Detection of undesirable substances in food and feed by near infrared hyperspectral imaging spectroscopy and chemometrics

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Introduction

Until now, food and feed safety as well as quality control analyses have been often carried out using classical techniques that have limitations in terms of adequation for the optimum implementation at the different steps of the food/feed chain and for the control of intermediate and end-products. Recent developments in analytical instrumentation and powerful data processing algorithms have extended the possibilities of spectroscopic techniques. They are more and more proposed in order to establish alternative solutions to classical techniques. This trend includes, among other, the development of NIR hyperspectral imaging methods combined with appropriated chemometric tools.

Study case 1: Detection of contaminants in cereals

The problematic

Cereal producers seldom have adequate means to separate cereal grains from various contaminants (harmful or not) that could be accidentally or voluntary included. For instance, in wheat grain one can find such substances as straw, damaged or spoiled grains, grains from other cereals (botanical impurities), insects or plastic. Although these impurities are usually less problematic than harmful contaminants, from an economic and technological perspective they can be a great damage problem for cereal producers and transformers (cereal producers are paid according to the quality of their harvest).

Tools and Procedure

Whiskbroom or plane scan imaging system **MatrixNIR™ Chemical Imaging instrument (Malvern instruments, Analytical Imaging, Columbia, MD, USA)**

Support Vector Machines (SVM) as discrimination technique

$$\min\left\{\frac{1}{2}\|w\|^2 + C\sum_{i=1}^{n}\xi_i\right\}$$

$$\forall i,\ y_i\cdot(w'\cdot x_i + b) \geq 1-\xi_i$$

$$K(x_i, x_j) = \exp\left(-\frac{\|x_i - x_j\|^2}{2\sigma^2}\right)$$

$$f_x(x_{new}) = sign\left(\sum_{i=1}^{SV}\alpha_i y_i k(x_i, x_{new}) + b\right)$$

