Impact of pasture feeding on the sensory aspects of milk and products

Food Quality & Sensory Science
Teagasc Food Research Centre
Moorepark
Fermoy
Co. Cork
Ireland P61 C996

kieran.kilcawley@teagasc.ie
Tel: 00 353 (0)25 42245
Mob: 087 9916157
ResearchGate
LinkedIn
Background

- Need to get information about potential sensory aspects of milk and dairy products produced from pasture based as opposed to TMR feeding systems
  - Irish context

- Presentation divided into two parts
  - Pasture (grass & grass/clover) vs. TMR feeding systems in relation to milk
  - Cross cultural sensory perception of Irish skim milk powder produced from these same feeding systems in Ireland, China & the USA (key markets)
Introduction

• Key Questions

1. Is the sensory profile of milk produced on pasture based feeding systems (grass or grass/clover) different to TMR feeding systems?

2. Are volatile compounds derived from these different feeding systems influencing sensory perception?

3. If so are these sensory differences perceived in same way by consumers in key markets for Irish dairy products? Ireland, USA & China

4. Are there volatile compounds in milk derived from pasture that could be used as potential biomarkers for authentication / traceability purposes?
Sensory and Flavour Chemistry

- **Sensory Analysis**
  - Sensory analysis tells you what a product tastes like, and if it's liked or disliked, but you have zero information on the compounds that influence sensory perception

- **Flavour Chemistry**
  - Flavour chemistry identifies the compounds present in the sample and their concentration/abundance levels

- **Sensometrics**
  - Merging data from both techniques can determine the key aroma active compounds influencing sensory perception
Sensory Tests

- **Consumer Analysis**
  - 100 Untrained panellists – idea is to represent consumer
  - Attributes evaluated linked to liking of appearance, flavour, texture and acceptability (hedonic)

- **Descriptive Sensory Analysis**
  - Trained assessors (5-10 assessors) work like calibrated instruments
  - Identify those attributes that best describe the product
  - Evaluate attributes in a structured scale in a very controlled environment.

- **Ranked Descriptive Analysis (RDA)**
  - 10 - 25 assessors familiar with the product use a smaller set of pre-determined attributes (based on product type), including hedonic attributes
  - Cheaper and faster combination of consumer and descriptive analysis
Flavour Chemistry Research

• Flavour
  • Comprised of taste and aroma (ratio 1:4)
  • Volatile aromatic compounds have a greater role in flavour perception
  • Volatile compounds can reach olfactory receptors by two ways

Directly by **Orthonasal Detection**: Odour is best reserved for the smell of food (before it is put into the mouth)

Indirectly by **Retronasal detection** via the throat: Aroma is the retronasal smell of food in the mouth
Flavour Chemistry Research

• Volatile Analysis 4 stages

Sample → Extraction / Concentration → GCMS → Data Processing

- Sulfur dioxide
- Acetone
- Acetic acid
- n-Hexane
- Hydroxyacetone
- Heptan-2-one
- Hexanoic acid
- Phenol
- Octanal
- Acetophenone
- Nonan-2-one
- Nonanal
- Octanoic acid
- Decanal
- 2,4-Di-tert-butylphenol
- 2,6-Tetrahydrofuran
- n-Decanoic acid
- 2,3-Dihydroxypropyl decanoate
- δ-Octalactone
- δ-Decalactone
- δ-Tetradecalactone
- cis-Hexadec-11-enolic acid
- δ-Tetradecalactone
- 3,7-Nonanediol
- Myristic acid
- Palmitic acid
- 2-Nonanone
- γ-Decalactone
- 3-Hydroxybutanoic acid
- Dodecanoic acid
- Palmitoleic acid
- Oleic acid
- Octadecanoic acid
- 2-Palmitoyl glycerol
- Myristic acid
- 3-Oleoyl glycerol
Volutiles in Milk from feeding systems

- **Direct Transfer**
  - Ingestion – Absorption – Blood – Mammary Gland
  - Inhalation – Lungs – Blood – Mammary Gland
- **Indirect Transfer**
  - Ingestion – Rumen Digestion/Lipid Oxidation – Blood – Mammary Gland
Basic Experimental Design

