Improving the Quality of Low Fat Cheddar Cheese

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Project Team:
T.P. Guinee (Leader)
M. Fenelon
B.T. O'Kennedy
E.O. Mulholland

The Dairy Products Research Centre
Moorepark, Fermoy, Co. Cork.

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Summary and Conclusions

The association between the type and level of dietary fat and the risk of arteriosclerosis and related health problems has led to greater consumer awareness and demand for reduced-fat foods. Compared to other low fat foods, the consumption of reduced-fat cheese as a percentage of overall cheese consumption, is still low (approx. 8% in the UK) but is growing at a faster rate albeit from a smaller volume base, than the mainstream full-fat cheese market. The low consumption has been attributed to the generally poor consumer perceptions of reduced-fat products, owing to flavour and texture defects. Reduced-fat Cheddar is frequently perceived as being dry, mealy, excessively firm and elastic and difficult to masticate and lacking typical Cheddar flavour and aroma.

Hence the aims of this study were to elucidate the contribution of fat to cheese biochemistry and texture and to improve the texture and flavour of half-fat Cheddar cheese by modifications in make procedure, the addition of a fat mimetic, and/or the use of novel starter cultures/bacterial culture adjuncts.

The main conclusions were as follows:

- A 'Moorepark Process' has been established for the production of half-fat Cheddar cheese with improved sensory acceptability. The flavour and texture of half-fat (17% w/w) Cheddar was improved by modification of the cheesemaking procedure and/or ripening conditions and through the use of novel starter cultures and/or bacterial culture adjuncts.
- Extensive databases have been compiled on:
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    - the effects of fat on the compositional, microbiological, biochemical, rheological and sensory properties of, and the yield of, Cheddar cheese.

    - the compositional, biochemical and sensory characteristics of commercial Cheddar cheeses of different fat levels, available on the Irish and UK markets.
- Reduction in the fat level of Cheddar cheese resulted in a marked deterioration both in texture and flavour due to:
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    - increases in cheese hardness and fracture stress, indicating that the cheese became more elastic, tough and less amenable to mastication.
    - a higher ratio of secondary-to-primary proteolysis
    - a reduction in the level of primary proteolysis and an increase in the concentration of hydrophobic peptides which are conducive to bitterness.

Commercial impacts

- Industry commissioned trials in pilot plant and in factory on the evaluation of starter cultures and/or culture adjuncts, and fat mimetic in the manufacture of reducted-fat Cheddar cheese, and a part-filled reduced-fat Cheddar cheese were successfully undertaken.

Research and Results

Survey of commercial Cheddar cheeses of different fat levels

Commercial Cheddar cheeses from Irish and UK retail outlets were arbitrarily categorised into three groups based on fat content, namely full-fat (FF; 30-36% w/w), reduced-fat (RF; 19-24% w/w) and half-fat (HF; 13-18% w/w). Fat level significantly influenced cheese composition but not the mean levels of primary or secondary proteolysis *(Table 1)*. There was no relationship between the flavour (as described by the label, e.g. mild, full-flavoured) and fat level.

However, the use of descriptive sensory analysis revealed that variation in fat level resulted in differences in the intensity of some sensory attributes.

Table 1. Composition and proteolysis in commercial Cheddar cheeses of different fat contents.

Fat category*			
	HF (13 - 18%)	RF (19 - 24%)	FF (30 - 36%)
1. Composition			
Moisture (g/100g)	45.2 (41.3-50.4)[a]	42.5 (38.7-45.2)[b]	35.6 (33.0.39.0)[c]
Protein (g/100g)	32.4 (30.4-33.7)[a]	29.8 (28.6-31.4)[b]	25.5 (25.5-27.3)[c]
Fat (g/100g)	15.7 (13.0-18.0)[a]	21.7 (19.5-24.0)[b]	33.6 (30.0-36.0)[c]
**FDM (g/100g)	28.6 (25.5-32.0)[a]	37.6 (34.6-40.6)[b]	52.2 (49.3-56.3)[c]
***MNFS (g/100g)	53.6 (49.2-57.9)[a]	54.3 (50.0-57.4)[a]	53.7 (50.4-56.4)[a]
S/M (g/100g)	4.3 (3.6-5.1)[a]	4.4 (3.1-5.8)[a]	5.6 (4.9-6.2)[b]
2. Proteolysis			
pH4.6 soluble N(%TN)	19.1 (13.4-23.7)[a]	18.2 (13.5-22.8)[a]	22.0 (15.2-27.5)[a]
PTAN (%TN)	5.3 (2.2-10.3)[a]	4.3 (2.2-7.1)[a]	4.2 (1.5-10.9)[a]
Free amino acids (mg/g)	14.2 (2.9-27.5)[a]	12.2 (5.7-21.8)[a]	10.0 (2.2-25.6)[a]

* Cheeses grouped on the basis of fat: half-fat (HF), reduced-fat (RF) and full-fat (FF).
** FDM, fat in dry matter.
*** MNFS, moisture in non fat substance.
[abc] Values within a row with a common superscript are significantly different (P < 0.05).

