Trends in Analytical Chemistry 83 (2016) 95–101

Contents lists available at ScienceDirect

Trends in Analytical Chemistry

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

Recent progress on nanomaterial-based biosensors for veterinary drug residues in animal-derived food

Dan Wu [a,b], Dan Du [b,c], Yuehe Lin [a,b,*]

[a] Key Laboratory of Chemical Sensing & Analysis in Universities of Shandong, School of Chemistry and Chemical Engineering, University of Jinan, Jinan 250022, China
[b] School of Mechanical and Materials Engineering, Washington State University, Pullman, WA 99164, USA
[c] Key Laboratory of Pesticide and Chemical Biology of the Ministry of Education of the PR China, College of Chemistry, Central China Normal University, Wuhan, 430079, China

ARTICLE INFO

Keywords:
Biosensor
Nanomaterials
Animal-derived food
Veterinary drug residues
Antimicrobial drugs
Antiparasitic drugs
Growth promoters
Electrochemical sensors
Electrochemiluminescent sensors
Photoelectrochemical sensors

ABSTRACT

Veterinary drugs mainly include antimicrobial drugs, antiparasitic drugs and growth promoters. They are extensively used for treatment and prevention of diseases in animals, promotion of animal growth, and feed efficiency. But the possible presence of veterinary drugs in animal-derived foods is one of the key issues for food safety which arouses great public concern. So it is very important to develop quick and accurate methods to detect veterinary drug residues in animal-derived food, and their quantity must be less than the maximum residue limits (MRL) defined in many countries on the basis of food safety. In recent years, nanomaterial-based biosensors have aroused a great attention because they have significant advantages such as high sensitivity, rapid response and low cost. This article is aimed to summarize recent progress on nanomaterial-based biosensors for veterinary drug residues in animal-derived food, mainly including electrochemical sensors, electrochemiluminescent sensors, and photoelectrochemical sensors.

Contents

1. Introduction

Animal-derived foods such as meat, milk and eggs are an important part of daily diets, and their consumption is rapidly increasing worldwide because they are a very good source of phosphorus and protein [1]. Hence, substantial research effort is devoted to developing control systems in order to ensure food quality and safety. As is well known, veterinary drugs such as antibiotics, antiparasitic and antifungal drugs, hormones, and growth promoters are used for treatment and prevention of diseases in animals, promotion of animal growth and feed efficiency. Although these drugs are effective in treating animal disease, potential residues could exist in animal-derived food in case of their wide use, abuse and misuse, which may cause adverse reactions and a decrease in the

* Corresponding author. Tel.: +509 335 8523; Fax: +509 335 4662
E-mail address: yuehe.lin@wsu.edu (Y. Lin).

http://dx.doi.org/10.1016/j.trac.2016.08.006
0165-9936/

efficiency for treating infection in humans. In view of these residues' toxicity and side effects, a number of regulatory authorities in different countries have established maximum residue limits (MRL) for veterinary drugs in different animal-derived foods. For example, the MRL of streptomycin (STR) established by the European Union (EU) in milk, muscle and liver are 500 ng/g [2]. The MRL for chloramphenicol (CAP) residues in animal-derived food is set to be 0.3 μg/kg by the EU [3]. Therefore, it is necessary to develop a method for monitoring veterinary drug residue levels, and to provide scientific health guidelines to the public.

Various techniques have been put forward for the detection of veterinary drug residues, including the high performance liquid chromatography (HPLC), gas chromatography-mass spectroscopy (GC-MS), liquid chromatography-mass spectroscopy (LC-MS), enzyme-linked immunosorbent assays, and bioluminescent-bacteria-based assays [4–8]. These methods have some limitations such as complicated pretreatment of samples, expensive instruments and professional operators although they are both sensitive and accurate. So it is not suitable to routine and rapid analysis of large numbers of samples using those methods. Biosensors, used for the detection of an analyte which integrates a biological component and a physicochemical detector [9], are very attractive for rapid monitoring of veterinary drug due to their simplicity and low cost.

The purpose of this paper is to review veterinary drug residues detection in animal-derived foods based on biosensors, mainly including electrochemical sensors, electrochemiluminescent sensors, and photoelectrochemical sensors, in recent years.

