Analytical comparison of online techniques to measure meat quality

Roehe, R.[1], Ross, D.W.[1], Duthie, C-A.[1], Craigie, C.R.[1], Font-i-Furnols, M.[2], Candek-Potokar, M.[3], Maltin, C.A.[4], Bünger, L.[1]

[1]Scotland's Rural College, UK;

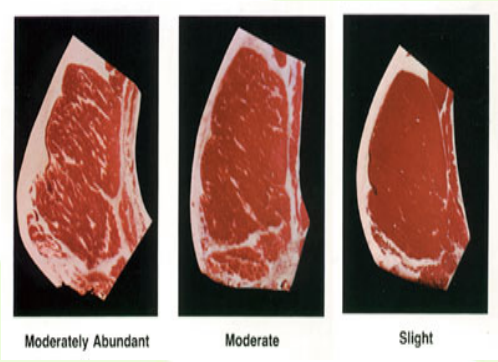
[2]IRTA, Spain

[3]Agricultural Institute of Slovenia, Slovenia

[4]Quality Meat Scotland, UK

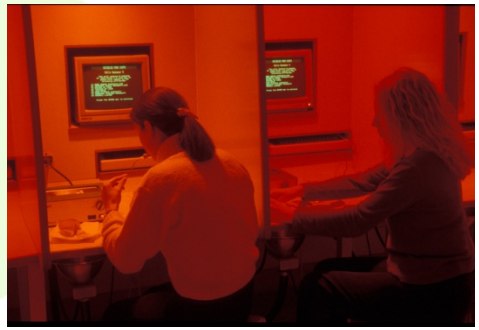
Meat quality

Carcass Quality



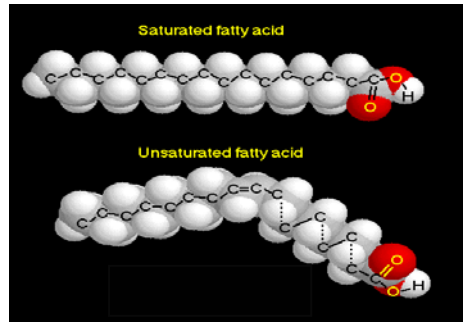
Lean
Fat
Bone

Meat Eating Quality



Tenderness
Juiciness
Flavour

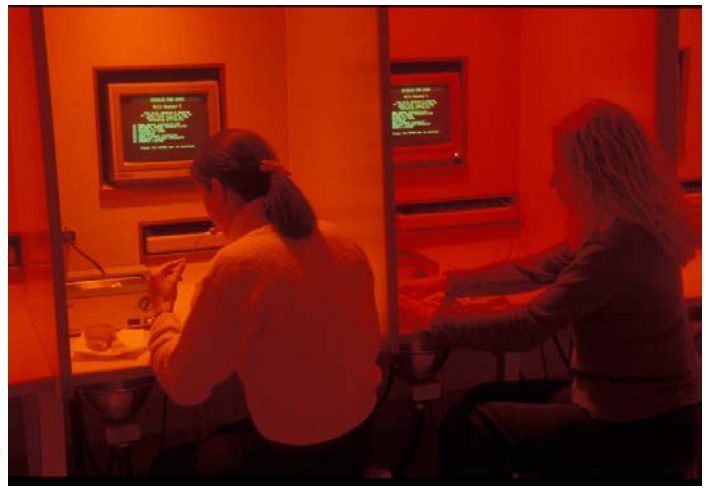
Nutritional Quality

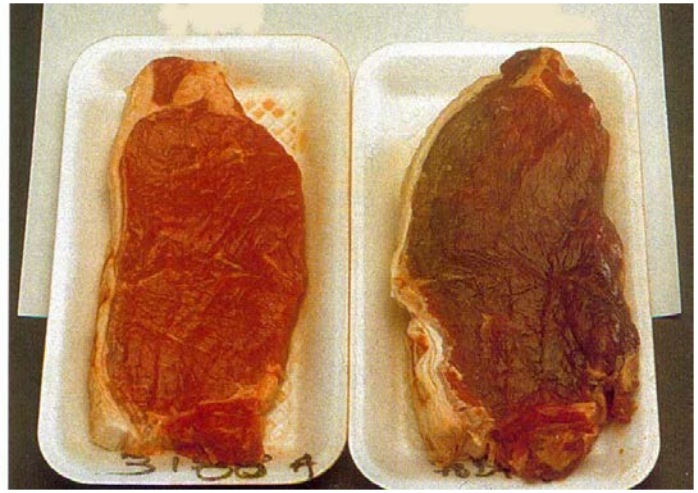


Proteins
Fatty acids
Minerals

Sensory and technological quality of meat

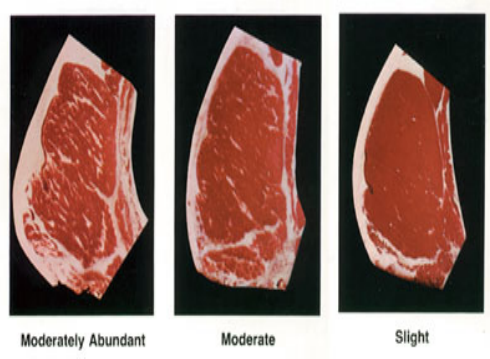
- **Sensory quality**
  - **Tenderness**
  - **Juiciness**
  - **Flavour**
- **Technological quality**
  - **Colour (myoglobin oxidation)**
  - **pH values**
  - **Water holding capacity**

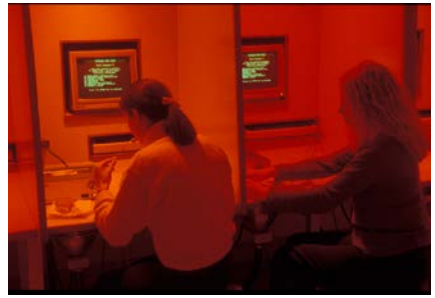


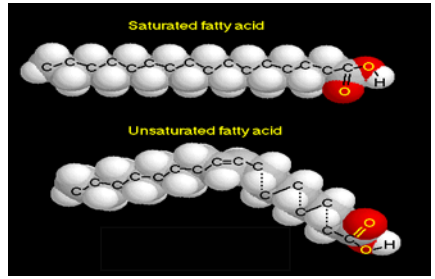


Nutritional quality

- **Meat**
  - **High quality protein**
  - **Array of micronutrients**
- **Concern**
  - **High concentration of saturated fatty acids**
  - **Obesity**
  - **Cardiovascular disease**
- **Improvement**
  - **Change in fatty acid profiles**







