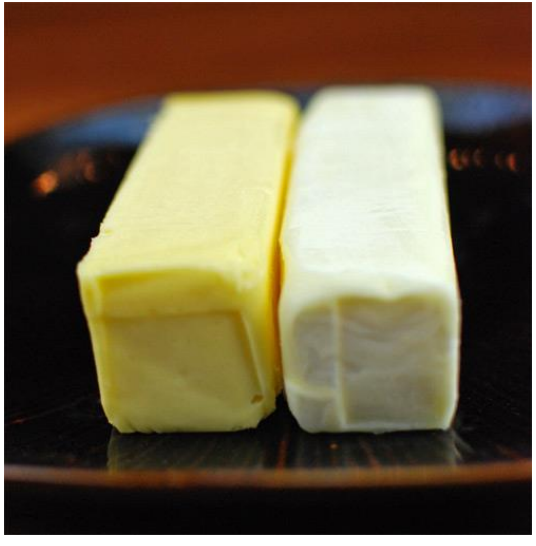
Drivers and trends for future dairy processing



Professor Alan Kelly
University College Cork, Ireland

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Processing milk – a fragile resource

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Physical separation, microbiological spoilage
Prevent with processing

Milk: a test-bed for processing

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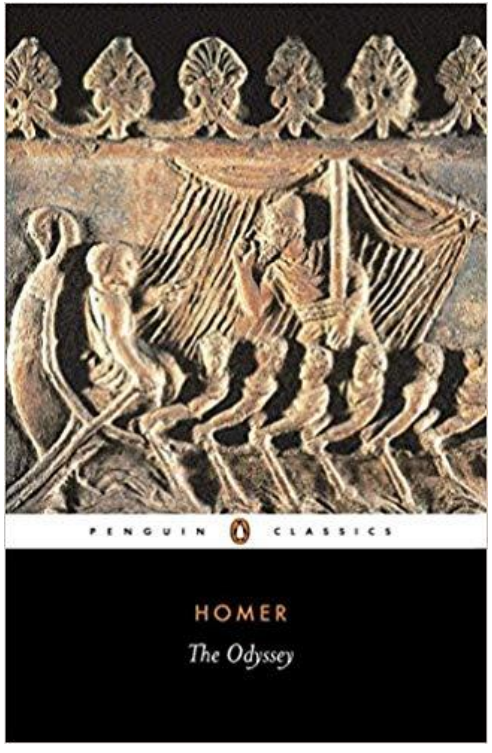

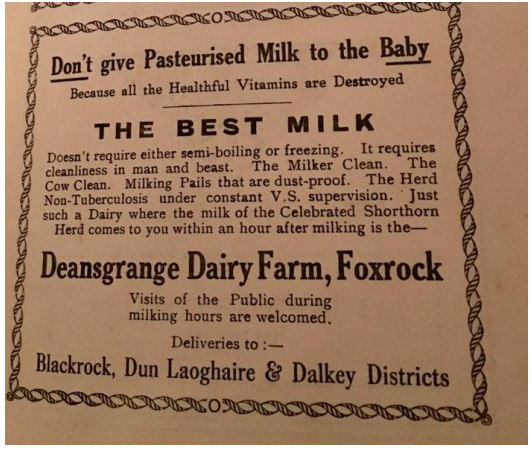

Processing dairy today

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University College Cork, Ireland

A complex matrix

- Multicomponent (fat, protein, lactose, minerals)
- Multiphase (emulsion, colloidal suspension)
- Biologically active (e.g., enzymes)
- Physically and microbiologically unstable

Complex processing

- Ensuring safety
- Stabilisation
- Separation
- Transformation
- Complexation

Drivers and threats for dairy processing today

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- Processed/ultra processed concerns
- Quality vs stability
- Threats from non-dairy ‘milks’
- Fear of dairy?
- Allergens
- Sustainability and the environment
- Animal welfare/veganism
- ‘Naturalness’
- Consumer confusion
- **New technologies**

Heavily processed food like ready meals and ice-cream linked to early death

Two major studies add to body of evidence against foods made with industrial ingredients

Processed foods make us fatter, lead to cancer, and are linked with early death. But what exactly is a processed food?

Industrial formulations typically with 5 or more and usually many ingredients. Besides salt, sugar, oils, and fats, ingredients of ultra-processed foods include food substances not commonly used in culinary preparations, such as hydrolyzed protein, modified starches, and hydrogenated or interesterified oils, and additives whose purpose is to imitate sensorial qualities of unprocessed or minimally processed foods and their culinary preparations or to disguise undesirable qualities of the final product, such as colorants, flavorings, nonsugar sweeteners, emulsifiers, humectants, sequestrants, and firming, bulking, de-foaming, anticaking, and glazing agents.

The Observer
Milk

Creamy, untreated and in a glass bottle: Britain's taste f

Dairy farmers cash in on a gr homogenisation and plastic

Freya Herring

Over 50 cases of food poisoning from raw milk investigated

Margaret Donnelly
EMAIL

PUBLISHED
20/01/2017 | 16:34

SHARE

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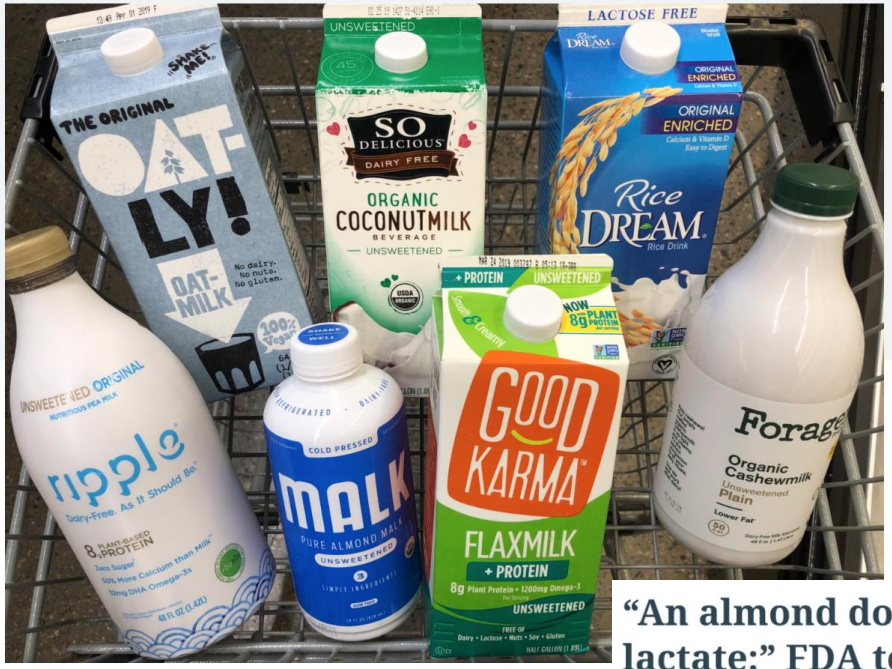
It is understood that the farm operated a vending machine on site for the distribution of milk.

Over 50 cases of cambylobacter food poisoning connected with the consumption of raw milk is being investigated by the Food Standards Agency in the UK.



The long read

White gold: the unstoppable rise of alternative milks

How wellness upstarts spoiled milk's healthy reputation – and built a billion-dollar industry from juicing oats and nuts.

By Oliver Franklin-Wallis

"An almond doesn't lactate:" FDA to crack down on use of the word "milk"

Beth Mole · 07/18/2018 5:32 pm · Policy

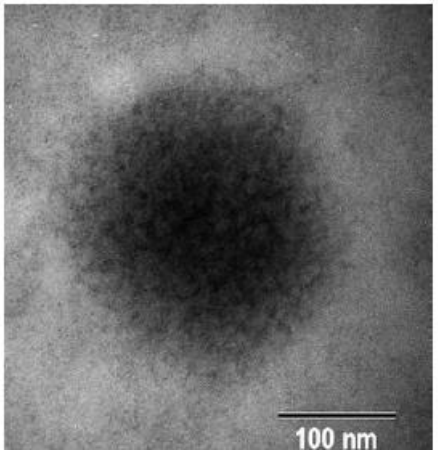
View non-AMP version at arstechnica.com

Reasons People Try a Non-Dairy, Milk-Alternative

- ✓Lactose intolerance
- ✓Milk allergy
- ✓Don't like milk, but like creamy taste or need a milk-like product for cooking
- ✓Vegan diet or lifestyle
- ✓Concerns about inflammation
- ✓Crohns and Colitis or inflammatory bowel syndrome
- ✓Concerns over antibiotics, pesticides, or hormones
- ✓Ethical concerns

A threat?

