



Using a Chemometric Approach to determine characteristics influencing consumer perception in Cheddar cheese

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Introduction – Cheddar Cheese



- Cheddar is the most popular cheese in the world

- UK, Ireland

- Cheddar accounts for 16% of total cheese production in Ireland

- Total Irish production is 1.2 million tonnes

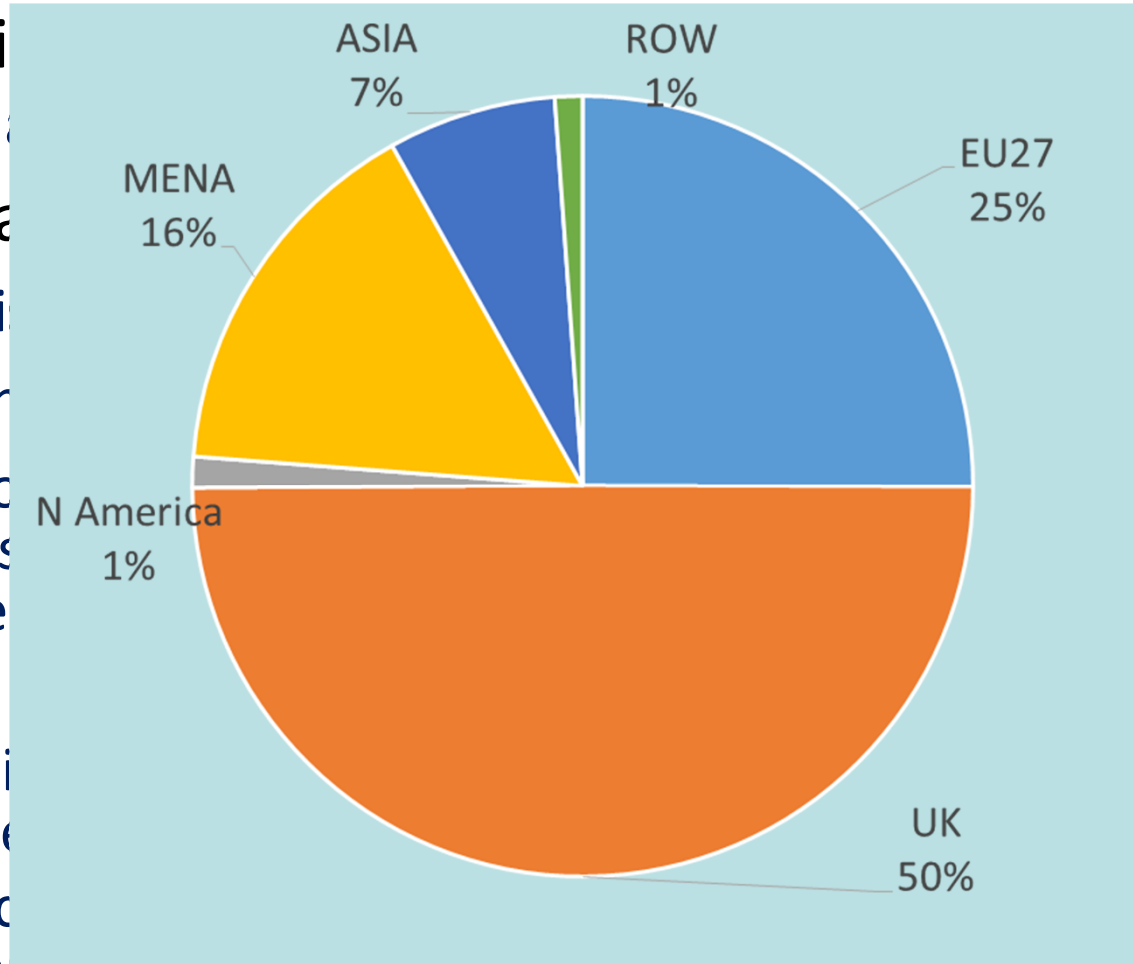
- Total Cheddar production is 192,000 tonnes

- UK accounts for 50% of total Cheddar production, which equates to 96,000 tonnes

- Brexit

- Tariffs likely to increase

- Currency fluctuations could impact on this market



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Introduction – Cheddar Cheese



