Synthesis of microcrystalline cellulose from raw feed stock – A Review

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Abstract: Reduction of waste and minimizing the cost of synthesis of products are the most important aspects of research and development in chemical and allied fields. Solid waste treatment is gaining importance due to its effect on the groundwater quality and soil quality. Solid waste can be dealt with by three principles, reduce, recycle and reuse. Reduction of solid waste by dewatering, reuse solid waste and recycling of non putrescible waste can reduce the solid waste treatment and disposal problem significantly. Many products like ethanol, acetic acid, microcrystalline cellulose, citric acid, pectic acids etc can be derived from waste materials. The use of agricultural materials for synthesizing various products is increasing. Microcrystalline cellulose (MCC) is one such product useful in bakery, dairy and beverage industry. It has also found applications in pharmaceutical industry. This product can be derived lignocellulosic biomass. Various treatment technologies can be use for pretreatment of biomass. Selection of raw material for MCC is based on factors such as raw material, composition, availability, toxicity, cost, byproduct generation, socioeconomic aspects. Acid hydrolysis is used for converting cellulose to MCC. This review aims to study various raw materials and methods for obtaining MCC from low cost feed stock.

1. Introduction

Solid waste treatment is gaining importance due to its effect on the groundwater quality and soil quality. Solid waste can be dealt with by three principles, reduce, recycle and reuse. Reduction of solid waste by dewatering, reuse solid waste and recycling of non putrescible waste can reduce the solid waste treatment and disposal problem significantly. Many products like ethanol, acetic acid, microcrystalline cellulose, citric acid, pectic acids etc can be derived from waste materials. The use of agricultural materials for synthesizing various products is increasing. Trash expulsion is has enormous environmental impact and is cause significant problems. We use a lot of things, reliably and for a short time.Later orchestrate them by throwing in the garbage. It is a creativity that can convert undesired waste into important raw material. Microcrystalline Cellulose (MCC) is sifted,efficiently depolymerized cellulose orchestrated by treating celulose. Alpha cellulose is obtained as a product from Lignocellulosic biomass. The degree of polymerization of MCC is conventionally under 400. Particle size ranges between 20 to 180 µm. Lignocellulose is the most abundant economical biomass. It is made out of cellulose, hemicellulose and lignin.

Cellulose is a typically happening polymer. It is contains glucose units related by a 1-4beta glycosidic bond. Hemicellulose is a copolymer of different C5 and C6 sugars that moreover exists in the plant cell divider. Lignin is a copolymer of sweet-smelling compounds conveyed through a biosynthetic cycle and structures a cautious layer for the plant at tissue level. Cellulose is by and large available in nature, yet similarly as especially cross associated lignocellulosic biomass.Lignin prevents the attack of reagents on cellulose during a cycle while hemicellulose viably isolates to shaoe results. Subsequently unique pretreatment systems have been endorsed to fabricate the reactivity of cellulose in rough material by executing both the sections. These pretreatments are named mechanical and compound. Mechanical pretreatment fabricate surface zone and substance pretreatment decreases the proportion of the irritation engineered mixes in the unrefined material. At the point when the unrefined material is pretreated it's set up to be to some degree depolymerized to give outcome, microcrystalline cellulose (MCC).

2. Gaps and current research

Katakojwala and Mohan havecarried out investigation on production of MCC from sugarcane Bagasse[1]. They used total three methods for extraction of MCC. In first method (MCC1) , MCC produced 0.93±0.01 g/g cellulose. They found that, in the second method (MCC2), MCC produced of 0.92±0.01 g from gram of cellulose. Whereas, in the third method, MCC produced 291 was 0.96±0.01 g/g cellulose. They obtained higher cellulose percent from second method. The important step in all the methods was depolymerization of cellulose in presence of H_2O_2 in presence of H_2SO_4 which favors acid hydrolysis where the long polymeric chain of cellulose break to result in small chains of glucose molecules, which was merely microcrystalline cellulose. According to them, the advantage of using hydrogen peroxide was, it can act as bleaching agent as well as delignifying agent and that result in complete removal of lignin and color of produced MCC. The result showed highest yield of MCC from extracted cellulose in third method.

