Temperature step changes:

A novel approach to control biofilms

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G.C. Knight, R.S. Nicol & T.A. McMeekin (2004). *Int. J. Food Microbiol.*, 93, 305-318

Research Team

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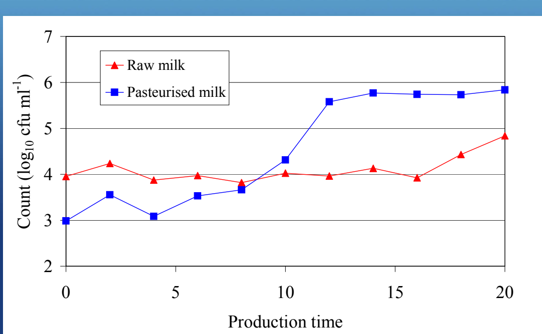
Summary

- Background
- Description of pilot plant
- Objectives of study
- Temperature step changes
- Mechanism
- Conclusions

Background

- In Australia milk used for production of cheese must undergo pasteurisation
  – Held at 72 °C for 15 seconds
  – Cooled to 35 °C for cheese making
- Processing time of 2-3 minutes
- Literature
  – Growth of thermoduric streptococci after 12 h production
  – Counts increase from 10^3 to 10^6 cfu ml^{-1}
  – Cool down side of regenerative section (50-35 °C)

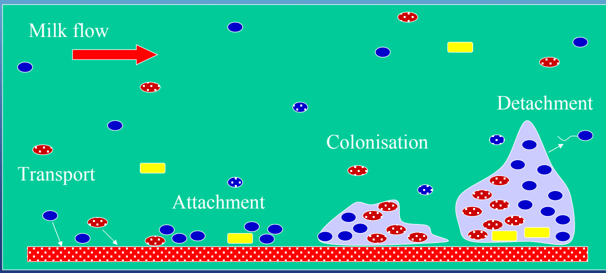
Counts of thermoduric streptococci in pasteurised milk



Biofilms

- Definition: A community of microorganisms adhering to a surface and embedded in a matrix of extracellular polymer material
- Are ubiquitous in nature
- Any surface placed into an aqueous environment will develop a biofilm community
- "Natural" mode for bacterial growth

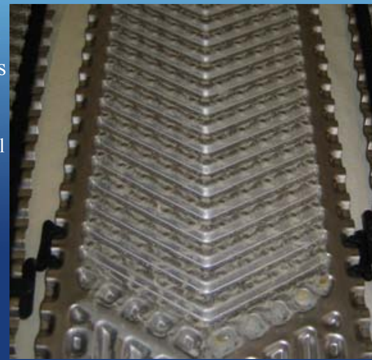
Biofilm formation



– Steps in biofilm development

Biofilms in dairy processing equipment

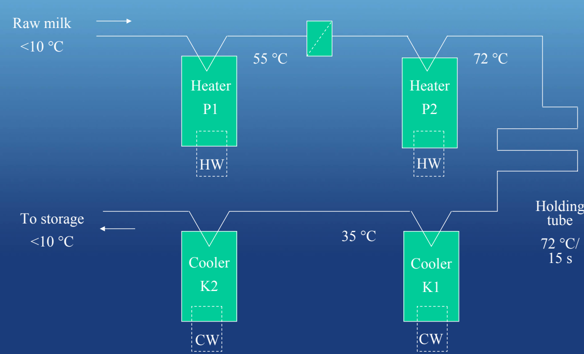
- Milk is highly nutritious
- Heat treatment processes
  - provide numerous surfaces at ideal temperatures for bacterial growth
- Trend to increase production run times between cleaning



Pilot plant-scale pasteuriser

- Trial conditions
  - 3000 l h^{-1} milk flow rate
  - Raw whole milk
  - Natural microflora

Layout of pilot plant



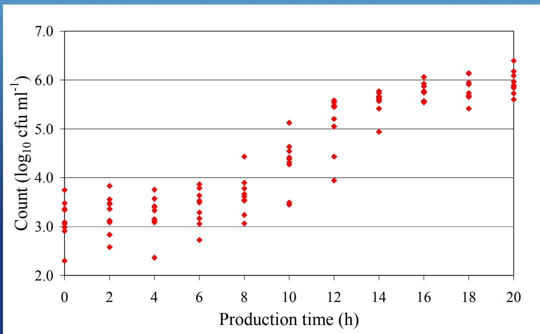
Sampling of the pilot plant

- Sample ports were located before and after each section of the pilot plant
- First cooling section (K1)
  - Cools from 72 to 35 °C
  - Internal sample points (55, 50, 45 °C)

