Discrimination between durum wheat and common wheat by NIR Hyperspectral Imaging

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Introduction

Durum wheat - DW (*Triticum durum*) is the main raw material in pasta production. Several major production countries, as Italy, France or Greece have decided that only pasta produced from durum wheat is permitted. According to current Italian rules, only a maximum of 3 % of CW is allowed to account for cross-contamination that may occur during common agricultural process. However, mixtures of both wheat species can be found due to accidental delivery problems or to fraudulent addition in order to reduce prices. Efficient methods for the detection of CW to DW products are therefore required. In this work, NIR hyperspectral imaging has been assessed as a fast method for the at-line and on-line discrimination between both species of wheat at the kernel and sample level.

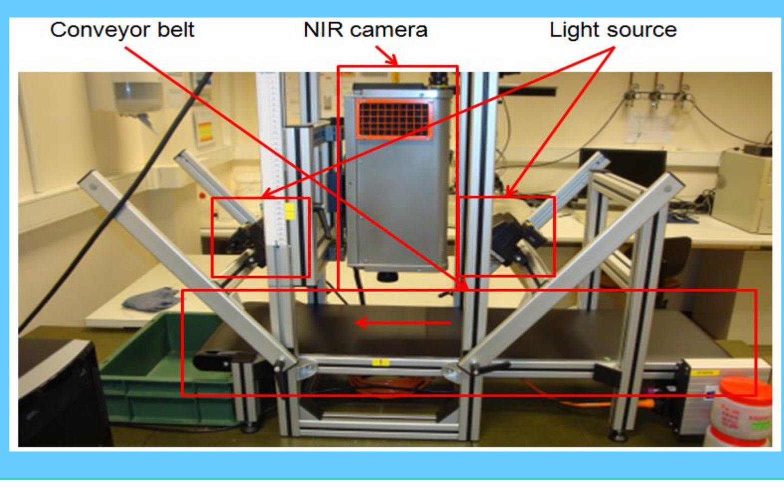
Samples

77 samples of DW and 180 samples of CW were collected in Belgium and Italy in 2014, 2015 and 2016. The aim was to cover enough quality variability of DW at the reception of the Barilla Company as well as a large variability in terms of varieties for CW.

Species	Year	Country	Set name	Nb samples	Nb kernels
DW	2014	Italy	DW1	20	320
	2015	Italy	DW2	32	511
	2016	Italy	DW3	25	400
CW	2014	Belgium	CW1	30	480
	2015	Belgium	CW2	35	560
	2016	Italy	CW3	25	400
	2016	Belgium	CW4	48	768
	2016	Belgium	CW5	42	666
Total				257	4,105

