Hyperspectral imaging for compositional information of sandwiches

15-11-2021, Martin Alewijn (WFSR)

WAGENINGEN
UNIVERSITY & RESEARCH

Goal

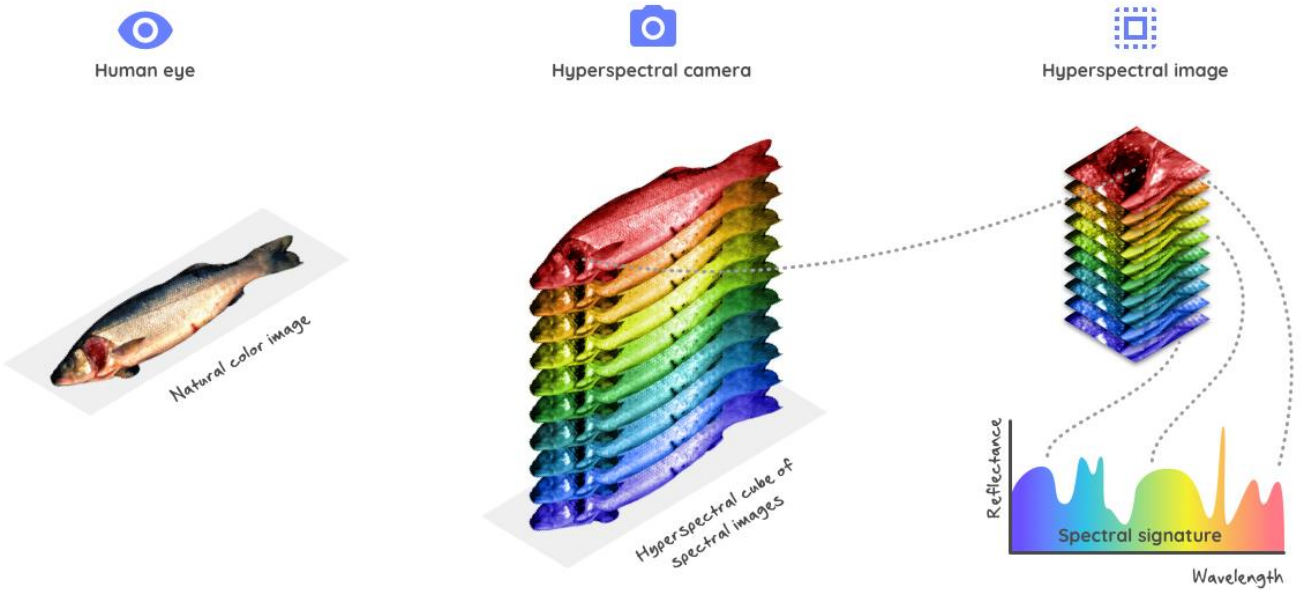
Contribute to determining food intake:

- Non-destructive determination of macronutrients in a real-life setting
- (Complex) sandwiches