Sensory analysis indicated that of the twenty-two terms used to describe the flavour, only three significantly distinguished cheeses of different fat content. These were the characteristics "buttery", "creamy" and "caramel", which increased in the order HF < RF < FF. The descriptive attributes "creamy", "buttery" distinguished full-fat cheeses from both reduced-fat and half-fat cheeses and the attribute "caramel" distinguished full-fat cheeses from half-fat cheeses. There were more marked sensory differences between cheeses in terms of flavour designation on the retail package (e.g. mature or mild). Mature cheeses (regardless of fat content) were significantly more "pungent", "cheddary", "fruity", "smoky" and "strong" than mild cheeses and significantly less "processed".

Numeric differences, in a stepwise order (mild < miscellaneous < mature) were found for "mouldy", "burnt caramel", "mushroom", "sweaty", "salty", "acidic", "bitter" and "astringent" attributes. These stronger flavours reflect the observed differences in proteolysis between cheeses as those with stronger flavours were typified by high levels of primary and secondary proteolysis. However, there were also inter-category differences for the stronger flavours which may reflect the different fat contents of cheeses in each category, or may reflect the manufacturers' flavour designation on the package.

Improvement of texture of half-fat (16-17%) Cheddar

Texture improvement, as reflected by a reduction in fracture stress and firmness, in half-fat cheese was achieved by:

- high heat treatment of milk (77ºC compared to 72ºC), an effect attributed to reduction in the degree of casein-casein aggregation due to the complexing of denatured whey proteins with the casein (Fig. 1).
- the addition of whey protein-based fat substitute (Dairy LoTM) to the cheese milk.
- raising curd milling pH in the range 5.35 to 5.75 (Fig. 2), an effect attributable to the increase in the moisture-to-protein ratio in the cheese.
- increasing the ripening temperature from 7 to 12ºC during the first 120 days of ripening, which resulted in an increase in the degree of casein degradation (as reflected by the higher levels of N solubility at pH 4.6) during maturation (Fig. 3).

Fig 1

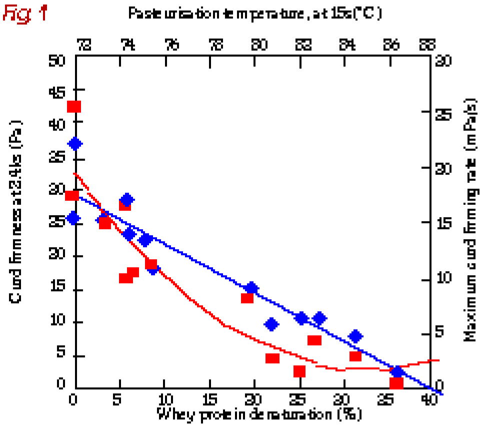

Fig. 1. Influence of pasteurisation temperature at 15 s and whey protein denaturation on the curd-forming properties of renneted reduced-fat milks: maximum curd firming rate during rennet coagulation (—)on the curd firmness attained at 2.4 ks after rennet addition (—).

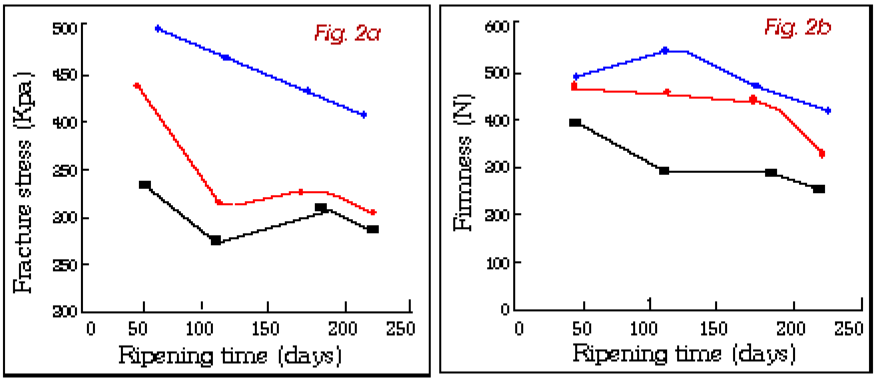

Fig. 2 (a & b) The rheological characteristics of full-fat (▬) and reduced-fat (17% w/w) Cheddar cheeses manufactured using a control (▬) or modified procedure (high pH at curd milling) (▬).

