Using Independent Component Analysis to process near infrared hyperspectral images for detecting powder food adulteration

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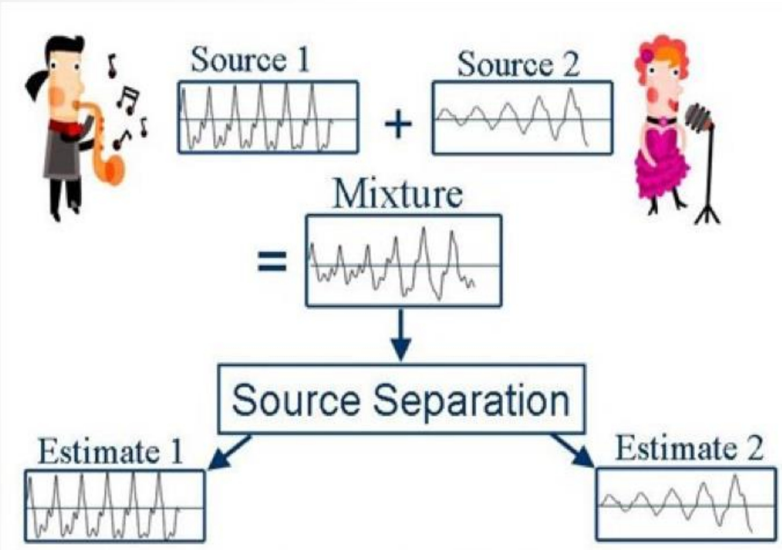
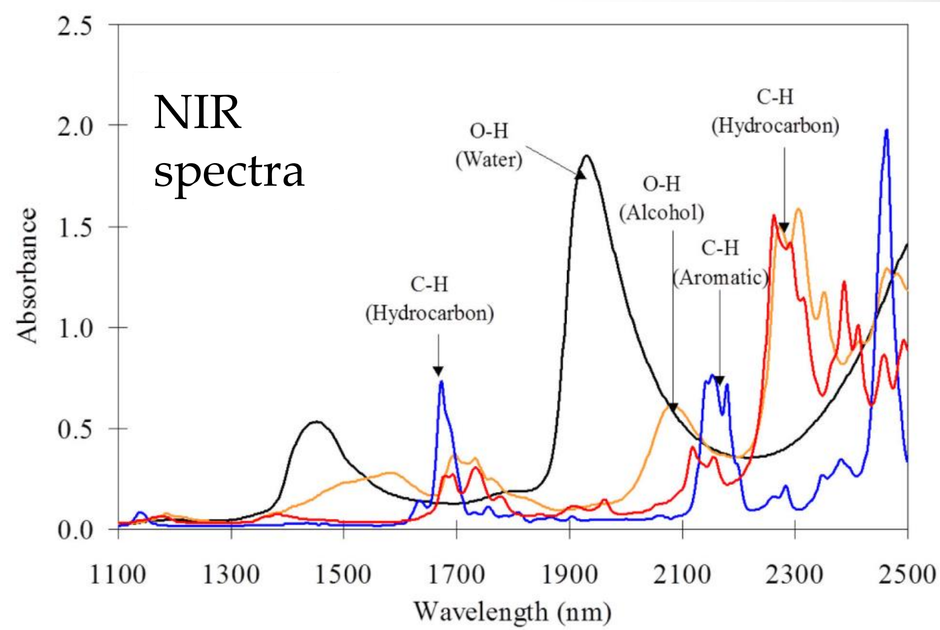
Blind Source Separation





Different pure sources combined to make one mixed signal

Theory of ICA

- Each observed sensor signal is assumed to be weighted sum of pure source signals.

- Weighting coefficients are proportional to concentrations of pure compounds :

$$\mathbf{x_1 = a_{11} \times s_1 + a_{12} \times s_2} \qquad \mathbf{x_2 = a_{21} \times s_1 + a_{22} \times s_2}$$

- In matrix notation :

$$\mathbf{X = A \times S} \qquad \dots (1)$$

Procedure

- ICA calculates a demixing matrix, **W**

- **W** approximates $\mathbf{A}^{-1}$, the inverse mixing matrix

- Pure component signals are recovered from measured mixed signals:

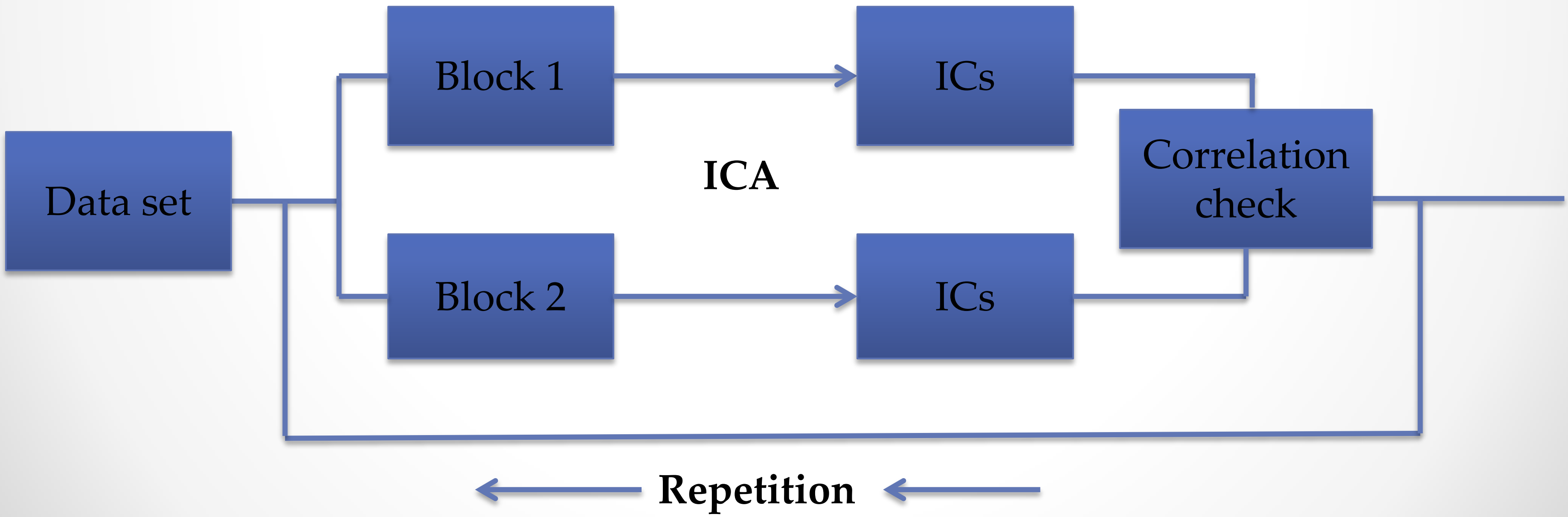
$$\mathbf{S} = \mathbf{W} \times \mathbf{X}$$

Algorithm used

- Joint Approximation Diagonalization of Eigenmetrices (**JADE**) algorithm
- Based on fourth order moment (**Kurtosis**)
- Gaussian distributions possess zero excess kurtosis
- JADE seeks **rotation** of mixed vectors to estimate source vectors with high kurtosis values.