→ **Hyperspectral imaging**

Source: PNGfind.com

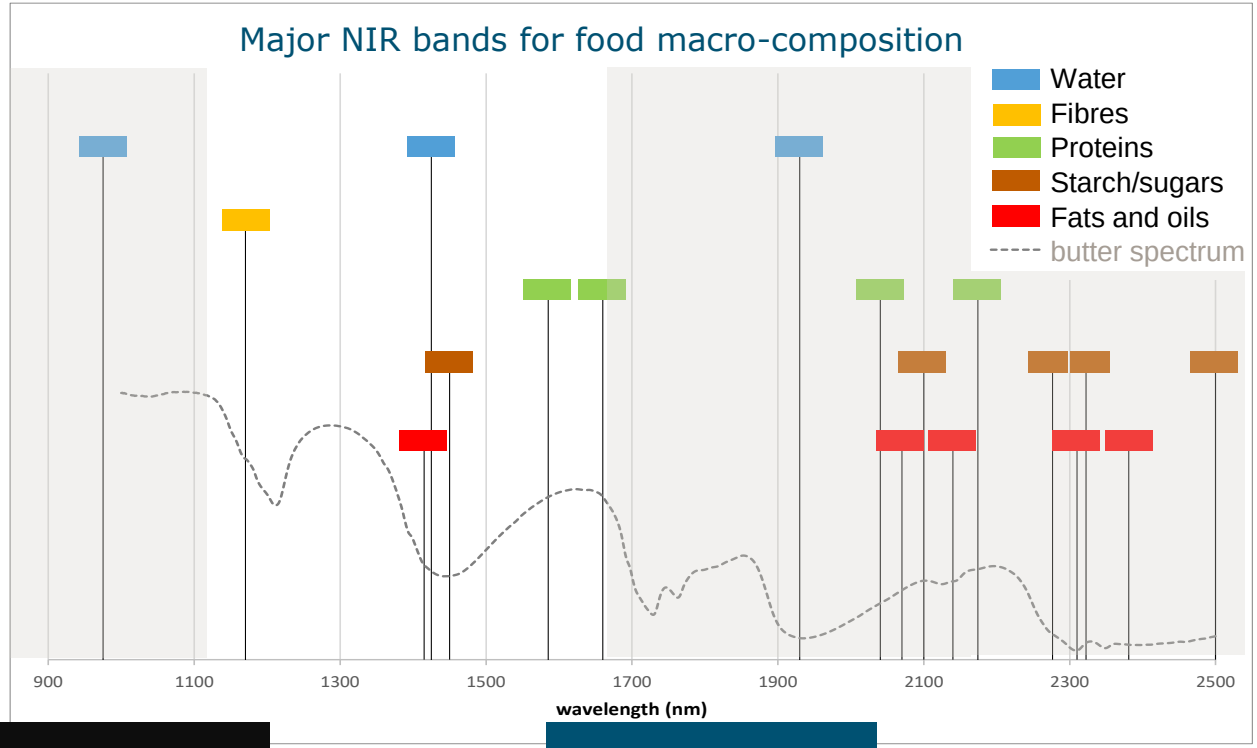
Hyperspectral imaging (HSI)



Source: condifood.com

- Yields a (sw)NIR spectrum for each pixel of ~0.1 mm^2

Information from NIR



3rd overtone region

1st overtone region

2nd overtone region

Combination band region

Adapted from:
https://doi.org/10.1016/j.jfoodeng.2020.109954

WAGENINGEN
UNIVERSITY & RESEARCH

Challenges

- Diverse foods – no calibration for all matrices!
- Complex sandwiches: unknown number and type of foods
- Uneven surfaces (reflectance!) + shadows
- Penetration depth NIR: couple of mm
    - Underlying food might influence the spectrum
    - Underlying food might be hidden

