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Determination of triclosan in antiperspirant gels by first-order derivative spectrophotometry

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Received March 21, 2011, accepted May 2, 2011

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Pharmazie 66: 740–743 (2011) *doi: 10.1691/ph.2011.1037*

A first-order derivative UV spectrophotometric method was developed to determine triclosan, a broad-spectrum antimicrobial agent, in health care products containing fragrances which could interfere the determination as impurities. Different extraction methods were compared. Triclosan was extracted with chloroform and diluted with ethanol followed by the derivative spectrophotometric measurement. The interference of fragrances was completely eliminated. The calibration graph was found to be linear in the range of 7.5–45 $\mu g \cdot mL^{-1}$. The method is simple, rapid, sensitive and proper to determine triclosan in fragrance-containing health care products.

1. Introduction

Triclosan, (5-chloro-2-(2,4-dichlorophenoxy) phenol (Fig. 1), is a synthetic, non-ionic, broad-spectrum antimicrobial agent, possessing antibacterial, antifungal and antiviral properties. It is widely used in a lot of routine health care products, such as toothpastes, mouth rinses, shampoos, soaps, bath products, handwash disinfectant, and antiperspirant products (Blinkhorn et al. 2009; Faoagali et al. 1999; Piccoli et al. 2002). It may be added to some textiles or home products (Devere and Purchase 2007). The United States Food and Drug Administration (FDA) has recognized it as either an over-the-counter (OTC) or a prescription drug (Jones et al. 2000). It is described in a monograph in the 24th USP. Additionally, triclosan was considered as an anti-malaria agent (Surolia and Surolia 2001). At the same time, the wide uses of triclosan naturally arise people's worry. Bacterial resistance may happen (Sasatsu 1993). Triclosan may be a potential non-steroidal estrogen (Foran et al. 2000). It had been demonstrated that triclosan might be transformed to chloroform (known as a potential carcinogen) in US water resources (Halden and Paull 2005). The safety problem of triclosan has been focused on. Therefore, the determination of triclosan is important.

Fragrances are widely used in health care products. Generally, the components of fragrances are complicated, and the amount of each component is low. Aromatic chemicals as the resource of flavour are the major chemical type in fragrances. They show ultraviolet (UV) absorption due to their special structure. In most cases, fragrances do not need to be determined in health care products due to their low concentrations. Furthermore, quantification, if needed, is very hard. However, they can be recognized as impurities and might interfer with the determination of the major components in health care products. To eliminate the fragrance interference with the determination of major components, some methods were developed, including liquid chromatography (Sanches-Silva et al. 2005), liquid chromatography/tandem mass spectrometry (LC-MS) (Quintana and Reemtsma 2004), gas chromatography/tandem mass spectrometry (GC-MS) (Morales-Munoz et al. 2005) and radioprobe liquid scintillation method (Moss et al. 2000). However, these methods are complicated and usually time consuming. In contrast, UV spectrophotometry should be a relatively simple and rapid method if the fragrances did not interfere with the determination. Moreover, the UV spectrophotometry instrument is cheap and can be easily equipped in small research units and the third world.

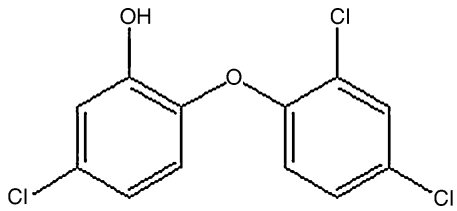


Fig. 1: Chemical structure of triclosan

Chromatography is commonly used to determine triclosan. In fact, chromatography is not necessary provided that all inferences can be eliminated. Therefore, the simple and rapid spectrophotometry may be a good option. However, the fragrance interference is hard to eliminate because the solubility of fragrances is similar to that of triclosan causing difficulties in separation. Derivative spectrophotometry is commonly used to eliminate the interference of impurities (El-Sayed and El-Salem 2005). In this paper, a facile and rapid first-order derivative spectrophotometric method was developed to determine triclosan in antiperspirant gels with enough sensitivity and complete elimination of fragrance interference.

2. Investigations, results and discussion

2.1. Effects of extraction solvents and pH on the determination of triclosan

Triclosan is alcohol-soluble and has the maximal UV absorption at 282 nm. Organic solvents were used to extract triclosan from gels. Extraction efficiency and interference were compared.