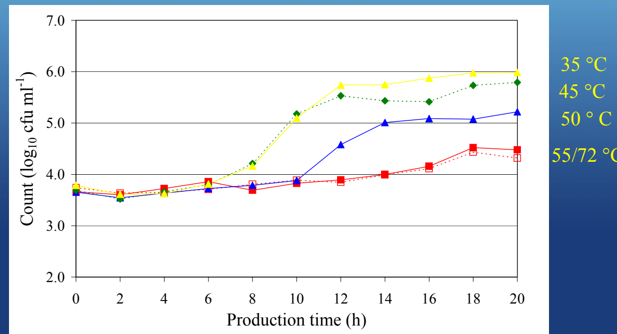
Objectives of study

- Confirm that thermoduric streptococci grow on surfaces in the pilot plant
- Confirm location of thermoduric growth
- Develop a method to control thermoduric growth and achieve 20 h continuous production

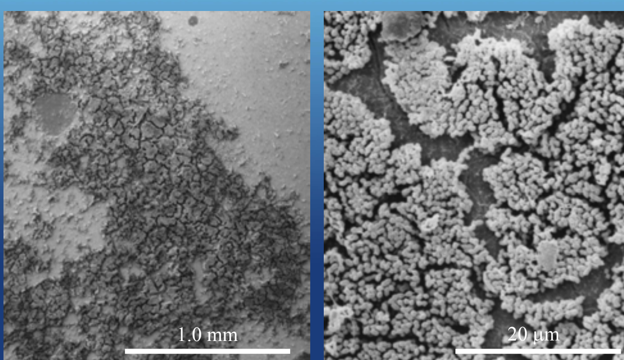
Thermoduric growth in the pilot plant



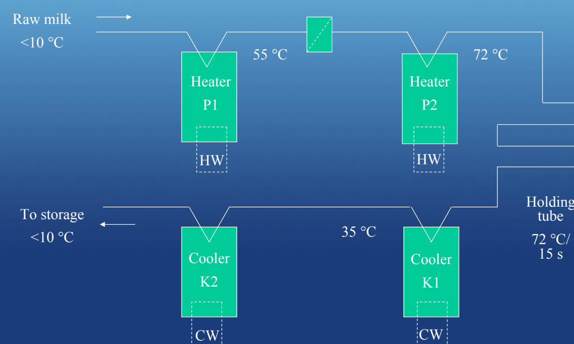
Location of growth – cool down side



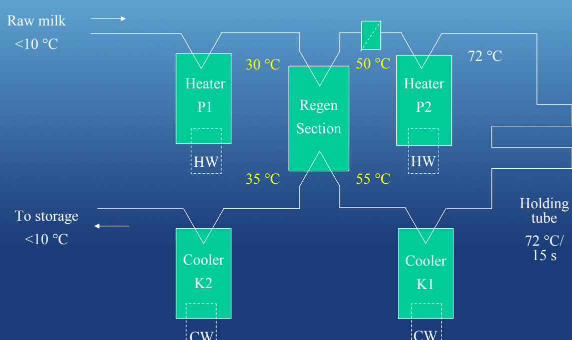
Biofilms on stainless steel surfaces (45 °C)



