

Short communication

Determination of cationic surfactants as the preservatives in an oral solution and a cosmetic product by capillary electrophoresis

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Abstract

In this study, a capillary electrophoresis method was developed for the determination of cationic surfactants, benzethonium and cetylpyridinium ions, which are commonly used as preservatives in various pharmaceutical and cosmetic products. Determination was performed in a fused-silica capillary using a mixed 75 mmol/L phosphoric acid and 50% acetonitrile electrolyte at pH 2.5. Analysis of benzethonium and cetylpyridinium ions was achieved in around 5 min. Repeatability in migration times (R.S.D.%) for benzethonium and cetylpyridinium ions were 0.3. The calibration curves were linear from 0.0125 to 0.400 mmol/L for benzethonium ions and from 0.025 to 0.400 mmol/L for cetylpyridinium ions. The minimum detection limits (signal-to-noise ratio = 3) are 1.47 and 4.30 $\mu\text{g/mL}$ for benzethonium and cetylpyridinium ions, respectively. The method was applied to the analysis of benzethonium ion in a cosmetic product and cetylpyridinium ion in a mouthwash. © 2004 Elsevier B.V. All rights reserved.

Keywords: Capillary electrophoresis; Cationic surfactant; Benzethonium; Cetylpyridinium

1. Introduction

Cationic surfactants composed of quaternary ammonium groups are extensively used as preservatives or antiseptic agents in industrial and commercial products. Due to their ability to stabilize emulsions and their antibacterial properties, surfactants used widely in cosmetics, hygiene products and some drugs are ingested by the human body. Although many surfactants are used interchangeably for the above purposes, their individual effects on health are different. Consequently, it is important to separate and individually analyze different surfactants. The common method to identify cationic surfactants is HPLC. More recently, capillary electrophoresis (CE) has been employed for the analysis of cationic surfactants [1–8]. The advantage of the CE methods is the considerable diminution in the sample preparation and analysis times, as well as in the reagent consumption. CE is particularly suitable in the analysis of complex matrices, owing to its higher resolving power. However, there are some

difficulties in the analysis of cationic surfactants with CE due to strong adsorption of the cationic species on the surface of silica capillary and micelle formation of the most cationic surfactants at low concentrations. These phenomena cause to insufficient resolution, peak tailing and irreproducible migration times. The addition of a high amount of organic modifier in background electrolyte reduces the above-mentioned phenomena, resulting in successful separation and determination of cationic surfactants [1,3]. Moreover, a low pH of the background electrolyte prevents adsorption of the analytes on the capillary surface, since the dissociation of the silanol groups on the capillary surface is decreased at the low pH.

The quaternary ammonium ions benzethonium (BZ) and cetylpyridinium (CP) are widely used as antimicrobial agents in the pharmaceutical preparations and cosmetics products. Two electrophoretic studies have been developed for the determination of CP in throat sprays, mouthwash, and candy-based lozenges [6,8]. There has been no report, to our knowledge, of BZ determination by CE methods.

In this paper, we report a simple and rapid CE method for the simultaneous determination of BZ and CP ions with

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direct UV detection. The method was applied to the analysis of two commercial products.

2. Experimental

2.1. Apparatus

A commercial capillary electrophoresis injection system (Prince Technologies, Emmen, Netherlands) in combination with an on-column variable wavelength UV–vis detector (Lambda 1000, Bishoff, Leonberg, Germany) was used. Separations were performed in a 50 μm i.d. fused-silica capillary (Polymicro Technologies, Phoenix, AZ, USA) with total and effective lengths of 59.5 and 48.5 cm, respectively. Automated capillary rinsing; sample injection, and execution of the electrophoretic runs were controlled by personal computer. Data processing was carried out with a commercial CE software (Caesar 1995, Prince Technologies, Emmen, The Netherlands). A Metrohm 654 Digital pH Meter with combined pH glass electrode was used for pH measurements.