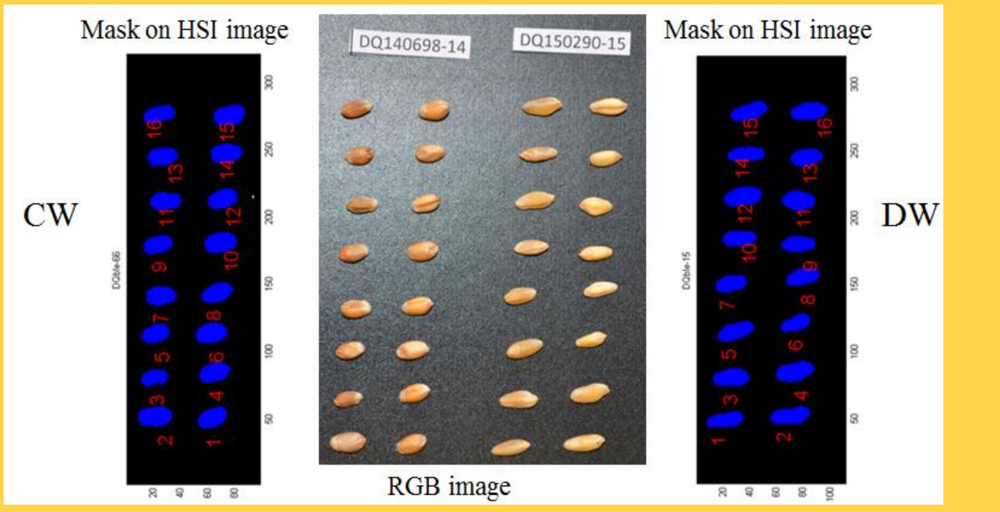
Instrumentation

NIR hyperspectral imaging system with a conveyor belt (Burgermetrics) was used. Near spectra (1118-2425 nm) were recorded in reflection mode with 32 scans by pixel (300 µm x 300 µm). NIR images at kernel level (16 kernels) and at sample level (200 g) were acquired for each sample.



Masking/extracting the information

To extract the data from the image, a mask to isolate the kernels was built by applying the density-based spatial clustering of applications with noise method (DBSCAN) procedure on each image.



Data treatment and results

Partial Least Squares Discriminant Analysis (PLS-DA) was used as classification method for the construction of the discrimination models. To discriminate DW from CW, four approaches were studied based on 8 morphological criteria (area, perimeter, circularity, maxFeret, minFeret, aspect ratio, roundness and solidity), NIR spectral profile, protein content (< 12 % / > 12 %) and ratio vitreous/not vitreous kernels. Models were developed with samples collected in 2014 (DW1,CW1) and 2015 (DW2, CW2) and were validated with samples collected in 2016 (DW3, CW3, CW4, CW5). The models were applied either on the 8 morphological criteria or to all the spectra at pixel level of the images. The results are presented at the kernel level (4105 kernels) and at the sample level (257 samples of +/- 4000 kernels) based on the individual approaches or by combining the approaches.

C1: Morphological criteria approach (kernel)

