

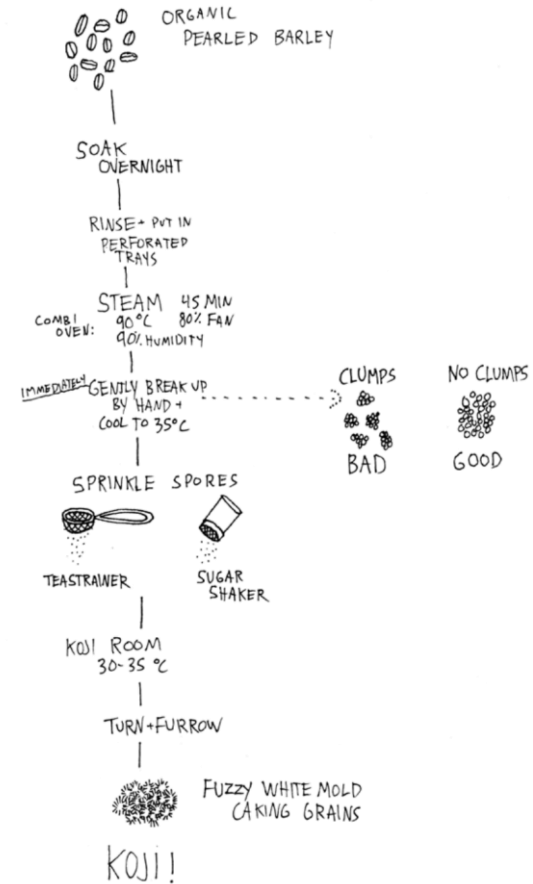
Fermentabot (2018-2019)

Micro-climate fermentation for upcycling of food waste (into Koji)

Sponsored by the Basque Culinary Center

Agenda

- 1) Mechanical Specifications and Requirements
- 2) Fermentabot 2.0 Design Overview
- 3) Notable Features
- 4) Early Stage Design Process
- 5) Humidification Testing and Prototyping
- 6) Testing Results
- 7) Next Steps for Development
- 8) Timeline



Fermentabot Project Overview

Mechanical Specifications and Requirements

1) Housing and storage

- Insulated food storage box and perforated food pans/cotton cloth

2) An “Environmental Chamber”

- A device that can be attached/removed from the catering box and contains all the mechanical actuators such as heaters and fans.

