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Portable DNA Detection Tool for Halal Monitoring Using Spectral Sensing

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ABSTRACT

Pork and its derivatives are non-halal in Islam, raising concerns about cross-contamination in food. With the growing number of Muslim tourists and Taiwan's efforts to expand its halal F&B exports, strict halal compliance and reliable detection methods are essential. Conventional techniques like PCR offer high accuracy but are limited by long processing times and the need for advanced laboratories. Recombinase Polymerase Amplification (RPA) presents a faster alternative, operating at a constant temperature without thermal cycling. This study developed an RPA-based device for real-time pork DNA detection using Fluorescein Amidite. Emission intensity was measured via a spectral sensor with excitation light and an Arduino system. Results showed that shorter distances between the light source and sample improved signals, while a green filter enhanced green light emissions. The optimal volume was 1.2 µL, and detection was effective down to 1 pg/µL, with lower concentrations producing weaker signals. Gel electrophoresis validated these findings.

Keywords: Halal authentication, DNA detection, spectroscopy, Arduino-based device

INTRODUCTION

Pork and its derivatives are non-halal, making rapid and sensitive detection crucial for halal compliance in Taiwan's food exports. Recombinase Polymerase Amplification (RPA) enables fast DNA diagnostics at 37 °C in 20 minutes, producing fluorescence signals via FAM-labeled probes detectable by portable devices (Li et al., 2019; Kissenkötter et al., 2020; Janudin et al., 2024). Lab-on-chip systems further enhance sensitivity for Point-of-Care (POC) use (Sánchez et al., 2022). This study introduces a portable Arduino-based device that applies these advantages to identify adulteration efficiently.

MATERIALS AND METHODS

In this study, the mitochondrial ND2 gene of *Sus scrofa domesticus* (GenBank: NC_000845) was targeted. Amplification used an Ice Blue laser (≈488 nm) to excite FAM-labeled DNA, producing green fluorescence at 520 nm. The chip, fabricated within 5 minutes using low-cost PMMA, was measured with an AS7262 spectral sensor placed 5 mm above and 2 mm laterally with a green filter, while the laser was aligned at 90°. The process is illustrated in Fig. 1.

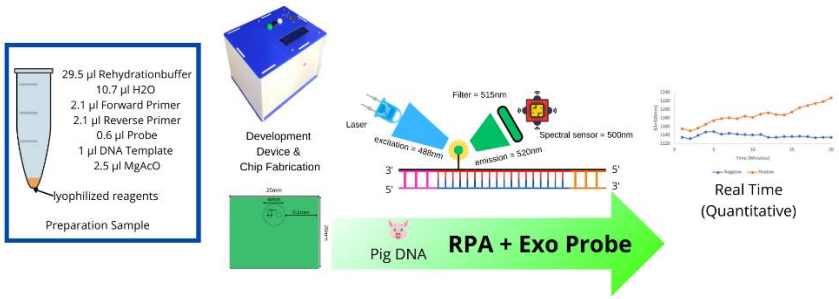

Fig.1 Graphical process of this experiment.

RESULTS & DISCUSSION

Exo-probe–based RPA amplification enables real-time detection of positive (DNA present) and negative (DNA absent) in Fig. 2 outcomes. A positive outcome is characterized by a noticeable increase in green fluorescence, confirming the presence of pork DNA. Conversely, in negative samples, only background fluorescence from the probe is observed, without a substantial rise in signal intensity. This finding demonstrates that the study successfully reached the minimum detection limit for pork DNA concentration specified in ISO/TS 20224-3:2020, namely 20 ng/µL to 200 ng/µL.

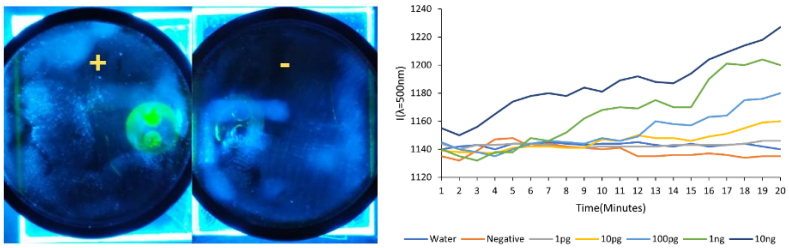

Fig.2 The results after amplification.

CONCLUSIONS

The portable device successfully detected pork DNA, and the results were further validated through gel electrophoresis. In addition, spectrometer-based analysis reliably distinguished between positive and negative samples using the RPA method, confirming both the specificity and sensitivity of the developed system.

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