- Cheddar is a Semi-hard cheese
 - Standard of Identify;
 - Max moisture of 39% (w/v) & a min Fat in Dry Matter of 50% (w/v)
 - Relatively uncompleted cheese to produce
 - Available as White or Red (vegetable colour added) from 2 months to >18 months
 - Mild, medium, mature and vintage
 - The reactions that produce Cheddar flavour are governed by many factors & the interaction of these factors! – Its complex
 - Milk quality, rennet, added bacterial cultures (wild cultures), production parameters, composition and ripening regimes



Project



- Background
 - Cheddar currently graded (selected) by individuals (production or retailers) for specific markets based on their own previous experience
 - The approach mainly looks for a lack of defects rather than positive attributes
 - The difficulty from a scientific viewpoint is that it is arbitrary and subjective



Project



- Objective
 - Preference mapping refers to a category of statistical methods used to relate consumer acceptance with a products characteristics
 - To utilize a Chemometric approach to link graded cheeses with sensory, and a in-depth analytical data to determine if we can find markers for mild, mature and vintage Cheddar cheese
 - We obtained 8 cheeses (24kg) cheeses that were selected by a grader as mild, medium and vintage for distinct markets



Analysis



- Compositional (pH, moisture, salt, fat, protein) & water activity
- Minerals (Na, P, K, Cu, Zn, Se, Mo & Mg)
- Carbohydrates (galactose & lactose)
- Organic acids (D- & L- Lactate),
- Biogenic amines (Cadaverine & histamine)
- β -carotene
- Biochemical analysis (free amino acids, free fatty acids, and peptides)
- Microbiology (starter, non-starter and ecoli)
- Texture (hardness, fracture stress, fracture strain, springiness, adhesiveness, cohesiveness, gumminess, chewiness & resilience)
- Colour: L*(lighter & darker), a*(red & green) & b*(yellow & blue)
- Sensory (Ranked Descriptive & Hedonics)

Results

Composition:

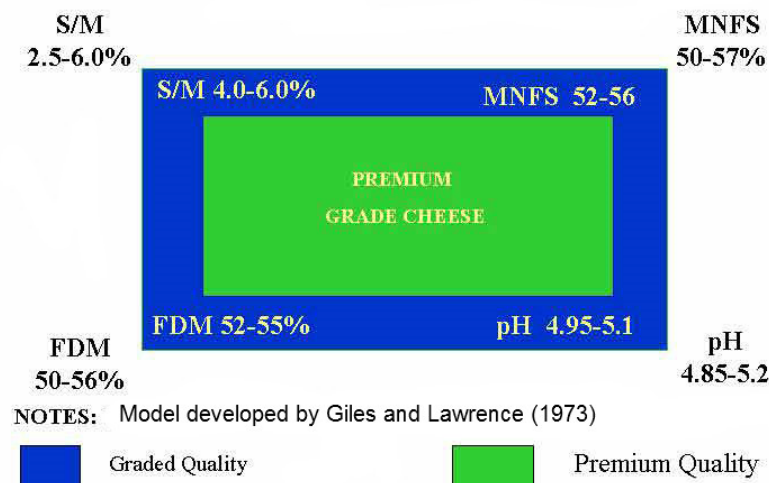
- pH out of spec for 2 mature & 1 mild
- S/M out spec of 1 mature
- MNFS out of spec for 1 vintage
- FDM out for 2 matures and 2 milds
- Moisture, fat, pH & Aw ($p < 0.001$)
 - In general moisture, fat, pH & Aw are higher in younger cheese

Minerals:

- Na, P, K, Cu, Zn, Se, Mo ($p < 0.001$), Mg ($p < 0.05$)
 - Na, P, K, Ca, Zn & Se (no pattern)
 - Copper and molybdenum higher in young cheese



