

1-1-1998

## Fourier Transform Infrared Spectrometric Determination of Benzyl Alcohol and Benzaldehyde(การวิเคราะห์หาปริมาณเบนซิลแอลกอฮอล์และเบนซาลดีไฮด์ ด้วย...)

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# Fourier Transform Infrared Spectrometric Determination of Benzyl Alcohol and Benzaldehyde

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## Abstract

Fourier transform infrared spectrometry (FTIR) was developed for the determination of benzyl alcohol and benzaldehyde. The method for quantification of benzyl alcohol is based on the second derivative FTIR measurement at  $1205.28\text{ cm}^{-1}$  which is the zero crossing of its major degradation product, benzaldehyde. A HPLC method was used as the reference method. The results obtained by the second derivative spectrometry were in good agreement with those found by the HPLC method. For the determination of benzaldehyde, direct measurement of the peak at  $1202\text{ cm}^{-1}$ , using the baseline established at  $1220\text{ cm}^{-1}$  for measurement correction was employed. The results obtained was in good agreement with the official method. The linear ranges were  $4.0\text{-}20.0\text{ mg ml}^{-1}$  and  $1.0\text{-}10.0\text{ mg ml}^{-1}$  for benzyl alcohol and benzaldehyde, respectively. Calibration graphs were linear with the correlation coefficients of 0.9999 for both analytes.

**Key words:** Fourier transform infrared spectrometry; benzyl alcohol; benzaldehyde; benzoic acid

## Introduction

Benzyl alcohol is an antimicrobial agent widely used as a preservative in pharmaceutical formulations. Benzyl alcohol is slowly oxidized to benzaldehyde and benzoic acid. The limit test for benzaldehyde in the USP (1) on benzyl alcohol is less than or equal to 0.2%. There are many different methods available for the determination of benzyl alcohol. According to the official methods, the USP and BP(2), the determination of benzyl alcohol involves the acetylation of benzyl alcohol with acetic anhydride in pyridine under reflux for 30 minutes and titrate the acid with 1 M sodium hydroxide VS using phenolphthalein as indicator, a blank determination was performed for calculation the volume of sodium hydroxide that is equivalent to benzyl alcohol. There have also been several reports using high performance liquid chromatography for benzyl alcohol determination (3-5).

Benzaldehyde is used as a flavoring agent in the place of volatile bitter almond oil. It is easily oxidized to benzoic acid. The USP and BP utilize a hydroxylamine

titrimetric method for the determination of benzaldehyde.

Fourier Transform Infrared Spectrometry (FTIR) has increased the importance as a method for the quantification of many compounds. The objective of this work was to demonstrate a simple, alternative FTIR technique with the ability to rapidly determine benzyl alcohol and benzaldehyde.

## Experimental

### *Materials and reagents*

Benzyl alcohol standard (Fluka guarantee) was obtained by Fluka (Switzerland). Benzaldehyde was bought from Sigma (St. Louis, MO, USA). All other reagents employed were of analytical-reagent grade.

### *Instrumentation*

A Perkin-Elmer (Norwalk, CT, USA) Model 1620 FTIR spectrometer, equipped with a deuterated triglycine sulfate (DTGS) detector, was employed to carry out the

absorbance measurements, with a resolution of  $4\text{ cm}^{-1}$ . The spectra were obtained using a demountable pathlength liquid sampling cell with  $\text{CaF}_2$  windows and  $0.1\text{ mm}$  polyethylene spacer. The spectra were collected with accumulating 20 scans. A single-beam spectrum of the empty cell was recorded as the background spectrum. Solvent subtraction, calculation of derivative spectrum, baseline correction and the measurement of absorbance were performed using Spectrum Lite software (Perkin-Elmer, Norwalk, CT, USA). For the determination of benzyl alcohol, five data points were used for each point calculation in the derivative spectrum.

#### Preparation of calibration solutions

All stock solutions were prepared by dissolving appropriate amounts of benzyl alcohol and benzaldehyde in  $\text{CCl}_4$ . Working standards were prepared by appropriate dilution of each stock solution to obtain the concentration ranges of  $4.0\text{--}20.0\text{ mg ml}^{-1}$  and  $1.0\text{--}10.0\text{ mg ml}^{-1}$  for the determination of benzyl alcohol and benzaldehyde, respectively.

#### Preparation of test samples

All test samples (single and mixed) were prepared by dissolving appropriate amounts of compounds in  $\text{CCl}_4$ .