Perfect Day™



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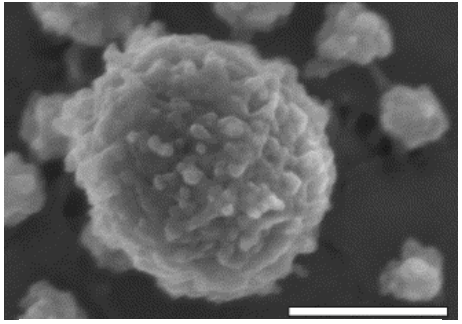

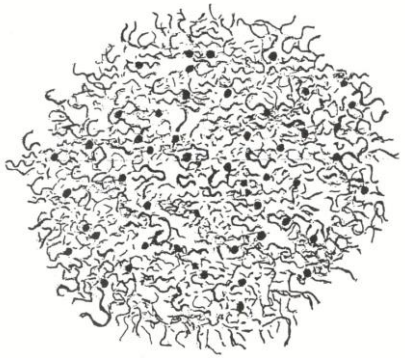

- Whey proteins ‘easy’ to produce by precision fermentation
- Caseins **are not** casein micelles
- Micelles (structure, PTM) a ‘wicked problem’

The A2 milk story

Identification of bioactive peptides and quantification of β-casomorphin-7 from bovine β-casein A1, A2 and I after ex vivo gastrointestinal digestion

Tora Asledottir [a,*], Thao T. Le [b], Bjørn Petrat-Melin [b], Tove G. Devold [a], Lotte B. Larsen [b], Gerd E. Vegarud [a]

[a] Faculty of Chemistry, Biotechnology and Food Science, Norwegian University of Life Sciences, Chr. Magnus Falsens vei 1, 1430, Aas, Norway
[b] Department of Food Science, Aarhus University, Blichers Allé 20, 8830, Tjele, Denmark

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ABSTRACT

This study investigated whether different genetic variants of β-casein (β-CN) give rise to different bioactive peptides during digestion. β-CN was purified from bovine milk of genetic variants A1, A2 and I, and digested with human gastrointestinal juices in a static ex vivo model. Mass spectrometry analyses revealed that the peptide ^{60}YPFPGPIPN^{68} was exclusively identified from variants containing proline at position 67. Most strikingly, the opioid peptide β-casomorphin-7, ^{60}YPFPGPI^{66}, was identified from both variants A1 and A2 after simulated digestion, though with concentration being somewhat higher after digestion of the variant A1, compared with variants A2 and I. The peptides ^{134}HLPLP^{138} and ^{133}LHLPLP^{138} were both identified after initial 5 min of duodenal digestion. In conclusion, genetic variation of β-CN may affect proteolysis during digestion; however, the release of β-casomorphin-7 (BCM7) does not seem to be linked solely to variant A1, as earlier suggested by relevant published literature on in vitro digestion.

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GM and future milk?

Genetically modified cows produce 'human' milk

Scientists have created genetically modified cattle that produce "human" milk in a bid to make cows' milk more nutritious.

Researchers say they are able to create cows that produce milk containing a human protein called lysozyme Photo: PA

Genetic Modification

News » China »
Science »
Science News »
Earth News »

In Agriculture

Spectacular striped tulip fields

GM cow: low allergy milk, but no tail

02/10/2012

Like 4.2k

By Ingrid Hipkiss

New Zealand scientists have created a new kind of milk – one that doesn't trigger allergies.

It comes from a genetically modified cow named Daisy, and her creators are hailing it as a scientific breakthrough. But opponents of GM say it's no more than a macabre experiment.

Scientists at AgResearch tried for six years to create a cow like Daisy. The eureka moment came when they milked her in April.

"We were very excited seeing the result," says Dr Stefan Wagner.

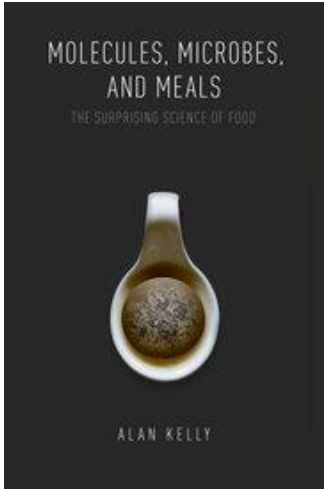
What scientists wanted was a cow that produced milk that could be drunk by the one in 50 people, mostly infants, who are allergic to milk. Their aim was to reduce a protein, called BLG, that triggered the allergy. What they got was even better.

"We could actually not see any of the protein," says Dr Wagner.

But anti-GM lobbyists are alarmed – not least because Daisy was born without a tail, and her creators aren't sure why.

"They've proved it in theory, but as I say, at what cost?" says Jon Carapiet, spokesman for GE Free New Zealand. "The animal's got no tail. What else the genetic engineering and cloning processes have done to it, we don't know."

Communication about milk in Ireland



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Grass-based milk production

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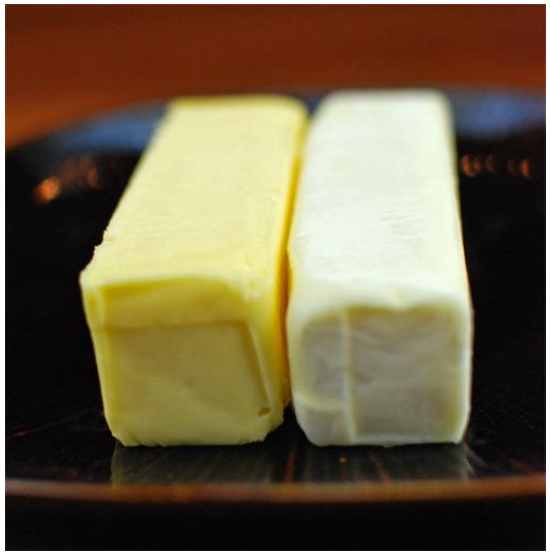

Irish dairy produce has better qualities than other countries - study

Updated / Monday, 12 Dec 2016 **16:32**

RTÉ News
@rtenews

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A new study by scientists has found that Irish full-fat cheddar cheese does not raise total blood cholesterol | Read more: bit.ly/2wgaT7O

12:25 pm - 27 Aug 2018

48 Retweets **165** Likes

Major research focus

J. Dairy Sci. 99:9441–9460
http://dx.doi.org/10.3168/jds.2016-11271

Quality characteristics, chemical composition, and sensory properties of butter from cows on pasture versus indoor feeding systems

Tom F. O'Callaghan,*†‡ Hope Faulkner,‡ Stephen McAuliffe,§# Maurice G. O'Sullivan,‖ Deirdre Hennessy,¶ Pat Dillon,¶ Kieran N. Kilcawley,‡ Catherine Stanton,*‡ and R. Paul Ross*‡¶[1]
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†Department of Microbiology, University College Cork, Cork, Ireland
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¶College of Science Engineering and Food Science, University College Cork, Cork, Ireland

J. Dairy Sci. 100:6053–6073
https://doi.org/10.3168/jds.2016-12508

Effect of pasture versus indoor feeding systems on quality characteristics, nutritional composition, and sensory and volatile properties of full-fat Cheddar cheese

Tom F. O'Callaghan,*†‡ David T. Mannion,* Deirdre Hennessy,§ Stephen McAuliffe,§# Maurice G. O'Sullivan,‖ Natasha Leeuwendaal,*‡ Tom P. Beresford,* Pat Dillon,§ Kieran N. Kilcawley,* Jeremiah J. Sheehan,* R. Paul Ross,*†¶ and Catherine Stanton*†[1]
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#School of Biological Sciences, Queen's University, Belfast, BT7 1NN, United Kingdom
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¶College of Science Engineering and Food Science, University College Cork, Cork, Ireland T12 YN60

