Quantitative Analysis of Meat Spoilage using VIS/NIR Spectral Imaging

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Meat spoilage study

- Minced beef shelf life
- Stored at 5° under
  - Aerobic conditions (normal atmosphere)
  - Modified atmosphere packaging (MAP) 40% CO2; 30% O2; 30% N2
- Measured at 12 hour intervals over 7 days

Data acquisition and microbiological analysis: Ammor, M.S., Argyri, A., Nychas, G.-J.E. (2009) Rapid monitoring of the spoilage of minced beef stored under conventionally and active packaging conditions using Fourier transform infrared spectroscopy in tandem with chemometrics. *Meat Science* 81, 507-514

Quantification of meat spoilage

- 50+ methods have been reported and are reasonably documented
- There is still a need for a method that is
  - Fast
  - Non-contact (repetice measurements on same sample)
  - Non-labor-intensive
  - Cost-efficient
  - Deals effectively with the heterogeneity of the sample
- Spectral imaging is a serious candidate

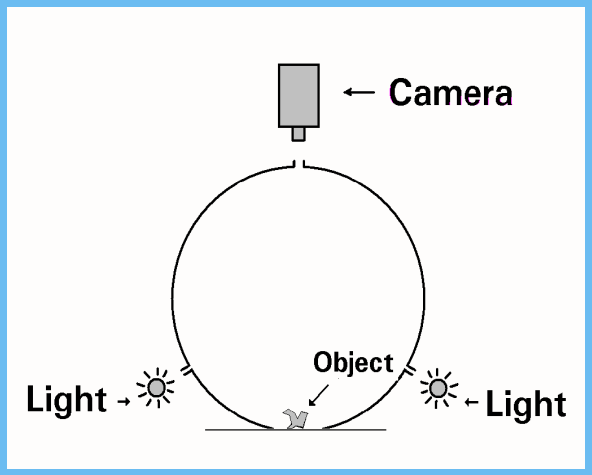
Measurements performed

- Microbiological analysis
  - Total viable count (TVC)
  - Pseudomonas
  - Brochothrix thermosphacta
  - Lactic acid bacteria (LAB)
  - Enterobacteriaceae
  - Yeast and moulds
- Other analyses
  - pH, sensory quality
- Multispectral imaging (Videometer)

VideometerLab 2

Laboratory device for multispectral imaging

- Up to 20 spectral bands in the range 360 nm to 1050 nm
- Up to 1600×1200 pixels per band
- Very homogeneous and diffuse illumination
- Strobed LED light source



Videometer A/S - Visionteknologi, Lyngsø Allé 3, 2970 Hørsholm

Meat spoilage effects in VIS-NIR

- Change existing muscle pigment states
- Generate new pigments/metabolites
- Change the surface chemical abundance on relevant compounds

Muscle pigments: myoglobins

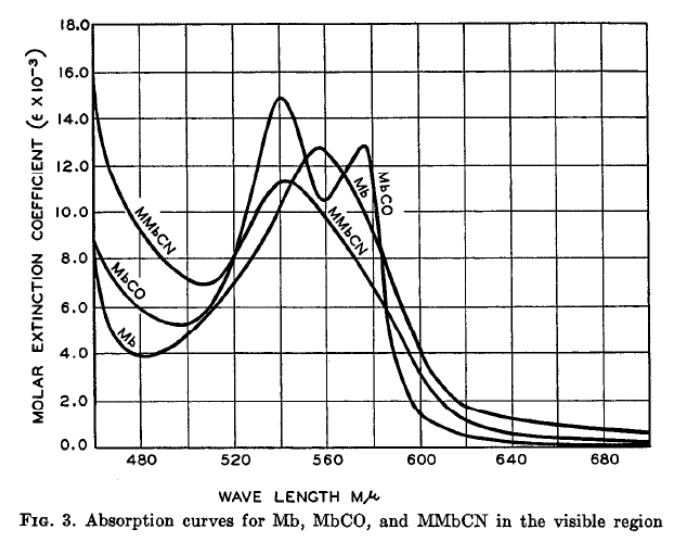
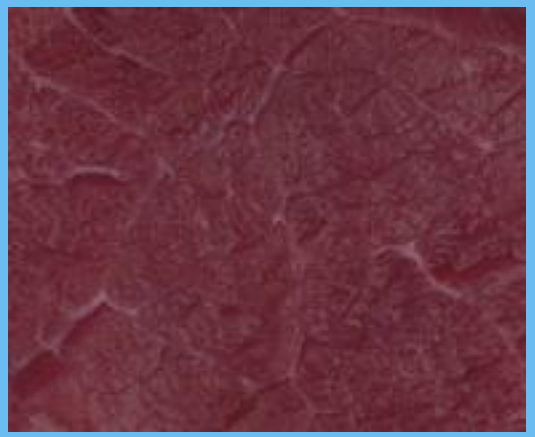


FIG. 3. Absorption curves for Mb, MbCO, and MMbCN in the visible region

- Myoglobin / Oxymyoglobin
  - It is the primary oxygen-carrying /storing pigment of muscle tissues
- Metmyoglobin
  - is the oxidized form of myoglobin.

Source: W. Bowen, 1948.