Deciding on number of ICs: *Random ICAbyBlocks*

Perform ICA by splitting data into two blocks and comparing correlations of ICs extracted from the two data blocks.



Peanut allergy

- Peanut allergy is a potentially life-threatening condition.
- European Directive **2003/89/EC** makes the labeling of all ingredients mandatory, especially food allergens used in the recipes of packaged foods.
- **Ubiquitous nature of peanut** in food industry makes dietary avoidance difficult, **a risk still persists**.

Sample preparation

- Sample mixtures of peanut in wheat flour **0.05 %** and **0.01 %** by weight
- Size of the ground nuts **500-1000μm** (EU-Institute for Reference Materials and Measurements)
- Particle size of wheat flour **100-212μm**
- **Aluminum platform** for sample representation

Camera specification

- Line-scan push-broom camera : HySpex (**SWIR 320m-e**)
- Spectral range **1000–2500 nm**
- Spectral sampling every **6 nm** and **256** spectral bands.
- Pixel size **408 × 261 μm**

newfood

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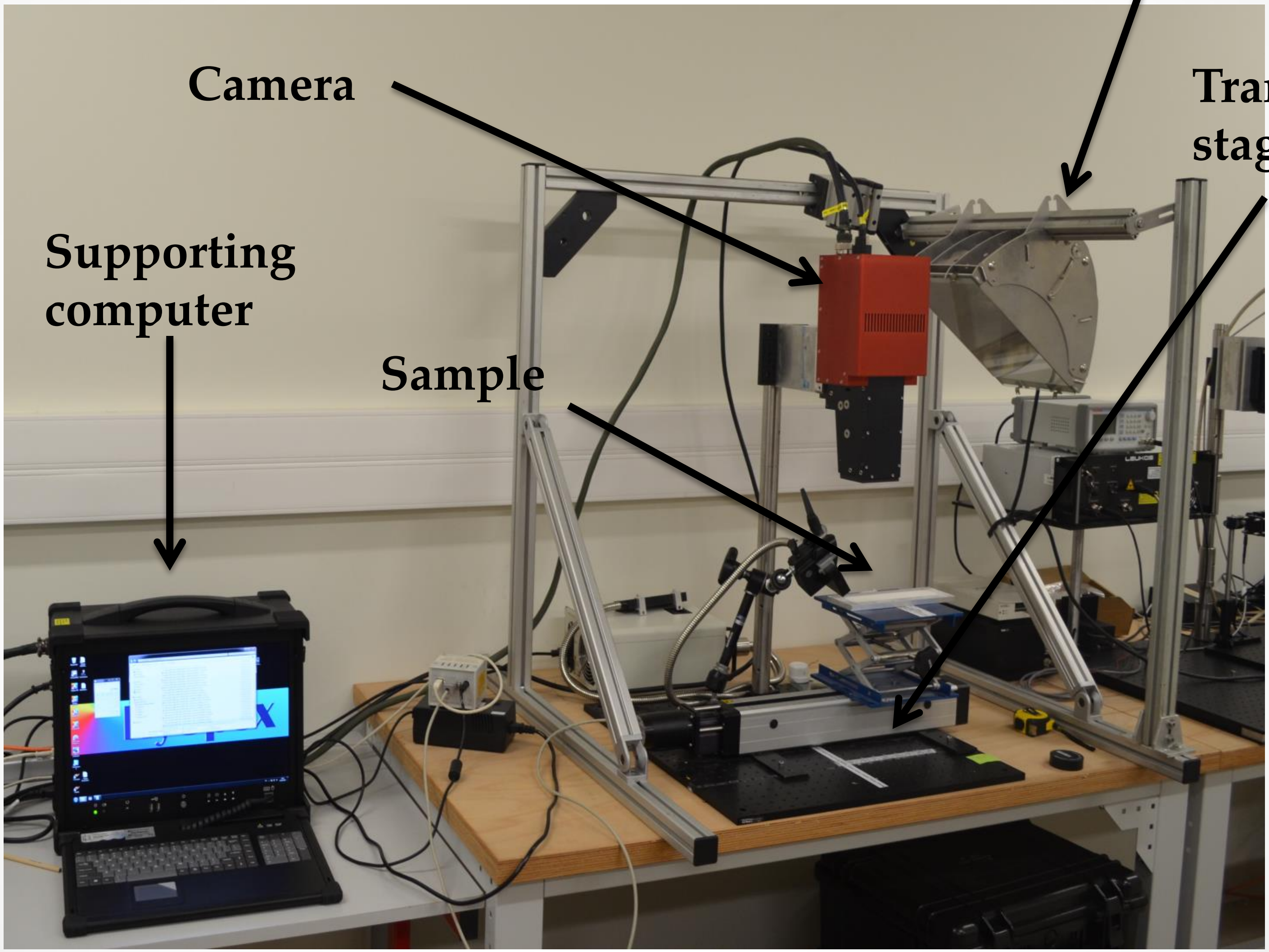
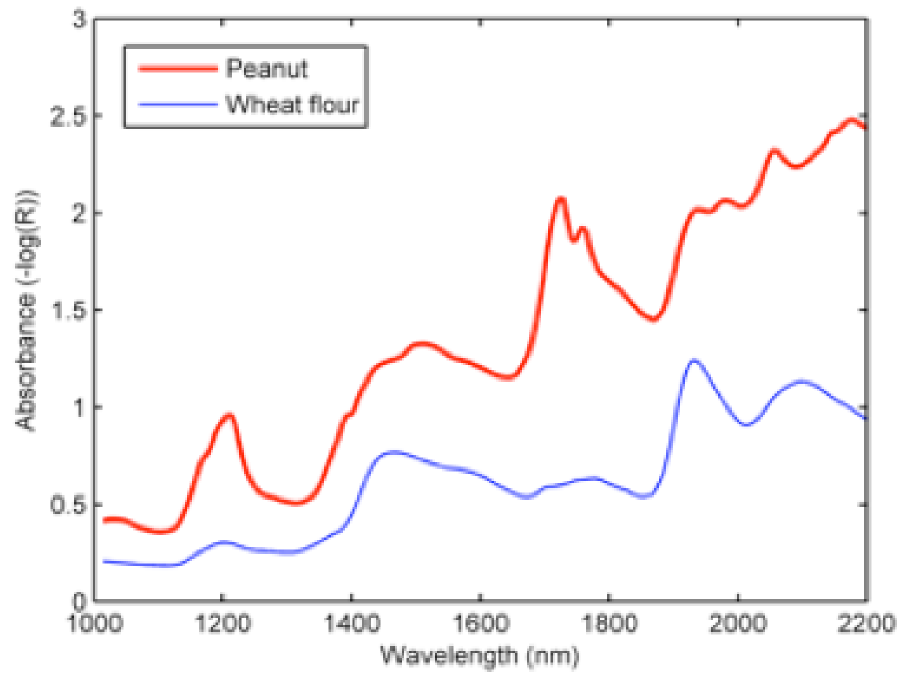
NIR hyperspectral imaging for detection of nut contamination

