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How cow characteristics and management influence the sensory properties of milk and cheese?

B Martin

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Co-workers:
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2INRA, Cheese Research Unit (URF), Aurillac, France

3INRA, Animal Product Quality, Theix, France
So far:
Many empirical observations but few experimental works

Context

Why?
To answer the questions of PDO cheese producers

*Link to “terroir”*

*Choice of specifications for milk production*

In France: 46 PDO dairy products, 10% of the milk (cow and goat) and 40 % for ewe milk

2/3 of the PDO cheeses originate from mountain areas
⇒ sustainability of farmers

Mountain: 25% of agricultural lands, 20% of the dairy farmers, 14% of the milk, higher production costs (+50 €/1000L)

Animal characteristics and feeding
⇒ sensory properties of dairy products

Comté  Cantal  Roquefort  Reblochon  St-Nectaire

2/3 of the PDO cheeses originate from mountain areas
⇒ sustainability of farmers

Mountain: 25% of agricultural lands, 20% of the dairy farmers, 14% of the milk, higher production costs (+50 €/1000L)
The INRA Auvergne facilities

INRA Marcenat
Experimental farm

INRA Aurillac
Cheese Research Unit
Pilot Dairy plant & Lab.

INRA Theix
Herbivore Research Unit
Animal Product Quality Unit
Laboratories
A focus on cattle milk and cheese sensory properties linked to:

Animal genetics

Animal feeding

Milk - Cheese
Sensory characteristics of Saint Nectaire cheeses according to the breed of cows

<table>
<thead>
<tr>
<th></th>
<th>Holstein</th>
<th>Montbéliarde</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat in dry, %</td>
<td>52,7</td>
<td>52,9</td>
</tr>
<tr>
<td>Yellow index</td>
<td>31,4</td>
<td>30,4</td>
</tr>
<tr>
<td>Sensory panel (/10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melting texture</td>
<td>3,0</td>
<td>** 4,2</td>
</tr>
<tr>
<td>Intense flavour</td>
<td>5,0</td>
<td>* 5,6</td>
</tr>
</tbody>
</table>

Results confirmed with Cantal cheeses

Martin et al., 2009

Verdier-Metz et al., 1995
Variant C of β-Cas from Tarentaise cows

Variant C of Cas-β

Specific structure of Cas-β

Slower breakdown of Cas-β leading to specific peptides

Large casein micelles, low Ca content

Less firm curd

Fat losses in the whey

FLAVOUR
pungent taste

YIELD
lower 12 to 15%

TEXTURE
less elastic

Delacroix-Buchet et Marie, 1995
Variant I of κ-Cas from Salers cows

‘Salers’ traditional system

Specific structure of κ-Cas

Slower coagulation

Milking with the calf

Low fat content of the milked milk

Specific microbial composition, low somatic cell count

Low Fat in Dry of the cheese

FLAVOUR
slower ripening
softer flavour

TEXTURE
more firm and granular
less melting

Guïadeur et al., 2011; Bianchi et al., 2014
A focus on cattle milk and cheese sensory properties linked to:

Animal genetics

Animal feeding

Milk - Cheese
Sensory properties of milk according to the nature of the forage

Raw milk

Pasture vs Hay (86%)  
Pasture vs Concentrate (65%) + Hay

More intense** and barn odour**

Results obtained by Triangle tests, in red light.  
Dubroeucq et al., 2002
Sensory properties of milk according to the nature of the forage

**Raw milk**

- **Pasture vs Hay (86%)**
  - * 48%

- **Pasture vs Concentrate (65%) + Hay**
  - ** 57%

- **Grass silage (85%) vs Maize silage (85%)**
  - * 47%

- **Grass silage (85%) vs Hay (85%)**
  - ** 53%

No off-flavours

Results obtained by Triangle tests, in red light. Dubroeucq et al., 2002

Grass silage and milk off-flavours:

- Milk can gain off-flavours ("feed" flavours) from poor-quality silages
- Off-flavours transmitted rapidly, both through respiratory and digestive routes
- Risk factors at farm level: - poor silage quality and poor air quality in the barn
  - feeding silage just before milking

Shipe et al., 1962; Urbach, 1990; Mounchili et al., 2004, 2005; Kalac, 2011
**Sensory properties of milk according to the nature of the forage**

**Raw milk**

- **Pasture vs Hay (86%)**
  - Results: 48%
  - Significance: *

- **Pasture vs Concentrate (65%) + Hay**
  - Results: 57%
  - Significance: ***

- **Grass silage (85%) vs Maize silage (85%)**
  - Results: 47%
  - Significance: *