OxyMb

MetMb

DeoxyMb

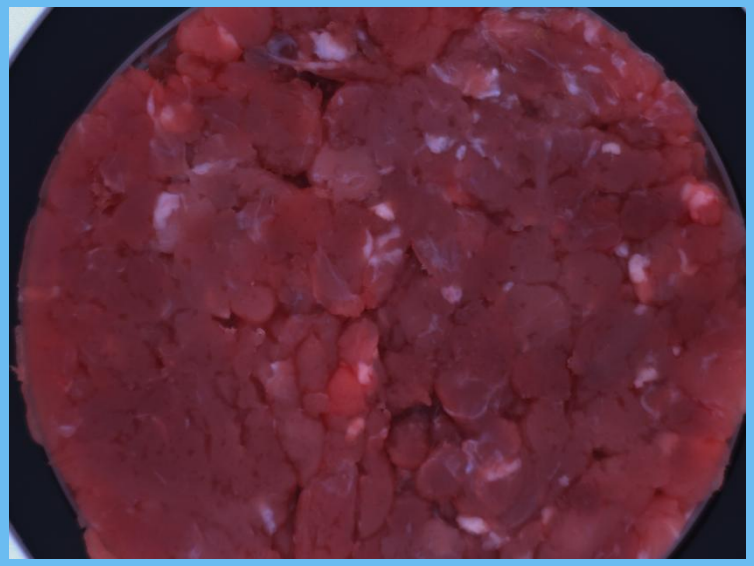
Image source Danish Meat Research

Before storage

1a

1b

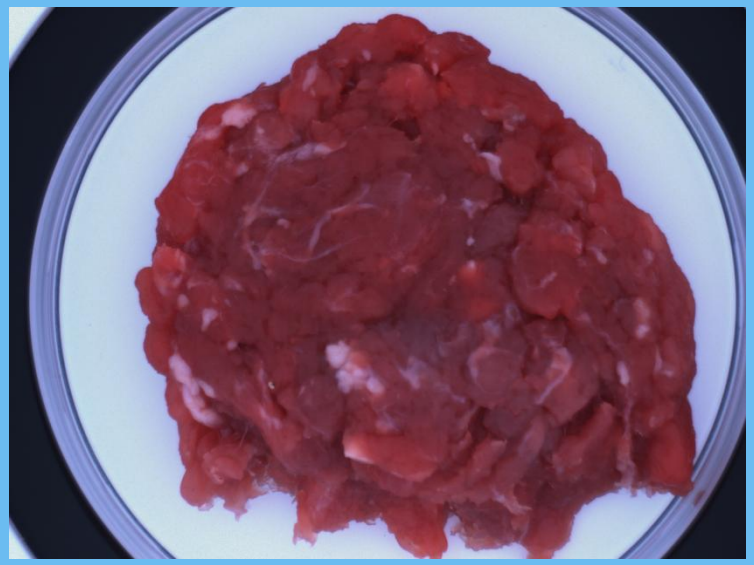
1c



1d

Aerobic storage

A4a



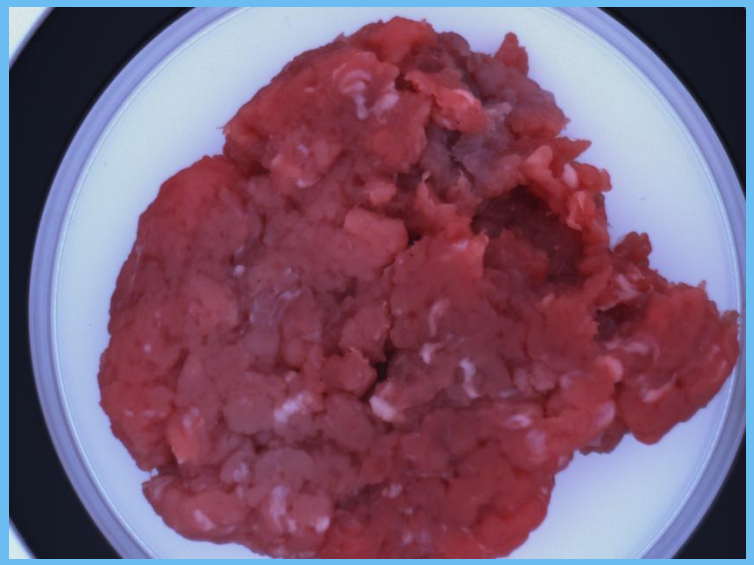
A8a

A12a

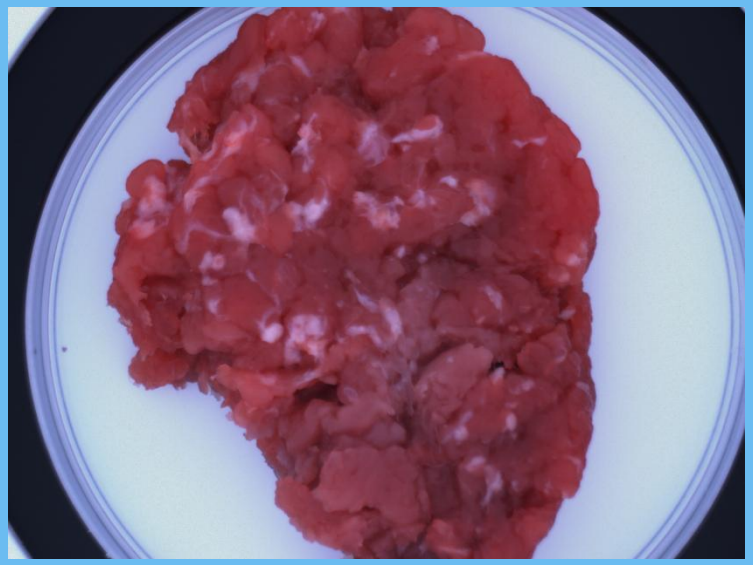
A13a

MAP storage

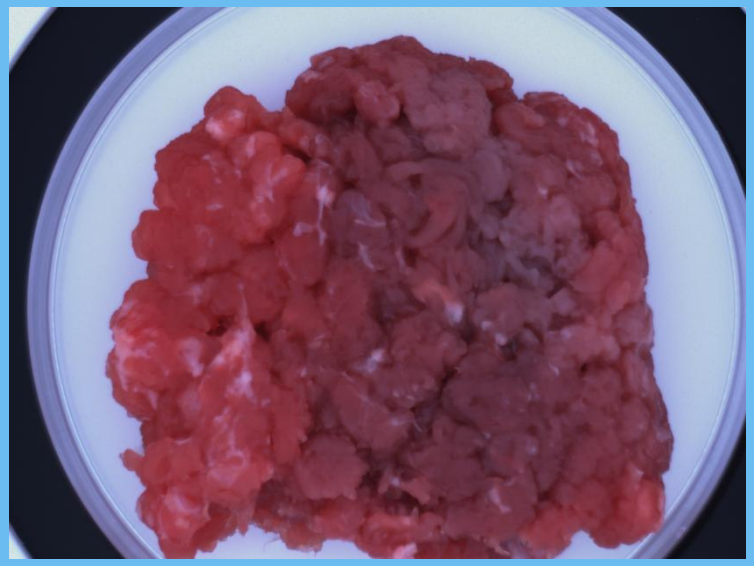
M4a



M8a

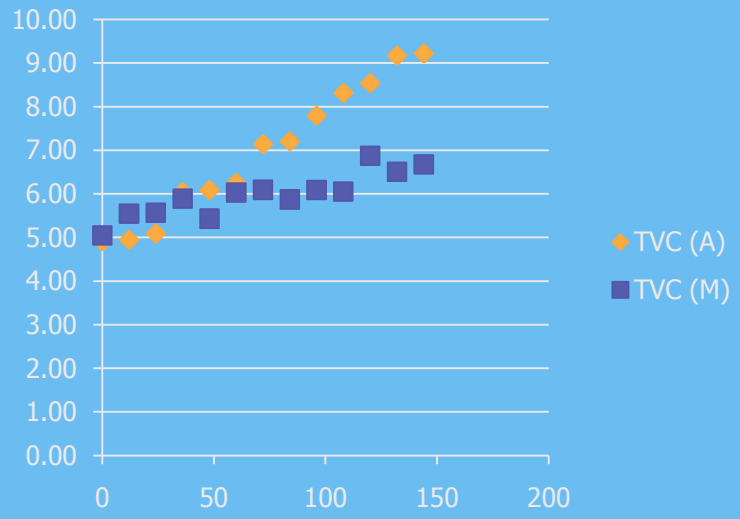


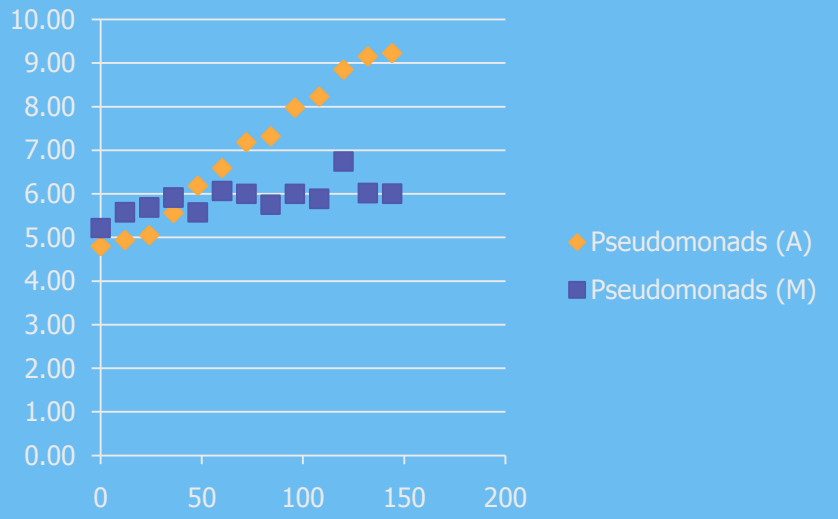
M12a

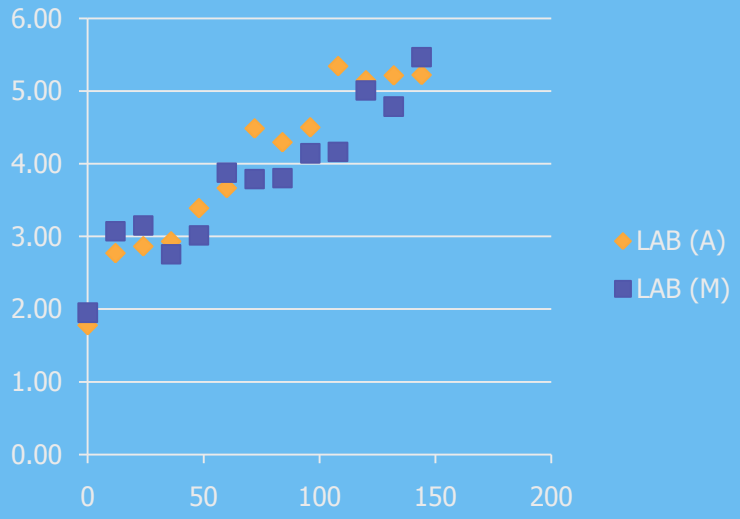


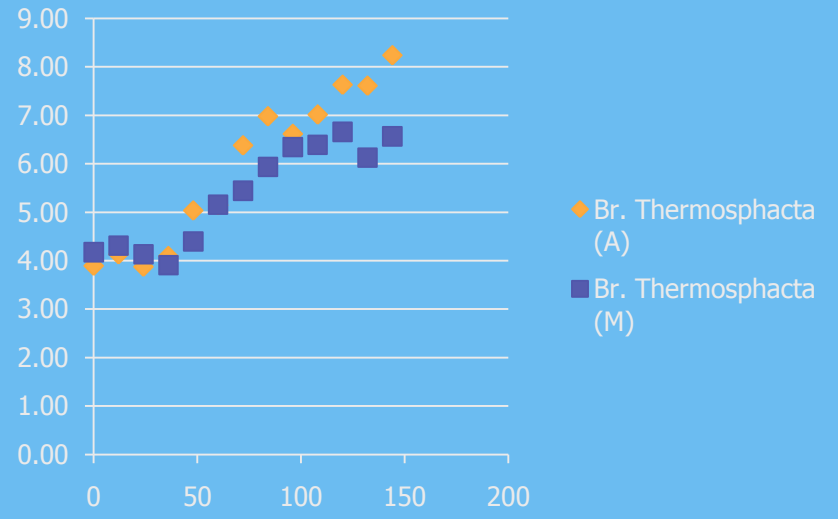
M13a

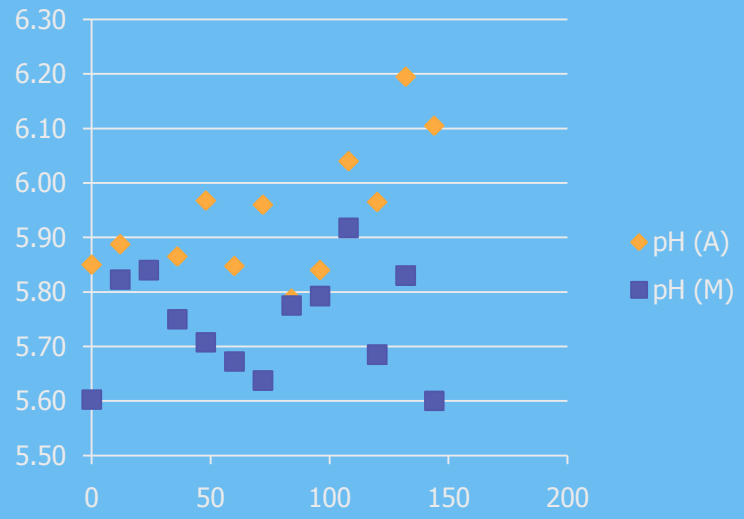
