Food Institutional Research Measure

Final Report

NOVEL STRATEGIES FOR OPTIMIZATION OF THE CHEDDAR CHEESE MANUFACTURING PROCESS

DAFF Project Ref No: 08RDC604
Start date: 1.10.2008
End date: 30.09.2013

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Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDMENTAL  APPLIED/PRE COMMERCIAL

X

Key words: (max 4)

Cheddar cheese, commercial optimisation, enzymes, physicochemical properties
1. **Rationale for Undertaking the Research**

   *This section should outline the rationale for carrying out the research and identify the need/problem to be addressed*

   Despite considerable research, it is still not possible to guarantee premium quality Cheddar cheese. In Ireland, 139,000 tonnes of cheese is made *per annum*, mostly Cheddar, from a pool of milk drawn from a small geographical area using starters and coagulants obtained from a limited number of commercial sources and often with identical technology. However, intra- and inter-factory variations in quality beset cheesemakers and have defied their best attempts to produce consistently premium-grade Cheddar. While cheesemakers pay close attention to pH, composition, ionic strength (NaCl) and temperature; it is possible that equally close attention to physicochemical and biochemical parameters which have to date received little attention, including oxidation-reduction potential, micro-scale distribution of enzymes, water activity, levels of residual lactose/lactate, and galactose (in cheeses made with starter systems containing *Streptococcus thermophilus*), may allow much more precise control of cheese quality and avoid specific defects. The parameters studied in this project could easily be measured and/or implemented in industry and could form part of future strategies for optimization of the Cheddar cheesemaking process and reducing variation in quality. Routine determination of some of these parameters will lead to the generation of new sets of quality parameters giving a competitive advantage to the Irish Cheddar cheese industry.

2. **Research Approach**

   *Specify the research methodologies employed, emphasising novel techniques and also outline any modifications from the original approved project proposal*

   This project drew together a team that has worked together successfully in the past and has a considerable published track-record in the area of cheese science. Each partner brought their unique expertise to the project with a view to providing the Cheddar industry with easily implementable approaches to improving consistency and quality. The research techniques adopted were state of the art for cheese science.

   **Task 1 Oxidation-reduction potential and its influence on Cheddar quality**

   Redox potential was measured during cheese manufacture of Cheddar, Emmental, Camembert and Gouda. Changes in redox potential may be attributed to both the cheesemaking protocol used and starter lactic acid bacteria and/or adjunct cultures added. In Cheddar cheese, the main drop in redox potential occurs during the cheddaring stage of manufacture and at the pressing stage.

   To evaluate the changes in redox potential in Cheddar cheese early in ripening, miniature electrodes were embedded into the cheese and pressed together with the cheese pieces. Our studies demonstrated that redox potential reaches its negative equilibrium value...
during overnight pressing and it doesn't change significantly during the early stages of ripening.

Strategies to control the redox potential during Cheddar cheesemaking included the addition of redox agents at the salting stage of the cheesemaking and our results from the volatile analysis support the hypothesis that redox potential has an influence on the development of cheese flavour during ripening.

Redox potential is a strain-specific characteristic and the selection of lactic acid bacteria used for cheesemaking can be done on the basis of their ability to influence redox potential in a Cheddar cheese model.

Redox potential of Emmental cheese was measured from the salting stage of the manufacture during ripening. Results shown that redox potential slowly decreased during the first days of ripening and it dropped to low negative values when the propionic acid bacteria started to grow.

**Task 2 Strategies for control of residual galactose in Cheddar**

MFRC screened a large number of *Str thermophilus* strains and selected strains based on their acidification rates, sugar metabolism and acidification rates. Cheesemaking was performed using one galactose-positive and one galactose-negative strain of *Str thermophilus*.

The effect of salting level (1.6, 2.7%) and culture type on Cheddar quality was evaluated as follows: (i) Starter *Lactococcus*, (ii) Starter *Lactococcus* + galactose-negative strain (DPC5095), (iii) Starter *Lactococcus* + galactose-negative strain (DPC5095) + *Lactobacillus paracasei* strain 4818, and (iv) starter *Lactococcus* + galactose-positive strain (DPC1796).