Acquisition

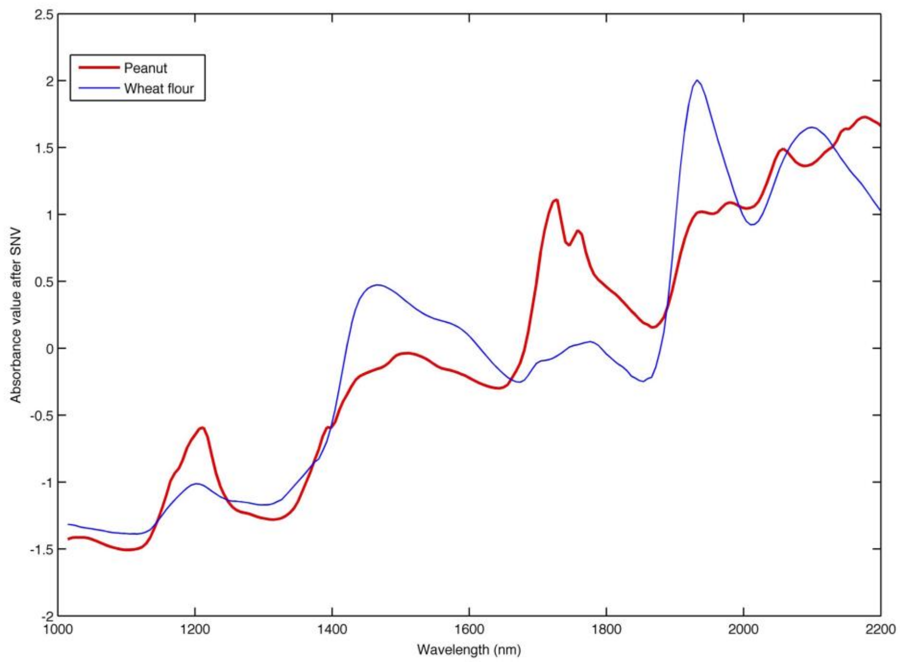


Hyperspectral camera setup

Spectral profiles of pure samples



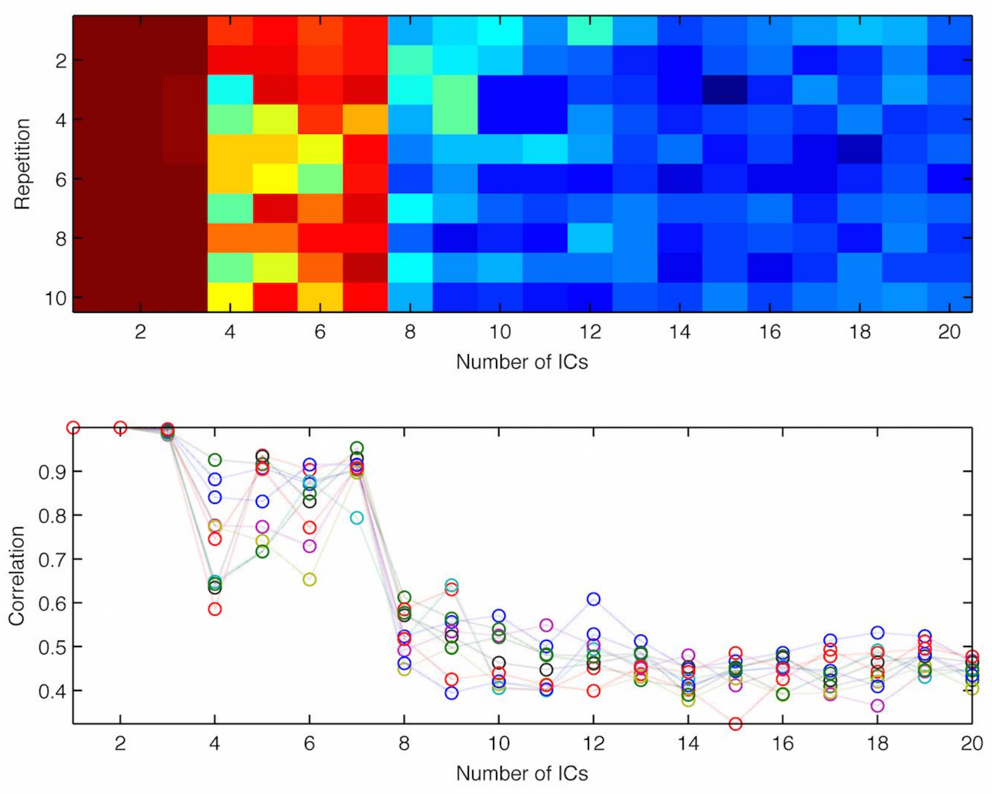
(a). Mean spectra



(b). Spectra after treatment (SNV)

