ID Design Press, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2019 Nov 30; 7(22):3878-3881.
https://doi.org/10.3889/oamjms.2019.524
eISSN: 1857-9655
Herbal Medicine in Pharmaceutical and Clinical Sciences

Characterization of Synthesized Sodium Carboxymethyl Cellulose with Variation of Solvent Mixture and Alkali Concentration

Henny Sri Wahyuni, Sri Yuliasmi*, Hanifah Siti Aisyah, Devi Riati

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Universitas Sumatera Utara, Medan 20155, Indonesia

Citation: Wahyuni HS, Yuliasmi S, Aisyah HS, Riati D. Characterization of Synthesized Sodium Carboxymethyl Cellulose with Variation of Solvent Mixture and Alkali Concentration. Open Access Maced J Med Sci. 2019 Nov 30; 7(22):3878-3881. https://doi.org/10.3889/oamjms.2019.524

Keywords: Carboxymethyl cellulose; A solvent mixture; Alkali concentration; A degree of substitution (DS); Infrared

***Correspondence:** Sri Yuliasmi. Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Universitas Sumatera Utara, Medan 20155, Indonesia. E-mail: yuliasmisri@gmail.com

Received: 25-Sep-2019; **Revised:** 17-Oct-2019; **Accepted:** 18-Oct-2019; **Online first:** 14-Nov-2019

Funding: This research did not receive any financial support

Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: CMC is one of the water-soluble polysaccharide derivatives obtained from cellulose. Alkalization and carboxymethylation process will influence the quality of the CMC. The use of a combination of mixed solvents and varying alkali concentrations in the synthesis process of CMC needs to be studied so that CMC can be synthesized with the proper characteristics.

AIM: This study was conducted to determine the characteristics of carboxymethyl cellulose synthesized using various solvents and NaOH concentrations.

METHODS: Carboxymethyl cellulose (CMC) was synthesized using solvent mixture, namely isopropanol: isobutanol (30: 70) and isopropanol:ethanol (50: 50) with varied concentration of NaOH of 5%, 10%, 15%, 20%, 25%, respectively. Synthesized CMC was characterized by an organoleptic test, pH, infrared analysis, and degree of substitution (DS).

RESULTS: The result showed that characteristics of synthesized CMC were different from one another. The organoleptic test showed that synthesized CMC uses isopropanol: isobutanol (30: 70) was coarse powder, odourless and tasteless, ivory until burlywood along with increasing NaOH concentration; while the synthesized CMC with isopropanol: ethanol (50: 50) was a colourless, odourless, tasteless and fine powder. The pH of synthesized CMC was neutral. Infrared profile of synthesized CMC indicated the existence of carboxyl functional groups in 1600-1640 cm^{-1} region. The degree of substitution value of formula II-5, II-10, II-15, II-20, II-25, IE-5, IE-10, IE-15, IE-20, and IE-25 were 0.885;0.757; 0.685; 0.592; 0.575; 0.611; 0.906; 0.603; 0.671; 0.751, respectively.

CONCLUSION: Characteristics of CMC vary depending on the type of solvent mixture and NaOH concentrations used in synthesis. The more polarity of a solvent mixture the more colourless and higher DS value of synthesized CMC. On the other hand, the more alkali concentration in synthesis CMC the more colour and higher DS value was acquired.

Introduction

Carboxymethyl cellulose (CMC) is an anionic molecule that can prevent the deposition of proteins at the isoelectric point and increase the viscosity of food products, due to the joining of the carboxyl group CMC with a positive charge group of the protein [1].

Synthesis of CMC is affected by several factors, including alkalization and carboxymethylation. The alkalization stage was carried out using reaction media (solvents) and NaOH with the aim of activating hydroxyl groups of cellulose which subsequently functioned as swelling agent [2]. The amount of alkali and solvent mixture will affect the number of dissolved monochloroacetic salt so that in large amounts it will facilitate and accelerate the diffusion of monochloroacetic salts to react with the hydroxyl group of cellulose. The reagent composition of alkalization and carboxymethylation in CMC synthesis greatly determines the quality of synthesized CMC [3].

The use of CMC is not only limited to the pharmaceutical industry, but also in the food, cosmetics and textile industries [4]. CMC circulating in

Indonesia has different qualities and still imported from overseas, such as China and India. CMC synthesis is simple, efficient and low cost. It includes alkalization and carboxymethylation reactions. One of the main factors in CMC synthesis is the alkalization process. Alkalization is carried out using NaOH to activate OH groups on cellulose molecules and function as developers, while carboxymethylation is accomplished by adding sodium monochloroacetate [5], [6].

