

Post-harvest Detection Of Impurities And Contaminants In Wheat Kernels Using Near-infrared Hyperspectral Imaging

Corentin DEMOITIÉ, Bruno GODIN, Vincent BAETEN and Philippe VERMEULEN

Walloon Agricultural Research Centre (CRA-W), Knowledge and valorisation of agricultural products Department, Gembloux, Belgium

Contact: c.demoitie@cra.wallonie.be

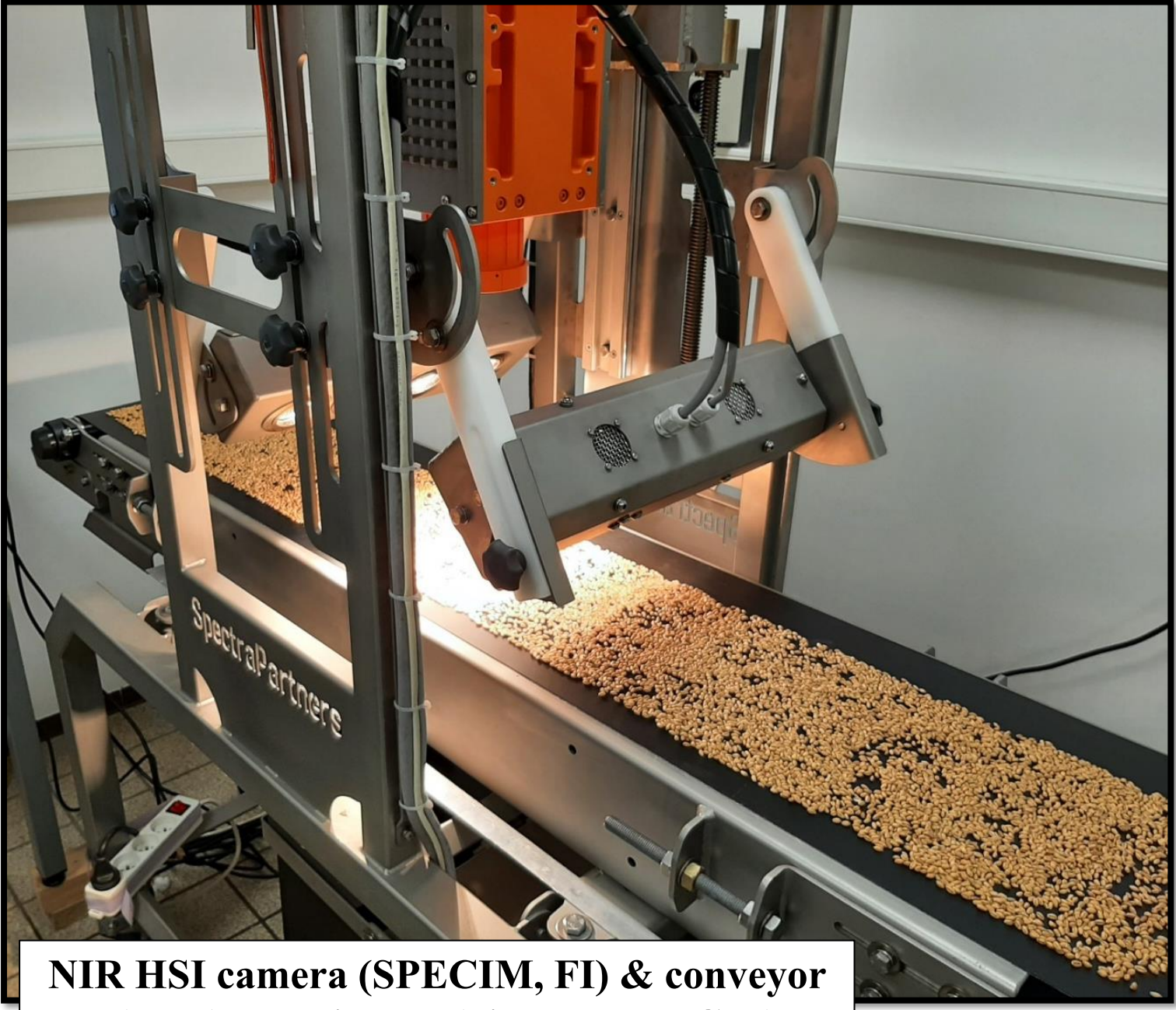
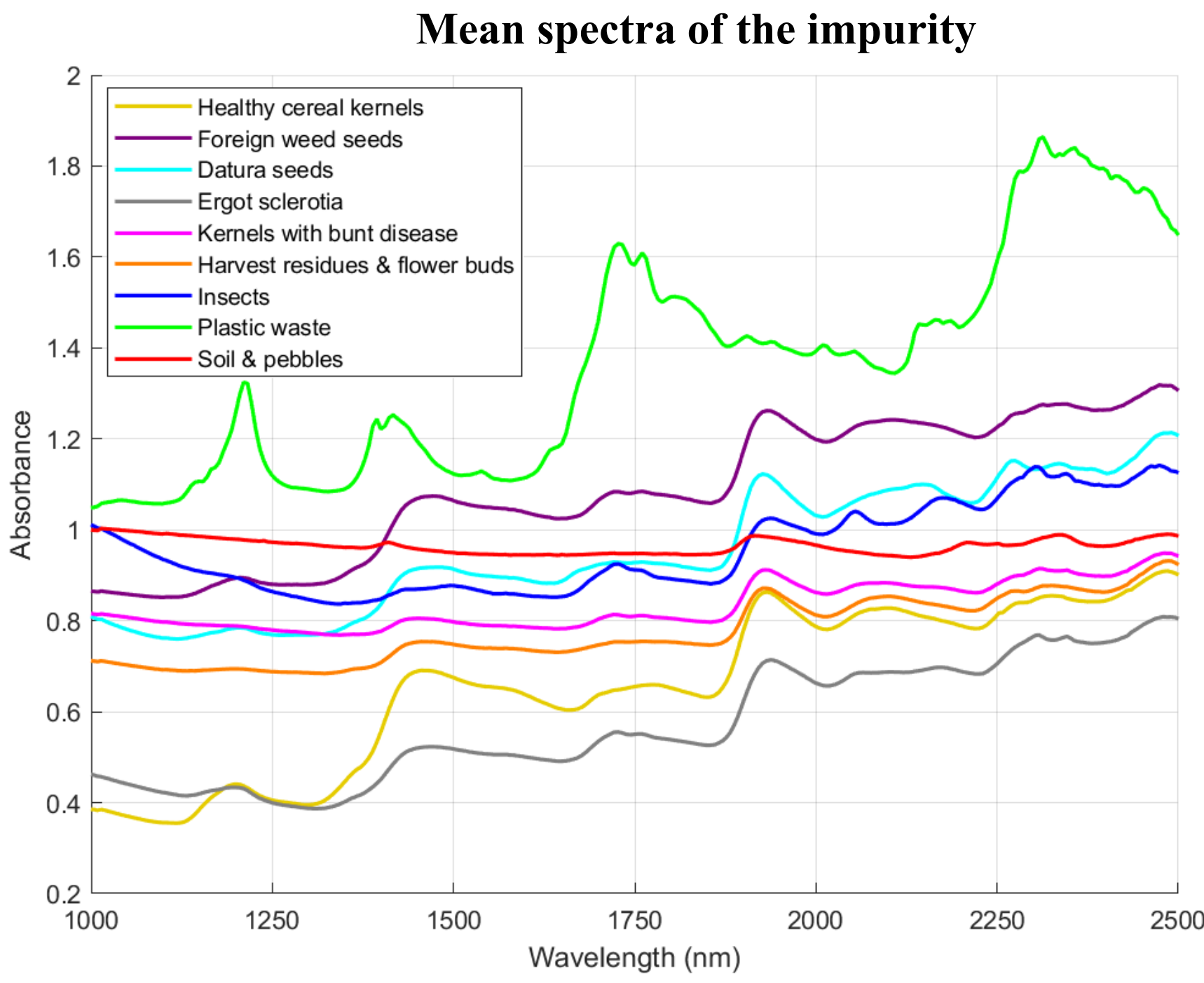
Wheat grain purity is an important **criterion of quality** impacting price, storage and further processing. The **identification** of undesirable **impurities** is especially necessary in the case of **contaminants** such ergot sclerotia, datura seeds or mycotoxins which are strictly regulated in the EU.