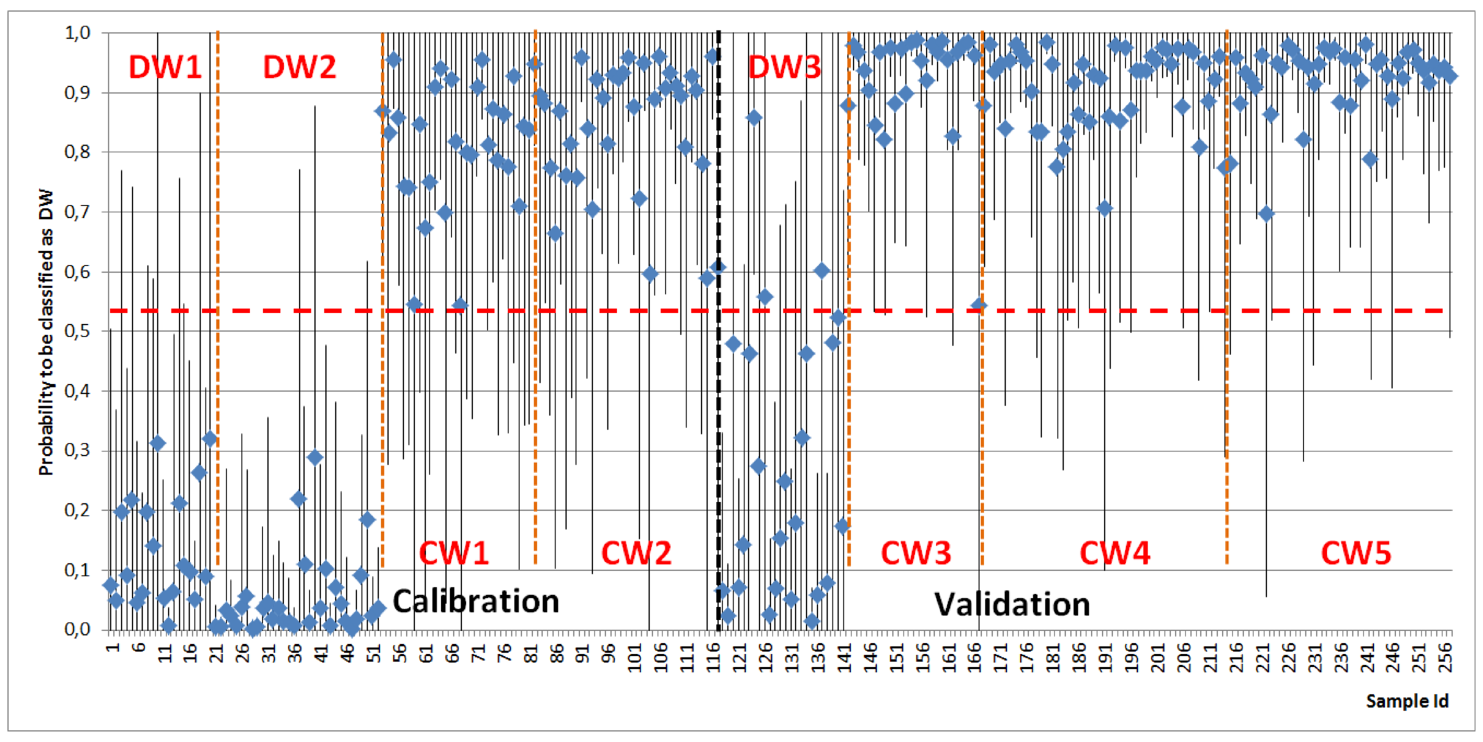


Figure 1: Probability to be classified as DW (◆: mean by image +/- 2 SD) after applying "morphological criteria" model on the 257 images of 16 kernels.

C3: Low / high protein content approach (sample)

