A thesis presented in partial fulfilment of the requirements for the degree of:

Doctor of Philosophy
In
Food Engineering and Technology

At Massey University, Palmerston North, New Zealand.

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2003
To my loving wife Lisa, for her help, support, encouragement and acceptance of long hours and stressful times.
Abstract

Fouling deposits were suspected of playing a pivotal role in the thermophile contamination problem experienced in the dairy industry during milk powder manufacture. The objective of this work was to investigate thermophile growth and develop an understanding of how fouling deposits affect thermophile contamination in milk powder plants.

Pilot plant and laboratory scale studies were carried out investigating:

- The release of thermophiles from fouled and un-fouled surfaces;
- The survival of thermophiles in fouling during cleaning;
- The rate of re-contamination of thermal equipment after incomplete cleaning;
- and the adhesion of thermophiles to fouled and clean stainless steel.

Thermophile contamination from the pilot plant equipment was also modelled mathematically.

The bulk milk thermophile contamination from sanitised fouled and un-fouled surfaces was found to be not significantly different, showing that fouling deposits by themselves do not increase the steady state amount of bulk contamination and that the more important factor is the amount of surface area available for colonisation within the temperature growth range of the thermophiles.

Milk fouling layers provided much greater protection against cleaning than that of biofilms alone. Thermophiles that survive cleaning or greater initial thermophile concentrations in the raw milk were shown to reduce the plant production time available before concentrations of thermophiles in the bulk milk became excessive (>1x10^6 cfu.ml\(^{-1}\)).

Therefore, cleaning procedures in milk powder plants need to remove or destroy all traces of thermophiles to allow the maximum possible run length. It is similarly important to obtain raw milk with the lowest possible thermophile load before processing.
During adhesion studies, the number of thermophilic bacteria adhering to stainless steel surfaces increased with bulk cell concentration and increasing contact time for adhesion. The adhesion rate of thermophiles to whole milk fouling layers was found to be around ten times higher than the adhesion rate to stainless steel.

Steady state modelling provided a quick estimate of the level of bulk milk contamination that can be expected, however it was dependent on obtaining accurate measurements of the surface numbers. Since surface numbers were underestimated by approximately a decade using techniques that dislodged but did not enumerate loosely adhered cells, the model under predicted the bulk milk contamination.

Unsteady state modelling predicted the trends observed in the experimental data and provided reasonable estimates of the bulk contamination that can be expected over time from the pilot plant. Predictions from the model after changes in key parameters provide an insight to the magnitude of any reduction in contamination that can be made.

The results of this work have demonstrated that thermopile contamination during dairy processing can be minimised through:

- Re/design operating equipment to minimise the residence time of the product in the range of 40-70°C.
- Minimising the contact surface area of thermal equipment by use of alternative direct heating technologies.
- Minimising fouling by management of milk quality, optimising processing conditions, hygienic design of the plant equipment and ensuring the product mix is suited to the plant.
- Ensuring that the plant is thoroughly clean at the commencement of each run through attention to equipment design and optimisation of cleaning procedures.
Acknowledgements

I would firstly like to thank my supervisor Tuoc Trinh and co-supervisors John Brooks, Graham Manderson and Kathy Kitson for their help and guidance throughout the course of my PhD studies.

The financial assistance of the former New Zealand Dairy Board, now part of Fonterra Co-operative Group Ltd.

Thanks to Jon Palmer for his assistance in learning the finer points of microbiological techniques and to Ann-Marie Jackson and Mike Sahayam for their general assistance in the microbiology laboratory.

In the initial stages of the study, Steve Flint, Bruce Hill and Tim Coolbear at the Fonterra Research Centre offered assistance with microbiology methodology and critique of the initial work.

The long experimental runs on the pilot plant would not have been possible without the help of the other postgraduate students. Thanks to Hayden Bennett, Richard Croy, Carol Ma, Mark Downey, Binh Trinh and Irma Wiryawan who volunteered their services to either operate the plant or assist with microbiological testing. Also thanks to Judy Farrand-Collins in the microbiology laboratory, who helped clean up after the experimental runs. The pilot plant was often operated outside the normal operational hours of the steam boiler. Thanks to Gary Radford and also the Massey University facilities management team for extending these normal operating hours so that steam could be supplied to the pilot plant whenever needed.

In helping to build the pilot plant, I would like to thank Byron McKillop and Don McLean for their help in the manufacture of equipment. Also thanks to Tony Mackereth from the Fonterra Research Centre for his assistance in designing direct steam injectors. Thanks also to Mark Dorsey for the electrical and process control work he carried out. Also thanks to the other postgraduate students, Hayden Bennett, Richard Croy, Carol Ma, Mark Downey and Binh Trinh, who helped design, construct and automate the
various parts of the pilot plant and who helped with fine tuning and continuous improvement.

Thanks to the undergraduate students Kate Osbaldiston, Ola Mohamed Aly, Jackie Ng and Stephen Millward for their work on thermophile adhesion, which helped sharpen the focus of further adhesion studies.

For his assistance with modelling techniques and the use of MATLAB, thanks to John Bronlund from The Institute of Technology and Engineering at Massey University.

Thanks to Liz Nickless and Al Rowland for training and assistance with the confocal microscope.

Thanks to Dave Woodhams for his helpful comments that helped keep the work aligned with the needs of the dairy industry and for his critique of reports submitted as part of the Plant Availability Project, of which this study was sub-project.

Identification of the thermophilic bacteria isolated from the pilot plant by random amplified polymorphic DNA (RAPD) analysis was carried out by Hugh Morgan and staff at Thermophile research unit at the University of Waikato.

Thanks to Hong Chen, Hugh Waters, David Powell and Keary Adeane from Fonterra for granting the time off work necessary to complete this thesis. Also thanks to Neil Walker and David Powell from Fonterra for financial assistance to print and bind the thesis.

Lastly thanks to my wife Lisa, for her help in preparing materials for and providing assistance during experimental runs. Also thanks for her support and encouragement throughout the course of my PhD.
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