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Biochip-based detection of foodborne pathogens

Christopher Pöhlmann and Thomas Elßner
Bruker Daltonik GmbH, Leipzig, Germany, C.Poehlmann@bruker.com

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Abstract

Critical infrastructure, such as the food supply chain, is at risk of malicious attacks which includes terrorism. Microbiological analysis is presently based on cultivation of samples and colony counting on selective media followed by microscopy and biochemical testing. These methods are time-consuming and laborious. In past, we demonstrated the application of the rapid portable immunoassay based biochip platform pBDi for multiplex detection of various biothreat agents including bacteria, viruses and toxins. Developed for use by non-scientific personnel, the biochip platform is easily operated, even while working in protective equipment under extreme conditions as well as in resource-limited settings. Here, we present an electrochemical biochip for multiplex detection of six foodborne pathogens (*Vibrio cholerae*, *Salmonella* spp., *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Shigella* spp., *Listeria monocytogenes*) exhibiting 20 minutes assay time. The detection event is strongly amplified in this system due to the high turnover of enzymatic reaction and the redox cycling procedure between interdigitated electrodes built into the experimental procedure. Limits of detection for multiplex detection of food pathogens are in the range of 10^3 – 10^6 CFU mL^{-1}. A standardized protocol for sample preparation of liquid as well as solid samples was successfully applied for detection of foodborne pathogens in various sample matrices. These results substantiate the comprehensive potential of the biochip platform pBDi for detection of all kinds of biological threat agents no matter whether has been used in civil or military environment.

Introduction

Foodborne pathogens pose a serious health risk in higher-income countries where foodborne bacteria cause high numbers of hospitalizations and deaths each year. *E. coli* O157:H7, salmonellae, *C. jejuni*, and *L. monocytogenes* are the leading causes of bacterial food- and waterborne illnesses. Therefore, appropriate monitoring is essential to ensure safe food handling all along the food chain. Existing detection methods are long or tedious so we have developed a biochip system able to detect and identify various bacteria simultaneously in an automated manner.

Methods

- Detection platform pBDi integrated in a robust suitcase for use in the field by first responders (Fig. 1 A).
- Monoclonal capture antibodies against food pathogens are immobilized on electrodes of a biochip (Fig. 1 B).
- Inherent positive and negative control.
- Based on an automated electrochemical sandwich-ELISA (Fig. 1 C).
- Multiplex detection of up to 6 agents within 20 minutes.
- Very sensitive due to strongly amplified electrochemical detection system including a redox cycling process of enzyme product between interdigitated electrode structure (Fig. 1 C).
- Ready-to-use assays for multiplex detection of bioterrorism relevant bacteria, viruses and toxins available

