REVIEW PAPER

Nano aptasensors for detection of streptomycin: A review

Asefeh Dahmardeh Ghalehno [1], Majid Saeedi [2], Sajad Razavi Bazaz [3], Peyman Asadi [4], Majid Ebrahimi Warkiani [5,3]*, Rezvan Yazdian–Robati [6]*

[1]Department of Pharmaceutical Biotechnology, School of Pharmacy, Mashhad University of Medical Sciences, Mashhad, Iran
[2]Department of Pharmaceutics, Faculty of Pharmacy, Mazandaran University of Medical Science, Sari, Iran
[3]School of Biomedical Engineering and Institute for Biomedical Materials & Devices (IBMD), University of Technology Sydney, Sydney, NSW, 2007, Australia
[4]Student Research Committee, Department of Medical Nanotechnology, School of Advanced Technologies in Medicine, Mazandaran University of Medical Sciences, Sari, Iran
[5]Institute of Molecular Medicine, Sechenov University, Moscow, 119991, Russia
[6]Molecular and Cell biology Research Center, Faculty of Medicine, Mazandaran University of Medical Sciences, Sari, Iran

ABSTRACT

This review provides a literature update of the progress in optical and electrochemical aptasensors for the detection of streptomycin in human sera and animal-derived foods. The uncontrolled use of antibiotics and rising resistance to them, has created a global problem. Therefore, the detection and quantitation of antibiotics, i.e., streptomycin by robust, easy, and sensitive methods is in great demand. Among different strategies, new analytical methods for the efficient detection and quantitative determination of streptomycin have been developed. Aptasensors or aptamer-based biosensors have attracted more attention due to their unique recognition, simple fabrication, and significant selectivity, sensitivity, and specificity. Advantages of aptasensors will be highlighted in this review, with emphasis on methodological technique and specific properties of aptasensors developed for STR determination. In this review paper, we will focus on the recent development of aptasensors for streptomycin detection, considering the papers summarized in the data bases scopus and google scholar covering the period of time from 2013 till 2021.

Keywords: *Aptamer; Aptasensor; Bacteria resistance; Biosensor; Streptomycin*

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INTRODUCTION

Streptomycin (STR), an aminoglycoside antibiotic, is prescribed for overcoming several serious gram-negative bacterial infections in human and veterinary cares (1-3). Like other aminoglycoside antibiotics, STR has a narrow therapeutic range (low risk-benefit ratio). Its clinical usage is limited by some adverse effects of nephrotoxicity as well as ototoxicity (4). In addition, inappropriate use of STR leads to increase antibiotic resistance of bacteria, which is really harmful to the environment due to uncontrollable disturbance of such bacteria (5). Therefore, the need for finding a selective, sensitive, simple, and accurate monitoring technique is essential for the detection of STR in human sera as well as animal-derived foods while minimizing the resistance toward antibiotics. Biosensors are integrated analytical devices that consist of target recognition and signal transduction components. The principles of biosensors for quantitative or semi-quantitative analytical detection of target analytes is to translate the recognition target responses into quantifiable signals such as electronics or optics (6-8). Currently, aptasensors have been adapted for the rapid detection of different classes of antibiotics (9-13). One of the most common types of recognition elements

* *Corresponding Author Email: majid.warkiani@uts.edu.au; r.yazdian@mazums.ac.ir*
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in aptasensors is aptamers. Aptamers, as an example of functional molecules, are short, single stranded DNA or RNA (ssDNA or ssRNA) and can bind to a specific target, such as carbohydrates, peptides, and proteins. Aptamers with affinity to a specific target can be selected by an *in vitro* method called SELEX (Sequential Evolution of Ligand by Exponential Enrichment) (14). Nucleic acid aptamers provide notable alternative molecule tools in biosensor applications with high-resolution molecular discrimination and high specificity bind to desirable ligands. Low cost, cell-free chemical production, outstanding thermal stability, lack of toxicity, and approximately no immune response in comparison to traditional antibodies, make aptamers increasingly employed in sensor technology (15, 16).

