Assessment of Near Infrared hyperspectral imaging for the detection of fraudulent adulteration of durum wheat kernels

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Introduction

Several major pasta production countries, as Italy, France or Greece have decided that only pasta produced from **Durum wheat** - DW (*Triticum durum*) is permitted and that the use of **common wheat** - CW (*Triticum aestivum*), should be considered as fraud. Mixtures of DW and CW can happen in some cases of supply problem or depending of the fluctuation of prices. According to current Italian regulations[1], only a maximum of 3 % of CW is allowed to account for cross-contamination that may happen during post-harvest steps. Efficient analytical methods for the detection of accidental or intentional contamination of CW to DW products within the limits defined by the regulation are therefore required. Until date, all the studies dealing with the detection of CW in DW use macroscopy, microscopy or molecular biology based methods. In the present work, NIR (Near Infrared) hyperspectral imaging has been studied for the discrimination at the kernel level between both species of wheat.

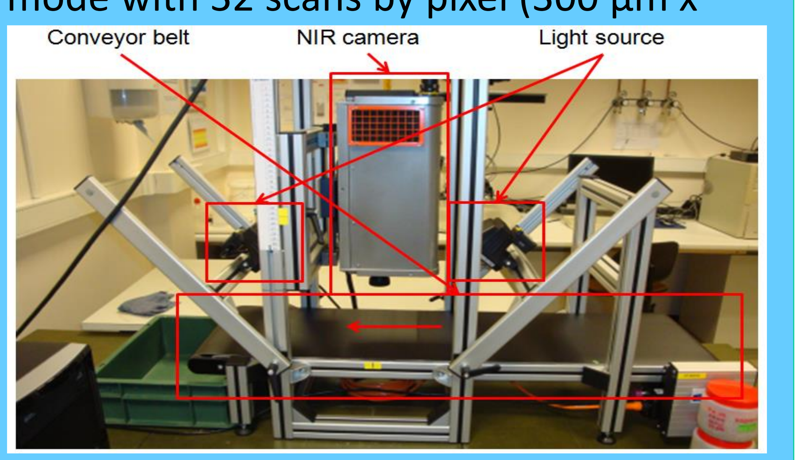
Samples

77 samples of DW and 180 samples of CW were collected respectively in Italy and Belgium 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	512
	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	672
Total				257	4112

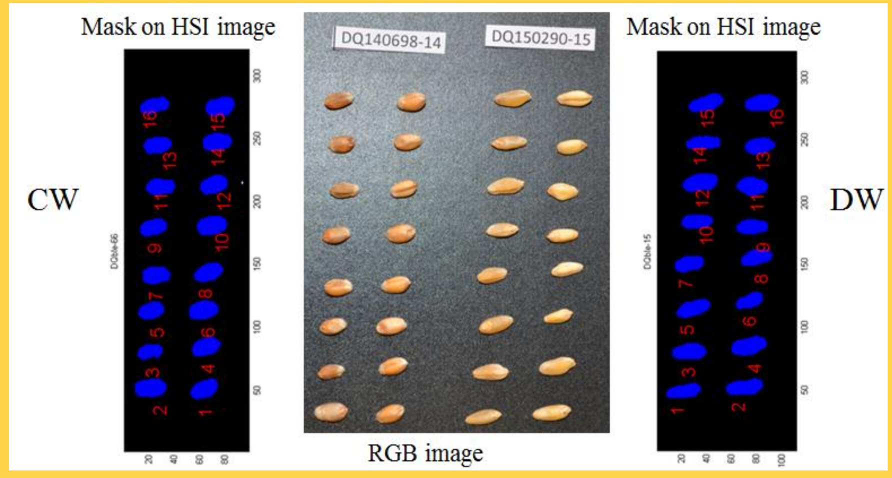
Instrumentation

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** (4112 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)