Microbiological analysis

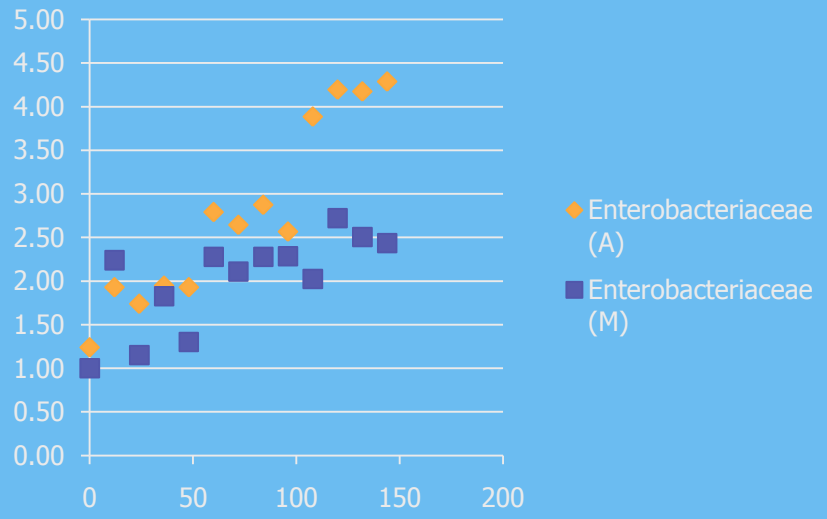


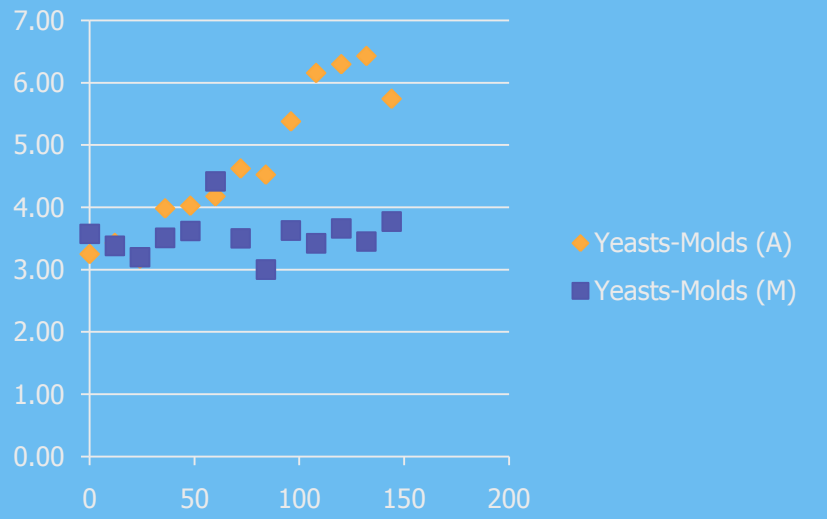







6.30
6.20
6.10
6.00
5.90
5.80
5.70
5.60
5.50
0
50
100
150
200
pH (A)
pH (M)


5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
50
100
150
200
Enterobacteriaceae (A)
Enterobacteriaceae (M)


7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
50
100
150
200
Yeasts-Molds (A)
Yeasts-Molds (M)

Canonical discriminants

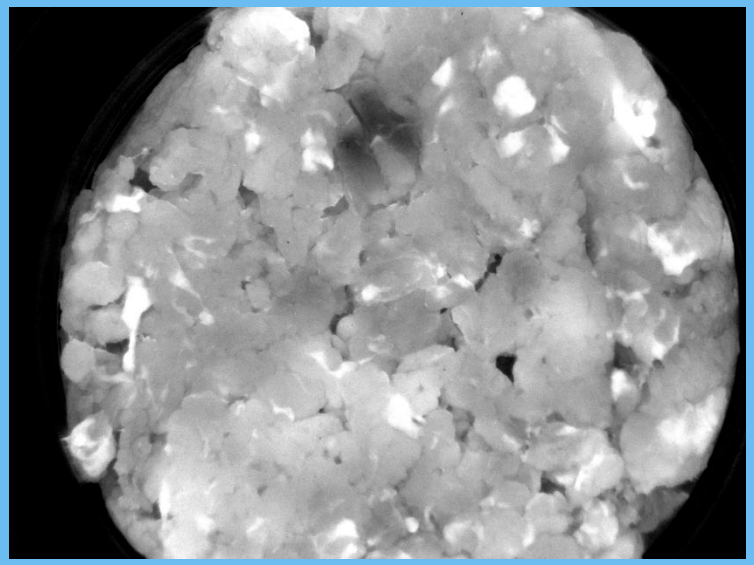
Find the **a** that maximizes the Rayleigh quotient

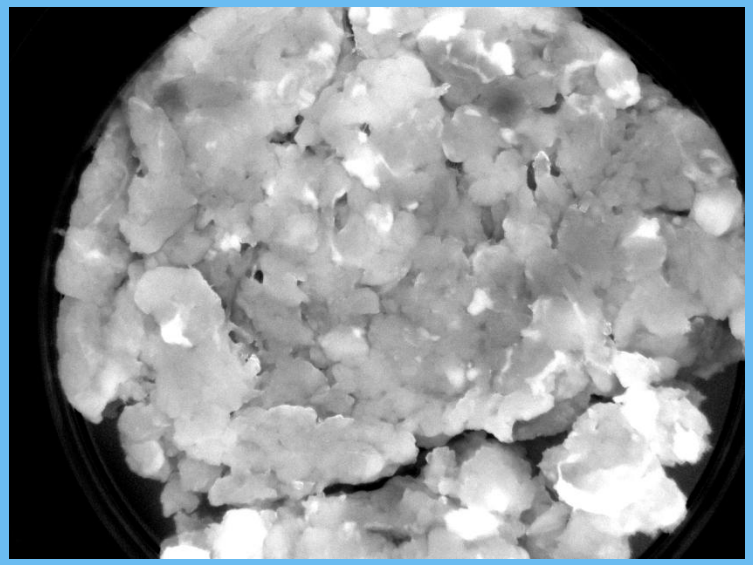
$$R(\mathbf{a}) = \frac{\mathbf{a}^{\mathrm{T}}\boldsymbol{\Sigma}_S\mathbf{a}}{\mathbf{a}^{\mathrm{T}}\boldsymbol{\Sigma}_N\mathbf{a}}$$

- where $\boldsymbol{\Sigma}_S = \mathbf{A}$, the among class dispersion, and $\boldsymbol{\Sigma}_N = \mathbf{W}$, the within class dispersion
- Maximizing this quotient originates back to Fischer (1936)
- Eigenvectors are called canonical discriminants functions or simply canonical discriminants
- The number of canonical discriminants CDs is limited by the rank of A. With two classes there is only one CD. With three classes there are two CDs
- Typically a supervised technique

