Nondestructive identification of benzoyl peroxide particles in wheat flour using SWIR hyperspectral imaging

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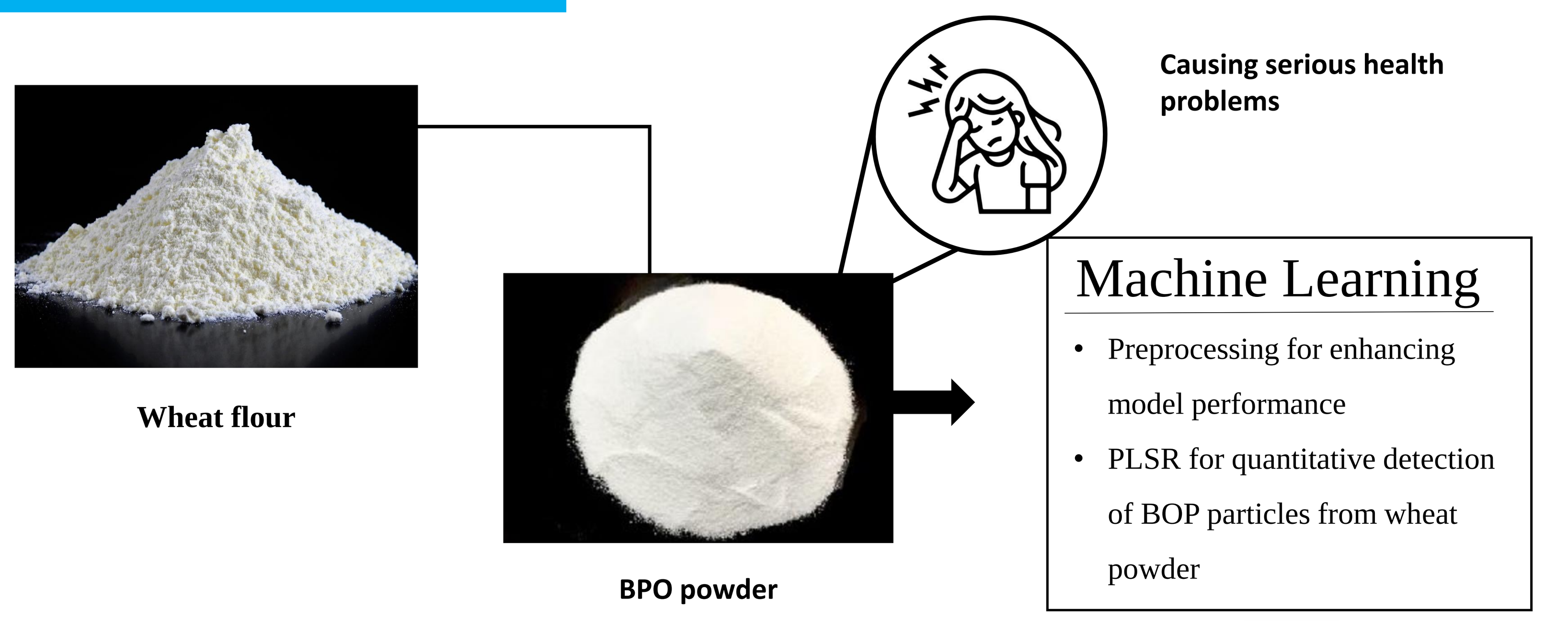
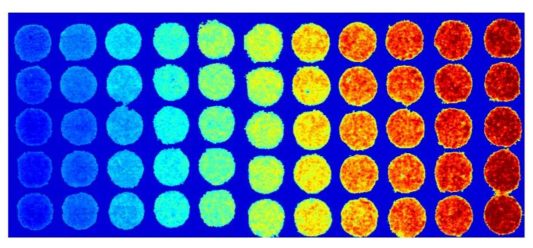
ABSTRACT Benzol peroxide (BPO) has been intensively used for a bleaching agent of wheat flour. However, its negative effects on human health caused various food safety issues. Therefore, developing nondestructive techniques for the rapid detection of BPO particles in wheat flour have been recently drawn substantial attentions in food safety and quality field. In the current study, a shortwave infrared (SWIR) hyperspectral imaging system (HSI) was suggested using the partial least square regression (PLSR) method. The developed SWIR HSI system consisted of a SWIR HSI camera, mercury cadmium telluride illumination, a sample translation unit for line scanning, and computing system for data analysis. To enhance the PLSR model performance, various preprocessing methods were applied and effective wavelength regions were selected. The developed SWIR system shown a high determinant coefficient (> 0.985) between predicted and actual values. Moreover, binary images for distinguishing BPO particles from wheat flour could be created by the developed model. Consequently, The developed SWIR HIS system and the PLSR model demonstrated a high potential for discriminating BPO particles in wheat flour and allowed for its quantitative evaluation.