Figure 1. RELATIONSHIP BETWEEN CHEDDAR CHEESE COMPOSITION AND GRADE QUALITY



Results



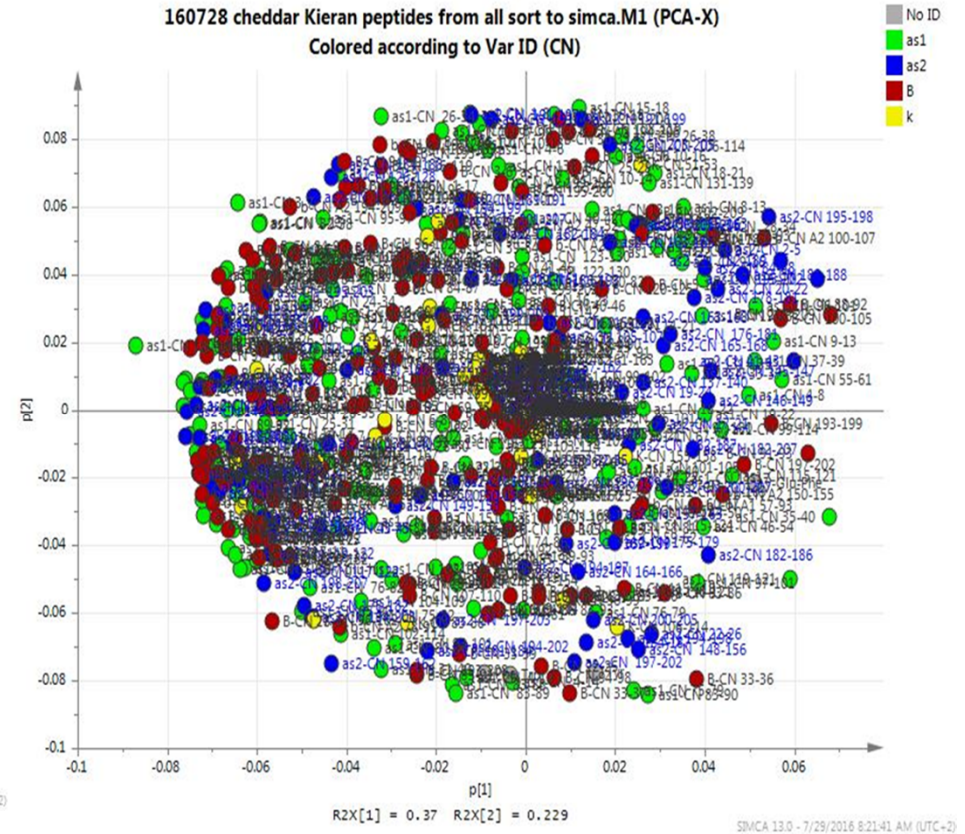
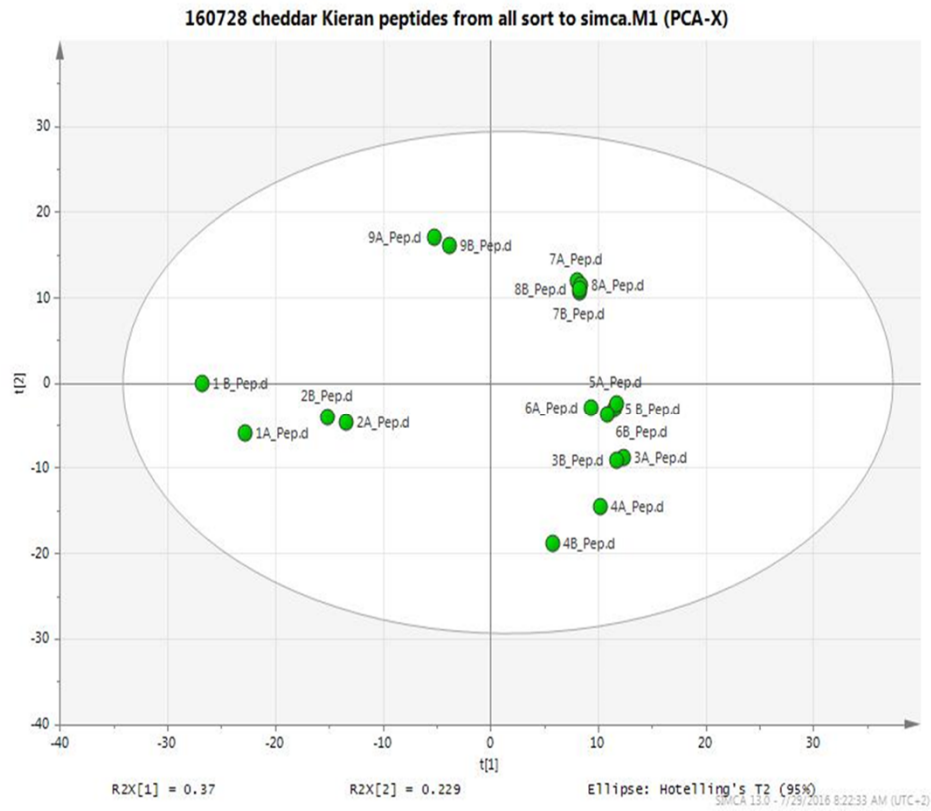
- Organic Acids:
 - D & L Lactate (no significance)
- Amines:
 - Levels low Cadaverine, histamine (not significant) slight increase with age
- Microbiology:
 - Lactococci, Streptococci, NSLAB & Thermophilic Lactobacilli ($p > 0.001$)
 - No E.coli present
 - Lactococci, Streptococci & NSLAB – No pattern
 - Thermophilic lactobacilli – vint>mat>mild
- Carbohydrates:
 - Galactose, lactose ($p < 0.05$)
 - Still some lactose in young cheese, Galactose also decreases with aging
- Free Fatty Acids (lipolysis)
 - Total range 922 – 1513 ppm
 - Mixed levels
 - Vint @ 1258ppm, Mild @ 1401ppm
 - C4, C12, C14, C18, C18:1 and total ($p > 0.001$)
 - C10, C16, C18:3 ($p > 0.05$)
 - No pattern