A total of 8 cheese treatments (each starter at two salting rates) were made in each trial, and trials were undertaken in triplicate. All cheeses were matured at 8 °C for 9 months and were analysed for composition (14 days) and for proteolysis, lipolysis, lactose metabolism, starter and non-starter bacteria, color changes, and texture changes (texture analyser); the cheese wheys were analysed for fat, protein and lactose.

**Task 3 Water activity, enzymes and cheese quality**

In a study of the variation in various compositional and ripening indices within commercial cheese blocks, ten 20 kg Cheddar cheese blocks originating from the same vat were sourced from a leading manufacturer post manufacture and ripened at 8°C. At each sampling time during ripening, five different locations across a diagonal slice of a single block of cheese were removed for analysis. The sampling pattern ensured that both exterior and interior locations of the commercial block were analysed. Each section of the block was analysed for localized distribution of water activity ($a_w$), activity of released intracellular ripening enzymes (Pep X and Pep N) and viability of starter and non-starter lactic acid bacteria. The distribution of salt, moisture, pH, buffering capacity, mineral and lactate content and texture of cheeses and the redox potential within the block were all monitored.
Flow cytometry and fluorescence activated cell sorting (FACS) methodology was developed to directly identify, differentiate and enumerate intact or permeabilised bacteria in cheeses and this technique was used to examine bacterial distribution and physiology within cheeses manufactured using mixed starter strains.

Viability and proteolytic activity of a commercial cheese mixed starter was evaluated in reconstituted skim milk (RSM) and 6L mini Cheddar cheeses during manufacture and ripening.

A range of pilot scale cheeses were manufactured with variations in compositional parameters and the effects on water activity and other parameters monitored. In agreement with data from commercial cheeses and the model cheese system, decreased $a_w$ during ripening was significantly negatively correlated with increases in various proteolytic indices. Therefore the preponderant factor controlling $a_w$ in Cheddar cheeses made using standard procedures appeared to be proteolysis, with typical variations in compositional parameters having a much lesser effect. This data highlighted the dynamic relationship between $a_w$ and proteolysis during ripening which may contribute to flavor production and overall cheese quality.

**Task 4 Control and effect of effects of lactose level to buffering on Cheddar cheese quality**

Four (x 4 vat) cheesemaking trials were undertaken to investigate effect of varying the lactose-in-moisture (L/M) content from 4.9 to 3.8 on the quality of Cheddar cheese. Increasing the L/M level resulted in higher levels of total lactate and D-lactate, higher pH values (ranging from ~ 0.15 at 90 d to ~ 0.3 units at 180 d), but had little effect on gross composition, galactose content, level of primary (pH 4.6 soluble N) or secondary (level of 5% tungsto-phosphoric acid or free amino acids) or cheese texture (firmness and fracture stress as measured using texture analyzer).

### 3. Research Achievements

Outline results achieved

**Task 1**
- Practical method for measuring redox potential of Cheddar cheese in industry.
- Detailed information on changes in redox potential during the ripening of Cheddar and how this parameter is influenced by starter systems
- The relationship between redox potential and grade quality of commercial Cheddar cheese

**Task 2**
- Screening of the Moorpark culture collection for galctose positive and galactose negative lactic acid bacteria.
- An extensive database on the effects of galactose positive or galactose negative strains of *St. thermophiles* strain and *Lactobacillus paracasei*, on the
composition and changes in the biochemistry and quality of full-salt and reduced-salt Cheddar cheese made with different pH at whey drainage, during ripening.

- Development of a new rapid method for screening potential adjunct strains for their contribution to cheese quality, based on sugar metabolism, salt sensitivity and acidification rate.
- A method of developing of Cheddar cheese variants with different flavour characteristics based on adjunct cultures and manufacturing conditions.

**Task 3**

- An understanding of the degree of variation in water activity, compositional and proteolytic indices arising in a range of commercial cheeses manufactured in 12 kg block formats.
- An understanding of the preponderant role of secondary proteolysis in the determination of water activity values in Cheddar cheeses during ripening.
- Development of a model system to evaluate the contribution of individual/combinations of compositional components on water activity.
- Evidence to suggest that differing proteolytic systems have an influence on water activity during early stages of Cheddar cheese ripening.