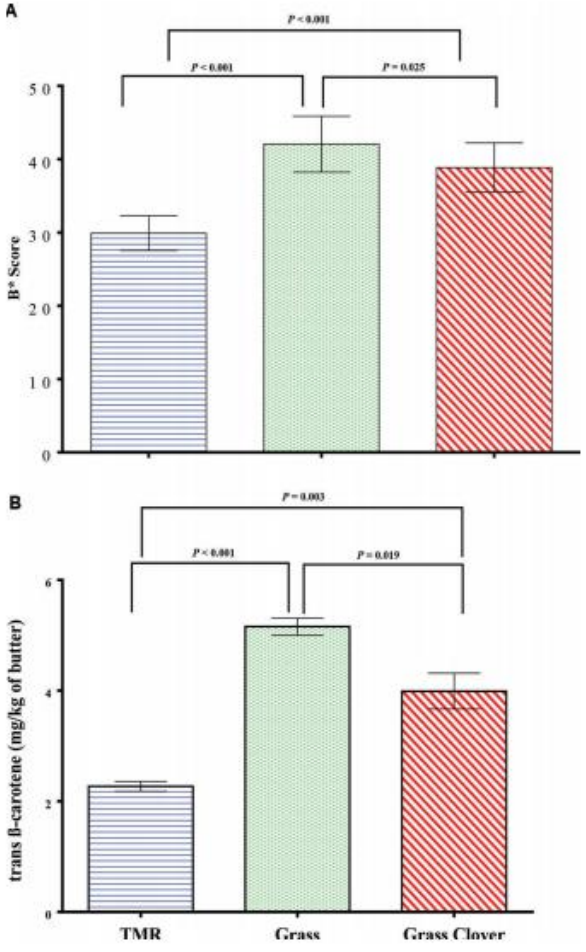
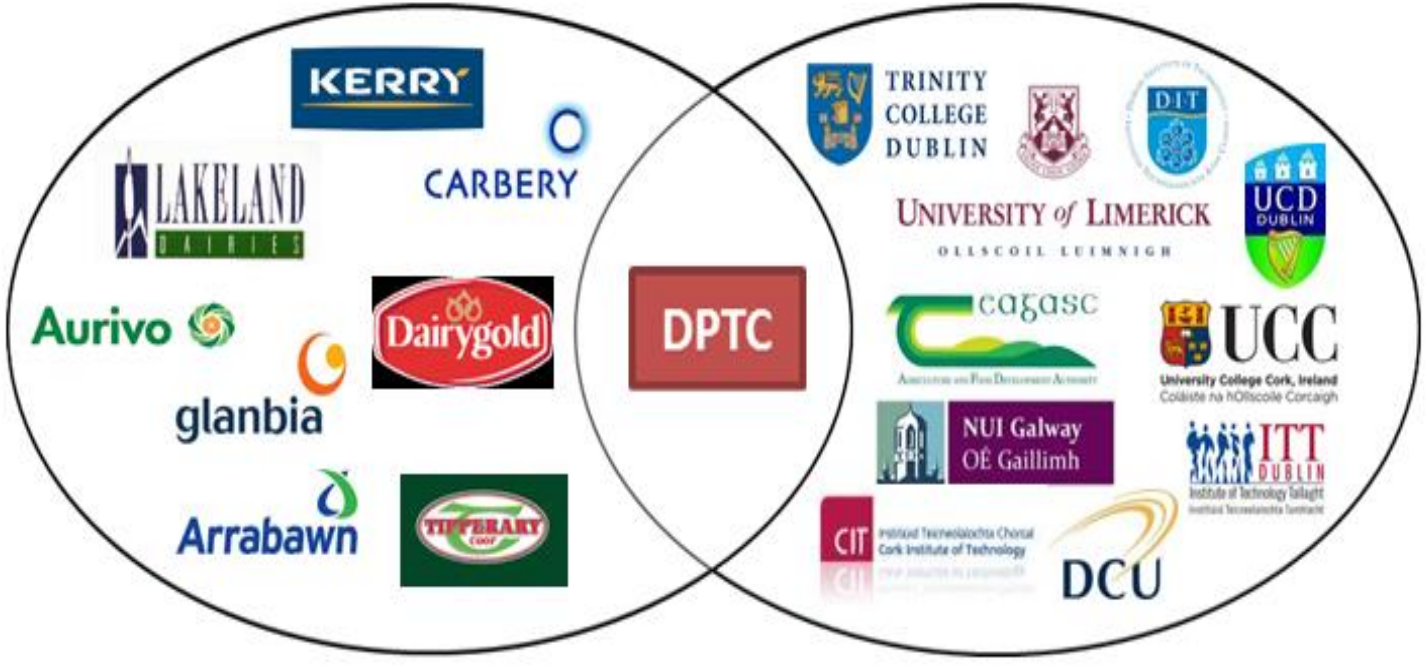


Figure 3. Relationship between cow feeding systems [TMR, perennial ryegrass (grass), and perennial ryegrass and white clover (grass clover)] and the color scores of butter in the blue–yellow axis (b*) and the *trans*-β-carotene content of butter. *Trans*-β-carotene and b* values appear to be positively correlated ($r = 0.899$); they are highest in pasture and lowest in TMR butters. Color version available online.

The industry-academia dairy complex

- Industry-led or –linked research and technology centres
- 5 year cycles, €15-25 million budgets
- 4-8 industry partners, 4-8 academic partners
- Enterprise Ireland/Science Foundation Ireland funding
- Major mechanism of dairy funding in Ireland – pros and cons



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DAIRY PROCESSING TECHNOLOGY CENTRE

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VistaMilk

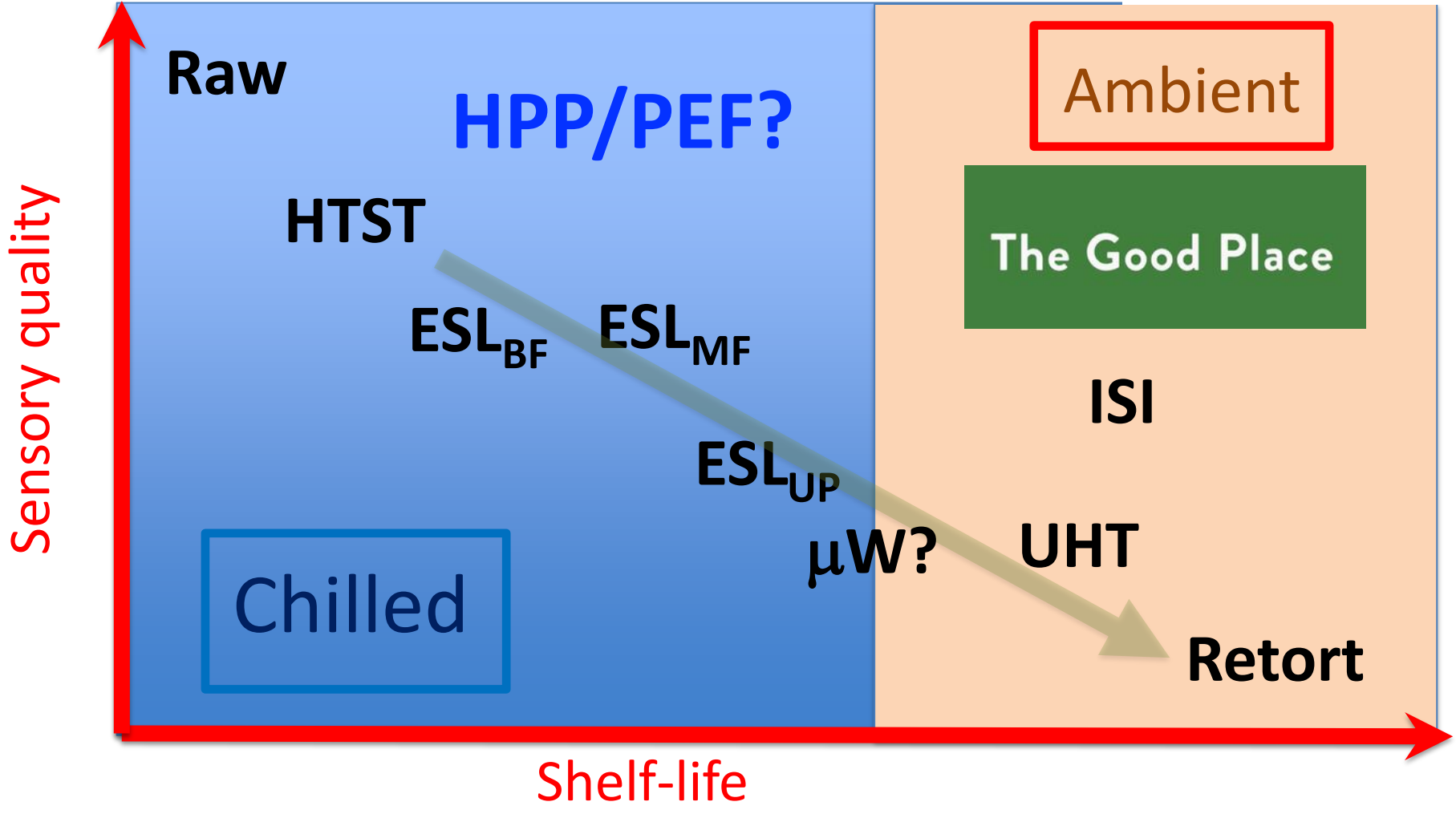
Novel approaches to milk processing

Table 8.1 Overview of different novel milk-processing methods and their efficacy for inactivation of bacteria, spores and enzymes, and their influence on the retention of sensorial characteristics of the treated product.

Milk-processing methods	Main process parameters	Development status for dairy products	Bacterial inactivation	Spores inactivation	Enzymes inactivation	Retention of sensorial characteristics
Microwave heating	Frequency, t, T	Laboratory scale	+	+/−	+/−	Improvement compared to conventional heating
High pressure (HP)	P, t, T	Pilot phase	+	+/−	−	Significant if operation is executed at room temperature
Pulsed electric fields (PEF)	Field strength, pulse number, frequency, and width	Pilot phase	+	−	−	Significant if operation is executed at room temperature
Ultrasound	Frequency, t	Laboratory scale	+/−	+/−	−	Ultrasound is effective in combination with increased temperature and pressure, but ultrasound itself has no significant effect
Microfiltration (MF)	Membrane type, flow conditions, P, cleaning frequency	Commercialised	+	+	−	Significant
Innovative steam injection (ISI)	t, T	Pilot phase	++	++	+	Improvement compared to ultra-high-temperature (UHT) treatment, similar to pasteurisation

Note: T = temperature; t = time; P = pressure; −negligible effect; +/− minor effect; + effect; ++ significant effect.

