Physical and Statistical Models for Optical Imaging of Food Quality

National Food Institute Day

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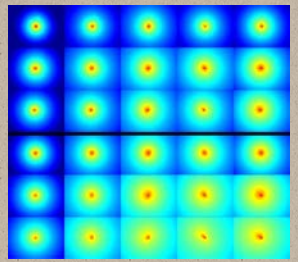
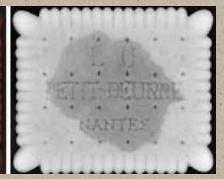






Why inspect food quality?

- Consumers expect
  - Large diversity of food products
  - Uniformly high quality
  - Fulfillment of both culinary and nutritional demands
  - Highest food safety standards

http://niemagazine.com/consumers-dictate-natural-sensory-qualities/

- We need efficient quality assessment and inline process control.

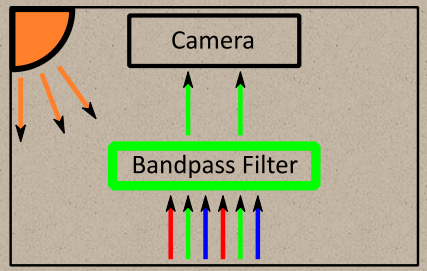
Why optical imaging?

- Food appearance carries information on
  - Size, shape, and color (obviously)
  - Organoleptic parameters (flavor, taste)
  - Texture, stability, and mouthfeel
  - Moisture content and storability
  - Ingredients: amounts of constituents

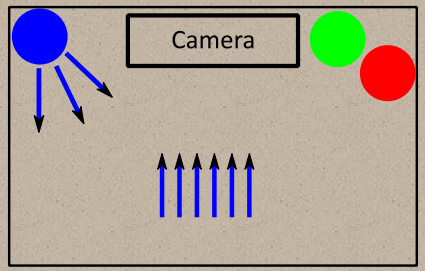
- Computer vision sensors enable noninvasive inline monitoring of food appearance.

Optical imaging methods

- Multispectral imaging

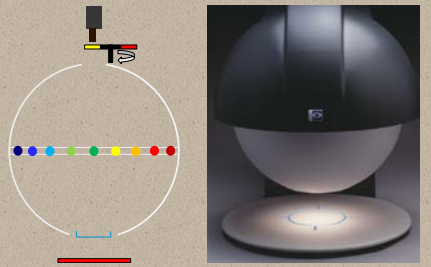


Transmission filters



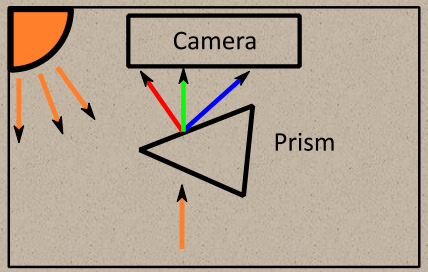
Controled illumination

example

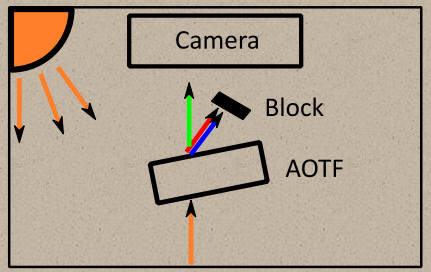


VidemeterLab

- Hyperspectral imaging



Pushbroom



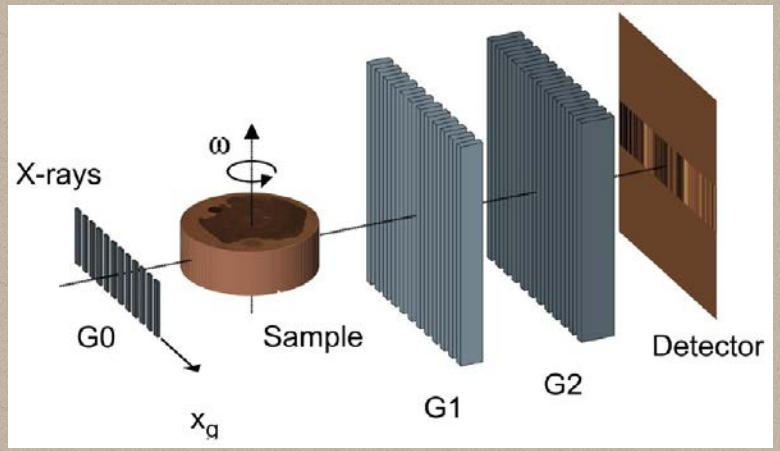
Acousto-Optic Tuneable Filter (AOTF)