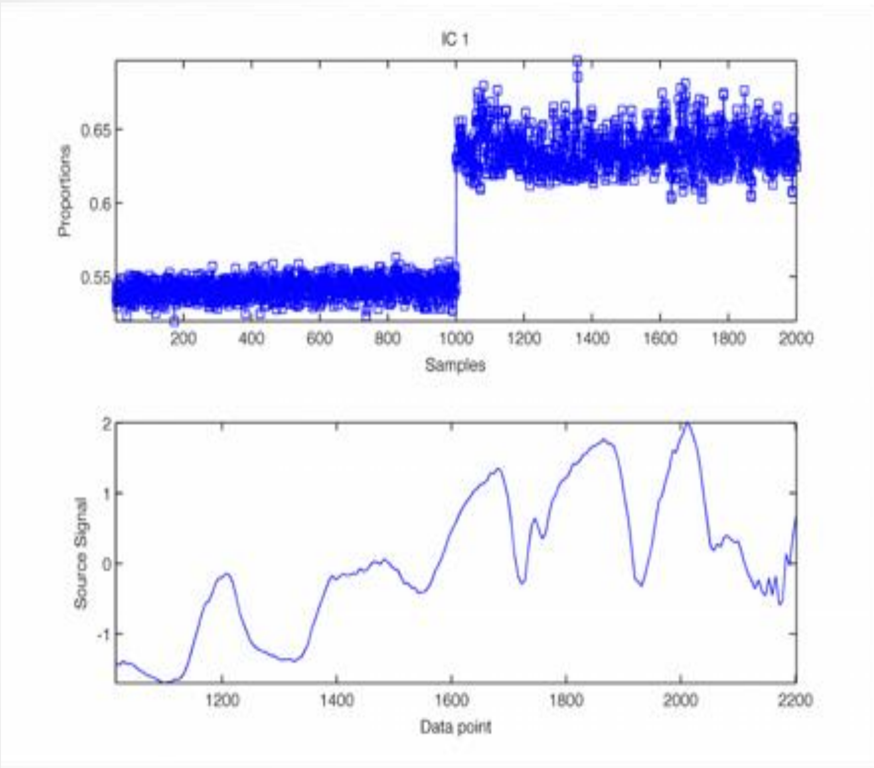
Random ICAbyblocks

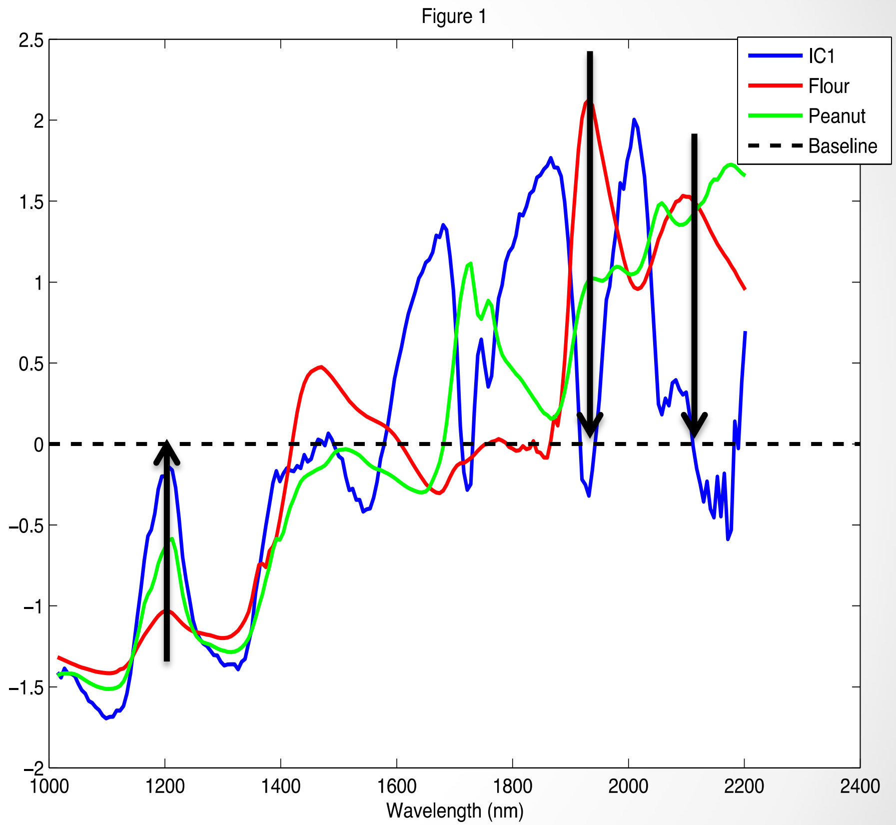
- **Two** blocks
- Performed up to **20 ICs**
- With **10** repetitions
- **7 ICs** had high correlations