- 54 Friesian cows split into three groups on three separate feeding systems

**Grass-only**
- Perennial ryegrass

**Grass-Clover**
- Perennial ryegrass with White clover: *Trifolium repenes* L.

**TMR**
- Grass, maize silage, soya, molasses, concs

- Raw & Pasteurised Milk
- Cheddar cheese, butter and skim milk powder
- Focus for this presentation is on Milk and Skim Milk Powder
PART 1
Milk
Flavour Chemistry Results Milk

Volatile Chemical Classes in Milk from different feeding systems

- Some correlation between volatiles in the forage and milk
- **TMR** quite different volatile profile from **grass** and **grass/clover**.
  - **↑** Ketones, terpenes
  - **↓** Hydrocarbons
- Seasonality effect
- Pasteurisation effect
Sensory Results Milk – Irish Consumers

Average hedonic results over the season

- Liking of appearance
- Liking of aroma
- Liking of flavour
- Liking of texture
- Overall acceptability

Grass
Clover
TMR
RDA Sensory Results Milk

- **RDA Sensory Testing**
  - Irish panels found 3 significant sensory differences in milks from the three feeding systems from 18 attributes evaluated.
Texture Perception

- The viscosity perception of the grass milk was higher (P<0.05) than the other milks

- This maybe due to fatty acid profile but could also be due to differences in compositional parameters
  - Fatty acid profile
  - Fat level higher in milk from grass feeding systems
• Colour
  • β-carotene levels (mg/kg) in milk were in the order of grass (0.34), grass/clover (0.26) and TMR (0.13) on average over the season

• β-carotene levels impacted on milk color in terms of b* value and sensory analysis (P<0.05)
  • Grass b* (16.057)
  • Grass/clover b* (15.852)
  • TMR b* (9.68)
Barnyard Aroma

- Highest in grass clover and lowest in TMR milk
  - Grass Clover > Grass > TMR

Correlation

- $P$-cresol is characterized as having a barnyard or cowy aroma and abundance correlated with sensory attribute scores ($P<0.05$)

- Derived from rumen metabolism of $\beta$-carotene
p-Cresol

- Abundance of p-cresol in these milks was low
  - Highly odor active (~4 ppb), fat soluble
  - Potential biomarker for dairy products derived from pasture based systems
- Levels did not correspond with β-carotene levels
  - Source rumen metabolism of β-carotene
  - Also rumen metabolism of aromatic amino acids (more digestible protein in grass and grass/clover than TMR feeding systems)
- Why were levels highest in milk from grass/clover?
  - Metabolism of isoflavone (formononetin) in the rumen is a factor – high content in clover, none in TMR
Summary of Milk Results

• Volatile profile
  • Significantly impacted by pasteurization
  • Significantly impacted by feeding system
  • Influenced by protein/carbohydrate ratio and fat content of the feeding system, presence of $\beta$-carotene and isoflavones
    • Evidence of direct and indirect transfer from feed to milk

• Sensory
  • Fatty acid profile likely impacted texture perception
  • $\beta$-carotene concentration influenced colour
  • P-cresol is responsible for barnyard/cowy aroma mainly associated with pasture feeding milk

• Biomarkers for pasture based dairy products
  • $\beta$-carotene, toluene, p-cresol and dimethyl sulfone
PART 2
Cross Cultural Sensory Study Skim Milk Powder
Cross Cultural Sensory Analysis

- Skim milk powder (SMP) produced from milk from pasture (grass & grass/clover) and TMR feeding systems

- Sensory Analysis (Ireland, China & USA)
  - Consumer Analysis
  - Ranked Descriptive Analysis (RDA)
  - Descriptive Sensory Analysis

- Flavour Chemistry
  - HS-SPME GCMS
  - HS-SPME ARROW GCxGC TOF (3-Dimensional)
Cross Cultural Sensory Analysis

- Skim Milk Powder (SMP)
  - Consumer studies
  - University College Cork
  - North Carolina University – Sensory Centre
  - Fujian Agricultural & Forestry University
  - Fixed Ballot at each site in duplicate
  - Sample prepared fresh (10% w/v) in deionised water
Cross Cultural Sensory Analysis

Consumer Analysis SMP – Ireland, China & USA

• **Summary**
  - USA consumers preferred SMP derived from TMR
  - Irish consumers preferred SMP from either grass or grass/clover
  - Chinese consumers perceived SMP samples differently to USA and Irish consumers.
  - All consumers preferred the appearance of SMP from TMR
Cross Cultural Sensory Analysis

