Talanta 105 (2013) 255–261

Contents lists available at SciVerse ScienceDirect

Talanta

journal homepage: www.elsevier.com/locate/talanta

Superparamagnetic surface molecularly imprinted nanoparticles for sensitive solid-phase extraction of tramadol from urine samples

Tayyebeh Madrakian *, Abbas Afkhami, Hediye Mahmood-Kashani, Mazaher Ahmadi

Faculty of Chemistry, Bu-Ali Sina University, Hamedan, Iran

ARTICLE INFO

Article history:
Received 1 October 2012
Received in revised form
10 December 2012
Accepted 13 December 2012
Available online 31 December 2012

Keywords:
Molecularly imprinted polymer
Magnetic nanoparticles
Tramadol
Solid-phase extraction

ABSTRACT

A rapid, selective, sensitive and accurate method based on superparamagnetic molecularly imprinted polymer nanoparticles (MMIPNPs) was developed for the determination of tramadol (TRA) in human urine samples. The MMIPNPs were prepared by coating SiO_2–Fe_3O_4 nanoparticles with polyaminoimide homopolymer and TRA as the template. The prepared MMIPNPs adsorbent was characterized by TEM, FT-IR, XRD and magnetometry. TEM images show that the Fe_3O_4 nanoparticles are well-enwrapped by the SiO_2 shell and further by an MIP layer. The prepared magnetic adsorbent is well dispersed in water and can be easily separated magnetically from the medium after loading with the adsorbate. Various parameters affecting the extraction efficiency of the MMIPNPs have been evaluated. The extracted TRA could be easily desorbed with a mixture of methanol and acetic acid and determined spectrophotometrically at 272 nm. A linear dynamic range was established from 3.0 to 200.0 ng mL^{-1} of TAR and the limit of detection was found to be 1.5 ng mL^{-1}. The proposed method was successfully applied for the determination of TRA in human urine samples.

1. Introduction

Tramadol, (2-[(dimethylamino) methyl]-1-(3-methoxyphenyl) cyclohexanol), TRA, is a centrally acting analgesic, prescribed for the treatment of moderate to severe pain [1]. The Food and Drug Administration (FDA) approved TRA in 1995 for legal use in the United States. Impairing side effects of TRA include dizziness, confusion, light-headedness or fainting spells, drowsiness, seizures and respiratory depression [2]. After oral administration, TRA demonstrates 68% bioavailability, with peak serum concentrations reached within 2 h. The elimination kinetics can be described as 2-compartmental, with a half-life of 5.1 h for TRA and 9 h for the O-desmethyltramadol (its main metabolite) after a single oral dosage [3–5].

Several analytical methods have been reported for the determination of TRA and/or its metabolites in a variety of biological matrices. These methods include: HPLC with UV [6–9], fluorescence [9,10], or diode array detectors [11]; gas chromatography (GC) [12]; three-phase hollow fiber liquid-phase microextraction/GC-MS [13]; and MS [14–17]. Simultaneous quantification of TRA and its metabolites in brain tissue of mice and rats [18], saliva [19], urine [19,20], amniotic fluid [21] and plasma [22,23] have been reported using different analytical techniques.

Pertinent sample preparation is crucial for obtaining meaningful results from the analysis of real samples, since it is the most tedious and time-consuming step and a possible source of imprecision and inaccuracy of the overall analysis. Solid-phase extraction (SPE) is widely used for the extraction and preconcentration of analytes in various environmental, food and biological samples. It is the most popular clean-up technique due to factors such as convenience, cost, time saving and simplicity and it is the most accepted sample pretreatment method today [24,25]. At present, there are several types of sorbents for SPE, including normal-phase, reversed-phase, ionic, and other special sorbents. However, due to their unsatisfactory selectivity, these traditional sorbents usually cannot separate analytes efficiently in complex biological or environmental samples [26]. A relatively new development in the area of SPE is the use of molecularly imprinted polymers (MIPs) for the sample clean-up and development of selective and sensitive analytical methods [27–30]. MIPs are synthetic polymers possessing specific cavities designed for a target molecule and are synthesized by the polymerization of different components. In the most common preparation process, monomers form a complex with the desired template through covalent or non-covalent interactions and then joined by using a cross-linking agent. After removing the template by chemical reaction or extraction, binding sites are exposed which are complementary to the template in size, shape, and position of

* Corresponding author. Tel./fax: +98 811 8257407.
E-mail addresses: madrakian@basu.ac.ir, madrakian@gmail.com (T. Madrakian).

0039-9140/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.talanta.2012.12.039

the functional groups, and consequently allow its selective uptake [24]. MIPs are often referred to as artificial antibodies. Unlike antibodies, MIPs are stable to extremes of pH, organic solvents and temperature which allow more flexibility in the analytical methods [26,27]. The use of MIPs for SPE involves conventional SPE where the MIP is packed into columns or cartridges [31,32] and batch mode SPE in which the MIP is incubated with the sample [33]. A major advantage of MIP-based SPE, related to the high selectivity of the sorbent, is achievement of an efficient sample clean-up.

In this study, we report a novel method of combining polyaminoimide homopolymer with superparamagnetic core-shell nanoparticles and TRA as the template (MMIPNPs) for the extraction of TRA from solutions. The performance of this method is comparable with most of the analytical instrumental methods reported for TRA determination such as GC-MS [13,34–36] and HPLC [37–40].

