International Journal of Chemical Studies

P-ISSN 2349–8528
E-ISSN 2321–4902
IJCS 2016; 4(5): 91-93

Received: 13-07-2016
Accepted: 14-08-2016

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Recent advances in analytical techniques for the determination of xylitol

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Abstract
Xylitol is a naturally occurring five-carbon containing sugar alcohol. It has attracted a lot of attention in the pharmaceutical, cosmetics, food, and dental industries due to its high sweetening ability, anticariogenic properties and possibilities for use in insulin-dependent diabetics. Thus, the establishment of a simple and rapid method for the determination of xylitol with high selectivity and sensitivity is of great significance to people's health. In this article the studies of detection methods for xylitol in recent years are reviewed.

Keywords: Xylitol, determination, detection, sensor

1. Introduction
Xylitol (CH_2OH $(CHOH)_3$ CH_2OH) is a sugar alcohol and is categorized as a polyalcohol consisting of five hydroxyl groups. It is a naturally occurring alcohol found in most plant materials, including several vegetables and fruits. And it has also been produced by chemical synthesis through catalytic hydrogenation of d-xylose and by the biological production of xylitol by a number of microorganisms and enzymes [1-3]. Because the sugar inhibits the growth of various bacteria, including Streptococcus mutans, which reduces the biofilm thickness, it is used in the prevention of tooth decay and is widely used as a sugar substitute in "sugar-free" chewing gums, mints, and candies. However, the consumption of large amounts of this sugar can produce side effects, including osmotic diarrhea, flatulence, and gastrointestinal pain [4-6]. Therefore, simple, rapid and sensitive determination of xylitol in body fluids, pharmaceuticals, and food samples is of great importance. In this paper, the attributes of different analytical technique for the determination of xylitol in recent years are reviewed.

2. Analytical Methods
2.1 HPLC method: High-performance liquid chromatography (HPLC) is a powerful tool that enables the separation of complex mixtures into individual components, and is a highly sensitive and reproducible analytical technique. In recent years, HPLC has been combined with many sensitive detection techniques and has experienced continuous improvement of stationary phases, which have improved its sensitivity and specificity. HPLC is currently widely used for the analysis of drugs and dosage forms with respect to quality control, quantitative determination of active ingredients and impurities, monitoring drug blood concentration in patients, and bioequivalence assessment [7, 8].
Grembecka *et al.* [9] reported a simple, sensitive and accurate method for simultaneous determination of glucose, fructose, sucrose, maltose, erythritol, mannitol, maltitol, sorbitol and xylitol by HPLC coupled to corona charged aerosol detector for the first time. The method was elaborated using a Shodex Asahipak, NH2P-50 4E, column packed with 5 μm shell particles and acetonitrile–water gradient mobile phase at 25 °C. The method showed wide concentration range and good accuracy. Limits of detection for nine analytes were in the range of 0.12–0.44 μg ml^{-1}, respectively. The results obtained for real samples illustrated the ability of the proposed method to quantify a range of sugars and sugar alcohols in a single analysis, making it appropriate for food analysis.

Tian *et al.* [10] established a method for determination of xylitol concentration by HPLC method combined with refractive index detector. The Rezex series of Ca^{2+} sugars and sugar alcohols column was used as separation column and the distilled water was used as mobile phase. When the concentration was 0.0005-15g/100mL, it had very good linear relation. The method was simple, rapid, accurate and suitable for large quantity sample analysis.

2.2 Electrochemical method: Electroanalytical techniques are a promising alternative for the determination of organic molecules in complex matrices, because they deliver lower cost and analysis time, high selectivity, and high sensitivity [11-13].

Lourenço *et al.* [14] presented the application of a boron-doped diamond electrode combined with differing voltammetric techniques to study the electrochemical behavior of xylitol, and to develop an analytical methodology for its determination in mouthwash. Xylitol underwent two oxidation steps in an irreversible diffusion-controlled process. The electroanalytical method developed yielded low detection of 1.3×10^{-6} mol L^{-1}, associated with good levels of repeatability and reproducibility and demonstrated the viability of the methodology for detection of xylitol in biological samples containing low concentrations.