Canonical discriminant images

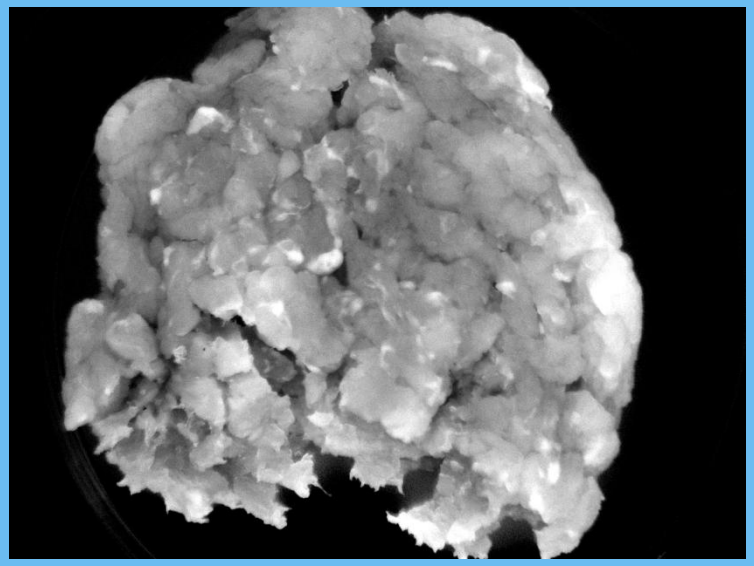
1a

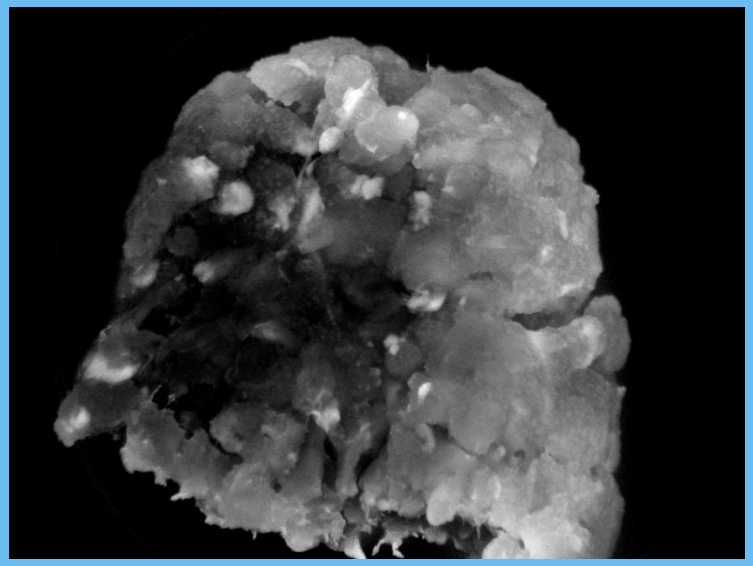




1b

M13a

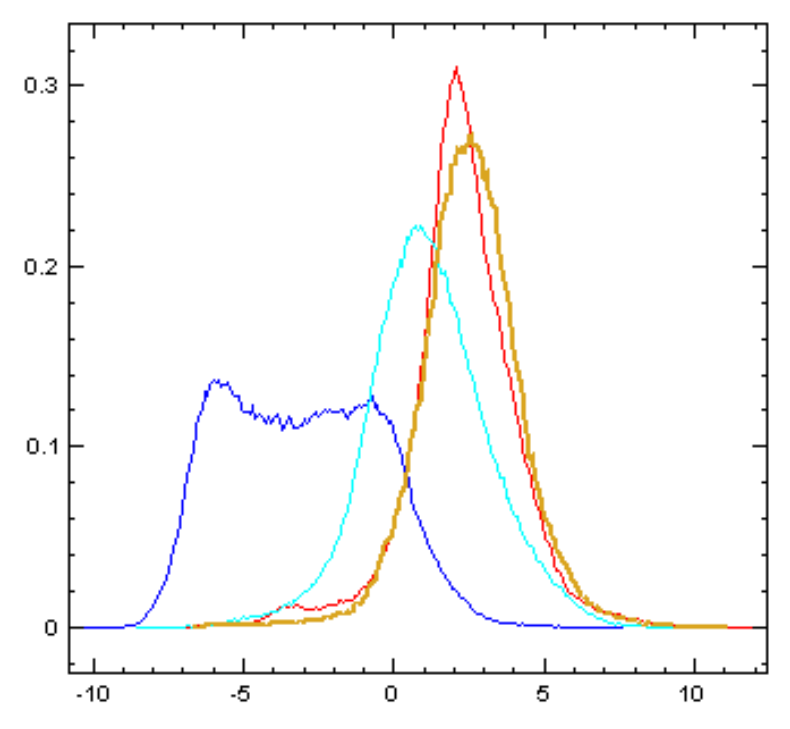




A13a

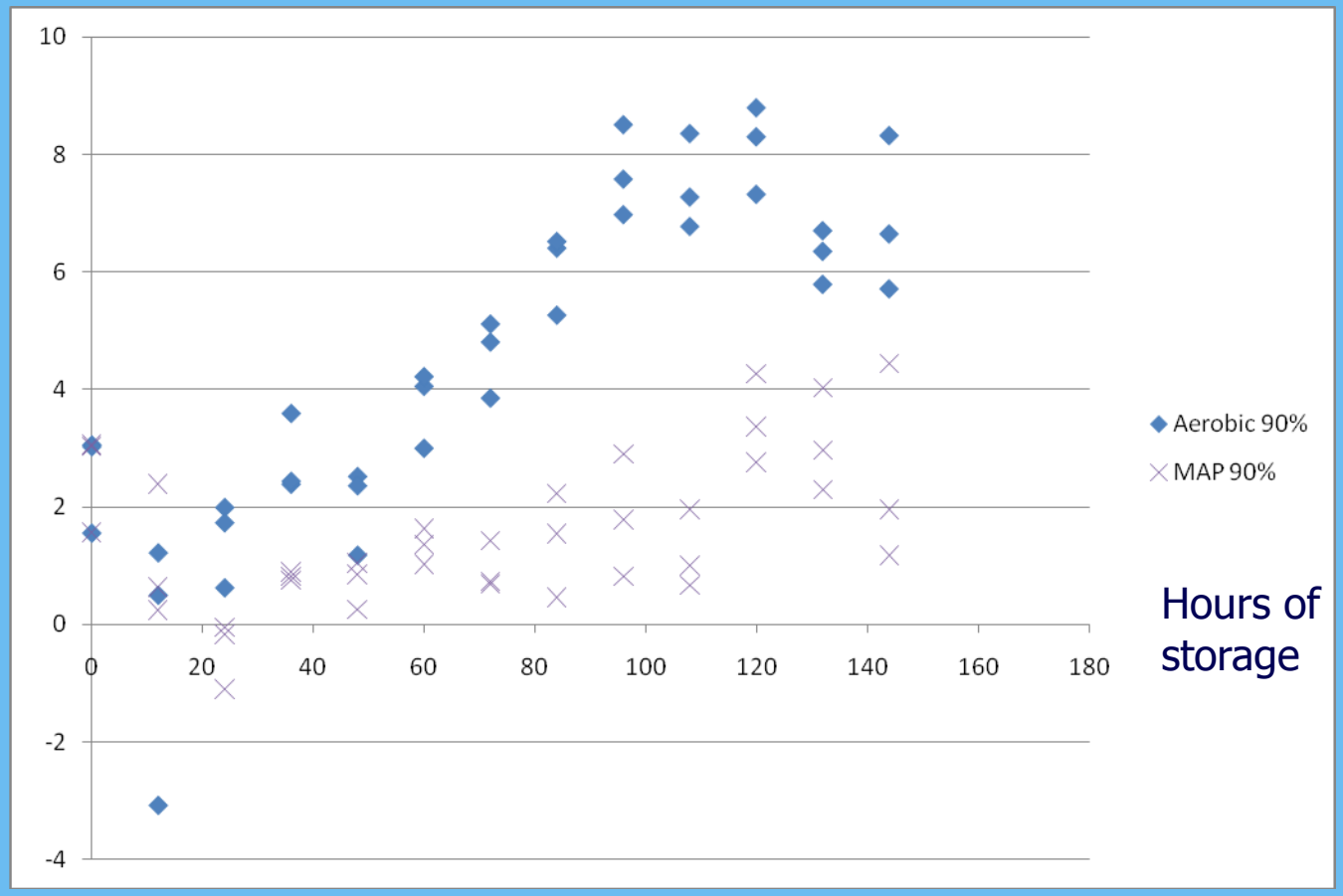
Canonical discriminant histograms

Histograms