Advantages of aptasensors will be highlighted in this review, with emphasis on methodological technique and specific properties of aptasensors developed for STR determination, focusing on the main analytical parameters such as linear range, the limit of detection (LOD) and sensitivity. As we know two aptamer against STR have been introduced by indipendent group with different efficiency. For the first time, ssDNA aptamer specific to streptomycin was reported by Zhou et al (17) with excellent specificity and sensitivity. In another study, Soheili et al , using a modified magnetic SELEX procedure, identified a 23-base sequence with high affinity and selectivity (Kd= 132.3 nM) against STR (18).

STR aptasensors

Optical and electroanalytical aptasensors proposed for the determination of STR will be discussed in the following sections.

Optical aptamer-based STR biosensors

The different sensing strategies proposed for the optical STR aptasensor determination have been based on colorimetric, fluorescent, and chemiluminescent measurements.

Colorimetric STR aptasensors

The most common method for the detection of STR in different samples is visual observation (19), in which the readout requires naked eyes for comparing the color depth (20, 21). Colorimetric detection has the inherent advantages of simplicity, low cost, and portability; however, due to the dependence on eyes for distinguishing the colors, this method mainly suffers from low detection sensitivity and accuracy (22). Gold nanoparticles (AuNPs) have raised an increasing interest in the development of colorimetric aptasensors for the detection of different antibiotics due to their ultra-high extinction coefficient of the surface plasmon resonance absorption, scattering properties, and also unique electronic features (23, 24) and, for the first time, Zhou *et al.* detected STR in honey in the range of 0.2–1.2 µM by means of a label-free AuNP-based colorimetric assay (17).

In another experiment, Liu and colleagues designed an aptamer-based colorimetric sensor for the detection of STR in milk and honey with LOD as small as 25 nmol/L (25). Generally, the preparation of DNA-modified AuNPs contains a multistep process and is relatively tedious; therefore, alternative methods using unmodified AuNPs were investigated, which depend on the alteration in electrostatic interaction between ss-DNA and ds-DNA with AuNPs. Negative ions stabilize AuNPs, and the repulsion between the negatively charged AuNPs prevents their aggregation. The addition of salt reduces the electrostatic repulsion force and causes the aggregation of AuNPs. The adsorption of the ds-DNA on the AuNPs is less probable due to the rigid structure of ds-DNA. In contrast, ss-DNA with uncoiled structure could get close to the AuNPs. The adsorption of ss-DNA onto the gold surface efficiently stabilizes the AuNPs against salt-induced aggregation. For the first time, Emrani *et al.* developped a dual aptasensor (colorimetric and fluorescence) for the detection of STR in milk and blood serum based on specific aptamer and its fluorescein amidite-labeled complementary strand (FAM-CS). In the absence of STR, STR aptamer/FAM-CS is stable, and by adding salt, a blue solution of aggregated AuNPs observed, and strong fluorescence emission was detected. The presence of STR prompts the formation of the aptamer-target block and releases the CS to coil around the surfaces of AuNPs to block the salt-induced aggregation. Therefore, a red-colored solution is observed, and the fluorescence of FAM-CS quenched by AuNPs. The LOD for colorimetric and fluorescence quenching of this designed dual aptasensors were reported as low as 73.1 and 47.6 nM, respectively (26).

A smartphone-based colorimetry of aptamer-conjugated AuNPs for quantification of STR was introduced by Liu *et al.* In this sensing platform, a battery-powered optosensing accessory was

mounted to the smartphone's camera for the detection of STR. The detection mechanism in this aptasensor to probe STR depends on the exceptional distance-dependent optical feature of AuNPs, changing its color from wine-red to blue color upon aggregation because of their size-dependent surface plasmon resonance absorption. After the addition of STR to the sample, STR bound to the aptamer, and subsequently, aggregation of AuNPs happens. The turnover process from the dispersion of AuNPs to aggregation form is correlated with the characteristic absorption peak shift from ~520 nm to ~625 nm. Increasing the STR concentration resulted in the systematic enhancement of the absorbance at 625 nm (A625) and the reduction of the absorbance at 520 nm (A520). Therefore, the changes of this absorbance ratio (A625/ A520) are recorded through a smartphone, on which an absorption spectrometer through dual-wavelength illumination was attached. The system provided a LOD of 12.3 nM and was evaluated with milk, honey and tap water samples, which confirms the applicability and reliability of this system towards the detection of STR (27).

