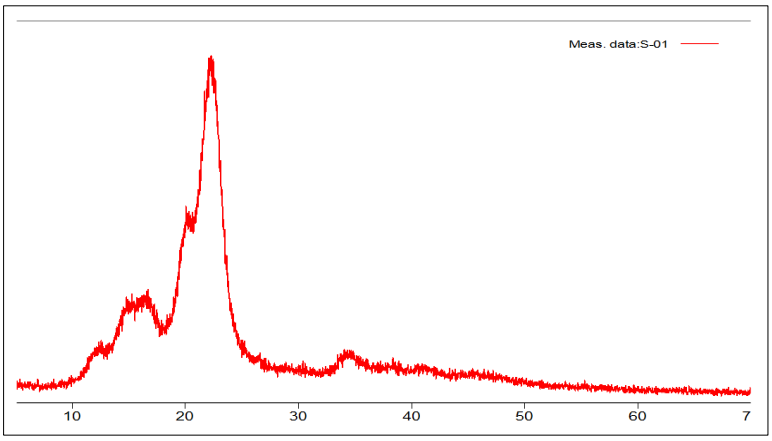
X-ray diffraction (XRD) is commonly used to analyze the identityof crystalline solids based on their atomic- scale structure of materials [13, 16]. About 2g of the pounded MCC obtained was placed and measured using XRD Bruker D8 Advance Eco Diffractometer. It was operated in reflection mode (40 kV, 35 mA) and used Cu-Kα radiation lamp (l1=1.54060 Å and l2=1.54439 Å).

This higher crystallinity in MCC used to get by removal of amorphous regions of cellulose by hydrolysis process which instigates hydrolytic cleavage of glycosidic bonds and helps to re-arrangement of cellulose molecules [17- 20]. When the crystallinity size and index increase, Strength of cellulose structure exhibits good tensile strength towards fiber [19]. This higher tensile strength is hoping to higher the mechanical properties of composite materials [21]. On the contrary, maximum percentage of lignin was removed during alkaline reaction which was then used for cellulose preparation while the exhausted amount of amorphous lignin was eliminated during acid hydrolysis of MCC [22].

The result of diffraction pattern was compared with the Powder Diffraction File database to find out the crystal size in the sample. The test was repeated using Avicel PH 101 as standard. The X-rd pattern of Avicel pH101 were taken from article. Then the XRD patterns show similar peak between Avicel pH101 MCC and MCC from jute fibre. When Reflection at 2-theta value of 20 to 30 shows the higher crystallinity both for prepared sample which was indicated by red color and the black color was standard Avicel pH-101 also shown same result.



2- Theta



2- Theta

Fig 3: X-rd spectra of a) Avicel pH101 [15] and b) MCC produced from jute

3.3 Pharmaceutical Standard Tests

pharmaceutical lab Parameters	**Acceptance Limit**	**Result**	
		Avicel pH-101	**MCC from Jute**
Characters	A white or almost white, fine or granular powder	white and fine or granular powder	off white to white and granular powder
Solubility	Practically insoluble in water, acetone, ethanol, toluene and dilute acids and in a 50 g/l solution of sodium hydroxide. It completely dissolves in ammoniacal solution of copper tetrammine.	Compatible	Compatible
Color Reaction			
1.	Violet-blue colour is develops when addition of iodinated zinc chloride solution	Compatible	Compatible
2.	Red colour is produced when addition of catechol in phosphoric acid	Compatible	Compatible
3.	A blue- purple colour is produced when addition of sulphuric acid in iodine solution	Compatible	Compatible
pH	5-7.5	6.625	6.045
Starch and dextrin	No blue or brownish colour is produced when addition of iodine	Compatible	Compatible
Loss on drying	Maximum 7.0 percent	5.50	9.42
Conductivity	Does not exceed the conductivity of the water by more than 75uScm^{-1}	21.7	51.7

CONCLUSION

The microcrystalline cellulose (MCC) which was isolated from the jute fiber was very compatible for pharmaceutically available used Avicel pH-101. Most of the pharmaceutical lab Parameters all are in the range .Due to do research in general laboratory instead of pharmaceutically graded lab our conductivity got higher. This problem can be solved very easily.so we can use our prepared MCC for pharmaceutical purpose. This will create a new horizon for diversification of jute fiber and also get a biodegradable raw material for Avicel pH-101.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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