An investigation was carried out on production of MCC from corn husk by using different acid alkali treatment method by Vora and Shah[2]. They extracted microcrystalline cellulose by using different acids such as HCL, Sulphuric acid and Nitric acid; alkali (Sodium Hydroxide) treatment and bleaching They used materials such as corn husk which was collected by the local farmers and chemicals like sodium hydroxide, hydrochloric acid, nitric acid and calcium hypo-chlorite and Avicel PH 101. They treated 1kg of corn husk with water and pulverized to husk powder. They washed extra slurry with refined water until the residue was nonpartisan to litmus paper and dried resultant cellulose for 6 hr. at 60°C. They observed the morphology of the treated microcrystalline cellulose by using Scanning electron microscope which showed a compact structure. They observed crystallinity of the produced microcrystalline cellulose range (73%-79%) by using X-ray diffraction. They observed the production of cellulose from corn husk which is cheaper source than the imported varieties.

Another investigation was carried out on production of cellulose from corn husking by Vora and Shah[3]. They used materials such as corn husk from local farmer and some chemicals like Sodium hydroxide, Sulphuric acid. They dried corn husk for seven days and then reduced the size by using mill. They filtered slurry and washed residue with with distilled water until the residue was neutral to litmus paper. They filtered cellulose material by using cotton cloth and the water squeezed out manually to find small lumps and calculated yield of cellulose. The result showed the preparation of Pharmaceutical grade cellulose is feasible.

An investigation was carried out on microcrystalline cellulose from maize husk powder by Ohwoavworhua et.al[4]. For the preparation of MCC, they used materials such as nitric acid, sodium nitrite, sodium sulphite, sodium hydroxide, xylene and groundnut husk from local mill at Abuja, Nigeria. They used two methods of pulping to delicate groundnut husk sample i.e. 1. Sodium Hydroxide Pulping, 2. Multistage Pulping. In first method, they delignified extractive free powder with aqueous sodium hydroxide and in second method they filtered cellulose material, water squeezed out manually to obtain small lumps. Their results showed

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that, by using sodium hydroxide pulp method, it was not possible to calculated yieldbecuase it contained unhydrolyzed materials but by using multistage pulping they calculated yield of 15%.

3.Production of Microcrysalline cellulose

An examination was done by Thygesen et.al for assurance of crystallinity and composition cellulose in plant fibres[5]. Authors saw that crystallinity conclusions were X-beam powder optical most ways abuse side-load (Bragg-Brentano) mode. Rietveld refinements supported the recently revealed crystalstructure of polyose polyose followedby integration of the crystalline and amorphous.Their resultsindicated that the determined polyose crystallinities were 90 100 g/100 g polyose in plant-based fibres and 60 70 g/100 g polyose in wood based mostlyfibres. These evidence are important in reference to study of various fibre composites and bio-ethanol production.

Another investigation carried was carried out on extraction and characterization of microcrystalline cellulose (MCC) present in different agro-industrial wastes such as walnut shells, corncob, and sugarcane bagass byHarini and Mohan[6]. Core carbohydrate was observed to possess a loosely finite linear bundle structure. Nanocrystalline carbohydrate fiber yield from walnut shell and sugarcane pulp carbohydrate were quite core carbohydrate.Their resultsindicated that the thermal stability of carbohydrate was high for walnut shell NCCF. Nanocrystalline carbohydrate fiber of core associated sugarcane pulp was found to possess an occasional thermal degradation temperature.

Sapkal et. al carried outan investigation on synthesis of MCC from cotton rags which is garment waste[7]. They used cotton rags which is easily available in local market and hydrochloric acid and iodine solution. Result showed that prepared sample had similar crystillinity, good thermal stability as well as less residue content.

An investigationwas carried out on synthesis of microcrystalline cellulose (MCC) from saccharum spontaneum by integrating alkaline delignification, chlorine-free bleaching, and acid hydrolysis treatmentsby Baruah et.al[8].They used an environment friendly and sustainable methodThey observed that to minimize acid concentrations, the acid reaction conditions were optimized exploitation Taguchi orthogonal L9 style that evaluated the influences of interval, temperature, acid concentration and resolution to pulp quantitative relation on the physical and chemical characteristics of MCC. Maximum MCC yield was observed to be eighty three. This method is favorable thanks to the utilization of terribly low (5% H_2SO_4) acid concentration, low corrosivity, effluent reduction, and cost-effectiveness.

Production of microcrystalline cellulose (MCC) from tea waste was carried out by Zhao et. al[9]. They observed that MCC can be prepared from tea waste by chemical and chemical reaction treatments. The chemical reaction conditions were optimized by AN orthogonal L9(3)4 experiment.Their experiments indicated that tea waste MCC had plastic structure and was polyose I kind.