Red: High correlation *Blue: Low correlation*

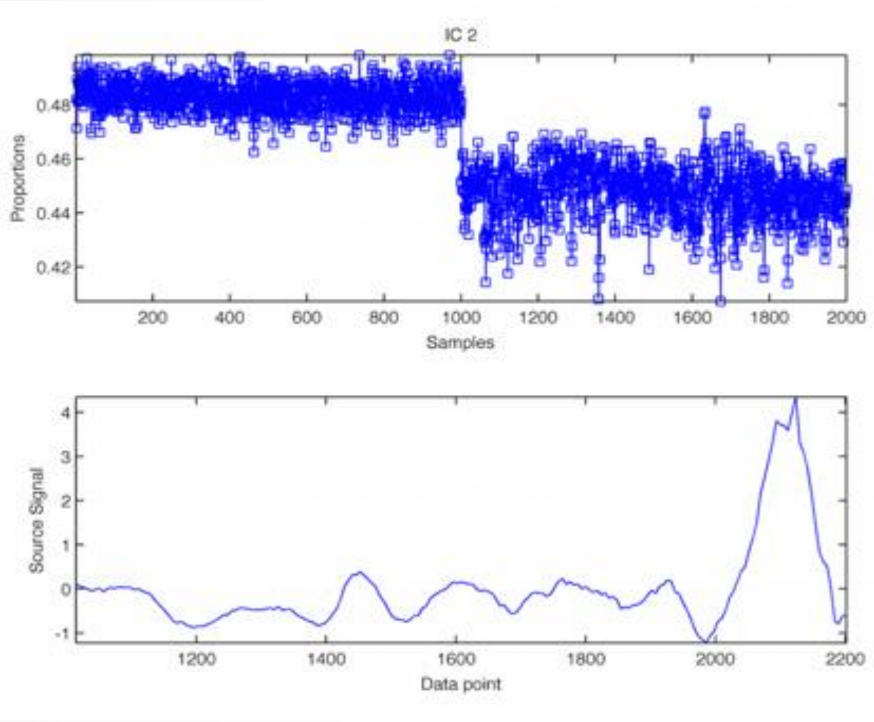
IC signals



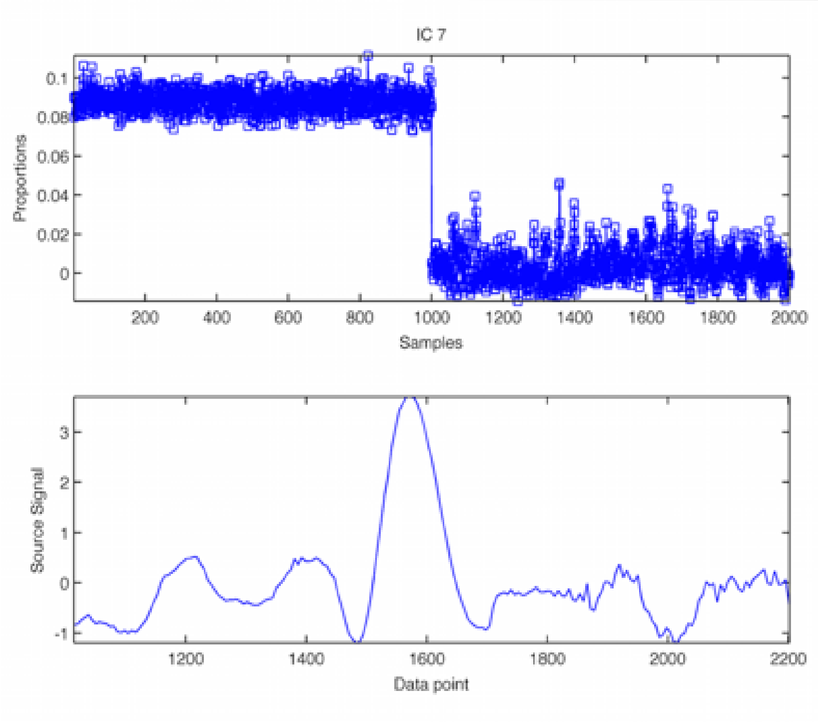


- *IC1 related to non-chemical variation*
- *At every peak in pure spectra, IC1 is tending to zero*
- *Bigger particle size of peanut could be a reason*

IC2 and IC7 related to starch



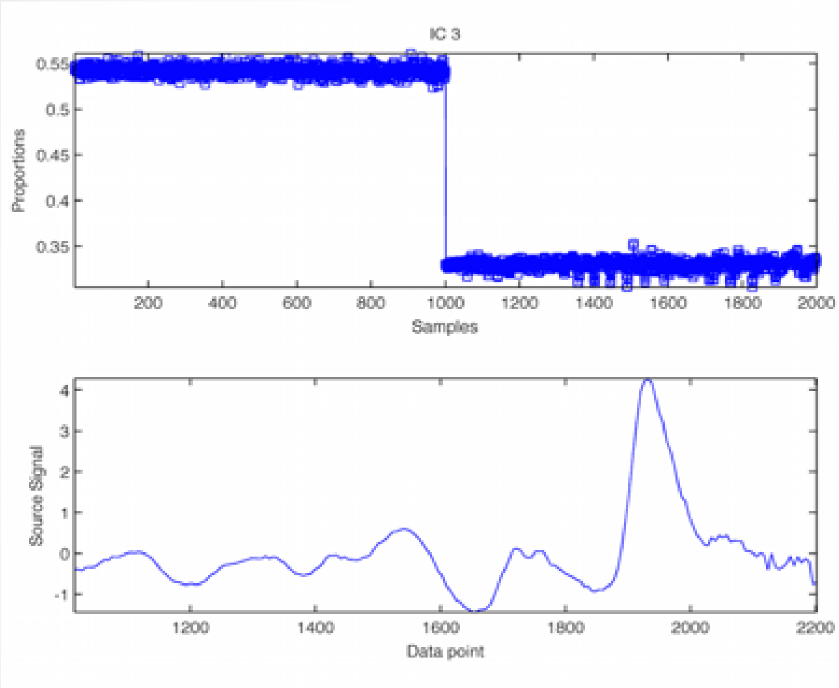
(a). Starch (2100 nm)



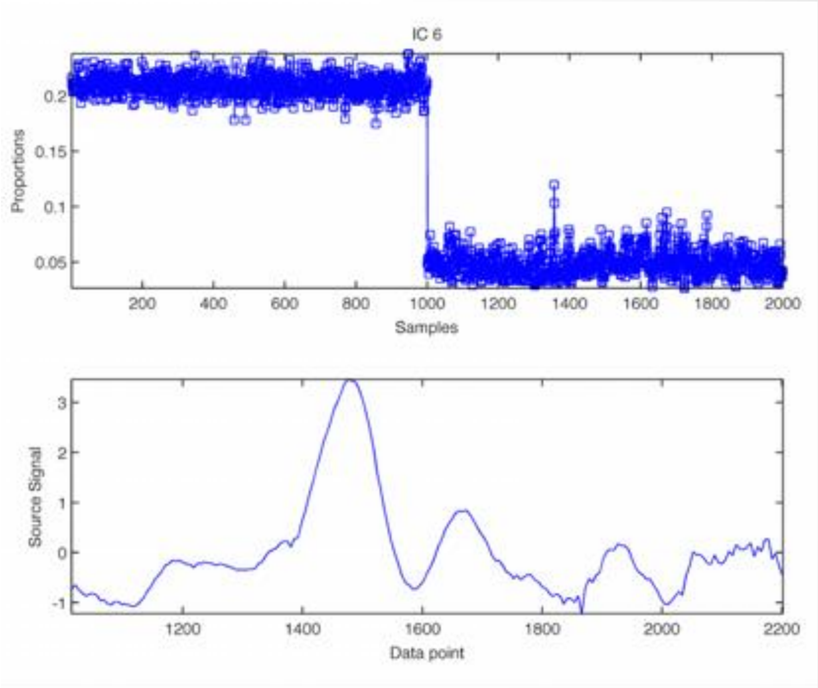
(b). OH stretching Starch (1580 nm)