2.2. Reagents

Benzethonium chloride, cetylpyridinium bromide and acetonitrile (MeCN) were purchased from Fluka (Buchs, Switzerland). Phosphoric acid was from Merck (Darmstadt, Germany). Other chemicals were of analytical grade. The cosmetic powder and the mouthwash samples were purchased from the local markets.

2.3. Procedure

Stock standard solutions of 10 mmol/L of BZ and CP ions were separately prepared in deionized water obtained from an Elgacan C114 filtration system. Calibration solutions were prepared by appropriate dilutions of these stock solutions so that the final solution contains 50% (v/v) MeCN. The addition of MeCN to the sample improves the peak shapes. The preliminary experiments showed that the powder sample contains only BZ and the mouthwash contains only CP. For the quantitative determination of surfactants, the proceeding procedure was followed.

Powder sample (1 g) was weighed. After the addition of 50 mL of deionized water, the solution was shaken for 15 min and filtered from. An aliquot of this solution was then filtered through a 0.45 μm cellulose acetate filter disc. 0.96 mL of the solution was collected, 0.04 mL of the internal standard stock solution (here CP) was added and the solution was diluted to 2 mL with MeCN.

0.50 mL of the mouthwash sample was taken and 0.04 mL of the internal standard stock solution (BZ) was added and the solution was diluted to MeCN-water to 2 mL.

The separation buffer was prepared from phosphoric acid and the buffer pH was adjusted with NaOH. To prepare the running buffers, certain amount of MeCN (v/v) was added

to the buffer solutions. All solutions were filtered through a 0.45 mm membrane filter.

For the simultaneous determination of surfactants, the detection wavelength was set at 210 nm. At the beginning of each working day, the capillary was flushed with 1 mol/L NaOH, water, and the running buffer, for 10 min each. A washing step of 2 min with buffer between runs was applied. Sample injection was carried out with pressure 4×10^{-3} MPa for 6 s at the anodic side. The analysis voltage was 28 kV. The measurements were performed at 30 °C.

3. Results and discussion

Cationic surfactants are adsorbed on the capillary inner surface due to electrostatic interaction between the positively charged groups of surfactant molecules and the negatively charged silanol groups on the capillary inner surface. In order to reduce capillary wall charge, electrophoretic separation should be performed at low pH. Increasing ionic strength of the running electrolyte and the addition of organic solvent also decrease the wall adsorption. Phosphoric acid was chosen as buffer in order to obtain a low pH buffer value. MeCN was added to the buffer as the organic solvent. In order to establish suitable conditions for good peak resolution and migration time, different MeCN ratios, phosphoric acid concentration, and pH were tested. Good peak resolution and shape of cationic surfactants were obtained using 75 mmol/L phosphoric acid and 50% MeCN as the running buffer at pH 2.5. The separation and determinations of CP and BZ were performed under these conditions. Fig. 1 shows the optimum separation electropherogram of the standard solution. Here, the sample solution contains 50% MeCN. Detection was accomplished at 210 nm. Under the optimized condition, the adequate peak resolution and sensitivities have been provided. The separation is fast; cationic surfactants migrate within 5 min. As the real samples we used contain only one of the surfactants, each surfactant was used as an internal standard for the other.

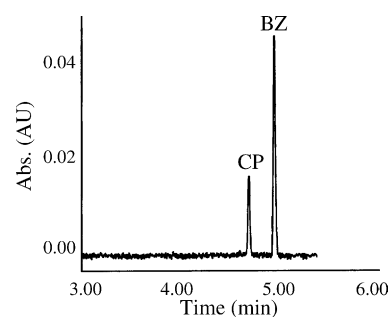


Fig. 1. Electropherogram of a standard mixture of surfactants. Background electrolyte: 75 mmol/L phosphate and 50% MeCN at pH 2.5. Injection, 4×10^{-4} MPa, 6 s; concentrations of surfactants are 0.2 mmol/L; voltage, 28 kV.

