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A portable smart-phone device for rapid and sensitive detection of *E. coli* O157:H7 in Yoghurt and Egg

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ABSTRACT

The detection of *E. coli* O157:H7 in foods has held the attention of many researchers because of the seriousness attributed to this pathogen. In this study, we present a simple, sensitive, rapid and portable smartphone based fluorescence device for *E. coli* O157:H7 detection. This field-portable fluorescent imager on the smartphone involves a compact laser-diode-based photosource, a long-pass (LP) thin-film interference filter and a high-quality insert lenses. The design of the device provided a low noise to background imaging system. Based on a sandwich ELISA and the specific recognition of antibody to *E. coli* O157:H7, the sensitive detection of *E. coli* O157:H7 were realized both in standard samples and real matrix in yoghurt and egg on our device. The detection limit *are* 1 CFU/mL and 10 CFU/mL correspondingly. Recovery percentages of spiked yogurt and egg samples with 10^3, 10^4 and 10^5 CFU/mL *E. coli* O157:H7 were 106.98, 96.52 and 102.65 (in yogurt) and 107.37, 105.64 and 93.84 (in egg) samples using our device, respectively. Most importantly, the entire process could be quickly completed within two hours. This smartphone based device provides a simple, rapid, sensitive detection platform for fluorescent imaging which applied in pathogen detection for food safety monitoring.

1. Introduction

Food safety remains a noteworthy concern around the world. *Escherichia coli* O157H7 is a serotype of *E. coli* and is one of the Shiga toxin producing types of *E. coli* that normally present in the gastrointestinal tract of humans and animals. The presence of risky levels of Enterohemorrhagic *E. coli* O157:H7 in food represents a serious threat to the security of the food supply and human wellbeing because of its ability to cause severe illness like hemorrhagic colitis, hemolytic uremic syndrome (HUS) and thrombotic thrombocytopenic purpura (TTP) (Karmali et al., 1983; Zeinhom et al., 2012).

Although bovine food products contaminated with bovine waste are the most common sources for *E. coli* O157:H7 outbreaks in the United States, the center for disease control (CDC) reported that *E. coli* O157:H7 outbreaks are not limited to any specific type of food (CDC, 2017). For example, other main sources of *E. coli* O157:H7 outbreaks originate from undercooked food products such as raw meat products, ready-to-eat salads, unpasteurized fruit juices, cheese curds, and raw milk (Armstrong et al., 1996; FDA 1998; CDC 2013).

The detection of *E.coli* O157:H7 in food samples continues to rely on selective culturing media which need a minimum of 2 days for detection and requires further confirmation tests (Zeinhom and Abdel-latif, 2014). Comparing with this method, the immunoassays such as conventional enzyme linked immunosorbent assay (ELISA) offers high selectivity, and reduced the detection time. Magnetic nanoparticles have been recently exploited as supports and carriers in biosensors for food safety. Besides large surface area and good biocompatibility, the outstanding advantage of magnetic nanoparticles is that the location and transport can be controlled by magnetic field (Chapman et al., 1994; Bennett et al., 1996; Tomoyasu, 1998; Fegan et al., 2004; Han et al., 2014; Wei et al., 2017). Fluorescent antibody staining is commonly used to detect the activity of injured and/or starved bacteria at a single cell level (Gunasekera et al., 2000). This fluorescent labeled techniques could achieve a rapid detection of specific bacterial cells (Nakamura et al., 1993; Tanaka et al., 2000; Yamaguchi et al., 2003).