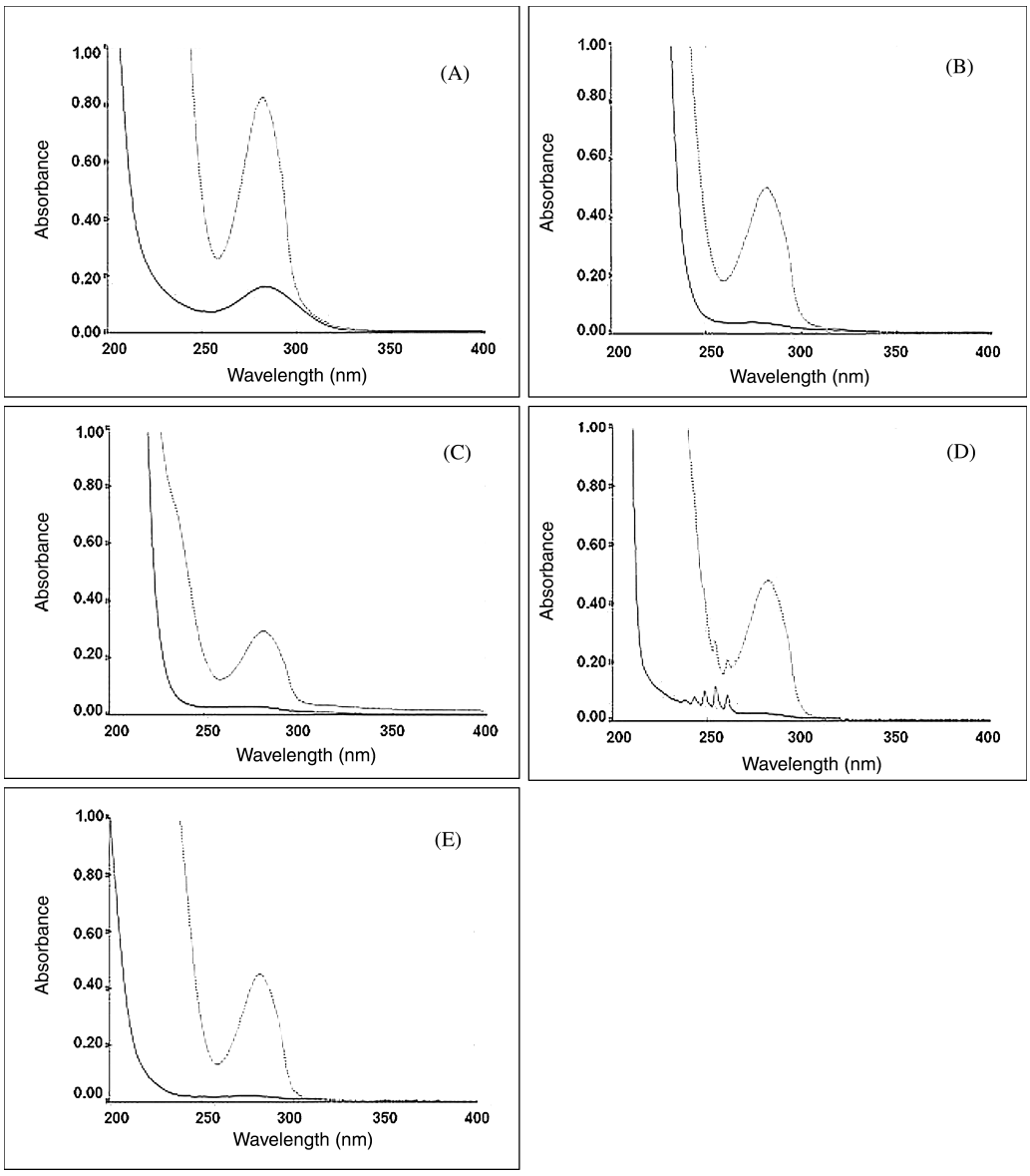


Fig. 2: Effects of extraction solvents on the determination of triclosan in gels. The upper dot curves were from the antiperspirant gels, and the lower curves were from the blank gels. The extraction solvents are ethyl ether (A); petroleum ether (B); methylene chloride (C); cyclohexane (D); and chloroform (E)

Ethyl ether and petroleum ether extracted some interfering components (Figs. 2A and 2B). The extraction efficiency of methylene chloride was lower than that of cyclohexane and chloroform (Figs. 2C, 2D and 2E). Cyclohexane is readily to evaporate and explode. Cyclohexane vapor could lead to human anesthesia (Bespalov et al. 2003). Chloroform was used widely as lab solvent to be suitable for extraction in this study. It was useless to adjust the pH of water phase when determining triclosan. This was related to the hydrophobicity of triclosan (Jug et al. 2011).