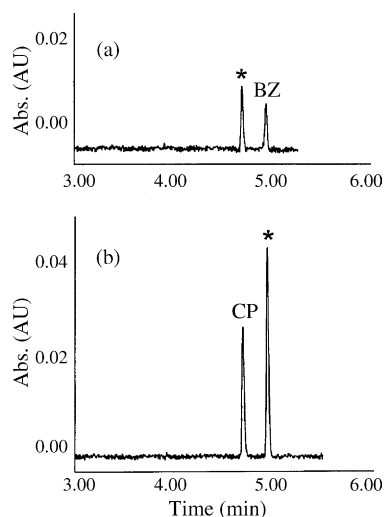


Fig. 2. Electropherogram of the samples. (*) Shows the peak of internal standard. (a) A cosmetic powder sample and (b) a mouthwash sample.

Table 1
Linearity and limit of detection values of BZ and CP

Surfactant	Regression equation	Correlation coefficient	LOD ($\mu\text{g/mL}$)
BZ	$y = 9.43810^{-4}x + 1.01710^{-5}$	0.9998	1.47
CP	$y = 3.12810^{-4}x + 2.17110^{-6}$	0.9995	4.30

A cosmetic powder and a mouthwash were analyzed using the optimized CE method. Sample solutions were prepared as described in the experimental section. Fig. 2a and b are presented electropherograms of the powder sample and the mouthwash sample, respectively. As seen from the electropherograms, peaks are seen clearly and there is not any unknown peak in this region.

3.1. Quantitative results

Linearity was checked by performing triplicate injections at five standard concentrations between 0.025 and 0.40 mmol/L for CP and 0.0125 and 0.40 mmol/L for BZ. The calibration curves were obtained using the least square regression method. The regression equations, coefficients of correlation, and LODs are shown in Table 1. Correlation coefficients for the linear fit are higher than 0.99. The LODs were calculated as the amount of compound that would still give a signal three times greater than the noise of the baseline. The quantitative amount of surfactants in the real samples were calculated based on the calibration curves and given in Table 1.

3.2. Repeatability

The repeatability of the method was tested by injecting a solution of commercial product successively seven times.

Table 2
Surfactant amount determined in samples and repeatability of the method for seven successive injections of samples

Surfactant	Surfactant amount found in the samples	%R.S.D. migration time	%R.S.D. peak area (A/t)
BZ	2275 mg/kg	0.3	3.6
CP	650 mg/L	0.3	3.3

Table 3
Recoveries of the sample

Added amount (mmol/L)	Recoveries for BZ (%)	Recoveries for CP (%)
0.025	102	101
0.05	101	102
0.1	98	98
0.2	100	102
0.4	100	99

The relative standard deviations (R.S.D.s) of migration times and relative areas (A/t) are given in Table 2. As seen in Table 2, the method exhibits a good repeatability.

3.3. Recoveries

To check the percent recovery, a standard solution of each surfactant at different concentration was added together with the internal standard solution to each cosmetic powder or mouthwash solution. Concentrations and recoveries are given in Table 3. The observed concentration values are in good agreement with the real contents. The method offers satisfactory accuracy.

4. Conclusion

A simple and rapid method for the simultaneous determination of cationic surfactants in the commercial samples has been proposed. The method does not require a pre-treatment process. Two surfactants can be simultaneously determined with a good resolution in the real samples. When the real sample does not contain one or other, each can be used as the internal standard.

We analyzed two commercial samples and found that the CE method is an accurate and reproducible technique for the determination of CP and BZ in the real samples. The main advantage of the fused-silica capillaries compared to packed columns are that sample extracts are directly injected without any purification step, easily washed between runs, and free of irreversible contamination of the matrix. The method promises to be applicable to the quality control of the products, containing cationic surfactants, since analysis time and cost are lower than with HPLC [9].

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