Cheese diversification & the IDB-Teagasc cheese programme: A milk quality perspective

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Overview

- Expanding milk pool
- The importance of cheese
- Role of cheese diversification
- IDB-Teagasc as part of cheese diversification programme
- Importance of milk quality for cheese diversification
  - Microbial perspective
  - Enzymatic perspective
  - Curd formation and quality perspective
- Conclusions
Increased Milk Pool

• Abolition of EU milk quotas in 2015
  • Projected 2.75 billion litre increase in Irish milk by 2020
  • Equivalent to an increase of approximately 50% (Food Harvest 2020).
• Significant processing challenges
  • Capacity
  • Seasonality of supply
  • Products and Markets: Diversification for
  • Consistency and quality
Why Cheese?

- Cheese has been targeted as a vital end-product
  - Continued increases in global cheese consumption,
  - High end-use versatility,
  - Potential for significant added value,
  - Potentially profitable outlet for surplus milk fat

- Historically not a major component of the Irish dairy product mix
- Share in milk utilisation has always lagged well behind that of European competitors.
- Changing…
Irish Cheese production and exports (000 tonnes)
Irish cheese exports
### Irish cheese exports by destination

<table>
<thead>
<tr>
<th>Partner Country</th>
<th>Tonnnes</th>
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<td>World</td>
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<tr>
<td>United Kingdom</td>
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<tr>
<td>Egypt</td>
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</tr>
<tr>
<td>China</td>
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</tr>
</tbody>
</table>

UK: 114,000 tonnes
EU (-uk): 39,700 tonnes
Dairy Consumption trends in Asia (%)

China
- Liquid Milk: 54%
- From Powder: 24%
- Cheese: 12%
- Yoghurt: 10%
- Dairy drinks:

S. Korea
- Liquid Milk: 38%
- From Powder: 28%
- Cheese: 12%
- Yoghurt: 18%
- Dairy drinks:

Taiwan
- Liquid Milk: 33%
- From Powder: 15%
- Cheese: 17%
- Yoghurt: 15%
- Dairy drinks:

Japan
- Liquid Milk: 33%
- From Powder: 10%
- Cheese: 22%
- Yoghurt: 13%
- Dairy drinks:

Source: Prof G Huo, Key Lab Dairy Science, NEAU, Harbin, China

The Irish Agriculture and Food Development Authority
Growth, but diversity necessary

Traditional cheese markets such as Cheddar changing

- UK cheese retail market- 415,000 tonnes  (Ref: G. Paul, Bradburys & IDB)
- 100,000 tonnes imported, 90,000 tonnes from Ireland
  - 1950 – 95 % Cheddar
  - 2013- 50 % Cheddar
- Areas of double digit growth: Artisan cheese, Continental/soft and Ing.

Diversification already in train in Irish cheese production:

- Continental type cheeses (Emmental, Jarlsberg, others under dev.)
- Dubliner cheese
- Regatto and other higher salt cheeses
- Growing interest in salt reduction
The IDB-Teagasc cheese programme

- Public private partnership – Dairy Innovation Centre
- Research capability & expertise of Teagasc:
  - Dairy chemistry and technology
- IDB’s market and distribution infrastructure and global reach.
- Develop a pipeline of new innovative products to meet specific consumer and customer needs in key global markets
  - Milk protein ingredient- recombined in market, to produce fresh cheese types common to markets within the Middle East.
  - European/continental-style cheese for retail markets
  - Cheddar (reduced-fat, reduced-salt content) for retail markets
Diversification requires change:

- Cultures: Thermophillic and/or heterofermentative mesophilic
- Temp: Max scald temperatures ($\geq 50\,^\circ\text{C}$)
  Ripening temperatures ($> 20\,^\circ\text{C}$)
- Salt Elevated contents (Regatto, Grana types)
  Reduced salt cheeses (Continental type, low salt)
- Openness Eye type: Aesthetic quality
  Propionic and Citric acid fermentations
  Curd quality
- pH/Acid Acidification profiles, curd pH (Vs Cheddar)
  Curd washing
  Curd drainage characteristics

How does milk quality interact with these changes?
Milk Quality

• Milk quality can be defined under many headings:
  • Microbial (both pathogenic and non-pathogenic bacteria);
  • Chemical
  • Compositional
  • Physicochemical
  • Enzymatic
  • Stage of lactation
Milk Microbial Safety & Quality