Improving the flavour of half-fat Cheddar

Having established a modified cheesemaking procedure which delivered an improved

texture, novel starter cultures and/or culture adjuncts were then used to obtain a parallel improvement in the flavour. Flavour improvement, as reflected by an increase in scores awarded by commercial graders, was achieved by two processes: (a) increasing the ripening temperature from 7 to 12ºC (during the first 150 days of ripening) of Cheddar cheese made using the modified make procedure and a bacteriocin-producing culture, and (b) the use of the modified make procedure in conjunction with selected commercial culture adjuncts *(Table 2).* Both of these treatments resulted in higher levels free amino acids (FAA) and low molecular mass peptides *(Fig. 4).*

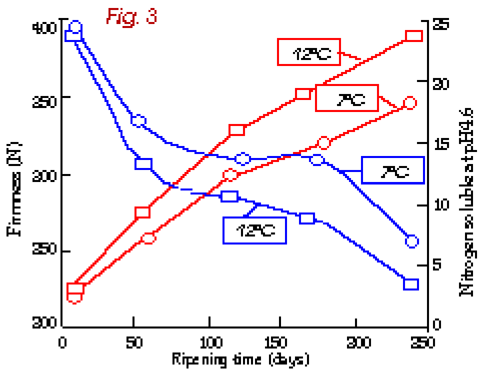

Fig 3. The firmness (▬) and levels of casein degradation (N soluble at pH 4.6) (▬) in half-fat Cheddar cheeses ripened at 7° or 12°C.

Table 2. The effect of ripening temperature and culture system on the grading scores awarded to half-fat Cheddar cheese by commercial graders after 90 and 180 days maturation.

		Ripening temperature	Flavour scores		Texture scores	
1	Starter culture type	(ºC)	90d	150d	90d	150d
	Control *(Lc. Lactis* ssp *cremoris/lactis)*	7	38.0	38.3	33.0	33.0
		12	38.3	38.8	33.0	32.3
	Bacteriocin producing *Lc. lactis* ssp*lactis*	7	38.0	38.0	33.0	33.0
		12	38.0	38.8	33.0	33.0
2.	Adjunct type	(ºC)	90d	180d	90d	180d
	None (control)	7	37.7	38.5	33	33
	Lb. Helveticus	7	38.5	39.3	33	32.7
	Blend of *Lb. Helveticus*, *Str. thermophilus, Lactococcus lactis* var *diacetyl lactis*, and *Leuconostoc cremoris*	7	38.0	39.0	33	32.7

**Lactococcus lactis* subsp *cremoris/lactis* was used as the acid producing strain in all trials investigating the effect on bacterial adjuncts on cheese quality.

The bacteriocin-producing culture used consisted of a single starter strain which both produces, and is immune to, a bacteriocin (*Lacticin 3147*), which is effective against non-starter lactic acid bacteria (NSLAB). The latter are an adventitious microflora which grow in all cheeses during ripening and can influence cheese flavour adversely or positively. Owing to the variability in population and strain composition, NSLAB can lead to inconsistencies in cheese flavour and quality. Their numbers in cheese tend to increase in cheese as the ripening temperature is elevated and as its moisture level is raised. The current use of the bacteriocin-producing culture enabled reduced-fat Cheddar with a high moisture-to-protein ratio to be ripened at relatively high temperature (e.g.12 compared to 7ºC) without the risk of spoilage by high populations of undesirable NSLAB.

