Analytica Chimica Acta 866 (2015) 90–98

Contents lists available at ScienceDirect

Analytica Chimica Acta

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

Ultrasensitive analysis of lysergic acid diethylamide and its C-8 isomer in hair by capillary zone electrophoresis in combination with a stacking technique and laser induced fluorescence detection

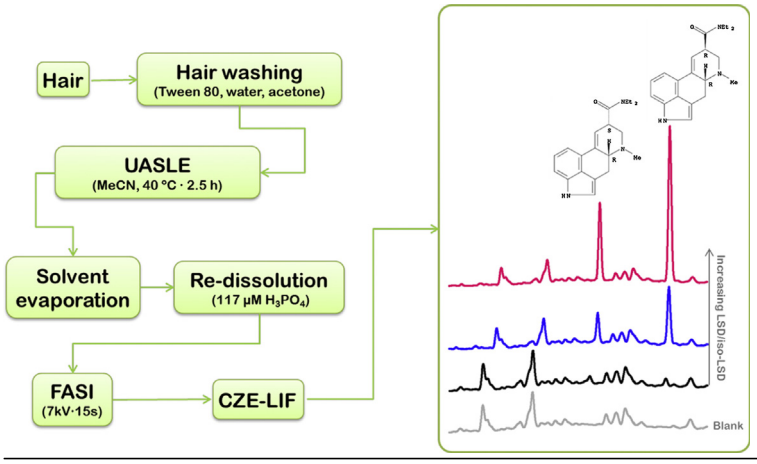
Diego Airado-Rodríguez, Carmen Cruces-Blanco, Ana M. García-Campaña *

Department of Analytical Chemistry, Faculty of Sciences, University of Granada, Campus Fuentenueva s/n, E-18071 Granada, Spain

HIGHLIGHTS

- New method based on CZE-LIF to monitor LSD and iso-LSD in hair.
- FASI used as on-line sample preconcentration technique for enhancing sensitivity.
- Ultrasound assisted solid–liquid extraction employed for drug extraction from the hair.
- Detection limits (3 S/N) around 0.100 pg mg^{-1} with RSD lower than 10%.
- Recoveries of 73.3 and 79.9% for LSD and iso-LSD, respectively.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 October 2014
Received in revised form 13 January 2015
Accepted 17 January 2015
Available online 23 January 2015

Keywords:
Lysergic acid diethylamide
Hair
Capillary electrophoresis
Field-amplified sample injection
Laser induced fluorescence detection

ABSTRACT

This article deals with the development and validation of a novel capillary zone electrophoresis (CZE) with laser induced fluorescence detection method for the analysis of lysergic acid diethylamide (LSD) and its isomer iso-LSD in hair samples. The separation of both analytes has been achieved in less than 13 min in a 72-cm effective length capillary with 75-μm internal diameter. As running buffer 25 mM citrate, pH 6.0 has been employed and separation temperature and voltage of 20 °C and 13 kV respectively, were applied. Field amplified sample injection (FASI) has been employed for on-line sample preconcentration, using ultrapure water containing 117 μM H_3PO_4 as optimum injection medium. Injection voltage and time have been optimized by means of experimental design, obtaining values of 7 kV and 15 s, respectively. Methylergonovine has been employed as internal standard in order to compensate irreproducibility from electrokinetic injection. The analytical method has been applied to hair samples, previous extraction of the target analytes by ultrasound assisted solid–liquid extraction at 40 °C for 2.5 h, employing acetonitrile as extracting solvent. Linear responses were found for LSD and iso-LSD in matrix-matched calibrations from around 0.400 up to 50.0 pg mg^{-1}. LODs (3 S/N) in the order of 0.100 pg mg^{-1} were calculated for both analytes, obtaining satisfactory recovery percentages for this kind of sample.

* Corresponding author. Tel.: +34 958242385; fax: +34 958243328.
E-mail address: amgarcia@ugr.es (A.M. García-Campaña).

http://dx.doi.org/10.1016/j.aca.2015.01.033
0003-2670/

1. Introduction

Lysergic acid diethylamide (LSD) is a potent hallucinogenic compound derivate of ergot alkaloids, which is active and results in a number of psychotropic effects at low doses. LSD is an illicit drug being one of the most potent. It is usually sold as blotter papers (small stamps) soaked at an average of 50 μg (10–100 μg) [1]. The employed small doses, together with its extensive hepatic metabolism [2], leads to LSD concentration in urine below 1 $\mu g\,L^{-1}$ within a few hours after ingestion of typical street doses [2]. LSD can undergo isomerization to iso-LSD by epimerization at the C-8 carbon (Fig. 1) and iso-LSD is a major contaminant in many illicit LSD preparations [3]. Although iso-LSD is a contaminant of LSD itself, it can be also employed as a marker of drug use, since it is frequently detected in body fluids from LSD users [3]. Concentration of both, LSD and iso-LSD in forensic samples, such as hair, drops to the low $pg\,mg^{-1}$ range. Thus, it is easy to understand that the use of these specimens in forensic science goes hand in hand with analytical development, and ultra-sensitive methodologies.

