

Introduction

Biological cells may regulate internal temperature by altering surface area to control heat transfer. This project developed a bioreactor that varies fluid temperature from 34–42 °C in 0.5 °C increments while enabling real-time microscopic observation of suspended cells. Studying cell morphology across temperatures provides insight into potential thermoregulatory mechanisms.

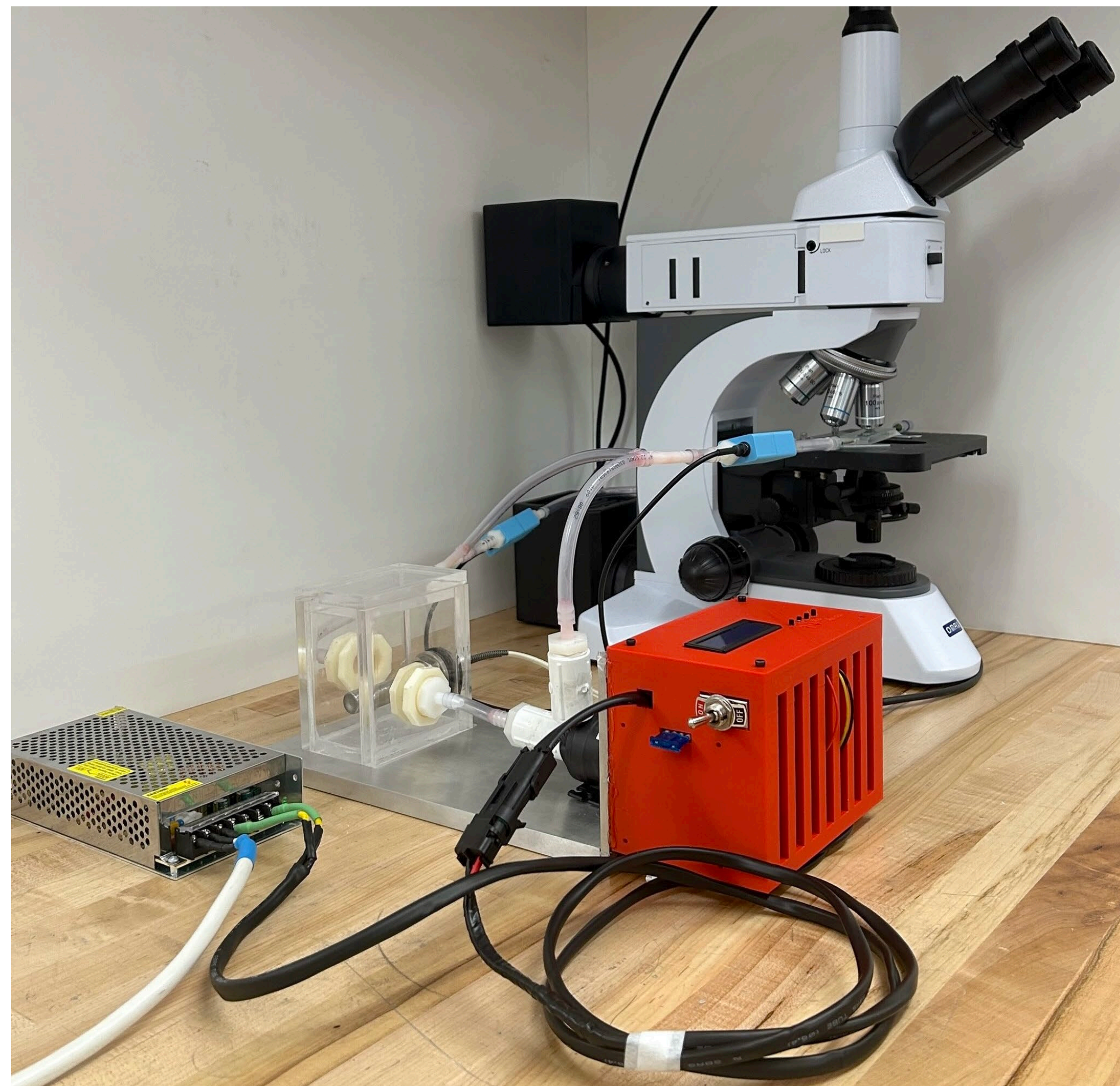


Figure 1 - Final design

Methods/Design

- **Heating & Sensing:** Immersion heater raises water temperature; RTDs monitor it at key locations.
- **Circulation:** Pump drives closed-loop flow from reservoir to microscope viewing area and back.
- **Control:** Arduino modulates heater power through a MOSFET using proportional control.
- **Purpose:** Closed-loop design promotes uniform temperature and minimizes evaporation during imaging.
- **Testing:** Step-response and control tests performed to characterize system behavior and verify temperature stability.

