

Traditional Gold-labeled and Nanozyme-enhanced Immunochromatographic Test Systems for Fluoroquinolone Detection in Food

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Abstract

Antibiotic residues, particularly fluoroquinolones, are among the major food-safety concerns because of their widespread use in animal husbandry and their serious public health effects. Rapid, highly sensitive, and selective detection methods are therefore essential to prevent antibiotic contamination of food products and minimize human exposure. In this study, we present a set of advanced immunochromatographic assay (ICA) technologies for the detection of fluoroquinolone antibiotics, specifically gatifloxacin (GAT) and two enantiomeric forms of ofloxacin (OFL), in various food matrices. Both traditional and nanozyme-enhanced ICAs using gold nanoparticles and catalytically active bimetallic nanoparticles (Au@Pd and Au@Ag) as labels were developed. The nanozyme-based platforms exploit peroxidase-mimicking signal amplification, yielding instrumental limits of detection as low as 0.8 pg/mL for GAT and 1.4 pg/mL for S-OFL. Sensitivity was thereby improved by up to 625-fold compared with traditional AuNP-based ICAs. For the first time, a multiplexed double ICA was developed for the simultaneous enantioselective detection of S- and R-ofloxacin isomers using a universal polyclonal antibody and distinct coating conjugates, with LODs of 0.001 ng/mL and 0.007 ng/mL, respectively, and negligible cross-reactivity. This approach enables integrated monitoring of pharmaceutical components that differ in biological activity. All developed test systems enable assays to be completed within 25 min and require only minimal sample preparation, making them suitable for on-site screening. Validation in milk and raw meat samples demonstrated recoveries of 77-115% and confirmed analytical performance consistent with reference HPLC and ELISA methods. The presented approaches provide powerful tools for robust, sensitive, specific, and stereospecific monitoring of antibiotic residues, directly supporting food safety and regulatory compliance. This study was supported by the Russian Science Foundation (grant no. 24-46-00026).

Keywords

Fluoroquinolone Antibiotics, Immunochromatographic Assay, Gold Nanoparticles, Bimetallic Nanozymes, Nanozyme-enhanced Detection, Stereospecific Analysis, Food Safety