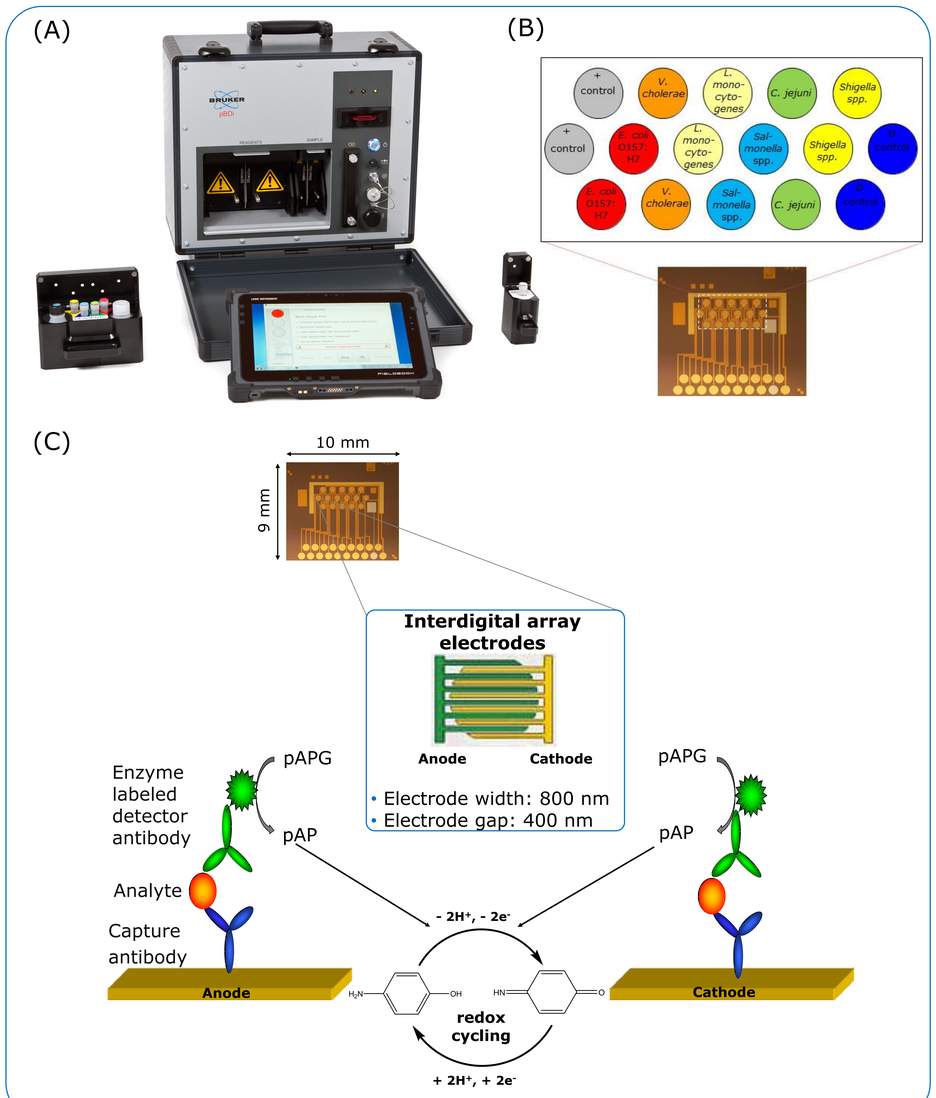

Fig. 1 (A) The pBDi platform. (B) Biochip layout for multiplex foodborne pathogens detection. (C) Principle of electrochemical sandwich ELISA.

Results

- Limit of detection down to 10^3 CFU/mL (Fig. 2)
- Highly specific detection of foodborne pathogens (Fig. 3)
- Minimal sample preparation procedure allows detection of foodborne pathogens in various food matrices with high recovery rates (Fig. 4)

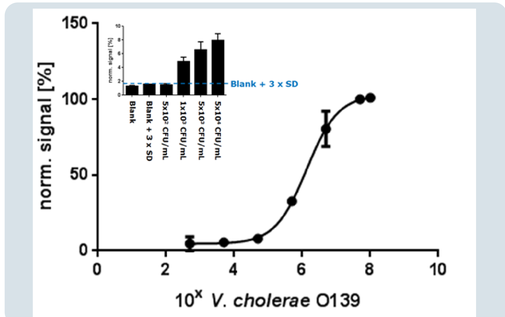

Fig. 2 Electrochemical signal as a function of *V. cholerae* O139 concentration (n=3).

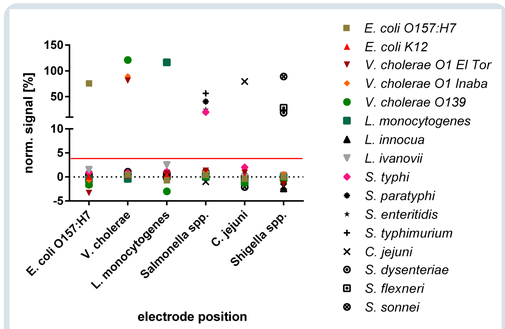

Fig. 3 Specificity of foodborne pathogen detection was assessed with high bacteria concentrations (≥ 5.0x10^6 CFU mL^{-1}). Results were defined as positive when the normalized signal exceeds the threshold value (red line).

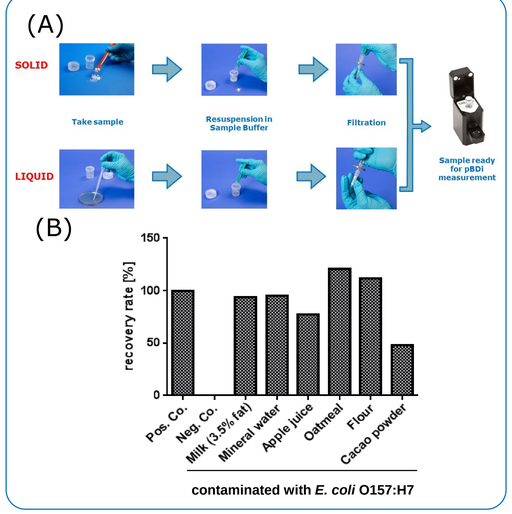

Fig.3 (A) Sample preparation procedure. (B) Recovery rates of detection of 3x10^5 CFU mL^{-1} *E. coli* O157:H7 in food matrices.

Conclusions

- Foodborne pathogens analysis in approx. 20 minutes with an automated procedure
- Parallel detection of six foodborne pathogens including positive and negative control
- High robustness towards food sample matrices
- Excellent sensitivity and specificity

pBDi