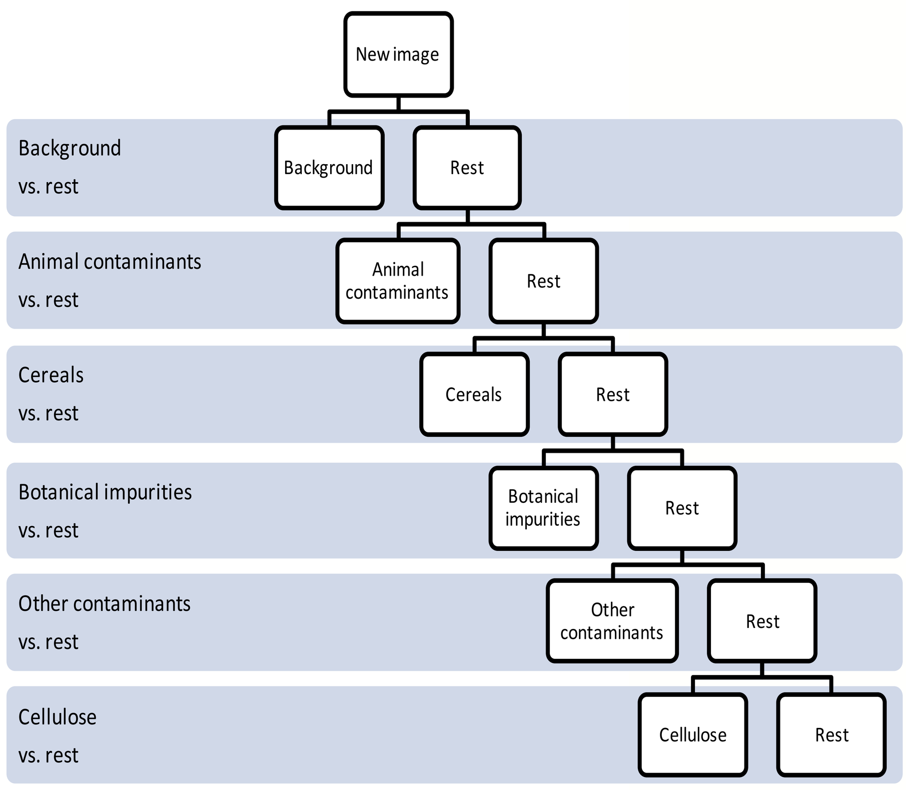


Figure 1: A dichotomic classification tree including SVM equations related to animal contaminants (insects), cereals (wheat, spelt and barley), botanical impurities (rapeseed), cellulose waste (wood and straw) and other contaminants (paintings, plastic and stones).

Some results

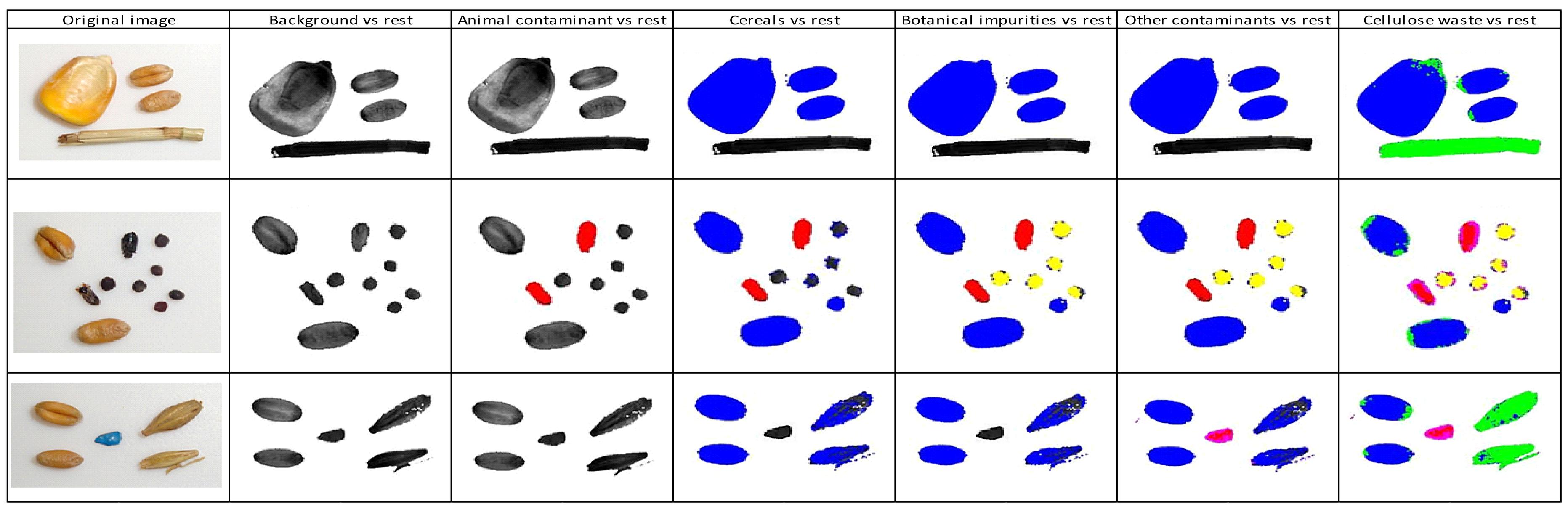


Figure 2: Examples of the application of the classification tree nodes. Each example includes the original image and the prediction images. Pixels are coloured as follows: detected as cereal are indicated in blue, detected as animal contaminant in red, detected as botanical impurities in yellow, detected as cellulose waste in green and detected as other contaminant in pink.

Study case 2: Assessment of cercospora leaf spots development on sugar beet leaves

The problematic

This study focuses on the contamination of plants by pathogens by detecting and following the *cercospora* leaf spots development on sugar beet leaves.