An investigation was carried out on production of MCC from Bamboo fiber by Rasheed et.al[10]. They administrated synthesis of MCC through acid hydrolysis method. They removed lignin from MCC by FT-IR analysis. They obtained pure MCC, albeit with small quantities of impurities and residue by Energy Dispersive X-ray (EDX) analysis. Result showed that isolated MCC has higher crystallinity as compared to commercial available MCC (74%).

Supian et. al studies production of microcrystalline cellulose from empty fruitbunch(EFB) with alkaline treatment, bleaching and acid hydrolysistreatment. [12]. Fourier change infrared spectroscopy (FTIR) investigation showed that the trademark peak of lignin and hemicellulose were missing in the range of the alpha cellulose and MCC. SEM demonstrated that the MCC had an unpleasant and minimized structure, like the business MCC, in spite of the fact that it displayed a lot more modest fragments.This study indicated that basic pre-treatment at 20% of NaOH focus gave the best outcome for creation of MCC from EFB.

Hydrolysis technique was utilized to separate microcrystalline cellulose (MCC) from oil palm by Haafiz et. al[13]. DifferentbMCC was changed over into polylactic (PLA) utilizing arrangement projecting method to create PLA/MCC composites by them. Their FT-IR investigation expressed that the corrosive hydrolysis didn't influence the compound structure of the cellulosic parts. They presumed that decrease in roughness at break of the PLA/MCC composites were seen because of the helpless scattering of MCC into PLA pieces. Thermal characterization indicated that the PLA and MCC composites have better thermal stability compared to pure PLA.

Examination was done on synthesis of microcrystalline cellulose (MCC) from oil palm fronds (OPF) utilizing chemo-mechanical cycle by Owolabi et. al[14]. They completed a few insightful strategies to decide the impact of AHP fixation on warm properties, morphological properties, tiny and glasslike conduct of separated MCC. Oil pulp fiber was then blanched with fermented sodium chlorite arrangement followed by the corrosive hydrolysis utilizing hydrochloric corrosive. Fourier transmission infrared (FTIR) examinations demonstrated that the AHP previously hydrolysis was utilized effectively to eliminate hemicelluloses and lignin from the fiber. They indicated that pre-treatment measure possibly affected the nature of the disengagement of MCC from oil palm fiber. Selective literature on production of Microcrystalline Cellulose is tabulated in Table 1.

Table 1. Literature study in Production of Microcrysalline cellulose

Ref. No.	Authors	Paper Title	Result
1	Ranaprathap Katakojwala, S. Venkata Mohan	Microcrystalline cellulose production from sugarcane Bagasse: Sustainable process development and life cycle assessment	Highest yield of MCC from extracted cellulose in third method
3	Roshni S. Vora,Yamini D. Shah	Production of Micro Crystalline Cellulose from Corn Husk and Its Evaluation as pharmaceutical Excipient	Production ofPharmaceutical grade cellulose from corn husk waste is feasible
5	Thygesen A, Oddershede J, Lilholt H, Thomsen AB	Cellulose content in plant fibers	The thermal properties of the cellulose samples were investigated by DSC on a simultaneous thermal analyzer samples weighing between 6 and 10mg were used
7	Yuvraj P. Chauhan∗, R. S. Sapkala , V. S. Sapkala And G. S. Zamre	Microcrystalline cellulose from Cotton rags	Prepared sample has similar crystallinity, good thermal and less residue content

11	Rizduan Ramli, Ridzuan Ramli, Rosli M. Yunus, Mohammad D.H. Beg, Norhafzan Junadi	Microcrystalline cellulose (MCC) from oil palm empty fruit bunch (EFB) fiber via simultaneous ultrasonic and alkali treatment	Produced MCC is a cellulose-1 polymorph with 73% crystallinity

4. Conclusions

In this review paper we have discussed about synthesis of microcrystalline cellulose from raw feedstock. Also, various methods/processes with different waste materials used by various investigators are summerized.

Solid waste treatment is one of the major problems faced by modern society. Increase in industrial and manufacturing sector is accompanied by increase in solid waste. Synthesis of various compounds by using solid waste as starting material can solve the disposal problem and also provide value added product. Microcrystalline cellulose(MCC) is one such product which can be obtained from waste material like bagasse or any other lignocellulosic biomass. MCC finds applications in pharmaceutical, bakery, dairy and beverage industry. Investigations on synthesis of MCC are aimed at increasing the yield, optimizing the procedure and finding the optimum manufacturing conditions. It can be concluded that synthesis of MCC can be carried out by various low cost materials. This reduces problem of solid waste generation especially from sugar industries, paper mills, distilleries and other industries with lignocellulosic biomass as solid waste.

