RESEARCH ON SODIUM CARBOXYMETHYL CELLULOSE: ANALYSIS OF SELECTED PHYSICAL PROPERTIES

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ИССЛЕДОВАНИЕ КАРБОКСИМЕТИЛЦЕЛЛЮЛОЗЫ НАТРИЯ: АНАЛИЗ ОТДЕЛЬНЫХ ФИЗИЧЕСКИХ СВОЙСТВ.

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ABSTRACT

This article presents information about cellulose, as well as one of its most important derivatives — sodium carboxymethyl cellulose — and some of its properties. In addition, Na-CMC solutions with concentrations of 0.01, 0.02, 0.03, 0.04, and 0.05 M were prepared, then diluted, and the pH levels of these solutions were also determined. Using the spectrophotometry method, the physical properties of Na-CMC at various concentrations were studied.

АННОТАЦИЯ

В данной статье представлена информация о целлюлозе, а также об одном из её наиболее важных производных — карбоксиметилцеллюлозе натрия (КМЦ-Na) и некоторых её свойствах. Были приготовлены растворы КМЦ-Na с концентрациями 0,01, 0,02, 0,03, 0,04 и 0,05 М, после чего они были разбавлены, и была определена их pH-среда. С помощью метода спектрофотометрии были изучены физические свойства КМЦ-Na при различных концентрациях.

Keywords: Cellulose, sodium carboxymethyl cellulose, spectrophotometry, spectrophotometer, degradation,

Ключевые слова: Целлюлоза, натрийкарбоксиметилцеллюлоза, спектрофотометрия, спектрофотометр, деградация

1. Introduction. Carboxymethyl cellulose (CMC) is a carboxymethyl derivative of cellulose, and its sodium salt (Na-CMC) is a water-soluble compound [1, 2]. Due to its excellent properties such as thickening, emulsifying, film-forming, and moisture retention, Na-CMC is widely used in the food industry, construction, medicine, biomedicine, household chemicals, textile, and paper production sectors [3–7]. Cellulose is a naturally abundant polymer known since ancient times. It is used in many branches of the national economy. Under various conditions, cellulose undergoes chemical reactions to form simple and complex esters that exhibit valuable physicochemical and operational properties.

Carboxymethyl cellulose, the carboxymethylated ether of cellulose, is a simple ether of cellulose and glycolic acid. It is produced in the form of its sodium salt (Na-CMC) through the interaction of alkaline cellulose with monochloroacetic acid or its sodium salt (MCA).

$$[C_6H_7O_2(OH)_3 * xNaOH]n + nx\ ClCH_2COONa \longrightarrow$$

$$\longrightarrow [C_6H_7O_2(OH)_{3}\text{-}x(OCH_2COONa)_x]n + nxNaCl + nx\ H_2O$$

The most common derivative of carboxymethyl cellulose is sodium carboxymethyl cellulose (Na-CMC). Sodium carboxymethyl cellulose appears as a white fibrous or granular powder. It is odorless, hygroscopic, soluble in water, and insoluble in ethanol, ether, and trimethylmethane. Na-CMC is used as a thickening agent in the food industry, as a drug carrier in the pharmaceutical industry, and as a binder and anti-redeposition agent in the household chemical industry. In the petrochemical industry, it can be used as a component of fracturing fluids in oil recovery.

Na-CMC also exhibits adhesive, thickening, strengthening, emulsifying, water-retaining, and suspending properties. For experimental purposes, Na-CMC solutions of required concentrations are prepared by dissolving the powdered form in water. However, when preparing accurately concentrated Na-CMC solutions on an industrial scale, certain technical issues may arise. In such cases, the Na-CMC concentration of the pre-prepared solution is first determined, and then the desired concentration is achieved by adding either powder or water accordingly.

Na-CMC is soluble in water; however, it dissolves more readily in water heated to 40–50 °C, forming high-viscosity solutions that do not obey Newtonian fluid laws. Its viscosity depends on factors such as the polymer content in the solution, the degree of polymerization, temperature, the nature of the solvent, and the pH of the medium.

