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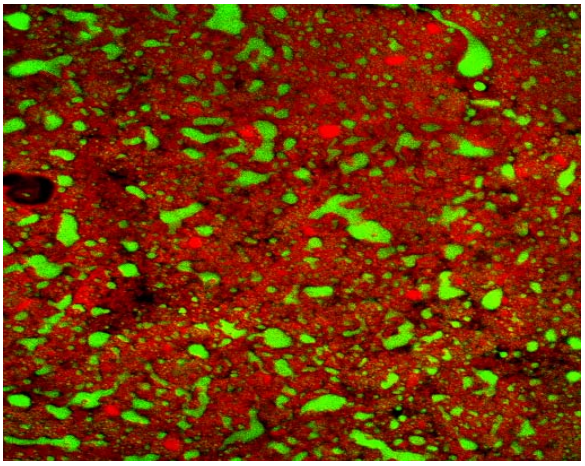
Secondary cheese processing



Key external stakeholders:

Irish manufacturers of cheese, processed cheese and milk protein powders, scientists with interest in the field of secondary cheese processing.

Practical implications for stakeholders:

Key production variables that significantly affect the characteristics of processed cheese products (PCPs) were identified: characteristics of the natural cheeses used, types and levels of emulsifying salts, product pH, and processing conditions. The research provided insights into the mechanisms by which these variables affect PCPs. They alter protein hydration, protein voluminosity and fat emulsification, all of which in turn influence the structure and continuity of the protein network that forms the structural framework of the PCP.

Main results:

1. Using a given generic formulation and product composition, PCPs with widely different functionalities could be achieved by alteration of natural cheese characteristics, emulsifying salt type and level, product pH and processing conditions.
2. Processing was accompanied by a large increase in the solubility of the protein of natural cheese and other ingredients (e.g., rennet casein) used in the formulation, as a consequence of emulsifying-salt mediated demineralisation; nevertheless, most of the calcium and phosphorous in PCP remain insoluble in the form of insoluble calcium phosphate or calcium citrate inclusions.
3. Reducing the level of emulsifying salt below a critical level prevented the successful formation of PCP, owing to insufficient calcium removal from, and solubilisation of, the natural cheese protein.
4. Increasing processing time, temperature and shear had similar effects on PCP properties, albeit differing in magnitude of effect: significant increases in firmness and elasticity modulus (G'), and reductions in the fracture strain and in the flowability and fluidity of the melted PCP.

Opportunity / Benefit:

The research provides an extensive database on how the functional properties of PCPs (e.g., texture, rheology and melt characteristics) may be altered by changing different process variables. It provides scientifically supported insights into the mechanisms operating during the manufacture of PCPs, and how these may be modulated for control of potential defects (such as *overcreaming*, oiling-off, low heat-stability) or customization of product characteristics. This database is available to Irish dairy companies by way of scientific publications and provision of customised workshops.

Collaborating Institutions:

N/A

Contact Tim Guinee Email: tim.guinee@teagasc.ie.

Teagasc project team: Dr. Tim Guinee
Dr. Brendan O'Kennedy
Catherine Mullins
Eddie Mullholland
External collaborators: NA

1. Project background:

Recent reports on the US and European cheese markets which together produce ~ 75% of total cheese (~ 13 M tonnes), suggest that cheese used by the ingredient and food service sectors account for at least ~ 30 % of all cheese consumed, but varies from ~ 60% in the USA to 45-50% in UK and Germany, to close to 0% in some east European countries (https://www.perscentrumrabobank.com/publications/food, http://www.girafood.com). It represents the fastest growth sector of cheese consumption, but the manufacture of ingredient cheese requires a relatively high R&D input to develop customer-specific solutions and/or to create novel attributes (e.g., defined deformation behaviour, heat stability, flow resistance, heat-induced fluidity, heating-induced congealing) that differentiate products and attract added value. Cheese products for this market are supplied in many different formats which may be sub-divided into different types/categories: natural named-variety cheeses (e.g., Mozzarella, Cheddar, Emmental), processed cheese products (e.g., slices, sauces, dips), analogue/imitation cheese products, and blends of the latter.

The functional requirements/attributes for cheese products used in these sectors are generally set out in business-to-business relationships which ensure that the cheese delivers a customized ingredient solution. The solutions sought by food service providers and manufacturers of prepared foods include:

- Protocols/formulations/technologies that give the band/range of values of the particular attributes required in the end application, e.g. flow of melted cheese, colour of melted cheese, oiling off, stringiness and chewiness.
- Optimal fit to further processing operations used in prepared foods (e.g., range of slicebality/shred/gratability values; stability: e.g., controlled oiling-off and/or melt during heating, freezing, reheating, altered pH environments)

Processed cheese products (PCPs) are ideally suited to food service/prepared foods, as processed cheese technology offers tremendous potential in diversifying/innovating stability and functional attributes. In contrast to PCPs, natural cheeses offer less flexibility to innovate functional attributes and the functionality is less stable because of protein hydrolysis and fat globule coalescence during maturation.

2. Questions addressed by the project:

The following questions were addressed by the project. What are the effects of alterations in the following variables on the physico-chemical and functional characteristics of PCPs?

- alterations of key processing parameters (time, shear, temperature)
- natural cheese characteristics (intact casein content, calcium-to-casein ratio, degree of proteolysis),
- substitution of cheese protein with milk protein ingredients (micellar casein, milk protein concentrate),
- type and level of emulsifying salts
- product composition (protein-to-fat ratio, pH, moisture)
- storage time and temperature

3. The experimental studies:

PCPs were manufactured at pilot-scale (2.5kg) under controlled conditions, with process variables (treatments) being varied according to experimental design. The PCPs were evaluated for gross composition, minerals, water soluble phase composition, proteolysis, water sorption characteristics (dynamic gravimetric vapour sorption analyzer), texture using large- (Texture analyzer) and low- (controlled stress rheometer) -strain deformation, microstructure (confocal laser scanning microscopy), and melt properties.
All treatments were performed in triplicate and data were statistically analysed using SAS software.