Introduction

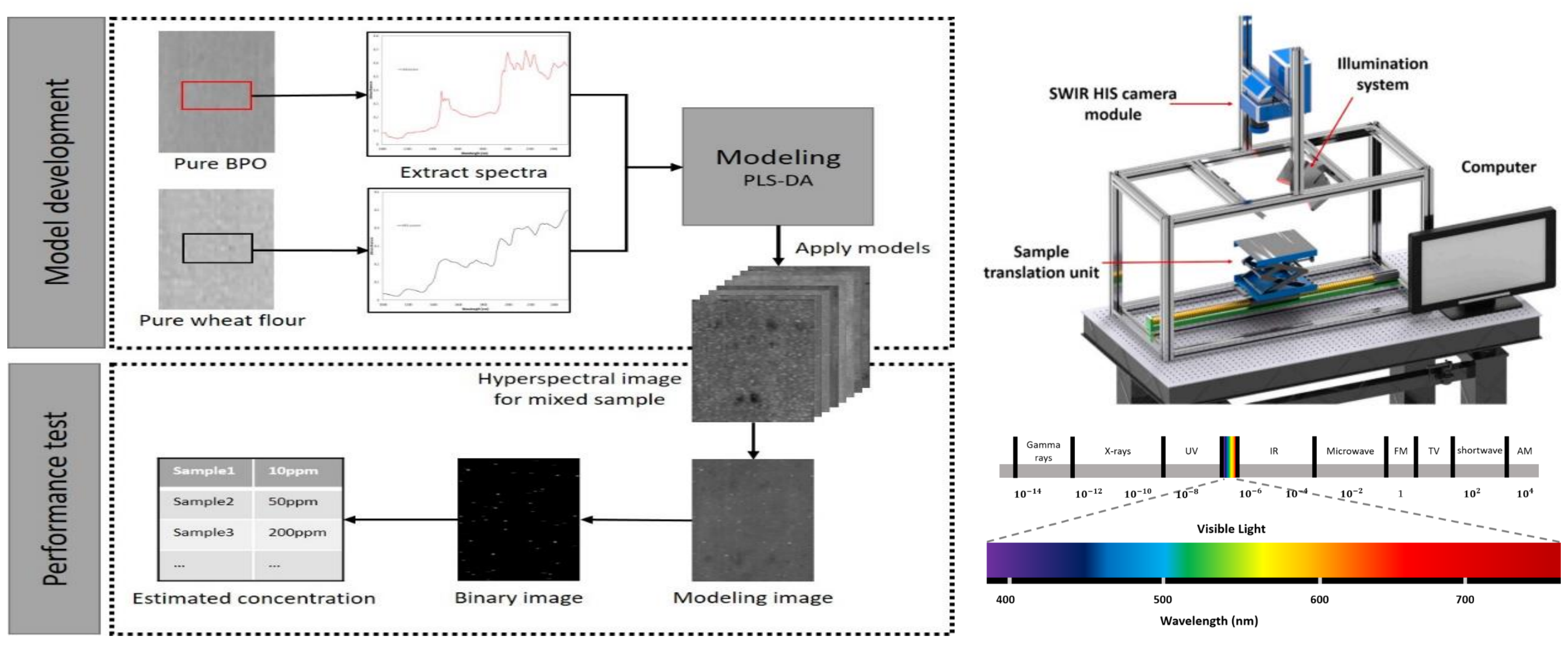


Benzol peroxide (BPO) has widely been used for approximately 30 years as a bleaching agent of wheat flour; however, the acceptable level of BPO is limited due to its negative effects on human health, such as poor nutrient and cancer risk. in order to accomplish rapid and simple detection of BPO, optical-based detection methods have also been studied, such as Fourier transform infrared (FTIR) spectroscopy, near-infrared (NIR) spectroscopy, infrared spectroscopy, and fluorescence spectroscopy. However, the spectroscopic-based detection techniques are performed using point-scan methods, which are unable to provide spatial information regarding the specimens. To overcome these limitations, line-scan-based hyperspectral imaging (HSI) techniques that can accomplish rapid detection with high accuracy has been recently developed. Therefore, the main objective of the current study was to develop an optimized model for the detection of BPO particles in wheat flour using an HSI system.