3) Air circulation heating/cooling system

- 12V Peltier Cooler
- 12V heating element
- 12V equipment-cooling fan

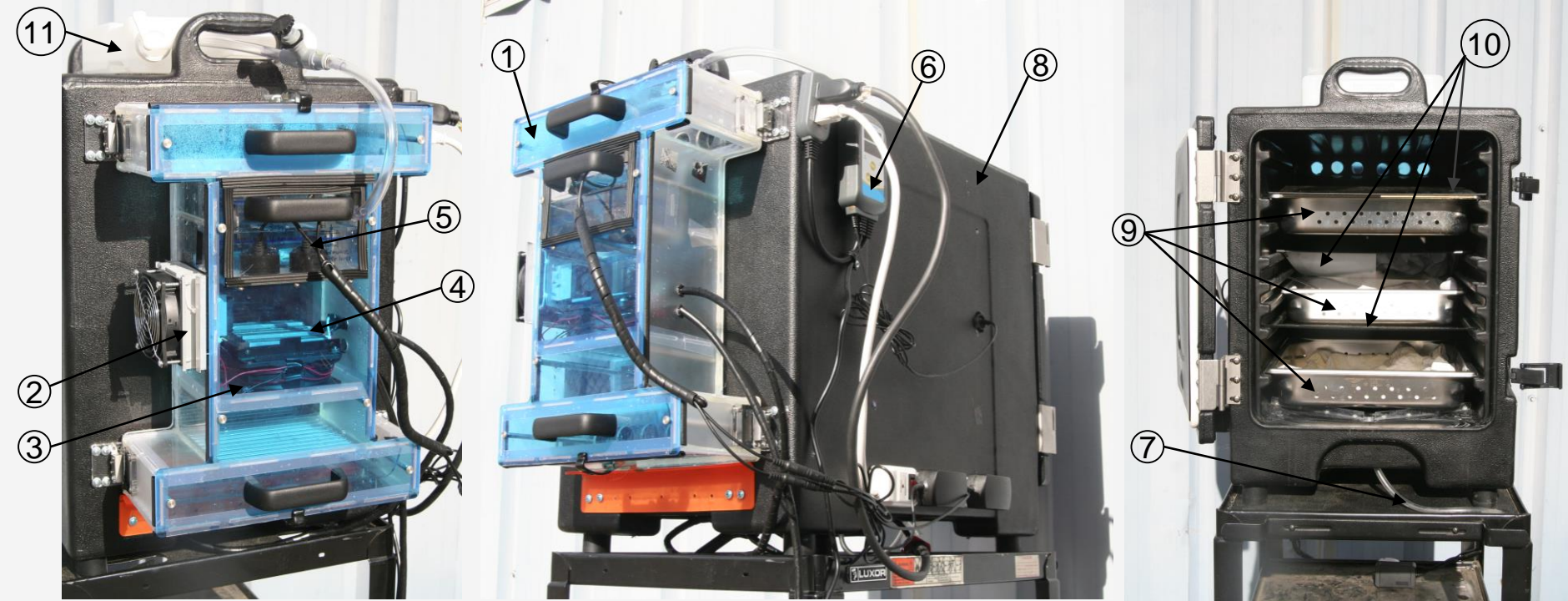
4) Humidification system

- External humidification cartridge
- Miniature ultrasonic fogging technology

5) Control System

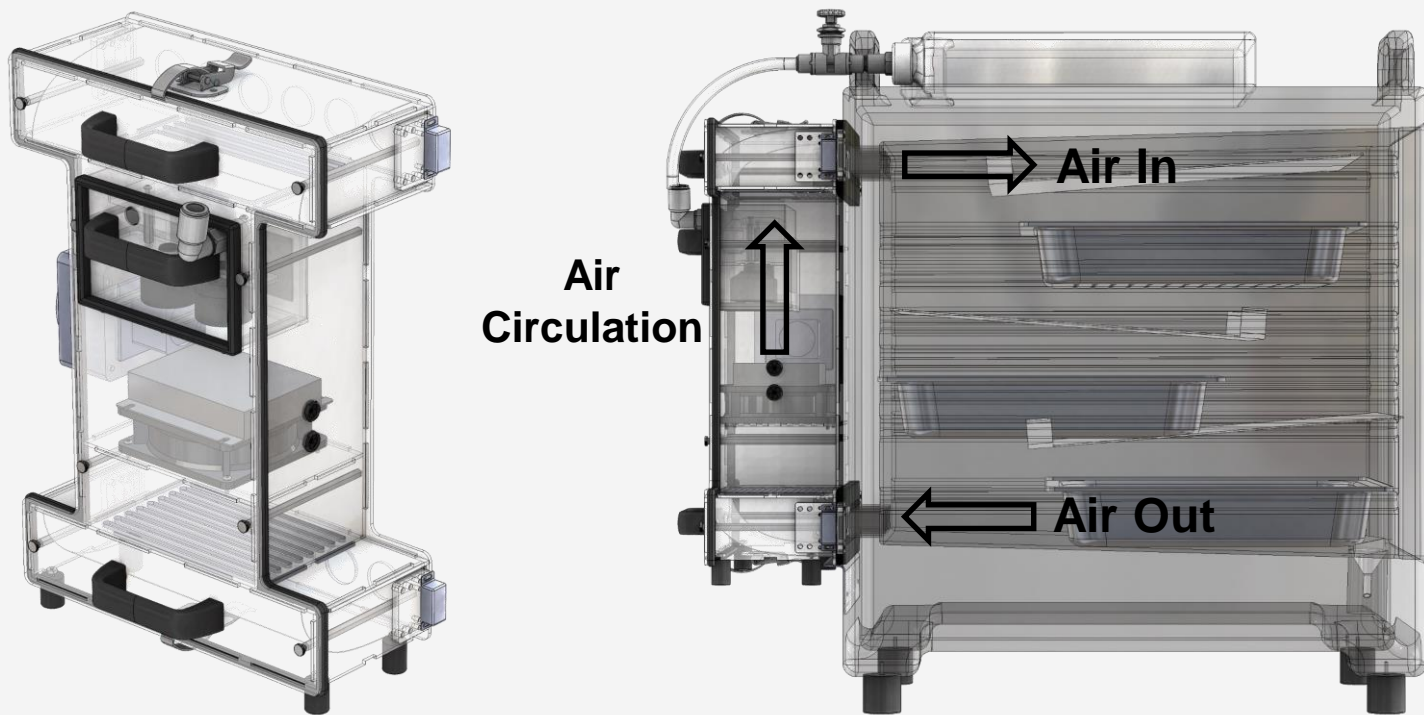
- Humidity and temperature control





Fermentabot 2.0 Project Overview

- 1. Environmental Chamber
- 2. Thermoelectric Peltier Cooling Unit
- 3. 12V Equipment Cooling Fan
- 4. Heater Unit
- 5. Humidifier Unit
- 6. Temp/Humidity Control System (with live readout)
- 7. Condensation Exit
- 8. Insulated Food Pan Carrier
- 9. Food Pans (with cloth covers)
- 10. Condensation Protectors
- 11. Humidifier Unit Refill Reservoir