Discrimination threshold DW/CW

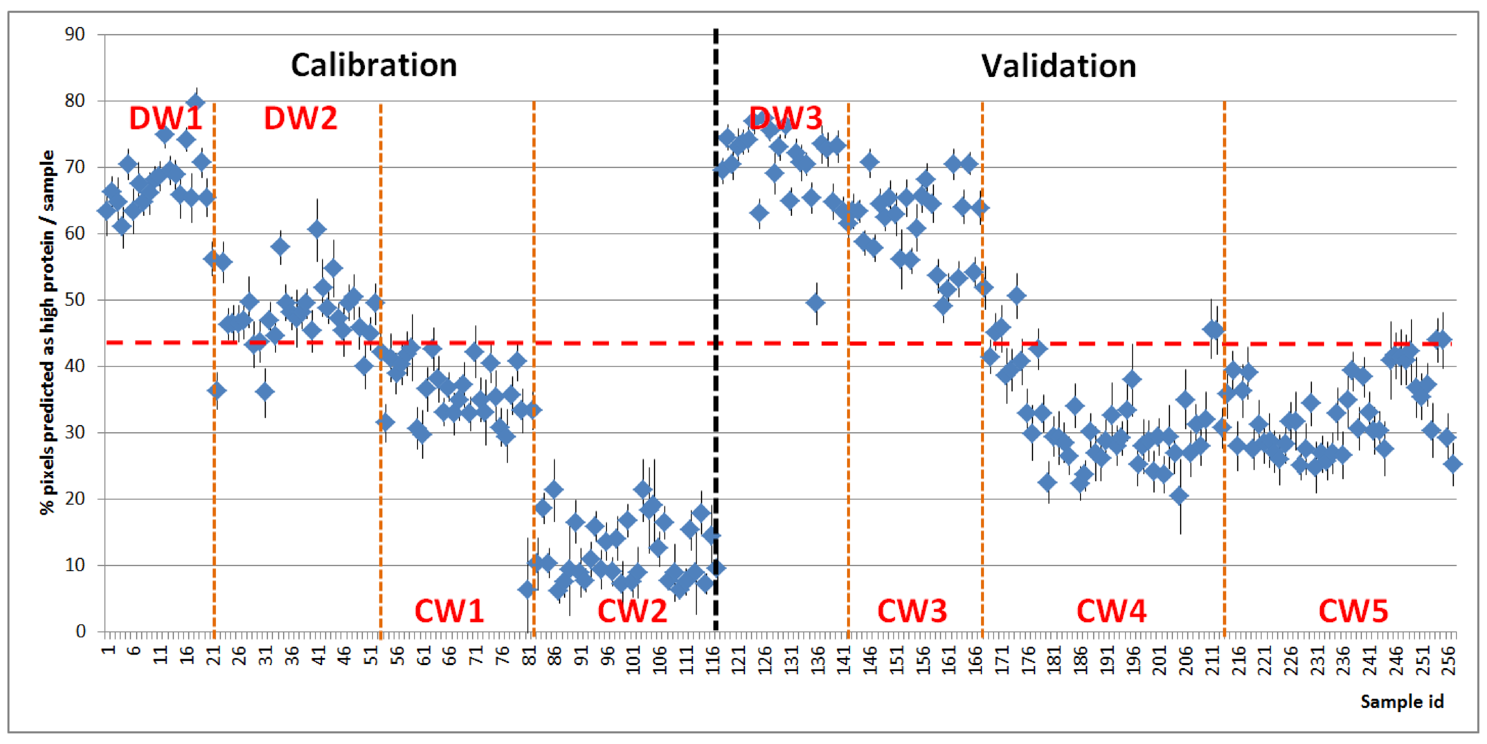


Figure 3: Percentage of pixels predicted as high protein (◆: mean by image +/- 2 SD) after applying "protein" model on the 257 samples of +/- 30 images (4000 kernels).

C2: NIR spectral profile approach (kernel)