Results



- Casein fractions: Indication of primary proteolysis
 - p-k-cn ($p>0.05$), α -s1-cn, α -s2-cn ($p>0.001$) & β -cn ($p>0.01$)
 - α -s1-1 (not significant)
 - p-k-cn – highest Vint
 - α -s2-cn & β -cn - vint>mat>mild
 - α -s1-1 – mild>mat>vint
- Free Amino Acids (Secondary proteolysis)
 - All free amino acids ($p>0.001$)
 - Most highest in mature, lowest in mild (intermediate for vintage)
 - Cysteine - highest in vintage
 - Arginine – highest in Mild

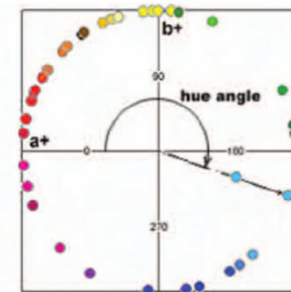
- Peptide Profiles



Results



- Texture:
 - Hardness, fracture stress, fracture strain, springiness, adhesiveness, cohesiveness, gumminess, chewiness and resilience ($p > 0.001$)
 - Fracture stress, fracture strain, adhesiveness, chewiness (no pattern)
 - Hardness, springiness higher in vintage cheese
 - Cohesiveness, gumminess & resilience Mild > Mat > Vint
- Colour:
 - L^* (lighter & darker), a^* (red & green) & b^* (yellow & blue) ($p > 0.001$)
 - b^* no pattern
 - L^* , a^* > Vintage is lighter and redder
 - (may reflect lower pH)