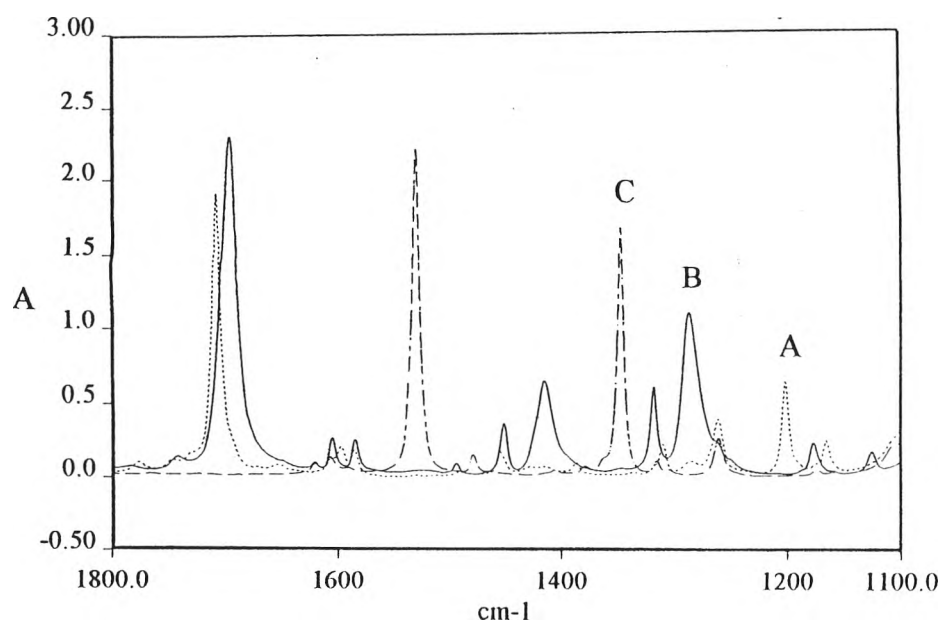
### Results and Discussion

For the determination of both benzyl alcohol and benzaldehyde,  $\text{CCl}_4$  shows absorption bands at the spectral

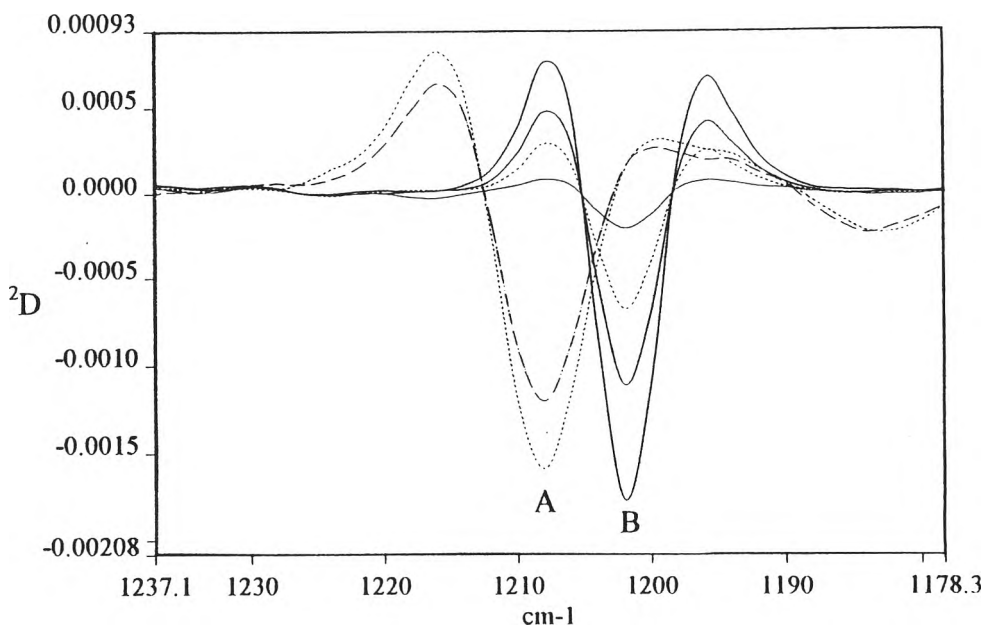
regions of interests. Thus, for quantitative work, the  $\text{CCl}_4$  spectrum was subtracted from the sample spectrum using a subtraction factor of 1.