Another property of AuNPs, dispersed in a liquid phase, is its intrinsic catalytic activity in which they can oxidize the substrate to form a variety of colored products. This can offer a particular signal output for aptameric colorimetric sensors. Using the catalytic property of AuNPs in STR detection, Zhao *et al.* built a colorimetric aptasensor with a linear range from 0.1 µM to 0.5 µM and a LOD as low as 86 nM in the milk sample .(28) According to this study, in the absence of STR, AuNPs were attached to STR1 aptamer and restrained its catalytic activity because of the shielding effect of ssDNA against substrates. When STR was added, STR1 aptamer was dissociated from AuNPs surface to bind to STR and made an STR-aptamer complex; hence, AuNPs peroxidase activity was significantly enhanced, enabling the AuNPs to oxidize the substrates.

Nanocomposites such as silica (silicon dioxide) have been widely used in different areas of study, including colorimetric aptasensors. Silica nanoparticles (SNPs) are ideal nanoparticles for the preparation of the sensor due to their convenient synthesis, high hydrophilicity, large specific surface area, high density, bio-compatibility, cost-effective process, excellent thermal and chemical stability and easy surface functionalization (29). Luan *et al.* developed a colorimetric STR aptasensor consist of porous SiO2 micro-beads, exonuclease enzyme and enzyme-linked polymer probes. The probe was made by ss-DNA binding protein labeled SiO2 micro-particles (P-SiO2-SSB) as capture probe and AuNPs with aptamer on Powervision™ regent (PV) (Apt-Au-PV) as nano-tracer. If the STR and Exonuclease I (Exo I) coexisted, the STR would combine with nano-tracer, and STR/Apt-Au-PV was formed. Hereafter, Exo I can digest Apt on STR/Apt-Au-PV to release the nano-tracer to recycle the reaction again and amplify the sensitivity. There is a large amount of horseradish peroxidases (HRPs) on the dendrimer PV surface and can catalyze H_2O_2-TMB (3,3',5,5'-tetra-methyl-benzidine) for color expansion. Results can be observed by a naked eye due to the recycling effect of Exo I and PV containing nano-tracer. Using this approach, a concentration down to 1 pg per ml in food tests was detectable (30).

A label-free aptasensor for the detection of STR in raw milk with LOD of 47.2nM introduced by Soheili *et al.* first., Specific aptamers for STR were identified by SELEX and employed together with magnetic beads with high affinity (Kd = 132.3 nM) and selectivity. The identified aptamer adsorbed onto the AuNPs and prevented AuNPs from aggregating. When aptamers interact with STR, they fell from the surface of colloidal AuNPs. Aggregation of AuNPs in the presence of salt along with a specific and visual color conversion from wine-red to blue allows simple interpretation of results See(Fig. 1) (18). Collectively, although STR nano-aptasensors based on colorimetry are now in the nascent phase, they can be promising tools for diagnostics of STR in both food and blood. Moreover, AuNPs can be suitable candidates for the design of AuNPs colorimetric STR sensing kits due to their higher extinction coefficient in comparison to traditional organic dyes result in high sensitivity. However, detection of STR in serum blood using commercial AuNPs aptasensor kits remains a challenge since the formation of AuNPs -protein corona which occupy the surface of the exogenous AuNPs. The surface coating of AuNPs with proteins such as PEG can addressee this problem (31).

Fluorescence-based streptomycin aptasensors

In analytical chemistry, the fluorescence technique is one of the most sensitive optical methods, which offer in the fabrication of aptasensors an increased selectivity, sensitivity,

