Identifying features of abscess caused by foot-and-mouth disease (FMD) vaccination in pork meat and detection through hyperspectral imaging

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I. INTRODUCTION

Foot-and-mouth disease (FMD) is a highly contagious viral illness that affects cloven-hoofed animals such as cattle, pigs, and goats, leading to substantial economic losses. Mass vaccination is a crucial preventative measure; however, vaccination can result in pork abscesses, compromising quality and causing financial setbacks. In Korea, vaccination is compulsory following FMD outbreaks, yet this has led to the emergence of abscesses in certain pork products. In this study, we delve into hyperspectral imaging techniques aimed at identifying FMD vaccine-associated abscesses, thereby offering potential for objective assessment and enhancing vaccination efficacy.

II. MATERIALS AND METHODS

The samples used in this study were pork hams obtained from a local meat factory. Pork meat samples with abscesses were collected from slaughtered pork carcasses, transported in a low-temperature vacuum, and stored in a refrigerator at 5°C until just before the experiment. Hyperspectral image acquisition was conducted using three different hyperspectral imaging systems (1000-2500 nm short infrared (SWIR), 400-1000 nm Vis/NIR, and 400-800 nm fluorescence hyperspectral imaging systems). After obtaining the hyperspectral images, the pork samples were used as reference data for physicochemical experiments (proximate contents, microbiome analysis, and H&E staining). The acquired image data were used for intensity calibration, and the mean spectrum was extracted from the meat, fat, and abscess areas. Finally, the total spectrum was calculated with 300 data points from the meat, 300 from the fat, and 300 from the abscess area for a classification model using partial least squares discriminant analysis (PLS-DA). Classification models were created using each set of spectral data. An ANOVA test was conducted to assess significance, and after identifying significant parameters, Duncan's multiple range test was performed for further analysis($P<0.05$).

III. RESULTS AND DISCUSSION

Table 1 presents the optimal results for each hyperspectral classification model. The best classification model for Vis/NIR achieved a 97.0% accuracy rate in abscess detection. The mean normalization preprocessing method proved the most effective for data preprocessing. Validation results from the fluorescent hyperspectral imaging system demonstrated a 96.2% accuracy rate using the mean normalization preprocessing method. Additionally, the SWIR imaging system yielded a 98.9% accuracy rate with the MSC preprocessing method. Latent variables (LV) are crucial in explaining model complexity, as high LV values can lead to overfitting (Kong et al., 2022). Therefore, it is essential to consider LV values when selecting the appropriate classification model. The SWIR classification model exhibited lower LV values and higher classification accuracy percentages in this study. This suggests that the SWIR hyperspectral system can efficiently detect -OH, -CH, and -NH bonding overtones compared to other ranges (Kim et al., 2023), leading to enhanced detection accuracy. Furthermore, the SWIR range appears capable of detecting collagen areas within fibrotic muscle tissue, although this data is not presented in this abstract. Consequently, the SWIR hyperspectral camera system or SWIR spectrum range holds promise for practical applications in abscess detection within real-world settings.

Table 1. Accuracy of pork abscess detection algorithm for each hyperspectral camera system using different preprocessing methods.

System type	Preprocessing method	LV	Calibration Set (630 spectrums)				Validation Set (270 spectrums)			
			ABS (%)	Meat (%)	Fat (%)	Total (%)	ABS (%)	Meat (%)	Fat (%)	Total (%)
Vis/NIR hyperspectral system	Mean norm	9	96.2	100	99.1	98.4	96.7	100	94.4	97.0
	Raw spectrum	21	45.2	95.7	44.1	61.7	42.2	100	49.4	63.9
Fluorescent hyperspectral system	Mean norm	11	94.6	100	100	98.2	88.7	100	100	96.2
	Raw spectrum	17	47.3	95.8	51.2	64.7	44.3	96.6	57.6	66.2
SWIR hyperspectral system	MSC	5	98.1	99.5	99.1	98.9	97.8	100	98.8	98.9
	Raw spectrum	11	24.8	99.5	40.8	55.0	15.6	90.8	35.4	47.2

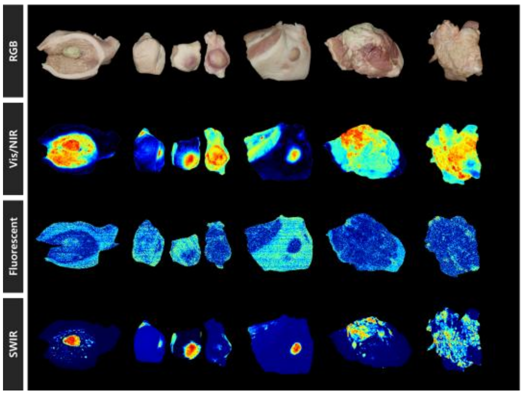

Figure 1. Chemical images from SWIR hyperspectral camera model for pork abscess detection.

IV. CONCLUSION

This study investigated the potential for detecting FMD vaccine-induced abscesses in pork using Vis/NIR, fluorescence, and SWIR hyperspectral imaging and confirmed the characteristics of abscesses. Vis/NIR and SWIR imaging led to high classification accuracy. However, fluorescence images showed lower accuracy, with the SWIR region's hyperspectral system exhibiting the highest accuracy in sample classification. Therefore, it is deemed advantageous to utilize the wavelength range of the SWIR region for device construction in the future.

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