Meat quality measured online in the abattoir

- Criteria for online measurement techniques
  - robust under abattoir conditions
  - applied as early as possible after post mortem
  - accurate prediction of several meat quality criteria
  - easy and fast to operate
  - cost-effective

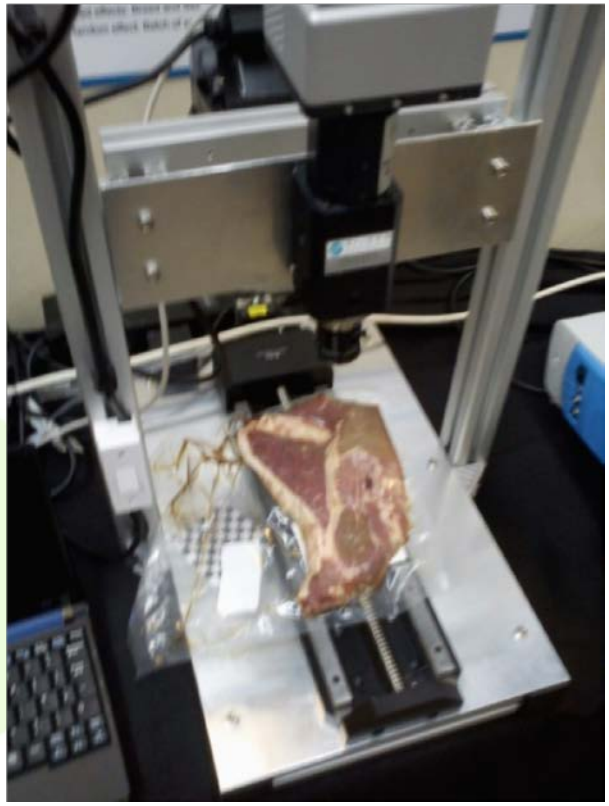
- Online measurement techniques
  - Visible Near Infrared spectroscopy (VisNIR)
  - Hyperspectral imaging (HSI)
  - Raman spectroscopy

Near infrared spectroscopy (NIR)

- Technique
  - Near infrared light from 800 to 2500nm
  - Reflection spectra due to vibration of specific molecules at specific wavelength

Literature review Prieto et al. (2009)

Hyperspectral imaging (HSI)



- Technique
  - Combination of imaging and NIR
  - For each pixel a NIR spectra is obtained
  - Differentiate between fat and lean tissue

Raman spectroscopy

- Technique
  - Measured the scattered light, when the laser light interacts with molecules of the samples
  - The difference between source and scattered light (Raman shift) is associated with certain molecules

What is NIR measuring?