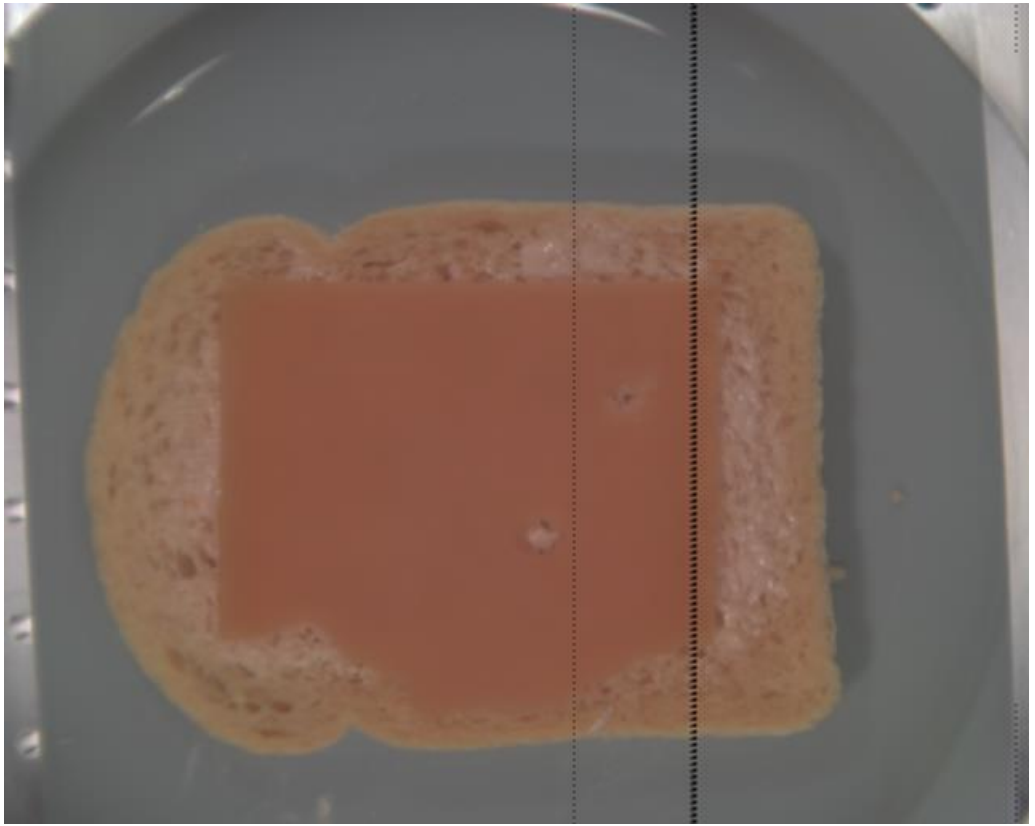
Equipment

- IMEC Snapscan SWIR C100U-0007
- Range 1116-1670 nm (108 bands)
- 640x512 pixels
- 15 seconds acquisition time

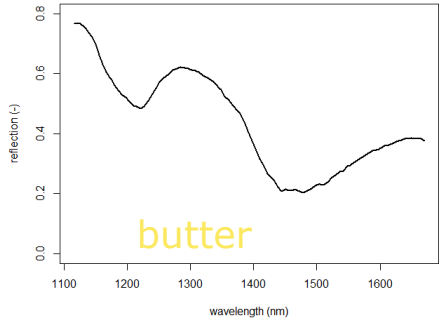
Raw data

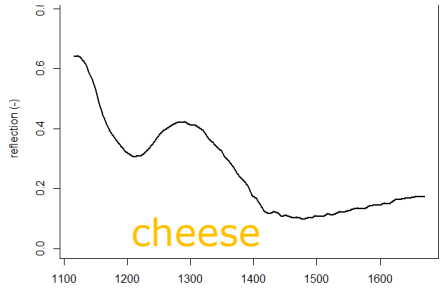
- 640×512×108 (w×h×λ) = 135MB ENVI file

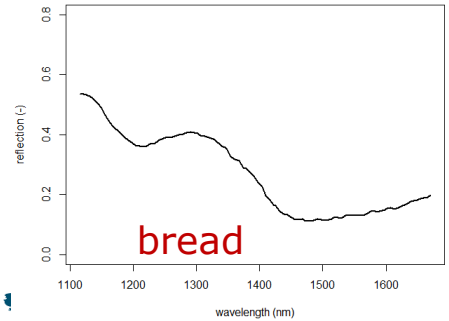
- *Example:*
  bread with butter and cheese as RGB
  - r = slice @ 1121 nm
  - g = slice @ 1374 nm
  - b = slice @ 1660 nm