and high efficiency (5). Quantum dots (QDs) (diameters between 1 nm to a few microns) as exceptional nano-fluore tags have been used in semiconductor-based aptasensors owing to their unique electronic and optical features, including high quantum yield, resistance to photo-bleaching, and high fluorescence and photochemical stability. However, toxicity is the main drawback of QDs. Gan and colleagues used a single stranded DNA binding protein (SSB) labeled quantum as a signal tag and exonuclease-assisted target recycling to achieve fluorescent "turn-on" aptasensor for the specific detection of STR in real milk samples. First, QDs were conjugated with the STR specific aptamer, showing weak fluorescence emission. Upon the addition of Exo I and STR into the reaction system, interaction between aptamer and STR occurs; therefore, QDs were re-dispersed into the solution, and the sensor "turns-on." Moreover, aptamers are amenable to decompose by Exo I to release a large number of targets. The free targets can re-bond preferentially to the aptamer to generate the next cycle. This assay showed a meaningful linear relationship in a range of 0.1-100 ng mL^{-1} and LOD of 0.03 ng mL^{-1}. This assay offers many advantages including simple experimental technique, avoiding phase separation and washing steps (32). The incorporation of different nuclease enzymes, such as exonuclease III or I, in the designing of aptasensors has been frequently reported (33). For example, Taghdisi *et al.* proposed a label-free fluorescent aptasensor based on exonuclease III activity (Exo III), aptamer complimentary strand and SYBR Gold. In this new target recycling-oriented amplification sensing platform, SYBR Gold works as a fluorescent dye, and Exo III digests the 3' -end of dsDNA. In the absence of STR, dsDNA is stable, and upon adding the Exo III, weak fluorescence intensity was detected. In the presence of STR, aptamer binds to its target and complementary strand released from STR aptamer. At this time, addition of SYBR Gold to reaction, resulted in strong fluorescence intensity. Using this enzyme amplified approach, the designed aptasensor shows a LOD down to 54.5 nM (34). However, the incorporation of Exo III may consider as the main disadvantage of this aptasensor since it complicates the detection process (5). Fluorescence assay has been utilized in smartphone-based systems to identify the formation complex of aptamer-STR using a fluorescent signal reader (35). As an example, a

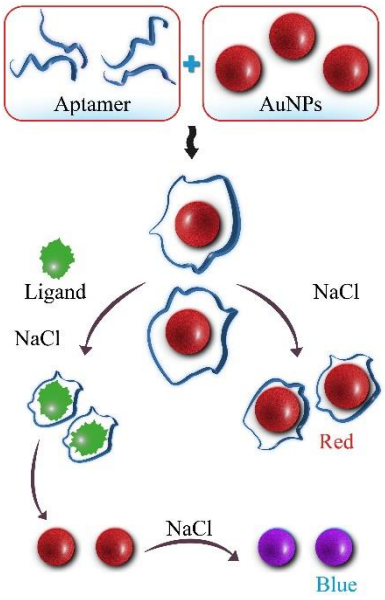

Fig 1. Examples of colorimetric aptasensor determination of STR: System based on the use of aptamers in the presence of salt

smartphone-based sensing platform was built for the indirect and fast quantification of STR. In principle, the excess STR aptamer with the complementary DNA strand forms the dsDNA and then combines with SYBR Green I, emitting visible green fluorescence. Increasing STR concentration in samples causes a decrease in fluorescence intensity, which is processed by *Touch Color* APP installed on the smartphone. Using this device, the LOD of STR was reported as low as 94 nM, with a linear ranging from 0.1 to 100 µM (36).

In general, among various metal NPs, QDs have been widely applied in structure of STR aptasensors due to their high quenching property. However, intrinsic blinking, low fluorescence and chemical instability may affect the sensivity of the sensing platforms using QDs. Using the fluorophores with time-resolved fluorescence characteristics may overcome to this issue (37).

Chemiluminescence (CL) sensors

Sun *et al.* designed a CL aptasensor containing aptamers as a specific recognition element and G-quadruplex DNAzyme (G-DNAzyme) as a catalyst and 3D graphene composite for highly selective and sensitive detection of STR. In the existence of target, STR specifically binds to aptamers; consequently, G-DNAzyme liberated from the surface of 3D graphene composite

into the sample solution. G-DNAzyme catalyzed the CL reaction of luminol-H_2O_2, leading to the quantitative identification of STR. As reported, the LOD of aptasensor was 9.2 ×10^{-14} mol/l in the concentration range of 1.4×10^{-12} to 2.8×10^{-9} mol/L in cucumber and milk samples (38).

A brief overview of STR optical aptasensors

In short, it can be concluded that the use of colorimetric methods is the most straightforward strategy to be employed in aptamer based sensors, which can easily identify the presence of analyte without any requirement for advanced and costly facilities as well as the adroit user. Labeling with fluorophores and quenchers in fluorescence aptasensors as another optical method may disturb the target-binding characteristics and recognition efficiency. According to the reported LODs, the CL-based aptasensors exhibited high sensitivity for the detection of STR, whereas the colorimetry method had the lowest sensitivity. The analytical characteristics of some of the available optical-based STR aptasensors are listed in Table 1.

