Discrimination of Absence or Presence of Pesticide Residue in Mulberry Leaf Using VIS-NIR Hyperspectral Imaging and Plsda

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Abstract. Fast and accurate discrimination of pesticide residue in mulberry leaf is very important for sericulture and silk textile industry. Therefore, a hyperspectral imaging approach with the spectral range of 390-1050 nm was used for the discrimination of pesticide residue in mulberry leaf. 120 mulberry leaves samples including 60 samples without pesticide residue and 60 samples with pesticide residue were imaged by the VIS-NIR hyperspectral imaging system. ENVI software was used to explore the region of interest and extract the corresponding spectral data. Partial least square discriminant analysis (PLSDA) was used to establish the discriminative model for the discrimination of pesticide residue in mulberry leaf and the model achieved 98.33% calibration accuracy and 93.33% prediction accuracy. A total of 9 important wavelengths were selected according to the regression coefficient in the PLSDA model. A simplified PLSDA model was developed based on the important wavelengths and it achieved similar results (96.67% and 93.33%). The results showed that the model based on the selected important wavelengths was comparable to the model based on the full wavelengths, and it was feasible to use hyperspectral imaging technology for discrimination of pesticide residue in mulberry leaf.

Introduction

The problem of disease and pest of mulberry trees is always the most problem for the farmers [1]. In order to prevent the mulberry leaves from being eaten by worm and obtain the good quality of the mulberry leaves for the silkworm, farms always spray pesticide on the mulberry tree [2]. However, most of modern farms are lack of the experience for pesticide, they can hardly identify whether the pesticide on the mulberry leaves is suitable for the eating of silkworms. If silkworms eat the pesticide leaves, they will be toxic and even die. This will cause the great influence of the production and quality of the silk, and the silk industry will be also affected. Therefore, fast and precise detection of pesticide residue in mulberry leaf is very important.

In general, the common methods for detecting the pesticide on the plant leaves are gas chromatography and high performance liquid chromatography [3]. Also these methods can get the relatively high precision, but the process is very complex and a lot of manpower and material are needed [4]. Therefore, it is necessary to develop a fast, accurate and simple method for the detection of pesticide residue. With the rapid development of the spectroscopic technology and computer technology, hyperspectral imaging technology is becoming important tool in the nondestructive detection application [5]. There are both spectral information and image information in one hyperspectral image, so the information of the hyperspectral image is very sufficient. Currently, some researchers have applied hyperspectral imaging technology into many fields. Li et al [6] used hyperspectral imaging technology for determination of dichlorvos residue on the surface of navel orange and found that hyperspectral imaging technology can meet the requirement of online fast
nondestructive detection. Leiva-Valenzuela et al [7] found that it was useful to use hyperspectral imaging technology to predict the firmness and soluble solids content of blueberries and the prediction accuracy is good. Liu et al [8] explored the feasibility of using hyperspectral imaging technology to predict the moisture content of the porcine meat, and developed the optimal RS-MLR model. However, there were few literatures referring to using hyperspectral image technology to discriminate pesticide residue in mulberry leaf.

In this paper, hyperspectral imaging system, ENVI software and PLSDA were used to develop a new optimal model for discriminating pesticide residue in mulberry leaf, and the new prediction model developed was tested using same unknown samples and it achieved good performance.

Materials and Methods

Chlorpyrifos is one of the most popular pesticides, and it is always used to prevent the tree from insect disease. Therefore, chlorpyrifos was chosen to obtain the samples. According to the recommended dose (1500 times diluent), chlorpyrifos was sprayed on the mulberry trees. At the next day, 60 mulberry leaves (with pesticide) were picked from the mulberry trees which had been sprayed chlorpyrifos, and the other 60 mulberry leaves (without pesticide) were picked from the mulberry trees without spraying any pesticide. After the collection of 120 mulberry leaves, all the samples were immediately sent to the spectrum laboratory for hyperspectral image acquisition.

Hyperspectral imaging system consists of the following parts: A hyperspectral imaging camera, an illumination unit which consists of two 150w halogen lamps, a control box, an electric displacement platform and a computer. In order to keep away from the distortion of hyperspectral image, the two halogen lamps were fixed on the angle of 45° to the horizontal, the exposure time was set as 20 ms and the movement speed of the electric displacement platform was set as 1.25 mm/s. Then the spectral cube software was used to capture the hyperspectral image of mulberry leaves, and a total of 120 hyperspectral image samples were obtained.