4. Main results:

1. Processing was accompanied by a large increase in solubility of protein (from ~ 12-20% of total protein in natural cheese to ~ 70 -90% in PCP) as a consequence of emulsifying-salt mediated demineralization. Nevertheless, most (~ 80%) of the calcium and phosphorous in PCP remain insoluble in the form of insoluble calcium phosphate or calcium citrate inclusions.

Contact Tim Guinee Email: tim.guinee@teagasc.ie.

2. Reduction of emulsifying salt below a critical level (< 0.75% for disodium orthophosphate) prevented the successful formation of PCP, owing to insufficient calcium removal from, and solubilisation of, the cheese protein.
3. Increasing processing time (1-32 min), temperature (70-95 °C) and shear (300 – 2700 rpm) had similar effects on PCP properties, albeit differing in magnitude of effect: in the unheated PCP, significant increase in firmness and elasticity modulus (G') and significant decrease in fracture strain; in the melted PCP, lower heat-induced flowability and fluidity. These effects, which led to firmer, more brittle and more melt-resistant PCPs, coincided with decreases in protein solubility (as measured by nitrogen solubility) and protein hydration (as measured by dynamic gravimetric vapour sorption analysis).
4. Reducing the intact casein content (from 95 to 75% of total; for example by prolonging the maturation period) or the calcium content of natural cheese from 29.8 to 19.6 mg.g^{-1} (for example by altering the pH at rennet addition) had the following effects on PCPs:
    a. reduced the firmness and fracture stress of the unheated product,
    b. increased the heat-induced flow and fluidity (loss tangent) of the melted product.
5. Increasing the pH of PCP from 5.1 to 6.3 (by pH adjustment of the hot melt formed emulsion in the cooker prior to cooling) significantly reduced soluble protein (from ~ 70 to 20% of total), and simultaneously led to significantly higher firmness and elasticity modulus (G') in the unheated PCP and lower flowability and fluidity of the melted PCP.
6. Increasing the protein-to-fat ratio of PCP from 2. 6 (~ 10.7% fat, ~ 27.7% protein) to 0.38 (~ 31% protein, ~ 11.7% protein), while retaining the ratio of protein-to-emulsifying salt ratio constant, led to significant increases in firmness and elasticity modulus of the unheated PCP, and significant decreases in the heat-induced-flow and fluidity of the melted PCP. These changes coincided with reductions in the levels of water-soluble protein and calcium.
7. Storage of PCPs at 4 or 25 °C over 180 days led to a significant increase in flowability and reduction in viscosity of the melted PCP, with the effect being more pronounced at 4 °C; conversely, the impact on firmness was relatively little. Increasing storage temperature from 4 to 25 °C significantly reduced water soluble N and calcium solubility, and increased the level of primary proteolysis. These changes were paralleled by a significant loss of water (~ 6% of total) from the PCP stored at 25 °C for 180 days.
8. Substitution of cheddar cheese protein to a level of 25% by milk protein concentrate or micellar casein powders (~ 80% protein) reduced the heat-induced flowability of PCP but had relatively little effect on firmness of the unheated PCP. The reduction in flowability increased with the heat treatment applied during manufacture of the MPC.

5. Opportunity/Benefit:

The research provides an extensive database on how the functional properties, such as texture, rehology and melt properties, may be altered by changing different process variables. It provides scientifically supported insights into the mechanisms operating during processed cheese manufacture, and how these may be modulated to control potential defects (such as *overcreaming*, oiling-off, low heat-stability) or to customize product characteristics. This database is available to Irish dairy companies by way of scientific publications and provision of customised workshops.

6. Dissemination:

The results of this project have been thoroughly transferred and in large part implemented by the Irish Cheese manufacturers and Processed cheese manufacturers. Technology Transfer occurred by extensive discussions on trouble shooting/product development with, provision of customised courses for, and other contract research Irish companies.

Main publications:

Guinee, T.P., O'Kennedy, B.T. (2009) 'The effect of calcium content of Cheddar-style cheese on the biochemical and rheological properties of processed cheese' *Dairy Science and Technology* 89: 317-333.

Guinee, T.P., O'Kennedy, B.T. (2012) ' Reducing the level of added disodium phosphate alters the chemical and physical properties of processed cheese' *Dairy Science and Technology* 92: (In press: http://www.springerlink.com/content/b00r825111w33374/fulltext.pdf)

Guinee, T.P. (2011) 'Effects of natural cheese characteristics and processing conditions on the rheology and texture: The functionality of cheese components in the manufacture of processed cheese' In *Processed Cheese and Analogues* (ed. Tamime, A. Y.), pp. 81-109, Blackwell Publishing Limited, London.

Contact Tim Guinee Email: tim.guinee@teagasc.ie.

Popular publications:

Guinee, T.P. (2007) 'Processed Cheese.' In *Cheese problems Solved* (ed. P.L.H McSweeney), pp. 365-388, Woodhead Publishing Limited, Boca Raton.

Guinee, T.P. (2011) 'Pasteurized processed cheese products'. In *Encyclopedia of Dairy Sciences, Second Edition* (eds. Fuquay J.W., Fox, P.F., McSweeney, P.L.H), 805-813, Academic Press, San Diego, USA.

7. Compiled by: T. P. Guinee

Contact Tim Guinee Email: tim.guinee@teagasc.ie.