- Microbial Safety
  - Raw milk can potentially contain pathogenic bacteria e.g. Salmonella spp, Listeria spp, *E. coli*, Campylobacter spp., *Mycobacterium bovis* and Brucella spp.
  - (Jayarao and Hennin, 2001; Rea, Cogan and Tobin, 1992)
  - Industrial scale diversification – pasteurisation
    - No greater safety threat than standard Cheddar types
Milk Microbial Quality

- Microbial populations in raw milk can influence cheese quality dependant on
  - Microbial profile and microbial load of the raw milk,
  - Ability to survive pasteurisation
  - Build-up of microflora within the cheese manufacture plant
  - Starter culture activity and acidity profiles,
  - Cheese type, composition and manufacture technology
  - Ripening temperature/environments.
Milk Microbial Quality

Coliforms (Enterobacter, Escherichia, Citrobacter, and Serratia)

- P.P.C. (or use of unpasteurized milk)
- First 24-48 h of manufacture - numerous small holes possible off-flavours
- H$_2$ and/or CO$_2$ gas as a by-product of lactose utilization.
- H$_2$ is poorly soluble in the aqueous phase of curd and therefore even small quantities can cause serious gas problems (Sheehan, 2011).

Yeast (Debaryomyces hansenii, Candida versatilis, Torulaspora delbrueckii)

- Heat sensitive & killed by pasteurisation.
- Contamination of equipment surfaces and by air
- Gas blowing in hard, semi-hard and soft cheeses.
- Some resistance reported to commercial sanitisers
  - (Sheehan, 2011; Tudor and Board, 1993; Welthagen and Viljoen, 1998)
Milk Microbial Quality

**NSLAB** Non-Starter Lactic Acid Bacteria

- Facultatively heterofermentative (mesophilic) lactobacilli (FHLs), Pediococci, Enterococci, and Leuconostocs

- Cell densities of $10^6$ - $10^8$ cfu/g during cheese ripening (Swearingen et al., 2001). (Beresford et al., 2001; Beresford and Williams, 2004; Thierry et al, 1998)

- Capable of growth at pH 5.5 to 6.2, in 4–6% salt and from 2 to 54 °C (Lynch et al., 1996).

- *L. paracasei, L. plantarum, L. rhamnosus* and *L. brevis* in Swiss-type cheese

- As cheese ripened *L. paracasei* began to dominate (Demarigny, 1996)
Milk Microbial Quality

- NSLAB affect quality of cheese: flavour defects, biogenic amine (BA) formation, gas formation, and secondary fermentations

- Gas production by FHLs such as *L. brevis* and *L. fermentum* (O’Sullivan et al, 2013)

- NSLABs capable of BA formation include *L. casei, L. curvatus, L. buchneri*, (O’Sullivan et al, 2013)

- Controlling the strains, and the proportions thereof, is emerging as a key issue to minimize cheese defects (McSweeney, 2007)
Milk Microbial Quality

• The ability of NSLABs and FHLs to survive pasteurisation important
  • Lactabacilli are generally not described as thermoduric, but
  • Some thermo resistance reported when assays involve milk (Jordan and Cogan, 1999).
  • Strains of *Lactobacillus brevis* did not survive pasteurisation
  • Strains of *Lb. buchneri* and curvatus were partially resistant showing a reduction on treatment of ~ 2 logs (Sanchez-Llana, Fernanadez & Alvarez, 2011)
• Cells injured by pasteurisation Vs total inactivation (non culturable)
  • but still capable of metabolic activity
  • Thus capable of generating defects in diverse cheese types during ripening
• Thus the importance of NSLAB profile/counts in milk
Milk Microbial Quality

- Swiss or Dutch-type cheese manufacture
  - Milk from Silage fed herds contain spores
- *Clostridium tyrobutyricum* or *C. butyricum* *C. sporogenes, C. beijerinckii*
  - Germination of spores and growth of clostridia during ripening
- Fermentation of lactate to acetate, butyrate, CO$_2$ and H$_2$
  - Late gas blowing defect in the cheeses.
- Due to anaerobic environment, higher ripening temps
- Low salt and acid content
Milk quality and microbiota

- Non–molecular methods (plate counts) selecting only specific strains - may introduce a degree of inherent bias
- Molecular methods - total DNA is extracted directly from the cheese overcoming any selective bias.
- Molecular methods - also functional analysis (active metabolic pathways).
  - Can also target specific defect causing strains/genes (decarboxylase genes)
Next Generation Molecular Techniques