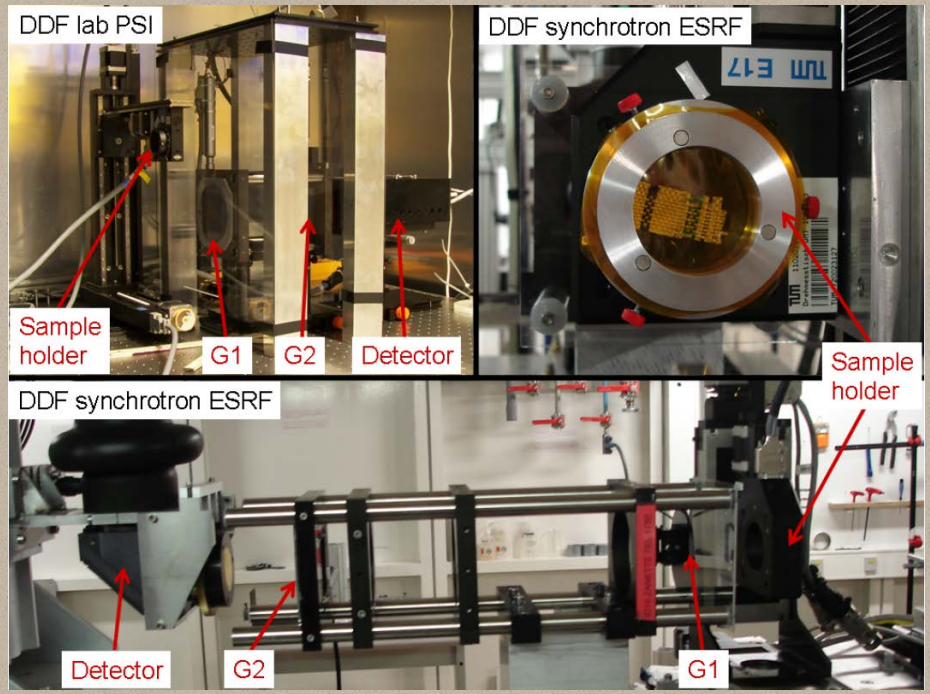
example

Static Light Scattering (SLS) instrument

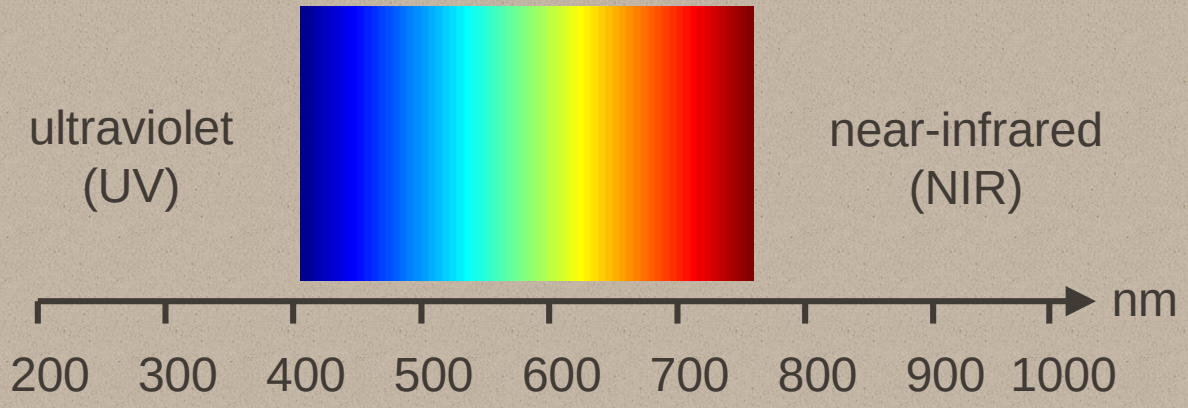
Optical imaging methods

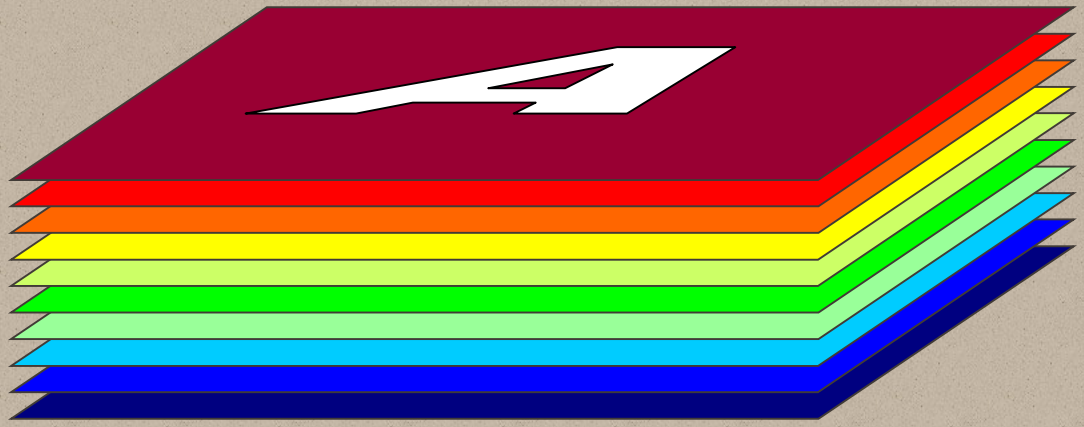
- Grating-based X-ray imaging





Multispectral imaging



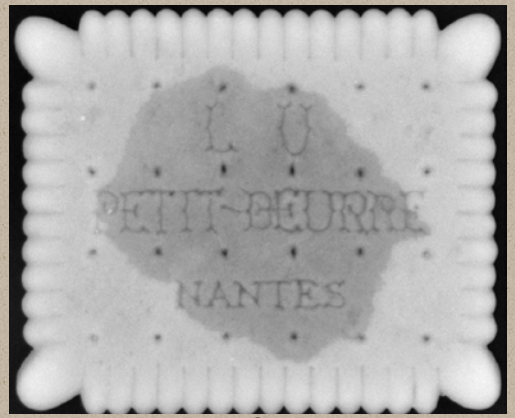


N images obtained at N specific wavelengths

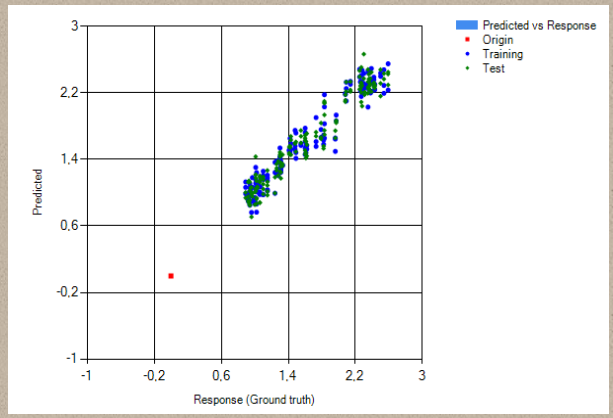
Example: biscuit quality

a. Biscuit with water drop in the centre (sRGB)
b. Spectrally extracted water absorption map

a.



b.