Kannan *et al.*[15] developed a facile, instep, and eco-friendly synthesis method for the preparation of mono-dispersed, low quantity palladium nanoparticle/carbon@functionllized carbon nanotube composite electro catalytic material for use in the electrooxidation of xylitol. The electrocataly studies were performed using voltammetric methods. The microscopic analysis showed 5-10 nm Pd nanoparticles that uniformly covered the carbon nanotube. The instep-formed carbon helped to improve the electrocataly activity of the catalyst.

2.3 Capillary electrophoresis method: In recent decades, capillary electrophoresis (CE) has been developed for trace analysis because of its small sample size of only nanoliters to femtolitere, short analysis time, and biocompatible environments. In addition, rapid separations are feasible with CE because high voltages can be applied to short capillaries and separation efficiency is not dependent on column length. To identify biological and pharmaceutical analysis, CE is coupled to a variety of detectors, including fluorescence, mass spectrometry, and electrochemical detection [16, 17].

Liu *et al.* [18] established a method for simultaneous determination of glucose, galactitol, mannitol, sorbitol, erythritol, xylitol and maltitol in food samples by CE with ultra-violet detection. After the glucose and sugar alcohols in food samples were combined with tetraborate to form borate complexe anions, the anions were separated on a capillary column with Borax buffer and detected at 195 nm. For shortening the analysis time, the electroosmotic flow was reversed by adding cetyltrimethylammonium bromide into the buffer. Under the optimized conditions, the detection limits of the method were < 0.1 g/L. This strategy is suitable for the determination of the glucose and six sugar alcohols in food samples.

Liu *et al.* [19] developed a new method for the detection of xylitol in food by CE with indirect ultraviolet detection. The separation was carried out using an uncoated fused-silica capillary with 50 μm i.d. and 60.2 cm total length. The separation voltage was -20 kV and the detection wavelength was 200 nm. The limits of detection and quantitation were 3.00 mg/L and 10.00 mg/L, respectively. The linear range between the corrected peak area and the concentration was from 10.00 to 300.0 mg/L with a correlation coefficient of 0.9994. The method was simple and fast and the analysis could be completed within 11 min, which was suitable for the determination of xylitol in food samples.

2.4 Other methods: In addition to these main approaches mentioned above for xylitol detection, still a few special techniques with high sensitivity have been applied. Rhee *et al.* [20] developed a xylitol oxidase-based flow injection analysis for monitoring of xylitol concentrations. Pospısilova *et al.* [21] proposed a strategy for the separation and determination of sorbitol and xylitol in multi-component pharmaceutical formulations by capillary isotachophoresis. Tian *et al.* [22] developed a rapid method for the determination of xylitol in the treating burley tobacco by ion chromatography.

3. Conclusions

Xylitol is a reduced sugar and has the beneficial effects for disease prevention when replacing sucrose. Due to its high sweetening ability, its anticariogenic properties, and its potential for use by insulin-dependent diabetics, xylitol has attracted much attention in the pharmaceutical, cosmetics, food, and dental industries [23, 24]. Therefore, the determination of xylitol in food, pharmaceutical products and living bodies especially for human is very important. This review has highlighted the significant developments in rapid and alternative techniques for the detection of xylitol in recent years. We believe the development of xylitol sensors with better sensitivity and specificity, lower cost, simplicity, along with *in vivo* analytical technique is still the future effort.

4. Acknowledgments

The work was supported by the Hebei Provincial Natural Science Foundation of China (No. B2015201161), Medical Engineering Cross Foundation of Hebei University (No. BM201108) and Training Programs of Innovation and Entrepreneurship for Undergraduates of Hebei University (No. 2016061).

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