- Volatile abundance in SMP from different feeding systems
- HS-SPME GCMS

Hierarchical cluster analysis

Variable Importance in Projection

VIP scores

Acetone
2-Butanone
2-Undecanone
Ethanol
Toluene
Hexanal
delta caprolactone
Pentanal
Heptanal
Dimethyl sulfone
3-Carene
1-Butanol
1-Pentanol
Benzyl alcohol
α-Pinene
Acetic acid
2-ethyl-1-Hexanol
Propanoic acid
Butanoic acid
Phenol
Decanal
Nonanal
2-Pentylfuran
Benzaldehyde
1-Hydroxy-2-Propanone
Acetoin

Acetoin
Acetic acid
Heptanal
2-Undecanone
1-Hydroxy-2-Propanone
Dimethyl sulfone
Pentanal
2-Pentylfuran
Nonanal
Propanoic acid

High
Low

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Cross Cultural Sensory Analysis

- Descriptive Analysis of SMP by USA panel only

- Summary
  - TMR SMP more sweet aromatic
  - Grass SMP greater salty taste
  - Clover/Grass SMP more cardboard, grassy/hay
  - Both Grass & Grass/Clover SMP had a Barny aftertaste that was absent in the TMR SMP samples
USA trained descriptive panel could discern a barny aftertaste in SMP derived from grass and grass/clover feeding systems but in SMP derived from TMR

- Likely to be p-cresol (barnyard/cowy aroma!)

- Lots of flavour chemistry analysis
  - Initially we could not find it but eventually managed to identify p-cresol in the SMP derived from grass feeding systems (not present in TMR SMP)
  - Even though levels are very low (low ppb) USA panels can still pick this aroma in SMP
  - Likely to be more evident in WMP as it’s a fat soluble volatile
Summary of CCS Results on SMP

- Differences in volatiles due to diet are carried into SMP from milk.
- Products of rumen metabolism (carotenoids, flavonoids, protein/carbohydrate ratio) and lipid content create most of the volatile compounds.
- Cultural differences in the perception of Irish SMP exist between Irish, USA and Chinese consumers.
- Sensory perception very much linked to familiarity with products from specific feeding systems.
  - USA prefer TMR derived SMP.
  - Irish least preferred SMP from TMR.
  - Chinese less discerning, but can distinguish TMR SMP.
  - USA trained panellists can discern a barny aftertaste in pasture derived SMP. Negative association (now been loosely classified as organic dairy flavour!)
1. Is the sensory profile of milk produced on grass (grass or grass/clover) different to TMR feeding systems? Yes
2. Are volatile compounds derived from these feeding systems influencing sensory perception? Yes
3. If so are these sensory differences perceived in same way by consumers in key markets for Irish dairy products (Ireland, USA & China)? No
4. Is there specific volatile compounds in milk derived from pasture that could be used as potential biomarkers for authentication / traceability purposes? Yes
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- North Carolina State University (MaryAnne Drake)
- University College Cork (Maurice O’Sullivan & Joe Kerry)
- Queens University Belfast (Stephan McAuliffe)
Impact of different forage on the volatile and sensory properties of brown milk

Introduction

For the study, we investigated the impact on volatile compounds by accompanying sensory properties of brown milk samples. The study involved the analysis of volatile compounds and sensory properties of brown milk samples collected from different forage types. The study was conducted over a period of 6 months, during which milk samples were collected from cows grazing on different forage types. The volatile compounds were analyzed using gas chromatography-mass spectrometry (GC-MS), and the sensory properties were assessed using descriptive analysis.

Results

The analysis of volatile compounds showed that the type of forage significantly affected the composition of volatile compounds in brown milk. The results indicated that the forage type influenced the production of specific volatile compounds, such as aldehydes, ketones, and esters. The sensory analysis showed that the forage type had a significant impact on the sensory properties of brown milk, with differences observed in the milk's aroma, taste, and texture.