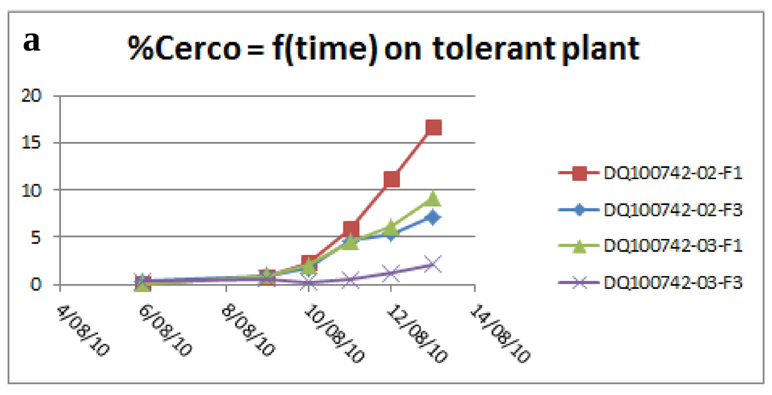
Tools and procedure

Push-broom or line scan NIR hyperspectral imaging system (**BurgerMetrics SIA, Riga, Latvia**

Four tolerant and four sugar beet plants susceptible to *cercospora* leaf spot were analysed using a during 6 days from the moment that the first symptoms were visible.

Support Vector Machines (SVM) discrimination models were built using two spectral libraries corresponding to the cercospora leaf spots and the health leaves.

The results show clear differences between tolerant and susceptible plants (Figure 4). The disease development is slower on tolerant plants and the necrosis covers less than 20% of the leaf area. For the susceptible plants, the infection is faster and 100% of the leaf area can be infected at the same time.



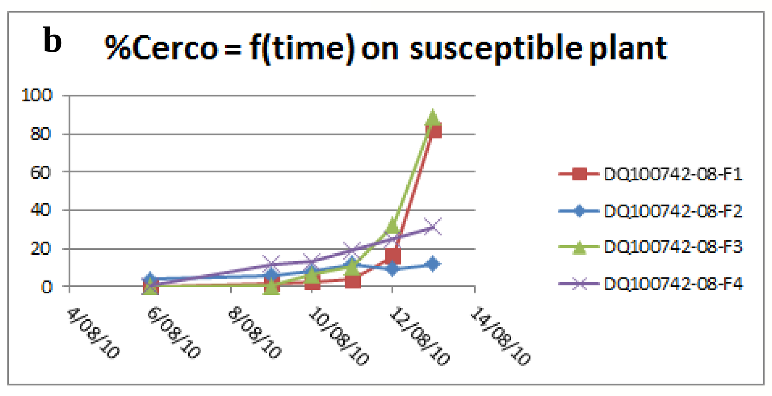
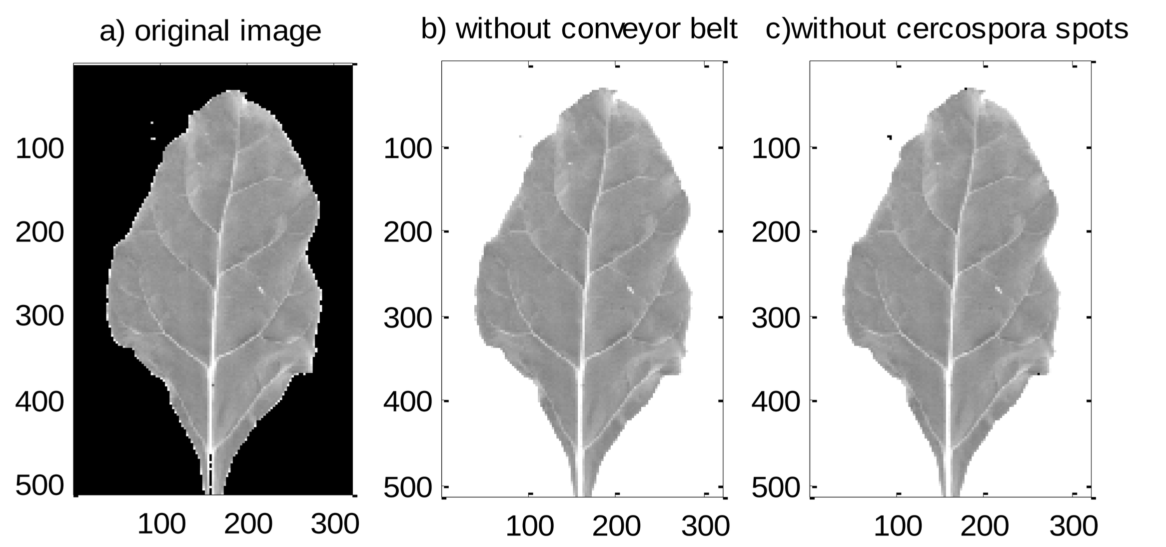


