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The Properties, Preparation and Applications for Carboxymethyl Cellulose (CMC) Polymer: A Review

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Received: 14 June 2022 **Accepted: 21 July 2022**

DOI: https://dx.doi.org/10.24237/djps.1804.608C

Abstract

Cellulose is one of the most frequently used natural polymers. Some characteristics of Carboxymethyl cellulose polymer have been studied, which is a semi-crystalline, non-toxic material. CMC polymer is made by several methods including homogeneous Procedures and heterogeneous Procedures. It also has many applications such as its use in Pharmaceuticals and Cosmetics, Drilling Fluids, Manufacture, and CMC-Based Drug Delivery Systems for Wound Infections. The aim of the review is to study a Carboxymethyl cellulose polymer, know some of its properties, take an example of mixing CMC with another polymer, know its properties, identify homogeneous and heterogeneous procedures for its preparation, and take examples of part of its applications.

Keywords: CMC, Properties, Preparation, Applications, A Review.

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الخصائص، التحضير، والتطبيقات لبوليمر كاربوكسي ميثيل السليلوز (CMC): مراجعة

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الخلاصة

السليلوز هو أحد البوليمرات الطبيعية الأكثر استخداماً . تمت دراسة بعض خصائص بوليمر كاربوكسي ميثيل السليلوز، وهي مادة شبه بلورية وغير سامة. يحضر بوليمر CMC بعدة طرق بما في ذلك الإجراءات المتجانسة والإجراءات غير المتجانسة . كما أن لديها العديد من التطبيقات مثل استخدامها في المستحضرات الصيدلانية ومستحضرات التجميل، سوائل الحفر، الصناعة، وأنظمة توصيل الأدوية القائمة على CMC لعلاج التهابات الجروح . الهدف من الرفيو هو دراسة بوليمر كاربوكسي ميثيل السليلوز، ومعرفة بعض خصائصه، وأخذ مثال على خلط CMC مع بوليمر آخر ومعرفة خصائصه، ومعرفة الإجراءات المتجانسة وغير المتجانسة لتحضيره، وأخذ أمثلة على بعض من تطبيقاته.

الكلمات المفتاحية: كاربوكسي ميثيل السليلوز، الخصائص، التحضير، التطبيقات، المراجعة .

Introduction

Plastic has evolved from a beautiful substance that makes life easier for us to a huge environmental worry [1]. Bio polymers have proven to be a viable alternative to petroleum-based polymeric materials, reducing dependency on dwindling crude oil stocks. Furthermore, many bio-based polymers, particularly bio-natural polymers like polysaccharides and proteins, are biodegradable. Biodegradability is also a desirable quality in many applications, including food packaging and agricultural uses and it adds to sustainability by reducing the waste impact of oily polymers [1,2].

Additional characteristics are required for some bio Polymer applications. Antimicrobial characteristics, for example, are advantageous in food packaging and biomedical devices, where bacterial contamination can result in major public health and safety issues.

Plant waste can be converted into valuable goods, which can assist to alleviate environmental issues [3]. Plant waste contains more than 85% (w/w) carbohydrate polymers, which can be transformed by chemical reactions and biochemical with products including starch, cellulose, and others [4,5].

Cellulose is an important component to develop a novel agricultural waste of biomaterials. Cellulose is abundantly found in plant cell walls and is usually coupled to lignin and hemicellulose, making pure extraction challenging. [6]. The molecular weight of cellulose is very high. Between the C-1 and C-4 pyranose rings, a linear homo polymer composed of repeated -D-glucopyranosyl units bonded to single oxygen atoms (acetal bonds). Development of fibrous crystalline poly bundles.

Crystalline regions are made up of a significant number of hydrogen bonds. Amorphous regions separate them and connect them. Because most of these hydrogen bonds must be released all at once in order to cellulose to disintegrate, it is insoluble. However, cellulose can be turned into a water-soluble gum by substituting it [7,8]. Cellulose comes in a variety of forms, including natural fibers (used in textiles and paper) and derivatives like Carboxymethyl cellulose and methyl cellulose.

Carboxymethyl Cellulose (CMC)

Carboxymethyl cellulose is a linear, non-toxic, anionic, long-chain low-cost water-soluble anionic polysaccharide with great film-forming ability; however, it has low conductivity, where studies indicate highest conductivity (1.43×10^{-3} S/cm) [9-17].

Several investigations have been conducted on the use of CMC in mono polymer electrolyte systems; however, due to its tiny elongation at break, highly stiff behavior of (8%), and lack of electrochemical stability required for electrochemical devices, certain issues limit its application in this sector. Furthermore, a single polymer with distinct chemical, mechanical, and physical properties cannot be used for a wide range of applications, particularly in energy storage devices [18]. Purified CMC is a powdered white to creamy powder that is tasteless and odorless [19,20]. Carboxymethyl cellulose is a nutritional chewing gum that is commonly used. It's used in a variety of industries, including food, pharmaceuticals, detergents, lubricants, and adhesives [20-27]. Figure (1) depicts the repeating CMC unit [28].