Notable Features

- The **Environmental Chamber** housing is laser cut from transparent acrylic sheets, and the assembled edges sealed with hot melt adhesive
- The food pans are staggered inside the **Carlisle Food Pan Carrier** to aid airflow, and **Condensation Protectors** help in preventing too much moisture from dripping onto the koji (though they may cause uneven heating/humidification, which will be investigated further)
- All materials used in the Fermentabot are non-corrosive and will endure continuous grow/cleaning cycles



Notable Features

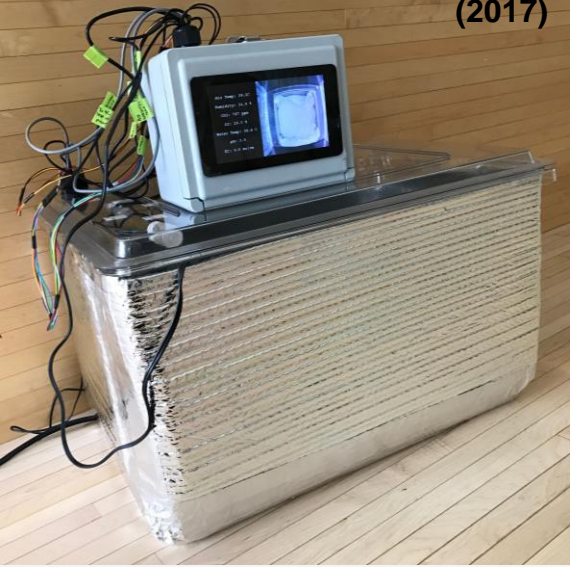
- **Environmental Chamber** can be detached from the **Carlisle Food Pan Carrier** (via grab latches), and disassembled without tools for cleaning
- The **FitNate** humidifiers have an operational life of 2000-3000 hours, or approximately 60-80 koji cycles, and the **Humidification Unit** was designed for easy removal of humidifiers for replacement, without tools
- The **Peltier Cooling Unit** will become operational upon software/hardware integration



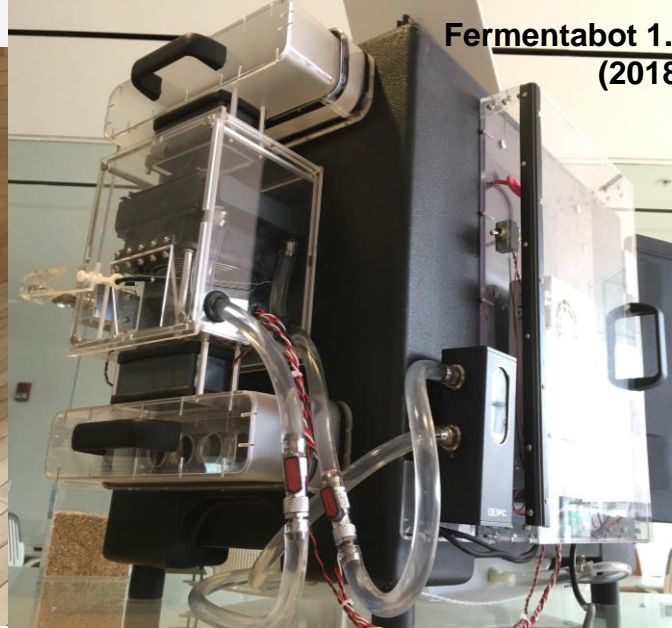
Notable Features – Interim Temperature/Humidification Control System

- **IHC-230** Plug-n-Play Humidity and Temperature Controller
- Temperature Range: -40°C~100°C
- Humidity Range: 5%-99.9%RH
- Setting over/under Range: +/- 1°/%