Electrochemical-based STR aptasensors

Electrochemical aptasensors have attracted considerable interest due to their simplicity, readily available miniaturization, low cost, fast processing, rapid response, and highly specific and sensitive detection of antibiotics (40-42). Electrochemical aptasensors compared to optical sensors require less amount of target molecules for the detection purpose (43, 44). Based on observed parameters, they can be classified into amperometric (current), voltammetric, impedimetric (impedance), and photoelectrochemical systems.

Amperometric methods

Amperometric biosensors measure the electric produced current from the oxidation or reduction taken place during the determination of the target analyte at a fixed potential value (8).

To the best of our knowledge, the first facile and label-free electrochemical aptasensor proposed for the quantitative determination of STR was reported by Yin *et al.* (45). In the fabrication of this sensing platform, AuNP-functionalized magnetic multi-walled carbon nanotube (Au@MWCNTs–Fe_3O_4) composites were exploited as a load matrix for fixing of nanoporous PtTi (NP-PtTi). They also served to improve the sensitivity of amperometric signal alloy. A linear relationship between the

Table 1. Analytical features of some optical-based streptomycin aptasensors

Biosensor type	Strategy	LOD	Sample	Ref.
Colorimetry	AuNP and aptamer	200 nM	Honey	(17)
Colorimetry	AuNP and aptamer	100 nM 125 nM	Milk Honey	(25)
Colorimetry	aptamer-conjugated AuNPs	12.3 nM	Milk	(27)
Colorimetry	aptamer and catalytic activity of AuNPs,	86 nM	Milk	(28)
Colorimetry	(P-SiO2-SSB) as capture probes (Apt-Au-PV) as Nano tracer	1 pg mL^{-1}	Milk	(30)
Colorimetry	aptamer-conjugated AuNPs	47.2 nM	Milk	(18)
Fluorescence	SYBR Green I combined with the dsDNA	94 nM	chicken and milk	(36)
Fluorescence	DNA binding protein labeled QDs and Exo I	0.03 ng mL^{-1}	Milk	(32)
Fluorescence	Exonuclease III (Exo III), SYBR Gold and aptamer complimentary strand	54.5 nM 71.0 nM 76.05 nM	Buffer Rat serum Milk	(34)
Colorimetry, Fluorescence	STR-induced release of complimentary strand from aptamer, strong interaction of ssDNA and AuNPs and no or less interaction of dsDNA and AuNPs	73.1 nM(CoL) 47.6 nM(FL)	milk and serum	(26)
Fluorescence	a fragment of the STR-specific split aptamer and silica	33 nM	water and PBS	(39)
Chemiluminescence	G-quadruplex DNAzyme and 3D graphene composite	92 ×10^{-4} nM	Milk, Cucumber	(38)

current and STR concentration was observed in the range of 0.05 to 100 ng ml^{-1} being LOD 7.8 pg ml^{-1}. The detection of STR in milk samples revealed that the potential applications of this aptasensor in the field of food analysis (45).

Voltammetric methods

Different voltammetric aptasensors have been reported for the detection of STR . They can be classified into cyclic voltammetry (CV), square wave voltammetry (SWV), differential pulse voltammetry (DPV) and linear sweep voltammetry (LSV).

Taking the advantages of large surface area and superior electrochemical conductivity of AuNPs, Danesh *et al.* reported an aptasensor for the detection of STR. They constructed the electrochemical aptasensor by immobilizing the thiolated STR biding aptamer on screen-printed gold electrodes. The addition of thiolated complementary DNA strand resulted in an arch-shape construct. Without analyte, the secondary arch-shape of Apt-CS repulsed electron transfer of [Fe(CN)6]3-/4- redox probe at a gold electrode. Conversely, adding of STR to the sample, aptamer binds to STR, conformation of aptamer changes and leaves the CS; meanwhile, addition of exonuclease I degrade the CS strand, resulting in an increased attraction of redox mediator [Fe(CN)6]3-/4- to the electrode surface; hence, the electrochemical signal increased. According to the findings of this work, using DPV and CV measurements of [Fe(CN)6]3-/4- at the proposed electrode, a LOD of 11.4 nM STR was achieved. Additionally, quantification of the STR in milk and serum confirmed the good efficiency of the designed sensor for the analysis of real samples (46). Another aptasensor proposed in the literature for the detection STR in milk was reported by Li *et al.* In that study, cadmium and lead ions were connected to the STR and kanamycin aptamer and then were fixed on the surface of multiwalled carbon nanotubes with high charge transfer by hybridization with complementary strands. Once the STR was present in milk, the ions bond to the specific aptamers and released into solution; at the same time, the variation in their reduction currents was detected by DPV, reaching a LOD of 36.45 pM with a linear range from 0.1 to 100 nM (47).

