INFLUENCE OF PLASTIC WRAP IN THE HYPERSPECTRAL DETECTION OF FRESH SPINACH LEAVES
(An expanded abstract)

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ABSTRACT: The appearance of plastic wrap makes it difficult to detect the quality and real shelf life of fruits and Vegetables. Discrimination and prediction of spinach leaves shelf life were achieved in use of hyperspectral technology combined with Partial Least Square - Discriminant Analysis (PLS-DA) on whether the plastic wrap covered the samples when taking the hyperspectral images. Regions of Interest (ROI) were selected to get the corresponding spectral data. A training set (NIR 200 × 202) and a prediction set (NIR 100 × 202) were distributed using KS algorithm. Taking advantage of these data, PLS-DA model was established to discriminate and predict the shelf life of spinach leaves covered with plastic wrap or not, and a satisfactory result was obtained when the samples were covered with plastic wrap. On the other hand, reflectance of spinach leaves would be reduced covering with plastic wrap using hyperspectral technology. But the internal basic information of spinach leaves reflected by spectrum were not affected.

KEYWORDS: spinach leaves, PLS-DA, plastic wrap, discrimination, shelf life

1. INTRODUCTION

Fresh spinach is a kind of nutritional vegetables (Fan, et al., 2014), which is rich in vitamins and carotenoids. While shelf life of spinach leaves is short because spinach leaves decay quickly with strong respiration and transpiration (Lara, et al., 2013) during post-harvest storage. Under this circumstance, plastic wrap takes advantage of its semi-permeable, membrane gas composition self-regulation, inhibition of the respiration metabolism to reduce nutrient consumption (Gowen, et al., 2010) and prolong the shelf life of fruits and vegetables. The appearance of plastic wrap makes it difficult for consumers to evaluate the quality and real storage time of spinach in the market. Therefore, it is of vital importance to research the influence of plastic wrap in the detection of fresh spinach leaves.

Spectrum detection technology are widely used to detect the quality and shelf life of fruits and vegetables because spectrum detection is rapid and non-destructive (Liu, et al., 2011). Loredana Lunadei etc. (Lunadei et al., 2011) used multispectral vision system and found the spectral information was closely related to the storage time of spinach in NIR region. Wang etc (Wang, et al., 2015) used hyperspectral imaging technology combined with chemometric methods to predict the shelf life of different degrees of browning banana, and this research proved that hyperspectral imaging technology combined with average spectral image information did well in prediction of banana storage.

However, samples were exposed to the light when taking the hyperspectral images from the above studies. Quality and shelf life of fruits and vegetables covered with plastic wrap are detected using spectral system rarely. Hyperspectral and chemometric methods were combined to be used in this study for studying the influence of plastic wrap in the hyperspectral detection of fresh spinach leaves.

2. MATERIALS AND METHODS
2.1 Sample preparation
Spinach samples were picked and purchased in November 25, 2015 morning at Zhejiang University, Zijingang Campus fruits and vegetables market, and immediately transported back to the lab. Since the main edible parts of spinach were the leaf blades (Bergquist, et al., 2006), so the root of spinach were cut off in this research. And only fresh unblemished leaf blades were chosen to be covered with plastic wrap then the blades were washed and drained several times before use (Siripatrawan, et al., 2011). To simulate real-shelf environment and avoid a single leaf anisotropy, 4 spinach leaves were put in each tray, 75 (300) samples were immediately placed in 4°C storage room. Sampling was performed at 0, 2, 4, 6, 8 days. At each sampling time 15 (60) spinach leaves were taken out to get spectral images with plastic wrap and without plastic wrap using a hyperspectral imaging system.

All samples were put on 19.5 × 14 × 2 cm food-grade PE trays, and then were covered with commercial low density polyethylene (PELLD) plastic wrap. Plastic wrap can cause light scattering resulting in spectral deviation. The spectral data could be affected by the thickness, uniformity and flatness of plastic wraps (Gowen, et al., 2010). Therefore, plastic wrap should be put flatly to make the spectral information reflect fresh spinach efficiently.

2.2 Chemometric methods
The classic Kennard–Stone (KS) algorithm (Galvão, et al., 2005) is aimed at selecting a representative subset from a pool of N samples. In order to ensure a uniform distribution between a training set (NIR 200 × 202) and a prediction set (NIR 100 × 202). KS follows a stepwise procedure in which new selections are taken in regions of the space far from the samples already selected.

Partial Least Square - Discriminant Analysis (PLS-DA) is a supervised discriminant method (Beghi, et al., 2015). It can be used for classification, identification and prediction of spectral data. PLS-DA were applied on spectral data in order to evaluate the influence of plastic wrap on classification and prediction performances.

3. RESULTS AND DISCUSSION
3.1 Spectrum Results of Spinach Leaves
In this study, hyperspectral imaging (HSI) system was used to obtain reflectance spectrum of spinach leaves (blades were facing the lens). Spectral data of Spinach samples were extracted using ENVI software (Version 4.6, ITT visual information solutions, Boulder, CO, USA). Regions of Interest (ROI) were selected in condition that they did not include veins, wrinkles, film attaching droplets and they had similar size. The spectral values of all pixels within the selected region of interest were averaged to obtain representative of spinach leaves’ spectral reflectance.