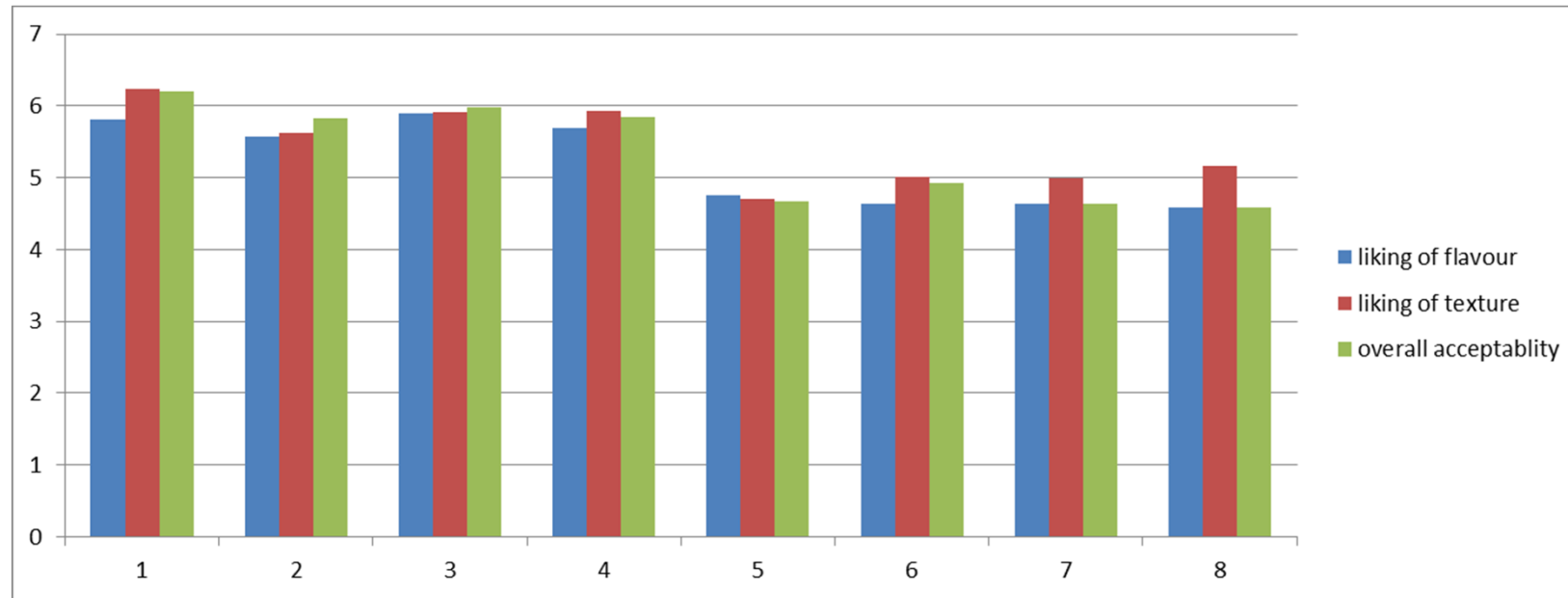


Results



- Sensory Hedonics:

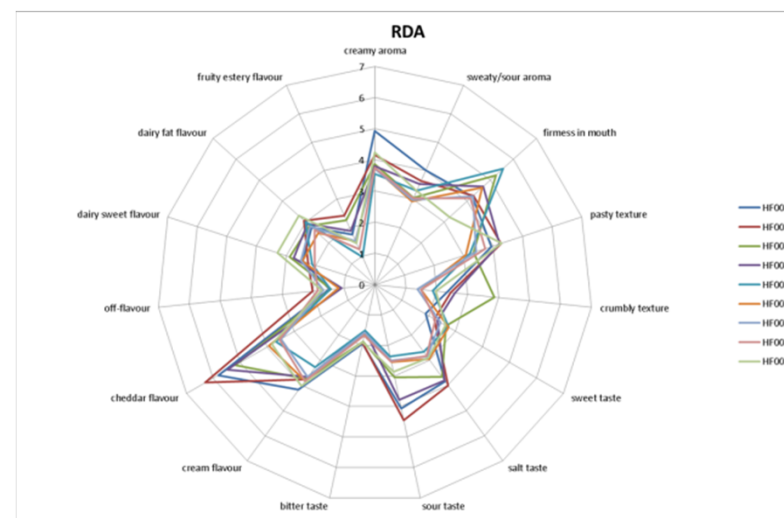
- Liking of appearance & liking of aroma (no statistical difference)
- Liking of flavour, liking of texture, overall acceptability ($p > 0.001$)
 - Vint>mat>mild