Analysis: Temperature Control

- System modeled as a first-order thermal process based on experimental step-response data.
- Transfer function derived to predict temperature dynamics and optimize controller parameters.
- Simulink simulations verified control performance, showing stable response within ± 0.5 °C.
- Experimental tests confirmed close agreement with model predictions, exhibiting stable temperature control.

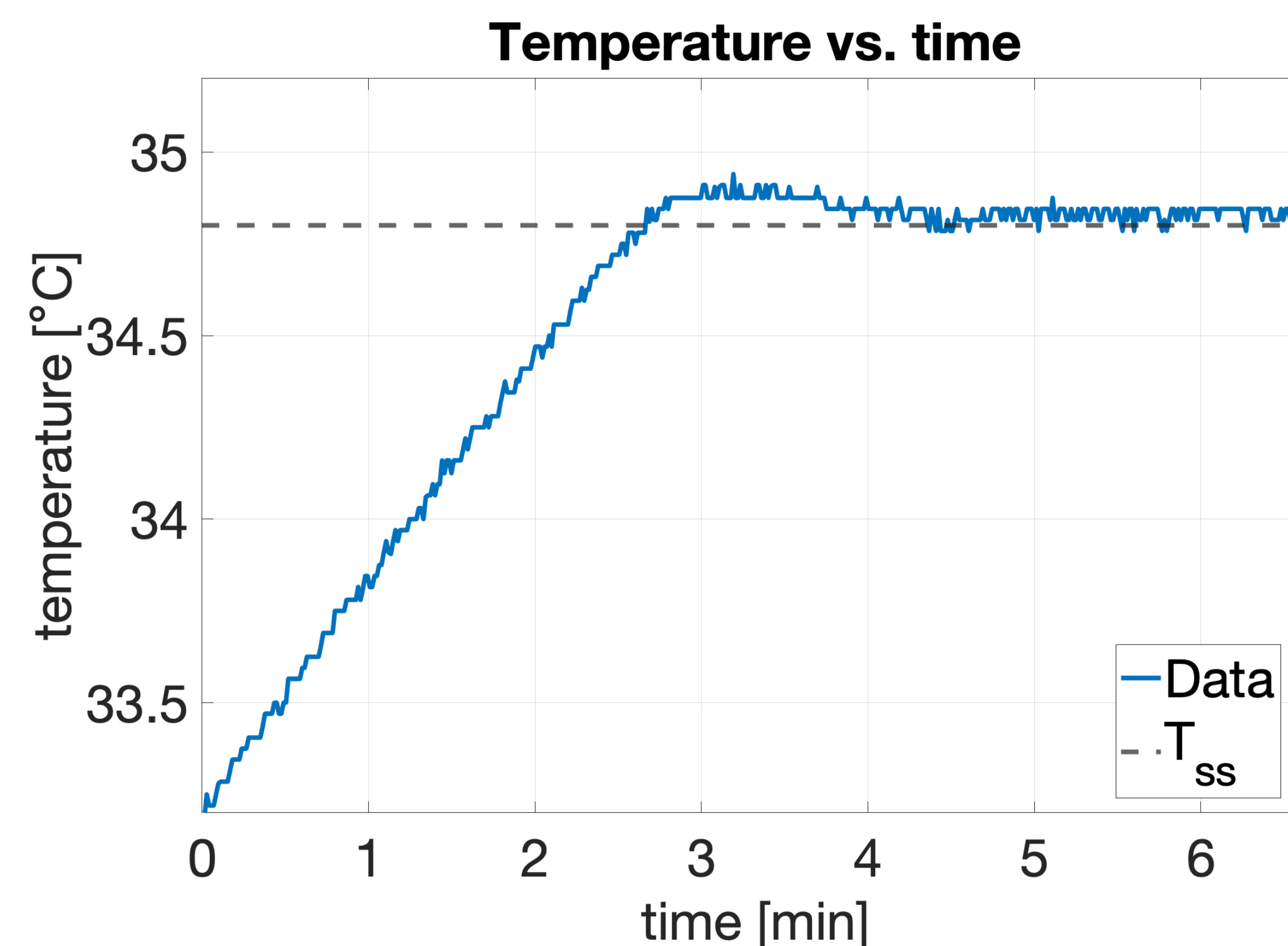


Figure 2 - Water heating control

Analysis: Cell viewing

- Yeast cells clearly visible within microchannel under microscope.
- Sharp contrast and focus achieved in viewing area.
- Resolution averaged 275 pixels per cell perimeter
- Imaging validated system's capability for observing temperature-dependent cell morphology.