SWIR Hyperspectral Imaging for powder detection

Materials & Methods



→Samples used in the experiment were prepared with 50ppm, 100ppm, 200ppm, 400ppm, 800ppm, 1600ppm, and 3200ppm, and the thickness of the BPO particles was adjusted to about 50μm.

→The sample movement speed was set to 2.5 mm/s and the movement distance was set to 150 mm, and the 3D hypercube of the photograph was given as 384*2000 pixels of 387 wavelengths.

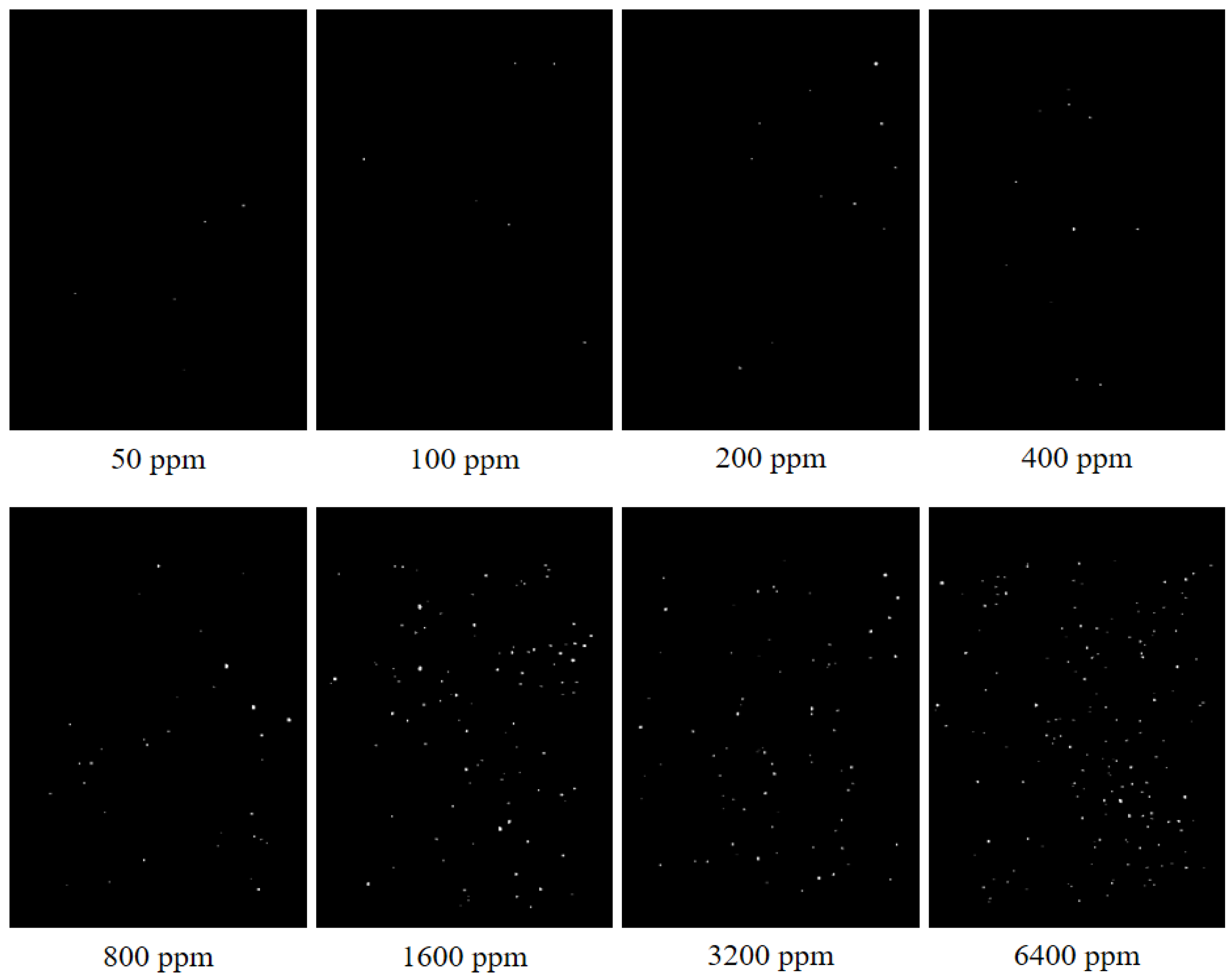
→The actual spectral response of the hyperspectral image was extracted by performing relative reflectance correction of the sample image using the white and black balance image.

→Data analysis was performed through spectral analysis, preprocessing, PLSR modeling, and hyperspectral image processing of BPO, wheat flour and various BPO-flour mixtures.