One of the key properties of Na-CMC is its ability to form highly viscous colloidal solutions that retain their viscosity over time. Research to date shows that the rheological properties of aqueous Na-CMC solutions depend not only on concentration, molecular structure, and molecular weight of the polymer but also on the degree of substitution [8].

In our study, we set out to investigate certain physicochemical properties of Na-CMC. Additionally, the pH environment of the prepared solutions was also determined.

2. Materials and methods

In this experimental study, sodium carboxymethyl cellulose (Na-CMC) was initially prepared in concentrations of 0.01, 0.02, 0.03, 0.04, and 0.05 M. These solutions were then diluted to obtain concentrations of 0.02, 0.04, 0.06, 0.08, and 0.1 mg/mL. Methylene blue was used and dissolved in deionized water.

Spectroscopic measurements were carried out using a UV-1800 model spectrophotometer manufactured by Shimadzu Corporation (Japan).

For the tests, 2 ml of each Na-CMC solution (0.02, 0.04, 0.06, 0.08, and 0.1 mg/mL) was mixed with 2 ml of methylene blue solution in separate beakers and stirred thoroughly. Color changes were then observed. Based on this, some of the properties of the solutions were studied using the spectrophotometric method.

To elaborate, spectrophotometry is a widely used method in various industries that allows for the quantitative measurement of the interaction between electromagnetic radiation and the studied material. A spectrophotometer is a high-tech device designed to measure the absorbance, transmittance, optical density, and concentration of substances through their spectral relationships under various electromagnetic wavelengths — primarily in the visible, infrared, and ultraviolet ranges. The most commonly used spectrophotometers operate in the ultraviolet and visible light spectra.

Aqueous and alkaline Na-CMC solutions are characterized by their high viscosity and non-Newtonian flow behavior [9]. Under the influence of diluted and concentrated acid or alkali solutions — both at room temperature and when heated — degradation occurs along the glycosidic bonds in the presence of oxygen To examine this behavior in Na-CMC, an aqueous solution was prepared and observed over a 10-day period at room temperature. A comparative study was conducted to determine the extent of degradation under two different conditions.

3. Results

Using the spectrophotometric method to determine the composition of Na-CMC, 10 drops of methylene blue were added to each solution, and changes in the solution were observed. The following pH values were recorded:

The pH values of Na-CMC solutions with different concentrations (as shown in Figure A) were as follows:

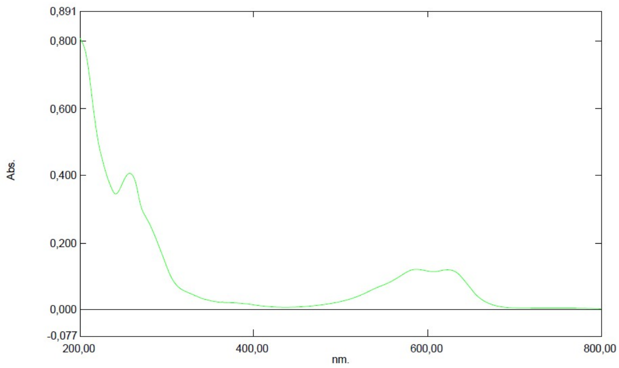
- 0.02 mg/mL solution: pH 7.81
- 0.04 mg/mL solution: pH 7.97
- 0.06 mg/mL solution: pH 8.04
- 0.08 mg/mL solution: pH 8.07
- 0.10 mg/mL solution: pH 8.11

a) 

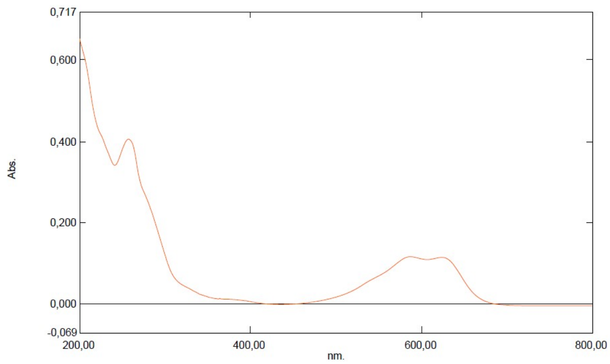
b) 