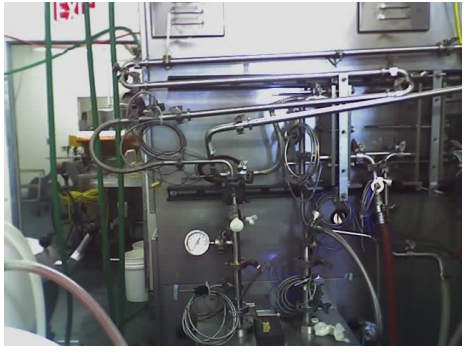
The milk processing map



An analogous problem in search of a novel solution: fruit juice

The problem:

- Heat-labile nutritional and sensory characteristics
- Short unprocessed shelf-life due to microbial spoilage

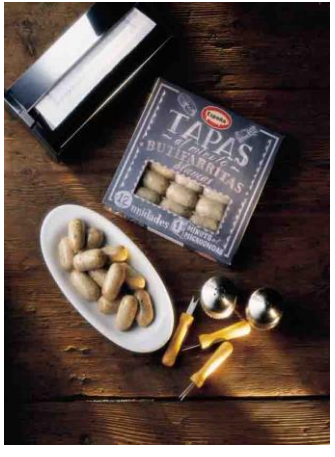


The solution:

- Use of high pressures or pulsed electric fields to achieve microbial inactivation while retaining fresh-like characteristics

High-pressure processing

- First shown to preserve milk over 100 years ago
- Commercially available food systems since 1990
- Exponential increase in applications in recent years
- Limited by scale, cost and batchwise nature
- Nevertheless, breakthrough success for specific food applications
- Minimal nonthermal processing



Introducing our new 330ml bottle for added convenience and on-the-go health.

Now available in over 100 of Irelands favourite stores including Supervalu, Londis, Spar and Centra!

Up to 5lbs of natural goodness in every bottle

Not all juices are created equal check out why cold pressing is the best!

HPP dairy products

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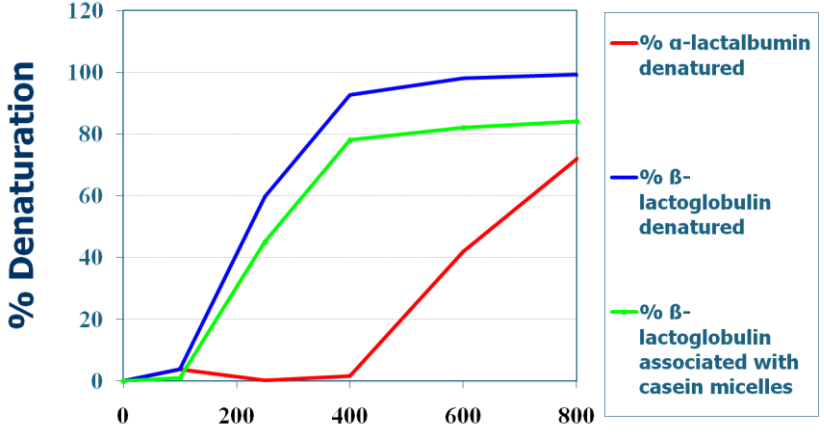
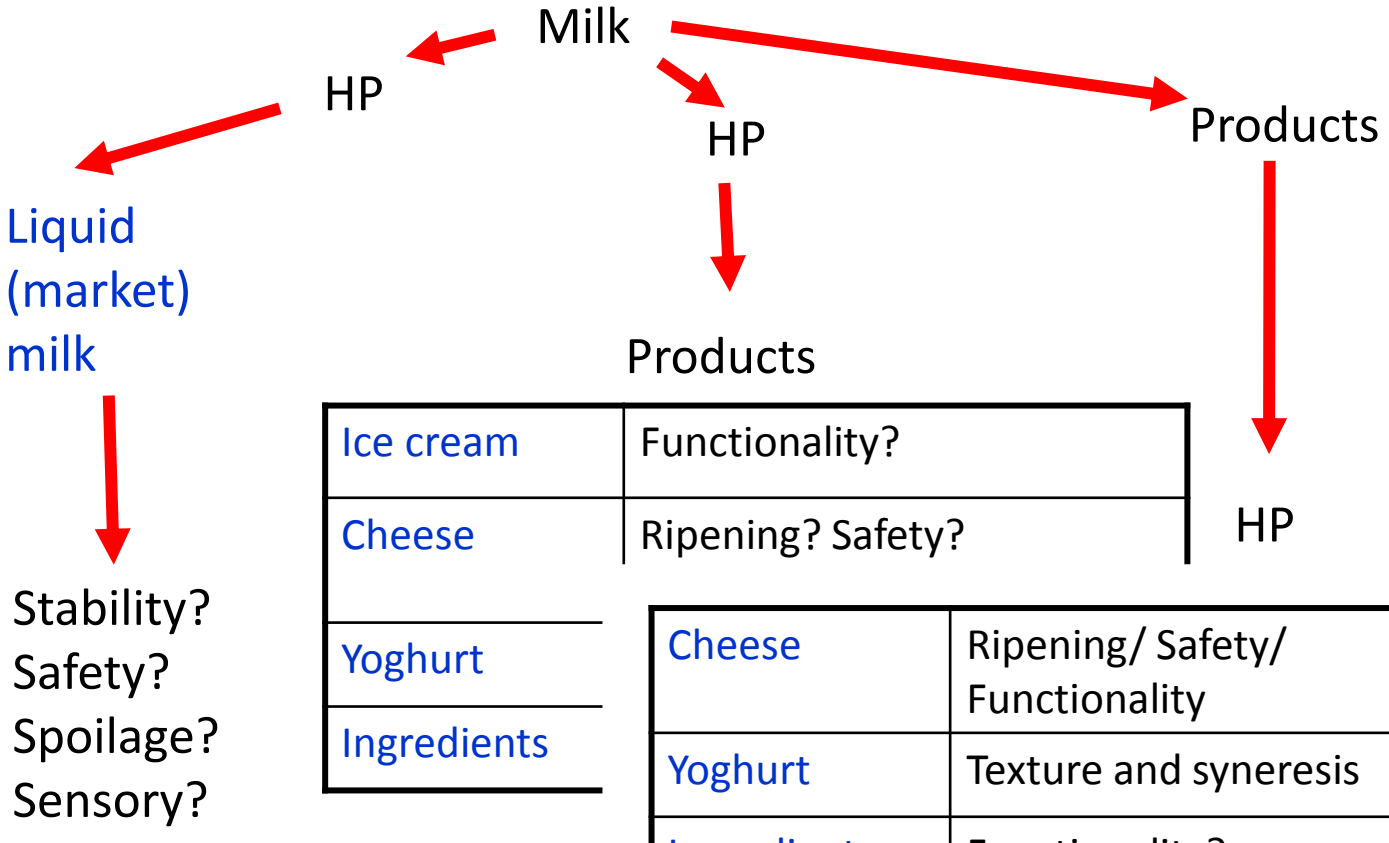
Effects of HPP on Milk Constituents

- ***Casein Micelles:*** disruption or aggregation (colour change)
- ***Minerals:*** solubilisation of colloidal calcium phosphate (CCP)
- ***Whey Proteins:*** denaturation and association with casein micelles
- ***Fat Globules:*** Size unchanged up to 600 MPa but creaming reduced
- ***Microbial inactivation:*** Most vegetative microorganisms inactivated by HP processing in range 400-600 MPa.



HPP and Dairy Processing



Ice cream	Functionality?
Cheese	Ripening? Safety?
Yoghurt	
Ingredients	

Cheese	Ripening/ Safety/ Functionality
Yoghurt	Texture and syneresis
Ingredients	Functionality?

High pressure and milk bioactives?

- Increasing interest in recovery of biologically-functional proteins from milk and whey
- How to achieve microbial stability without loss of such functionality?
- Potential for use of HPP at tailored conditions of pH
- Commercialised for colostrum products

(19) **United States**

(12) **Patent Application Publication**
Palmano et al.

(10) **Pub. No.: US 2008/0166466 A1**

(43) **Pub. Date: Jul. 10, 2008**

(54) **HIGH PRESSURE PROCESSING OF METAL ION LACTOFERRIN**

(86) PCT No.: **PCT/NZ2006/000038**

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NEWS HEADLINES > **PRODUCTS**

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Fonterra innovation takes colostrum into functional beverages

By Jess Halliday, 29-Mar-2007

Related topics: Products

Fonterra has developed a technique that allows colostrum to be added to ready-to-drink beverages with a longer shelf-life, opening up opportunities for new kinds of products and building sales of the ingredient in Asia.

The problem that remains…..