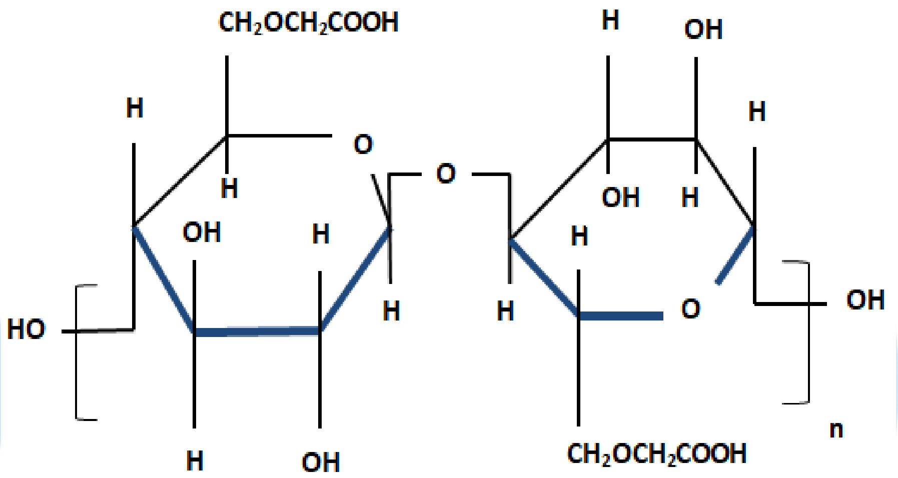

Figure 1: The monomeric structure of Carboxymethyl cellulose (CMC) [28].

Carboxymethyl Cellulose (CMC) Properties

For both industrial and academic research teams, CMC Polymer is a source of inspiration. CMC Polymer, which is extensively employed in drug delivery, have numerous qualities including hydrophilic, bio-adhesive, pH sensitive, non-toxic, and gel-forming capabilities.

Properties of (PVA/CMC) composites

- The models were prepared by casting process, in which certain proportions of polymers (CMC) and (PVA) were mixed, and studies of optical and thermal properties were performed. The optical results showed that the value of (absorption edge) gradually increased when the concentration of (CMC) polymer was increased. The results of (Glass

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phase transition (Tg)) showed that (Tg) increases when the concentration of the two polymers is equal, reaching (102 °C). Thermo gravimetric analysis (TGA) measurements were also carried out in order to determine the thermal stability of the materials, and according to the results of (TGA), the weight loss ranged between (54-80)%, where the highest percentage of weight loss reached at (50:50) for polymers (PVA:CMC) and less. Weight loss ratio at (0:100) for polymers (PVA: CMC) [29].

- For possible uses in optical and electronic properties, numerous studies on the electrical and optical characteristics of polymers have been conducted. Understanding the charge transport mechanisms in those materials is the aim of research is to examine its electric properties. These mechanisms may undoubtedly be altered by a variety of processes, such as plasticization, mixing, copolymerization, and the addition of salts or ceramic fillers. Researched electrical and dielectric properties of PVA/CMC/ZnO nano rods made by casting method. The findings demonstrated that whereas ac conductivity adhered to Jonscher's equation, de conductivity had Arrhenius behavior that was getting better with temperature. Due to their considerable improvement in ac and de conductivity, this nano composites had been proposed as possible candidates for applications like electrochemical devices [30].

Preparation of Carboxymethyl Cellulose (CMC)

1. Heterogeneous Procedures

CMC was first prepared in 1918, and it was commercially commercialized in early 1920 [31]. Heterogeneous processes in cellulose slurry techniques, by the interaction of mono chlorinated acetic acid or sodium salt with swelling of cellulose in NaOH (aqueous solution) and an additional organic solvent, are fully supported in the large-scale synthesis of CMC. (Figure 2) [32,33].

Some review publications have focused on CMC with substitution scores DS ranging from 0.5 to 1.5 [30-34]. The distribution of Carboxymethyl functions inside the AGU, as well as the CMC characteristics and properties, were also investigated. ^{13}C NMR and 1H spectroscopy, as well as extremely acidic anion exchange chromatography, were used to characterize them [35-37]. Which Carboxymethyl Functions are distributed in the AGU Along With O-2 F O-6 A O-3 mathematically Processing of the 13c NMR Spectra Revealed the CMC Composition of Monomer, i.e. all differently modified molar units that formed the polymer chain.

2. Homogeneous Procedures

Apart from the research on heterogeneous actions, cellulose as a solvent attracts much attention for heterogeneous reactions. A variety of cellulose derivatives were synthesized using proprietary and non-protonated cellulose proprietary solvents [38].