- Wheat flour has higher starch

IC3 and IC6 related to moisture



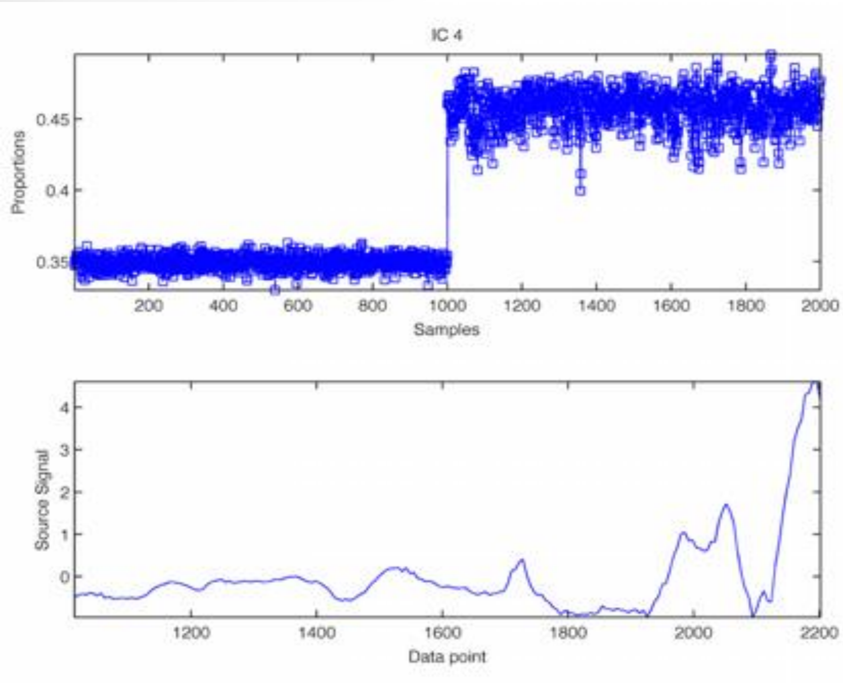
(a). OH stretching (1940 nm)



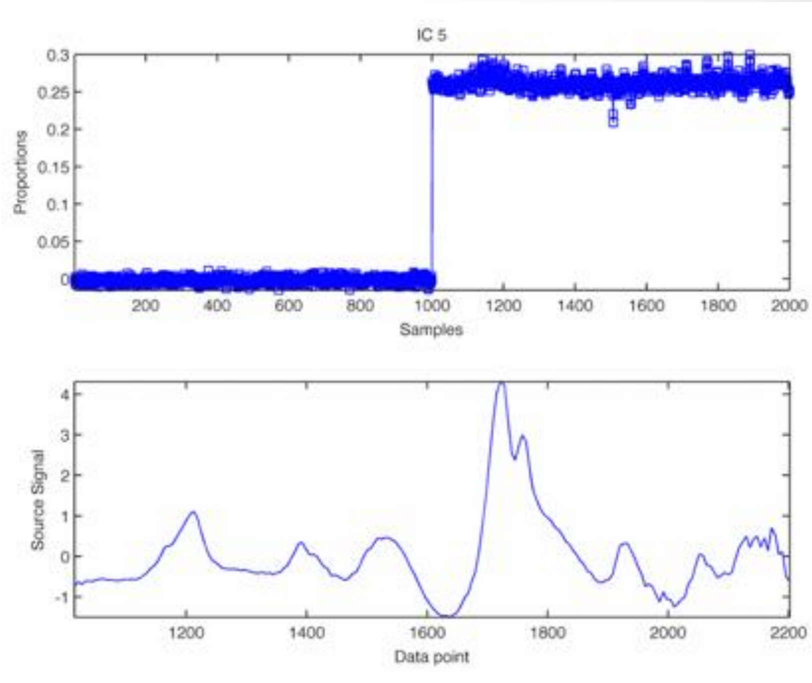
(b). OH stretching (1450 nm)

- Wheat flour has higher moisture

IC4 and IC5 related to fatty acid



(a). Amide function (2030 nm)



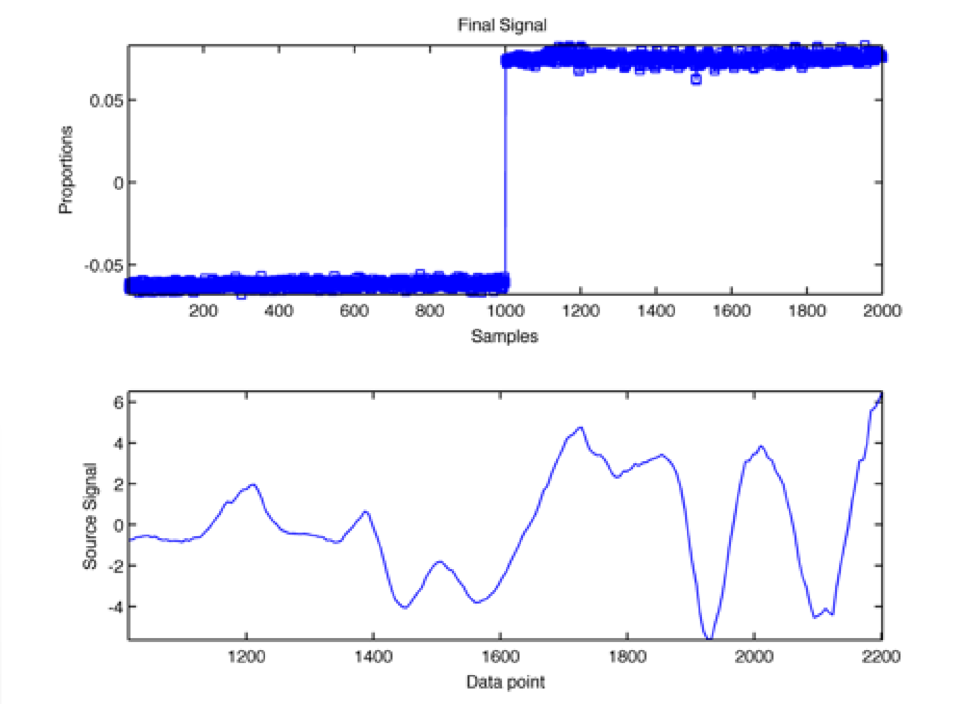
(b). Fatty acid and overtone (1734, 1395, 1200 nm)