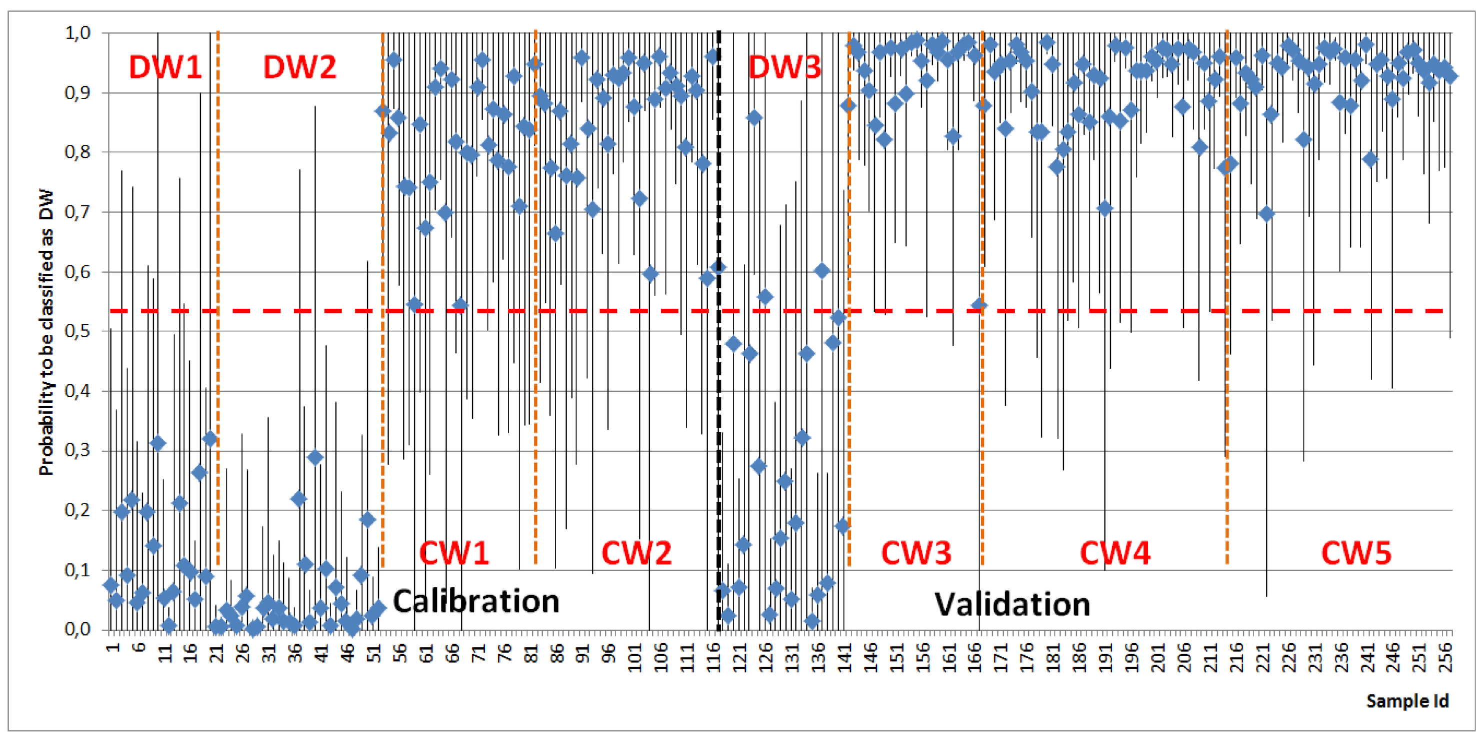


Figure 1: Probability to be classified as DW (◆: mean by image +/- 2 SD) after applying "morphological criteria" model on the 257 images of 16 kernels.

C3: Low / high protein content approach (sample)