- Heat-resistant bacterial spores are also pressure-resistant
- Applications need to control spores by other methods
- Potential for sterilisation at lower temperatures combined with high pressures
- Also possible interest in germinating spores by pressure for later inactivation by heat or pressure
- Otherwise, need chilled products

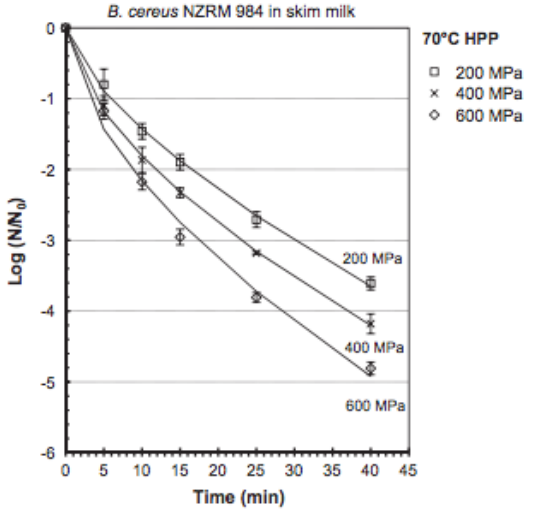


Fig. 2. Weibull model fitted to the inactivation of psychrotrophic *B. cereus* NZRM 984 (=ATCC 11778) spores in skim milk at high pressure (200, 400, and 600 MPa) combined with 70 °C (data points are average ± standard deviation).

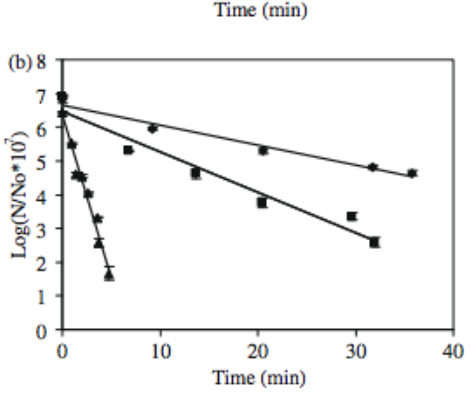


Fig. 5. Uncorrected (a) and temperature corrected (b) survivors of *C. sporogenes* 11437 spores in high-pressure treated milk at 700 MPa and different temperatures: (♦) 80 °C, (■) 90 °C, (▲) 100 °C.

What is cold pressed raw milk?

Through careful herd management and more hygienic milking practices, we begin with healthier cows, then our high quality milk goes directly from cow to bottle. After sealing the bottles, they're placed under extreme cold water pressure, via a patented, world first, cold pressing technique that is equivalent to taking the milk six times deeper than the deepest part of the ocean. This eliminates any harmful bacteria, whilst being gentler on milk's nutrients - thus retaining more of milk's natural goodness. The result is a milk that's deliciously creamy and as close to drinking milk direct from the cow as you can get. We reckon it's going to change the world. Well, the milk world.

Is it safe to drink?

We use a 3 stage process to guarantee our cold pressed raw milk is 100% safe to drink, which involves:

Careful herd management
Our cows are well fed, regularly checked by a vet and all of them carry heat-time monitors (a fitbit for cows) tracking their activity and sleep patterns in real time.

More hygienic milking practices
We pay extra attention to cleaning our milking equipment and our cow's udders.
It's all part of a food safety plan especially designed for our dairy.

Cold high pressure to make it safe
Our patented cold pressure production method removes the harmful bacteria in raw milk, whilst retaining more of milk's natural goodness.

The NSW Food Authority has approved our cold pressing method as being as safe or safer than heat pasteurization and every batch of Made by Cow milk is tested before it goes out to stores.

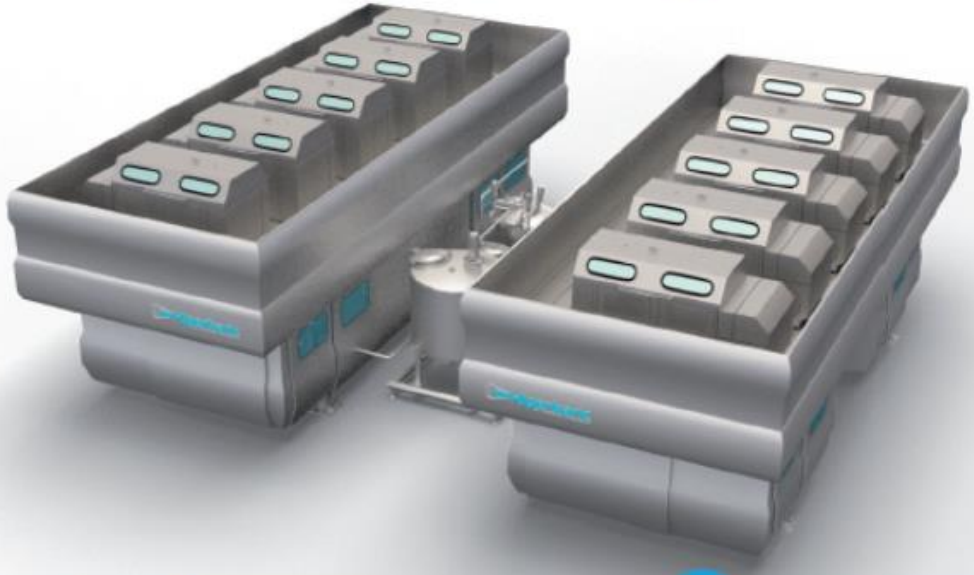
Made by Cow does not condone the purchase or drinking of un-treated milk.


cold pressed raw milk
750ml
ELBA


cold pressed raw milk
750ml
ELBA

Largest available systems

Throughput kg/hour [pounds/hour]	3,020 [6,660]
Vessel Capacity Litres [US liq. Gallons]	525 [150]
Throughput litres/hour [gallons/hour]	10,000 [2,640]
Capacity Litres [US liq. Gallons]	1,050 [277]
Vessel diameter insid [inches]	
Bulk Processing	Before bottling
Vessel Efficiency	95%



Pulsed electric field (PEF) technology

Uses strong pulsed electric currents (20-80 kV/cm) to inactivate microbial cells in food placed or flowing between electrodes

- Preserves food with little or no actual heat
- Avoids negative effects on sensory and nutritional quality associated with heat treatments
- Commercialised for fruit juices

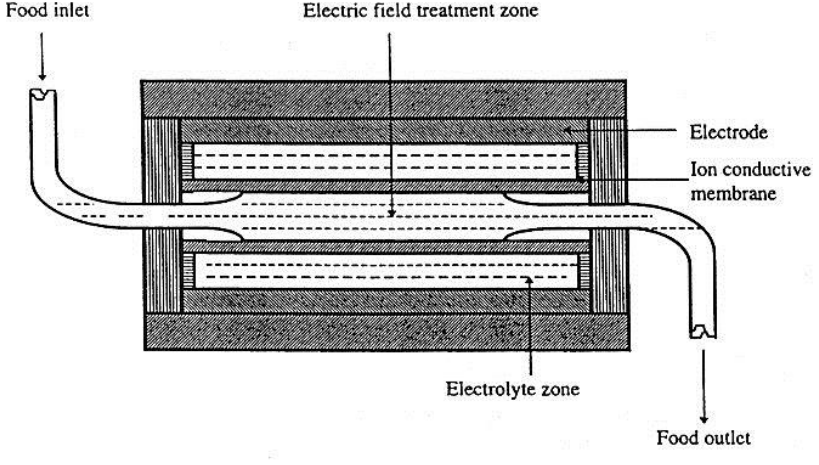


FIGURE 5 Continuous chamber with ion conductive membranes separating the electrodes and the food designed by Dunn and Pearlman. (From Ref. 6.)

FoodEngineering

Home

TECH FLASH

Fresh juice processor automates pasteurization with continuous process

Holland's Hoogesteger first in Europe to use pulsed electric field te

By Jaan Koel, Contributing Editor November 28, 2012

KEPT FRESH WITH Pure Pulse

Pulsed Electric Field (PEF)

Higher probiotic value

Bacterial spore control

Improved quality

Increased shelf life

Better production planning

ELEA COOLDAIRY™. BETTER TASTE, LONGER SHELF LIFE, PRESERVED NUTRITIONAL VALUE.

COOLDAIRY™

Our CoolDairy™ (10, 100 and 1000) range of systems has the ability to process both food and non-food liquid or semi-liquid products. The Elea PEF process works in a way that can inactivate bacteria which leads to an increased shelf-life. Freshness and quality are retained due to the delicate low temperature process

This range of systems is able to fulfill capacities between 50L and 10,000L per hour and each of our CoolDairy™ systems benefits from a hygienic integrated CIP and SIP ready design.

These systems offer customisation of the process to fit within your existing production line and therefore control is placed in the hands of the operator. You can be reassured that this range of systems is compliant with all HACCP requirements and the modular nature of the CoolDairy™ is easy to configure and maintain.

Continuous microwave heating

MicroMilk

AMT
Advanced Microwave Technologies

- Microwave heating enabled a 3-fold faster temperature rise in comparison to conventional indirect heating using heat exchangers
- No significant differences in the physico-chemical (e.g. furosine and HMF formation), microbiological, nutritional (e.g. vitamin B1) and organoleptic characteristics (color and taste) of the milk between both processes.
- The product quality achieved using microwave pasteurization is thus comparable to that of conventional pasteurization.