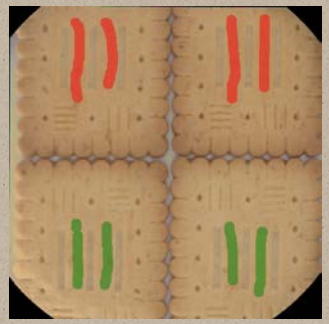


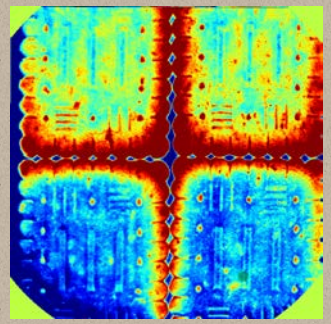
c.

c. Predicted %Moisture from 8 spectral image features versus the %Moisture from evaporation device.

Example: biscuit quality

- Normalized canonical discriminant analysis for measuring
  - browning index

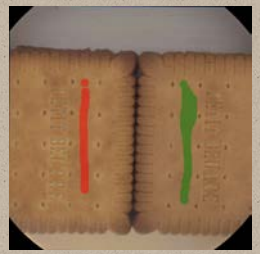


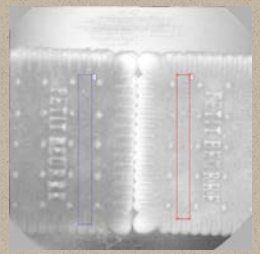


yellow/red – higher browning

bluish – conforming

  - glazing vs. non-glazing





darker gray – glazing

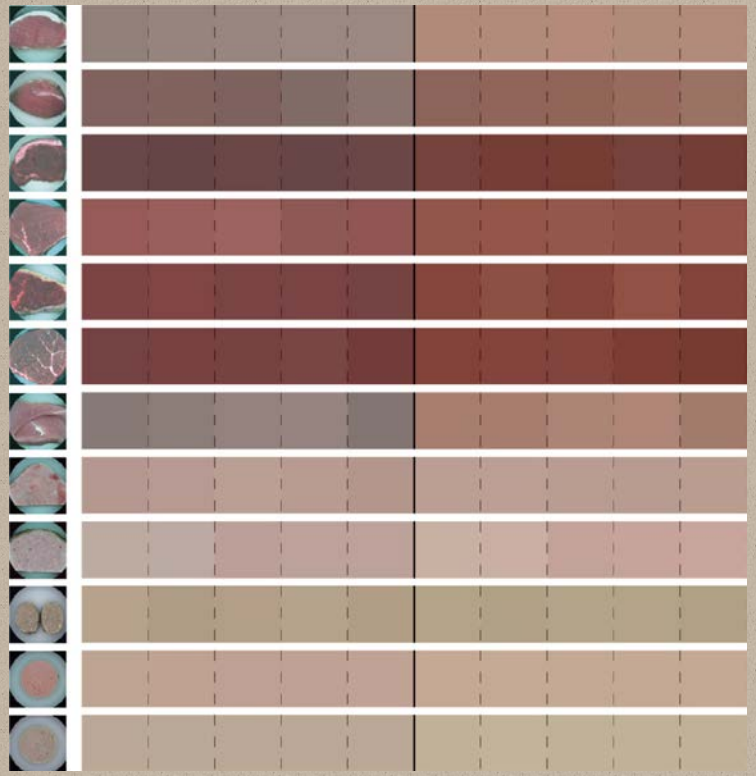
lighter gray – non-glazing

Example: meat study with DMRI

Minolta colorimeter

VideometerLab

Meat samples



Raw

Cooked

Example: meat study with DMRI

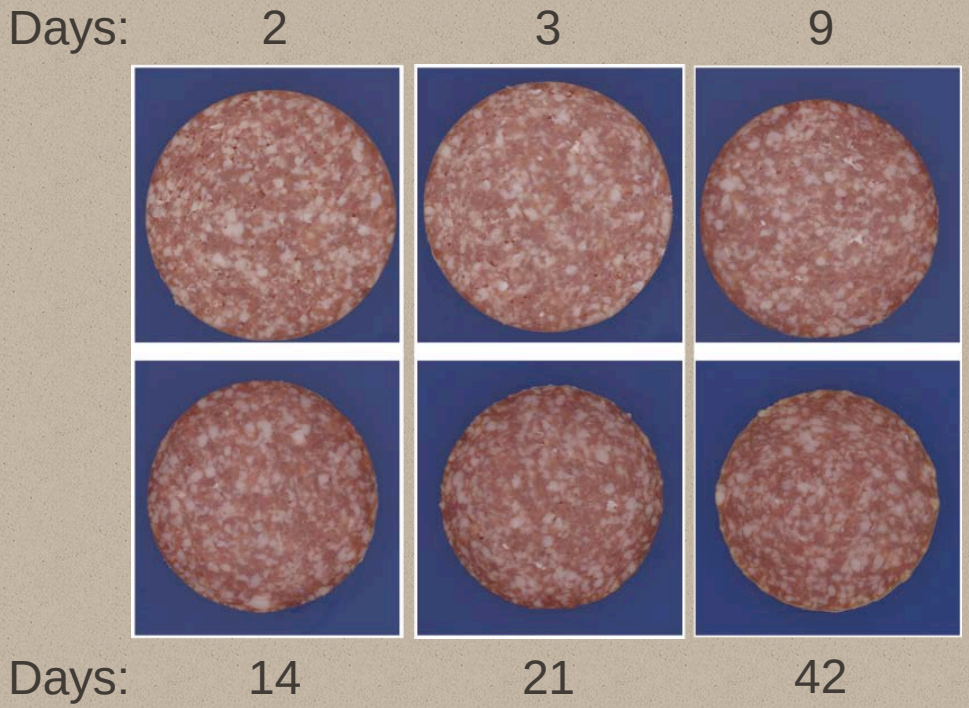