These processes influence the resulting CMC quality. Quality of CMC can be seen from a value of the degree of substitution, viscosity, pH as a product characteristic. Substitution degree values can be obtained from infrared spectra of each synthesized CMC. The higher the DS value, the better quality of the CMC. This study was conducted to determine the characteristics of synthesized CMC using a mixture of solvents and different concentrations of NaOH. Characterization of CMC is carried out by determining the value of the degree of substitution, functional group, organoleptic (colour) and pH.

Material and Methods

The materials in the study were microcrystalline cellulose commercial (Avicel®), distilled water, isopropanol, isobutanol, ethanol 96%, sodium hydroxide (NaOH), sodium mono chloroacetate (SMCA), methanol 96%, glacial acetic acid (Smart-Lab.). The instrument used in this research were pH meter Hanna and FT-IR Shimadzu Spectrophotometer.

The synthesis was carried out using a solvent mixture, namely isobutanol-isopropanol and isopropanol-ethanol with the addition of NaOH concentration of 5%, 10%, 15%, 20%, 25% respectively. Five grams of microcrystalline cellulose added 100 ml of solvent mixture. Then 20 ml of NaOH solution with varying concentrations was added for 1 hour while stirring at 25°C. After completing the carboxymethylation process, added 4 grams of sodium monochloroacetate while stirring in 3 hours at 55°C. It was filtered and the residue soaked for 24 hours by 100 ml of methanol. It was neutralized using a solution of glacial acetic acid, then filtered and the residue was dried in an oven at 60°C. The formula of synthesis can be seen in Table 1.

Table 1: The formula of Sodium CMC synthesis

Formula	Solvent mixture	NaOH	SMCA
II-5	Isopropanol: Isobutanol (30: 70)	5%	4 grams
II-10		10%	
II-15		15%	
II-20		20%	
II-25		25%	
IE-5	Isopropanol:ethanol (50: 50)	5%	
IE-10		10%	
IE-15		15%	
IE-20		20%	
IE-25		25%	

The all of synthesized CMC was tested in an organoleptic test, including colour, taste, odour, texture and pH measurement. 0,25 grams synthesized CMC was dissolved in 25 ml distilled water and heated at 70°C while stirring. The solution was cooled and measured at room temperature [6].

The functional group of the synthesized CMC at different solvent mixture and various NaOH concentrations were characterized by FTIR. About 0,3 mg of dry sample was mixed with 3 mg KBr and ground homogeneously. The mixture was compressed and analysed by FT-IR Shimadzu between 400-4000 cm^{-1}.

The degree of substitution was determined by comparing the absorbance of the carboxyl group and methine of infrared spectra of each sample ($R_{relative} = A_{carboxyl\ group} / A_{methine\ group}$). DS relative was computed by equation [7]:

$$DS_{relative} = R_{relative\ (CMC)} - R_{relative\ (microcrystalline\ cellulose)}$$

Results

Each of synthesized sodium CMC had different characteristics. Characterization of sodium CMC consisted of an organoleptic test, pH measurement, analysis of infrared spectrophotometry, and determination of the degree of substitution. The all of the synthesized sodium CMC was tested in an organoleptic test, including colour, taste, odour and texture. The organoleptic characteristic of synthesized sodium CMC can be seen in Table 2. Table 2 indicates that the synthesized sodium CMC has a variety of colour and texture, while odourless as well as tasteless.

Table 2: Organoleptic characteristic of synthesized Sodium CMC

Formula	Colour	Odour	Texture	Taste
II-5	White	O	Coarse powder	T
II-10	Ivory	D	Coarse powder	A
II-15	Wheat	O	Coarse powder	S
II-20	Burlywood	U	Lump hard	T
II-25	Burlywood	R	Lump hard	E
IE-5	White	L	Fine powder	L
IE-10	White	E	Fine powder	E
IE-15	Ivory	S	Fine powder	S
IE-20	Ivory	S	Coarse powder	S
IE-25	Ivory		Coarse powder	

The next characteristics were pH measurement. The all of the synthesized sodium CMC showed the pH was between 6.8-7.2. The pH of synthesized sodium CMC can be seen in Table 3. It indicates the synthesized sodium CMC was neutral and had similar quality with the commercial CMC.

The functional groups of synthesized sodium CMC were also determined by Fourier Transform Infrared to ensure carboxymethylation had been formed. The infrared spectrum of synthesized sodium

CMC was shown in Table 4.