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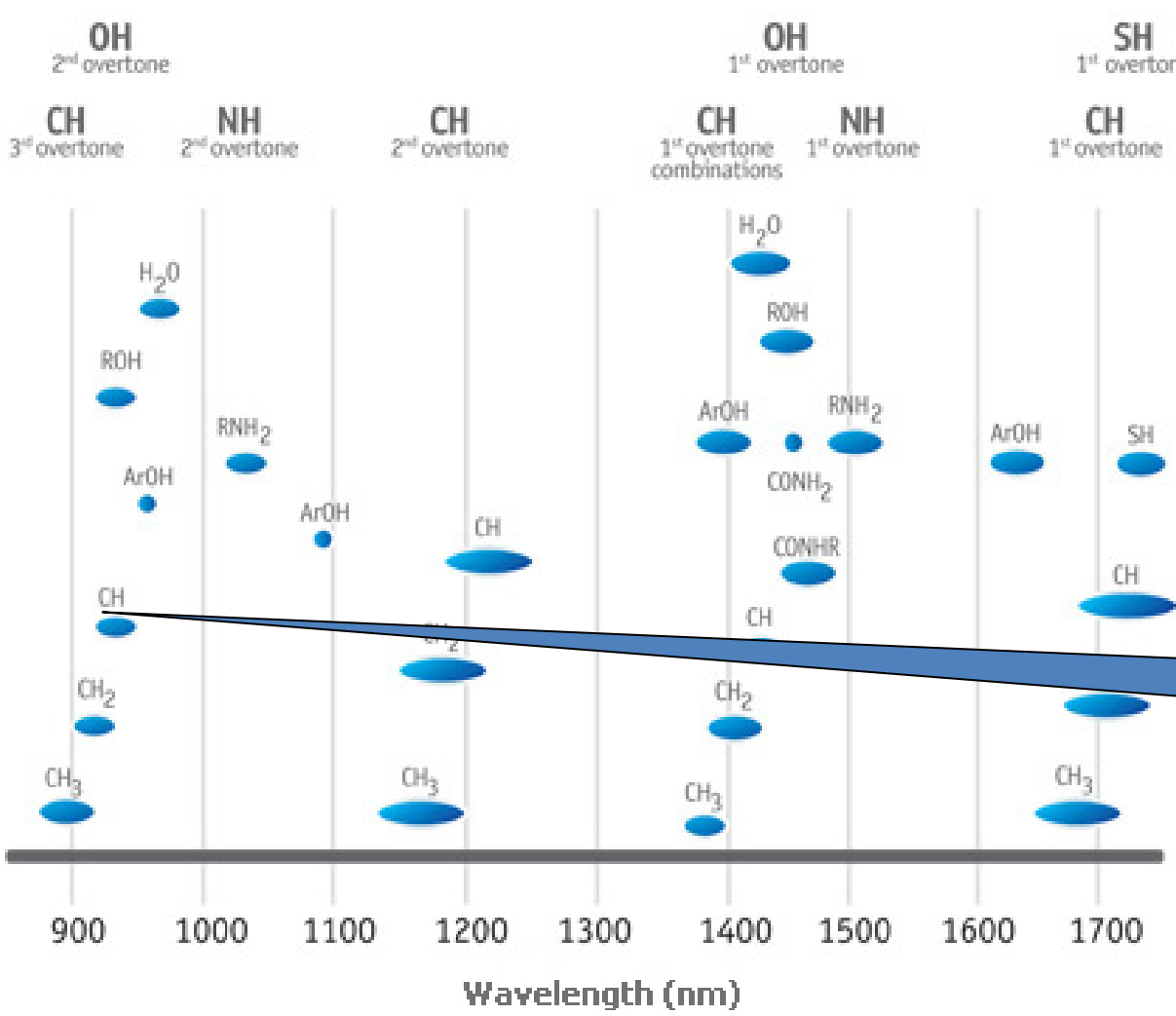
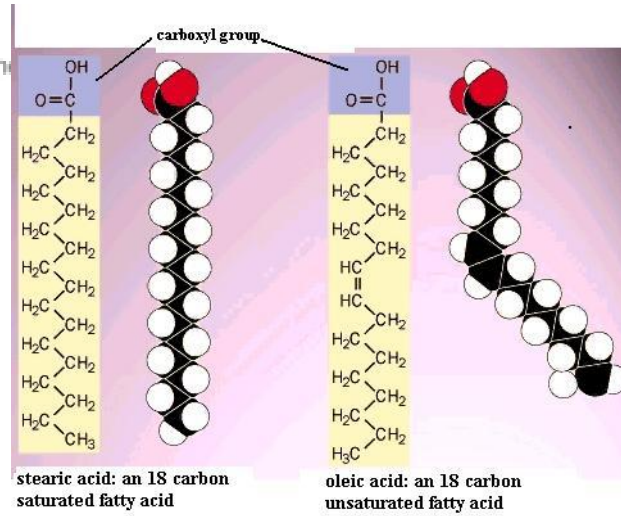
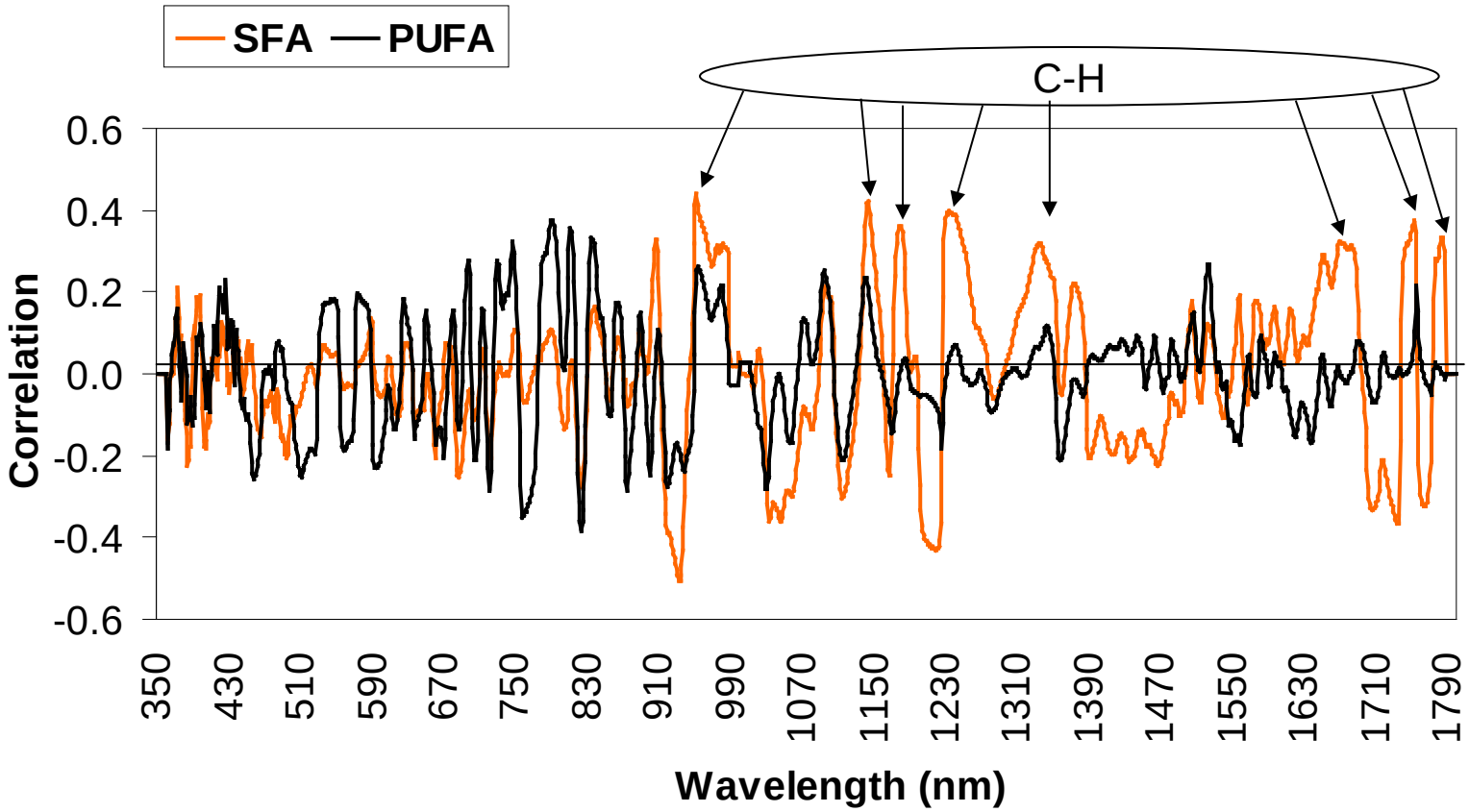




