Visible and near infrared hyperspectral imaging to early detection of fungal infection in strawberry fruits

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Introduction

Strawberries (*Fragaria ananassa* Duchesne) are one of the most popular berry fruits in the world. Due to their delicate structure, this fruits are susceptible to mechanical injury, desiccation, decay and physiological disorders during harvest and storage (Reddy at al., 2000). The heaviest economic losses are the result of fungi infections, which can occur both on immature fruits pre-harvest, or on mature fruits at harvest or in the postharvest storage stage (Guidarelli et al., 2011). The most common pathogens of strawberries are *Botrytis cinerea* and *Colletotrichum acutatum*.

Recent studies illustrate the wide applicability of HIS on detection of fungal infections in fruits, seeds and plants, some examples are its application for identifying fruits infected with citrus black spot (Kim et al., 2014), detection of A. glaucus, Aspergillus niger and Penicillium spp infected wheat kernels and early detection of biotic stresses caused by fungal species belonging to the genus *Alternaria*, a pathogen of oilseed rape (Brassica napus L.) (Baranowski et al., 2015).

The objective of this study was to determine the efficiency of visible and near infrared hyperspectral imaging technique to early detection of fungal infection caused by *Botrytis cinerea* and *Colletotrichum acutatum* in strawberry fruits.

Materials and methods

The experimental samples were 'Senga Sengana' strawberries, handharvested in the local farm located in Lubelskie region. Two pathogenic fungi, namely are *Botrytis cinerea* and *Colletotrichum acutatum* were used for inoculation. Strawberry fruits were immersed in spore suspension of appropriate fungal pathogens (or sterile distilled water as a control. After inoculation fruits were stored in a dark chamber at 20ºC with 85% relative humidity.

A VNIR camera with an ImSpector V10E imaging spectrograph (400-1000 nm) and a SWIR camera with a N25E 2/3" imaging spectrometer (1000-2500 nm) (SPECIM, Finland) were used to acquire the hyperspectral images.

In this study, hyperspectral data were acquired at a wide wavelength range (450-2500 nm). For reducting data dimensionality and selecting the most significant wavelengths that contributed the most to the classification, Principal Component Analysis (PCA) was carried out on a dataset of strawberry samples. Prior the analysis Savitzky-Golay pretreatments were used to reduce environmental and texture effects on the samples and to smooth spectral noise. Control samples and various days of fungal infected fruits were classified using six different models.

Results

Figure 1. shows a comparison of the mean reflectance spectra in VNIR (a) and SWIR (b) region of the strawberry fruits on various days after inoculation by *Botrytis cinerea* fungi and non inoculated fruits with shaded error bar, representing standard deviations for all control measurements (four days).

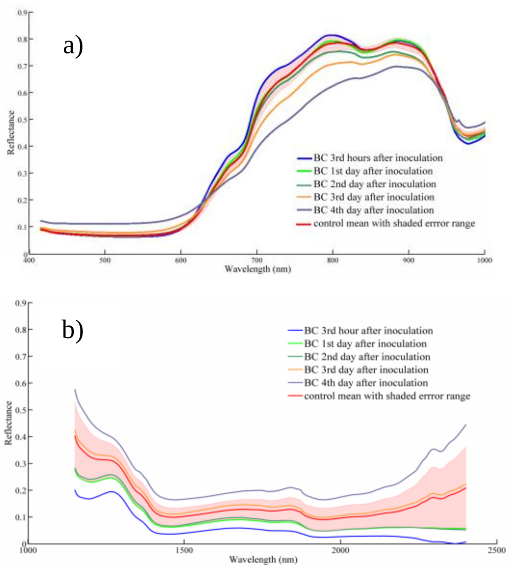

Fig 1 Mean spectral characteristics in VNIR (a) and SWIR (b) range of Botrytis cinerea infected and non infected strawbery fruits during four days storage

In general the reflectance spectral curves of different groups of strawberry fruit samples were closed and similar in shape. The significant differences between spectral charactetrists of inoculated and non inoculated fruits throughout the whole spectral range.

It can be observed that infected fruits showed lower spectral reflectance than healthy fruits, even when symptoms are still not visible. However the highest changes were observed in the range from 500 to 800 nm, what can be connected with changes in content of chemical compounds such as phenolic and anthocyanin content. Moreover changes in the reflectance intensities exhibited at different NIR wavelengths can be related to the chemical structure of fruits. Also, the resulting biochemical changes due to the metabolic activity of fungi on strawberry fruits can be detected by the difference in the reflectance spectra. The SWIR spectrum (1000- 2500 nm) was important in the discrimination between infected and non infected fruits. In this region two pominent peaks were observed at 1270 and 1850 nm and one minor peak at 1400 nm.Variation at these wavelengths could be associated with strawberry fruit attributes such as water content, fungal infection or hardness.

To differentaite between the *Botrytis cinerea* or *Colletotrichum acutatum* infected strawberry fruits from healthy strawberries fruits six classification models were tested using 500 *Botrytis cinerea* infected strawberry fruits, 500 *Colletotrichum acutatum* infected strawberry fruits and 500 control fruits. From all studied classifiers the best classification accuracy (93% of correctly classified instances) was achieved by SVM model for *Botrytis cinerea* infected strawberry fruits. The simillar classification accuracy (90% of correctly classified instances) was obtained for identification *Colletotrichum acutatum* infected strawberry fruits.

Conclusions

A hyperspectral imaging system in the VIS\NIR region was investigated to evaluate the possibility of fast and nondestructive method to identify healthy and fungal infected strawberry fruits. The hight classification accuracies obtained in this study indicated that hyperspectral imaging analysis can discriminate strawberry fruits infected with fungi from healthy ones, thus limiting the presence of toxins in food. This mathod also allowed early detection of fungal infection on strawberry fruits even before producing any visible symptoms.

References

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