**Task 4**

- Results showed that increasing the L/M level resulted in higher levels of total lactate and D-lactate, higher pH values, but had little effect on gross composition, galactose content, level of primary (pH 4.6 soluble N) or secondary (level of 5% tungsto-phosphoric acid or free amino acids). Cheese firmness increased significantly with the mostly washed cheese, however, fracture stress as measured using texture analyser were not significantly differ. No consistent differences were noted between the varying levels of L/M and the populations of starter bacteria (~ 10^7-10^8 cfu/g on day 1) or non-starter lactic acid bacteria NSLAB (~ 10^7 cfu/g at 180 d).
- Grading of cheese at 9 months by commercial graders indicated that higher wash water levels resulted in cheeses having a sweeter taste and a creamier, less-chewy mouthfeel.
- Increasing the milk protein from to 3.3 and 4.0% using UF and the lactose-in-moisture (L/M) ratio in the cheese was varied (4.9, 4.3 and 3.8) either by adding lactose to the milk or by washing the cheese curds) indicated that increasing the level of curd washing in the vat and concentrate milk protein reduced concentrations of lactose, LLAMc and total sugars-to-protein ratio in cheese, increased cheese pH, especially at advanced ripening times (not by protein), increase the protein levels decrease the moisture and MNFS in cheese and significantly effect on hardness, fracture strain and fracture stress, hardness of high protein cheese tended to be harder, increased fracture stress and fracture strain, cheese becoming more elastic - less brittle. In sensory Analysis, high protein cheeses tended to have caramel, buttery and sweet/cheesy flavor, also have fruity and savoury odor, while low protein cheeses tended to have more savoury, onion,
farmyard and pungent flavor, more acid taste. With increased curd washing, the cheeses were tended to be more fruity, buttery, sweet and had less 'farmyard' flavor.

- The effect of varying cheese CaP levels indicate that decreasing the cheese-milk pH at the start of cheese-making (pH 6.25) and drain pH during cheese manufacture (pH 5.85) lead a reduction of CaP content in the cheese. In this modified method, CaP in cheese reduced, however the cheese moisture was kept constant. There was an inverse relationship between the level of curd washing and cheese pH (up to 6 months), and reducing the CaP content resulted in a reduction in cheese pH after 3 month ripening. High CaP washed cheeses tended to be harder.

4. Impact of the Research
Provide a summary of outcomes of research and outline the benefits of the research to end users, e.g. industry, consumers, regulatory authorities, and scientific community etc.

The overall objective of this project was to investigate novel approaches to improve the consistency of ripening of Cheddar cheese. The first parameter studied was oxidation-reduction (redox) potential which we feel could become an additional parameter used to select microorganisms candidates as starters in fermented dairy products. Thus, the development of strategies to measure continuously changes in redox potential of a product and to control, and adjust if necessary, the redox potential values during cheese manufacturing and ripening could be useful for the future of the dairy industry. The second approach investigated focused on recent changes to the composition of culture systems used for Cheddar manufacture, principally due to the common inclusion of *St. thermophilus* for its resistance to bacteriophage attack. Since *St. thermophilus* metabolizes only the glucose moiety of lactose, galactose can accumulate during manufacture leading to various technological problems. In addition, galactosaemia is a problematic condition for some consumers, and persistence of galactose in Cheddar could cause illness in this susceptible group. We found that adjunct strains of galactose-positive *St. thermophilus* and *Lactobacillus paracasei* significantly reduced residual galactose in Cheddar cheese. Hence, the use these galactose-positive adjucts in combination with process modification can eliminate the problems associated with residual galactose, and also provide a means of developing customised Cheddar cheese variants. Another parameter that could cause variation in cheese quality is small differences in water activity. Water activity (aw) is one of the most important physicochemical parameters that influence the stability of foods. Results of this study suggest that a significant degree of variation can occur in water activity along with other compositional/proteolytic indices in commercially manufactured Cheddar cheese blocks. This indicates that further process control measures should be adopted to ensure consistency both within and between Cheddar cheese blocks at commercial scale. It would also appear that monitoring of water activity in conjunction with the normal compositional parameters could be a useful and rapid indicator of the degree of secondary proteolysis. The seasonal variation in milk lactose, protein and mineral levels and different lactate levels in commercial Cheddar cheese has been found to have a significant effect to the
final cheese quality. The results of this project clearly indicated that curd washing regimes can optimise the level of residual lactose in cheeses made with different protocols (e.g., milk protein levels, pH at set and at whey drainage, different calcium levels) and thus optimise its quality.