Figure 4: Cercospora development on leaves from tolerant (a) and susceptible (b)

Some results

RGB pictures **SVM results**



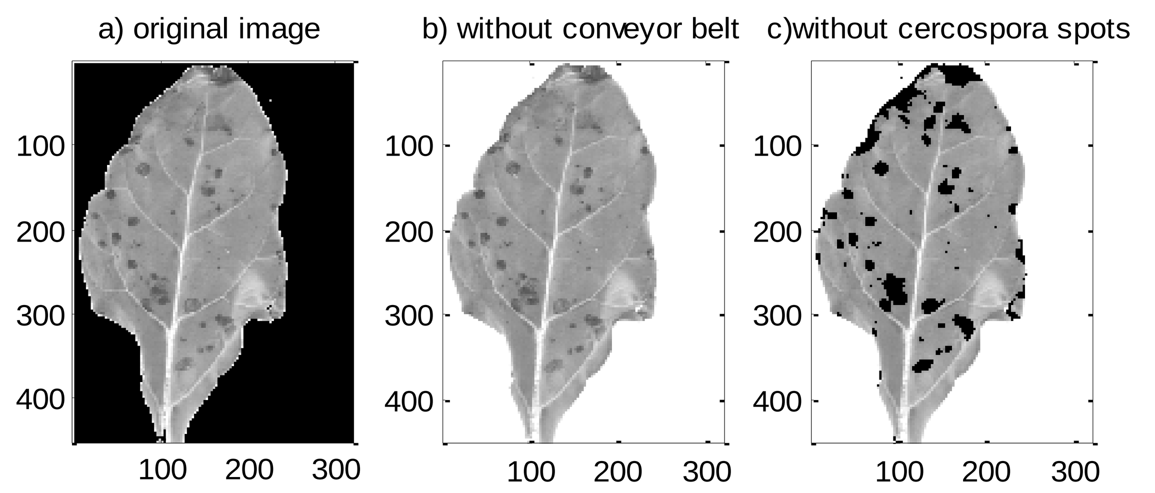


Figure 3: RGB picture and SVM and results, showing the cercospora leaf spots observed at 2 dates (3 days before the first symptoms and 3 days after the first symptoms) on a leaf from a tolerant plant inoculated by spray with cercospora and analysed using the **push-broom or line scan** hyperspectral imaging system.
Figure a shows the image at 1000 nm. Figure b shows the pixels detected as health leaf or cercospora leaf spots background removal. Figure c shows, in black, the pixels detected as cercospora leaf spots.

Conclusion

These two study cases have shown the advantages of using NIR hyperspectral imaging spectroscopy and chemometrics in order to integrate them into automatic cereal control procedures at the service of the seed, food and feed sectors as well as useful tools as a decision support tool for the quality control and the plant breeding.

References

Baeten, V., Fernández Pierna, J.A. & Dardenne, P. (2007). *Hyperspectral imaging techniques: an attractive solution for the analysis of biological and agricultural materials*. In: Techniques and Applications of Hyperspectral Image Analysis, Editors, Hans F. Grahn & Paul Geladi.

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