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DEPARTMENT OF MECHANICAL ENGINEERING

TITLE OF THESIS:	MECHANICAL CHARACTERIZATION OF SINGLE MICROBIAL CELLS USING MEMS
TIME/DATE:	9:00am, Tuesday, May 23, 2017
PLACE:	Room 3107, The Mona Campbell Building, 1459 Lemarchant Street

EXAMINING COMMITTEE:

Dr. Xinyu Liu, Department of Mechanical Engineering, McGill University (External Examiner)

Dr. Marek Kujath, Department of Mechanical Engineering, Dalhousie University (Reader)

Dr. Yuan Ma, Department of Electrical Engineering, Dalhousie University (Reader)

Dr. Ted Hubbard, Department of Mechanical Engineering, Dalhousie University (Supervisor)

DEPARTMENTAL REPRESENTATIVE:	Dr. Robert Bauer, Department of Mechanical Engineering, Dalhousie University
CHAIR:	Dr. Djordje Grujic, PhD Defence Panel, Faculty of Graduate Studies

ABSTRACT

In this study, the mechanical properties of single yeast cells (baker's and brewer's strains) were measured by an on-chip PolyMUMPs MEMS squeezer in aqueous media. An electrothermal actuator with mechanical amplifiers was used to press single cells against a compliant reference spring. The actuator reached a total displacement of approximately 2.5 μm underwater. Deformations of the cell and the reference spring were measured with nanoscale resolution using optical Fourier Transform techniques. Finite Element Analysis was used to simulate the entire system (squeezer and cell).

Rupture force, stiffness, and hysteresis were measured for a total of 22 baker's yeast cells (Saccharomyces cerevisiae). An abrupt reduction in the cell stiffness and the appearance of cracks indicated the rupture force was reached. The average rupture force was 0.47 ± 0.10 μN. The average pre-rupture cell stiffness was 9.3 ± 3.1 N/m; the post-rupture stiffness dropped to 0.94 ± 0.57 N/m. Cells squeezed below the rupture force showed residual deformations below 100 nm while cells squeezed past rupture showed residual deformations between 470 and 960 nm.

Additionally, 31 baker's yeast cells had their stiffness measured during repetitive loading cycles (fatigue tests). Cell stiffness decreased as the cycle number increased. Cells tested up to 268 cycles reached a plateau of 23% of the initial stiffness (drop of 77%) after approximately 200 cycles. Cell viability showed a correlation with stiffness, the cells became less viable as the stiffness decreased.

Finally, 32 brewer's yeast cells had their stiffness and rupture force measured. The brewing cells were evenly divided into 6 groups sorted by 2 species (lager and ale) and 3 fermentation phases (start, middle, and end). Across all fermentation phases ale cells ruptured under an average force of 0.28 ± 0.05 μN, while lager cells ruptured at 0.47 ± 0.10 μN.

This study serves as a proof of concept of a MEMS device able to investigate the mechanics of individual microbial cells. The results presented here complement previous yeast cell mechanics assessments performed by nanoindentation and microplate compression techniques. Researchers and brewers may use this technology to better understand physical differences in their yeast populations.