There were 75 (4 leaves per tray) trays covered with plastic wrap, a total of 300 samples of leaf blades. According to the above steps 300 average spectral curves could be obtained. After removing their films, another 300 average spectral curves were obtained. Spectral curves were presented in figure 1. After removing noise regions in the spectral curves, 202 bands spectral information in the 950-1630 nm were chosen for subsequent analysis.
The difference of spectral curves of spinach leaves detected with and without film was obvious. The reflectance of spinach leaves detected without film was always higher than that with film in the period of spinach shelf life in this study. Light from HSI system was probably scattered through film, which led to a loss of reflectance of spinach leaves. However, hyperspectral detection of fresh spinach leaves was acceptable in examination of contents because the spectral curves were in the same trend whether there are films covering samples.

Figure 1 Spectral curves of spinach leaves detected with and without film
3.2 The Performance of PLS-DA Model

PLS-DA model was established between spectrum and storage time of spinach leaves. Results of PLS-DA model was shown in Table 1. $R^2$ of the training set and prediction set were high, and RMSE were low when samples were detected with plastic wrap. The results of samples without plastic wrap were worse than them. However, $R^2$ of the prediction set which samples were detected with plastic wrap was 0.926, RMSEP of it was 0.385, which indicated that PLS-DA was feasible in predicting storage time of fresh spinach leaves with plastic wrap.

Table 1 Performance of PLS-DA model for correlating between spectral measurement and storage time

<table>
<thead>
<tr>
<th></th>
<th>Without plastic wrap</th>
<th>With plastic wrap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>$R^2$</td>
<td>0.932</td>
</tr>
<tr>
<td></td>
<td>RMSEPC</td>
<td>0.513</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td>0.868</td>
</tr>
<tr>
<td>Prediction</td>
<td>$R^2$</td>
<td>0.886</td>
</tr>
<tr>
<td></td>
<td>RMSEPC</td>
<td>0.668</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
<td>0.777</td>
</tr>
</tbody>
</table>

3.3 Confuse Matrix of prediction results in NIR Region

The whole spectrum of the sample matrix was divided into a training set [near-infrared (NIR) 200 × 202] and a prediction set (NIR 100 × 202) matrix by KS algorithm [27]. By using the spectral reflectance of the training set and a pre-assigned value of the known sample virtual level (1,2,3,4,5) to establish a PLS-DA model, the prediction spectral values were substituted into the discriminant model for predicting the corresponding results. The rank value compared predicted and actual sample. The value of this level would determine where the real category was established (inclusive of 15 potential variables at NIR band) using PLS-DA, if the predicted value was in the rank value ± 0.5 range, which discriminant analysis results are shown in Table 2.

Table 2 Confuse Matrix of prediction results in NIR regions

<table>
<thead>
<tr>
<th>Shelf-life</th>
<th>Without plastic wrap</th>
<th>With plastic wrap</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 d</td>
<td>12 0 0 0 0</td>
<td>16 0 0 0 0</td>
</tr>
<tr>
<td>2 d</td>
<td>8 8 6 0 0</td>
<td>4 13 2 0 0</td>
</tr>
<tr>
<td>4 d</td>
<td>0 12 12 2 0</td>
<td>0 5 15 0 0</td>
</tr>
<tr>
<td>6 d</td>
<td>0 0 2 14 7</td>
<td>0 0 3 20 5</td>
</tr>
<tr>
<td>8 d</td>
<td>0 0 0 4 12</td>
<td>0 0 0 0 15</td>
</tr>
<tr>
<td>Accuracy</td>
<td>60% 40% 60% 70% 60%</td>
<td>80% 75% 75% 100% 75%</td>
</tr>
<tr>
<td>Total Accuracy</td>
<td>58% 81%</td>
<td></td>
</tr>
</tbody>
</table>

Note: The row direction represented the true number of storage days of spinach leaves. The column direction represented the results predicted by PLS-DA model.

As can be seen from Table 2, No matter whether samples were detected with or without plastic wrap, determination accuracy in the 6th day was higher than other storage days in NIR region. In addition, determination accuracy in storage of samples with plastic wrap was higher than that of samples without plastic wrap universally. The difference was related to the model results mentioned in above paragraph. All in all, the determination accuracy in storage of samples covered with plastic wrap was satisfactory in this study.
4. CONCLUSIONS

Reflectance of spinach leaves would be reduced covering with plastic wrap using hyperspectral technology. But it did not affect internal basic information of spinach reflected by spectrum. Discrimination and prediction of spinach leaves’ shelf life were achieved in use of hyperspectral technology combined with PLS-DA on whether the plastic wrap covered the samples. Total discriminated accuracy were 58% and 81% when spinach leaves were covered with plastic wrap and without plastic wrap. With the development of plastic wrap in the preservation of fruits and vegetables, more attention should be put on the use of hyperspectral technology for quality testing and shelf life prediction of fruits and Vegetables covered with plastic wraps. Technical supports would be offered for rational purchase of consumers in this way.

REFERENCES


