A feasibility study for the prediction of the technological quality of ham with NIR spectroscopy

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Introduction:

Muscle quality is a key factor in the French cooked ham industry: no phosphate and carraghenan allowed in the « Jambon cuit supérieur » process.

Cooking yield is controlled by measuring the Semimembranosus ultimate pH.

<table>
<thead>
<tr>
<th>pH24 / cooking yield corr.</th>
<th>publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70</td>
<td>Gueblez et al. (1990)</td>
</tr>
<tr>
<td>0.84</td>
<td>Alviset et al. (1995)</td>
</tr>
<tr>
<td>0.79</td>
<td>Vautier et al. (2011)</td>
</tr>
</tbody>
</table>
Introduction:

Ultimate pH - one of the best indicators for the « PSE-like zone » defect risk level  
(Vautier et al., 2008)

This defect increases the rate of « paste-like » structure on slices of cooked ham
Introduction:

Ultimate pH measurement is difficult in industrial conditions:
- rate of production lines
- calibration stability
- versatile environment
- maintenance (electrodes)

Nowadays, processed meat industry need a more accurate technique to predict process yields
Introduction:

Visible + NIR spectroscopy appears as a dedicated alternative for meat quality prediction:

- Some interesting work on drip loss (Savenije et al., 2006; r =0.58)
- Visible spectroscopy produced satisfying cross validation results for cooking yield prediction (Vautier et al., 2011)
- Spectrum collection frequency up to 600/hour
- Low effect of industrial environment on NIRS device (contact probes)
Objectives:

- To confirm the precision of NIRS prediction of the cooking loss and PSE-like zones
  - External validation data set

- To explore multiple muscle/probe couples for bone-in and deboned pork hams
Materials and methods:

Sampling:

- 110 individual cooked hams
- “Jambon Cuit Supérieur”
- Processing performed following industrial standards and materials

2 data sets:

- Calibration data set (n=74)
  - PLS regression determined by cross validation
- External validation data set (n=36)
Materials and methods:

Spectrometer:

- **ASDI labspec5000** device
- Spectrum range used: between 350 and 1800nm
- 2 contact probes

![Labspec5000](image1.png)  
**Labspec5000**  

![Insertion probe](image2.png)  
**Insertion probe**  
**(two ways optical path)**

![Surface probe](image3.png)  
**Surface probe**
Materials and methods:

Raw material = deboned hams

Semitendinosus  R.Femoris  Biceps Femoris  Semimembranosus  Gluteus Medius
+ Vastus  + Adductor

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Materials and methods:

NIRS measurements:

- **Semimembranosus (SM)**

  - Surface probe
  - Internal surface

  - Insertion probe
  - Muscle inside, 2cm from the internal surface
Materials and methods:

NIRS measurements:

- **Semitendinosus (ST)**
  - Surface probe
  - Internal surface

- **Gluteus Medius (GM)**
  - Surface probe
  - Muscle section
Materials and methods:

NIRS measurements:

- **Biceps Femoris (BF)**
  - Surface probe
  - Internal surface

- **Vastus Lateralis (VL)**
  - Surface probe
  - External surface
Materials and methods:

Ham processing with individual traceability:

- Deboning
- PSE-like zone quotation
- NIRS measurements
- Ultimate pH

- Brine injection
- Cooking yield
- Tumbling and cooking / individually vacuum packed hams / 5 hams per mould

Commercial product
- Slicing yield

High frequency slicing line
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Results for cooking yield prediction:

1 – Gluteus Medius calibration

(n = 74)

<table>
<thead>
<tr>
<th>Cross validation (1/3)</th>
<th>Calibration (3/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rmsev min.</td>
<td>Nb PLS factors</td>
</tr>
<tr>
<td>2.80</td>
<td>3</td>
</tr>
</tbody>
</table>
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Results for cooking yield prediction:

1 – Gluteus Medius external validation

\[ r = 0.82 \] / error = 1.62

\[ R^2 = 0.6739 \]

\[ y = 7.9587x + 41.193 \]

\[ R^2 = 0.5956 \]

observed cooking yield (%) predicted cooking yield (%)

observed cooking yield (%)

predicted cooking yield (%)

Cooking yield NIRS predicted vs observed

Observed cooking yield vs ultimate pH

\[ r = 0.77 \] / error = 1.53
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Results for cooking yield prediction:

2 – Semimembranosus calibration

Surface probe

(n = 74)

Cross validation (1/3)  Calibration (3/3)

<table>
<thead>
<tr>
<th>Rmsev min.</th>
<th>Nb PLS factors</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.68</td>
<td>3</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Results for cooking yield prediction:

2 – Semimembranosus calibration

Insertion probe

(n = 74)

<table>
<thead>
<tr>
<th>Cross validation (1/3)</th>
<th>Calibration (3/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rmsev min.</td>
<td>Nb PLS factors</td>
</tr>
<tr>
<td>2.69</td>
<td>1</td>
</tr>
</tbody>
</table>
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Results for cooking yield prediction:

2 – Semimembranosus external validation

Surface probe

- Cooking yield
- NIRS predicted vs observed
- $r = 0.69$ / error = 2.37

Insertion probe

- Cooking yield
- NIRS predicted vs observed
- $r = 0.54$ / error = 2.11
Results for cooking yield prediction:

3 – Other muscles **external validation**

<table>
<thead>
<tr>
<th>Probe</th>
<th>Muscle</th>
<th>External validation (n=36)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface probe</td>
<td><em>Vastus Lateralis</em></td>
<td>0.60</td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td><em>Biceps Femoris</em></td>
<td>0.53</td>
<td>1.94</td>
</tr>
<tr>
<td></td>
<td><em>Semitendinosus</em> (internal surface)</td>
<td>0.55</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td><em>Semitendinosus</em> (external surface)</td>
<td>0.28</td>
<td>2.64</td>
</tr>
</tbody>
</table>
Results for PSE-like zones classification:

- Only presence/absence classification was used (IFIP scale shows 4 grades)

- Same PLS procedure as for cooking yield but based on discriminant analysis
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Results for PSE-like zones classification:

<table>
<thead>
<tr>
<th>Probe</th>
<th>Muscle</th>
<th>Correctly classified (%)</th>
<th>% false positive/% false negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td><em>Gluteus Medius</em></td>
<td>60</td>
<td>77 / 23</td>
</tr>
<tr>
<td></td>
<td><em>Semimembranosus</em> (internal surface)</td>
<td>84</td>
<td>57 / 43</td>
</tr>
<tr>
<td>Insertion</td>
<td><em>Semimembranosus</em> (muscle inside)</td>
<td>77</td>
<td>65 / 35</td>
</tr>
</tbody>
</table>
Conclusions:

1 – Cooking yield prediction

- Best results for:
  contact probe / *Gluteus Medius*

  external validation: $r=0.82$ / error=$1.62$

  *(cooking yield standard deviation=3.6)*

- Availability on deboned and bone in hams
Conclusions:

2 – PSE-like zone classification

- Efficient on *Semimembranosus* only
- Best results with the contact probe

84% correct classification vs 77% (insertion probe)
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Thank you for your attention