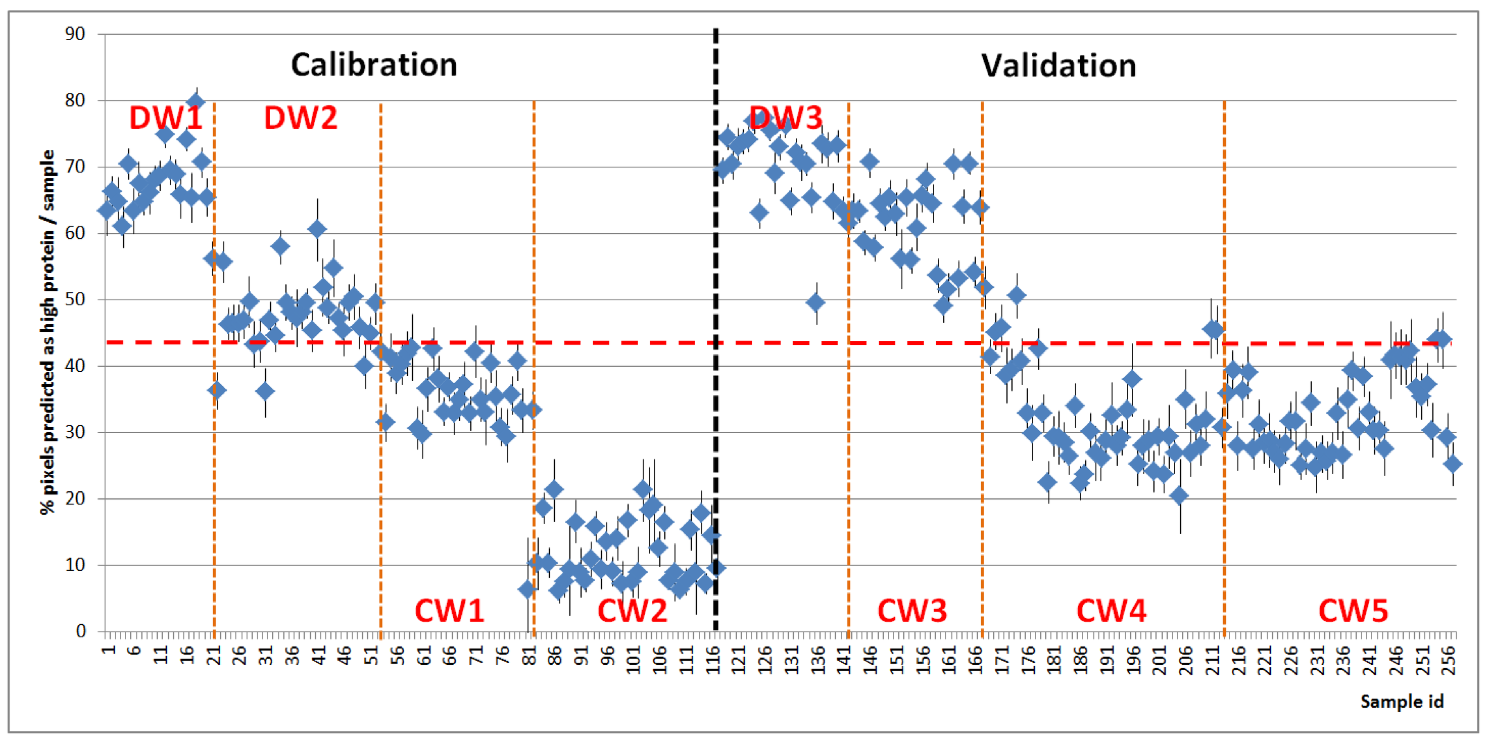


Figure 3: Percentage of pixels predicted as high protein (◆: mean by image +/- 2 SD) after applying "protein" model on the 257 samples of +/- 30 images (4000 kernels).

Discrimination threshold DW/CW

C2: NIR spectral profile approach (kernel)