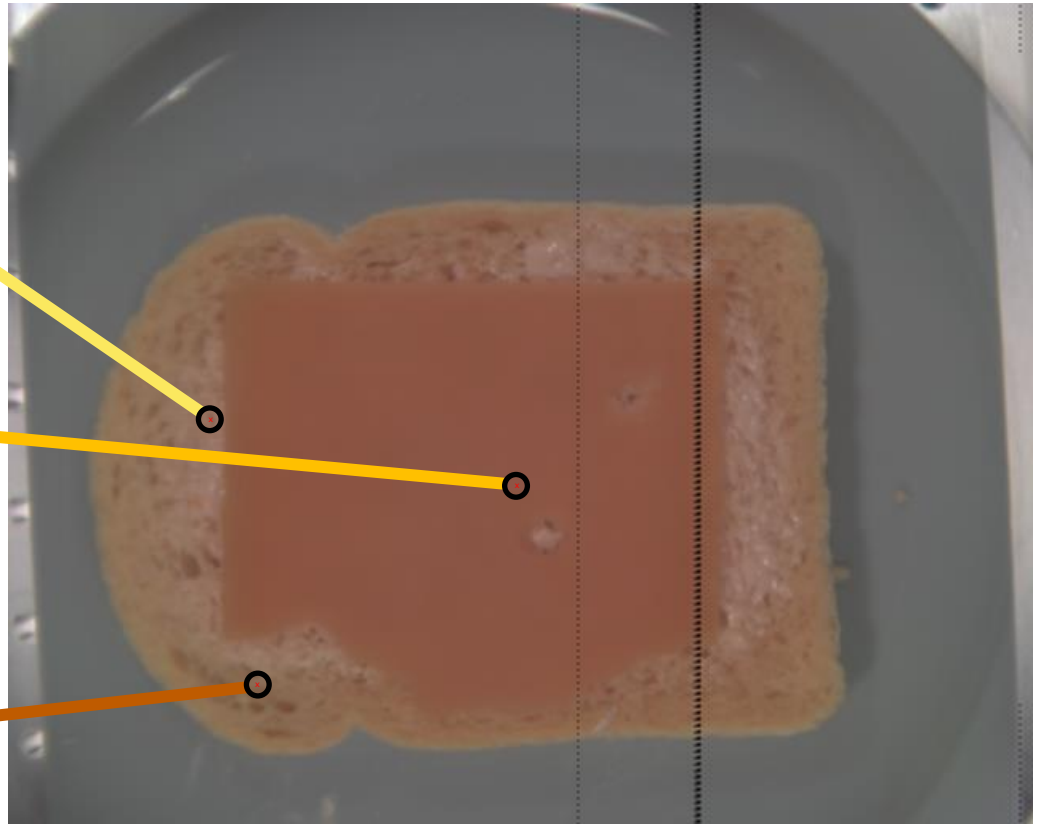


WAGENINGEN
UNIVERSITY & RESEARCH

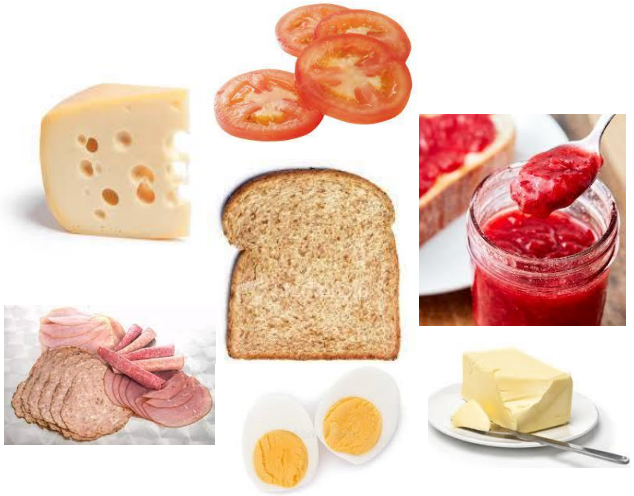

butter
reflection (-)
0.0
0.2
0.4
0.6
0.8
1100
1200
1300
1400
1500
1600
wavelength (nm)


cheese
reflection (-)
0.0
0.2
0.4
0.6
1100
1200
1300
1400
1500
1600


bread
reflection (-)
0.0
0.2
0.4
0.6
0.8
1100
1200
1300
1400
1500
1600
wavelength (nm)



Multivariate modelling



- No suitable univariate markers
- Relatively few (independent) observations
- Need for a robust, interpretable algorithm

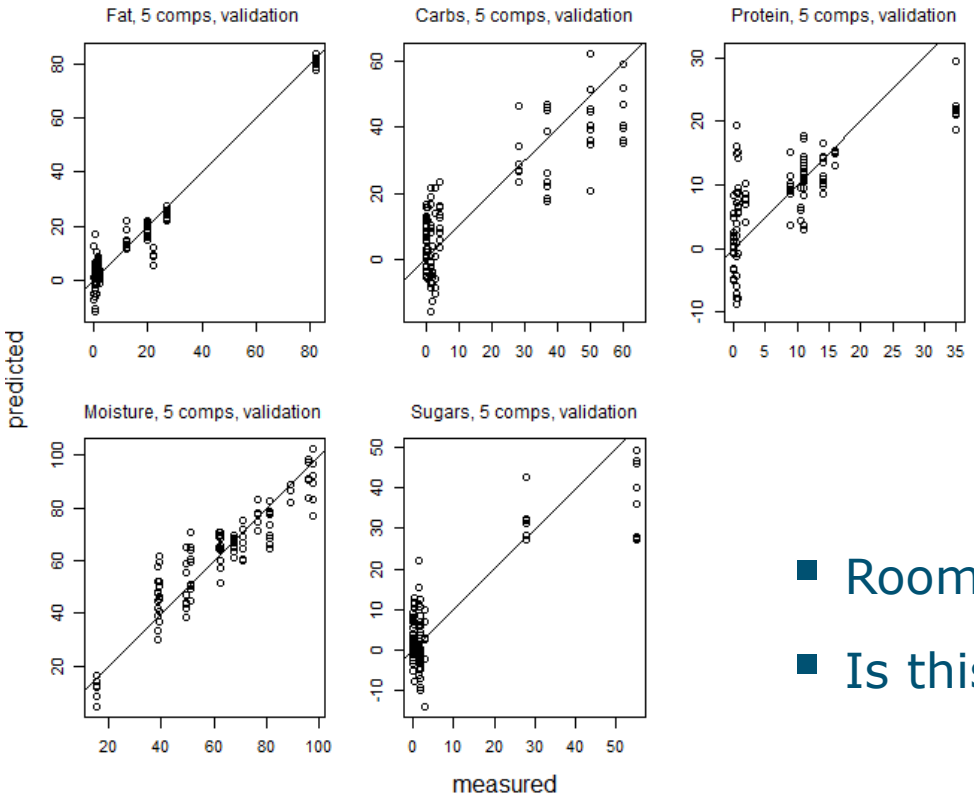
- 13 selected food types from actual consumption profiles
- Covering range of interest
- Total 104 scans selected