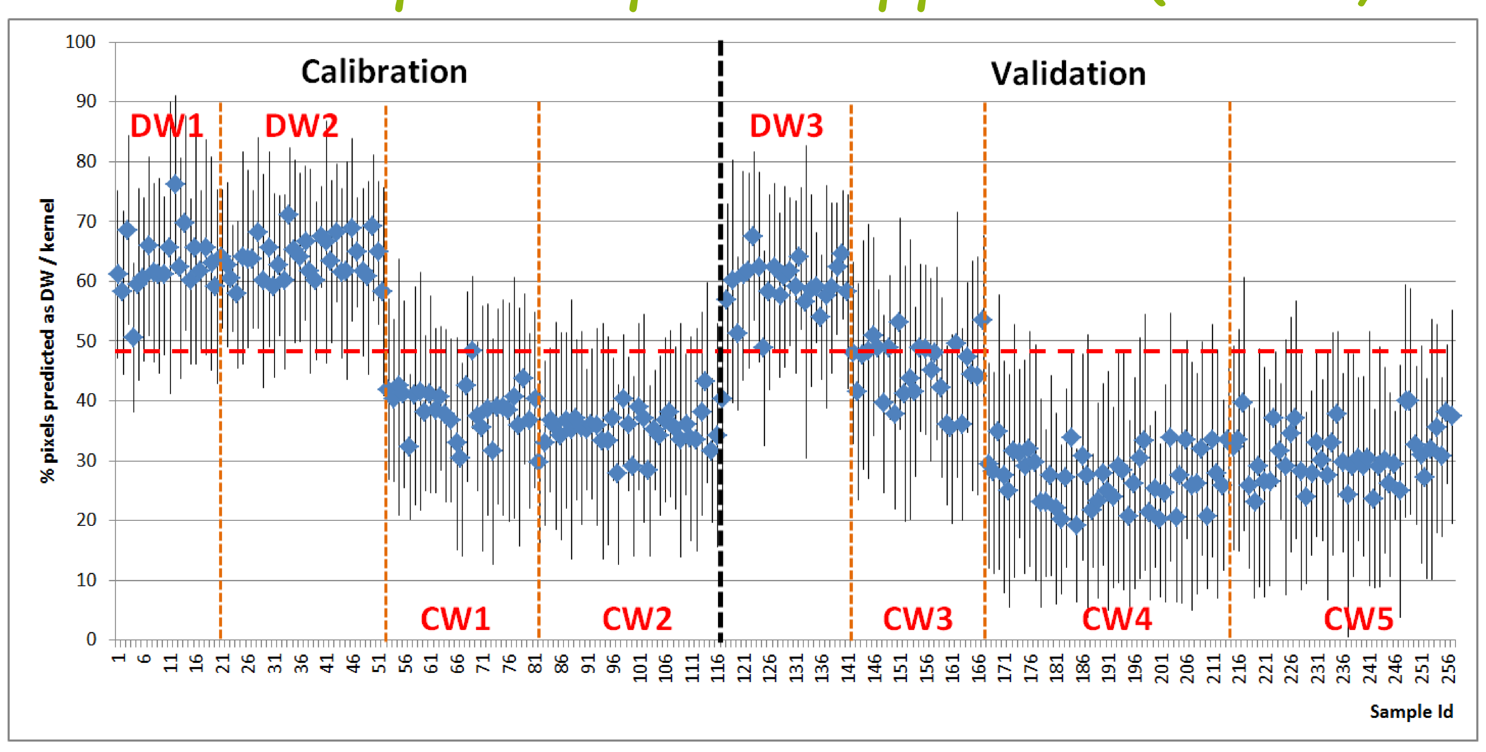


Figure 2: Percentage of pixels predicted as DW (◆: mean by kernel +/- 2 SD) after applying "NIR spectral profile" model on the 257 images of 16 kernels.

C4: Vitreous /not vitreous kernels approach (sample)