Discussion

The results of this study highlight the importance of forage type in determining the volatile and sensory properties of brown milk. The findings suggest that different forage types can influence the production of specific volatile compounds and, consequently, the sensory properties of brown milk. Further research is needed to elucidate the mechanisms underlying these effects and to explore the potential implications for milk production and quality.
• **β-carotene Metabolism**
  - β-carotene is degraded by rumen bacteria to a number of volatile compounds, one of the most abundant is **Toluene**
  - The abundance of toluene corresponds to the concentration of β-carotene in milk, also noted for Butter and Cheddar +
  - Both β-carotene and toluene are potential biomarkers for pasture based dairy products
    - Neither are exclusively present in pasture derived dairy products, but are present at higher concentrations
    - Toluene is described as **nutty, bitter, almond, sweet, pungent, caramel, fruity, plastic & rancid** aroma, but is not very odour active. Thus we did not find any correlation between sensory characteristics and toluene concentration in milk, cheese or butter
Flavour Chemistry Research

- Two important factors that govern the impact of volatile compounds on sensory perception:
  - Concentration and odour activity

- The majority of volatile compounds do not interact with the human sensory system as the concentrations are too low
- Sensory active compounds evoke a sensory signal and may be perceived but in a mixture of sensory active compounds most do not influence sensory perception
- Those sensory active compounds that do influence sensory perception are known as key character compounds (3-5% of all the volatiles present)
Sensory & Flavour Chemistry - Milk

• Sorptive Extraction using GCxGC TOFMS
Terpenes

- Implicated as influencing the sensory properties of milk and dairy products from forage
  - Low diversity and abundance in monocultures (rye-grass)
    - Thus little transfer into milk
  - We did not find any correlation with sensory perception
  - Odor activity of terpenes are low
  - Likely have an impact in milk (possibly cheese) derived from wild natural pastures (Alpine areas)
    - Dicotyledones typically contain more terpenes than monocotyledons
  - Can be biosynthesized and bioconverted (poor biomarkers)
    - During ensiling, in the rumen and possibly in cheese ripening
Sensory & Flavour Chemistry - Milk

- Proteins
  - Increased available protein for rumen metabolism from pasture based forage \textit{vrs} conserved forage TMR
  - Branched & Aromatic amino acids
    » We did not any correlation with volatiles in milk
  - Sulphur Compounds derived from methionine
    » \textbf{Dimethyl sulfone} higher in grass and grass-clover milk than TMR
    » Other studies have also found the same
    » From the oxidation of dimethyl-disulfide
    » High odor activity –\textit{sulfurous, burnt, hot milk}
    » We did not find any correlation with sensory perception
Profiling Milk from Grass

Effect of different forage types on the volatile and sensory properties of bovine milk

Hope Faulkner,† Tom F. O'Callaghan,∥ Stephen McAuliffe,∥∥ Deirdre Hennessy,∥∥∥ Catherine Stanton,∥
Maurice G. O'Sullivan,† Joseph P. Kerry,† and Kieran N. Kilcawley∥
†Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork, P61 C996, Ireland
∥School of Food and Nutritional Sciences, University College Cork, T12 YT20, Ireland
∥∥Animal & Grassland Research and Innovation Centre, Teagasc Moorepark, Fermoy, Co. Cork, P61 C996, Ireland
∥∥∥School of Biological Sciences, Queen's University, Belfast, BT17 1NN, United Kingdom

Review
Factors Influencing the Flavour of Bovine Milk and Cheese from Grass Based versus Non-Grass Based Milk Production Systems

Kieran N. Kilcawley ∥∥∥∥, Hope Faulkner ∥∥∥∥, Holly J. Clarke ∥∥∥∥, Maurice G. O’Sullivan ∥∥∥∥ and Joseph P. Kerry ∥∥∥∥
∥∥∥∥ Teagasc Food Research Moorepark, Fermoy, Co., P61 P996 Cork, Ireland; hopefaulkner@hotmail.co.uk (H.F.);
∥∥∥∥ Holly.clarke@teagasc.ie (H.J.C.)
∥∥∥∥ Department of Nutritional Sciences, University College Cork, T12 R229 Cork, Ireland;
∥∥∥∥ maurice.osullivan@ucc.ie (M.G.S.); joe.kerry@ucc.ie (J.P.K.)
∥∥∥∥ ∥∥∥∥ Correspondence: Kieran.kilcawley@teagasc.ie; Tel.: +353-25-42245

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Assessors found significant differences for some specific attributes between these SMP samples based on diet. Both the CLV and GRS SMP samples had a Barny aftertaste that was absent in the TMR samples. The GRS and CLV SMP samples scored highest for grassy/hay and the GRS SMP also scored highest for Salty taste. The CLV SMP sample had...