2.2. Effects of other ingredients in gels on the determination of triclosan

After extraction from antiperspirant gels, the ethanol dilution had the same absorption spectrum as that of triclosan alone, although the ethanol dilution from blank gels had a little absorption in the absorption field of triclosan (Fig. 3). The interference should result from the other ingredients in the gels. The other ingredients except for HPMC were treated as described above, and the spectra of their ethanol dilutions were obtained. Chlorhexidine acetate, AHC, LAO and allantoin did not show any interference because they are water-soluble and hardly enter the chloroform phase. However, the fragrances showed significant absorption due to lipophilicity (Fig. 3). Fragrances are mainly composed of aromatic chemicals, and show the similar soluble behavior as triclosan.

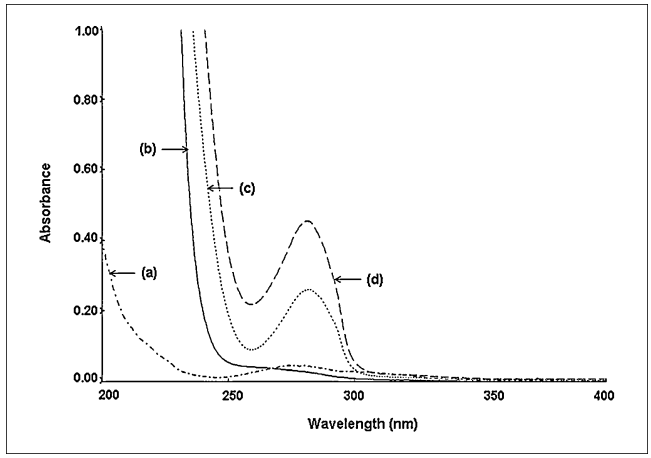


Fig. 3: Spectra of ethanol dilutions from the fragrances (a), blank gels (b), antiperspirant gels (c), and triclosan solutions (d)

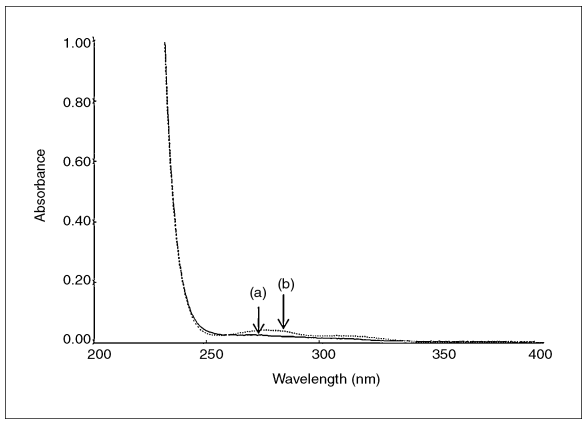


Fig. 4: Spectra from the blank gels processed with vacuum distillation (a) and heating method (b)

2.3. Elimination of fragrance interferences

Heat and vacuum may make fragrances evaporating. Unfortunately, after the heating and vacuum distillation treatments, the blank gels still interfered with a little absorption at 282 nm (Fig. 4). Therefore, the physical removing process is useless.

2.4. Determination of triclosan in the antiperspirant gels

The maximal first-order derivative value of the ethanol dilution from the antiperspirant gel appeared at 294.6 nm though the blank samples did not interfere (Fig. 5). Therefore, first-order derivative spectrophotometry can be applied to determine triclosan in antiperspirant gels and other similar health care products without interference of fragrances. The linear regression equation was $A = -9.18951 \times 10^{-5}$ 0.00192C (with a correlation coefficient $r = 0.9993$), and the linear range was between 7.5−45 μg/mL. The recovery and precision results of high, median and low concentrations were 94.0%, 98.4%, 102.6%, and 0.74%, 1.11%, 0.24%, respectively. Therefore, the method was reliable with a good recovery and precision.

3. Experimental

3.1. Materials

Triclosan was supplied by Ciba Refinement (China) Co., Ltd. An antiperspirant, aluminum hydroxychloride (AHC) was purchased from Suzhou Yongda Fine Chemical Co., Ltd. (China). Chlorhexidine acetate was from Jinzhou Jiutai Pharmaceutical Co., Ltd. (China). Hydroxypropylmethylcellulose (HPMC), detergents and other agents in the antiperspirant gels were purchased from Beijing Suntec Technical Development Co., Ltd. Fragrances including Trevi®, China Soap®, Fruit Dew® and Vivid®, were kindly supplied by Charabot Fragrance Co., Ltd. (France). All the other reagents were in analytical grade. Double distilled water was used. A UV-vis spectrophotometer (UV2501-PC, Shimadzu, Japan) was used.

