DEVELOPMENT OF SIMPLIFICATION BEEF CHEMICAL COMPONENT PREDICTION MODEL USING THE BAND SELECTION METHOD

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I. INTRODUCTION

In Korea, the industry has a growing demand for beef carcass classification based on oleic acid content. Spectrometers are commonly used to classify oleic acid; the system used in Japan is a spectrometer that utilizes the 750-1000 nm range, making it easy to measure oleic acid content. However, beef has diverse marbling patterns, sizes and a significant variation between carcasses. In addition, the measuring position is different between Korea (between the 13th rib and the 1st lumbar vertebra) and Japan (between the 6th and 7th ribs), making applying the existing spectrometer system difficult. Hyperspectral or multispectral imaging methods could be a viable solution. Still, the line-scan hyperspectral imaging system faces difficulties in acquiring a field of view (FOV) due to the cutting area height. To overcome this issue, a research team aims to develop a snapshot SWIR multispectral camera system in the 1000-1700 nm range to measure the chemical components of beef carcasses. This article presents a preliminary study to identify important wavelength information necessary for predicting proximate components(moisture, crude protein, crude fat content, %) and oleic acid content in the loin area of beef using the hyperspectral imaging system and band selection methods.

II. MATERIALS AND METHODS

The beef samples used in this study were 156 Hanwoo steers, and the *longissimus dorsi* muscle was selected as the sample for the experiment. They were sliced to a thickness of 2 cm for the experiment. The hyperspectral imaging system used in this study was capable of capturing images in the 1000-2500 nm range, but only the 1000-1700 nm range was used in this study to identify important wavelengths. After the imaging was completed, the samples were immediately processed by removing external fat and connective tissue and were then ground for the chemical experiment. The acquired images were corrected for intensity using black and white reference samples, and the average spectrum of the uniform area was extracted. The extracted wavelength information and actual measurement values were used to construct a Partial Least Squares Regression (PLSR) model and expressed in terms of the coefficient of determination (R^2) and root mean square error (RMSE). Interval PLS, Weighted Regression Coefficient (WRC), Sequential Feature Selection (SFS), Successive Projection Algorithm (SPA), and Stepwise Regression were used for wavelength selection.

III. RESULTS AND DISCUSSION

Table 1 shows chemical experimental results. As BMS increased, water and protein content decreased, and fat content significantly increased ($P<0.001$). Table 2 shows the result of the prediction model using the SWIR hyperspectral camera system. The whole band model of proximate and oleic acid models showed an R^2_P value above 0.90. However, the selected band model R^2_P decreased following the band number's decreasing. It is judged to be due to the decrease in the available wavelength information of the prediction model. The selected band model for proximate components was constructed using under six wavelength information, and an R^2_P of over 0.8 was predicted, with an RMSEP of less than 3%. According to *Caporaso et al.* (2021), the standard deviation (SD) of the AOAC method 922.06 for fat content analysis by acid hydrolysis ranges from 0.7% to 7.5%, depending on the type of food analysed. It is judged that the results of this study showed an acceptable range of

RMSEP. For oleic acid, a model was constructed using ten wavelengths, and an R2P of 0.64 and an RMSEP of 2.5% were obtained. And final chemical images of each chemical prediction model are in Figure 1.

Table 1 Proximate and oleic acid results of each different grade beef *longissimus dorsi* muscle

Meat grade	1++			1+	1		2		3	SEM	P value
BMS grade	9	8	7	6	5	4	3	2	1		
Moisture (%)	52.1^{e}	55.5^{d}	54.5^{de}	60.2^{c}	60.9^{c}	62.6^{bc}	65.4^{b}	64.8^{b}	72.5^{a}	0.08	<0.001
Crude protein (%)	16.5^{f}	18.0^{e}	18.0^{e}	19.3^{d}	19.5^{cd}	19.8^{cd}	20.6^{c}	22.2^{b}	24.2^{a}	0.32	<0.001
Crude fat (%)	29.3^{a}	24.3^{b}	24.9^{b}	18.7^{c}	17.9^{c}	11.8^{e}	13.1^{de}	11.8^{e}	4.1^{f}	1.08	<0.001
Oleic acid (%)	14.2^{a}	11.5^{b}	12.7^{a}	8.8^{c}	8.2^{c}	5.5^{d}	6.0^{d}	5.5^{d}	1.3^{e}	0.58	<0.001

SEM: Standard error of the mean; BMS: beef marbling score

Table 2 Beef meat proximate (moisture, crude protein, crude fat) and oleic acid contents prediction model result using full and selected bands using SWIR hyperspectral imaging

Model	Parameter	Band numbers	Calibration set		Prediction set	
			R^2_C	RMSEC (%)	R^2_P	RMSEP (%)
Full band model	Moisture	120	0.94	1.44	0.94	1.60
	Crude protein	120	0.93	0.63	0.90	0.68
	Crude fat	120	0.94	1.82	0.93	1.77
	Oleic acid	120	0.89	1.31	0.91	1.19
Selected band model	Moisture	4	0.80	2.83	0.81	2.48
	Crude protein	5	0.86	0.88	0.83	0.92
	Crude fat	6	0.87	2.78	0.86	2.68
	Oleic acid	10	0.78	1.86	0.64	2.50

R2c: coefficient of determination for calibration set; R2P: coefficient of the determination for prediction set; RMSEC: root mean square error of the calibration set; RMSEP: root mean square error of the prediction set.

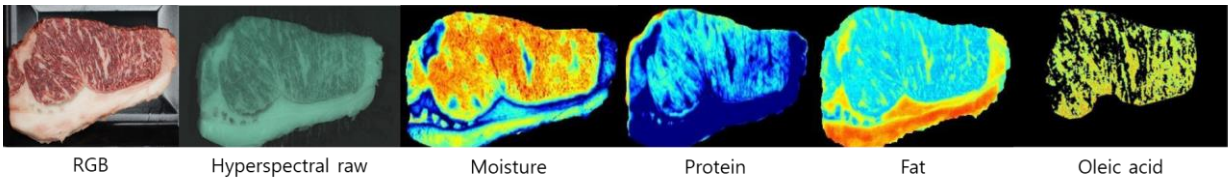

Figure 1. Chemical image of moisture, crude protein, crude fat, and oleic acid in BMS 9 based on prediction models

IV. CONCLUSION

Based on these results, it is judged that it is possible to select wavelengths that can be used in multispectral cameras ranging from 1000 to 1700 nm. In the future, a multispectral camera system will be built using the established wavelength information to create an integrated system that can be utilized in slaughterhouses.

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