Novel thermal:
Innovative steam injection milk process

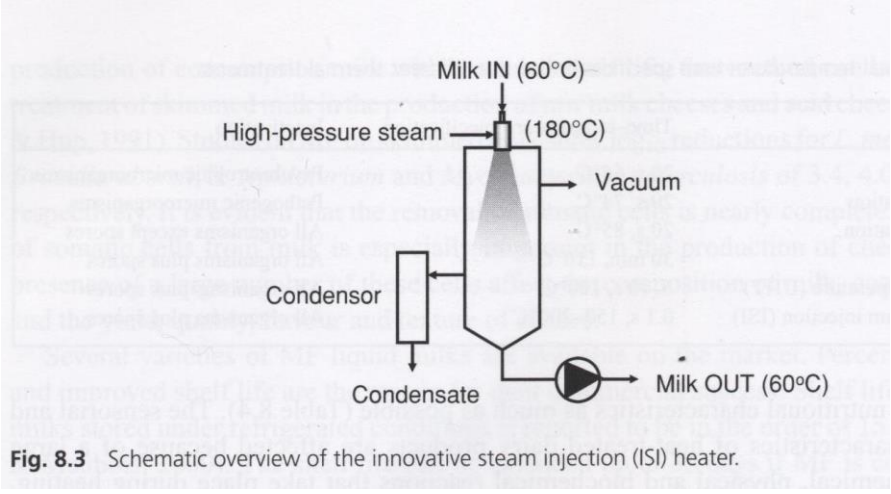


Fig. 8.3 Schematic overview of the innovative steam injection (ISI) heater.

- Very high temperatures for very short times
- 0.1 s at 150-200°C
- No holding time
- More expensive than conventional UHT

Table 1 - Effect of different heating technologies on whey proteins and bacterial spores in milk

Technology	Time(s)	Temperature (°C)	Denaturation of whey proteins (%)	Log reduction *B. stearothermophilus* spores	Log reduction *B. thermodurans* spores
Pasteurization	15-1	72-80	4-8	0	0
Indirect UHT	20-5	130-145	75-90	6	0-3
Direct UHT	6-2	142-150	60-85	6	0-4
ISI	0.1	160-180	25	6	3-4

Source : Tamime (2009)

Cavitation: Combining heating and homogenisation?

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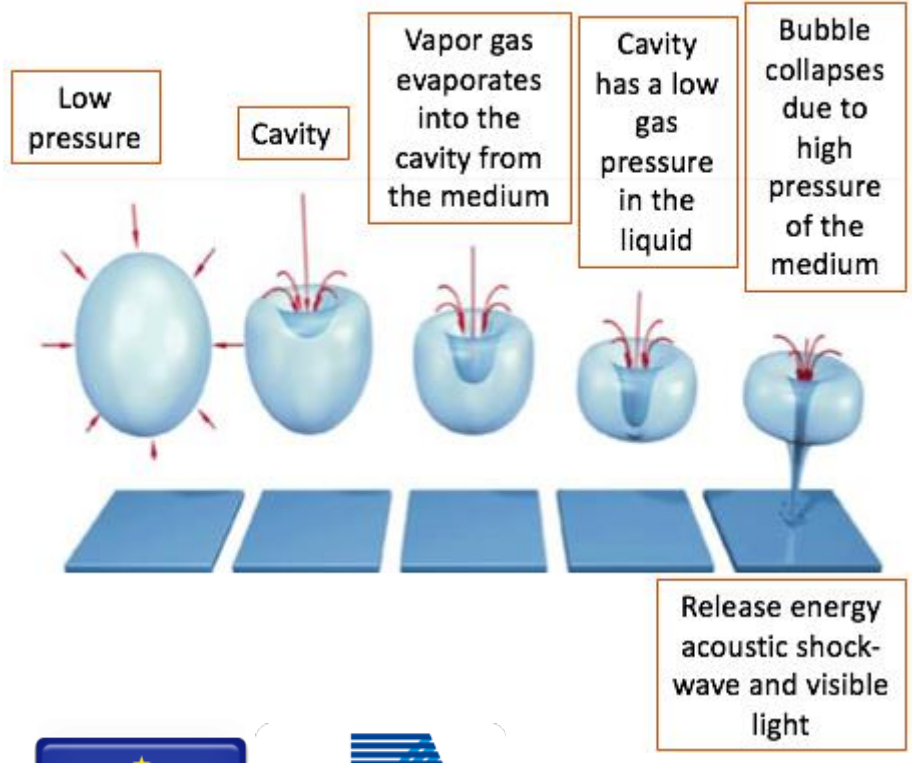
EU FCHR project:

Fluid Cavitation Hydrodynamic Reactor

Can cavitation replace the homogenisation and pasteurization steps in dairy processing?



SEVENTH FRAMEWORK PROGRAMME

FCHR prototype

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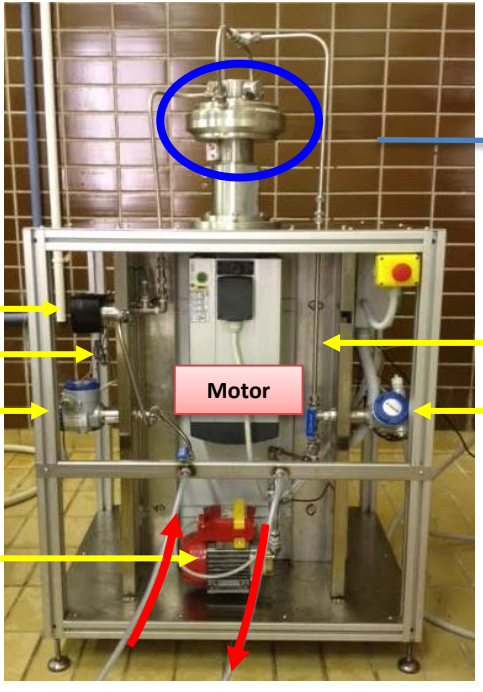
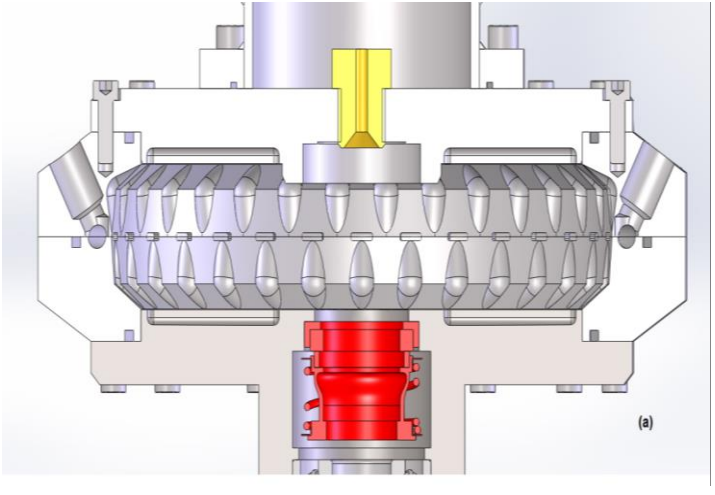
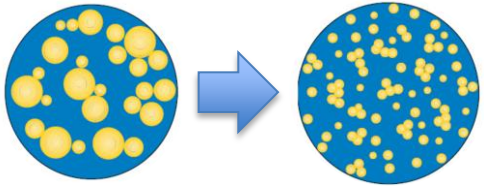