2. Discussion

2.1. Detection of antimicrobial drugs

Antimicrobial drugs are used to kill microbes or inhibit their growth in animals and to improve production efficiency in food-producing animals. They involve antibiotics, as well as synthetic and semisynthetic compounds that have the same effects. Common antimicrobial drugs, having a variety of actions to influence bacterial survival and growth, include penicillins and cephalosporins (inhibition of cell wall synthesis), tetracyclines, phenicols and aminoglycosides (inhibition of protein synthesis), and sulfonamides and fluoroquinolones (inhibition of DNA function) [10]. However, it is well known that they may give rise to some problems for some reasons such as direct toxicity of the residues or possible involvement in allergic reactions [11]. Given the toxicity of potential residue in animal-derived food and potential health risk to the public, the detection of antimicrobial drug residues has very important significance.

2.1.1. Electrochemical sensors

Electrochemical sensors have drawn considerable attention in many fields such as food safety, disease diagnosis and environmental monitoring [12–15]. They work by detecting electrochemical changes of electrode interfaces. It is well known that good electrode materials not only have excellent catalytic activity, conductivity, and biocompatibility to accelerate signal transduction but also amplify biorecognition events with specifically designed signal tags, resulting in high sensitivity [16]. Various nanomaterials, including carbon nanomaterials, metal nanomaterials, silica nanoparticles (NPs) and other functionalized NPs, have been employed for detecting antimicrobial drug residues in animal-derived food.

Liu and co-workers firstly synthesized a novel and redox-active magnetic molecularly imprinting polymer (mMIP) using Au(III)-promoted molecularly imprinted polymerization with streptomycin residues (STR) templates on magnetic beads by the one-pot method. Then they developed an electrochemical sensor for simple and sensitive determination of STR in food [17] using the above polymer. It can be seen from Fig. 1 that the amount of glucose oxidase-labeled streptomycin on the mMIP nanospheres decreased with the increase of streptomycin in the sample, resulting in the change of the current. The results for milk and honey analysis obtained from mMIP-based sensors were in agreement with those obtained from the HPLC method. Compared with the detection limit for liquid chromatographic-mass spectrometry (50 ng/mL) [18], fluorescent aptasensor (54.5 nmol/L) [19] and electrochemical aptasensor (11.4 nmol/L) [20], the proposed sensor for the determination of streptomycin residues has lower detection limit (10 pg/mL).

2.1.2. Electrochemiluminescent sensors

Due to the combination advantages of chemiluminescence and electrochemistry, ECL has been proven to be a useful detection method with high sensitivity and selectivity [21]. ECL is a kind of

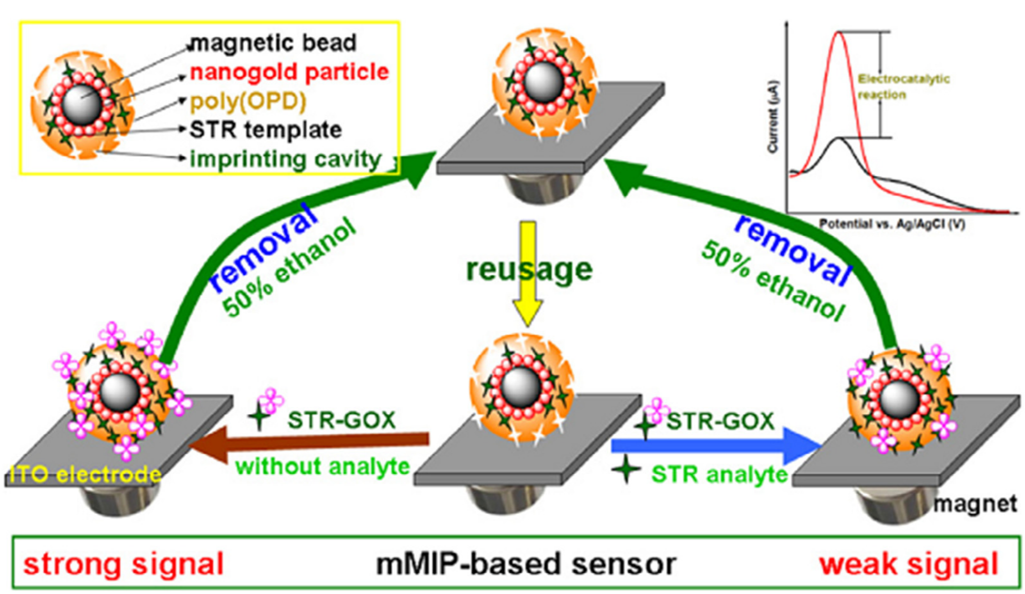

Fig. 1. Schematic illustration of competitive-type electrochemical sensor for the detection of streptomycin (STR) residues. (Reproduced from [17]).