- **Grass silage (85%) vs Hay (85%)**
  - Results: 53%
  - Significance: **

- **Hay (85%) vs Maize silage (85%)**
  - Results: 31%
  - Significance: ns

- **Hay (85%) vs Concentrate (65%) + Hay**
  - Results: 32%
  - Significance: ns

- **Monospecific past. vs Diversified past.**
  - Results: 35%
  - Significance: ns

- **Hay vs Hay + aromatic plants (5%)**
  - Results: 36%
  - Significance: ns

Results obtained by Triangle tests, in red light.
Dubroeucq et al., 2002 & Martin et al., unpublished
# Forage and cheese sensory properties

## General trends

<table>
<thead>
<tr>
<th></th>
<th>Maize silage</th>
<th>Hay</th>
<th>Grass Silage</th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow colour</td>
<td>–</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>→ β carotene in milk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm texture</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>→ Lower melting point of unsaturated fatty acids</td>
<td></td>
<td>→ Proteolysis</td>
<td></td>
</tr>
</tbody>
</table>

- Firm texture:
  - Maize silage: +
  - Hay: –
  - Grass Silage: –
  - Pasture: –

- Yellow colour:
  - Maize silage: –
  - Hay: +
  - Grass Silage: ++
  - Pasture: +++
Forage and cheese sensory properties

**General trends**

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</tr>
<tr>
<td>Flavour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversity / intensity</td>
<td>-</td>
<td>+/−</td>
<td>+/−</td>
<td>+/++</td>
</tr>
</tbody>
</table>

→ β carotene in milk

→ Lower melting point of unsaturated fatty acids

→ Proteolysis

→ ???

**Hypothesis**

Forages (diet x animal)

- microflora
- plant 2nd comp.
- protein
- fat
- urea, Mls
- enzymes
- fatty acids

Milk

- acidification
- draining
- Starters

Ripened Cheese

- fresh cheese
- ripening
- Odorous & sapide compounds
## Forage and cheese sensory properties

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<td>-</td>
<td>+/-</td>
<td>+/-</td>
<td>+/+++</td>
</tr>
<tr>
<td></td>
<td>→ ???</td>
<td></td>
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<td></td>
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</table>

Many interactions with the process...
Forage and cheese sensory properties interaction with pasteurisation

- Native microflora (or compounds altered by pasteurisation) play a key role in the effect of forages on cheese flavour.
- Milk microflora varies according to animal feeding.

Verdier-Metz et al., 2009

Link to terroir disrupted by pasteurisation?

Verdier-Metz et al., 2000, 2002; Martin et al., 2013
Botanical composition of forages and cheese sensory characteristics

On-farm conditions
► Cheese sensory properties are modified when the botanical composition of the pasture changes

Grasslands from lowland rich grasses and legumes
Intense taste and cabbage or pungent flavours

Abondance cheese
associations
Bugaud et al., 2001;
Martin et al 2005

Grasslands rich in a wide variety of highland dicot.

Experimental conditions
► the effect of the biodiversity of pastures on cheese flavour is weaker and varies during summer

Coppa et al., 2011

Bosset et al 1999, Buchin et al 1999,

Intense taste and cabbage or pungent flavours

Fruit, hazelnut and cooked milk flavours
Botanical composition of forages and sensory characteristics of Beaufort cheese

Comparison of cheeses made on 3 different plots of the alpine pasture

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Plot 1 2200 m</th>
<th>Plot 2 2050 m</th>
<th>Plot 3 2500 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Festuca rubra</td>
<td>38 %</td>
<td>47 %</td>
<td>30 %</td>
</tr>
<tr>
<td>Agrostis capilaris</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Nardus stricta</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

Aromatic species

- ++
- =
- -

Compounds issued from proteolysis
- (Aldehydes)
- (esters)

Cheeses
- Plot 1
- Plot 2
- Plot 3

Animal Od
- Intense Od
- Benzene derivatives

Animal Ar
- A intense
- Spicy
- Acid
- Salted
- Pungent

Martín et al., 2002

✓ indirect effect of terpenes on the activity of the microbial ecosystem of cheese?
Terpenes:

- Large family of compounds
- Originate from plants
- Odorous compounds when concentrated
- In forages, nature and composition of terpenes = f(botanical composition, phenological stage)
- Identified in milk and cheese
- Transferred rapidly from plants to milk

Cornu et al., 2002
Terpenes in grass and in cheeses
(Abondance cheese)

Terpenes composition in grass

Mountain diversified pasture

Pasture rich in Graminae

Terpenes composition in cheeses

Bugaud et al., 2001
Do terpenes explain the effect of the botanical composition of grasslands on cheese?