In recent years, **near-infrared hyperspectral imaging** (NIR HSI) has shown its potential as an efficient, fast and non-destructive tool for wheat quality evaluation and impurities detection. This study aims at exploring the ability of a linescan NIR hyperspectral camera (1000-2500 nm) to **assess the purity** of cereal samples and to **detect different categories of impurities and contaminants**.

Material and method

Various impurities from discarded sorting fractions of cereal samples cultivated in Wallonia (Belgium) in 2023 and 2024 as well as others issued from a historical collection were **gathered and visually identified**.

The 8 impurity groups (107 samples) and 4 types of cleaned hulled cereals (12 samples of common wheat, durum wheat, rye and triticale) were measured with a **linescan NIR hyperspectral camera** (SWIR model, SPECIM, Finland) working in the spectral range from **1000 to 2500 nm** and coupled with a custom-built **conveyor belt** acquisition system (RMA Techniek, The Netherlands).



Performances of the cereal impurities PLS-DA models applied consecutively on a pixel basis

Model level	Classes	Preprocessing	Latent variables	Sensitivity (Val) [%]	Specificity (Val) [%]
Model 1	Soil & Pebbles vs. Rest	SNV	5	99.3	97.0
Model 2	Plastic Waste vs. Rest	SNV	3	99.2	100
Model 3	Insects vs. Rest	SNV + 1st Deriv. (order 2, wind. 3 pt)	5	96.3	98.2
Model 4	Harvest residues (straw) & flower buds vs. Rest	SNV + 1st Deriv. (order 2, wind. 5 pt)	7	85.3	85.4
Model 5	Kernels with bunt disease vs. Rest	SNV + 1st Deriv. (order 2, wind. 5 pt)	9	77.2	89.8
Model 6	Ergot sclerotia vs. Rest	SNV + 1st Deriv. (order 2, wind. 7 pt)	9	92.9	97.4
Model 7	Datura seeds vs. Rest	SNV + 1st Deriv. (order 2, wind. 5pt)	9	95.4	95.8
Model 8	Foreign weed seeds vs. Healthy cereal kernels	SNV	8	94.1	94.8

Classification models

The images acquired were used to build **spectral libraries** of the identified **impurity classes**. Different samples of each class were kept to create a **calibration dataset** and a **test independent dataset**.

A K-means clustering was used to build a **hierarchical classification** of the 9 classes mean spectra of calibration and evaluate the **spectral similarity** between the groups.

Then, **8 classification models** (PLS-DA) were developed and optimized. The models were made to be **applied in a dichotomic way** to hyperspectral images of cereal samples and to **consecutively detect the impurities** present on a pixel basis. The **background pixels** are **isolated** by thresholding the PC1 values from a PCA of the whole image.

