# Cell-wall mechanical properties of *Saccharomyces cerevisiae*

by

**Alexander Evans Smith**

Thesis submitted for the degree of
Doctor of Philosophy

in

The University of Adelaide, Australia
Department of Chemical Engineering
Faculty of Engineering

June 1999

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent for this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Signed:_

Date: 10-September-1999

# Acknowledgments

I wish to acknowledge the guidance and encouragement of my supervisors: Dr Anton Middelberg, Dr Ken Moxham, Dr Brian O'Neill, Prof. Colin Thomas and Dr Zhibing Zhang. The work presented in this thesis was financially supported by the Australian Government (in the form of an Australian Postgraduate Award) and the CRC for Tissue Growth and Repair (in the form of a supplementary scholarship and contribution to operating expenses).

I wish to thank Prof. Colin Thomas and Dr Zhibing Zhang for providing access to their micromanipulation facilities at the University of Birmingham (UK). I am particularly grateful to Carlo Shiu and Jenny Blewett for guidance regarding the experimental side of the micromanipulation technique. This work would not have been possible were it not for the generous support of the British Council in the form of a Postgraduate Bursary. I also wish to thank Prof. John Bridgewater for the invitation to conduct part of this work as a Visiting Researcher at the University of Cambridge (UK).

Financial support in the form of a Frank Perry Scholarship in Engineering and a Research Abroad Scholarship from the University of Adelaide is gratefully acknowledged, along with a Travel Grant from the CRC for Tissue Growth and Repair.

I would also like to thank my family and friends for their continued support, particularly Nicholas Kotlarski and Andrew Kleinig.

*'Life has a range of magnitude narrow indeed compared to that with which physical science deals; but it is wide enough to include three such discrepant conditions as those in which a man, an insect and a bacillus have their being and play their several roles. Man is ruled by gravitation, and rests on mother earth. A water-beetle finds the surface of a pool a matter of life and death, a perilous entanglement or an indispensable support. In a third world, where the bacillus lives, gravitation is forgotten, and the viscosity of the liquid, the resistance defined by Stoke's law, the molecular shocks of Brownian movement, doubtless also the electric charges of the ionised medium, make up the physical environment and have their potent and immediate influence on the organism. The predominant factors are no longer those of our scale; we have come to the edge of a world of which we have no experience, and where all our preconceptions must be recast.'*

Sir D'Arcy Wentworth Thompson
*On Growth and Form*,
2nd Edition, 1942, pp77.

# Summary

Prediction of cell breakage in bioprocessing at the fundamental level of fluid-cell interactions is limited by the lack of measurements on the cell-wall mechanical properties. A suitable approach has not been developed to determine the fundamental cell-wall mechanical properties of single biological cells.

This thesis develops a suitable approach by combining the single-cell compression experiment with a mechanical model to determine the cell-wall mechanical properties of the yeast *Saccharomyces cerevisiae*.

A novel mechanical model is developed with finite element techniques. This model describes the compression of a liquid-filled inflated-sphere between two parallel surfaces where the walls are taken to be permeable. A parametric study conducted with this model determines dimensionless parameters that must be measured in conjunction with the compression experiment to ensure unique solution for the cell-wall mechanical properties.

Experimental methods are developed to measure these dimensionless parameters. These measurements are performed in conjunction with compression experiments. Cell-wall mechanical properties are uniquely extracted from this data with the mechanical model. This approach is also applied to determine the cell-wall mechanical properties in exponential and stationary phase of a batch fermentation.

These measurements are highly significant as they are the first that can be coupled with the general equations of motion to predict cell-breakage at the fundamental level of fluid-cell interactions. They are also the first to quantify the changes in cell-wall mechanical properties that accompany changes in growth phase. Future work is required to relate the cell-wall mechanical properties to the underlying molecular components and their assembly in the cell wall.

# Table of Contents

# List of Figures

# List of Tables