#### Determination of benzyl alcohol

As shown in Fig.1, benzyl alcohol shows two sharp peaks from C=C ring stretch at  $1496$  and  $1454\text{ cm}^{-1}$ . The former band is overlapped with its minor degradation product, benzoic acid. The latter is overlapped with both benzoic acid and its major degradation product, benzaldehyde. Another interesting band of benzyl alcohol at  $1207\text{ cm}^{-1}$  which is the characteristic of O-H bending (6), possibly augmented by C-H in plane bending, is partially overlapped with the phenyl-C bond stretching band (7) of benzaldehyde which occurs at  $1202\text{ cm}^{-1}$ . The profiles of the first derivative spectra display considerable overlap with benzaldehyde. Second derivative spectrum, however, gives zero-crossing at  $1205.28\text{ cm}^{-1}$  of benzaldehyde as shown in Fig. 2. Using the zero-crossing measurement at this wavenumber allows the direct determination of benzyl alcohol in the presence of benzaldehyde. The amplitudes (peak to base measurement) at this wavenumber ( ${}^2D_{1205.28}$ ) exhibit good linear responses to the benzyl alcohol concentrations,  $4.0\text{--}20.0\text{ mg ml}^{-1}$ , with the correlation coefficients of 0.9999 (Table 1). The detection limit, obtained from the sensitivity of the calibration graph and for  $3s_b$  ( $s_b$  = standard deviation of a blank) was found to be  $1.05\text{ mg ml}^{-1}$ .



**Fig. 1.** Solvent subtracted absorbance spectra of A, benzyl alcohol ( $16\text{ mg ml}^{-1}$ ); B, benzaldehyde ( $2\text{ mg ml}^{-1}$ ), and C, benzoic acid ( $2\text{ mg ml}^{-1}$ ) in  $\text{CCl}_4$



**Fig. 2.** Solvent subtracted second-derivative spectra of A, benzyl alcohol (16 and 20 mg ml<sup>-1</sup>); and B, benzaldehyde (0.1, 0.3, 0.5, and 0.8 mg ml<sup>-1</sup>) in CCl<sub>4</sub>

**Table 1** Regression analysis of benzyl alcohol and benzaldehyde

Analyte	Range mg ml <sup>-1</sup>	Regression equation <sup>a</sup>	r <sup>c</sup>	sd <sup>b</sup>	
				Slope	Intercept
benzyl alcohol	4.0 - 20.0	${}^2D_{1205.28} = 1.13 \times 10^{-5} - 4.32 \times 10^{-5} C$	0.9999	$3.77 \times 10^{-7}$	$1.65 \times 10^{-5}$
benzaldehyde	1.0 - 10.0	$A_{1202} = -2.35 \times 10^{-4} + 3.16 \times 10^{-2} C$	0.9999	$7.70 \times 10^{-4}$	$5.88 \times 10^{-4}$

<sup>a</sup> Each calibration graph was obtained from 8 experimental points.

<sup>b</sup> Average of 5 determinations.

<sup>c</sup> Correlation coefficient.

In order to examine the interference effects of its degradation products, recovery experiments were carried out on the solutions containing 8.0 mg ml<sup>-1</sup> of benzyl alcohol in the presence of 5-25 % of benzaldehyde and benzoic acid. The good recoveries obtained, as shown in Table 2, indicate that both benzaldehyde and benzoic acid do not cause interferences. In addition, the standard deviations for five determinations are satisfactorily low indicating the good reproducibility of the proposed method.

To test the accuracy of the second-derivative FTIR method for the analysis of real sample, the HPLC method described by Di Pietra et al. (3) was used as the reference method. The comparison of the proposed method and the reference method was summarized in Table 3. The calculated t- and F-test values did not exceed the theoretical values at the 95% confidence level, indicating the good agreement of the proposed method with that of the HPLC method.

**Table 2** Compositions and recoveries for artificial mixtures of benzyl alcohol and its degradation products

Benzyl alcohol mg ml <sup>-1</sup>	Benzaldehyde		Benzoic acid	
	Added %	Recovery % ±sd <sup>a</sup>	Added %	Recovery % ±sd <sup>a</sup>
8.0	5.0	99.42 ± 0.31	5.0	99.89 ± 0.24
8.0	10.0	98.07 ± 0.69	10.0	98.72 ± 1.23
8.0	15.0	97.95 ± 0.80	15.0	98.59 ± 0.95
8.0	20.0	98.17 ± 0.66	20.0	98.17 ± 0.66
8.0	25.0	98.74 ± 0.31	25.0	98.74 ± 0.31

<sup>a</sup> Values indicated are the recoveries (%) of benzyl alcohol, average of five determinations ( the corresponding standard deviation).