Xue *et al.* designed a detection system of STR based on QD tags attached with aptamers. In this platform, the STR aptamers were hybridized with a complementary strands (cDNA1s). In the presence of STR, STR bonded to their corresponding aptamer, STR aptamers dissociated the duplex DNAs, and the cDNA1s released. The free cDNA1s were then bonded with their corresponding Cap-DNAs, which are fixed on the Au electrode surface by self-assembly. After that, the prepared PbS, CdS, and ZnS QDs-tagged cDNA2s were hybridized with the other parts of the cDNA1s on the Au electrode surface. The captured QDs prompt the electrochemical signals, monitored by SWASV technique (48). Yin and colleagues fabricated three similar electrochemical STR aptasensors based on the fixation of the aptamer on the surface of modified electrodes with various nanocomposites, including MWCNTs/copper oxide (CuO)/AuNPs (49), AuNPs/magnetic MWCNTs/nanoporous PtTi alloy (45), and porous carbon nanosphere graphene/Fe_3O_4/AuNPs (50).

Electrical impedimetric spectroscopy (EIS) methods

EIS method is a robust and non-destructive approach that has recently been exploited as diagnostic tool (51). An aptasensor with improved sensitivity of STR detection was reported by Roushani *et al* using thiolated STR aptamer immobilized on the AgNPs/GQDs-N-S/AuNPs/GCE. Under optimum conditions, the EIS signals were proportional to STR concentration from 0.01–812.21 pg·ml^{-1} with LOD of 0.0033 pg ml^{-1} (52).

Ghanbari and Roushani synthesized a simple impedimetric electrochemical aptasensor based on a new signal amplification approach for the selective and sensitive detection of STR. They immobilized AuNPs on the SH group of graphene quantum dots (GQDs) via bonding of Au-S and then fixed onto the surface of a glassy carbon electrode. Aptamer grafted on the surface of the electrode via the interaction of aptamers thiol group and made Apt/AuNPs/GQD-SH/GCE nanoaptasensor. Upon the adding of STR to sample, Aptamer and STR were conjugated, and the variation in signal transduction exhibited a broad linear range from 0.1 - 700 pg/ml (53).

Photoelectrochemical sensors (PEC)

Xu *et al.* fabricated a QD-based photoelectrochemical aptasensor with amenable detection of STR in honey samples. This nanoaptasensor mainly comprise of Cadmium Telluride (CdTe) QDs fixed by single-walled carbon

nanohorns (SWCNHs) onto an ITO electrode and aminated aptamer. This device can generate photocurrent, which is sensitive to STR in the surrounding solution. Under irradiation of visible light and in the absence of the STR, the photocurrent intensity diminished while in the presence of STR in honey samples, this situation changes obviously; aptamer bond to STR and released from the modified electrode, and a photocurrent was generated. This aptasensor exhibited LOD of 0.033 nM and linear response ranging from 0.1 nM to 50 nM (54). Okoth *et al* designed aMo-doped BiVO4 (Mo-BiVO4) and graphene nanocomposites system sensitive to STR determination in commercial veterinary drugs. Authors used photoactive materials to fabricate a visible light-driven photoelectrochemical biosensor. Mo-BiVO4 on graphene enhanced charge transfer rate and the absorption of visible light, causing an improvement in the photocurrent intensity. Without analyte, a weak photocurrent response was observed due to the steric hindrance effect. After incubation with STR, the photocurrent response was obviously enhanced. Linear photo-response to STR in the 0.1 -100 nM range, with a LOD of 0.0481 nM was obtained by this PEC aptasensor. The applicability of this sensor was successfully tested in commercial veterinary drugs (55).

A brief overview of electrochemical methods

As shown in Table 2, the voltammetry-based platforms are among the most common approaches used for the detection of STR using aptasensors. The need of low analyte amounts, reusable nature of the system and fast response, highly sensitivity, simple miniaturization, low-cost as well as fast detection capability are some of the advantages of these methods (57). However, this strategy suffers from certain drawbacks, such as false positive results made from the presence of matrix electrolytes and insufficient control on the working electrode (58).