- ***PLS**-modelling*

Nutrient	*(g / 100g)*		
	min	mean	max
Fat	0	14	82
Protein	0	8	35
Moisture	15	62	98
Carbohydrates	0	15	60
Sugars	0	7	55

WAGENINGEN
UNIVERSITY & RESEARCH

Multivariate modelling – fitting statistics



Nutrient	RMSEP	R^2
Fat	5.0	0.95
Protein	6.6	0.55
Moisture	8.3	0.86
Carbohydrates	10.9	0.73
Sugars	8.1	0.72

- Room for improvement...
- Is this sufficient for our goal?

WAGENINGEN
UNIVERSITY & RESEARCH

Predictions

- Processing times: (on Intel® Xeon® E-2176M 6Core, 2.70GHz, Win-10, R 3.6)

Step	time (s)
Raw file loading (135 MB)	35
Data preprocessing (mean-center + spectral stdev-scaling)	3
Predicting composition (327,680 spectra x 5 nutrients)	0.3
(Re)organising and saving results (8 MB)	12
Total (per file)	50.3

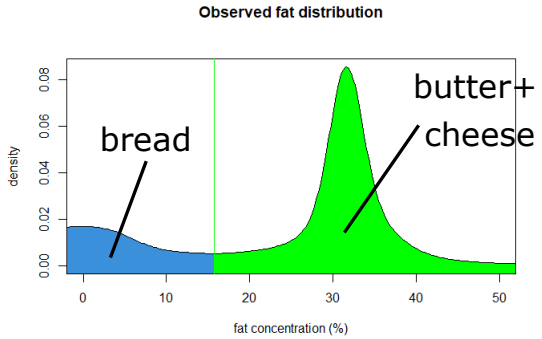
- Yields fat-, protein-, moisture-, carbs-, sugar- concentrations...

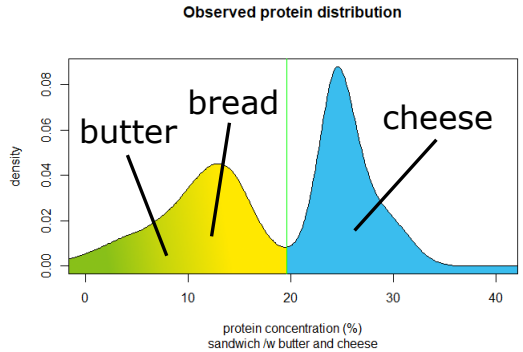
  as function of x- and y- position of the image...

Clustering

- Ideally: based on colour - (d)RGB image analysis
- Number of foodstuffs visible unknown
- Many tools available (kMeans, HC, metaheuristic,...)

- *For now:* clustering based on detecting groups in each nutrient's distribution
- Background removal