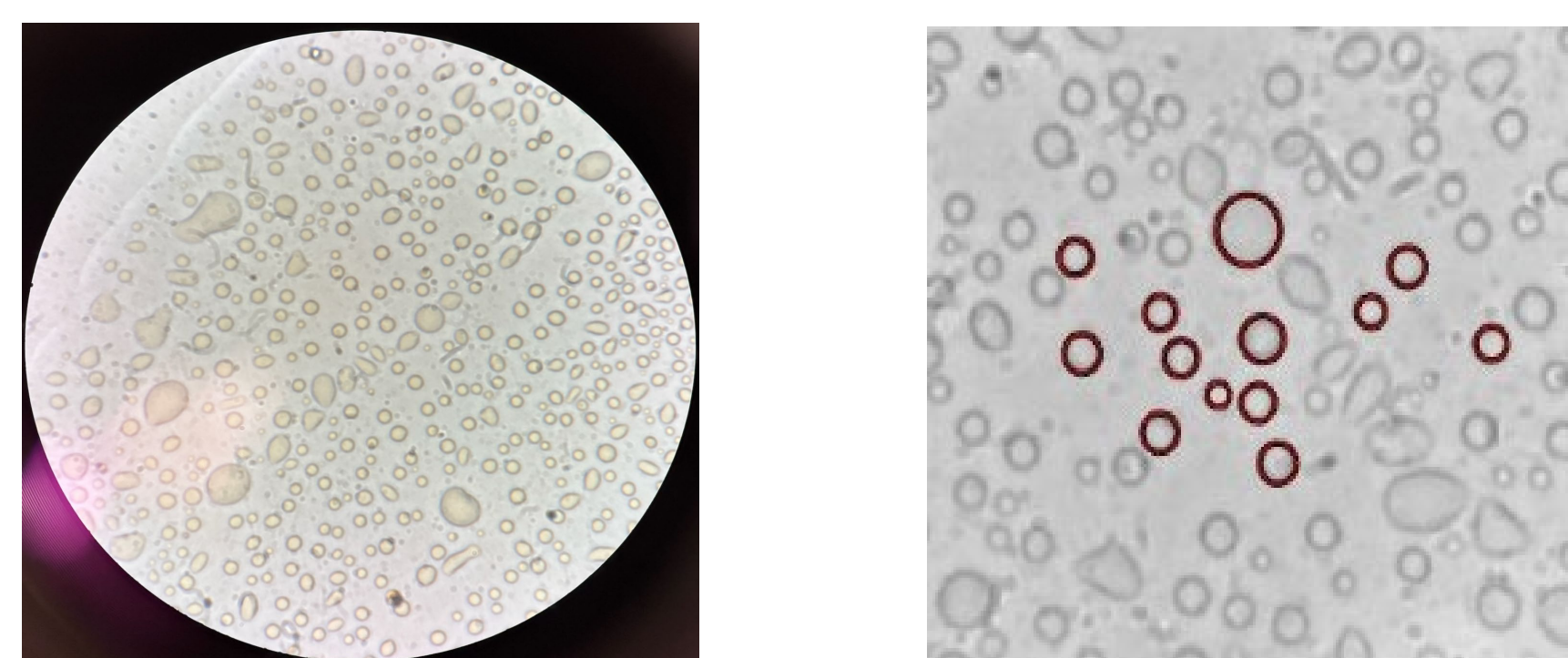


Figure 3 - Field of view of microscope (left) and computed cell perimeters (right).

Design Metrics

User-defined Specification	Target	Design
Viewing area must fit under microscope	2 x 8 x 2 cm	2.5 cm x 7.5 cm x 0.5 cm
Heater must supply sufficient power	20 W	150 W
Temperature reading accuracy	0.1 °C	0.5 °C
Sub-degree temperature control	± 0.5 °C	± 0.5 °C
Temperature range	34-42 °C	22-50 °C
Cell image must obtain perimeter with enough pixels	50 pixels	275 pixels
Media evaporation must be non-significant	5%	<1%

Results

- **Temperature Control:** Stable within ± 0.5 °C of setpoint using proportional-integral control (meets ± 0.5 °C goal).
- **Thermal Behavior:** System follows a first-order response with experimental and simulated data closely matching
- **Temperature Gradient:** Maximum of 1 °C across 0.2 m flow path \rightarrow uniformity acceptable but can be improved.
- **Evaporation:** <1 % mass loss after one hour \rightarrow negligible energy loss.
- **Imaging:** Yeast cells clearly visible; >50-pixel perimeter resolution achieved.

Conclusions

The final bioreactor met most of the design goals, achieving ± 0.5 °C temperature control, minimal evaporation, and clear cell imaging. The system now provides a validated platform for studying thermal regulation mechanisms in biological cells. Future work includes integrating automated imaging and improving thermal uniformity for higher-precision biological experiments.