Mountain sward rich in aromatic plants

Conclusions
* no effect of terpenes on:
  - cheese microbial counts
  - cheese volatile compounds
* Direct influence of terpenes on cheese sensory properties with high concentrations

 Tambambé et al., 2008

Indirect influence of terpenes not validated
→ Addition of terpenes in milk ≠ plant ingestion?
→ Terpenes = markers of other plant secondary compounds?
Conclusions

Significant effects of cow characteristics and management on cheese sensory properties

*Confirm the empirical observations of the farmhouse cheesemakers*

Effects $<$ or $<<$ effects of cheesemaking process

*Good control of process is necessary to study the effect of breeds and diets on cheeses*

Interactions identified with different aspects of the process

*Some technologies are better suited than others to reveal the effect of breeds and diet*

We can only partly explain the effects

*Due to the presence in milk and cheeses of compounds directly transferred from diet or produced by animals or microbes*

Role of raw milk microflora? Interactions with substrate?
Conclusions

Objective references for cheesemakers (PDO, …)
- Refine the understanding of the ‘link to terroir’
- Develop appropriate specifications so that cheeses reflect the best the uniqueness and diversity of the terroir

Interest of grass (pasture from biodiverse grasslands) and local breeds for the sensory quality of cheese

*Interest to preserve the biodiversity (animal, plant species and microbes) for the cheese quality*

Before making decision, we have to consider:
- Other aspects of the quality (safety, nutrition, image...)
- Impacts on the sustainability of farmers (economy, environment and social)
Thank you for your attention
What is a PDO Product?

• Definition of PDO: « a product that originate from a territory and whose characteristics are linked mainly to the geographical environment including human and natural factors »

EU regulation n°510/2006

▷ « typicity » (specific characteristics) linked to terroir

• Definition of terroir: defined geographical area where a human community built during its history a collective know-how for production based on a system of interactions between physical, biological and human factors

▷ some conditions of milk production are linked to terroir

Source: Casabianca et al., 2011
Forage and cheese sensory properties interaction with cheese model

Pasture
Pasture
Pasture

Strong

Flavour

Soft Cheese (250 g)

Texture

Firm

White

Melting,

Yellow

→ higher relative abundance of surface flora, determinant for ripening process of small cheeses. Surface flora provided by starters (≠ animal diet).

Hay

Hard cheese (1.7 kg)

Swiss cheese (10 kg)

Verdier et al., 2009
Erosion in consumer confidence in dairy products

*Safety, environmental and nutritional issues*

Increasing demand about information concerning animal characteristics and management

*Positive image of local breeds and grass based diets*

Increasing demand for « terroir » products with high sensory quality

*Animal characteristics and management are part of the « terroir »*

**Link between animal characteristics and management and cheese sensory quality?**
The sensory characteristics of dairy products first depend on cheesemaking process (collective know-how)!

1 raw material = huge diversity of dairy products

The milk characteristics (chemical and microbiological quality) also play a major role when modifications of milk are restricted

In similar processing conditions, we observe great sensory differences:

Reblochon cheeses made with different milks

Martin et al., 1997
How can we explain the effect of the botanical composition of grasslands on cheese?

Terpenes from aromatic plants proposed to explain the effect of pasture botanical composition

* inhibitors of the production of volatile compounds by micro-organisms?

<table>
<thead>
<tr>
<th>Essential oil added in milk</th>
<th>0</th>
<th>+ 0.1 µg/L</th>
<th>+ 3 µg/L</th>
</tr>
</thead>
</table>

| Microbial counts | | | |
| Volatile Compounds (other than added) | | | |
| Sensory Properties (0-7) | | | |
| ‘Thymus’ Aroma | | | |

| Swiss cheese | | | |
| Hard Cheese | | | |

Marginal modifications

Terpenes = markers of other plant secondary compounds

Buchin et al., 2006
Tornambé et al., 2008
Associations between Abondance cheese sensory properties and pasture characteristics

Axis 1 & 2 of a Principal Component Analysis.

Pasture characteristics: active variables
Cheese characteristics: illustrative variables

Bugaud et al., 2001