- Peanut has higher fatty acid and amide

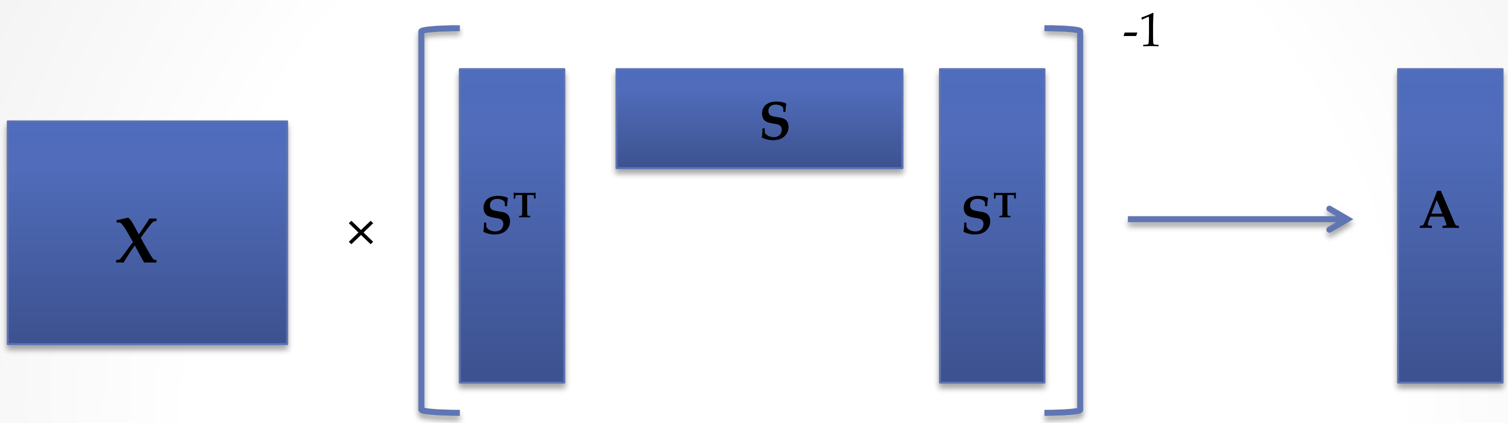
Synthetic Unmixing Signal

Calculate the difference between the sum of peanut ICs and the sum of wheat flour ICs

Signal (S) = IC1+IC4+IC5 − (IC2+IC3+IC6+IC7)



Unmixing of HSI



X = Unfolded hyperspectral image

S = Synthetic unmixing signal

S^T = Transpose of synthetic signal

A = Proportions values

Validation of synthetic signal

- A **hyperspectral** image with known position of peanut **was simulated**.
- Synthetic signal was tested for classification.
- **High contrast** was **obtained** for pixels representing peanuts.