Furthermore, cellulose legalization has long been a focus of cellulose research since it leads to specialized cellulose derivatives in the polysaccharide backbone and provides a better knowledge of the complex transformation mechanisms. Various types of non-aqueous solvents, such as N, N-dimethylacetamide/lithium chloride DMAc/LiCl, have been studied as reaction intermediates for homodimeric Carboxylates in cellulose [39,40].

Carboxymethyl binding is achievable in the presence of solid NaOH particles, according to reports on CMC synthesis in the DMAc/LiCl system. CMC has a different distribution of ether groups and different characteristics, such as a favored substituent at the O-6 location and a mass-like distribution of Carboxymethyl groups along polymer backbone [30,40,41].

In a one-step synthesis of N-methylmorpholine-N-oxide NMMNO and dim ethyl sulfoxide/ammonium tetra fluoride DMSO/TBAF, CMC with DS values greater than 2.2 is available [42].

Completely homogenous Carboxymethyl cellulose with sodium monochloroacetate can be used in the presence of an aqueous sodium hydroxide solution, such as Ni(tren) (OH) 2 [tren = tris(2-aminoethyl) amine]. The roles of the hydroxyl groups were derived in the order C-6PC-2>C-3 for CMC [43] using a statistical distribution of substituents beside the polymer chain. Water solubility has the lowest DS is 0.4, which corresponds to commercial samples.

A precise concentration is necessary for all Carboxymethyl processes, whether using an aqueous or a suspension of sodium hydroxide. Furthermore, homogeneous Carboxymethyl cellulose has been observed in a 7 percent wt NaOH/12 wt percent NaOH solution, a powerful cellulose solvent [44].

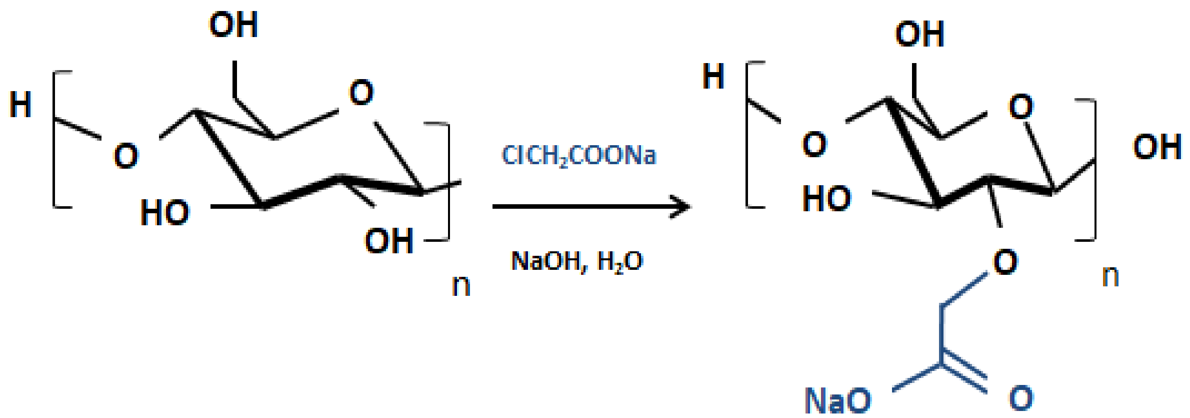

Figure 2: Synthesis and Structure of (CMC) [45].

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Some Articles on Preparation (CMC)

Table 1: Showing Some Details of Scientific Articles for Preparation of (CMC).

Polymer	Preparation Methods	Type of Studies	The Results	References
CMC derived from office paper.	Precipitation Method.	The coagulation flocculation process of the MB Dye	the CMC-3 was effective for methylene blue dye removal with highest percentage (98.14%) at pH 9.0.	[46]
CMC Derived from Empty Fruit Bunch.	Precipitation Method.	TGA, FT-IR, X-ray and SEM.	The modification of cellulose to CMC Was confirmed by FTIR, XRD and SEM analyses.	[47]
CMC Derived from Waste Disposable Paper Cups.	Precipitation Method.	DS, FE-SEM, FT-IR, XRD and TGA.	CMC showed ribbon and rod-like shapes with a diameter of 25-50 µm.	[48]
CMC from Palm Bunch and Bagasse Agricultural Wastes.	Precipitation Method.	FTIR.	FTIR confirmed the substitution of a carboxymethyl group on the cellulose structure.	[49]
Facile and green synthesis of ZnFe2O4@CMC.	Precipitation Method.	FESEM, EDS, FT-IR, TEM, XRD, VSM, BET, and UV-DRS.	confirmed the formation of pure-phase spinel ferrites, small agglomeration and ferromagnetic properties of ZnFe2O4@CMC.	[50]
CMC-Based Hydrogel from Sugarcane Bagasse.	Precipitation Method.	Heavy Metal Ion Desorption and welling Degree Measurement.	(GA) as a cross-linking agent showed the property of selective adsorption for Cu(II) ions. The adsorbed Cu(II) ions were effectively desorbed from the hydrogel.	[51]

Some Application of CMC

CMC is beneficial in applications that require hydrophilic colloids. As demonstrated in Figure (3), its capacity to raise water density, suspend particles in aqueous environments, stabilize emulsions, delay crystal development, absorb moisture from the atmosphere, and create films are the major qualities that boost its commercial worth [52,53].