Table 3: The pH of synthesized sodium CMC

Formula	pH
II-5	7.1
II-10	7.3
II-15	6.9
II-20	6.8
II-25	7.1
IE-5	6.9
IE-10	7.2
IE-15	7.1
IE-20	7.1
IE-25	7.2

The broad spectrum at 3000-3600 cm^{-1} is due to O-H stretching. The peak at wavenumber 2900-2800 cm^{-1} indicates -CH aliphatic. The wavenumber 1000-1200 cm^{-1} demonstrates -O- stretching. The peaks at a wavenumber of 1600 and 1400 cm^{-1} with strong absorption shows of the presence of substituent of carboxymethyl. This result explained that carboxymethylation had been substituted on microcrystalline cellulose molecules as well as commercial CMC. Infrared spectrum gave other information that used to determine the degree of substitution value.

Table 4: Wavenumber of Infrared Spectrum of Synthesized Sodium CMC

Functional Group	Wavenumber (cm^{-1})									
	II-5	II-10	II-15	II-20	II-25	IE-5	IE-10	IE-15	IE-20	IE-25
OH	3344.57	3421.72	3398.57	3421.72	3421.72	3406.09	3421.72	3421.72	3417.86	3398.57
-CH alifatic	2897.08	2916,37	2897.08	2931.80	2935.66	2889.37	2927.94	2881.65	2893.22	2931.80
COO-	1600.92	1600.92	1600.92	1589.34	1570.06	1600.92	1600.92	1600.92	1597.06	1589.34
$-CH_2$	1415.75	1415.75	1415.75	1415.75	1415.75	1419.61	1415.75	1415.75	1415.75	1415.75
CO-	1056.99	1060,85	1060.85	1060.85	1060.85	1049.28	1056,99	1060.85	1056.99	1060.85

The degree of substitution value was calculated based on comparing of carboxyl group and methine absorbance of each synthesized sodium CMC. The DS value of the degree of substitution can be seen in Table 5. It describes the different degree of substitution of sodium CMC. The maximum DS was obtained from the IE-10 formula using solvent isopropanol: ethanol (50: 50) with a NaOH concentration of 10%.

Table 5: Degree of substitution value of CMC synthesized

Formula	DS
II-5	0.882
II-10	0.757
II-15	0.685
II-20	0.592
II-25	0,575
IE-5	0.611
IE-10	0.906
IE-15	0.603
IE-20	0.671
IE-25	0,751

Discussion

Characteristics of Sodium CMC were obtained from synthesis depend on the type of mixed solvent, and the concentration of alkali used. Organoleptic observation, especially regarding product colour, is one of the visual profiles that becomes the first impression on consumers in assessing a product [1]. Synthesis of CMC products had differences and changes in colour along with the addition of NaOH. The tone of the products was produced tend to be yellowish or brownish along with the higher concentration of NaOH. The colour change that occurs is due to the influence of the intrinsic colour of the NaOH solution and the presence of a competitive reaction to produce CMC and the reaction results in addition to sodium glycolate [8].

The infrared spectrum of synthesized sodium CMC with a variation of solvent mixture and NaOH concentration gave differing in spectrum absorbance between one another. Each infrared spectrum of synthesis formulas showed peak sharpness variations and experienced a slight shift in wave number for carboxyl groups. According to Adinugraha et al., [9], carboxyl groups in salts form have peaked about 1600-1640 cm^{-1} and 1400-1450 cm^{-1}. It demonstrates that synthesized sodium CMC has the same functional groups with the commercial NaCMC.

One of the critical characteristics of sodium CMC was a degree of substitution (DS). The highest value of the degree of substitution was acquired in a mixture solvent of isopropanol: ethanol (50: 50) was 0.91 compared with a solvent mixture of isopropanol: isobutanol (30: 70). The mixed solvent ratio that used would affect the ability of SMCA to form carboxymethylation and the higher level of a polarity of the solvent, the higher the ability of SMCA to penetrate the cellulose structure.

The degree of substitution (DS) also strongly dependent on NaOH concentration. The rigid crystalline structure of microcrystalline cellulose is difficult to disrupt to ensure penetration of the monochloroacetic acid at lower levels of NaOH into the interlocking polymer chains resulting in a lesser degree of substitution. Higher DS was obtained using 10% NaOH concentration. According to Pushpamalar et al., [10] the influence of NaOH with various levels that DS from CMC has increased along with the increase in NaOH concentration, but at too high a concentration of NaOH will cause DS values to decrease. The event occurred because of two ongoing and competitive reactions. The first reaction involves the hydroxyl group of cellulose with SMCA in the presence of NaOH to form CMC molecules. The second reaction occurs between NaOH and SMCA which can form sodium glycolate [11]. It could be interpreted that the presence of too high NaOH concentration will cause the excessive formation of sodium glycolate due to side reactions between NaOH and SMCA.

