HANDHELD SCANNER FOR RAPID ASSESSMENT OF HYGIENE STATUS IN MEAT SLAUGHTERING AND MEAT HANDLING FACILITIES

Fartash Vasefi[1*], Hamed Taheri Gorji[1,2], Kouhyar Tavakolian[2], Mahsa Aliee[1,2], Insuck Baek[3], Moon S Kim[3], Chanson Hwang[3], Albenones Mesquita[4], Eurione A.G. da Veiga Jardim[4], Rolando Mazzoni[4]

[1]SafetySpect Inc., Grand Forks, ND, USA

[2]Biomedical Engineering Program, University of North Dakota, Grand Forks, ND, USA

[3]USDA/ARS Environmental Microbial and Food Safety Laboratory, Beltsville, MD, USA

[4]NeoGene Ltds. Goiânia, Brazil

*Corresponding author email: fvasefi@safetyspect.com

I. INTRODUCTION

In meat processing facilities, the complexity of operations leads to hygiene challenges, as the entire process involves multiple stages like slaughtering, cutting, deboning, and packaging. Each stage carries distinct hygiene risks, complicating the monitoring and maintenance of cleanliness throughout the process. Additionally, the risk of cross-contamination is high due to the handling of raw meat and the use of shared equipment and surfaces, requiring meticulous control and cleaning procedures to manage. Pathogens such as *Salmonella, Listeria, and E. coli* are invisible to the naked eye and traditional microbial testing methods are often slow, delaying necessary corrective actions. Maintaining consistent adherence to hygiene standards and regulatory compliance also proves difficult across different shifts and among all workers, necessitating thorough training and monitoring to ensure protocol compliance. The current practice involves visual inspection and limited swab testing which cannot cover the size and variety of surfaces at risk. Moreover, organic residues from meat processing can form biofilms on equipment and surfaces, which are not only tough to remove but also harbor pathogens, requiring effective cleaning methods to eradicate these biofilms. The environmental conditions in meat processing facilities, typically cold and damp, further complicate sanitation efforts and can diminish the efficacy of disinfectants and sanitizers, adding another layer of challenge to maintaining hygiene standards. In this abstract, we are presenting initial investigation of UVC fluorescence imaging system to assess facility hygiene as case study for the first time without a scientific methodology to prove a hypothesis.

II. MATERIALS AND METHODS

Fluorescence imaging has been successfully utilized to detect contamination on meat carcasses [1], Despite its success in carcass inspection, fluorescence imaging has not yet been reported as a tool for inspecting hygienic environmental surfaces. In this study, we evaluated a handheld fluorescence imaging system, Figure 1(a), that utilizes UVC LEDs for excitation at 275 nm and emission at 350 nm. This system specifically targets amino acids—components found in nearly all proteins—which serve as effective markers for detecting protein residues on surfaces using UVC fluorescence imaging. The handheld scanner, named Contamination Sanitization Inspection and Disinfection (CSI-D+), employs pulsed UVC LEDs to illuminate contaminated surfaces. A UV-sensitive CMOS camera, synchronized with the LED pulses, captures both fluorescence and ambient light. The fluorescence images are then derived by subtracting the image taken with the LED turned off from the image taken with the LED turned on. This process allows the operator to detect contamination on surfaces in bright ambient light conditions.

III. RESULTS AND DISCUSSION

Two cases utilizing the CSI-D+ system to identify contaminated surfaces with 275 nm excitation illustrate the system's efficacy. In the first case, a rack of cutting knives that had already undergone a cleaning procedure was inspected. As shown in Figure 1(b), there were no visible signs of contamination on the knife handle.

However, Figure 1(c) reveals that the CSI-D+ system detected contamination not visible to the naked eye. Consequently, the specific knife was subjected to a second cleaning procedure. A follow-up inspection using the CSI-D+ system validated the knife's complete cleanliness as shown in Figure 1(d). In the second case, a meat scale was inspected before and after cleaning. Initially, the surface had not been cleaned as shown in Figure 1(e), and the inspection ensured that the CSI-D+ system's readings, Figure 1(f), correlated with the visual contamination observed. After the cleaning procedure, the meat scale was scanned again, and Figure 1(g) shows the verification of the cleaned surface, confirming the system's accuracy in detecting and validating cleanliness.