Figure 1. a) Solutions of Na-CMC with concentrations of 0.02, 0.04, 0.06, 0.08, and 0.1 mg/ml (respectively) b) Color change observed in the 0.02, 0.04, 0.06, 0.08, and 0.1 mg/ml Na-CMC solutions upon the addition of methylene blue

In **Figure B**, the results obtained from determining the composition of Na-CMC using the spectrophotometric method — after adding 10 drops of methylene blue and observing the changes in the solution — are presented as follows:



1.



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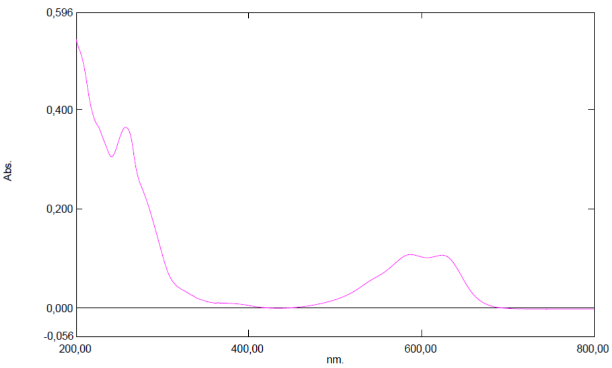

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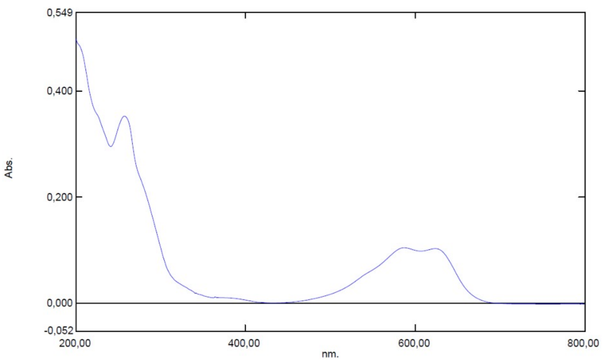

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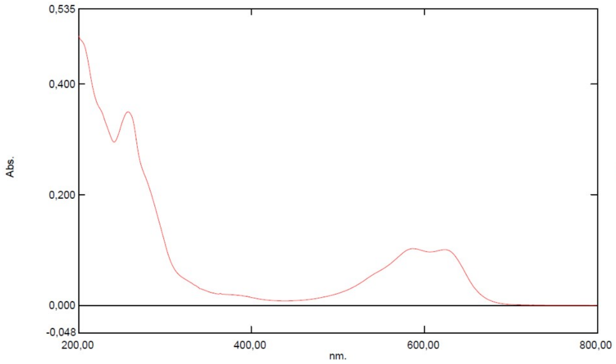

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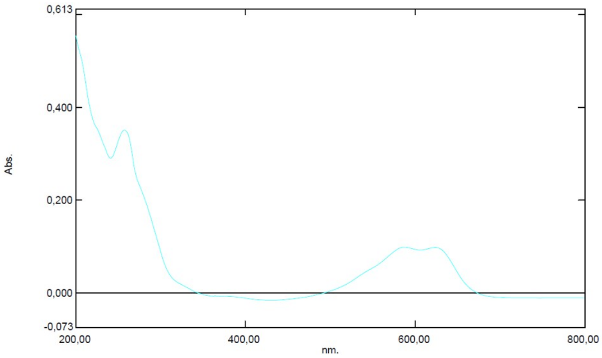

6.

Figure 2. Results

As mentioned above, when Na-CMC samples dissolved in two different solvents were observed, the following conditions were noted. In the first sample, under open surface conditions, and in the second sample, under vacuum conditions, the first sample underwent changes over 10 days and experienced degradation.