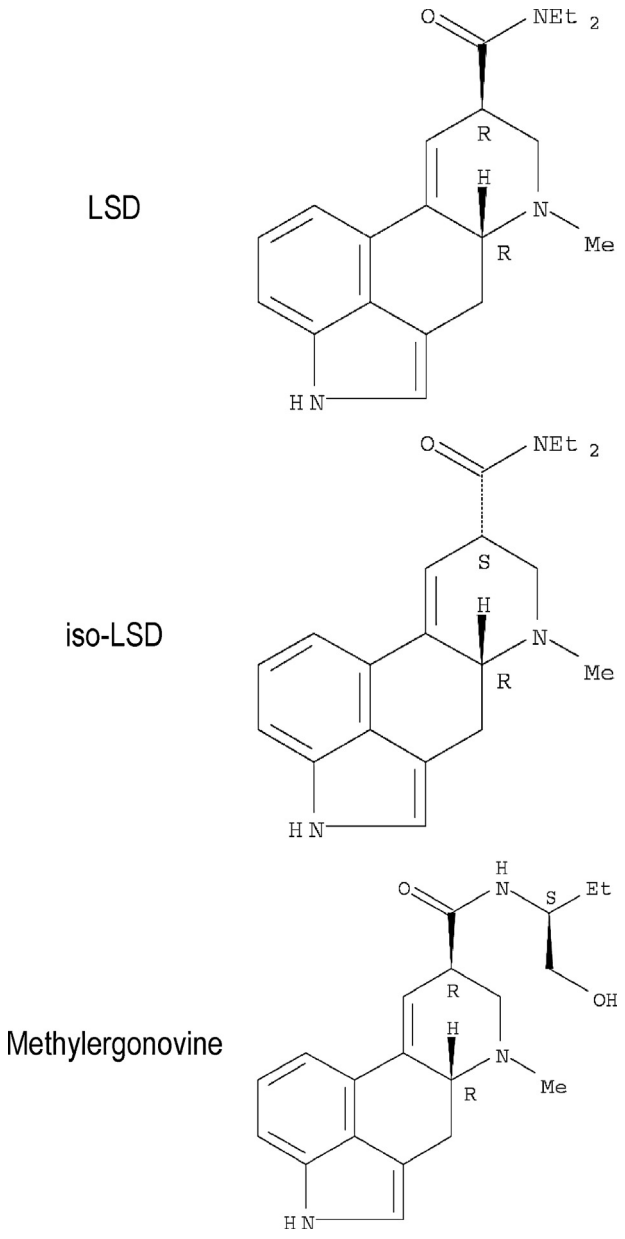


Fig. 1. Molecular structures of lysergic acid diethylamide (LSD), iso-lysergic acid diethylamide (iso-LSD), and methylergonovine, employed as internal standard.

Blood and urine have traditionally been the most employed biological specimens for the investigation of drugs of abuse, and they play a key role in routine forensic analysis. However, attention has been paid also to other "alternative samples", which present the advantages of being easier to collect and more difficult to adulterate [4]. Nevertheless, concentration of drugs in those alternative samples is usually lower than in typical fluids, thus their use with forensic purposes is never possible without highly sensitive analytical methodology. Hair, saliva and sweat can be cited within these alternative samples. Nowadays, hair analysis is routinely used as a tool for detection of drug use in forensic science, traffic medicine, occupational medicine and clinical toxicology [5,6]. Some recent reviews also describe the analytical techniques and sample preparation methods for determination of drugs of abuse in hair samples [7,8]. Hair analysis is for instance a powerful tool for evaluating opiate exposure during pregnancy, which aids in the diagnosis of neonatal withdrawal syndrome and enable to draw up a foetal opiate exposure profile [9] and has also been employed in the case of drug-facilitated crimes [10].

CE has lately gained in popularity as a supplementary and in some extent an alternative technique to the much more accepted LC. CE presents clear advantages, such as speed, minimal need of sample, reduced consumption of organic solvents, relatively low cost [11], high mass sensitivity, suitability for coupling with MS and a broad application spectrum spanning from inorganic ions to large DNA fragments [12], but its main disadvantage versus LC is the lack of sensitivity. The two main sources responsible for the high detection limits in CE are the short optical path-length for on-capillary optical detection and the low volume of sample introduced in the capillary with traditional injection methodologies. Sensitivity can be enhanced directly at the detection point, by either using extended light path cells like bubble cells [13] and Z-shaped cells [14] or employing detection systems more sensitive than photometric, such as laser-induced fluorescence (LIF) or electrochemical detection (EC). On the other hand, lower detection limits can be also achieved by means of increased analyte mass loading via on-line (or on-capillary) sample pre-concentration techniques, which is normally performed by manipulating the composition of the sample and background solutions together with simple injection procedures [15–17]. These procedures result in sample stacking, produced from the velocity change of the analytes between the sample zone and the separation buffer zone [18,19]. Field amplified sample injection (FASI) has been the employed stacking technique in this work. FASI is based on a mismatch between the electric conductivity of the sample and that of the running buffer. Preconcentration in FASI is achieved when sample, diluted in a solvent of lower conductivity than that of the carrier electrolyte, is electrokinetically injected. As a consequence of the application of the injection voltage, an enhancement of the electric field strength occurs in the low-conductivity zone, which induces an increase of electrophoretic velocities. If electrokinetic injection is performed in normal polarity mode, cations move rapidly and concentrate in sharp bands in the tip of the capillary at the boundary between the sample and the separation buffer. Once in the separation buffer, the injected components of the sample migrate in different zones according to their charge/mass characteristics [20]. In an article published by our research group, it has been shown how FASI can be successfully combined with CZE-UVD for the analysis of LSD among other drugs of abuse in human urine [21].

An excellent review on strategies to improve sensitivity in CE, specifically for the determination of drugs in biological fluids was published in 2000 [22]. Special emphasis is made in the fact that it does not exist a general common method for drugs