Results

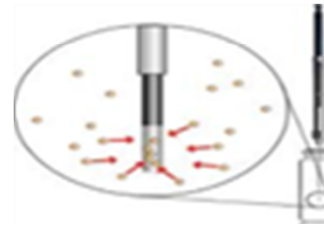
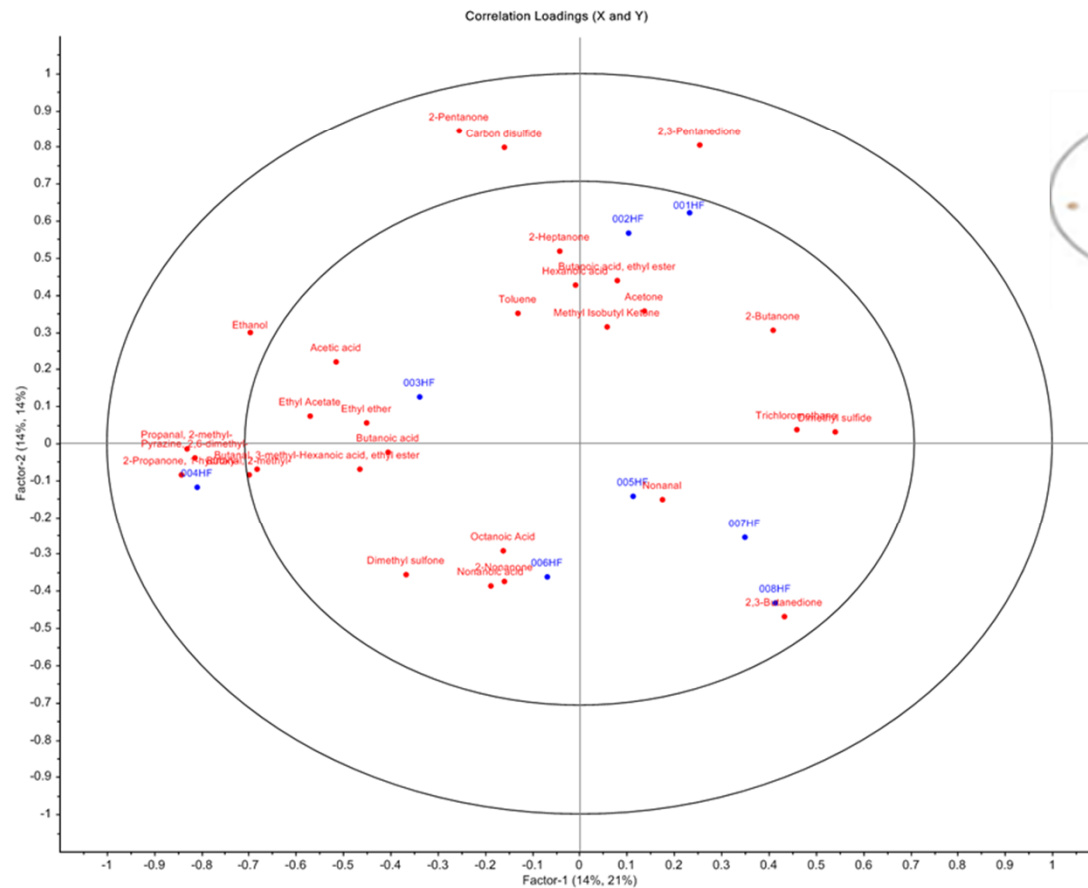


- Ranked Descriptive Analysis:
 - Cream aroma, sweet/sour aroma, pasty texture, sweet taste, bitter taste, cream flavour, off-flavour, dairy sweet flavour, dairy fat flavour – no statistical difference
 - Firmness in mouth, crumbly texture, salt taste, sour taste, cheddar flavour ($p > 0.001$),
 - Colour and fruity estery flavour ($p > 0.05$)
 - Salt, sour & cheddar flavour highest in vint
 - Crumbly texture lowest mild
 - Colour highest in mild,
 - Firmness & fruity - no pattern



Results

- Volatiles HS-SPME, Hi-Sorb and TD by GCMS

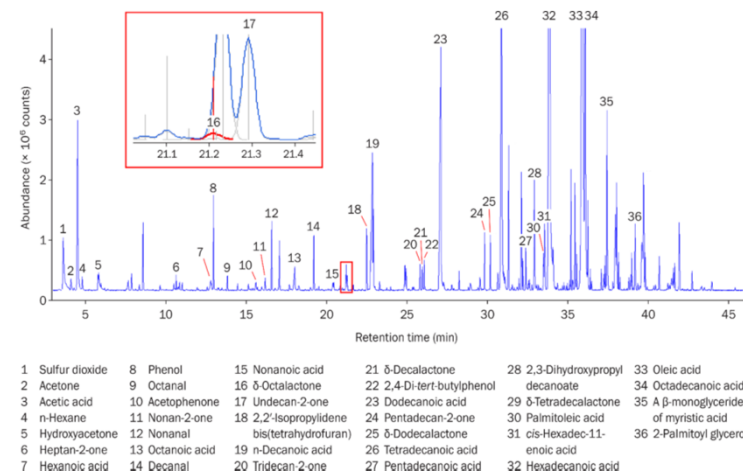
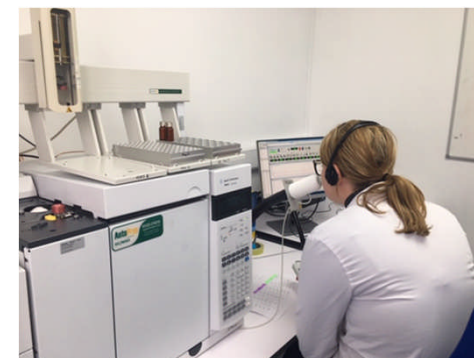




Results



- Gas Chromatography Olfactometry:
 - Trained panelists smell individual peaks (volatile compounds)
 - Method to discern which volatiles are odour active or those that are actually contributing to aroma (flavour) perception.
 - Odour activity of the volatile compounds and its relative concentration
 - ~3-5% of volatiles are odour active