CONCLUSIONS AND FUTURE PERSPECTIVES

The most commonly applied conventional detection methods for STR determination in

Table 2. Analytical features of some Electrochemical-based streptomycin aptasensors

Biosensor type	Strategy	LOD	Sample	Ref.
Amperometric	Au@MWCNTs–Fe3O4/NP-PtTi composite onto a glassy carbon electrode (GCE) surface.	7.8 pg ml^{-1}	Buffer	(45)
Voltammetric	structure of aptamer (Apt)-CS conjugate and gold electrode and based on exonuclease I (Exo I)	11.4 nM 14.1 nM 15.3 nM	Buffer Milk Rat serum	(46)
Voltammetric	multi-walled carbon nanotubes (MWCNTGr) and carbon nanofibers-gold nanoparticles (CNFs-AuNPs)	36.45 pM	Milk	(47)
Voltammetric	Aptamers and quantum dot (QD) tags	10 nM	milk	(48)
Voltammetric	multiwalled carbon nanotube–copper oxide–gold nanoparticle nanocomposites	0.036 ng ml^{-1}	Buffer	(49)
Voltammetric	porous carbon nanosphere and multifunctionalgraphene composite (GR–Fe3O4–AuNPs)	0.028 ng/ml	Buffer	(50)
Impedimetric	(AuNPs) and thiol graphene quantum dots (GQD-SH)	0.0033 pg ml^{-1}	Serum	(52)
Impedimetric	AuNPs/GQD-SH as nanocomposite and K3Fe(CN)6/K4Fe(CN)6 as the redox probe	0.033 pg ml^{-1}	Serum	(53)
PEC	CdTe quantum dots-single walled carbon nanohorns (CdTe-SWCNHs) nanocomposite	0.033 nM	Honey	(54)
PEC	Mo-doped BiVO4 (Mo-BiVO4) and graphene nanocomposites	0.0481 nM	commercial veterinary drugs	(55)
Voltammetric and Impedimetric	thiolated aptamer and gold nanoparticles adsorbed on the surface of reduced graphene coated-pencil lead graphite electrode	0.8 × 10 − 18 M	milk	(56)

food and clinical samples are based on capillary electrophoresis (CE) and chromatography, using both, gas (GC) and liquid (LC) chromatography, mainly based on the use of Mass spectrometry detection in LC(LC-MS).However these methods have some limitations, such as skillful technicians, expensive and non-portable laboratory instruments, and time-consuming sample preparation procedures. Hence, alternative detection and monitoring assays are required for rapid and sensitive detection. Biosensors offer an exciting alternative to the traditional methods for STR determination due to their high selectivity, portability and rapid in-situ application. Among various biosensors, aptamer-based sensors (aptasensors) has gained much traction in clinical, biological, and environmental science due to rapid, simple, and sensitive detection of targets. Streptomycin abuse could cause severe side effects and recently fabricated aptasensors have been proposed for its detection in humans. However some of the proposed systems have some difficulties such as non-specific interaction, time-consuming, and functional problems. For instance, the applicability of some described aptamers depends on such experimental conditions as pH, temperature, ionic strength and viscosity. Besides, some of the aptamers mentioned above are only functional in buffer solutions of standards without application in real samples. To overcome these drawbacks, researchers are attempting to design fast, cheap, and simple sample preparation methods. Electrochemical and optical aptamer aptasensor for streptomycin detection based on optical and electrochemical measurements offer simplicity, portability, and high sensitivity. Target-induced strands displacement is another signal transduction strategy in aptamer-based biosensors for STR detection. The challenge in these replacement reactions is that the affinity of the aptamers towards the targets must be stronger than the complementary strand DNA. According to recent studies, the most frequently antibiotics detected by aptasensors are kanamycin, tetracycline, chloramphenicol, and oxytetracycline. So, there is a great potential for specific aptasensors development for other antibiotics like streptomycin. In conclusion, regarding the advantages of aptamer over antibody it can be noticed that aptasensors technonoly is cheaper than antibody one and thus has a big potential for commercial, clinical applications as well as point-of-care detections.

CONFLICT OF INTEREST

There is no conflict of interest in this article.

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