- Both instruments discriminate between raw and cooked meat.
- Problems in using a colorimeter:
  - Integrates over large surface patch (misses variations).
  - Light penetration depth too large (not good for bright red meat at early days of display).
  - No spectroscopy.
- Computer vision systems solve these problems.

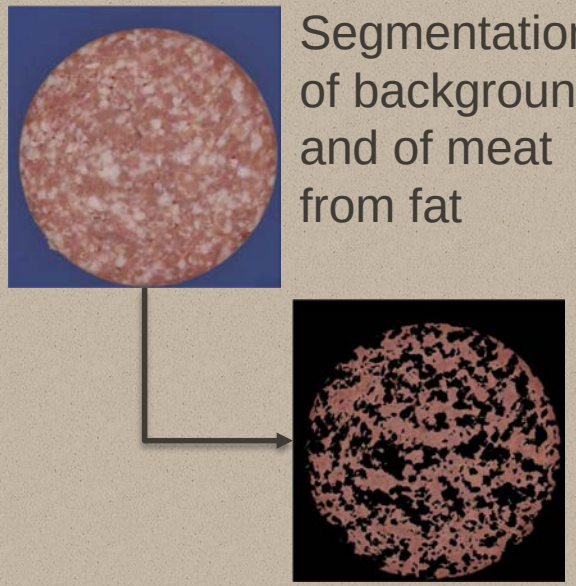
colorimeter

projector

Example: Salami study with DuPont

- Salami fermentation process after production.

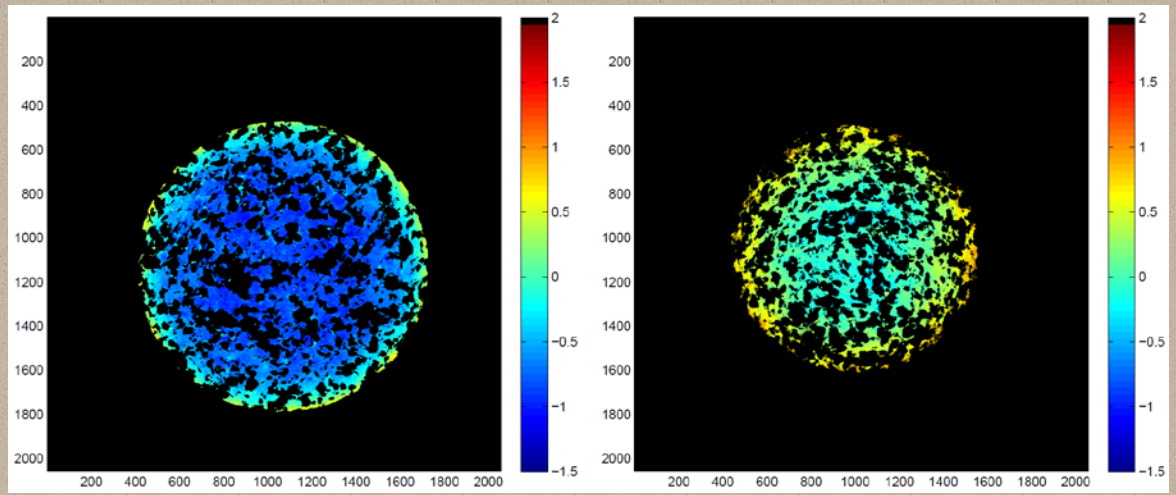




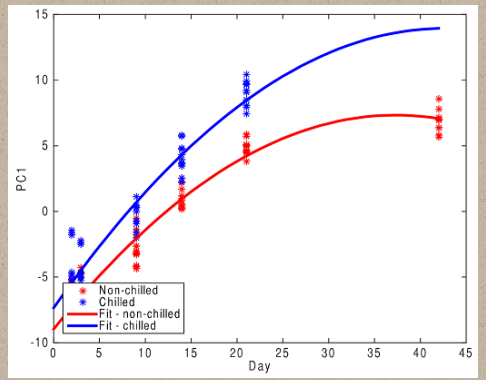
Example: Salami study with DuPont

- Statistical meat color scale
  - Darker blue is fresh meat
  - Yellow and orange represent fermented meat