While a total of 5 different bacterial adjuncts were assessed, two in particular were found to enhance the flavour, and contribute novel sweet flavours to the cheese, when used with the modified cheesemaking process. The use of these adjuncts, which consisted mainly of thermophilic Lactobacilli and *Streptococcus thermophilus* var *lactics* and *Leuconostoc* resulted in significantly higher levels of free amino acids and lower molecular mass (<500 Da) peptides compared to the control half-fat Cheddar *(Fig. 4 a & b).*

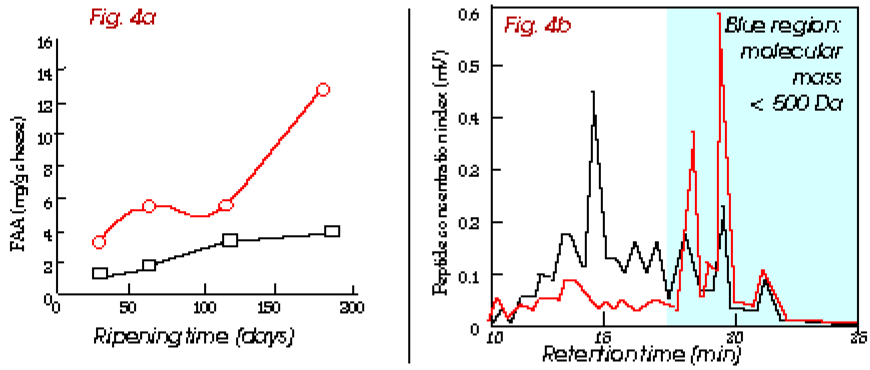

Fig. 4 a & b. The effect of adding bacterial adjunct (Lb. helveticus) on the development of non volatile flavour compounds, i.e. free amino acids (a) and low molecular mass peptides (b), in half-fat Cheddar cheese. Cheeses: without adjunct control (▬), cheese with adjunct (▬).

The effect of fat level (i.e. in the range 5 to 33%) on the composition, yield, biochemical, textural and sensory characterisitcs of Cheddar cheese

Analysis of experimental Cheddar cheeses of varying fat content (i.e. full-fat, 33% w/w; light, 22% fat; reduced-fat, 17% w/w; and low-fat, 5% w/w) revealed that reduction in fat level was paralleled by:

- an increase in the concentration of structural paracasein matrix per unit volume and a lower extent of fat globule clumping (Fig. 5)
- lower levels of primary proteolysis, as measured by N solubility at pH 4.6 (as % total N)
- higher levels of secondary proteolysis, as measured by levels of free amino acids (% w/w).
- marked increases in hardness, firmness and toughness as detected using textural profile analysis (Fig. 6)
- a slower growth rate of non-starter lactic acid bacteria in the cheese and

- a linear reduction in actual cheese yield, with that of the low-fat cheese being only ~66% of that of the full-fat cheese.

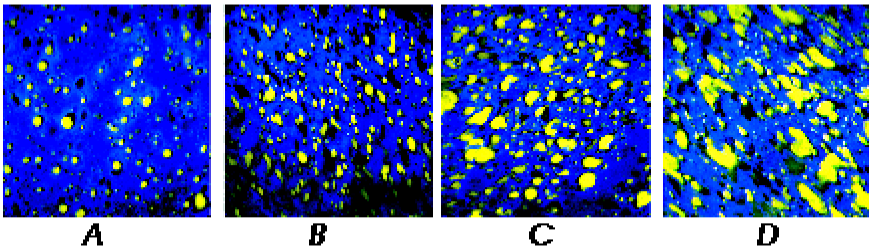

Fig. 5. Confocal laser scanning micrographys of Cheddar cheeses of varying fat content (%w/w): A, 6: B, 17; C, 22 and D, 33. Blue = protein matrix, yellow = fat phase.

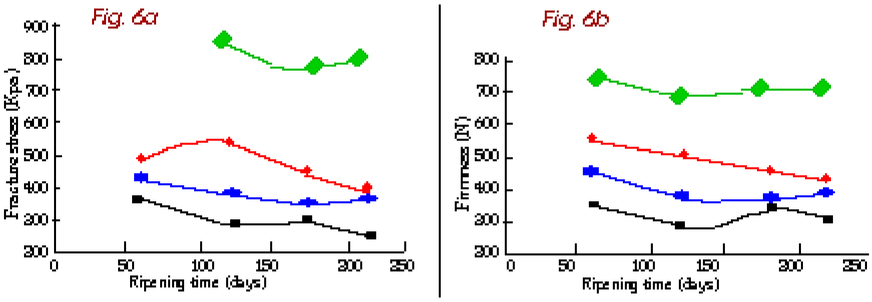

Fig. 6 a & b. The effect of fat content on the rheological characteristics of Cheddar cheese; full-fat (▬), reduced-fat (▬), half-fat (▬) and low-fat (▬).

For further information, contact:

Dr T.P. Guinee

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