Traditional and new methods to assess beef quality

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France and *UK
The concept of quality and reference methods at the consumer end

*Post-mortem* prediction of beef quality at the abattoir or by beef retailers

Prediction of beef quality at the producer level
Quality can be defined as
“the properties of a product that contribute to and satisfy the needs of end-users”.

Quality is thus a social concept, i.e. a convergence between end-user expectations and product characteristics.
The new concept of quality

Quality traits not visible

True and perceived quality traits

Perceived but not true quality traits

Science is here to reduce this gap
The first problem: What does enhancing quality of animal products mean?

For consumers, products should be:
- safe
- healthy
- traceable
- consistent
- diverse
- convenient

- product differentiation
- added value
- sustainability

are important for the producers and society.
The second problem: the diversity of end-users

Producers

Abattoirs and retailers

Consumers
At the consumer end, the diversity of food preference

In Japan, raw fish and marbled beef

In Europe, cooked fish and lean beef
Sensory Assessment (1/6)

- The optic impression
- The odour or aroma impression (while smelling and while tasting)
- The taste impression
- The consistency or texture impression
Beef: Comparisons of beef quality from 15 breeds by Sensory Panels in UK and Spain

Approach used:-
Trained assessors in both countries
UK & Spain, 8 point intensity category scales

Common profile across countries
Texture, Juiciness, Beef Flavour Intensity, Abnormal flavour intensity & Overall Liking.

(Nute et al., 2006)
Calibration results for texture
UK = 1.4 + 0.6 ES (n=206 paired values)

Fitted Line Plot
UK = 1.411 + 0.6187 ES

S 0.676257
R-Sq 53.1%
R-Sq(adj) 52.8%

Possible to relate the two panels for texture and Flavour

(Nute et al., 2006)
Overall liking

Fitted Line Plot
Overall liking = 3.318 + 0.4489 Overallcal

(S 0.607014
R-Sq 15.1%
R-Sq(adj) 14.5%) Appear to be differences between the 2 panels. These are hedonic (preference judgements) Differences probably related to the meat they are used to eating.

(Nute et al., 2006)
Lamb Odour Intensity, Tenderness, Juiciness, Lamb Flavour Intensity.

- Similar sensory results were produced in both UK and Spain
- Lamb flavour higher in grass fed lambs
- Linolenic C18:3 n-3 higher in grass fed lambs
- Abnormal flavour reduced in grass fed lambs
- Linoleic C18:2 n-6 lower in grass and higher in concentrate fed lambs.
Consumer Assessment (untrained people)

- Does it taste good, do I like it.
Summary

- The concept of quality and reference methods at the consumer end
- *Post-mortem* prediction of beef quality at the abattoir or by beef retailers
- Prediction of beef quality at the producer level
Requirements for physico-chemical methods

- Accuracy
- Not so expensive
- Rapid
- Capability to be fully potential fully automated
- Non-invasive
- Should bring a benefit by being related to the desired quality trait
Prediction of ageing time to improve tenderness

Individual variability in meat tenderness

Lepetit et Hamel, 1998
Ageing and tenderness
Important for beef

Toughness

Rigor mortis

Ageing

Amplitude

Speed

Basal Toughness (connective tissue)

14 days

Time Post-mortem

Myofibres (proteases)
Mechanical methods

- Based on shear, tensile, compressive or torsional strain
- Correlation between them
- Myofibrillar resistance on day 2 is predictive on that on day 8
- Poor correlation between raw and cooked beef
- More or less correlated with tenderness ($R^2=0.5$ max).
- The Warner Bratzler shear force is considered as a reference
Electrical methods (1/3)

Impedance = resistance and capacitance components

Direction of electrical current

Low impedance

High impedance

Longitudinal

Transverse

High ratio of impedance before ageing

Low ratio of impedance after ageing

Low impedance after ageing
Electrical methods (2/3)

Myofibrillar resistance by compression (N/cm²) vs. Electrical anisotropy

(Lepetit et al., 2002)
A circular captor

diameter: 8 cm.