5. **Exploitation of the Research**

Outline the outcomes of the research that have commercial or economic importance and provide details of Intellectual Property / licences / patents generated. Details of outputs adopted by industry should also be provided.

This project has demonstrated that close control of physicochemical parameters other than temperature and pH could be a strategy to reduce variability in the quality of commercial Cheddar cheese. While further research in a commercial context is necessary, the techniques developed in this project could be used in a laboratory context and during processing in-line or at-line.

6. **Summary of Research Outputs**

(a) Intellectual Property applications/licences/patents
   None

(b) Innovations adopted by industry
   None

(c) Number of companies in receipt of information
   Proxis-Développement Company, Levallois, France

(d) Outcomes with economic potential

| New technology - test methodologies | Methodologies for measuring redox potential of cheese and affect of aw on cheese quality |
---|---|

(e) Outcomes with national/ policy/social/environmental potential
   None

(f) Peer-reviewed publications, International Journal/Book chapters.


The following papers are in preparation:


Caldeo, V., Broadbent, J., and McSweeney, P.L.H., Effect of lactic acid bacteria on changes to the oxidation-reduction potential during the simulated pressing stage of Cheddar cheese.

(g) Scientific abstracts or articles including those presented at conferences


(h) National Report
None

(i) Popular non-scientific publications
None

(j) Workshops/seminars at which results were presented (excluding those in (g))

ChedOpt Workshop, Teagasc Moorepark 3.12.13

Abstract (FIRM-funded) - Despite considerable research and control of important physicochemical parameters such as pH, temperature and ionic strength (salt), it is still not possible to guarantee premium quality Cheddar cheese variations in quality continue to beset cheesemakers. This workshop will cover the results of the Cheddar Optimisation FIRM project that studied physicochemical and biochemical parameters which have to date received little attention, including oxidation-reduction potential, micro-scale distribution of enzymes, water activity, levels of residual lactose/lactate, and galactose (in cheeses made with starter systems containing Streptococcus thermophilus). Consideration of these factors may allow much more precise control of cheese quality and avoid specific defects.
**Section 11:**

**Total Expenditure of the Project:** €735,973

**Total Award by FIRM:** €738,962

**Other Sources of funding:** -

### Breakdown of Total Expenditure

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<th>MFRC</th>
<th>U1</th>
<th>Total Project</th>
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<tr>
<td></td>
<td>€</td>
<td>€</td>
<td>€</td>
<td>€</td>
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<tr>
<td>Contract Staff</td>
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<tr>
<td>Other (please specify):</td>
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<tr>
<td>Sub-Contracting Costs</td>
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<td>Overheads (***)</td>
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<td>53,302</td>
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**7. Permanent Researchers**

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<tr>
<th>Institution Name</th>
<th>Number of Permanent staff contributing to project</th>
<th>Total contribution (months)</th>
<th>Average time contribution per permanent staff member (months)</th>
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<td>Moorepark</td>
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**8. Researchers Funded by FIRM**

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<td>PhD postgraduates</td>
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<td>31.00</td>
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<td>Temporary researcher</td>
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<td><strong>Total</strong></td>
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<td>160.36</td>
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</table>
9. Postgraduate Research

Total Number of PhD theses: 2

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date.


Total Number of Masters theses: 0

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date.

10. Involvement in Food Graduate Development Programme

<table>
<thead>
<tr>
<th>Name of Postgraduate / contract researcher</th>
<th>Names of modules attended</th>
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<tr>
<td>Veronica Caldeo</td>
<td>Industrial Scale R&amp;D</td>
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<td>The National and Global Food Sector</td>
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12. Future Strategies

Outline development plans for the results of the research.

A number of companies attended the workshop on this project held in Teagasc Moorepark on 3 December 2013; however, none have yet adopted the technologies developed in this project. It would be desirable to pilot these technologies under industrial condition and to design a large-scale project to correlate these parameters with the quality of industrial
Cheddar cheese. The research team continues to work in the general area of these projects.

13. Industry Collaboration

*Summarise details of industry collaboration in the research project.*

Cheeses were obtained from Dairygold and that company was kept abreast of results. A number of companies attended the workshop on this project held in Teagasc Moorepark on 3 December 2013.