C-H bonds: fatty acids

Correlation coefficient between groups of fatty acid content and absorbance



Correlation coefficient between individual fatty acid content and absorbance

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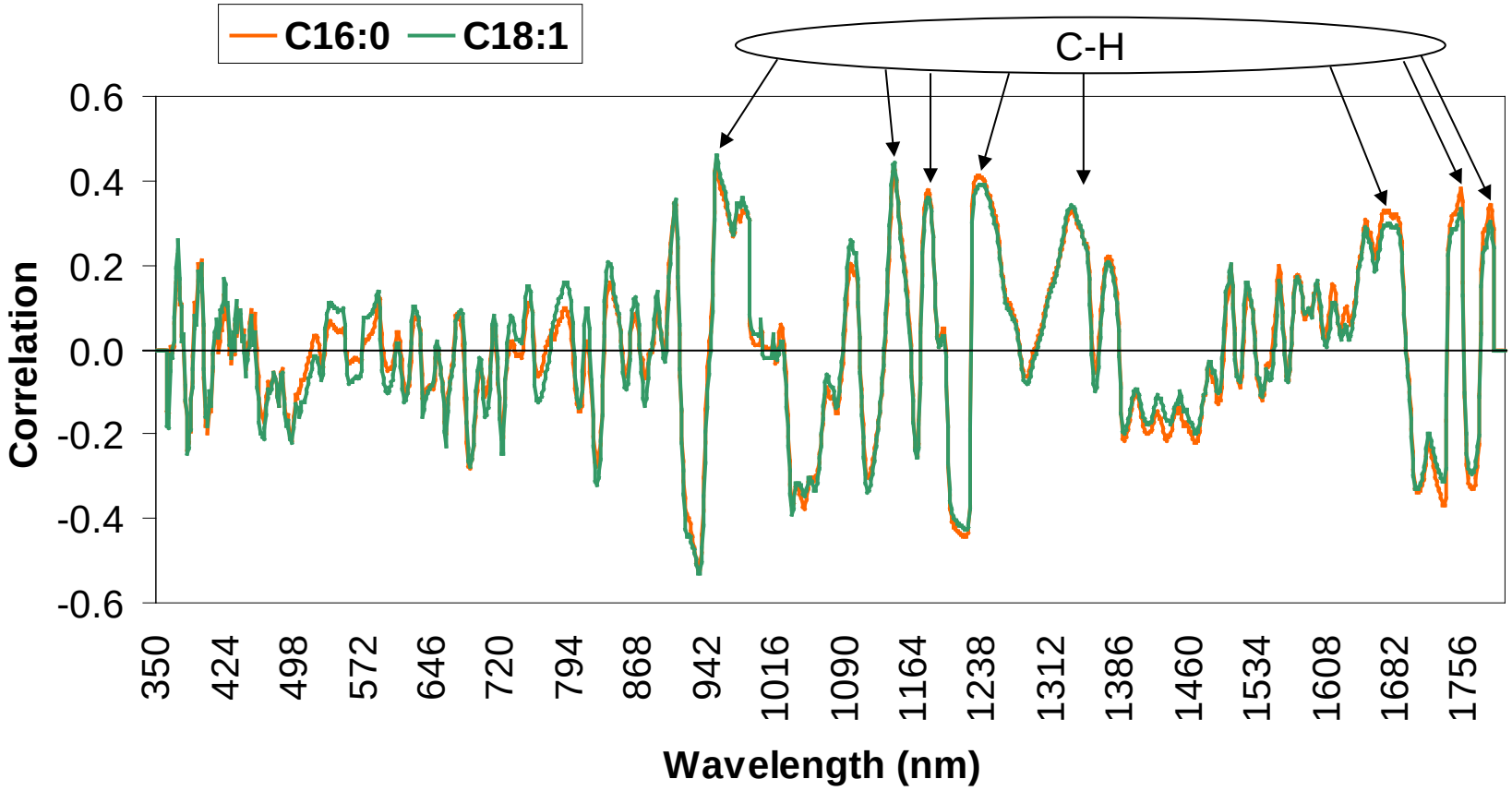
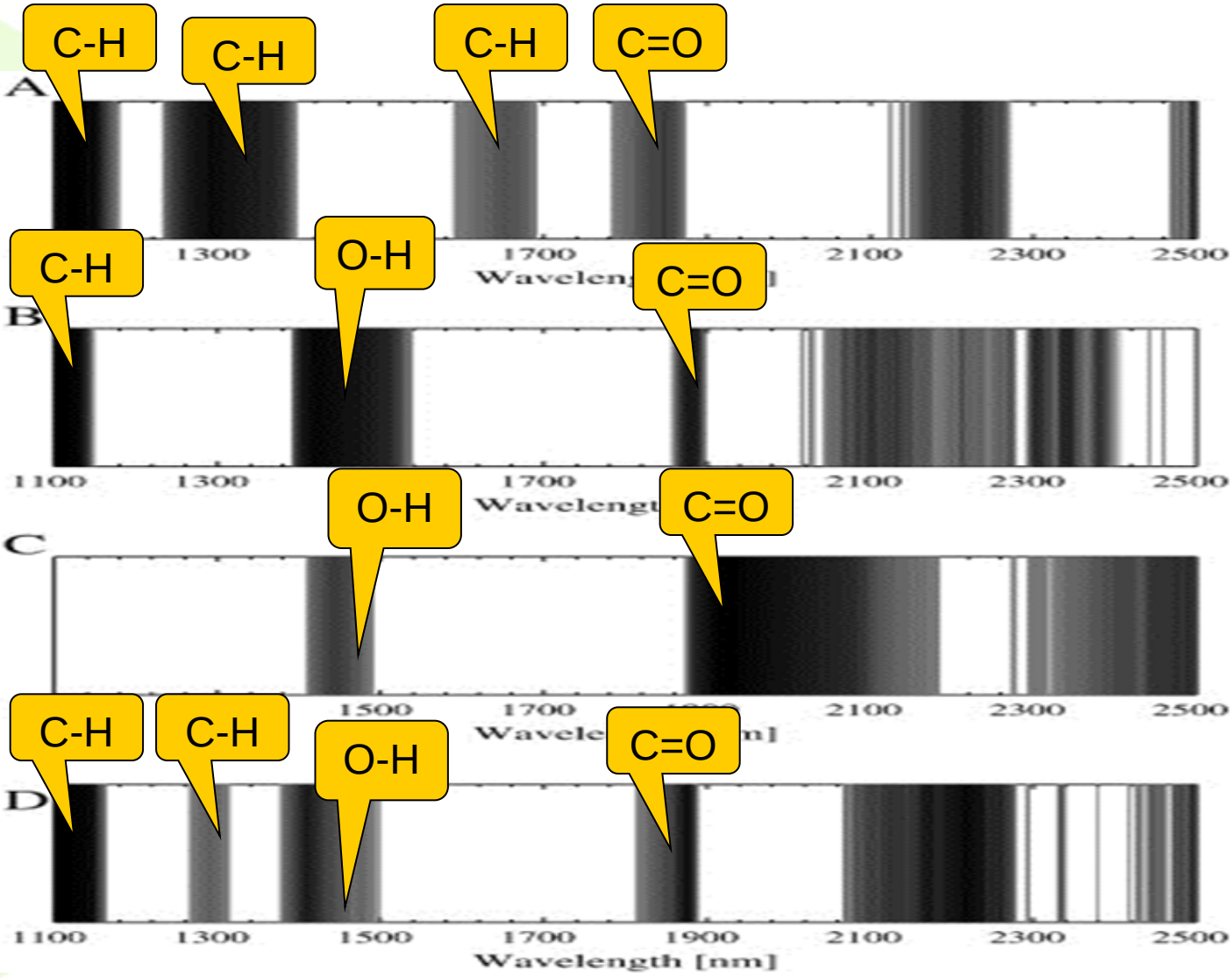


Understanding the relationship between chemical data and NIR



Linoleic acid
C18:2n-6
81%

±-Linolenic acid
C18:3n-3
10%

Eicosadienoic acid
C20:2n-6
4%

Polyunsaturated fatty acids

Boschetti et al. (2013)