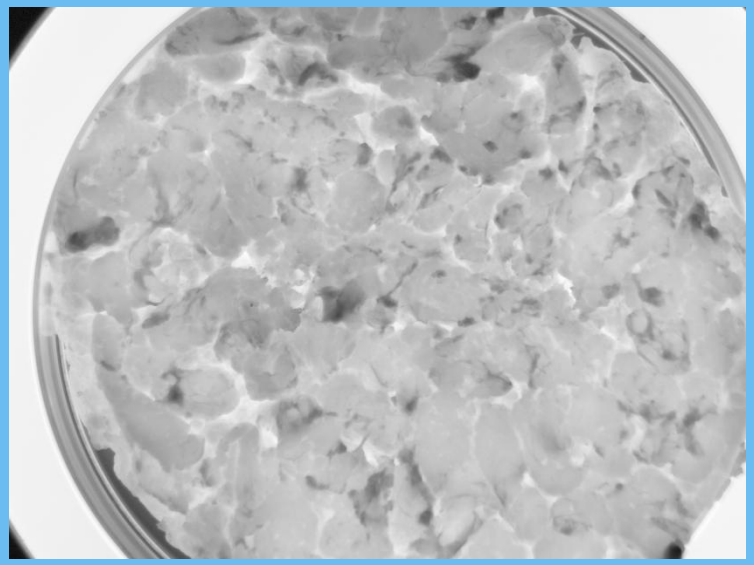


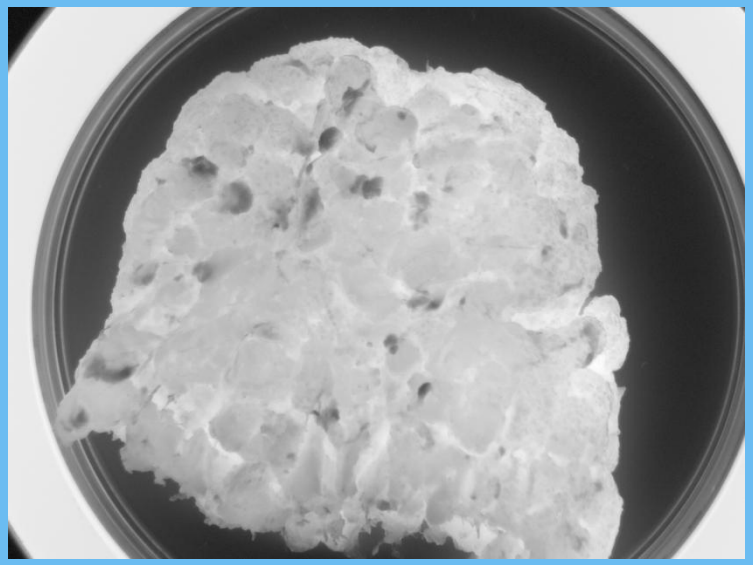
- Red – Before storage (1a)
- Brown – Before storage (1b)
- Cyan – MAP storage (M13a)
- Blue – Aerobic storage (A13a)

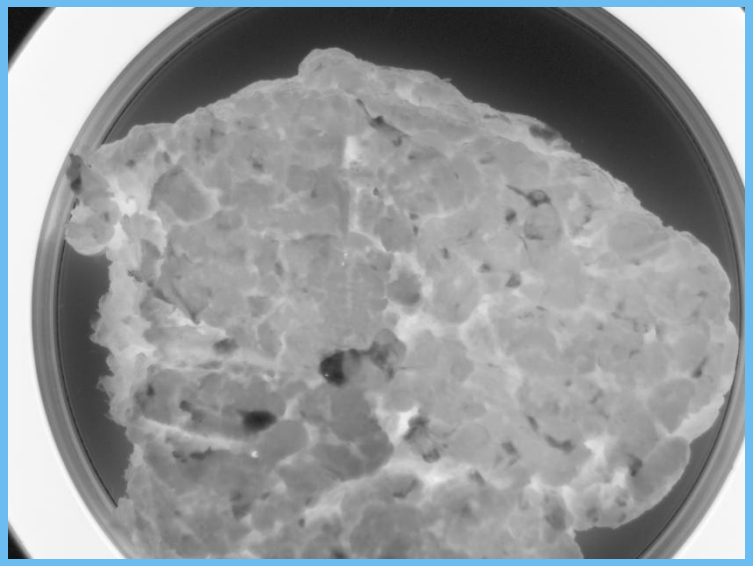
Canonical discriminant plots
90% quantile CDF (negated)