**Table 3** Comparison of second-derivative FTIR and HPLC values for the determination of benzyl alcohol

Benzyl alcohol	Recovery % ±sd <sup>a</sup>	
	HPLC	FT-IR
Brand I	99.63 ± 0.36	99.55 ± 0.59
	t = 0.25	(2.31) <sup>b</sup>
	F = 1.09	(6.39) <sup>b</sup>
Brand II	100.60 ± 0.67	100.12 ± 0.80
	t = 1.02	
	F = 0.36	

<sup>a</sup> Values indicated are the average of five determinations ± the corresponding standard deviation.

<sup>b</sup> Values in parentheses are the theoretical values at p = 0.95.

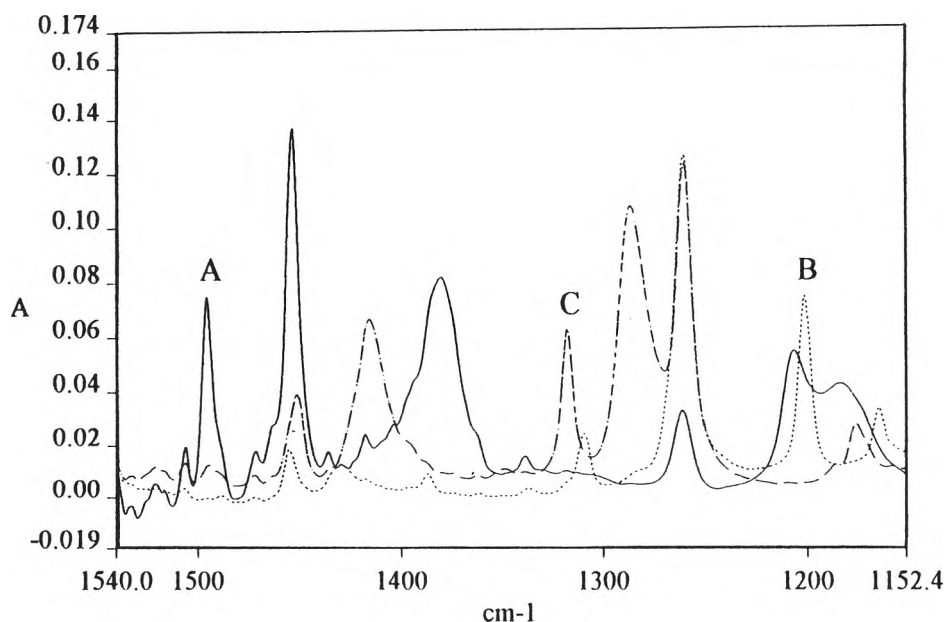
### Determination of benzaldehyde

For the determination of benzaldehyde the carbonyl band of benzaldehyde at 1708 cm<sup>-1</sup> is very sensitive, however, it is overlapped with that of benzoic acid as seen in Fig. 3. The phenyl-C band at 1202 cm<sup>-1</sup> of benzaldehyde is free from overlapped with benzoic acid or its common interference, nitrobenzene (Fig. 3). Quantification analysis of benzaldehyde is therefore carried out by direct measuring the absorbances at 1202 cm<sup>-1</sup>, and using the baseline established at 1220 cm<sup>-1</sup> for measurement correction.

Under the above-mentioned method, the linear correlation with high value of correlation coefficient (0.9999) was obtained at the concentration range of 1.0-10.0 mg ml<sup>-1</sup>, the detection limit was found to be 0.01 mg ml<sup>-1</sup> (Table 1).

The interference effect of benzoic acid was investigated by adding various amounts of benzoic acid into the fixed concentration of benzaldehyde (4.0 mg ml<sup>-1</sup>) and analyzing these mixtures with the proposed method. The results obtained (Table 4) indicate that benzoic acid as high as 200% of benzaldehyde does not interfere with the direct FTIR determination of benzaldehyde. The low standard deviations verify the good reproducibility of the described method.

The official method, hydroxylamine titration, was used as the reference method for the determination of benzaldehyde. As shown in Table 5, the calculated t- and F-test values did not exceed the theoretical values at the 95% confidence level, indicating the good agreement of the FTIR method with that of the official method.