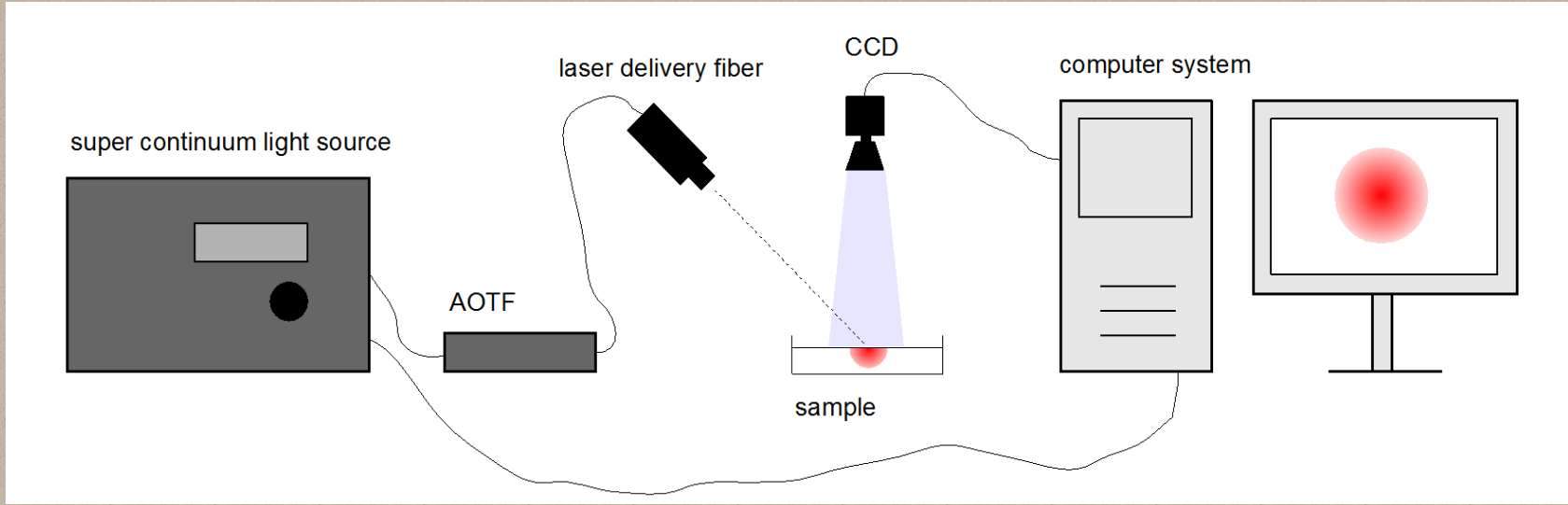
Days: 2 42



Significant color difference between chilled and non-chilled.

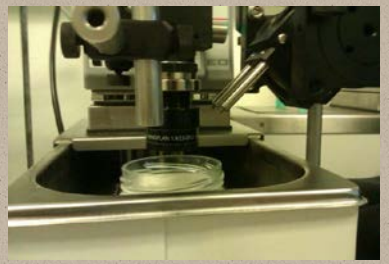


Hyperspectral imaging

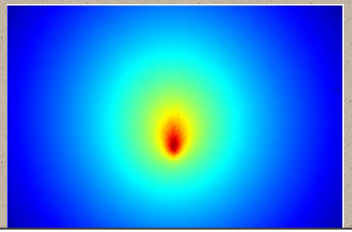


lab setup

in situ setup



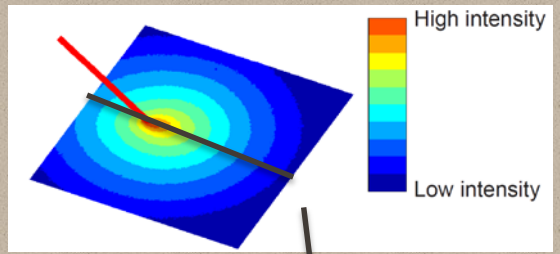
sample image
(log transformed, false colours)



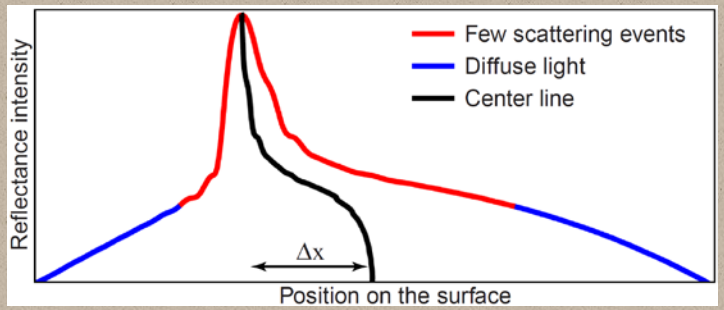
Milk (1.5%), at 900 nm

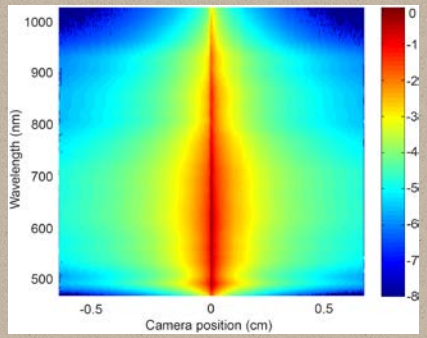
Example: milk fermentation

- Spectroscopy for measuring scattering and absorption properties.