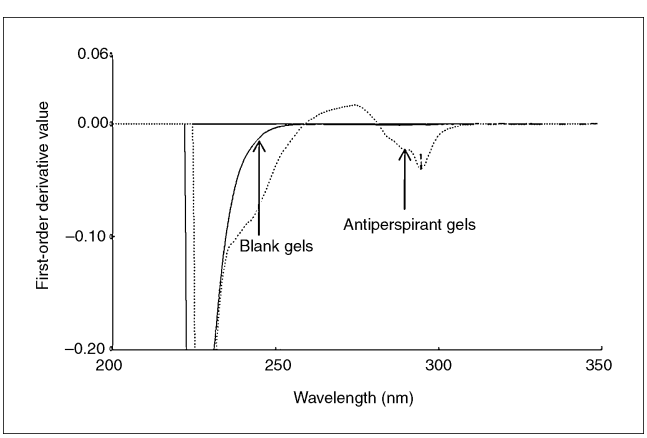


Fig. 5: The first-order derivative spectrum of antiperspirant gels and blank gels

3.2. Preparation of antiperspirant gels

AHC, lauramidopropyl amine oxide (LAO, surfactant), lactic acid, allantoin and chlorohexidine were dissolved in water, and mixed with the triclosan solution in propylene glycol under heat. HPMC and pigments were added under agitation. After cooling, a viscous gel was formed. Water-soluble tea plant oil and fragrances were added into the gel with thorough agitation. A blank gel without triclosan was also prepared as described above.

3.3. Spectra of the ingredients of antiperspirant gels

In a preliminary experiment, the spectrophotometric determination of triclosan in gels was interfered by the other ingredients after extraction with organic solvents. Therefore, the other ingredients of gels were investigated to estimate which one interfered. Generally, every ingredient was dissolved or dispersed in water, and then chloroform was added to extract. After centrifugation, the organic phase was pipetted and diluted with ethanol for scanning on the UV spectrophotometer.

3.4. Spectral investigation of antiperspirant gels

A gel (1.5 g) containing triclosan or not was mixed with water (3 mL), and agitated to disperse thoroughly. Chloroform (10 mL) was added and strongly hand shaken for 2 min. The mixture was centrifuged at 2600 rpm for 15 min. The chloroform phase (1 mL) was pipetted into a 10-mL volumic flask and ethanol was used to dilute. The ethanol solutions were scanned within the UV field.

To eliminate the interference of fragrances, two methods were tried as follows. (1) Heating method. The blank gel (1.5 g) was mixed with water (10 mL), agitated, and incubated at 80 °C for 20 min. After cooling, chloroform (10 mL) was added, and the following process was the same as the above. (2) Vacuum distillation. The similar procedures were applied except the chloroform phase was evaporated to dry under vacuum. Then chloroform (10 mL) was added to dissolve the possible residues, and 1 mL was pipetted followed by dilution with ethanol to 10 mL and scanning.

3.5. Determination of triclosan in antiperspirant gels

The gel (1.5 g) was accurately weighted into a 10-mL beaker, and water (3 mL) was added. The mixture was thoroughly agitated, and transferred to a 25-mL separating funnel. The residues were washed twice with a little water, and transferred to the funnel. Chloroform (10 mL) was added. The sample was strongly hand-shaken for 2 min, and then kept for more than 2 h until separating organic phase entirely. The organic phase was removed and maintained for 20 min to be clear. A sample (1 mL) was pipetted, diluted with ethanol to 10 mL, and scanned. The first-order derivative data of spectra were calculated by UVPC v3.91 Personal Spectroscope Software of Shimadzu with $\Delta\lambda = 10$ nm and scaling factor = 1.0. The amount of triclosan was calculated based on the values at 294.6 nm.

The pH value of the above water dispersion was about 4.0. In order to investigate the effect of dispersion pH on triclosan extraction, HCl or NaOH solution was used to modify the water dispersion to pH 3.0 or 6.5 followed by extraction with chloroform. Substituting chloroform, other organic solvents including methylene chloride, cyclohexane, petroether ether and ethyl ether, were also used to extract triclosan.

3.6. First-order derivative spectrophotometry

Triclosan stock solutions (3.0 mg mL^{-1}) were prepared by dissolving 300 mg of triclosan in a 100-mL volumetric flask with chloroform. Then 0.25, 0.5, 0.8, 1.0, 1.2, 1.5 mL of the above solution were diluted to 10 mL with ethanol, respectively. The first-order derivative absorbance of each sample was measured at 296.4 nm. The calibration curve was plotted.

Blank gels of 1.5 g were added with the above triclosan stock solution of 0.8, 1.0, 1.2 mL, respectively. Chloroform of 9 mL was added, and the samples were intensely hand-shaken for about 2 min. The following procedure was the same as described in the section "Determination of Triclosan in Antiperspirant Gels".

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