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Novel Strategies for Optimization of Cheddar Cheese Manufacturing Process

Key external stakeholders:
Dairy Industry

Practical implications for stakeholders:
Consistency in terms of quality and yield are vital in ensuring an economic return from the commercial production of Cheddar cheese. Seasonal variation in the lactose content of Irish milk and residual galactose accumulation in cheese arising for introduction of new starter systems have the potential to impact on Cheddar cheese quality.

- Starter culture systems were developed that can greatly reduce residual lactose levels in ripening cheese and curd washing during manufacture was demonstrated as a means of controlling lactose levels in cheese and thus improving consistency in manufacture of quality cheese.

Main results:
Starter systems containing galactose metabolizing *St. thermophilus* and *Lb. paracasei* strains have the potential to remove residual galactose from ripening cheese and reduce some of the quality issues associated with galactose in cheese including off flavors, inconsistency in composition and browning on cooking.

Curd washing during manufacture was demonstrated as a means of reducing unfermented lactose in, and altering the sensory properties of, Cheddar cheese.

Opportunity / Benefit:
Starter systems investigated as part of this project demonstrated that levels of residual galactose that accumulate in cheese manufactured using *St. thermophilus* containing starter systems can be controlled.

The data generated clearly indicate how curd washing regimes may be applied for cheesemaking under different conditions (milk protein levels, pH at set and at whey drainage, different calcium levels) to control the level of lactose and lactic acid in the cheese from a quality perspective, and to differentiate sensory properties.

Collaborating Institutions:
UCC, UL

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1. Project background:

The large scale commercial Cheddar cheese industry recognized early the importance of controlling compositional parameters that could be measured easily in industry (moisture-in-non-fat substances, pH, NaCl, fat-in-dry-matter) as the key to their strategy for producing consistently high quality cheese. While many of these parameters are monitored by Irish Cheddar producers, production of premium quality cheese still cannot be guaranteed. The key objective of this project is to investigate other parameters likely to cause variation in quality but which could also be determined easily in industry within a quality assurance programme with a view to developing further process and product-specific strategies for maximizing Cheddar quality. Such factors include levels of residual galactose and lactose-to-protein ratio in the cheese. On completion of this project, it is envisaged that a number of easily implementable approaches to monitoring and optimizing quality will be developed.

2. Questions addressed by the project:

- How does variation in milk lactose content influence residual lactose and lactic acid levels in Cheddar cheese?
- What is effect of varying residual lactic acid in Cheddar cheese?
- Does residual galactose impact Cheddar cheese quality and can strategies based on starter systems be developed to control it?
- Can we develop strategies to control the effects of lactose level to buffering on Cheddar cheese quality?

3. The experimental studies:

To assess the impact of residual lactose on cheese quality a bank of *Streptococcus thermophilus* were evaluated for lactose metabolism, production of galactose, salt sensitivity and acidification rate. Galactose-positive and galactose-negative strains were evaluated in cheese-making as adjuncts cultures. The interactive effect of pH at whey drainage (pH 6.15 and 6.45) or salting level (1.6 and 2.7%) and use of galactose positive/negative *St. thermophilus* strains on Cheddar cheese quality were evaluated in triplicate pilot scale cheese manufacturing trials followed by a full ripening study.

To assess the impact of lactose-in-moisture (L/M) content of the cheese, cheeses were manufactured at pilot scale where the lactose levels were altered either by addition of lactose to the cheese milk or through curd washing during manufacture. Using these approaches L/M was varied from 5.3 to 3.8.