Near-infrared (NIR) spectroscopy to predict fatty acid groups in beef

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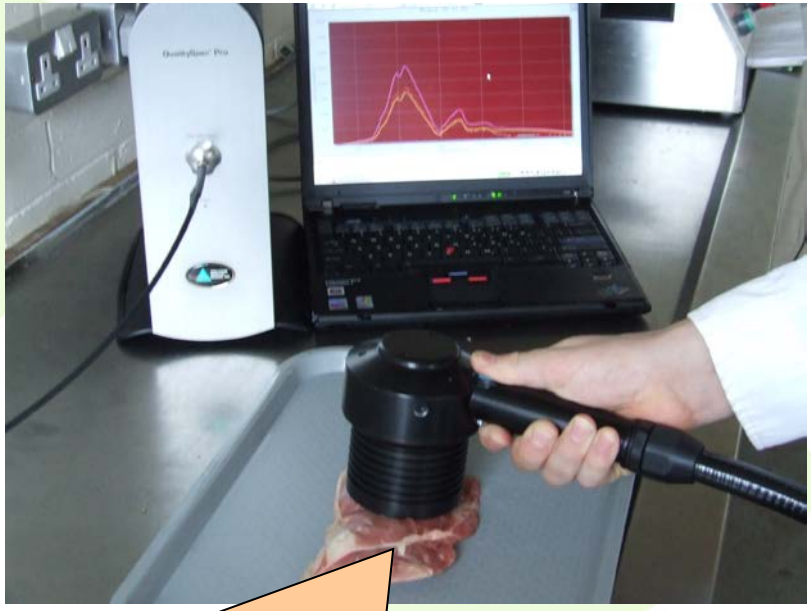

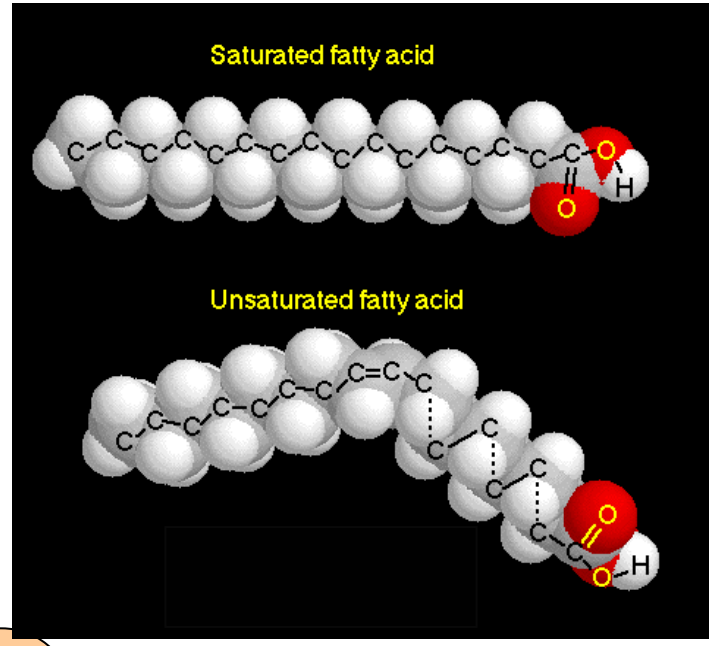

NIR measures & groups of fatty acids:

R^2=0.68 saturated fatty acids (SFA)

R^2=0.75 monounsaturated fatty acids (MUFA)

R^2=0.64 polyunsaturated fatty acids (PUFA)

R^2=0.75 intramuscular fat (IMF)

Prieto et al. (2011)

Near-infrared (NIR) spectroscopy to predict fatty acid profiles in beef

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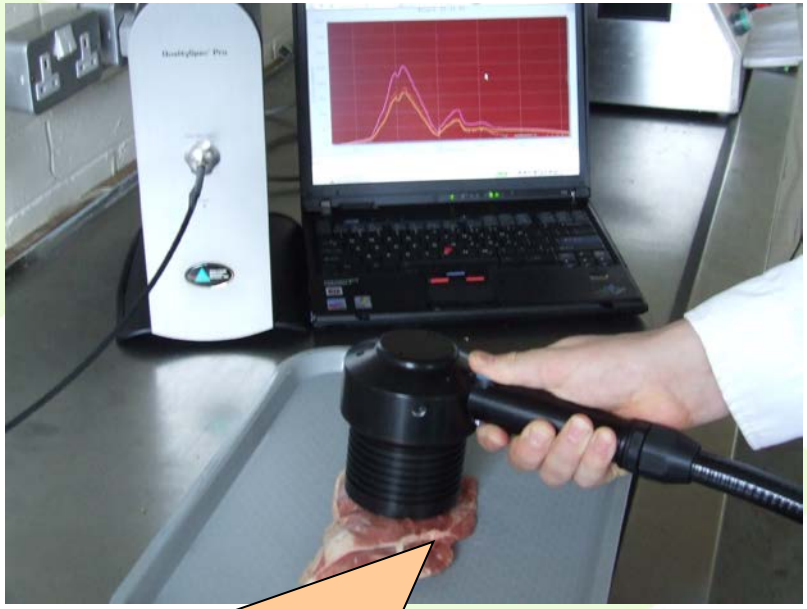

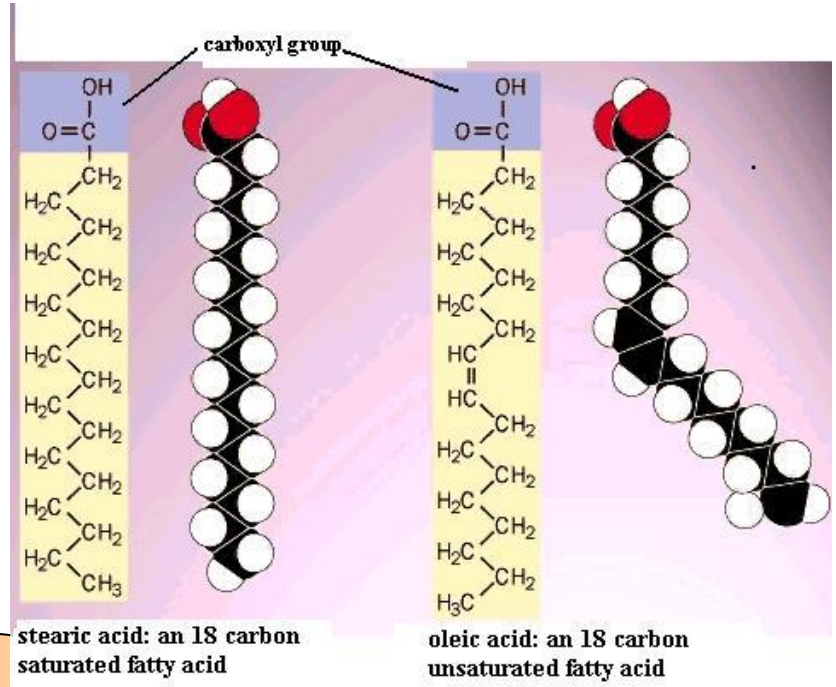

R^2=0.69 Palmitic acid (C16:0)