2. Experimental

2.1. Reagents and materials

All the chemicals used were of analytical reagent grade or the highest purity available from Merck Company (Darmstadt, Germany). Double distilled water (DDW) was used throughout. All glassware were soaked in dilute nitric acid for 12 h and then thoroughly rinsed with DDW. The TRA stock solution was prepared weekly and stored at +4 °C. Working standard solutions of different TRA concentrations were prepared daily by diluting the stock solution.

2.2. Apparatus

The size, morphology and structure of the nanoparticles were characterized by transmission electronic microscopy (TEM, Philips, CM120, 100 kV). The crystal structure of the synthesized materials was determined by an X-ray diffractometer (XRD, 38066 Riva, d/G, Via M. Misone, 11/D (TN) Italy) at ambient temperature.

A Metrohm model 713 pH-meter was used for pH measurements. A single beam UV-mini-WPA spectrophotometer was used for the determination of TRA concentration in solutions. The mid-infrared spectra of Fe_3O_4, silica-coated magnetite nanoparticles (SiO_2–Fe_3O_4) and MMIPNPs in the region 4000–400 cm^{-1} were recorded by a FT-IR spectrometer (Perkin–Elmer model Spectrum GX) using KBr pellets. A 40 kHz universal ultrasonic cleaner water bath (RoHS, Korea) was used.

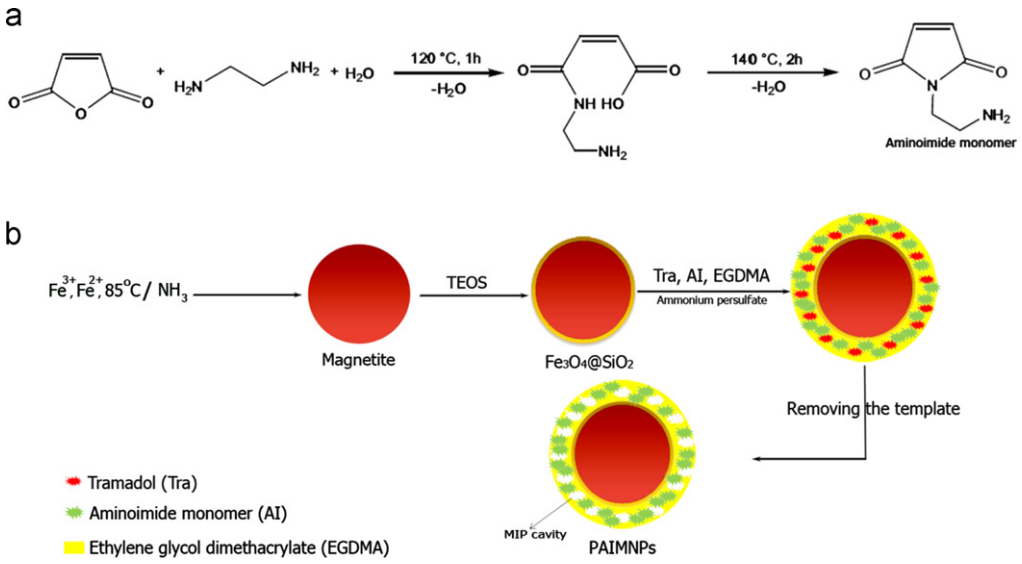
The magnetic properties of bare Fe_3O_4, Fe_3O_4–SiO_2 and MMIPNPs nanoparticles were measured with a vibrating sample magnetometer (VSM, 4 in. Daghigh Meghnatis Kashan Co., Kashan, Iran).

2.3. Preparation of nanostructured SiO_2–Fe_3O_4

The magnetite nanoparticles (Fe_3O_4) were prepared by the conventional co-precipitation method, with minor modifications [41]. $FeCl_3 \cdot 6\,H_2O$ (11.68 g) and $FeCl_2 \cdot 4\,H_2O$ (4.30 g) were dissolved in 200 mL DDW with vigorous stirring at 85 °C under nitrogen gas atmosphere. Then, 20 mL of 30% aqueous NH_3 was added to the solution. The color of the bulk solution changed from orange to black immediately. The magnetite precipitates were washed twice with DDW and once with 0.02 mol L^{-1} sodium chloride by magnetic decantation. Then, to the magnetite nanoparticles prepared above (0.8 g) was added an aqueous solution of tetraethoxy silane (TEOS, 10% (v/v), 80 mL), followed by glycerol (60 mL). The pH of the suspension was adjusted to 4.6 using glacial acetic acid, and the mixture was then stirred and heated at 90 °C for 2 h under nitrogen atmosphere. After cooling to room temperature, the suspension was washed sequentially with DDW (3 × 50 mL), methanol (3 × 50 mL), and DDW (5 × 50 mL).

2.4. Preparation of MIP and non-imprinted polymer (NIP)

The aminoimide monomer used for preparation of the polyaminoimide homopolymer was synthesized according to a previously reported procedure [42]. Briefly, the aminoimide monomer was synthesized by slow addition of maleic anhydride (1 g) to the solution of ethylenediamine (1 mL) in DDW (20 mL). The solution was heated to 120 °C for 1 h, until all the water was removed and ethylenediamine reacted with maleic anhydride through ring opening. Then, the unsaturated aminoimide monomer was prepared by heating the reaction product to 140 °C for 2 h. In order to prepare MMIPNPs, the aminoimide monomer was homopolymerized in the presence of Fe_3O_4–SiO_2 (0.5 g), ammonium persulfate (0.1 g, as the initiator), ethylene glycol



Scheme 1. Reaction involved in the synthesis of MMIPNPs.