extract profile



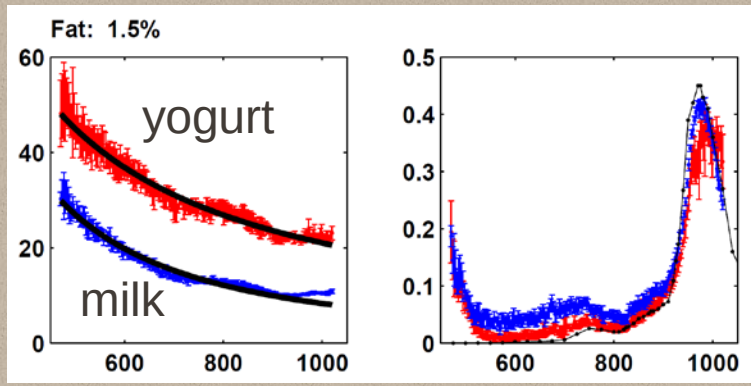


spectroscopy

oblique incidence reflectometry

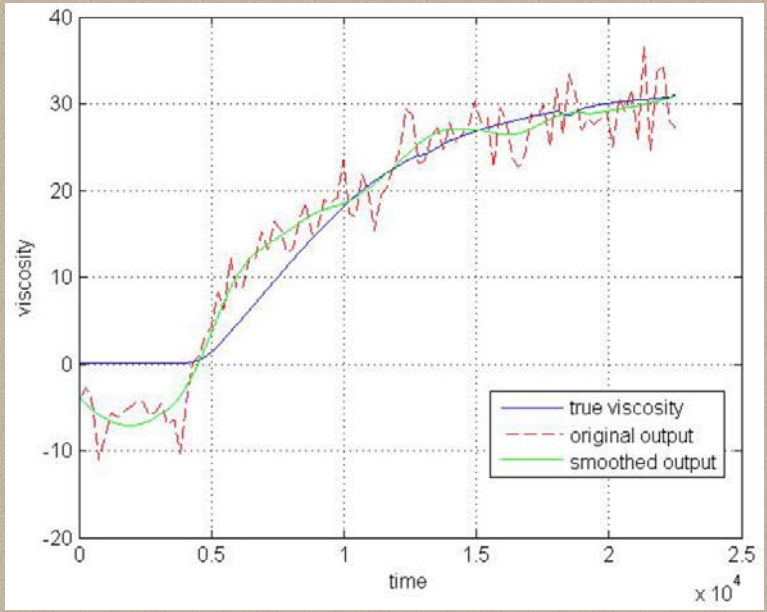
infer optical properties

reduced scattering [1/cm] absorption [1/cm]