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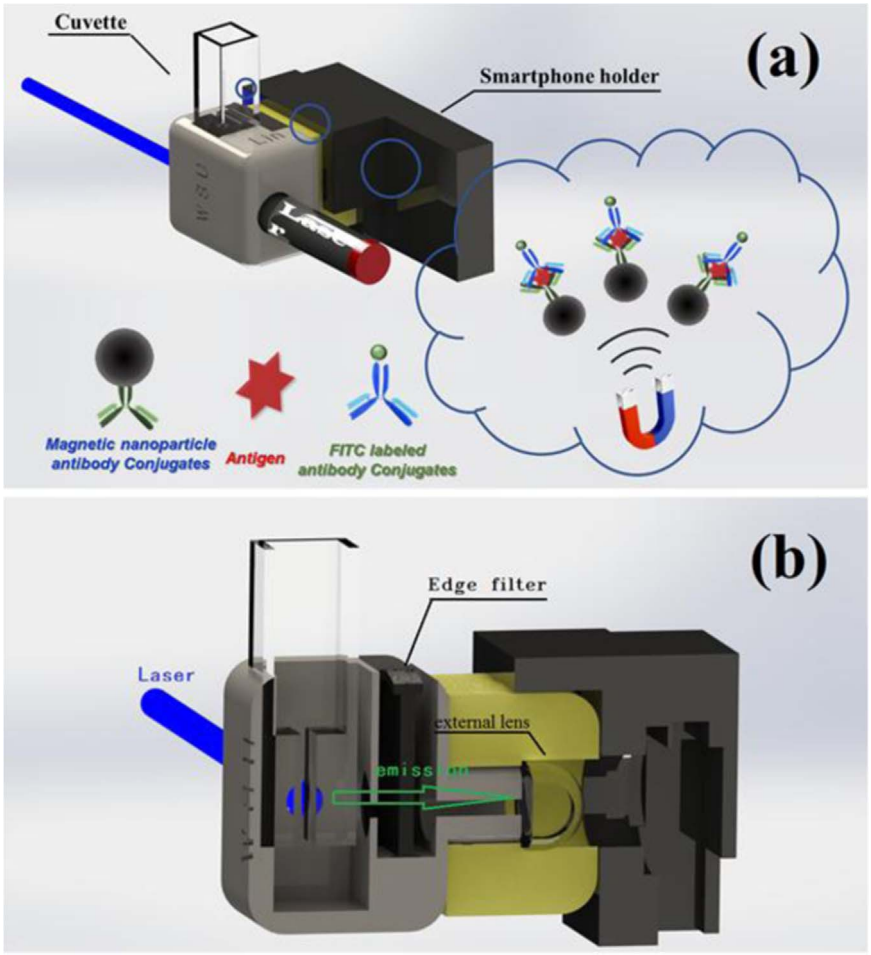

Scheme 1. Schematic illustration of the portable smartphone based device with sandwich immunosensor for *E. coli* O157:H7 detection.

Those methods improve the sensitivity of the ELISA, however, expensive and large microplate readers for signal output were still required for testing (Strachan and Ogden, 2000; Kaittanis et al., 2010; Manguiat and Fang, 2013). In this manner, the general cost of detection is still high to anticipate wide-scale application, particularly in developing countries (Salyers and Whitt, 2002; Lui et al., 2009). To lower the cost of detection and realize the onset of contamination, it is important to develop a simple, onsite, sensitive, low cost and small platform that can quickly detect *E. coli* O157:H7 in food samples for food safety monitoring.

In recent years, smartphones or other commercial electronics devices have been emerging as powerful platforms to develop low cost, portable and readily accessible alternatives to achieve some of the advanced detection application (You et al., 2013; Petryayeva and Algar, 2014; Zangheri et al., 2015). The smartphone based application holds enormous potential over others due to its multifunctional and high-quality camera. The feasibility of smartphone based applications makes them ideal platforms for conducting a variety of tests – including DNA (Wei et al., 2014), small molecules (Zangheri et al., 2015) and metal ions (Xiao et al., 2016). Many researchers have used smartphone for fluorescent detection (Coskun et al., 2013; Rayendran et al., 2014; Barbosa et al., 2015). Despite all of the promising progress, fluorescence detection on a smartphone device remains a big challenge, mostly due to low signal-to-noise ratio.

Here we demonstrate a compact and lightweight optical device attached to the existing camera module of a smartphone for detection of *E. coli* O157:H7. This field-portable fluorescent imager on the cell phone involves three parts : excitation light resource, sample chamber and signal collection system. Instead of using expensive complicated optical component, we only employed a long pass filter and a focusing lens for collecting the image. Through the 3D printed case, the three parts were assembled in a small bulk. We demonstrated the application of this device for food pathogen detection. The results were collected by the proposed portable smartphone based platform and commercial laboratory microplate reader. According to our reported results, the portable smartphone based device is highly sensitive and was comparable to the commercial microplate reader. Based on the classical sandwich ELISA design, the specific, rapid detection of *E. coli* O157:H7 in foods were realized within 2 h on this portable platform.

2. Experimental section

2.1. Reagents and materials

E. coli O157:H7 EDL933 was obtained from the STEC center at Michigan State University. *Salmonella* Enteritidis PT30 was from American Tissue Culture Collection (ATCC, Manassas, VA). *Listeria innocua* (NRRL B-33197) was obtained from USDA ARS culture collection. *Staphylococcus aureus* (91.48) was an isolate from mastitic cows was obtained from school of food science at Washington State University. Magnetic beads conjugated antibody (Dynabeads anti-*E. coli* O157:H7, Rev. No. 007, Dynal Biotech, Oslo, Norway) was purchased from Thermo Fisher scientific (Phadia US).

Fluorescein isothiocyanate (FITC)-labeled rabbit polyclonal antibody was purchased from Abcam (Cambridge, MA). Phosphate-buffered saline (PBS, 0.01 M phosphate buffer, 0.0027 M potassium