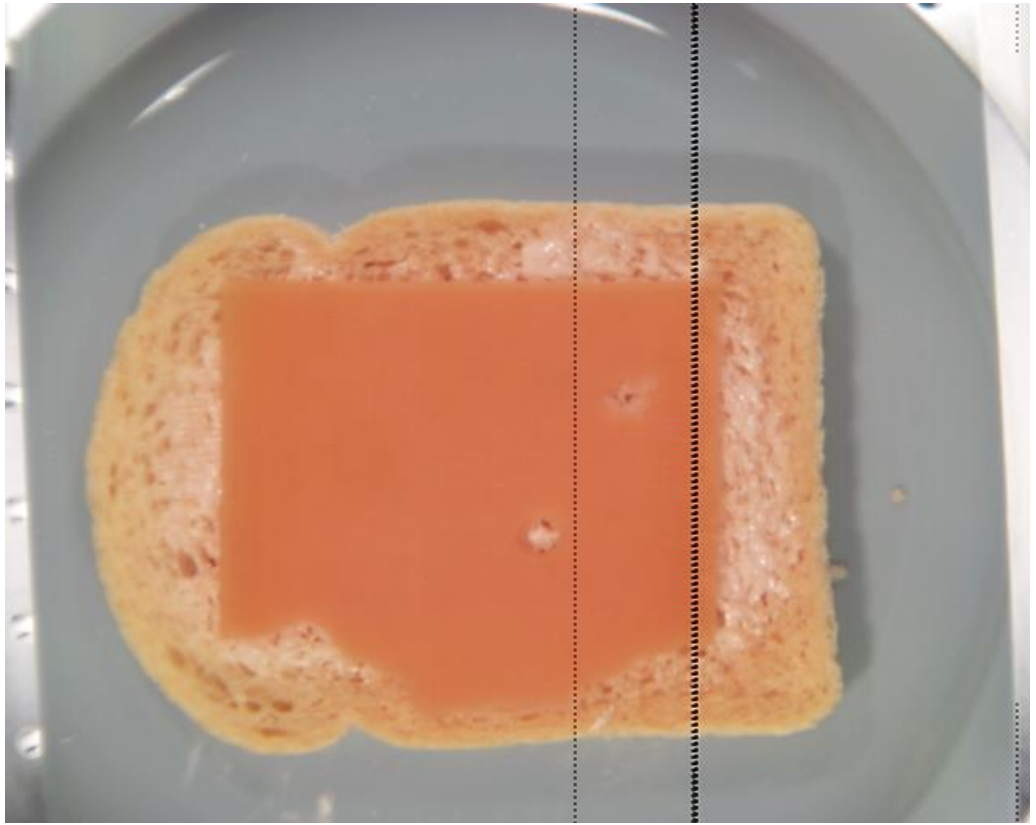


Results (image processing for bread/butter/cheese example)