References

[1]. RP Katakojwala, SV Mohan. Microcrystalline cellulose production from sugarcane Bagasse: Sustainable process development and life cycle assessment, Journal of Cleaner Production, 249, 2020, 119342, https://doi.org/10.1016/j.jclepro.2019.119342.

[2]. RS Vora, YD Shah. Extraction, Characterization of Microcrystalline Cellulose obtained from corn husk using different acid alkali treatment method, Indo American Journal of Pharmaceutical Sciences, 8, 2017, http://doi.org/10.5281/zenodo.846367.

[3]. Roshni S. Vora,Yamini D. Shah, Production of Micro Crystalline Cellulose from Corn Husk and Its Evaluation as pharmaceutical Excipient, 2(11), 2015.

[4]. Frank O. Ohwoavworhua, Tiwalade A. Adelakun , Augustine O. Okhamafe, Processing pharmaceutical grade microcrystalline cellulose from groundnut husk: Extraction methods and characterization, International Journal of Green Pharmacy, 4, 2009.

[5]. Thygesen A, Oddershede J, Lilholt H, Thomsen AB, cellulose content in plant fibers, 4(3), 2017, 106-114.

[6]. K. Harini, C. Chandra Mohan, Isolation and characterization of micro and nanocrystalline cellulose fibres from the walnut shell, corncob and sugarcane Bagasse, International Journal of Biological Macromolecules, 2020, https://doi.org/10.1016/j.ijbiomac.2020.07.239.

[7]. Yuvraj P. Chauhan∗, R. S. Sapkala , V. S. Sapkala And G. S. Zamre, Journal Of Microcrystalline Cellulose From Cotton RAGS, 18.03.2009.

[8]. Julie Baruah, Ramesh Chandra Deka, Eeshan Kalita, Greener production of microcrystalline cellulose (MCC) from Saccharum spontaneum (Kans grass): Statistical optimization, International Journal of Biological Macromolecules, Volume 154, 2020, 672-682, https://doi.org/10.1016/j.ijbiomac.2020.03.158.

[9]. TZhao, Z Chen, X Lin, Z Ren, B Li, Y Zhang. Preparation and characterization of microcrystalline cellulose (MCC) from tea waste, 11, 2017, https://doi.org/10.1016/j.carbpol.2017.12.024.

[10]. Masrat Rasheed, , Mohammad Jawaid, Zoheb Karim, Luqman Chuah Abdullah, Article Morphological, Physiochemical and Thermal Properties of Microcrystalline Cellulose (MCC) Extracted from Bamboo Fiber, Molecules 25, 2020, 2824.

[11]. R Ramli, RM Yunus, MDH Beg, N Junadi. Microcrystalline Cellulose (MCC) From Oil Palm Empty Fruit Bunch (EFB) Fiber via Simultaneous Ultrasonic and Alkali Treatment, International Journal of Chemical, Materials and Biomolecular Sciences, 9(1), 2015, 8-11.doi.org/10.5281/zenodo.1337783.

[12]. MAF Supian, KNM Amin, SS Jamari, S Mohamad. Investigation on pre-treatment process in Microcrystalline cellulose (MCC) from oil palm empty fruit bunch (EFB), Journal Chemical Engineering and Industrial Biotechnology (JCEIB), 3, 2018, 87-96; https://doi.org/10.15282/JCEIB-V3-09.28/3/2018/3.3.

[13]. M.K. Mohamad Haafiz, Azman Hassan, Reza Arjmandi, Zainoha Zakaria, Microcrystalline Cellulose From Oil Palm Empty Fruit Bunches as Filler in Polylactic Acid, Article of Department of Bioprocess and Polymer Engineering,Polymers and Polymer Composites, volume 24(9), 2016, 675-689. DOI:10.1177/096739111602400901.

[14]. OFAW Taiwo, MS Hossain, MRN Fazita, MKM Haafiz, MH Hussin. Influence of alkaline hydrogen peroxide pre-hydrolysis on the isolation of microcrystalline cellulose from oil palm fronds, International Journal of Biological Macromolecules, 11, 2016. https://doi.org/10.1016/j.ijbiomac.2016.11.016.