Figure 3. Na-CMC sample degraded under open-air conditions

In the second sample, no changes were observed. However, when the second sample was heated in a dry air oven, degradation occurred.

4. Discussion. In the first figure above, when the spectrophotometric analysis of water was performed, an absorption value of 0.118 was recorded at a wavelength of 597 nm. Following this, the spectra of Na-CMC solutions at various concentrations mixed with methylene blue solutions are presented. The absorption values at 597 nm are shown in the spectral analysis results of Figure 2. For the 0.02 mg/mL solution, the value was 0.13; for the 0.04 mg/mL solution, it was 0.109; for the 0.06 mg/mL solution, it was 0.104; for the 0.08 mg/mL solution, it was 0.1; and for the 0.1 mg/mL solution, it was 0.096. As can be seen, the absorption of methylene blue at 597 nm sharply decreased as the Na-CMC concentration increased.

Thus, the absorption level at 597 nm or the maximum absorption wavelength shift of MB is related to the Na-CMC concentration, and based on this, a mathematical relationship can be established between these parameters.

Table 1.

Values

№	Wavelenght {nm}	Concentration {mg/ml}	Absorbtion
1	597	0,00	0,118
2		0,02	0,113
3		0,04	0,109
4		0,06	0,104
5		0,08	0,1
6		0,10	0,096

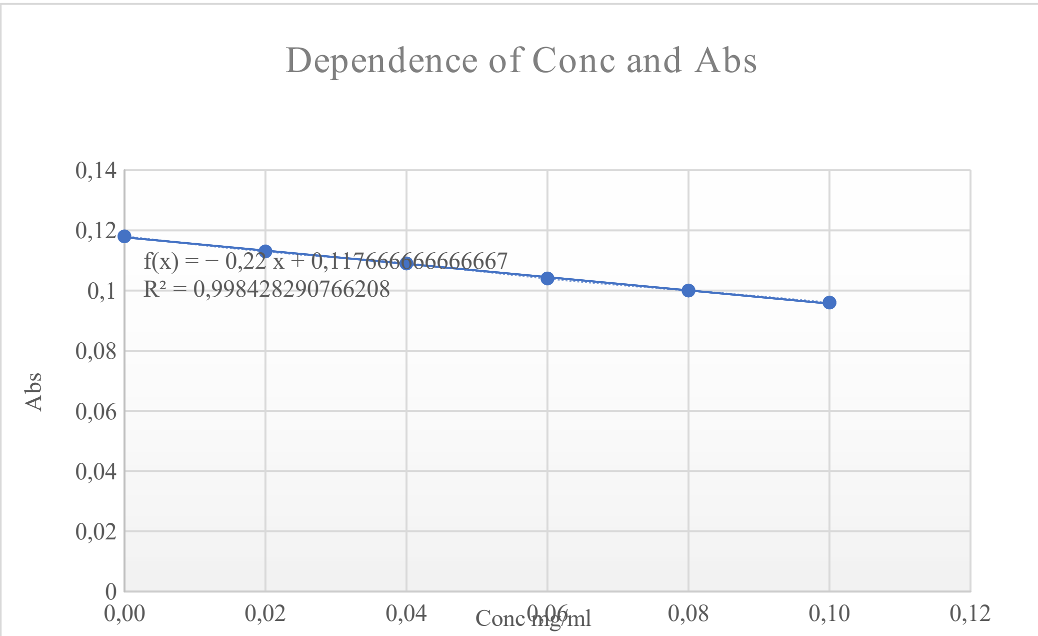

Figure 4. Diagram of the Adsorption Dependency of Na-CMC

5. Conclusions

A spectroscopic method based on methylene blue as an indicator has been developed to determine the concentration of Na-CMC in aqueous solutions. The results show that this method provides good accuracy and sensitivity for analyzing Na-CMC concentrations. The analysis results indicate that, when Na-CMC aqueous solutions are tested using the UV-1800 spectrophotometer, the absorption value decreases as the concentration of Na-CMC in the solution increases. Since spectroscopic measurements can be quickly performed, this method is considered suitable for process control in industrial settings.

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