MNF 1





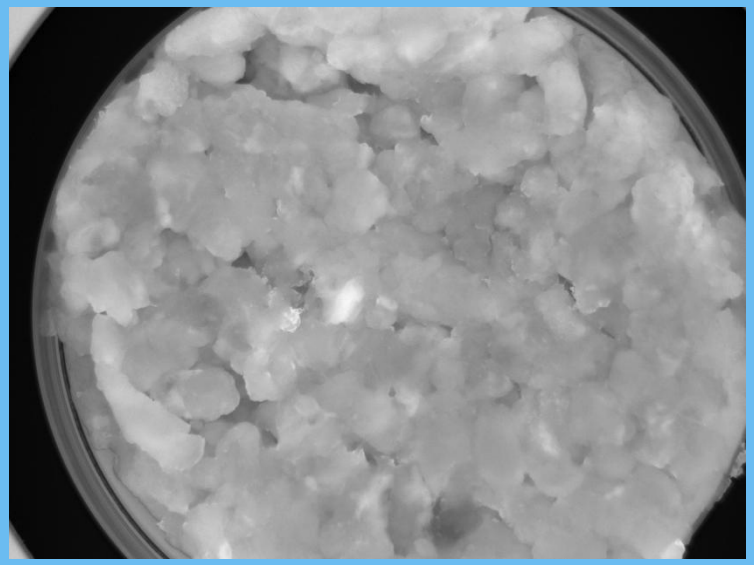


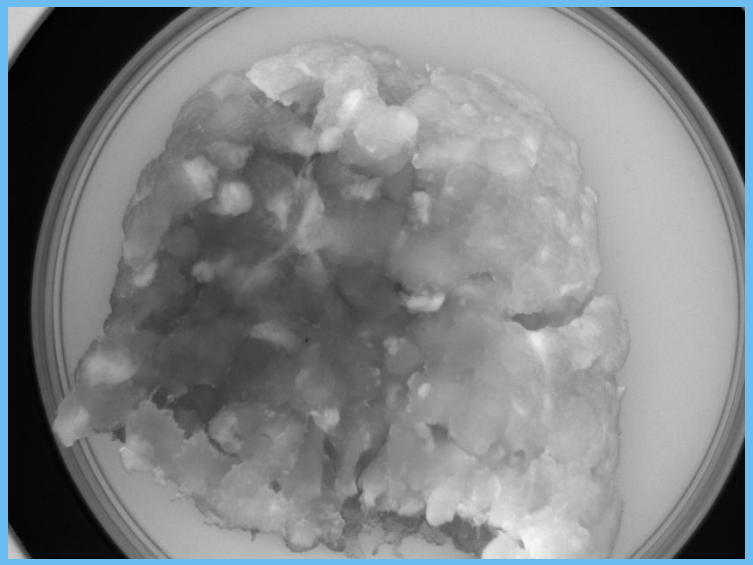
Upper left: No storage

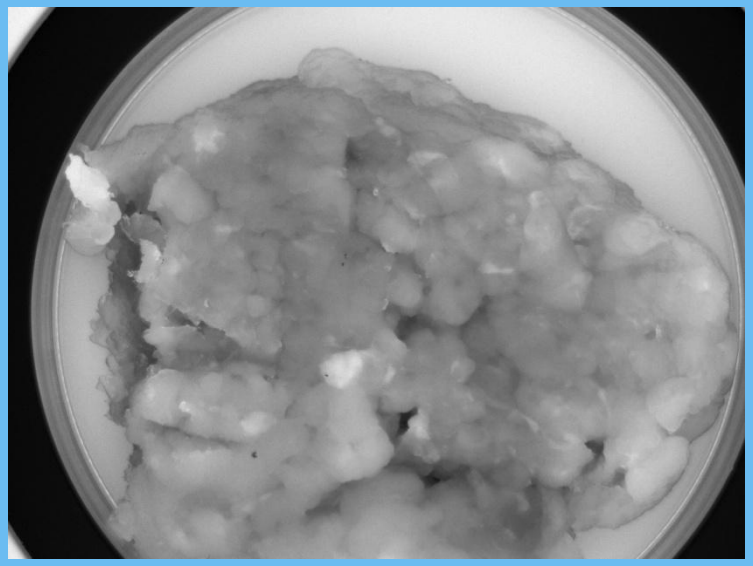
Upper right: Aerobic

Lower right: MAP

MNF 2





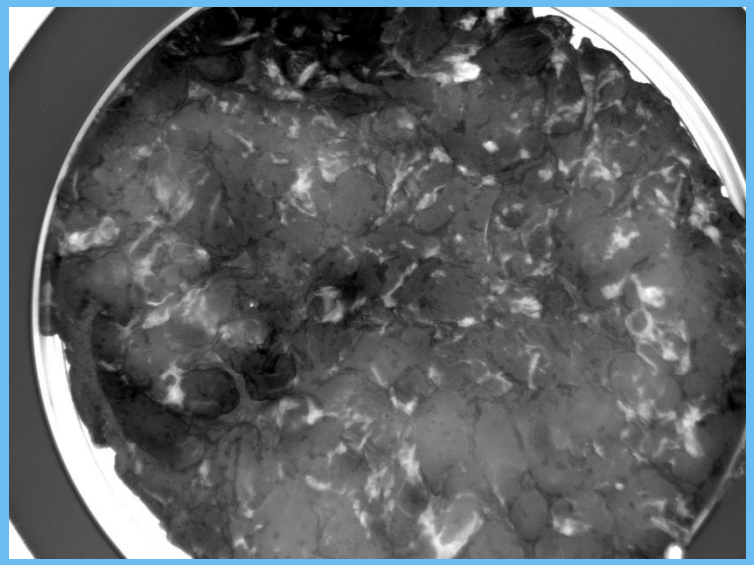


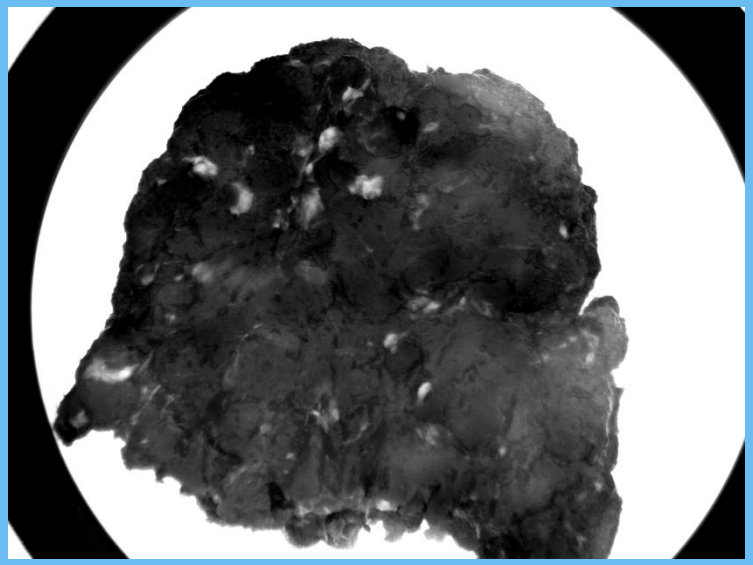
Upper left: No storage

Upper right: Aerobic

Lower right: MAP

MNF 3

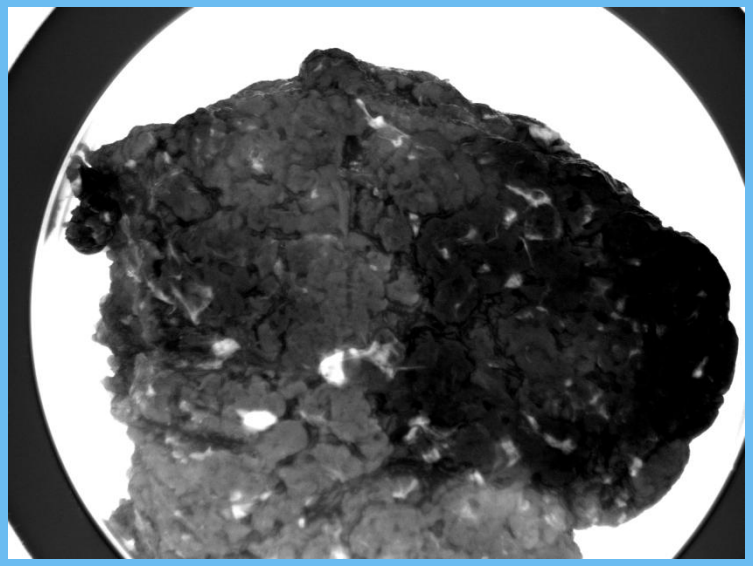




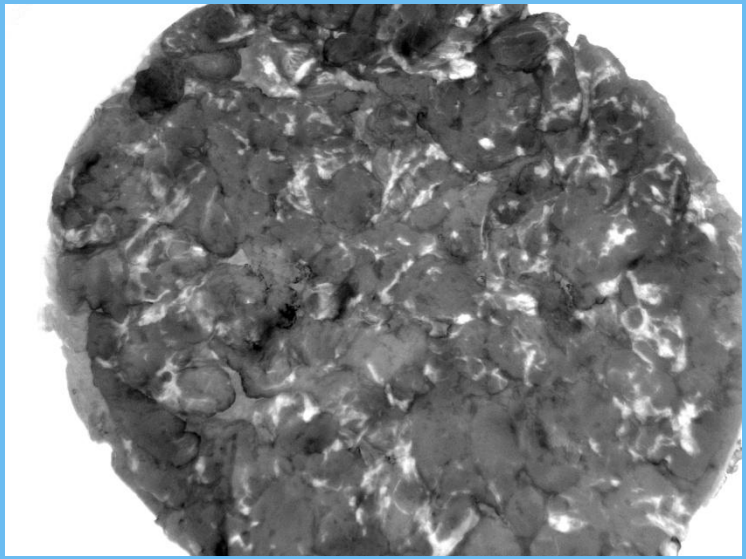
Upper left: No storage

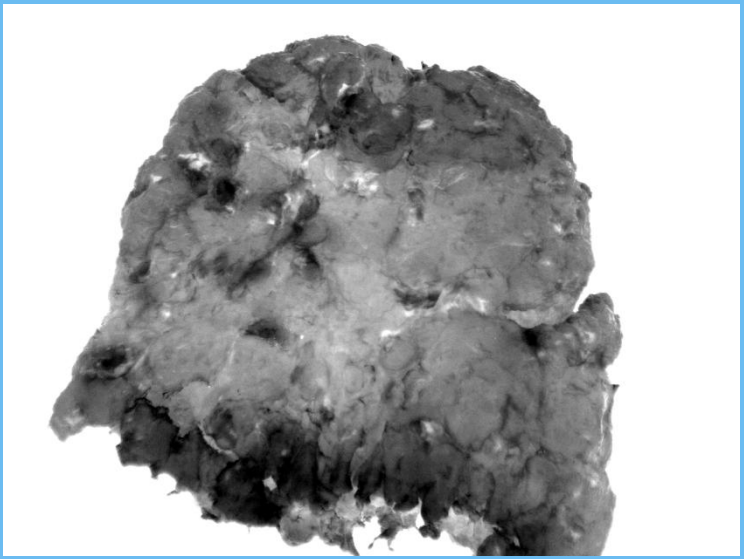
Upper right: Aerobic

Lower right: MAP



MNF 4

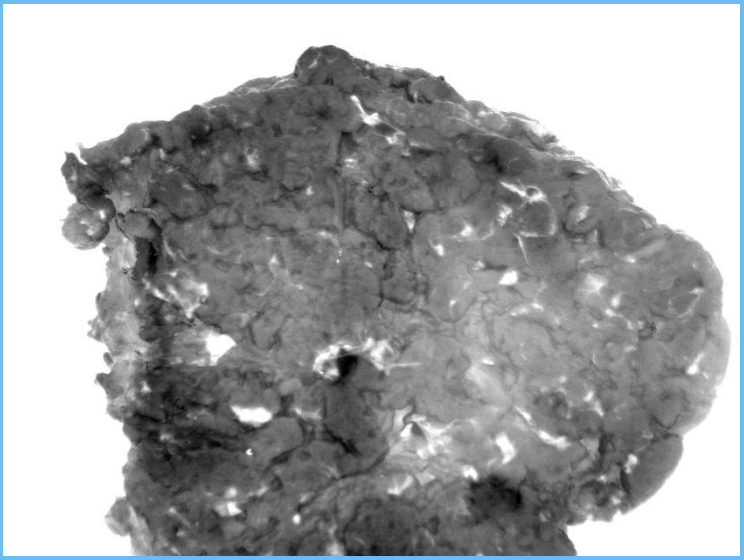




Upper left: No storage

Upper right: Aerobic

Lower right: MAP



Conclusions

- Color and surface chemistry changes during meat spoilage may be monitored using VideometerLab
- Heterogeneity of changes becomes apparent and may be measured
- A canonical discriminant function (CDF) shows that
  - Aerobic storage gives a large a bimodal change in color
  - Aerobic storage gives most color change from 50 to 90 hours storage
  - MAP storage gives a smaller but significant and unimodal change in color
  - The changes above can be directly quantified from the histogram of the CDF