During the acquisition of hyperspectral image samples, CCD dark current, light source color temperature drift and other factors would affect the quality of the samples, so the hyperspectral image should be corrected by using the method in this paper [9].

Selection of appropriate region of interest (ROI) is the very important step, it concerns the performance of the model and plays key role in the final results. Therefore, a square region (64×64 pixels) around the center of the image was selected in this paper. Then the spectral reflectance data were obtained by averaging all the pixels in the ROI. Finally, 120 spectral curves were acquired. The spectral region is from 390-1050 nm and the image resolution is 672 × 512 with a spectral resolution of 2.8nm.

Partial least squares discriminant analysis (PLSDA) is an effective classification algorithm which is based on the partial least squares regression analysis, and it has been applied in many fields [10]. In this paper, the labels of the pesticide sample were set as 0 and the labels of the no pesticide sample were set as 1. Then PLSDA was used to develop the relationship between spectral data and labels.

Results and Discussion

As there were a lot of noise in the first 50 wavelengths and the last 50 wavelengths, these low signal-to-noise wavelengths were removed, so the spectral region was narrowed down to 452-983 nm. The processed 120 spectral curves were shown in the Fig 1(a). In addition, the mean spectral data were also calculated by averaging the extracted spectra from the no chlorpyrifos mulberry leaves and chlorpyrifos mulberry leaves, the mean spectral curves were shown in the Fig. 1(b).

Fig.1 depicts the raw spectral curve of all samples and the mean spectral curve of the no chlorpyrifos samples and chlorpyrifos samples. It can be seen that the spectral difference between no chlorpyrifos sample and chlorpyrifos sample is obvious, especially in the range of 500-700 nm and 750-950 nm. This can provide some theoretical basis for the following modeling.
The selection of a good method for modeling is very important, it plays a key role in the precision and stability of the model. PLSDA is a classification method based on modeling the differences between several classes with PLS, and it can establish a classification model quickly and effectively. Therefore, PLSDA was used to develop the model in this paper. At first, all the samples were divided into two groups, 60 samples of which were selected for the calibration set, and 60 samples of which were selected for prediction set. Then the PLSDA model was developed to discriminate the categories of the samples by using full spectral data. The result of PLSDA model using full spectral data was shown in the Table 1.

However, the PLSDA model based on full spectral data can hardly meet the need of online industry application. In order to establish a rapid and simple model, 9 important wavelengths were selected according to the regression coefficient from PLSDA analysis. There were 468.6, 504.8, 715.6, 722.1, 804, 861.7, 905.4, 928 and 970.7 nm. The result of regression coefficient from PLSDA analysis was shown in the Fig. 2.

After the important wavelengths were determined, PLSDA method was used to establish the rapid and simple model by using the extracted 9 important wavelengths when the calibration set and prediction set were of the same. The result of the new PLSDA model was shown in the table 1.

<table>
<thead>
<tr>
<th>Model</th>
<th>Input data</th>
<th>Latent number</th>
<th>Accuracy (%)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full spectral data</td>
<td>15</td>
<td>98.33</td>
<td>93.33</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Important spectral data</td>
<td>6</td>
<td>96.67</td>
<td>93.33</td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from table 1 that both the two PLSDA models achieved good performance, the calibration accuracy of the model based on full spectral data is 98.33% and the prediction accuracy is 93.33%. The calibration and prediction accuracy of the model based on important spectral data were 96.67% and 93.33% respectively. Compared with the model based on the full spectral data, the model based on important spectral data achieved similar results. Therefore, the method of important spectral data selection in this paper was very useful especially when the input data is very large for the modeling.
Conclusions

Based on the hyperspectral imaging system, 120 hyperspectral image samples of mulberry leaves were acquired, ENVI software was used to determine the region of interest and extract the spectral data of each sample. PLSDA method was employed to establish the model for discrimination of pesticide residue in the mulberry leaves. Two PLSDA models (one based on full spectral data and the other based on important spectral data) were compared according to the accuracy of calibration set and prediction set. Finally, experiments show that the two models both achieved the good performance. The results in this paper can be used for reference to identify the pesticide residue of other crops in nondestructive testing methods.

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