1. Raw result

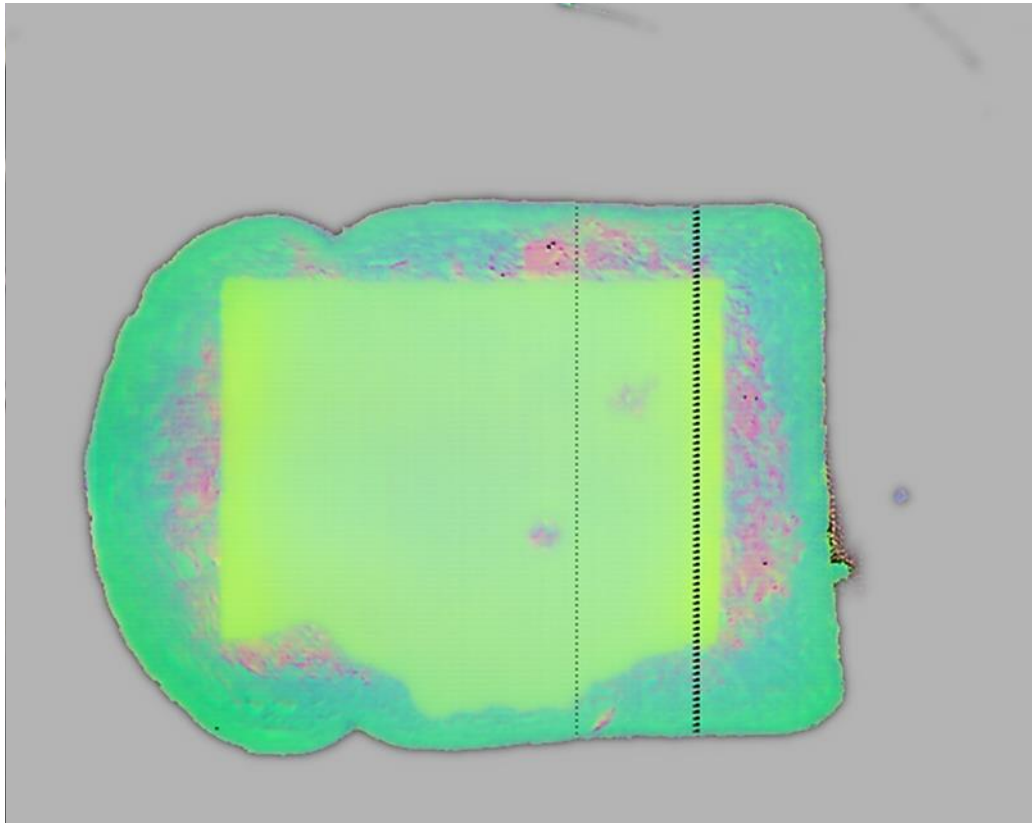
   3 selected wavelengths

   as RGB-image



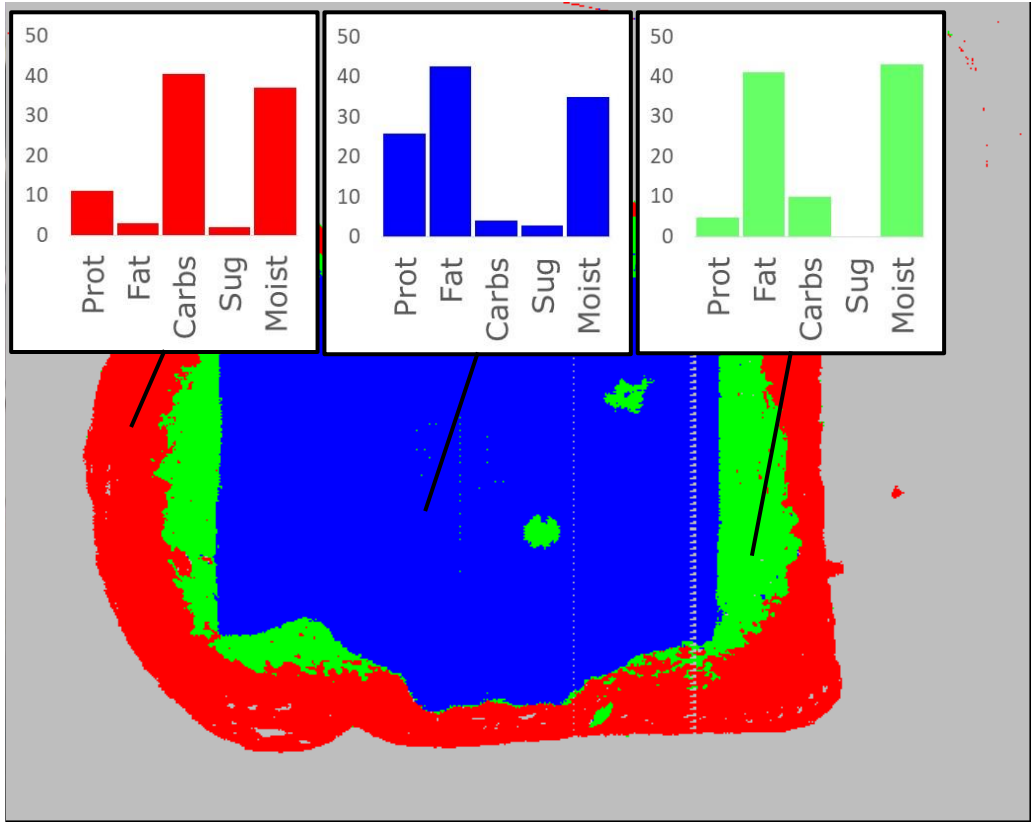
Results (image processing for bread/butter/cheese example)

1. Raw result
   3 selected wavelengths
   as RGB-image
2. False-colour image
   R ∝ fat%
   G ∝ protein%
   B ∝ moisture%



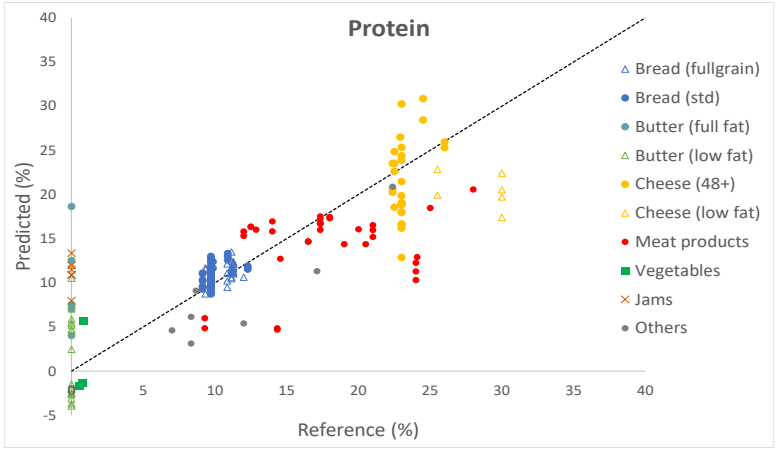
Results (image processing for bread/butter/cheese example)