4. Main results:

The results of cheese-making trials to assess the interactive effects of drain pH and starter culture system indicated that:

- Increasing the drain pH from pH6.15 to pH6.45 increased the cheese moisture content by ~2%; reduced fat, protein, salt and pH at day 14 of cheese ripening time; and also reduced the counts of *St. thermophilus* throughout ripening.
- The cheese manufacture time was ~30 minutes faster than the control cheese when using galactose positive *St. thermophilus.*
- By using the galactose negative *St. thermophilus,* there was an accumulation of residual galactose in cheese during ripening (~0.2%). However, at higher drain pH, the residual galactose in the cheese made with the galactose negative strain was much lower (~ 0.05%).
- Galactose-positive or galactose-negative strains had no significant effects on primary or secondary proteolysis during cheese ripening.
- Reducing the drain pH from 6.45 to 6.15 resulted in: a 1% increase in cheese protein. This in turn led to a decrease in the moisture and MNFS and significantly decreased hardness, fracture strain and fracture stress.
- With respect to sensory analysis, high drain pH control cheese had a fruity flavor, creamy texture

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and a fruity/savory odor. Cheese made with the galactose-negative *St. thermophilus* at high drain pH had a sweaty and rancid flavor. Cheese made with a galactose positive *St. thermophilus* strain at high drain pH tended to have a salty taste and sweaty odor. Low drain pH control cheese had a buttery flavor, caramel odor and sweet taste. Cheese made with galactose-negative or galactose-positive *St. thermophilus* at low drain pH had a pungent flavor and odor and had an acid taste.

The results of cheese-making trials to assess the interactive effects of salt level and starter culture system indicated that:

- Reducing the salt levels resulted in higher levels of total lactate in cheese hence lower pH, reduced levels of lactose, proteolysis, hardness and fracture properties.
- Cheeses made with adjunct cultures had higher levels of proteolysis, especially, secondary proteolysis as measured by PTA-SN and total free amino acids.
- By using the galactose negative *St. thermophilus*, there was an accumulation of residual galactose in cheese during ripening (~0.1%). However, at lower salt level, the residual galactose in the cheese made with the galactose negative strain was much lower (~ 0.02%).
- Inclusion of a galactose positive *Lactobacillus paracasei* strain in combination with the galactose negative *St. thermophilus* strain as the adjunct culture significantly reduced the residual galactose in cheese during ripening and lowering the cheese pH.
- Sensory analysis indicated that high salt cheeses had a more sweet, buttery, salt, and acid flavor attributes while the control cheese is caramel and bitter and the cheese made with galactose positive *St. thermophiles* strain is more sweaty, fruity and buttery, and the cheese made with galactose negative *St. thermophiles* strain is fruity and acid, and the cheese made with galactose negative *St. thermophiles* strain plus galactose positive *Lb. paracasei* strain is salty, pungent and rancid.
- Low salt cheeses had a bitter, pungent bunt and rancid flavor attributes in which the control cheese is bitter, caramel and buttery while the cheese made with galactose positive *St. thermophiles* strain is more waxy, sulphur and rancid, and the cheese made with galactose negative *St. thermophiles* strain is fruity and sweet, and the cheese made with galactose negative *St. thermophiles* strain plus galactose positive *Lb. paracasei* strain is caramel, buttery and acid.

The results of cheese-making trials to assess the impact of lactose-in-moisture (L/M) content of the cheese that:

- Reducing the L/M level, through increased curd washing, resulted in lower levels of residual lactose, total lactate and D-lactate and higher pH values, but had little effect on gross composition, galactose content, level of primary (pH 4.6 soluble N) or secondary (PTA or free amino acids) proteolysis, or on the levels of starter bacteria (~ 10^7-10^8 cfu/g on day 1) or non-starter lactic acid bacteria NSLAB (~ 10^7cfu/g at 180 d). Nevertheless, reducing the L/M content led to cheeses that were, overall, firmer and less brittle, that had lower levels of some volatile compounds. Sensory evaluation found that reducing the L/M content resulted in Cheddar cheeses being less acid, more buttery, sweeter, saltier and creamier than non-washed cheeses that had more 'sweaty', pungent and farmyard-like sensory notes. Residual lactose content in the 270-day old cheese varied from ~ 0.2% in the control non-washed cheese to ~ 0% in washed-curd cheese with an L/M of 3.9.