FCHR
HYDROCAVITATOR TECHNOLOGY

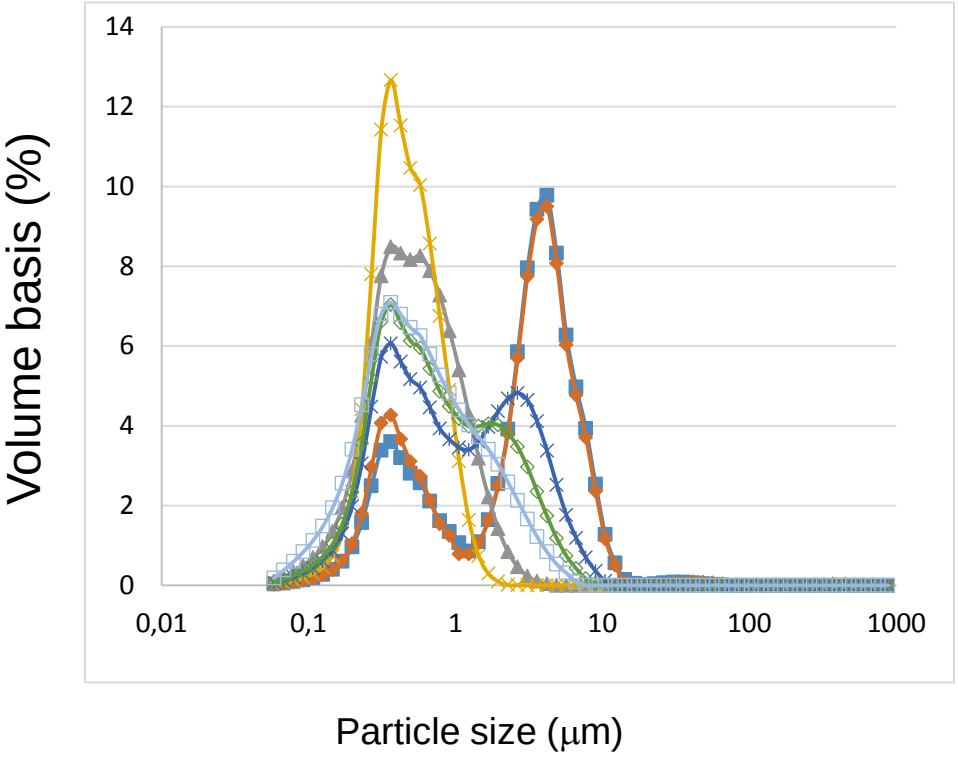
Homogenization by FCHR



Raw milk

Homogenised milk

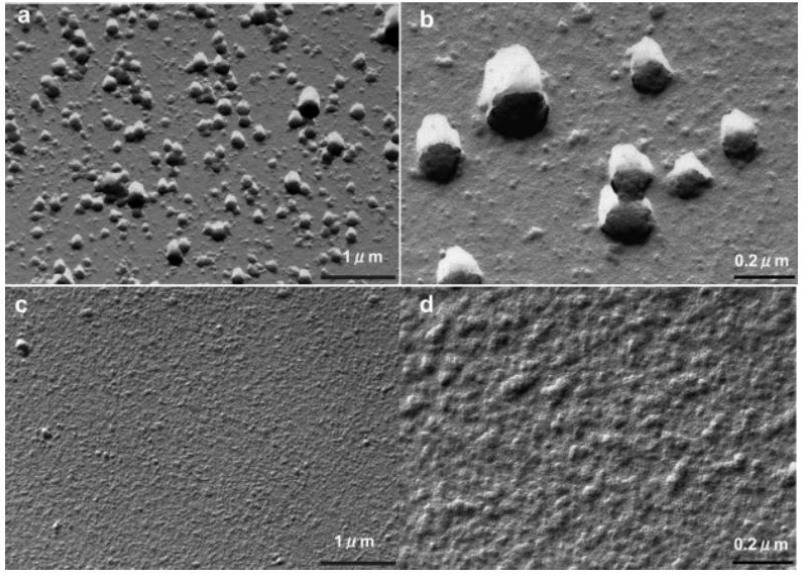
- Raw milk
- Pasteurised milk
- Pasteurised and homogenized 1 passage
- Pasteurised and homogenized 2 passage
- FCHR 6000 RPM 1 passage
- FCHR 6000 RPM 2 passage
- FCHR 6000 RPM 5 passage



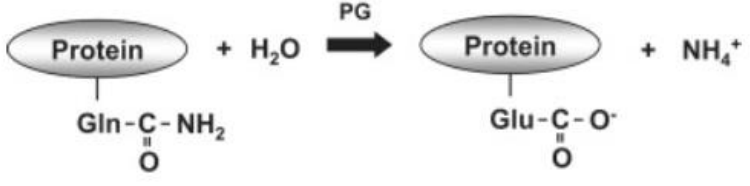
- Bacterial inactivation possible (> 5 log LAB) after 5 passages, but efficiency of process not comparable to conventional HTST/pasteurisation

Enzymatic Modification: Protein Glutaminase and Milk Functionality

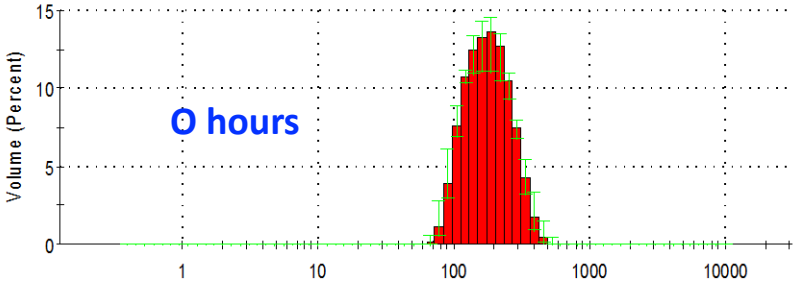
- Enzyme produced by soil bacterium *Chrysobacterium proteolyticum*
- Deamidates proteins by conversion of glutamine residues to glutamic acid
- Increases negative charge on proteins
- Reported effects on clearing of milk, dispersion of casein micelles, improved acid gel formation

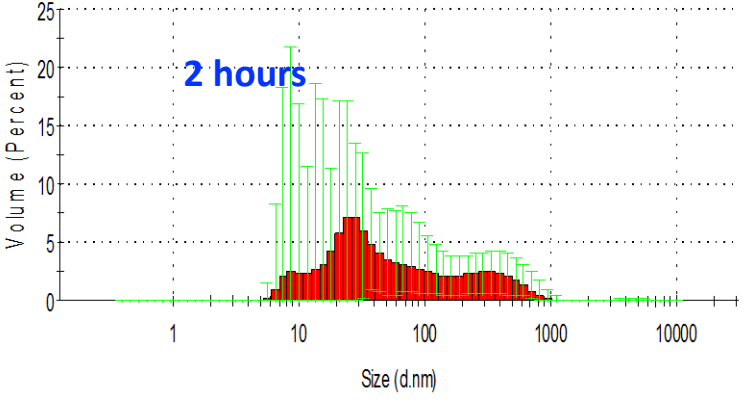


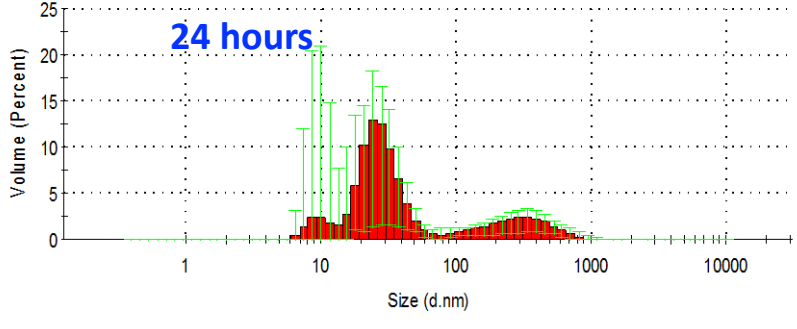
Miwa *et al* (2010)