Results



•Key Volatiles in Mild Cheddar Cheese

No	Volatile Compound	Aroma	Source	OT (ppm)
	Aldehydes			
1	3-Methyl butanal	Malty, cocoa	Amino acids	0.012
2	Benzaldehyde	Bitter, almond, sweet cherry	Amino acids	0.003
3	Nonanal	Citrus, green, fatty, floral	Lipid oxidation	0.001
4	2-Methyl butanal	Cocoa, coffee, malty, almond	Amino acids	0.0009
	Acids			
5	Butanoic acid	Rancid cheese, sharp	Lipid hydrolysis	1.274
6	Acetic acid	Vinegar, sour, pungent	Carbohydrate, amino acids	22
	Ketones			
7	2,3-Butanedione	Buttery	Carbohydrate, citrate	0.005
8	Acetone	Chemical, pungent	Carbohydrate	<500
9	2-Nonanone	Fruity, musty, rose, tea-like	Lipid oxidation	0.02
10	1-Octen-3-one	Mushroom	Lipid oxidation	0.01
	Sulphur			
11	Methional	Boiled baked potato	Amino acids	0.0002
12	Dimethyl sulphide	Cabbage, strong onion	Amino acids	0.00016
13	Trimethyl sulphide	Ripe cheese, garlic	Amino acids	0.00001
	Esters			
14	Ethyl butanoate	Pineapple, banana, melon	Ethanol & Butanoic acid	0.001
15	Ethyl octanoate	Apricot, fruity, fatty, floral	Ethanol & Octanoic acid	0.07
16	Ethyl hexanoate	Pineapple, banana, fruity	Ethanol & Hexanoic acid	0.001
	Alcohols			
	Other			
17	Trichloromethane	Hay	Water, feed	0.1
18	3-Carene	Sweet, turpentine	Feed	?

Results

•Key Volatiles in Mature Cheddar Cheese



No	Volatile Compound	Aroma	Source	OT (ppm)
	Aldehydes			
1	3-Methyl butanal	Malty, cocoa	Amino acids	0.012
2	2-Methyl propanal	Malty, cocoa, green	Amino acids	0.0007
3	Benzaldehyde	Bitter, almond, sweet cherry	Amino acids	0.003
4	Nonanal	Citrus, green, fatty, floral	Lipid oxidation	0.001
5	Heptanal	Fatty, green, woody, fruity	Lipid oxidation	0.003
6	2-Methyl butanal	Cocoa, coffee, malty, almond	Amino acids	0.0009
7	Butanal	Pungent, malty, green		0.018
	Acids			
8	Butanoic acid	Rancid cheese, sharp	Lipid hydrolysis	1.274
9	Hexanoic acid	Cheesey, goaty, sharp	Lipid hydrolysis	0.036
10	Acetic acid	Vinegar, sour, pungent	Carbohydrate, amino acids	22
	Ketones			
11	1-Hydroxy-2-propanone	Sweet, green, burnt, caramellic	Amino acids	?
12	2-Heptanone	Blue cheese, fruity, sweet	Lipid oxidation	0.009
13	1-Octen-3-one	Mushroom	Lipid oxidation	0.01
	Sulphur			
14	Carbon Disulphide	Sweet	Amino acids	3
15	Methional	Boiled baked potato	Amino acids	0.0002
	Esters			
16	Ethyl acetate	Solvent, fruity	Ethanol & Acetic acid	0.005
17	Ethyl butanoate	Pineapple, banana, melon	Ethanol & Butanoic acid	0.001
18	Ethyl octanoate	Apricot, fruity, fatty, floral	Ethanol & Octanoic acid	0.07
19	Ethyl hexanoate	Pineapple, banana, fruity	Ethanol & Hexanoic acid	0.001
	Alcohols			
20	Ethanol	Alcoholic	Carbohydrate	200
21	Heptanol	Fatty, sweet, green	Lipid oxidation	0.52
22	1-Pentanol	Green, fusel oil, woody	Lipid oxidation	0.73
	Other			
23	Toluene	Nutty, bitter, almond	Feed & amino acid	>500
24	2,6-Dimethyl-pyrazine	Nutty, chocolate, cocoa	Maillard (metabolism)	3100