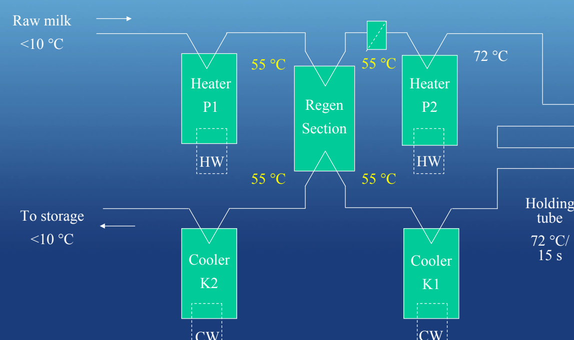
Pilot plant - original layout



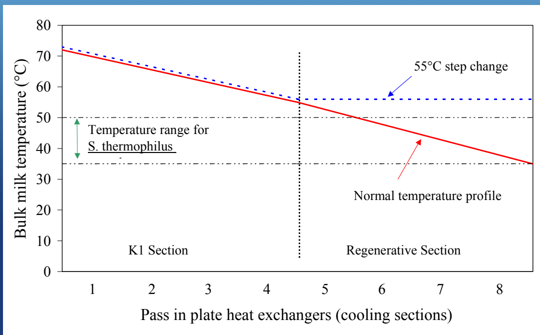
Pilot plant with regenerative section



Example: Step change to 55 °C



Temperature profiles – cool down side

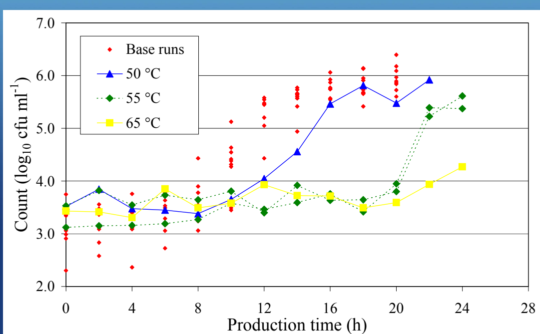


Temperature step changes

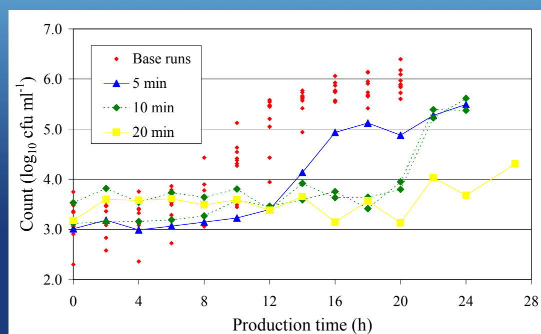
- Step change temperature 55 °C
- 10 min step change duration
- 60 min normal operating conditions

- Variables
  - Step change temperature (50, 55, 65 °C)
  - Step change duration (5, 10, 20 min)
  - Time between step changes (60, 120 min)

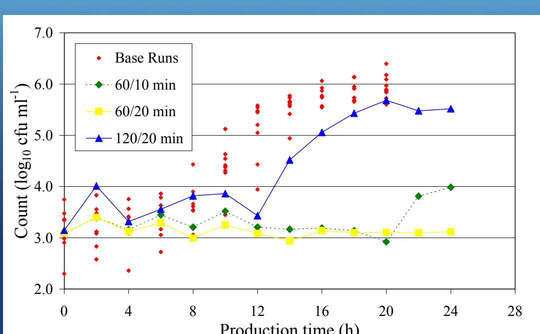
Influence of step change temperature



Influence of step change duration (55 °C)



Influence of period between step changes (55 °C)



Summary: Temperature step changes

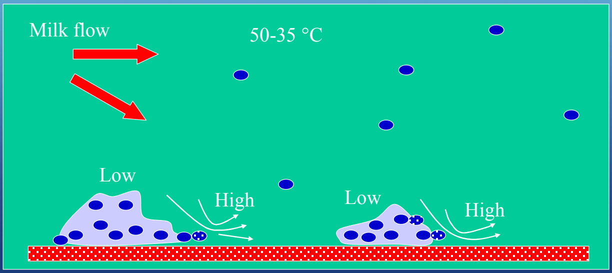
- 20 h continuous production can be achieved using step change conditions of:
  - 55 °C step change temperature
  - 10 min duration
  - 60 min interval between step changes

- Increased production time
  - Increase step change temperature
  - Increase duration

Mechanism – How do step changes work?

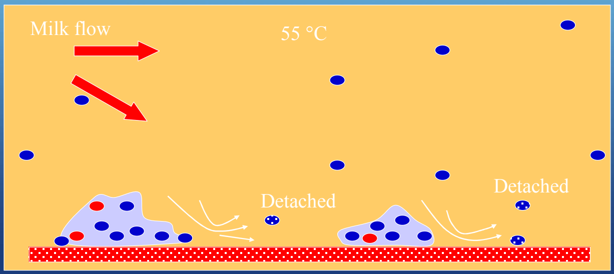
- Biofilm development represents a balance between:
- Microbial metabolism
  - Reproduction (nutrients, temperature)
  - Production of extracellular polymers (EPS) – provides strength for adhesion
- Shear stress
  - Firmly bound bacteria remain attached
  - Weakly bound bacteria detach
  - Areas with low shear forces – ideal for biofilm development

Mechanism - standard conditions



- Biofilm development in areas with low shear forces
- Cell replication, EPS production

Mechanism - step changes conditions



- Cell metabolism is stopped
- Loss of cells from microcolonies
  - removal by shear forces
  - Inactivation by heat?

Conclusions

- Growth of thermoduric streptococci occurred on the cooling side of the pilot plant between 50 and 35 °C
- Implementation of step changes results in a reduction in energy efficiency
- 20 h continuous production can be achieved using step change conditions of:
  - 55 °C step change temperature
  - 10 min duration
  - 60 min interval between step changes

Thank you