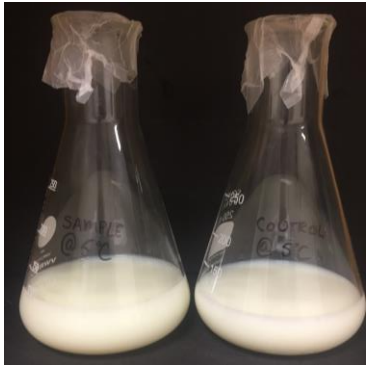
Protein Glutaminase and Casein Micelles







Skim milk incubated at 50 ℃ **(optimum temperature for enzyme)**

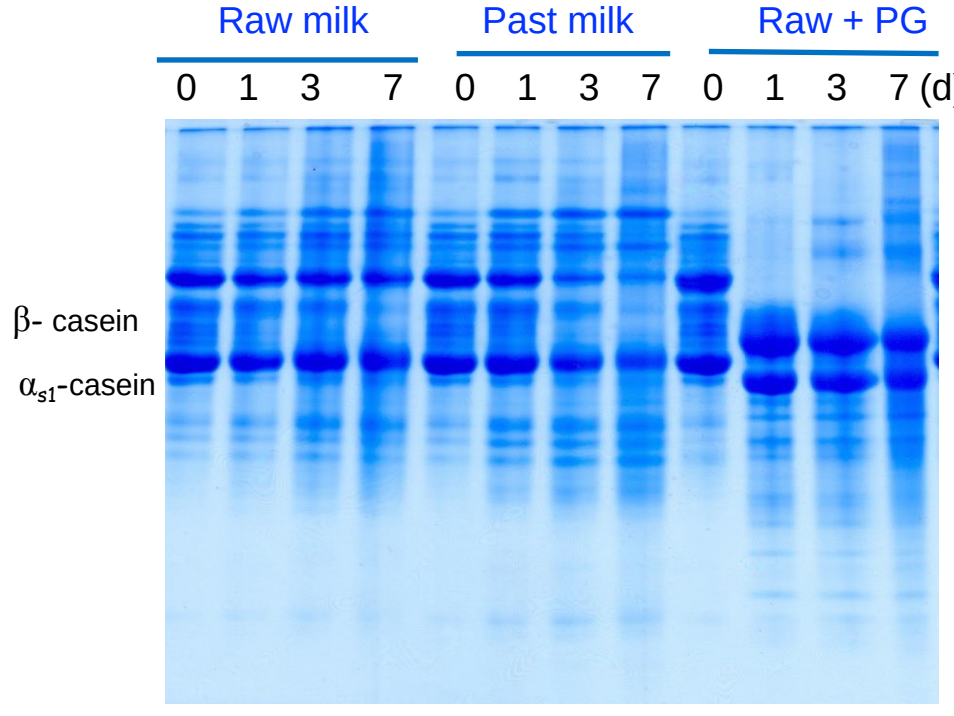


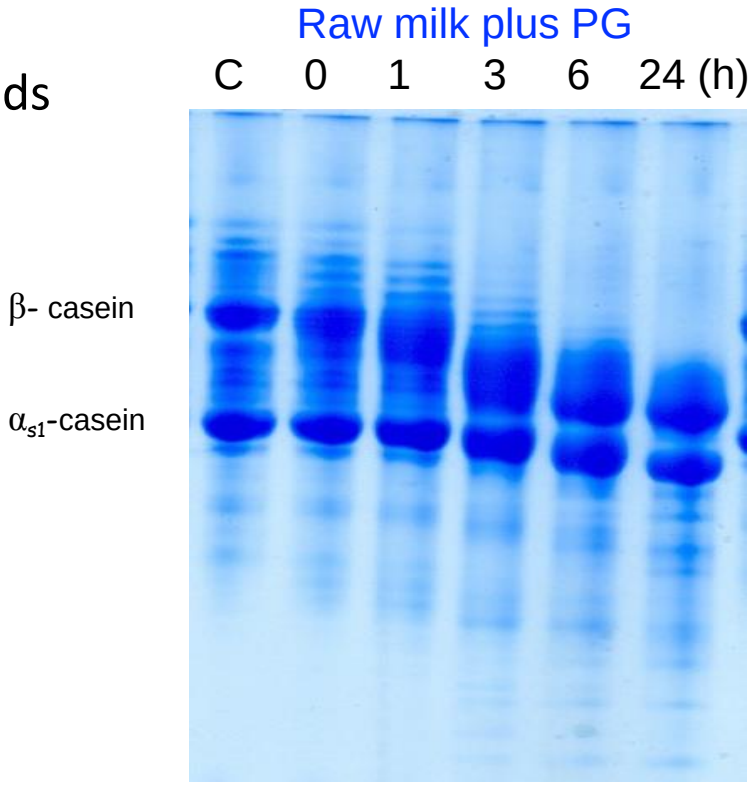
24 h, 5 ℃

24 h, 50℃

Protein Glutaminase and Caseins

- Dramatic, progressive and irreversible effects on casein mobility in electrophoresis
- β-casein affected more than α_{s1}-casein (depends on AA sequence)





Apparent inhibition of proteolysis

Barriers to uptake of new processing technologies

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1. High capital costs
2. High running costs (e.g., energy utilisation)
3. Commercial availability (lack thereof)
4. Batch or continuous processing
5. Scale of production and throughput
6. Validation by recognised authorities
7. Not a single answer to processing – hurdle approach to preservation and shelf-life (especially with chilled distribution)

Need new processing conditions roadmaps

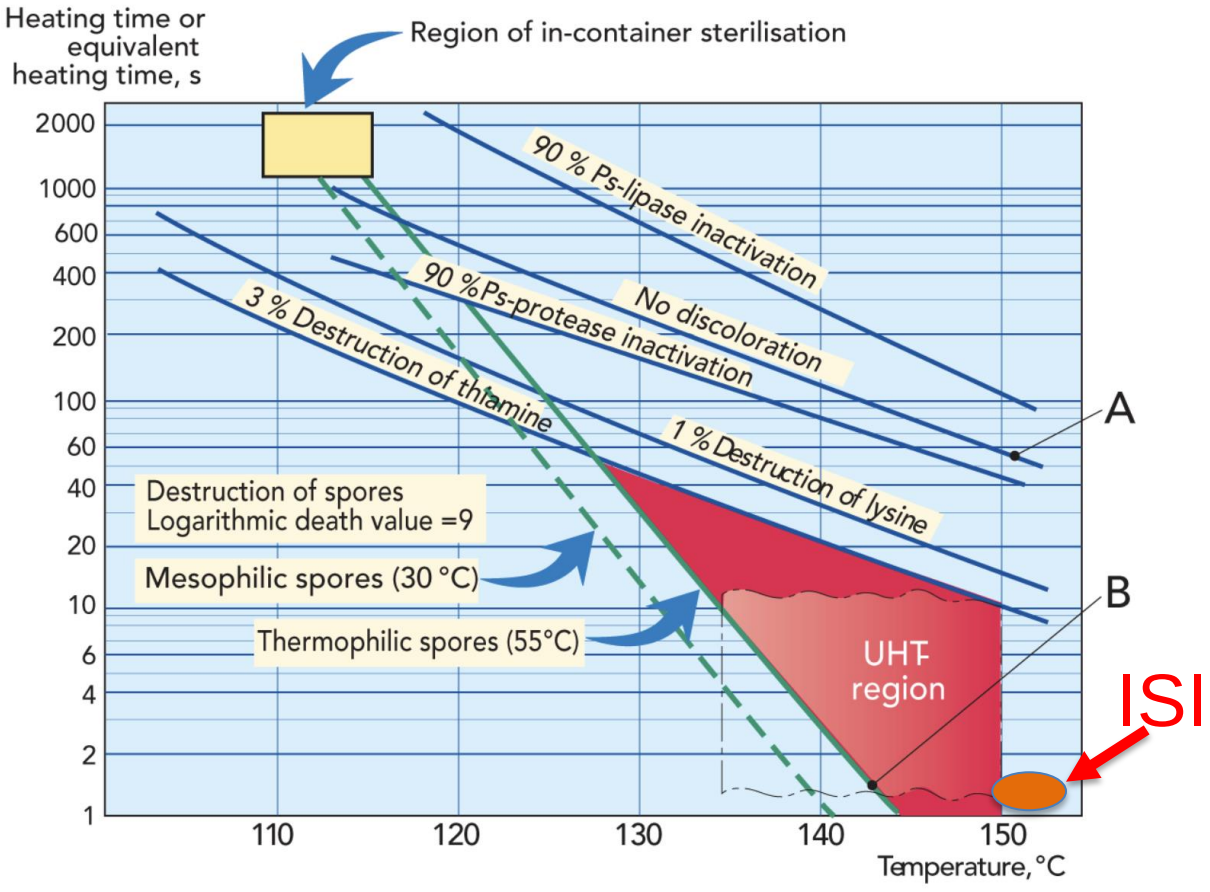
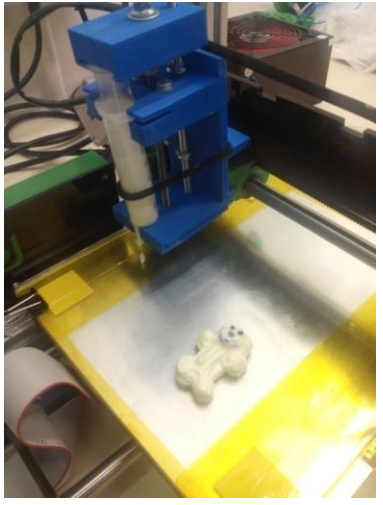


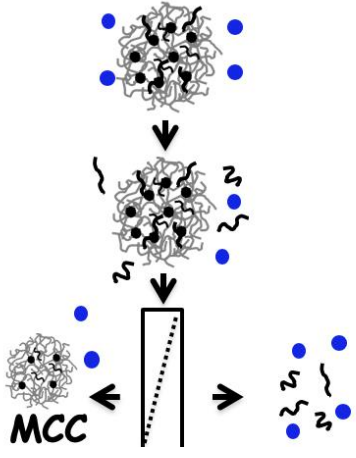
Fig. 9.4

Limiting lines for destruction of spores and effects on milk. The values within brackets (30 °C and 55 °C) express the optimal growth temperatures of the vital types of corresponding spore forming microorganisms.Source: Kessler

Conclusions: the future of dairy?

- Existential threats from multiple sources (fast-moving vs fads?)
- Sector exploring ‘advanced minimal processing’
- Technological advances in multiple other areas (fractionation, customization)
- Milk a source for huge range of ‘non-milk ingredients’

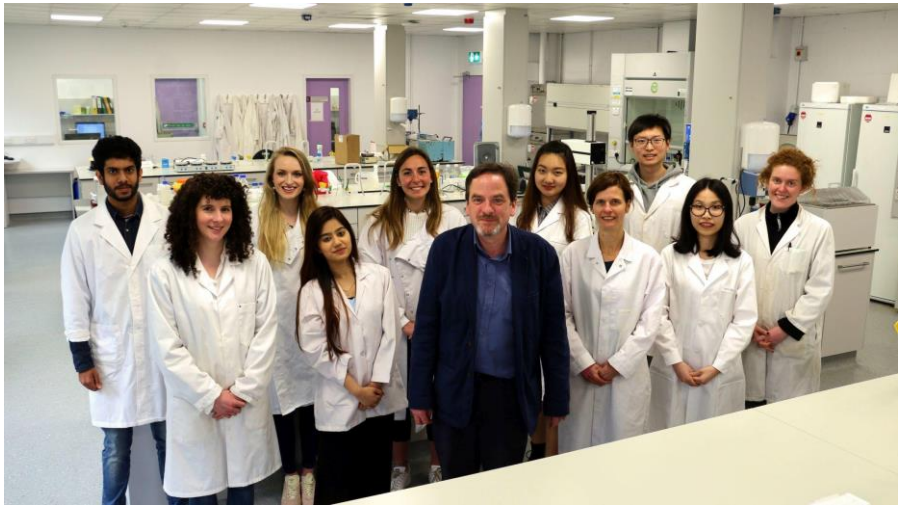




Thank you!!

Collaborators

Especially
Dr Seamus O'Mahony, UCC
Prof Thom Huppertz, WUR



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