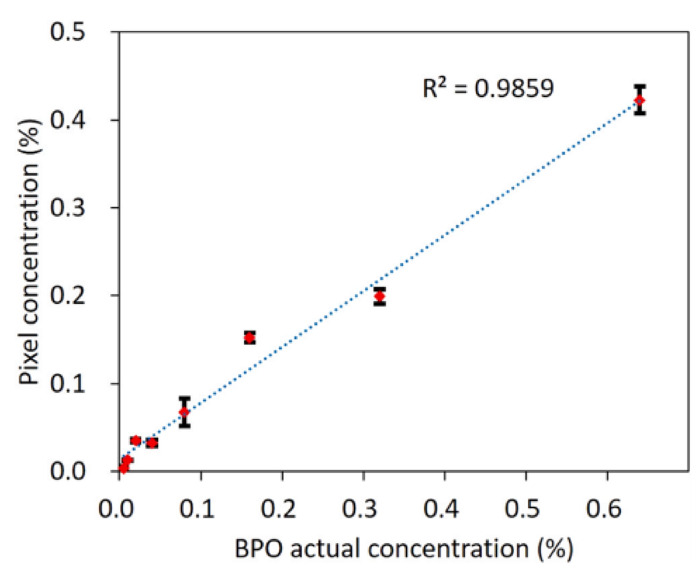
Result and Discussion

Wavelength range	Preprocessing	R_C^2	SEC	Factors	R_v^2	SEV	R_p^2	SEP
Full wavelength	Smoothing	0.999	0.017	2	0.999	0.017	0.999	0.017
	Mean normalization	0.999	0.017	2	0.999	0.017	0.999	0.017
	Max normalization	1.000	0.009	2	1.000	0.009	1.000	0.009
	Range normalization	0.999	0.016	2	0.999	0.016	0.999	0.016
	MSC	1.000	0.008	2	1.000	0.008	1.000	0.008
	SNV	1.000	0.007	2	1.000	0.007	1.000	0.007
	Savitzky golay 1st	0.999	0.017	2	0.999	0.018	0.999	0.018
	Savitzky golay 2nd	0.998	0.025	2	0.997	0.025	0.997	0.026
	Raw	0.999	0.016	2	0.999	0.017	0.999	0.016
Effective regions	Smoothing	0.999	0.017	2	0.999	0.017	0.999	0.017
	Mean normalization	0.999	0.015	2	0.999	0.015	0.999	0.015
	Max normalization	1.000	0.007	2	1.000	0.007	1.000	0.007
	Range normalization	0.999	0.018	2	0.999	0.018	0.999	0.018
	MSC	1.000	0.007	2	1.000	0.007	1.000	0.007
	SNV	1.000	0.006	2	1.000	0.006	1.000	0.006
	Savitzky golay 1st	0.999	0.015	2	0.999	0.015	0.999	0.015
	Savitzky golay 2nd	0.998	0.021	2	0.998	0.022	0.998	0.021
	Raw	0.999	0.018	2	0.999	0.018	0.999	0.018

→As a result of the PLSR model for detecting benzoyl peroxide of flour using full and effective wavelength regions, we developed the SNV method within the EW region, the PLSR model with the lowest values for SEC, SEV, SEP, and PLS factors.



→It was difficult to distinguish PO particle pixels, so BPO (1) and flour (0) were binarized. The threshold was defined as 0.5, and the pixel was defined as BPO when the spectral prediction approached 1. It can be seen from the figure that as the BPO level in flour increases, the number of white dots in the figure also



→Between the actual concentration and the expected concentration of BPO in the flour correlation picture.

Conclusion

In the current study, we proposed an optimal PLSR model that was developed in the SWIR region and its hyperspectral imaging system and image processing method to detect BPO particles in wheat flour. The EW region was selected using the iPLS method and RMSEV value in order to improve the model performance. Moreover, various pre-processing methods were performed and compared to one another to help develop a more robust prediction model. The BPO pixels in wheat flour were acquired from binary images of the PLSR model and a quantitative evaluation was then performed by counting the BPO pixels in the binary images. The BPO pixels in the binary images exhibited various intensities and sizes as a result of the BPO particles used in this study being irregular and the sample thickness being thicker than the penetration depth of the light source used. These issues will be considered in future studies to develop more precise models according to different wavelength regions and BPO particle size. Even with these experimental limitations of the current study, the predicted and actual BPO pixel concentrations showed a linear relationship and the determinant coefficient was 0.985. Therefore, this study clearly demonstrated that the developed PLSR model, hyperspectral system, and image processing methods were able to detect BPO particles in wheat flour at a concentration as low as 50 ppm with a high accuracy under SWIR illumination.