**Fig. 3.** Solvent subtracted absorbance spectra of A, benzaldehyde (20 mg ml<sup>-1</sup>); B, benzoic acid (20 mg ml<sup>-1</sup>); and C, nitrobenzene (20 mg ml<sup>-1</sup>) in CCl<sub>4</sub>.

**Table 4** Comparisons and recoveries for artificial mixtures of benzaldehyde and benzoic acid

Benzaldehyde mg ml <sup>-1</sup>	Benzoic acid Added %	Recovery % ± sd <sup>a</sup>
4.0	50.0	97.48 ± 0.26
4.0	100.0	97.89 ± 0.42
4.0	200.0	98.38 ± 0.25

<sup>a</sup> Values indicated are the recoveries (%) of benzaldehyde, average of three determinations ± the corresponding standard deviation.

**Table 5** Comparison of FTIR and the official method (hydroxylamine titrimetric method) for the determination of benzaldehyde

Benzaldehyde	Recovery % ± sd <sup>a</sup>	
	FT-IR	Official method
Brand I	99.69 ± 0.86 t = 1.43 F = 2.55	99.08 ± 0.44 (2.31) <sup>c</sup> (6.39) <sup>c</sup>
Brand II <sup>a</sup>	84.48 ± 0.98 t = 0.71 F = 3.08	84.14 ± 0.45

<sup>a</sup> Brand II is the old benzaldehyde sample.

<sup>b</sup> Values indicated are the average of five determinations ( the corresponding standard deviation.

<sup>c</sup> Values in parentheses are the theoretical values at p = 0.95.

## Conclusions

The described FTIR methods permit the accurate determinations of benzyl alcohol and benzaldehyde without the interferences from their degradation products. The proposed methods have a potential for application in quality control laboratories for analysis of benzyl alcohol and benzaldehyde samples as they are simple, rapid and show good accuracy and precision.

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## การวิเคราะห์หาปริมาณเบนซิลแอลกอฮอล์และเบนซาลดีไฮด์ ด้วยเทคนิคฟูเรียร์ทรานสฟอร์ม อินฟราเรดสเปคโตรเมตรี

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**บทคัดย่อ :** เทคนิคฟูเรียร์ทรานสฟอร์มอินฟราเรดสเปคโตรเมตรี (FTIR) ได้นำมาใช้สำหรับพัฒนาการวิเคราะห์หาปริมาณเบนซิลแอลกอฮอล์และเบนซาลดีไฮด์ การวิเคราะห์หาปริมาณเบนซิลแอลกอฮอล์อาศัยวิธีอนุพันธ์อันดับสอง โดยวัดที่ความถี่  $1205.28 \text{ cm}^{-1}$  ซึ่งเป็นจุดผ่านศูนย์ (zero crossing) ของเบนซาลดีไฮด์ ซึ่งเป็นผลิตภัณฑ์เสื่อมสลายของเบนซิลแอลกอฮอล์ ผลการวิเคราะห์ด้วยวิธีการดังกล่าวนี้มีความสอดคล้องกับผลการวิเคราะห์ด้วยเทคนิคโครมาโตกราฟีแบบของเหลวสมรรถภาพสูง (HPLC) ที่ใช้เป็นวิธีวิเคราะห์สำหรับอ้างอิง การวิเคราะห์หาปริมาณเบนซาลดีไฮด์ ทำโดยการอ่านค่าการดูดกลืนแสงที่ความถี่  $1202 \text{ cm}^{-1}$  โดยใช้ค่าสัญญาณพื้นฐาน (baseline) ที่ความถี่  $1780 \text{ cm}^{-1}$  ในการปรับแก้ค่าจากการวัด ผลการวิเคราะห์มีความสอดคล้องกับผลการวิเคราะห์ด้วยวิธีจากเกสซ์ตำรับ วิธีการวิเคราะห์ดังกล่าวมีความสัมพันธ์ระหว่างความเข้มข้นกับค่าการดูดกลืนแสงเป็นเส้นตรง ( $r=0.9999$ ) ในช่วงความเข้มข้น 4.0 ถึง  $20.0 \text{ mg ml}^{-1}$  สำหรับเบนซิลแอลกอฮอล์ และ 1.0 ถึง  $10.0 \text{ mg ml}^{-1}$  สำหรับเบนซาลดีไฮด์

**กุญแจคำ :** เทคนิคฟูเรียร์ทรานสฟอร์มอินฟราเรดสเปคโตรเมตรี, เบนซิลแอลกอฮอล์, เบนซาลดีไฮด์, กรดเบนโซอิก