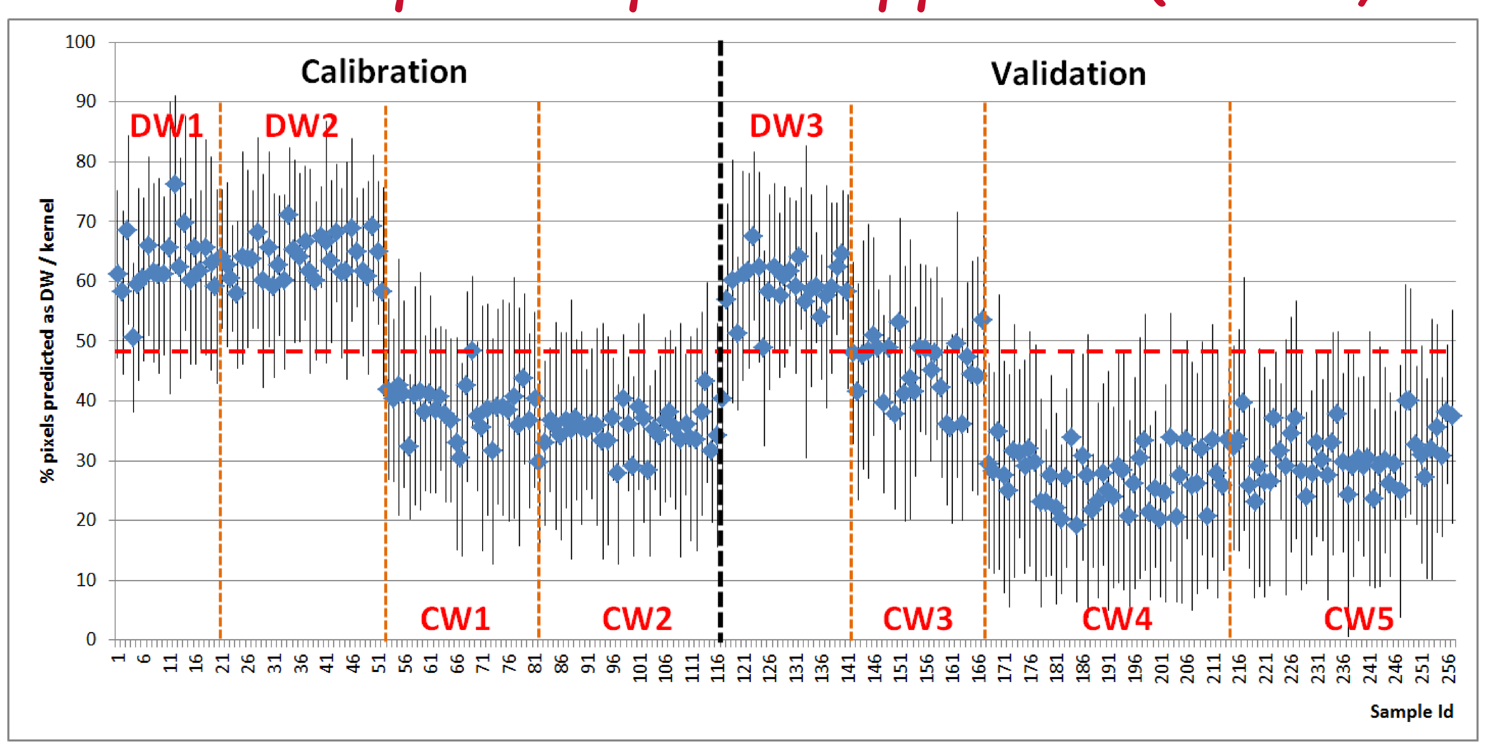


Figure 2: Percentage of pixels predicted as DW (◆: mean by kernel +/- 2 SD) after applying "NIR spectral profile" model on the 257 images of 16 kernels.

C4: Vitreous /not vitreous kernels approach (sample)