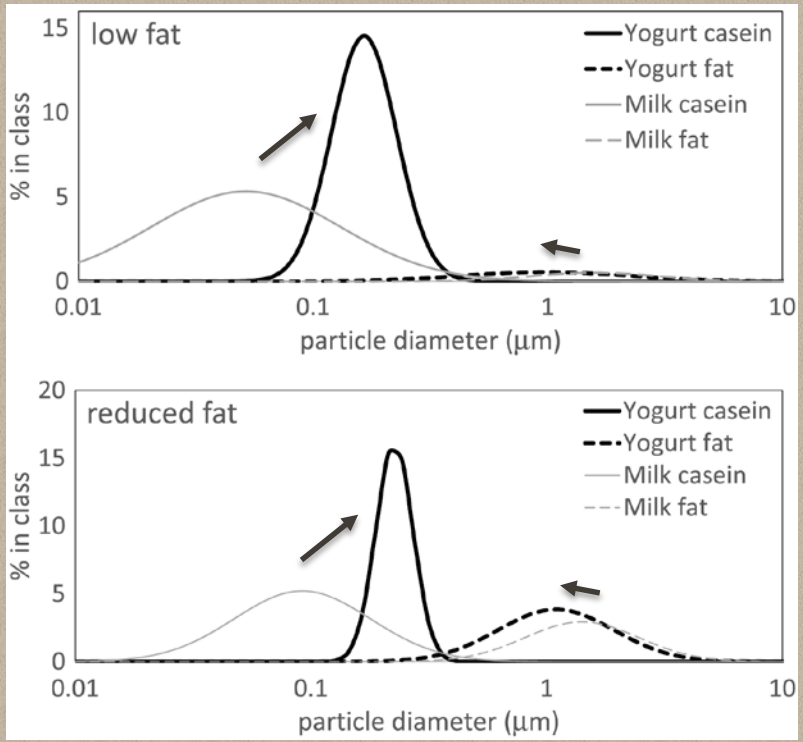


Example: milk fermentation

Statistical profile analysis for estimating viscosity

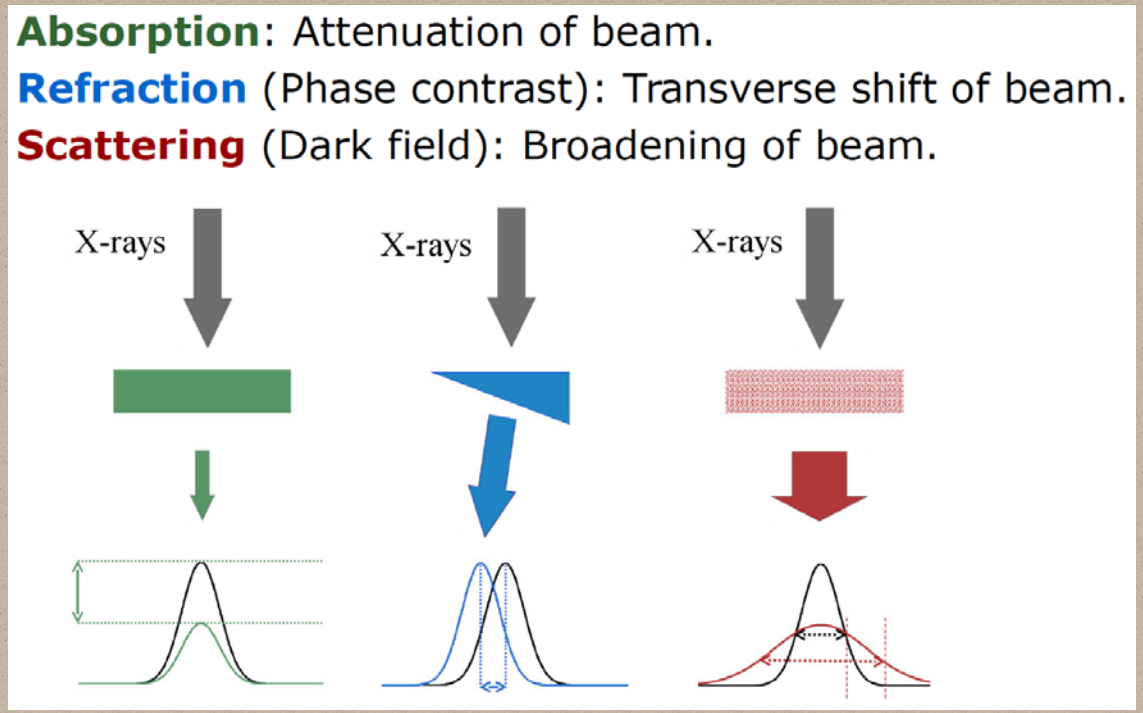


Physical model for particle sizing based on optical properties



Grating-based X-ray imaging

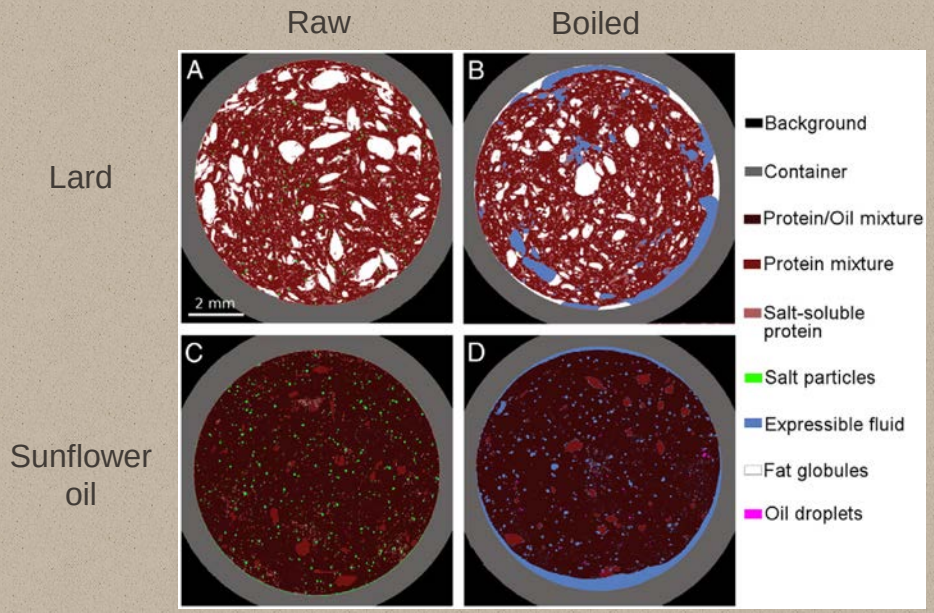
- When we need to investigate subsurface features.
- Three contrast mechanisms are used in grating-based imaging:

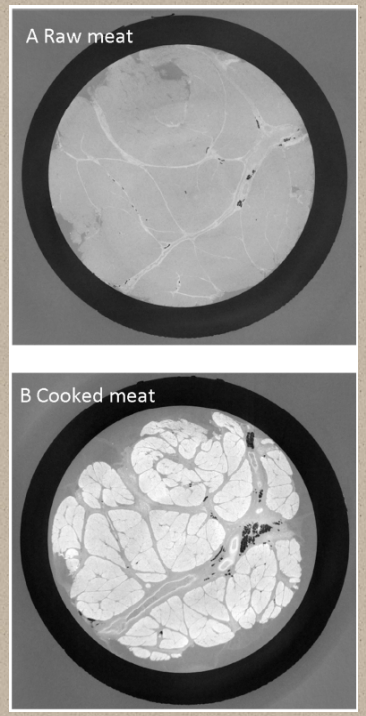


Example: heated meat products

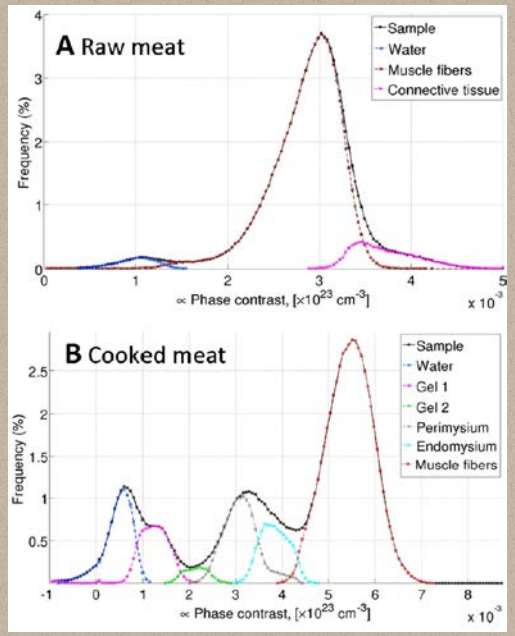
- Evaluating heat induced changes of micro-structure and cooking loss.