Discrimination threshold DW/CW

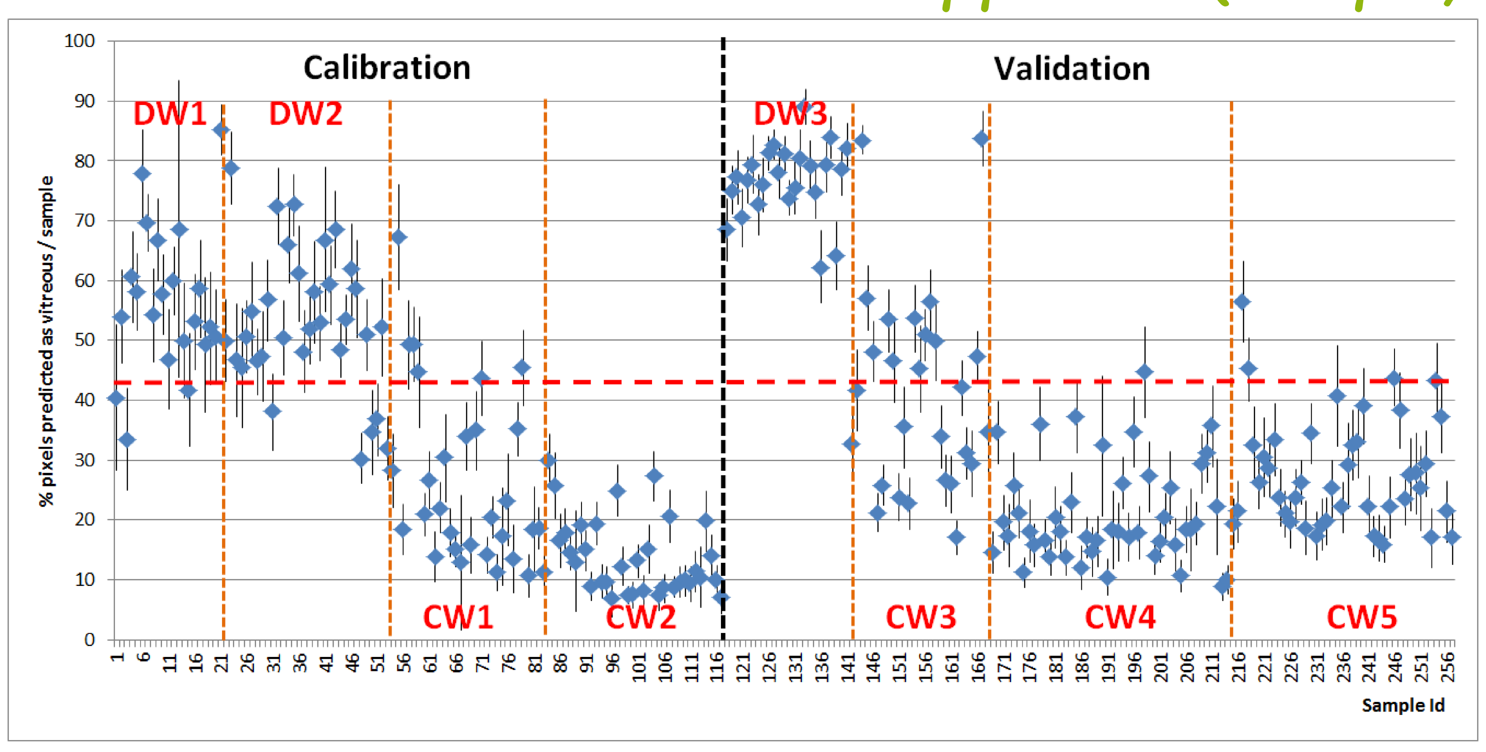


Figure 4: Percentage of pixels predicted as vitreous (◆: mean by image +/- 2 SD) after applying "vitreous" model on the 257 samples of +/- 30 images (4000 kernels).

Data fusion – combination of the 4 approaches

The data fusion consists on combining the predicted value obtained by each approach individually and to calculate a new indicator. A kernel is classified as CW if both approaches lead to a classification as CW. In the other cases, the kernel is classified as DW.

At sample level, for approaches based on 16 kernels, a new indicator of DW is calculated as the percentage of kernels classified as DW for each sample. For approaches based on 200 g samples, another indicator of DW is calculated based on the threshold defined for each approach +/- 2 SD. The probability for each sample to be classified as DW is assessed by calculating the average of these indicators.

Table 1 shows the number and the percentage of CW and DW kernels or samples rightly classified according to the number of criteria used.

		on 4,105 kernels				on 257 samples			
		DW (1,231 kernels)		CW (2,874 kernels)		DW (77 samples)		CW (180 samples)	
		Nb	%	Nb	%	Nb	%	Nb	%
	1 criterion	*1 right criteria*		*0 right criteria*					
Morphological criteria	C1 (16 kernels)	1,084	88.1	2,712	94.4	73	94.8	180	100
NIR spectral profile	C2 (16 kernels)	1,156	93.9	2,618	91.1	77	100	174	96.7
Protein content	C3 (200 g)					74	96,1	147	81,7
Vitreousness	C4 (200 g)					70	90,9	158	87,8
	2 criteria	*1 or 2 right criteria*		*0 right criteria*		*mean 2 criteria*		*mean 2 criteria*	
	C1+C2 (16 kernels)	1,216	98.8	2,471	86.0	77	100	180	100
	C3+C4 (200 g)					75	97,4	168	93,3
	4 criteria					*mean 4 criteria*		*mean 4 criteria*	
	C1+C2+C3+C4					76	98,7	178	98,9

Table 1: Discrimination results between DW and CW kernels and samples according to 1, 2 or 4 criteria.

Conclusion

This study shows the potential of NIR hyperspectral imaging combined with chemometrics to propose solutions for sorting kernels at the entrance of the production chain according to the species (morphological and NIR spectral profile), the protein content and the vitreousness.

Acknowledgements

The project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No.613688 (FoodIntegrity). The authors thank Nicaise Kayoka for technical support.

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