Results

•Key Volatiles in Vintage Cheddar Cheese



No	Volatile Compound	Aroma	Source	OT (ppm)
Aldehydes				
1	3-Methyl butanal	Malty, cocoa	Amino acids	0.012
2	2-Methyl propanal	Malty, cocoa, green	Amino acids	0.0007
3	Benzaldehyde	Bitter, almond oil, sweet cherry	Amino acids	0.003
4	Nonanal	Citrus, green, fatty, floral	Lipid oxidation	0.001
5	Heptanal	Fatty, green, woody, fruity	Lipid oxidation	0.003
Acids				
6	Butanoic acid	Rancid cheese, sharp	Lipid hydrolysis	1.274
7	Hexanoic acid	Cheesy, goaty, sharp	Lipid hydrolysis	0.036
8	Octanoic acid	Cheesy, sweaty	Lipid hydrolysis	1.4
Ketones				
9	2,3-Pentandione	Pungent, sweet, caramel, buttery	Amino acids	?
10	Acetone	Chemical, pungent	Carbohydrate	<500
11	2-Pentanone	Floral, fruity, wine, chemical	Lipid oxidation	2.3
12	2-Butanone	Solvent	Lipid oxidation	50
13	2-Nonanone	Fruity, musty, rose, tea-like	Lipid oxidation	0.02
14	1-Octen-3-one	Mushroom		0.01
Sulphur				
15	Carbon Disulphide	Sweet	Amino acids	3
16	Methional	Boiled baked potato	Amino acids	0.0002
Esters				
17	Ethyl acetate	Solvent, fruity	Ethanol & acetic acid	0.005
18	Ethyl butanoate	Pineapple, banana, melon	Ethanol & butanoic acid	0.001
19	Ethyl octanoate	Apricot, fruity, fatty, floral	Ethanol & Octanoic acid	0.07
Alcohol				
20	2-Ethyl-1-hexanol	Orange, rose, sweet	Lipid oxidation	?
21	2,3-Butanediol	Fruity	Carbohydrate/Amino acid	50
Other				
22	Toluene	Nutty, bitter, almond	Feed & amino acid	>500

Conclusions



- Texture
 - Some key quality parameters out of spec, but best for Vintage cheese
 - Crumbly texture was positively correlated to three free amino acids (ala, glu, gly), proteolysis and fracture stress
 - Firmness in the mouth positively correlates with pH and the minerals Ca, P and Na.
 - pH and Ca have key role in cheese texture
- Proteolysis
 - Peptide profiling - Definitive link to peptides and maturity
 - likely key taste peptides accumulating with age (ongoing)
- Lipolysis
 - Little impact, certainly not re abundance
 - Most lipolysis – milk and in the vat, substrates for some key volatiles over aging

Conclusions



- Sensory

- Vintage and mature Cheddars were typically preferred by the sensory panel
- “Cheddar flavour”, “liking of aroma” and “sour taste” strongly positively correlated to three ketones (2-heptanone, 2-nonanone and 2-pentanone) – β -oxidation of fatty acids
- “Salt taste”, “liking of flavour” and “fruity estery aroma” were strongly positively correlated to the volatile compound 3-carene, free amino acids (leu, met, phe, ala, val, tyr, glu and gly) and proteolysis
 - Unlikely as 3-carene is sweet, turpentine. FAA appears important – NB amino acids and level of proteolysis
- Sweet taste positively correlates with the volatile compound 2-methyl butanal
 - Unlikely as 2-Methyl butanal malty, dark chocolate, almond, cocoa, coffee aroma

Conclusions



- Volatiles
 - Odour activity and abundance is key
 - The following compounds influenced the aroma (flavour) of mild, mature and vintage cheeses – abundance increasing with age
 - 3-methyl butanal, benzaldehyde, methional (from amino acid metabolism)
 - Butanoic acid (lipolysis)
 - 1-Octen-3-one (lipid oxidation)
 - Ethyl butanoate & Ethyl octanoate (ethanol + fatty acid)
 - Ketones
 - 2-Heptanone, 2-Nonanone & 2-Pentanone with liking aroma, Cheddar flavour & sour taste
 - Other volatiles compounds were present for either mild, mature or vintage, e.g.
 - 2,3-butanedione (mild), 1-Hydroxy-2-propanone (mature), Toluene (vint)

Conclusions



- More analysis required
 - Peptide profiling (taste peptides)
- Best to do initial screen to eliminate analysis sets not having an impact
 - Then get as much samples analysis (data) as possible
 - 8 samples was a limitation of the this study
- Concept works
 - Best that you know your product as well as possible in order to discount some statistical associations that could not be true

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Questions

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