DISCRIMINATION OF FRESH FROM FROZEN THEN THAWED BEEF

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Abstract – This paper describes how hyperspectral imaging and partial least squares-discriminate analysis (PLS-DA) can successfully classify fresh and thawed beef. One hundred samples, 50 fresh and 50 frozen than thawed, where scanned. The images were analyzed and its mean spectra were used in the PLS-DA. The percentage of correct classification in the prediction samples, i.e., external data set, was 95%.

Key Words – Hyperspectral imaging, near infrared, partial least squares-discriminate analysis.

I. INTRODUCTION

Freezing is a widely-applied process for food conservation all over the globe. It can increase shelf life and preserve organoleptic characteristics of food. However, the freezing process may cause the irregular formation of ice crystals, damaging the cell structures of meats, increasing meat exudates and thus, nutrients loss. Not to mention protein degradation and lipid oxidation when meat is kept frozen for long period or if it suffers temperature fluctuation during storage [1]. Therefore, to recognize if the meat is fresh or thawed is an important challenge for industry, especially the ones specialized in ready-to-eat products. This paper presents hyperspectral imaging (HSI) in the near infrared range as a fast and non-destructive technique to classify fresh and thawed beef.

II. MATERIALS AND METHODS

One hundred beef samples from *Longissimus* muscle were purchased directly from a local slaughterhouse (50 fresh and 50 frozen, vacuum packed). All samples were kept at 4 °C overnight so the frozen samples were thawed. After blooming (20 min), all samples were scanned by hyperspectral reflectance imaging system SisuCHEMA SWIR (Specim Spectral Image Ltd., Oulu, Finland) in the spectral range of 1,000-2,500 nm (resolution of 10 nm – total of 256 wavelengths, WL).

After image correction [2], the images were cut to the region of interest (ROI), 121 x 41 pixels, and 1000 - 2400 nm (224 WL). The mean spectra matrices were pre-processed using Multiplicative Scatter Correction (MSC). Partial least squares-discriminate analysis (PLS-DA) was applied on the dataset (the X matrix consisted of the spectral information and the Y matrix consisted of a column vector mapping the two classes, fresh and thawed). Calibration (n = 63) and prediction (n = 37) datasets were defined using Kennard-Stone algorithm [3]. In this work, the model was statistically validated by using the sensitivity, specificity and class error for the calibration (Cal), cross-validation (CV) and prediction test set (Pred) [2]. All data analysis was completed with MATLAB R2013a (The Mathworks Inc., Natick, MA, USA).

III. RESULTS AND DISCUSSION

Figure 1 (left) represents the score plot for PCA from non-preprocessed spectra where the first and second principal components (PCs) explained, together, 90% of the spectral variance, and it shows that there is a tendency grouping between fresh and thawed sample classes along PC1, due, probably, to protein content (1350 and 1665 nm, Figure 1, right).

The statistical assessment of the classification performance is presented in Table 1. The first point to observe is the similarity between the values obtained for calibration, cross-validation and external prediction. This indicates that the models are not under or over-fitted. Additionally, the sensitivity and specificity values obtained for a single class (fresh or thawed) in external prediction were greater than 0.92. That means that

there is a probability higher than 92% of classifying correctly the meat samples in its corresponding category. The overall accuracy for PLS-DA prediction model was 95% (Table 2).

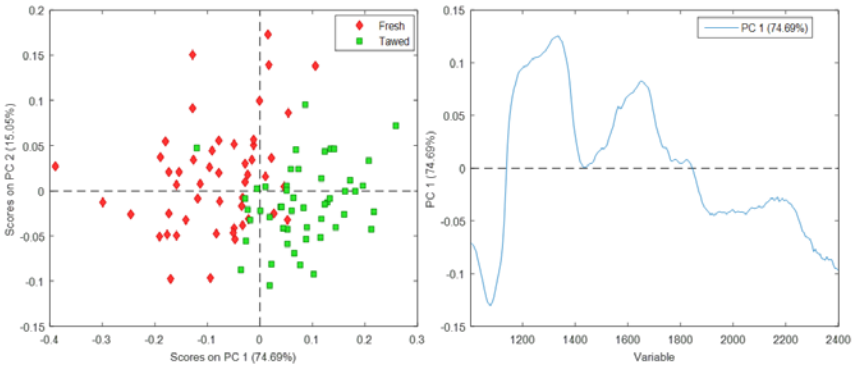

Figure 1: PCA score plot (left) and corresponding loading of PC1 (right).

Table 1: Sensitivity, specificity and classification error for the two classes of beef.

	Sensitivity			Specificity			Class error		
	Cal	CV	Pred	Cal	CV	Pred	Cal	CV	Pred
Fresh	0.946	0.919	0.923	0.923	0.923	0.958	0.065	0.079	0.059
Thawed	0.923	0.923	0.958	0.946	0.919	0.923	0.065	0.079	0.059

Cal = Calibration, CV = Cross validation, Pred = Prediction

Table 2: Confusion matrix for prediction results.

	Actual class		% Correct classification prediction samples
	Fresh	Thawed	
Predicted as Fresh	12	1	95
Predicted as Thawed	1	23	

IV. CONCLUSION

This short paper demonstrates that hyperspectral image can be successfully applied as a rapid and non-destructive tool to classify beef as fresh or thawed with 95% accuracy.

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