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A REVIEW OF MICROCRYSTALLINE CELLULOSE: STRUCTURE, APPLICATIONS, AND LIMITATIONS

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ABSTRACT

Microcrystalline cellulose usage in various fields, such as food, pharmaceutical, medical, cosmetic and polymer composites industries.[2] Microcrystalline cellulose has recently gained more interest owing to its renewability, non-toxicity, economic value, biodegradability, high mechanical properties, high surface area and biocompatibility.[1,2] Microcrystalline cellulose functions as a binder, disintegrant, texturizer, and stabilizer. Additionally, it also addresses current limitations in microcrystalline cellulose use, such as moisture sensitivity and compatibility with certain polymeric matrices.[2] Microcrystalline cellulose is one of the most important tablet excipients to its outstanding dry binding properties, enabling the manufacture of tablets by direct compression.[3] Microcrystalline cellulose based active films offer an innovative approach to extending the shelf life of food products by delivering antimicrobial protection and inhibiting lipid oxidation.[4] This review explores the structure microcrystalline cellulose, its diverse applications, and the associated limitations that may impact its utility.

KEYWORDS: Microcrystalline Cellulose (MCC), Structure, Pharmaceutical Excipient, Limitations, Food Additives.

INTRODUCTION

Microcrystalline cellulose (MCC) is a tasteless and odorless white crystalline powder made up of porous particles. Microcrystalline cellulose is slightly soluble in a 5% w/v solution of sodium hydroxide (NaOH) but practically insoluble in water, acid solutions, and some organic solvents.[5] It is relatively stable physically and chemically in ambient conditions, and it is normally stored in dry and cool environments. Microcrystalline cellulose is an essential supplementary excipient in the pharmaceutical sector, particularly as a tablet excipient, in addition to being an ingredient in food and cosmetic products.[5] Cellulose, the most abundant polymer present on this planet, represents an important class of renewable biopolymers. Cellulose is commonly employed for versatile industrial applications, attributable to its excellent biodegradability and sustainability.[6] The cellulose and MCC extracted from different plants and their parts exhibit differences in their physical characteristics such as water absorbability, polymerization, porosity, and crystallinity. Three methods are mainly used to prepare MCC by hydrolysis of the cellulose, including acid hydrolysis, enzymatic hydrolysis, and microbial hydrolysis. Among these methods, acid hydrolysis is considered the most suitable as it produces microcrystalline cellulose with high crystallinity index.[6] With more people looking for planet-friendly and safe materials, researchers are doubling down on finding better ways to produce microcrystalline cellulose (MCC) and discovering exciting new uses for it.

Structure

Microcrystalline cellulose is made up of simple sugar chains—specifically, D- glucose units linked together in a straight line (β-1→4 bonds). These chains pack tightly into strong, orderly crystalline regions, with a few looser, disordered areas mixed in.

Compared to natural cellulose, microcrystalline cellulose chains are much shorter, usually just 100 to 300 glucose units long. This compact structure, along with its high crystallinity, gives microcrystalline cellulose some standout qualities—like being incredibly compressible, great at soaking up water, and remarkably stable under different conditions.

Applications

- Microcrystalline cellulose-based active packaging:

Cellulosic fibers and their derivatives are promising materials for food packaging because they are renewable, biodegradable, and improve the structure, strength, and heat resistance of composite materials. Their strong hydrogen bonds help create a durable network by firmly connecting the microfibers.[10]

- Application of microcrystalline cellulose in the food system:

Microcrystalline cellulose also known as cellulose gel, is a purified form of cellulose made by breaking down fibrous cellulose into a gel-like material. It is considered safe and widely used in the food industry beyond its role as dietary fiber. It is commonly found in desserts, ice cream, toppings, low-fat mayonnaise, salad dressings, beverages, bakery fillings, fruit fillings, and dairy and non-dairy creams.[10,7]

- Application of microcrystalline cellulose as excipients

1. The Perfect Binder**:**
   - Microcrystalline cellulose acts like a gentle glue, holding powdered ingredients together without altering their effectiveness.[8]
   - It ensures tablets stay intact during production, packaging, and handling.[8]

2. Disintegration Superpower
   - When you swallow a tablet, helps it break apart quickly, releasing the drug for optimal absorption.[9]
   - This means faster relief for patients, whether it's a painkiller, antibiotic, or vitamin.[9]

3. Direct Compression
   - Many tablets are made by compressing powders directly (no messy wet granulation needed). Microcrystalline cellulose is a superstar here because it compresses smoothly without cracking.[9]
   - This saves time, energy, and costs in manufacturing.

4. Bioavailability Booster
   - Some drugs struggle to dissolve properly in the body. Microcrsytalline helps by creating a porous structure that allows better water penetration, enhancing drug release and absorption.

Limitations

Microcrystalline cellulose as certain limitations that may restrict its applications

- Limited Solubility: Microcrystalline cellulose is insoluble in water and organic solvents, which can hinder its use in certain formulations requiring complete dissolution.
- High Production Costs: The production process of microcrystalline cellulose involves acid hydrolysis, washing, and drying, making it relatively expensive compared to native cellulose.
- Batch Variability: Variations in source materials and processing conditions can lead to differences in particle size, crystallinity, and performance, affecting consistency in applications.

- Potential for Tablet Capping and Lamination: In pharmaceutical formulations, improper use of microcrystalline cellulose can lead to issues such as tablet capping and lamination.

CONCLUSION

Microcrystalline cellulose is a valuable material with extensive applications in pharmaceuticals, food, cosmetics, and industrial sectors. Its unique properties renewability, biocompatibility, and impressive mechanical strength make it an attractive alternative to non-renewable materials, offering both environmental and functional. However, challenges such as solubility, cost, and variability must be addressed to further optimize its potential in future applications. Ongoing research into modified and functionalized microcrystalline cellulose derivatives may offer new solutions to overcome these limitations and expand its usability**.**

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