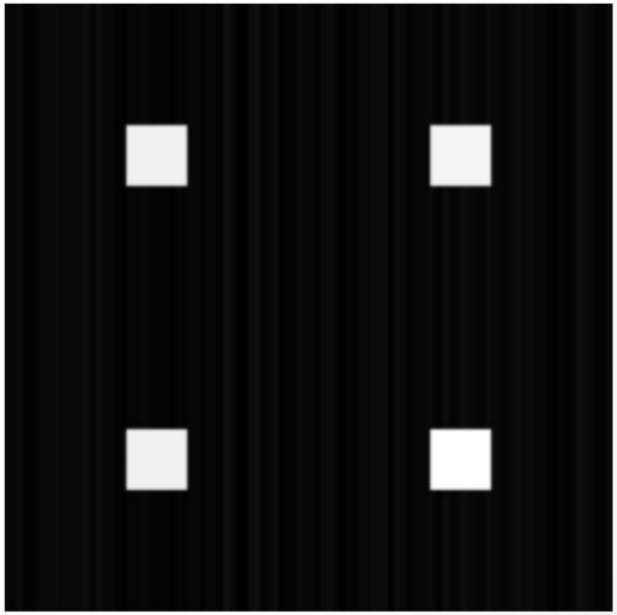


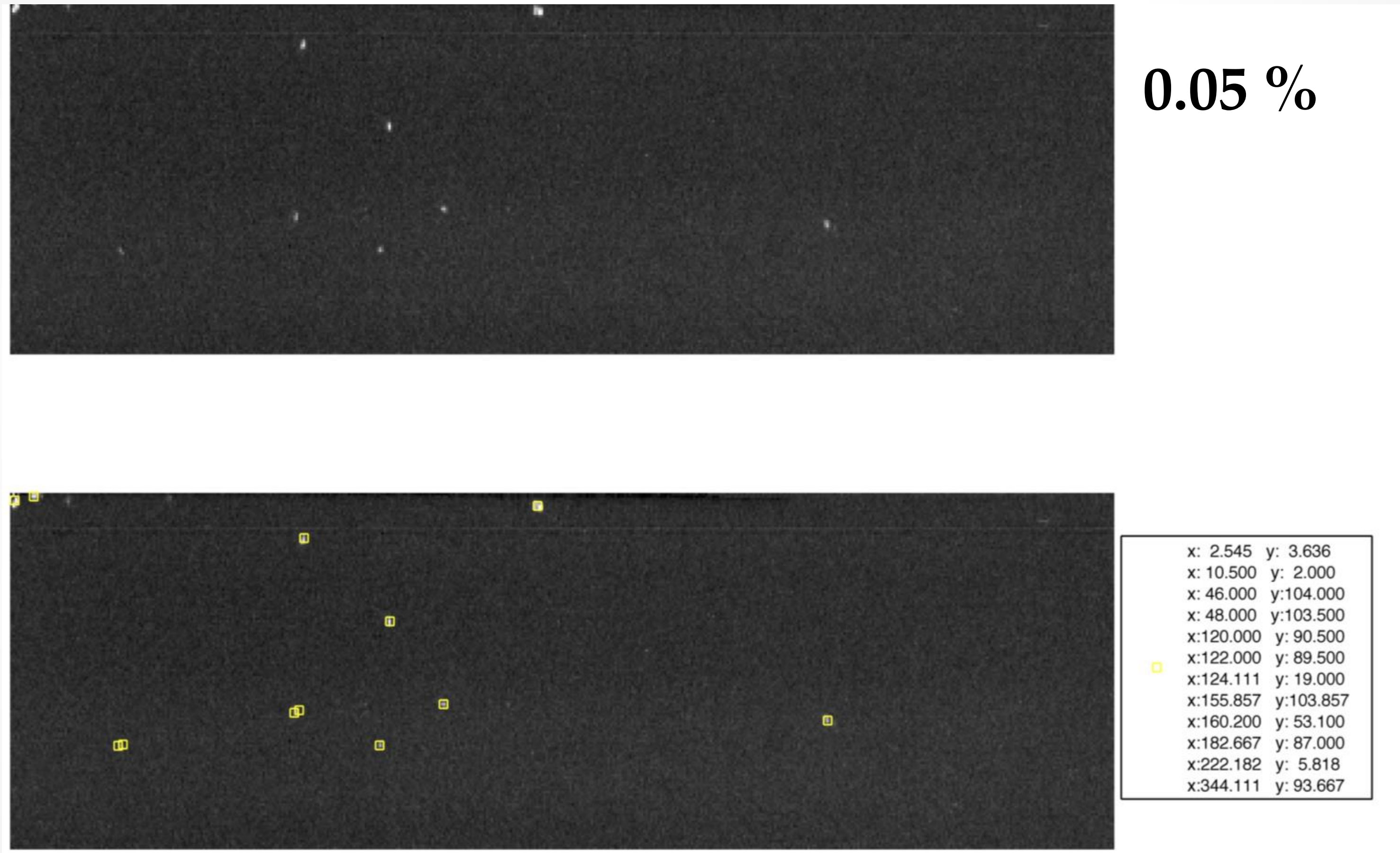
Image segmentation

- **Connected Component labeling** to detect pixels with enhanced contrast.
- Classification map generated with manual threshold.
- **Regionprop** function in Matlab was used to extract spatial locations

Results

Before processing (0.05 %)

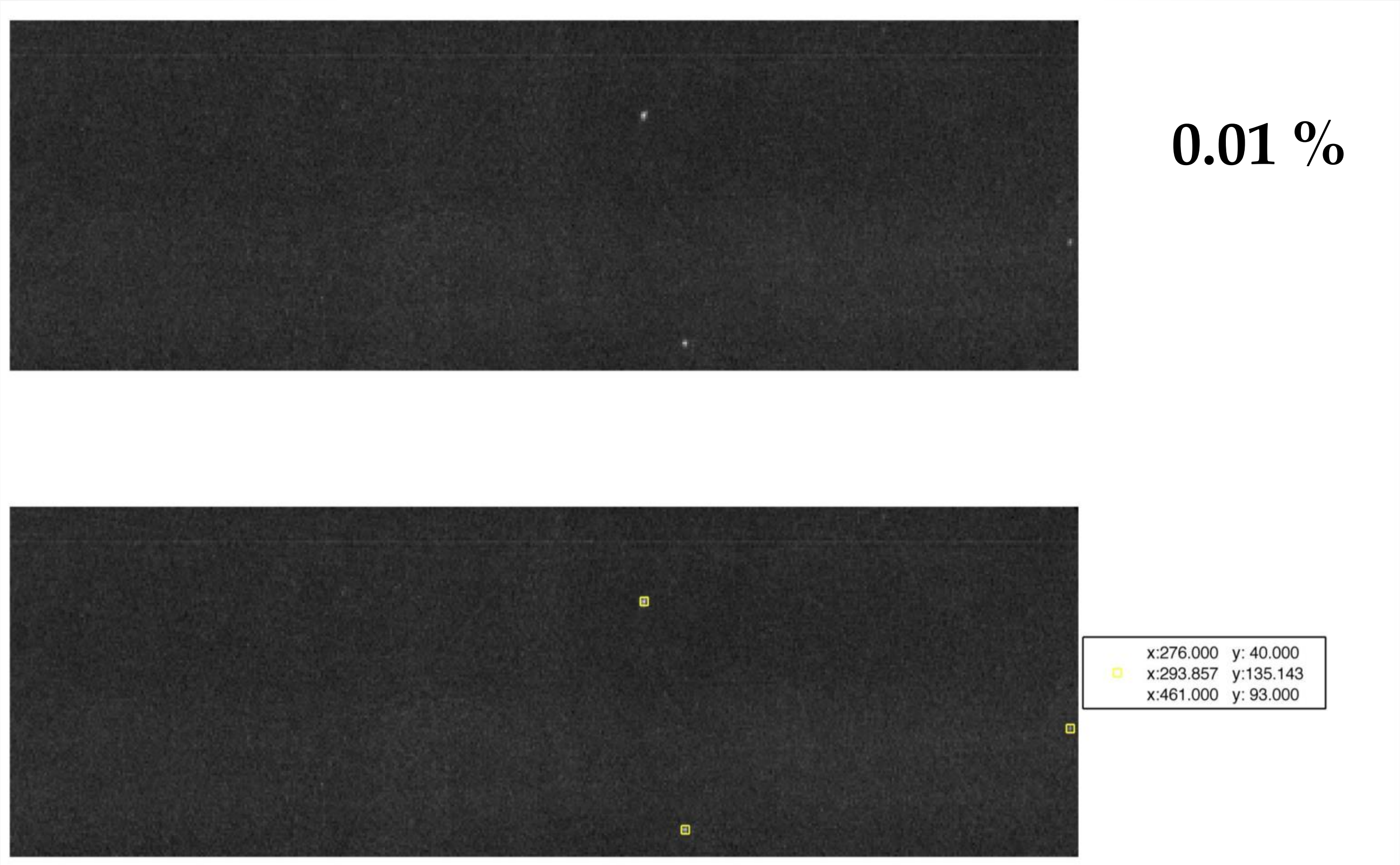
After processing



Proportions images and extracted features image for 0.05% peanut traces in wheat flour (146 × 464 pixels).

Before processing (0.01 %)

After processing



Proportions images and extracted features image for 0.01% peanut traces in wheat flour (146 × 464 pixels).

Conclusions

- Detection of peanut traces was possible down to 0.01 %.
- ICA provided an easy understanding of underlying source signals
- Source signals can be easily used for classification and regression analysis.
- HSI with ICA can be used for quantitative prediction of the chemical constituents, with simultaneous representation of their spatial distribution.

Thank you

Peanuts free zone!