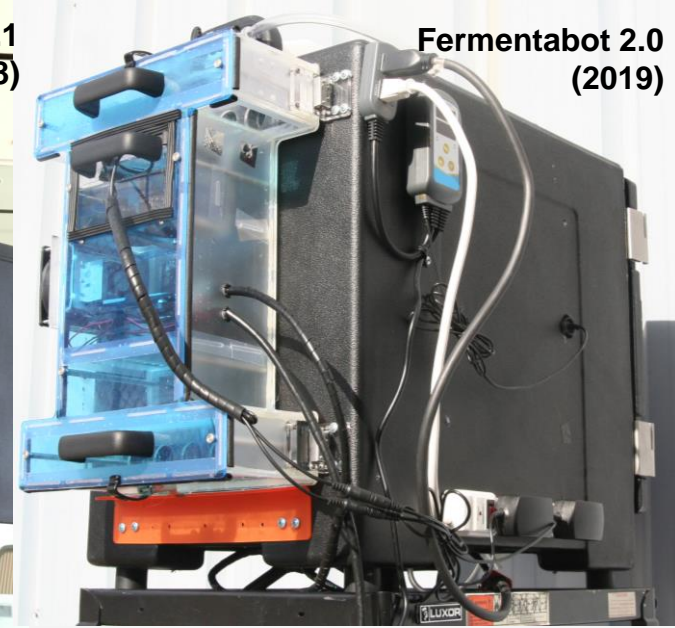
Fermentabot 1.0
(2017)



Fermentabot 1.1
(2018)

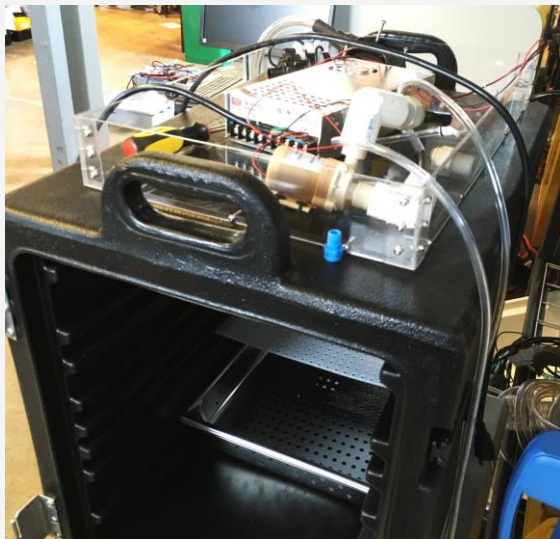


Fermentabot 2.0
(2019)



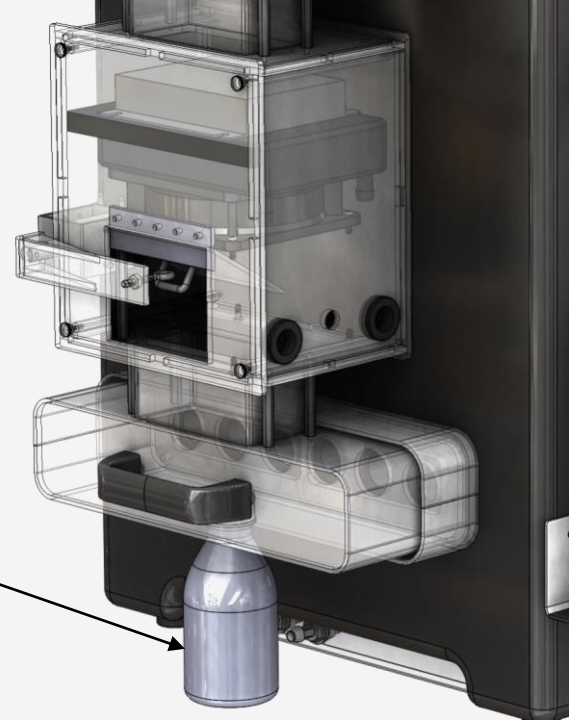
Design Progress - Overview

- Iterative prototyping – “Fail Fast and Fail Often”
- Rapid fabrication of prototypes/housings/electronics helped form an understanding of the system’s functionality
- Design focused on minimal use of tools for disassembly and maintenance
- Using off-the-shelf components to create a sealed environmental system