NaOH solutions that exceed the critical limit can destroy the shape of natural cellulose crystals to turn into an amorphous form which will make the amorphous structure re-oriented and combine to form

another crystalline structure. This process will cause the cellulose structure to be denser and difficult to penetrate by chemical reagents [12]. Amorphous form can improve the performance of the carboxymethylation process. On the other hand, below the value of the critical concentration of NaOH, the increasing concentration facilitates the conversion of the amorphous form. However, if the concentration of NaOH is shallow, it is not enough to destroy the crystal structure so that the carboxymethylation process does not run well.

The solvent mixture and NaOH concentration were used in synthesis affect the characteristics of sodium CMC. The more polarity of solvent mixture that used in synthesis sodium CMC the more colourless and higher DS value of synthesized CMC. The more alkali concentration, the more colour and a higher DS value of synthesized CMC were acquired. On the other hand, DS value was linearly correlated to the polarity of solvent mixture and alkali concentration. It is concluded that the quality of CMC as an excipient in the pharmaceutical industry can be affected by the solvent mixture and alkali concentration.

References

1. Nisa D, Putri WDR. Cellulose Utilization in Cacao Pod Husk (Theobroma cacao L.) as Raw Material for CMC (carboxymethyl cellulose) Synthesis. Jurnal Pangan dan Agroindustri. 2013; 2(3):34-42.

2. Nur'ain N, Nurhaeni N, Ridhay A. Optimization of Reaction to the Synthesis of Carboxymethyl Cellulose (CMC) from Corn Stalk (Zea mays L.). KOVALEN. 2017; 3(2):112. https://doi.org/10.22487/j24775398.2017.v3.i2.8717

3. Wijayani A, Ummah K, Tjahjani S. Characterization of carboxy methyl cellulose (CMC) from Eichornia crassipes (Mart) Solms. Indonesian Journal of Chemistry. 2010; 5(3):228-31. https://doi.org/10.22146/ijc.21795

4. Shui T, Feng S, Chen G, Li A, Yuan Z, Shui H, et al. Synthesis of sodium carboxymethyl cellulose using bleached crude cellulose fractionated from cornstalk. Biomass and Bioenergy. 2017; 105:51-8. https://doi.org/10.1016/j.biombioe.2017.06.016

5. Futeri R. Synthesis Carboxyl Methyl Cellulose (CMC) with Addition Method from Durian Seed. Scholar Research Library. Der Pharmacia Lettre. 2016; 8(19):262-268.

6. Mulyatno HA, Pratama OI, Inayati I. Synthesis of carboxymethyl cellulose (CMC) from banana tree stem: influence of the ratio of cellulose with sodium chloroacetate to properties of carboxymethyl cellulose. EQUILIBRIUM. Journal of Chemical Engineering. 2017; 16 (2).

7. Singh RK, Khatri OP. A scanning electron microscope based new method for determining degree of substitution of sodium carboxymethyl cellulose. Journal of Microscopy. 2011; 246(1):43-52. https://doi.org/10.1111/j.1365-2818.2011.03583.x PMid:22150298

8. Alizadeh Asl S, Mousavi M, Labbafi M. Synthesis and Characterization of Carboxymethyl Cellulose from Sugarcane Bagasse. Journal of Food Processing & Technology. 2017; 08(08). https://doi.org/10.4172/2157-7110.1000687

9. Adinugraha MP, Marseno DW, Haryadi. Synthesis and characterization of sodium carboxymethylcellulose from cavendish banana pseudo stem (Musa cavendishii LAMBERT). Carbohydrate Polymers. 2005; 62(2):164-9. https://doi.org/10.1016/j.carbpol.2005.07.019

10. Pushpamalar V, Langford SJ, Ahmad M, Lim YY. Optimization of reaction conditions for preparing carboxymethyl cellulose from sago waste. Carbohydrate Polymers. 2006; 64(2):312-8. https://doi.org/10.1016/j.carbpol.2005.12.003

11. Zhao H, Cheng F, Li G, Zhang J. Optimization of a process for carboxymethyl cellulose (CMC) preparation in mixed solvents. International Journal of Polymeric Materials. 2003; 52(9):749-59. https://doi.org/10.1080/713743713

12. Zhang J, Li D, Zhang X, Shi Y. Solvent effect on carboxymethylation of cellulose. Journal of Applied Polymer Science. 1993; 49(4):741-6. https://doi.org/10.1002/app.1993.070490420