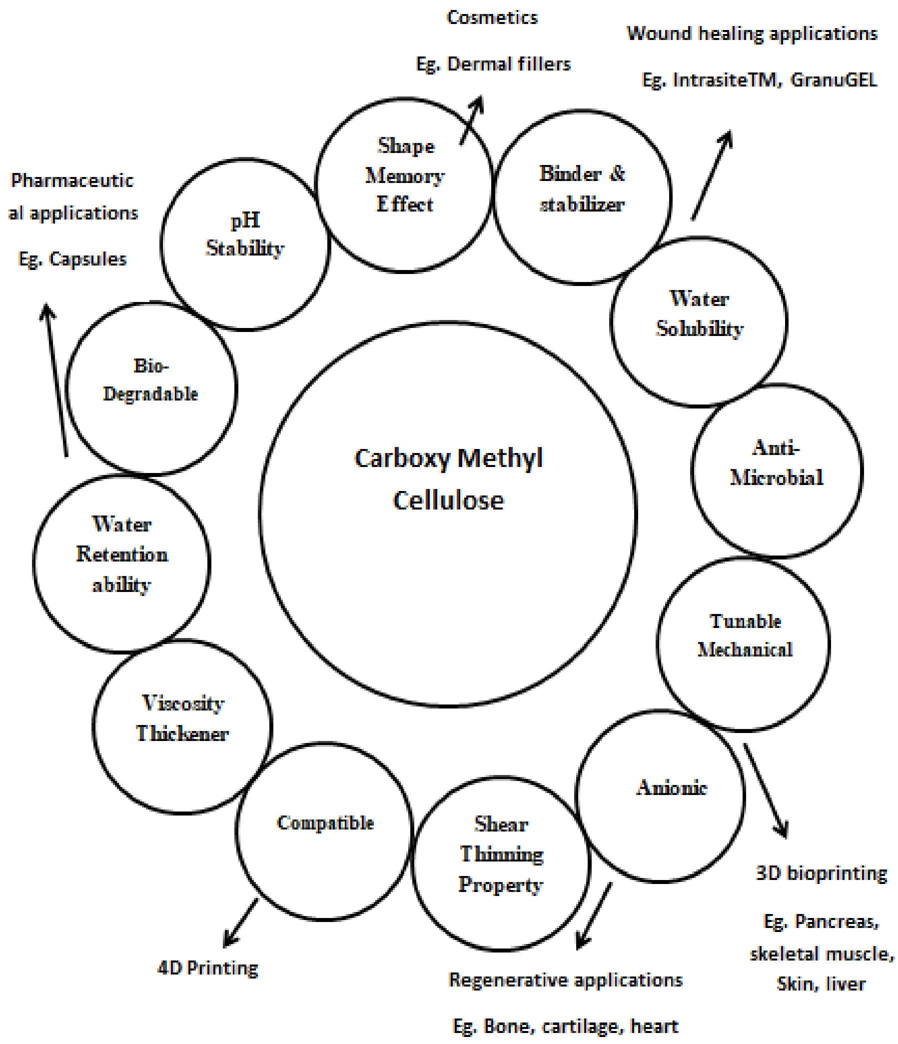

Figure 3: CMC properties and biomedical applications.

- Pharmaceuticals and Cosmetics
- Drilling Fluids
- Manufacture
- CMC-Based Drug Delivery Systems for Wound Infections

Conclusion

The necessity for cellulose and its derivatives has been underscored by the demand for biodegradable and biocompatible polymers. Researchers have concentrated on CMC because of its remarkable properties, including water solubility, facial gel behavior, water absorption ability, structural stability, pH stability, much-adhesiveness, biodegradability, biocompatibility, and the FDA has approved some clinical procedures. This review covers the physical and synthetic features of CMC, as well as its preparations and uses in pharmaceuticals, cosmetics, and CMC-based drug delivery systems for wound infection, drilling fluids, and manufacturing. Due to its numerous advantages in several domains, CMC is garnering a lot of attention in biomedical applications. Their qualities can be altered by manipulating their structures to improve their suitability for various applications. It can also be used to make protective masks against the Coronavirus. To develop and improve these active compounds, more well-designed research will be required.

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