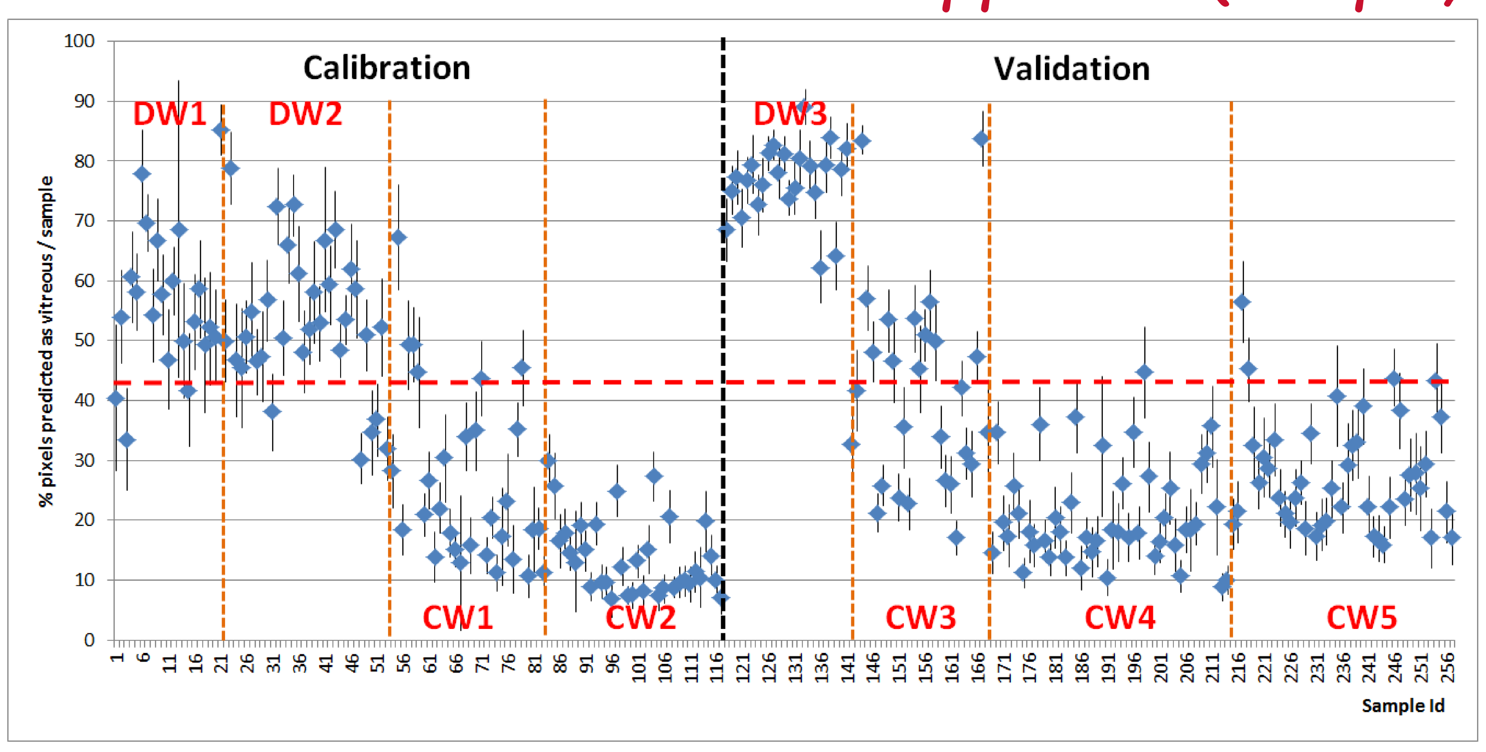


Figure 4: Percentage of pixels predicted as vitreous (◆: mean by image +/- 2 SD) after applying "vitreous" model on the 257 samples of +/- 30 images (4000 kernels).

Discrimination threshold DW/CW

Data fusion – combination of the 4 approaches C1, C2, C3 and C4

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 (Figures 1 and 2) lead to a classification as CW. In the other cases, the kernel is classified as DW.

		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 criterion*		*0 right criterion*					
Morphological criteria (Figure 1)	C1 (16 kernels)	1,084	88.1	2,712	94.4	73	94.8	180	100
NIR spectral profile (Figure 2)	C2 (16 kernels)	1,156	93.9	2,618	91.1	77	100	174	96.7
Protein content (Figure 3)	C3 (200 g)					74	96,1	147	81,7
Vitreousness (Figure 4)	C4 (200 g)					70	90,9	158	87,8
	2 criteria	*1 or 2 right criteria*		*0 right criterion*		*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: Number and percentage of CW and DW kernels or samples rightly classified according to the number of criteria used.

At **sample level**, for approaches based on 16 kernels (Figures 1 and 2), 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 (Figures 3 and 4), 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.

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 (C1) and spectral (C2) criteria), the protein content (C3) and the vitreousness (C4).

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Répondre aux questions d'aujourd'hui et relever les défis de demain

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