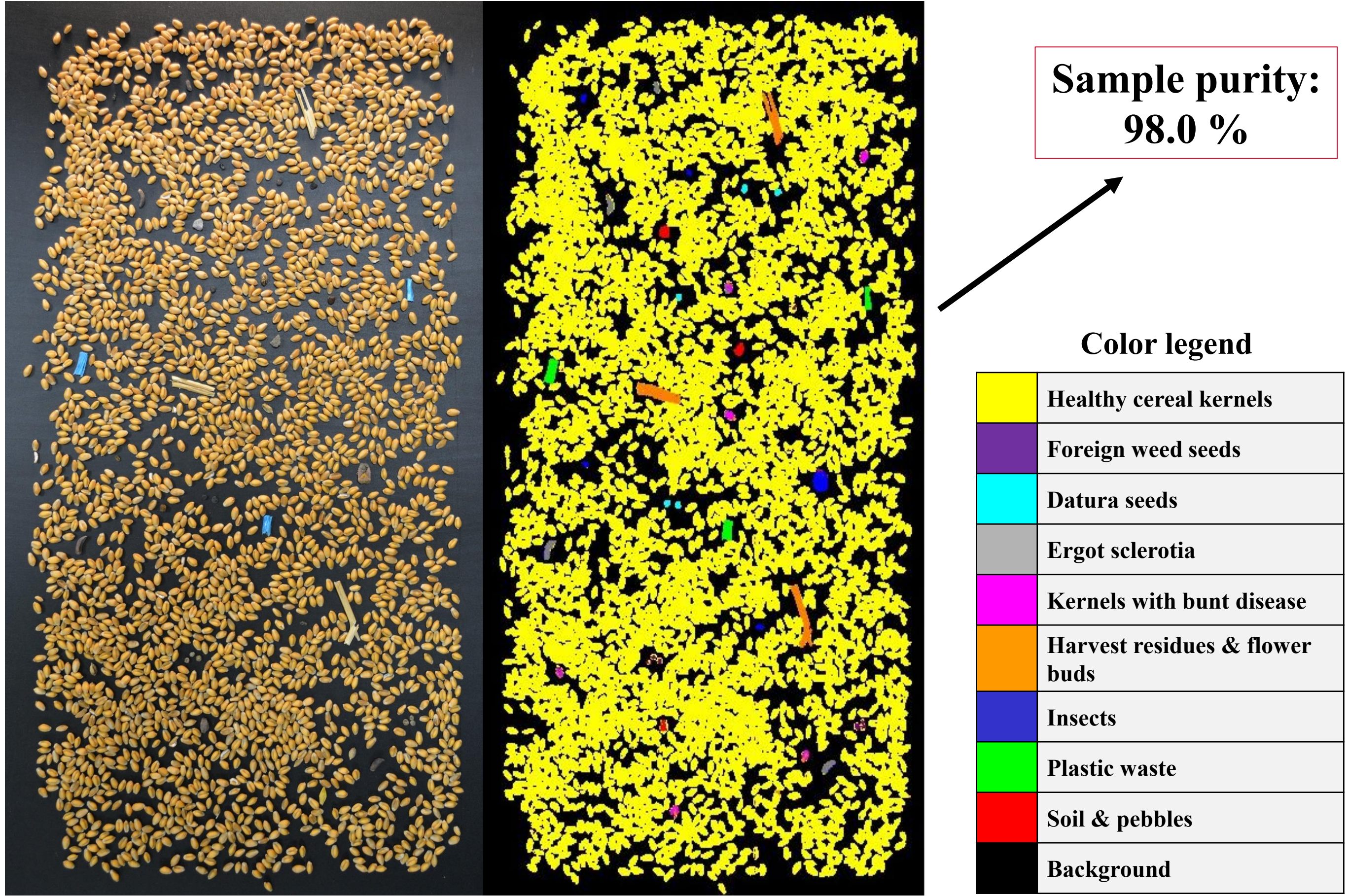
Results and discussion

The **best performances** were unsurprisingly obtained for the three first **models** classifying **non-plant materials** with few errors in validation. **Sensitivities and specificities above 90 %** were reached for ergot sclerotia and datura seeds, both **regulated contaminants**, as well as for foreign weeds seeds which are undesirable but not regulated. While the detection **performances of harvest residues** such as straw particles could be improved, they are **sufficient** to signal the need for further cleaning. In the case of **kernels with bunt disease**, the **low sensitivity** is due to the spectral similarity of the kernel hulls, but **high specificity** could still be achieved.

Purity assessment results are expressed as a pixel ratio which is a **good indication** about the need for further cleaning but not sufficient to quantify the regulated **contaminant, reference methods are still needed**.

While visible imaging could be enough for detecting some impurities such as ergot sclerotia, specific **spectral features** found **above 1700 nm** such as lipids bands were of particular interest and provide a **more precise detection**.

Purity assessment and specific detection of impurities



NIR HSI proved to be a **promising tool** to provide a fast **assessment of sample purity**. This method allows for an **efficient detection** of the tested **contaminants** including hard to notice particles thanks to characteristic **spectral differences**. It could be used as a **preliminary screening** step to inform about the **need** for further **cleaning** or the implementation of more **precise quantification** methods in the case of regulated contaminants. The **following step** would be to couple the camera with a **sorting system** to remove the detected impurities and improve the quality of the batch analyzed.

Acknowledgements

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