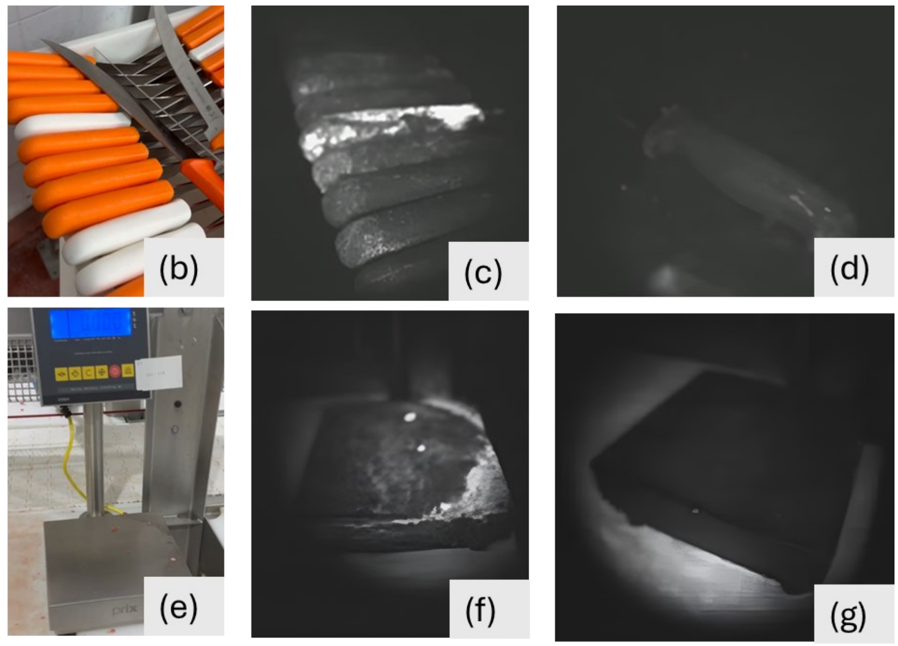

Figure 1. (a) CSI-D+ system, (b)-(d) cutting knife inspection after cleaning, (e)-(g) meat scale inspection before cleaning.

IV. CONCLUSION

In conclusion, the study demonstrated the effectiveness of the handheld fluorescence imaging system (CSI-D+) in identifying protein residues on surfaces within meat processing facilities. The use of UVC LEDs for excitation and a UV-sensitive CMOS camera for capturing fluorescence images provides a rapid and efficient method for detecting contamination. This approach addresses the limitations of traditional microbial testing methods, which are often slow and incapable of real-time monitoring. The CSI-D+ system's ability to reveal biofilms and protein residues that are invisible to the naked eye offers a significant advancement in maintaining hygiene standards and preventing cross-contamination. By implementing such technology, meat processing facilities can improve their cleaning protocols, ensuring adherence to hygiene regulations and reducing the risk of foodborne pathogens. This study underscores the potential of fluorescence imaging as a vital tool in the continuous effort to enhance food safety and sanitation practices in the meat processing industry.

The combination of fluorescence imaging and machine learning techniques offers significant benefits, particularly in training models to identify and segment contamination consistently. By training fluorescence images with known contamination data, a segmentation model similar to the one described in previous studies can be developed. This model allows users with varying skill levels to operate the scanner and obtain reliable, consistent results.

REFERENCES

1. Gorji, H.T.; Shahabi, S.M.; Sharma, A.; Tande, L.Q.; Husarik, K.; Qin, J.; Chan, D.E.; Baek, I.; Kim, M.S.; MacKinnon, N.; Morrow, J.; Sokolov, S.; Akhbardeh, A.; Vasefi, F.; Tavakolian, K. (2022) Combining deep learning and fluorescence imaging to automatically identify fecal contamination on meat carcasses. Scientific reports 12(1):2392.