R^2=0.71 Stearic acid (C18:0)

R^2=0.76 Oleic acid (C18:1n-9)

R^2=0.60 ±-Linolenic acid (C18:3n-3)

Prieto et al. (2011)

Omega-3 PUFA reduce cardiovascular disease risk

Near-infrared (NIR) spectroscopy to predict tenderness of beef

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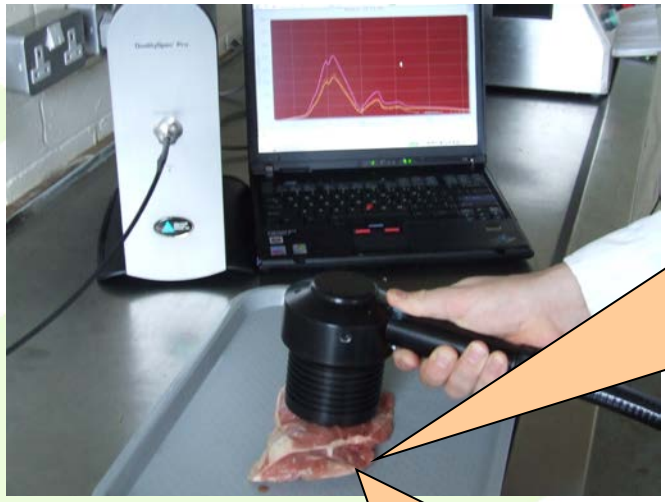

NIR & taste panel traits:

R^2=0.28 tenderness

Prieto et al. (2009)

NIR & physical tenderness measurements:

R^2=0.37 Volodkevitch shear force

R^2=0.54 Slice shear force (3 days)

R^2=0.31 Slice shear force (14 days)

Near-infrared (NIR) spectroscopy to predict numerous meat eating quality in beef

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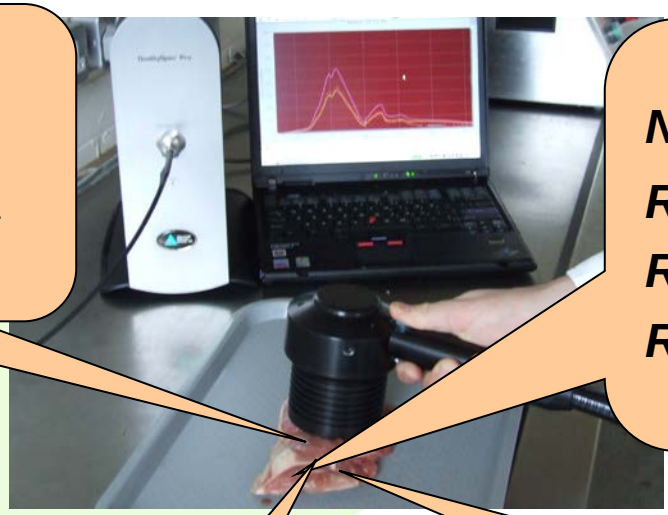
NIR & water holding capacity:

R^2=0.35 Cooking loss



NIR & taste panel traits:

R^2=0.28 tenderness

R^2=0.21 juiciness

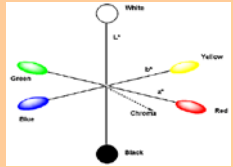
R^2=0.59 flavour

NIR & colour:

R^2=0.86 L* colour

R^2=0.86 a* colour

R^2=0.91 b* colour



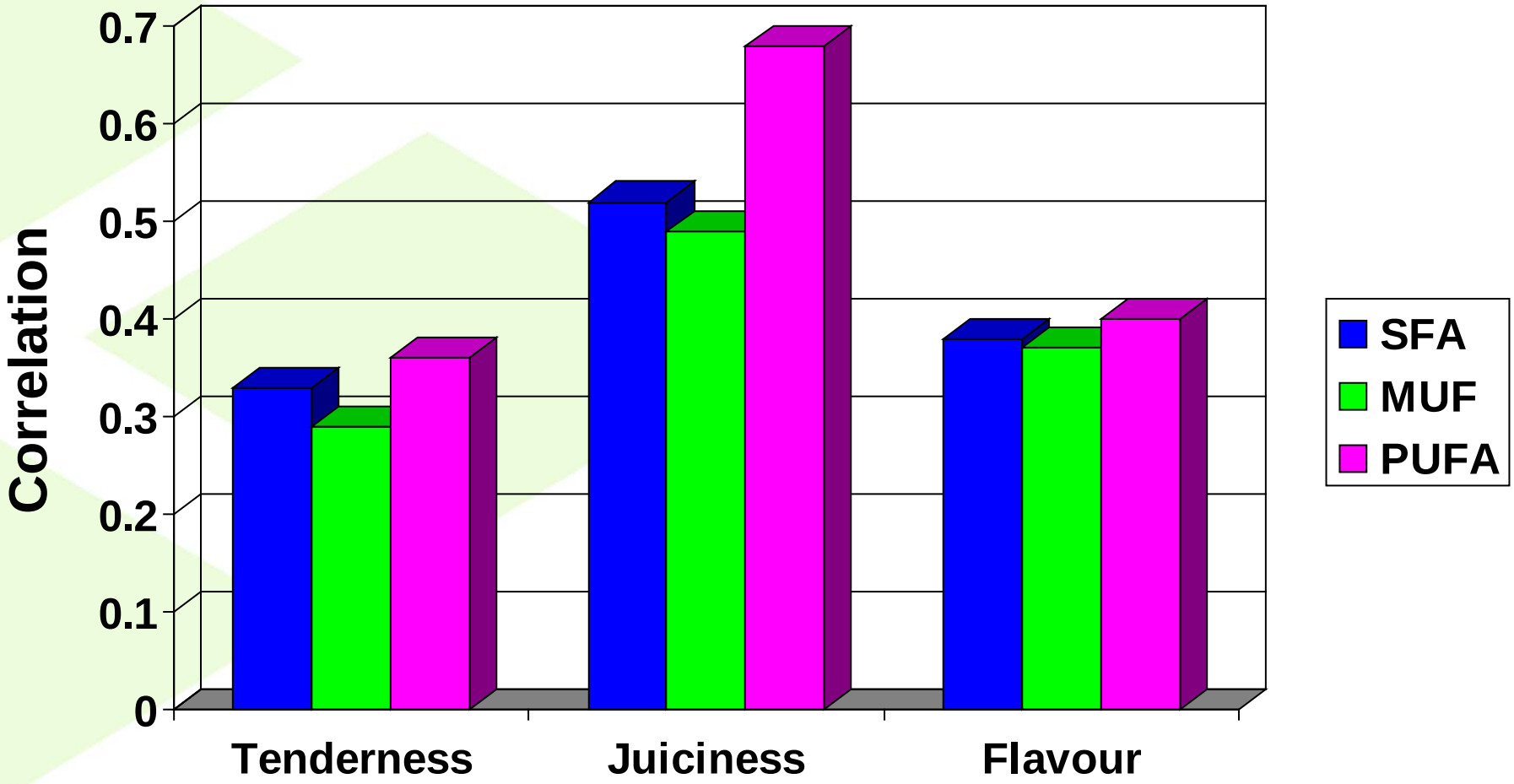
NIR & pH value:

R^2=0.59 pH value

Prieto et al. (2009)

Craigie (2012)

Associations between fatty acids & sensory characteristics



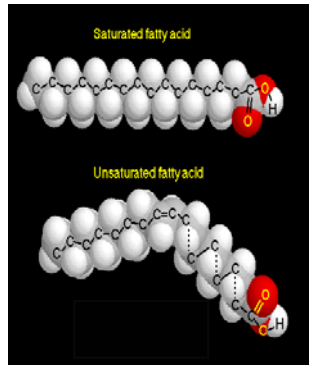
Correlations: Fatty acids & technological characteristics

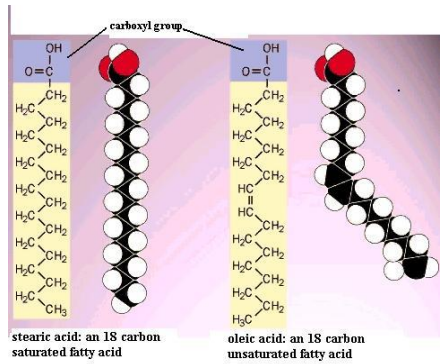
Fatty acids	Colour (L)	pH value	WHC
SFA	0.59***	0.54***	0.54***
MUFA	0.56***	0.53***	0.53***
PUFA	0.75***	0.74***	0.70***

*** P < 0.001

Influence of sample preparation on the accuracy of NIR measurements

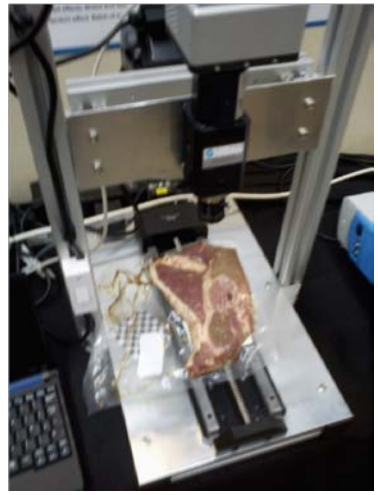
- **NIR spectroscopy on meat samples ground, freeze-dried, vacuum-packed and stored at 80°C until analysis (e.g. Zomeño et al., 2012)**
  - Intramuscular fat (R^2 = 0.98, RPD = 7.57)
  - Saturated fat (R^2 = 0.96, RPD = 5.08)
  - Monounsaturated fat (R^2 = 0.98, RPD = 6.68)
  - Polyunsaturated fatty acid (R^2 = 0.83, RPD = 2.40)
  - Palmitic acid, C16:0 (R^2 = 0.96, RPD = 4.93)
  - Stearic acid, C18:0 (R^2 = 0.90, RPD = 3.20)
  - Oleic acid, C18:1n-9 (R^2 = 0.97, RPD = 6.10)
  - ±-Linolenic acid, C18:3n-3 (R^2 = 0.94, RPD = 3.93)





Hyperspectral imaging (HSI)

- Hyperspectral imaging
  - Near infrared spectra for each pixel
  - Differentiate between fat and lean tissue
  - Differentiate between all components of meat



Hyperspectral imaging in beef

- **HSI & physical tenderness**:
  - R^2=0.77-0.83 Slice shear force (El Masry et al., 2012)

- **HSI & colour:**
  - R^2=0.92 L* colour (Wu et al., 2012)
  - R^2=0.92 a* colour (Wu et al., 2012)
  - R^2=0.94 b* colour (Wu et al., 2012)

Hyperspectral imaging in pork

- **HSI & water holding capacity:**
  - R^2=0.79 Drip loss, Honikel 1998
- **HSI & fat content:**
  - R^2=0.83 Intramuscular fat
- **HSI & sensory characteristics (trained panel):**
  - R^2=0.54 Tenderness
  - R^2=0.49 Juiciness
- **HSI & colour:**
  - R^2=0.90, L* colour
  - R^2=0.72 a* colour
  - R^2=0.85 b* colour

Barbin et al. (2012 or 2013)

Hyperspectral imaging (HSI)

- Robust measurements
  - Under abattoir conditions
- Statistical analysis
  - Partial least squares regression (PLSR)
  - Principal component (PCA)
  - Artificial neural networks
  - Discriminant analysis
  - Hierarchical clustering
  - Support vector machine regression

Raman spectroscopy

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- Raman spectroscopy

Raman spectroscopy in beef

- **Raman & sensory characteristics (trained panel)**
  - R^2=0.65, RMSEP/x=18% tenderness
  - R^2=0.62, RMSEP/x=16% juiciness
  - R^2=0.26, RMSEP/x=16% flavour
  - R^2=0.67, RMSEP/x=11% overall acceptability

- **Raman & physical tenderness:**
  - R^2=0.75, RMSEP/x=20% Warner-Bratzler shear force

Beattie et al. (2004)

Raman spectroscopy in pork

- Raman & sensory characteristics (trained taste panel):
  - R^2=0.99, PA=41% tenderness (Wang et al., 2012)
  - R^2=0.99, PA=21% chewiness (Wang et al., 2012)
  - R^2=0.98, PA=44% juiciness (Wang et al., 2012)

    (PA = prediction accuracy given 10% error tolerance)

- Raman & fatty acid composition (melted-fat tissue):
  - R^2=0.96-0.99 SFA (Olsen et al., 2007)
  - R^2=0.96-0.91 MUFA (Olsen et al., 2007)
  - R^2=0.98-0.95 PUFA (Olsen et al., 2007)
  - R^2=0.98-0.97 Iodine value (Olsen et al., 2007)