Meat emulsion





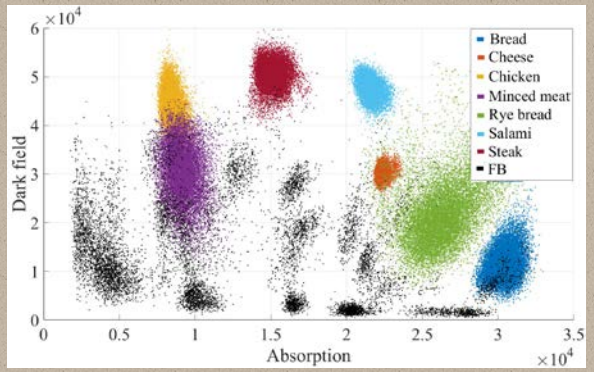
Beef

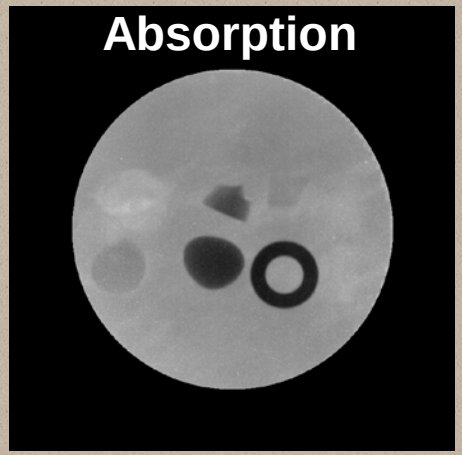


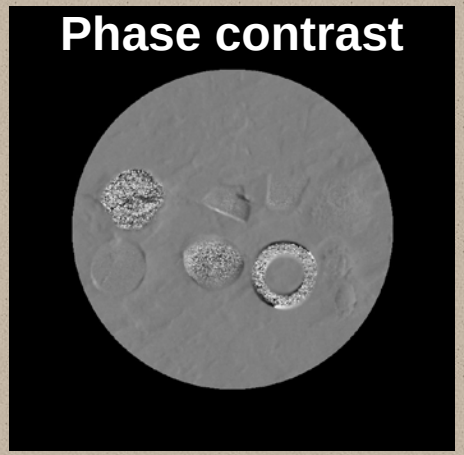
Example: detecting foreign objects

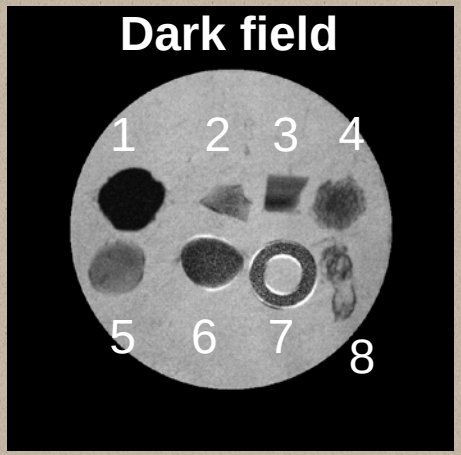
Combined multimodal intensity and texture features give best detection results.

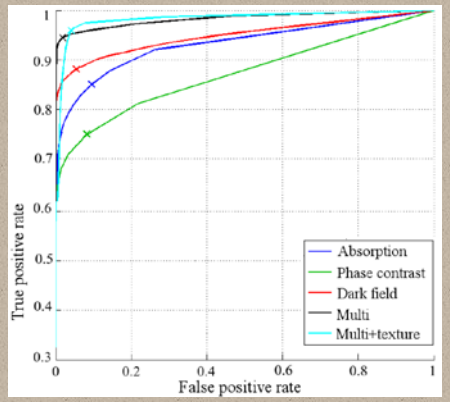
Normal food model











Detection rates

Conclusion

- Optical imaging is very useful when moving toward more and better automation in food quality control.

- Choice of instrument is important:
  - VideometerLab is good for detecting spectroscopic differences between different sample regions.
  - Static light scattering (SLS) is good for detecting emulsion differences in seemingly similar substances.
  - Grating-based X-ray imaging is good for detecting foreign objects or subsurface/volumetric features.

Credits

- Camilla Himmelstrup Trinderup (postdoc, DTU Compute)
- Otto Højager Attermann Abildgaard (PhD, DTU Compute Alumnus)
- Hildur Einarsdóttir (PhD student, DTU Compute)
- Jens Michael Carstensen (Associate Professor, DTU Compute)
- Line Harder Clemmensen (Associate Professor, DTU Compute)
- Jacob Lercke Skytte (postdoc, DTU Food)
- Sara Sharifzadeh (PhD, DTU Compute Alumna)
- Knut Conradsen (Professor, DTU Compute)
- Anders Bjorholm Dahl (Head of Image Section, DTU Compute)
- Bjarne Ersbøll (Head of Statistics Section, DTU Compute)
- Rasmus Larsen (Head of Department, DTU Compute)

- Research projects: CIFQ and NEXIM

Thank you for your attention

- Computing milk appearance using light scattering by fat and protein particles.