- The response of altering L/M content of cheeses, through curd washing, differed depending on the calcium content of the cheese. The mean pH of standard-calcium cheeses (SCa, 770 mg/100g) over the 270-d ripening period increased significantly with curd washing and ripening time, in contrast to the reduced-calcium cheese (RCa, 660 mg/100 g), for which pH was not affected by either of the latter parameters. The RCa washed-curd cheeses had a more buttery, caramel odor and flavor, and a more bitter, less sweet, and nutty taste than the SCa washed-curd cheeses, whereas the RCa non-washed cheeses had a more pungent and less fruity flavor, a less fruity odor, a saltier, more-bitter, and less acidic taste, and a more astringent mouthfeel than SCa non-washed cheeses. The level of unfermented lactose decreased in all cheeses during the 270-day maturation period, with levels in the RCa non-washed-curd cheese being significantly higher than that in all other cheese (washed and non-washed SCa cheeses, washed RCa cheese) at all ripening times.

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- Increasing the milk protein from to 3.3 and 4.0% using UF and varying the L/M ratio in the cheese indicated that increasing the level of curd washing and concentrated milk protein reduced concentrations of lactose and total sugars-to-protein ratio in cheese, increased cheese pH, especially at advanced ripening times (not by protein), increased the protein levels and decrease the moisture and MNFS in cheese. High protein cheese tended to be harder, exhibit increased fracture stress and fracture strain. Sensory Analysis indicated high protein cheeses tended to have caramel, buttery and sweet/cheesy flavour, with a fruity and savoury odour, while low protein cheeses tended to have more savoury, onion, farmyard and pungent flavour and more acid taste. With increased curd washing, the cheeses tended to be fruitier, buttery, and sweet and had less 'farmyard' flavour.

5. Opportunity/Benefit:

The composition of culture systems used for Cheddar manufacture has changed in recent years, principally due to the common inclusion of *St. thermophilus.* Since *St. thermophilus* primarily metabolizes only the glucose moiety of lactose, galactose accumulates during manufacture leading potential problems including flavour defects, compositional inconsistency, browning on cooking. The starter systems developed in this project significantly reduced residual galactose in Cheddar cheese and these can be adapted for large scale commercial production.

The current study has shown that significant levels of unfermented lactose may remain in Cheddar cheese even after long maturation times of 270 days, with the magnitude being influenced by the lactose level in the milk, the extent of curd washing and calcium content of the cheese. Residual lactose may be undesirable to those consumers predisposed to lactose intolerance. The current study has found curd washing to be a very effective means at reducing and controlling the levels of residual lactose in Cheddar cheeses varying in calcium content. This is particularly relevant to Irish manufacturers who process milk with large seasonal- and lactational- changes in lactose content into cheese. Apart from being a tool to reduce the level of residual lactose in cheese, curd washing also, via its effects on pH and calcium distribution between soluble and colloidal states, proved to be means by which the sensory properties of cheese can be differentiated, to an extent that varies with lactose level in milk, extent of curd washing and calcium content of the cheese.

6. Dissemination:

The research has been presented at a number of national and international conferences including the 8th Cheese Symposium, Cork, 39th and 41st Annual Research Conference, Food, Nutrition & Consumer Sciences. Cork, Teagasc Walsh Fellowship Seminar, Dublin and IDF Cheese Ripening & Technology Symposium, Madison, Wisconsin, USA.

Main publications:

Hou, J., Hannon, J.A., McSweeney, P.L.H., Beresford, T.P. and Guinee, T.P. (2012). Effect of curd washing on composition, lactose metabolism, pH, and the growth of non-starter lactic acid bacteria in full-fat Cheddar cheese. *International Dairy Journal* 25, 21-28.

Hou. J., Hannon. J.A., McSweeney. P.L.H., Beresford. T.P., Guinee. T.P. (2014). Effect of curd washing on cheese proteolysis, texture, volatile compounds, and sensory grading in full fat Cheddar cheese. *International Dairy Journal*. 34: 190-198.

Hou, J., McSweeney, P.L.H., Beresford, T.P. and Guinee, T.P. (2014). Effect of curd washing on the properties of reduced-calcium and standard-calcium Cheddar cheese. Journal of Dairy Science 97, 5983–5999.

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