Prediction of several meat quality criteria using imaging techniques

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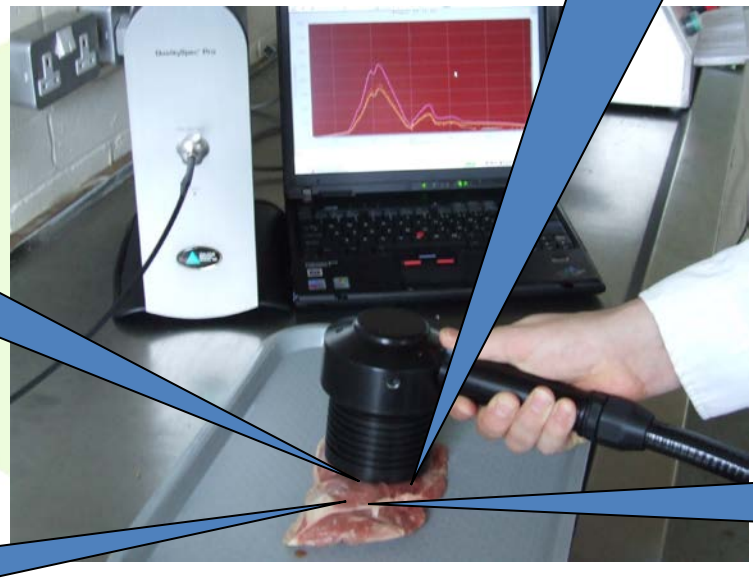
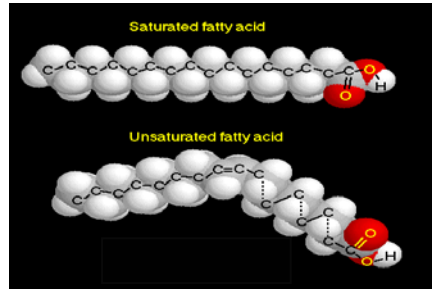
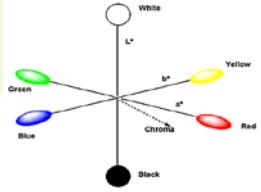
Sensory characteristics



Fatty acid profiles

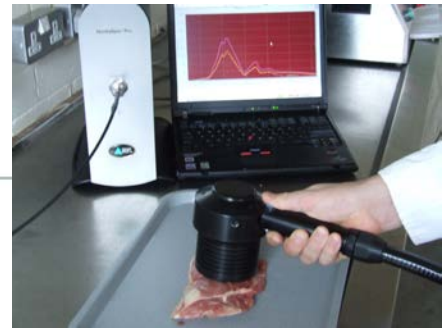


Colour & cooking loss



Physical tenderness measurements

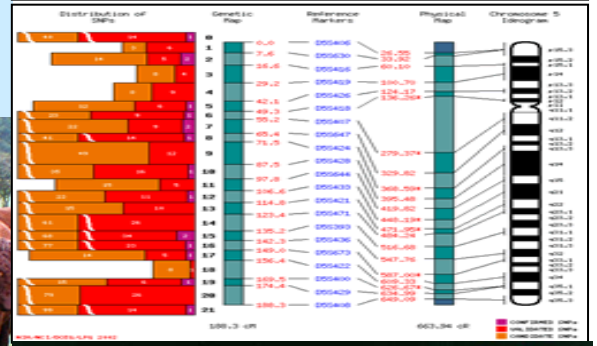
Conclusions: VisNIR

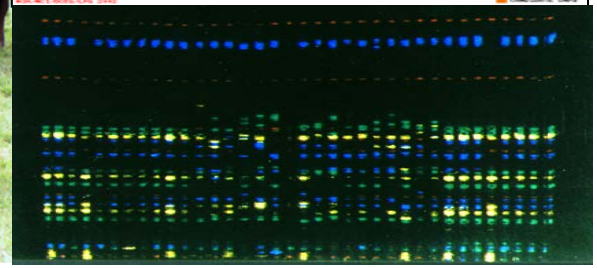


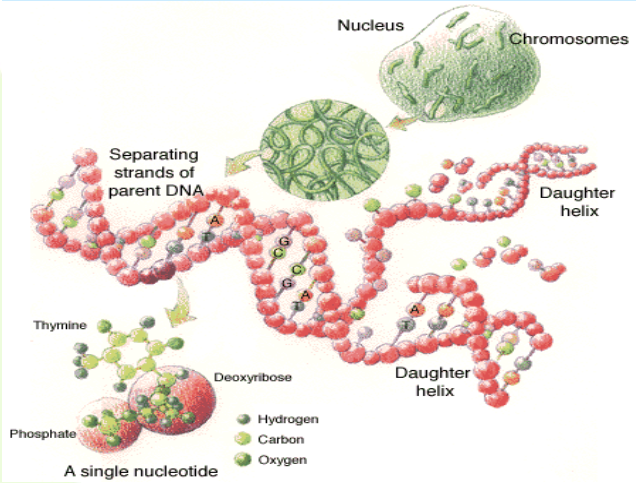
- **NIR could be used on-line measurement for meat quality**
  - **Early (in the abattoir)**
  - **Fast**
  - **Non-invasive**
  - **Cost-effective**
  - **Simultaneous measurements of other technological and sensory criteria**
  - **Moderate prediction accuracies under abattoir conditions**
- **Implementation**
  - **Value-based marketing system**
  - **Sorting of carcasses by using thresholds (Shackelford)**
  - **Genetic improvement programmes**

Genomic selection for meat quality

- SNP-Chip identifies >770,000 genomic markers
- Used of sequence information







Conclusions: Hyperspectral imaging

- **HSI could be used on-line measurement for meat quality**
  - **Early (in the abattoir)**
  - **Fast**
  - **Non-invasive**
  - **Cost-effective**
  - **Simultaneous measurements of other technological and sensory criteria**
- **High potential to be used in the abattoir**
  - **Substantial more information than NIR**
  - **Improvement of the robustness of the equipment under abattoir conditions**
  - **Improvement of the statistical analysis of the image data**

Conclusions: Raman spectroscopy

- **Raman could be used on-line measurement for meat quality**
  - **Early (in the abattoir)**
  - **Fast**
  - **Non-invasive**
  - **Cost-effective**
  - **Simultaneous measurements of other technological and sensory criteria**
  - **High potential to predict meat quality characteristics**
- **Usefulness in the abattoir**
  - **Sensitive detectors may be influenced by abattoir conditions Moss et al. (2010)**
  - **Increase in spectral noise is expected**

General conclusion

- **High potential of these spectral technique for measuring meat eating and nutritional quality**

- **Improvements**
  - **Robustness under abattoir conditions**
  - **Statistical methodology**
  - **Better understanding what the spectral technique is measuring**

Acknowledgements

Scottish Government and FAIM Cost action for financial support