Rectus Abdominis
Fluorescence: emission of photons following excitation by light of molecules exhibiting conjugated double-bonds.
Intrinsic fluorophores

<table>
<thead>
<tr>
<th>Fluorophore</th>
<th>Excitation</th>
<th>Emission range</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tryptophan (proteins)</td>
<td>280 nm;</td>
<td>300-400 nm</td>
<td>330 nm</td>
</tr>
<tr>
<td>Vitamin A (in fat)</td>
<td>322 nm</td>
<td>350-500 nm</td>
<td>387 nm, 440 nm</td>
</tr>
<tr>
<td>Pyridinoline (collagen)</td>
<td>380 nm</td>
<td>400-550 nm</td>
<td>440 nm, 460 nm</td>
</tr>
<tr>
<td>Riboflavin (vit B2)</td>
<td>380 nm</td>
<td>400-650 nm</td>
<td>530 nm (reduced) 475 nm (oxidized)</td>
</tr>
</tbody>
</table>

NIR methods

Bands of absorbance in the near-infrared region (800-2500 nm)

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1409 nm, 1460 nm, 1910 nm</td>
</tr>
<tr>
<td>Protein</td>
<td>1187 nm, 1690 nm, 2235 nm</td>
</tr>
<tr>
<td>Fat</td>
<td>1212 nm, 1722 nm, 2306 nm</td>
</tr>
</tbody>
</table>
Spectroscopic techniques are rapid and non destructive (require little or any sample preparation)

Spectra allow to predict qualitative (texture, tenderness, ..) and quantitative (quantify a component) parameters

NIR technique : useful for measuring constituents > 0.1% :
- water, protein, fat, collagen

Fluorescence technique : 100-10000 times more sensitive than other spectrophotometric techniques, allowing to quantify components present in micro-molar to nano-molar ranges
The development of predictive methods based on spectroscopic techniques requires:

- large databases with spectra and data from the reference method

- chemometric methods for data pre-processing, calibration modeling and transfer of calibration models

- chemometric methods allow development of reliable and stable calibration models for the prediction of the considered parameter

| Sensory analysis / Fluorescence spectroscopy (R) | 0.95 |
| Texturometer / Fluorescence spectroscopy (R) | 0.92 |
Summary

- The concept of quality and reference methods at the consumer end

- *Post-mortem* prediction of beef quality at the abattoir or by beef retailers

- Prediction of beef quality at the producer level (sensory traits, healthiness, traceability)
From the muscle tissue to meat quality

Up to 1/3 of tenderness variability can be explained.
Total collagen amount is low in *longissimus*. Taking into account technical and biological variability, you need to calculate the number of animals and of technical replications to detect any significant difference.

(Listrat & Hocquette, 2004)
Some results

With 1200 young bulls, variance explained by the animal effect

Intramuscular fat content (n=2): 93%
Collagen content (n=3): 61%
Muscle fibre area (n=2): 81%
Colour (n=5): 85%
Shear force (n=10): 28%
Tenderness (12 sensory assessors): 8-20%
Flavour (12 sensory assessors): 2-4%
Image analysis

Histology

Thick Frame

Complete frame

Magnetic Resonance Imaging

To draw the connective tissue frame

(Sifre-Mounier et al., 2006)
Ageing and tenderness

Important for beef

Toughness

Rigor mortis  Ageing

Basal Toughness (connective tissue)  14 days

Speed

Amplitude

Activity
Amount of protein (e.g.: ELISA)

Myofibres (proteases)

Characteristics of fibre types are important for ageing (not completely understood)
The potential benefits of genomics

The detection of new genes which are differentially expressed between “good” and “not good” beef

(Eggen & Hocquette, 2004)
Transcriptomics and Proteomics: Identification of markers of tenderness

\[ R^2 = 0.63 \]

Expression level of DNAJA1

Tenderness score

High tenderness

Low tenderness

(Bernard et al., 2006)

(Bouley et al., 2004)
Genetic markers (1/2)

Australia

GeneSTAR Marbling is a DNA-based diagnostic that tests for a major gene associated with marbling in beef cattle. It is believed there are a small number of genes that have a major effect on marbling.

CAPN1 (proteolysis), CAST (inhibitor), LOX (collagen synthesis): toughness

These tests have been validated in a limited number of breeds and breeding systems.