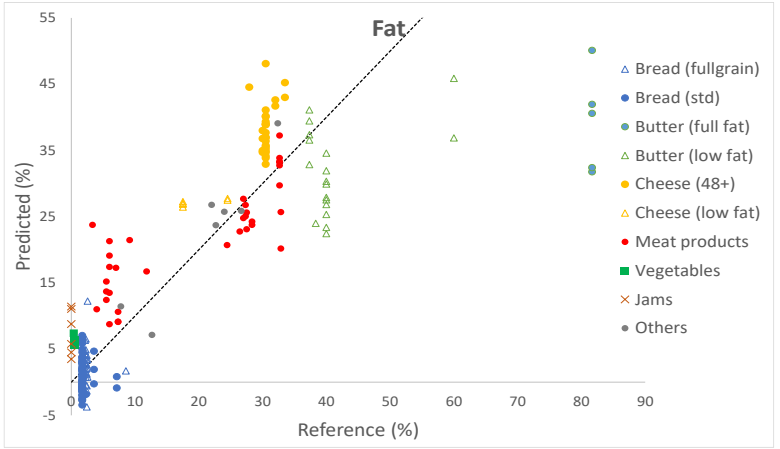
1. Raw result
   3 selected wavelengths
   as RGB-image
2. False-colour image
   R ∝ fat%
   G ∝ protein%
   B ∝ moisture%
3. Nutrient-density based clustering
   random colour per cluster

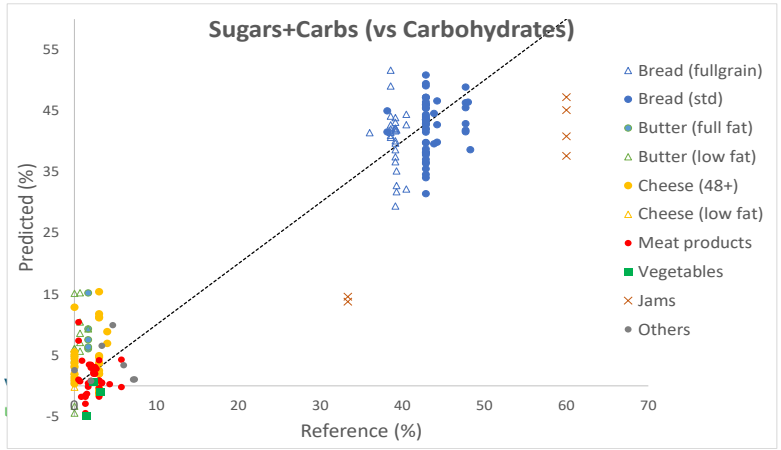


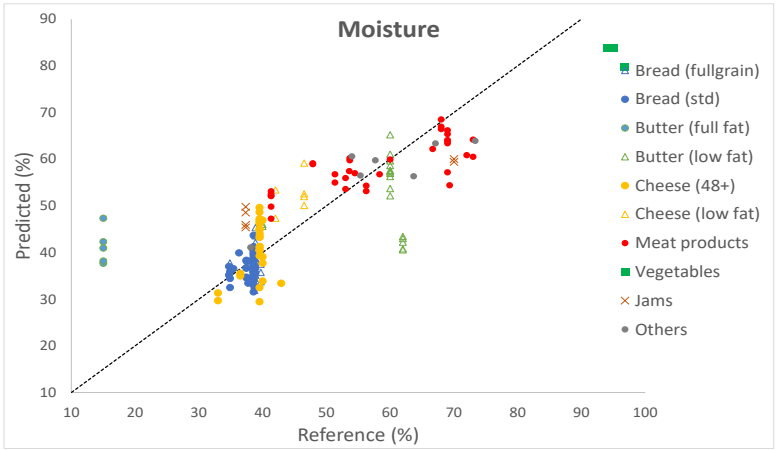
WAGENINGEN
UNIVERSITY & RESEARCH

Validation set – reference vs medians from auto-segmented HSI scans









Outlook

- A one-step macronutrient quantification from HSI data is feasible

  Suitable to discriminate foods & tentative identification

- Subsequent matrix-specific models might increase performance

  Prediction of butter fat% (<±10%) and layer thickness (<±60mg/cm^2)

- Data quantity is a potential limitation for practical use

- Needs additional data for food intake estimation...

Thank you for your attention!

Special thanks to:

Yannick Weesepoel (WFSR)

Judith Mueller-Maatsch (WFSR)

Hajo Rijgersberg (WFBR)

Hannelore Heuer (WFBR)

Freek Daniels (WFBR)

Mireille Baart (WU-HNE)

NWO (grant Dutch Research Agenda,
"Meten en detecteren van gezond gedrag")