- Pyrosequencing: 16S rRNA analysis (16S used for typing bacteria to genus level)
- Allows for microbial composition to be determined

**Microbial Composition**

- Sutterella
- Lachnospira
- Bifidobacterium
- Clostridium
- Bacteroides
- Enterobacter
- Streptococcaceae
- Faecalibacterium
- Ruminococcus
- Lactobacillus

**Functional Potential**

- RNA processing
- Chromatin structure
- Energy production
- Cell division
- Amino-acid metabolism
- Nucleotide metabolism
- Carbohydrate metabolism
- Coenzyme metabolism
- Lipid metabolism
- Translation
- Transcription
- Replication
- Cell wall/membrane biogenesis
- Cell motility
- Protein folding and turnover
- Nucleotide metabolism
- Secondary metabolite biosynthesis
- General function prediction only
- Function unknown
- Signal-transduction mechanisms
- Intracellular trafficking
- Defense mechanisms
- Cytoskeleton

**Ref:** Paul Cotter group TFRCM

- Illumina Sequencing: Used for Shotgun/Meta-genome sequencing
- Data generated allows for compositional and functional analysis
Milk Microbial/Enzymatic Quality

**Psychrotrophic bacteria** (Pseudomonas fluorescens and P. putrefaciens)

- Activity of proteinases (Lemieux and Simard, 1991; McSweeney, 2007)
- Heat stable (unaffected by pasteurization)
- Bitter hydrophobic peptides from C-terminal region of \( \beta \)-casein and in \( \alpha_{s1} \)-casein
- Accumulate during cheese ripening (Lemieux and Simard, 1991).
- Lipases leading to lipolysis of fat negative flavour attributes
Milk quality: enzymes

- Plasmin content of milk varies with advancing stage of lactation (Richardson and Pearce, 1981).
- Milk and cheese plasmin levels influence cheese ripening & quality
  - High levels of plasmin in milk
    - Longer rennet gelation times
    - Lower gel firmness, more porous, open structured rennet gel
    - Less connectivity between the particles and clusters making up the gel matrix (Guinee and O’Brien, 2010).
- Addition of plasmin or of mastitic milk
- Poorer eye formation in cheeses manufactured from early lactation milk partly attributed to a lower concentration of plasmin
  (Lawrence, Heaps and Gilles, 1984)
Milk quality: enzymes

- Plasmin has a relatively high heat stability (Kaminagowa, Mizobuchi, & Yamauchi, 1972) and a pH optimum of 7.5 (Grufferty & Fox, 1988).
- The contribution of plasmin to primary hydrolysis of caseins is more pronounced in cheeses where high cooking temperatures are used during manufacture (Steffen, Flueckiger, Bosset, & Ruegg, 1993; Sousa et al., 2001).
- Due to
  - increased plasminogen activation resulting from inactivation of plasmin inhibitors and
  - inhibitors of plasminogen activators being lost in the whey during cheesemaking (Farkye & Fox, 1990; Somers & Kelly, 2002).
- Implications for Swiss, Swiss Cheddar-hybrid types and Grana type cheeses
Milk quality: Physico-chemistry and curd structure

• Cheddar and late lactation milk (Guinee and O’Brien, 2010)
  • Poor rennet coagulability
  • Impaired curd syneresis
  • Higher moisture
  • Lower fat recovery to cheese

• Eye-type cheeses (Akkermann et al, 1996)
  • During manufacture, flow of whey through interconnected pores between curd grains—important for eye quality
    • Geometry of drainage column
    • Moisture content of curd grains
    • Amount of curd fines

Stage of Lactation

The Irish Agriculture and Food Development Authority
Conclusions

• Cheese is a key dairy product for “Ireland Inc.” Whey for IMF.

• Markets are changing….Diversification…. IDB- Teagasc PPP.

• Milk quality impacts hugely on cheese quality esp. diverse types

• Microbial quality - Non culturable but metabolically active
• Enzymatic quality- Higher temp profiles implication for enzymes
• Stage of lactation- Continental types equally/ more demanding..

• Milk quality and cheese quality are inextricably linked ….

.................. cheese consistency work in progress
The IDB-Teagasc cheese programme: A milk quality perspective

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