Review by Kühn et al., 2005. EAAP Publ. 112
SNP-DNA Profiling: Past and future (2/2)
technology

Manual procedure (high cost)

Automatic procedures and data analysis (low cost)
Safety: food contamination by bacteria, The chip from GeneScan

The NUTRI®Chip is a ready-to-use chip for the analysis of foodstuffs. It provides fast and sensitive detection of bacterial contaminations.
Animal product components and Nutritional properties (1/2)

♦ PROTEIN (fish, meat): 16 – 22% with a well balanced IAA content
  ◆ Highly digestible protein with high biological value

♦ MICRONUTRIENTS contribute to meet human needs
  • In beef, Vitamins B (B1, B2, B6, B12, niacin), minerals and trace-elements (zinc, heminic iron.....)

♦ LIPID: emphasis on fat content and on the positive role of n-3 PUFA and CLA
  ◆ reduce cardio vascular diseases (sudden cardiac death), inflammatory diseases, diabetes, cancer
  ◆ enhance brain development

♦ REQUIREMENTS
  • Accuracy, sensitivity, reproducibility, ...
The Metabolic Profiler™ is a concept to investigate metabolism in humans, animals, plants and cells based on expandable hardware and integrated software from sample preparation to metabolite identification, quantification and statistical evaluation of metabolite patterns (e.g.: amino acid profile, fatty acid profile, mycotoxins, …)

Dedicated, integrated system, with a combined NMR and MS approach for metabolic profiling
Traceability (1/2)

Ability to trace the history, application or location of an entity by means of recorded identifications.

- Traceability back to the origin
  - Geographical origin
  - Animal identity
  - Breed
  - Genetic

- Traceability of process
  - Production systems including feeding diets
  - Processing
  - Conservation processes
  - Adulteration of products
The next challenge

Necessity to combine different methods or different markers

Great variability of the response.

Development of analytical tools to quantify specific compounds in the product, or the animal tissues and fluids

**Plant biomarkers**
- Carotenoids, terpenes, flavonoids

**Metabolite markers**
- Fatty acid composition
- Volatile compounds

**Physical markers**
- H, O Isotopes: geographical origins (latitude, altitude)
- C, N Isotopes: alimentation

**New approaches**
- Near infrared spectroscopy
- Genomics

Traceability (2/2)
The Future of research on quality ...

- ... should improve the available methods
- ... should address statistical issues
- ... should take advantage of the huge scientific and technical progress (genomics, integrative biology, etc)
- ... should meet new consumer expectations (healthiness, safety, etc) and societal challenges (sustainability, etc)
“the properties of a product that contribute to and satisfy the needs of end-users”.

Quality is thus a social concept, i.e. a convergence between end-users expectations and product characteristics.

Taureau de Camargue

Natural Livestock practices

Culture & Tradition

Taste and Flavour
A great success: modeling beef tenderness (to be completed in other countries)

The next challenge: the introduction of genomic markers

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Cooking</th>
<th>Grade</th>
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</thead>
<tbody>
<tr>
<td>Hang (AT/TC/TS/TX)</td>
<td>Sex (M, F)</td>
<td>Est. % Bos Indicus</td>
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<tr>
<td>Grade</td>
<td>Cuts</td>
<td></td>
</tr>
<tr>
<td>AT</td>
<td>Tenderloin</td>
<td>TDR062</td>
</tr>
<tr>
<td>Cuts</td>
<td>Cube Roll</td>
<td>CUB045</td>
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<tr>
<td>AT</td>
<td>Striploin</td>
<td>STR045</td>
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<tr>
<td>Oyster Blade</td>
<td>OYS036</td>
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<tr>
<td>USDA Marbling</td>
<td>130</td>
<td></td>
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<tr>
<td>USDA Ossification</td>
<td>100</td>
<td></td>
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<tr>
<td>USDA Marbling</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>USDA Marbling</td>
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<tr>
<td>Days Aged (min 5)</td>
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<tr>
<td>Quarter Point Ribfat</td>
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<tr>
<td>Ultimate pH</td>
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<tr>
<td>AUSMEAT Meat Code</td>
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<td>Saleyard? (Y/N)</td>
<td></td>
<td></td>
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<tr>
<td>Wght/App. Mat.</td>
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</table>
The best method to improve beef consumption is Communication.
Thank you for your attention

For any question, send an E-mail to hocquet@clermont.inra.fr