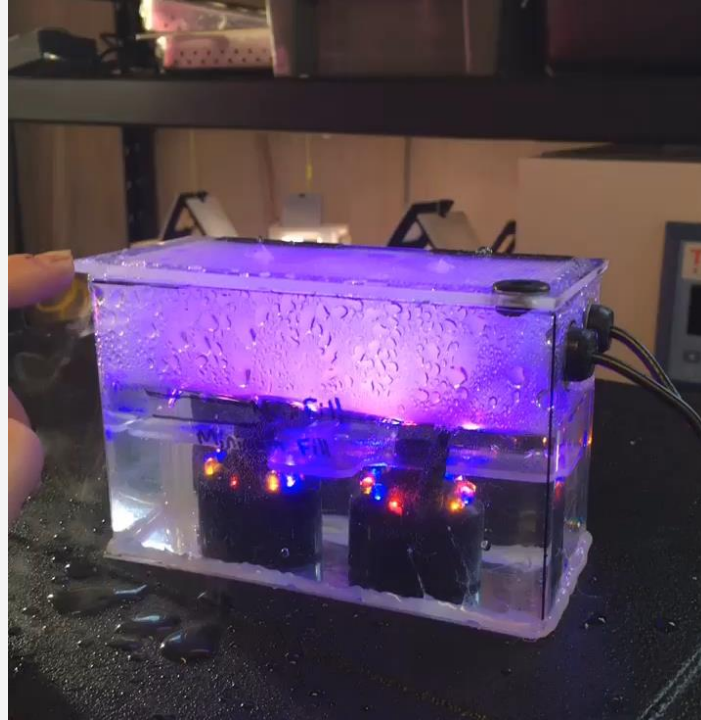
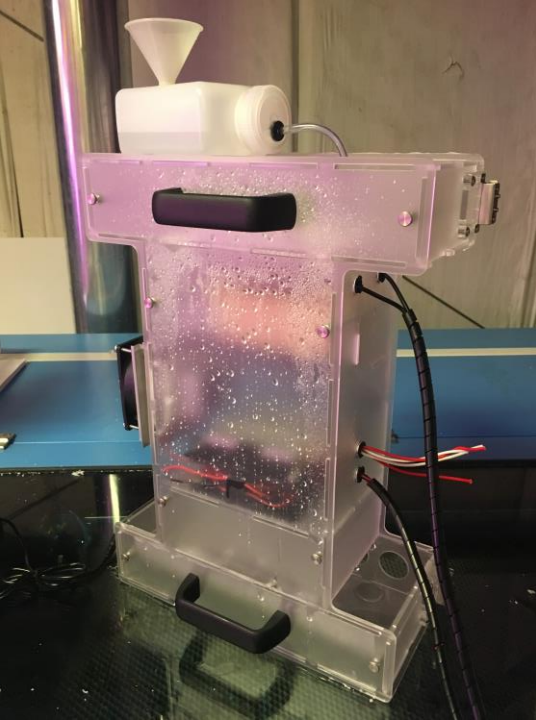
Design Progress – Early Stage

- Initial designs considered water heater/chillers for controlling ambient temperature (based on *OpenAg Germinators*)
- External enclosures were considered for any onboard electronics/power supplies
- OpenAg already had inventory of heating units, fans, tubing, chillers, pumps etc. for rapid prototyping
- Off-the-shelf components were to be used whenever possible



Humidification Testing and Prototyping – Early Stage

- Integration of various off-the-shelf solutions to characterize the system's humidification capacity
- Pressurized water through spray nozzles created too much direct condensation on the cotton cloth
- Bottlecap humidifiers did not provide enough moisture to the system
- Iterative testing led to the selection of an ultrasonic fogger



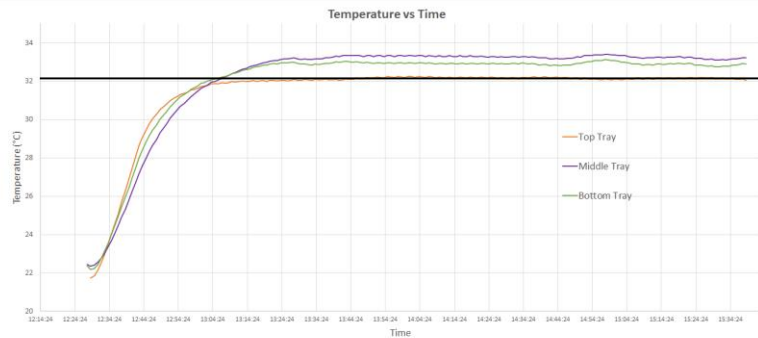
Humidification Testing and Prototyping

- Final selection: **FITNATE Ultrasonic Mist Maker**
- **Environmental Chamber** design necessitated both off-the-shelf and custom solutions
- Various designs were considered for integrating the humidifier and controlling humidity levels
- Testing showed that two **FitNate** units were necessary to reach required humidity levels

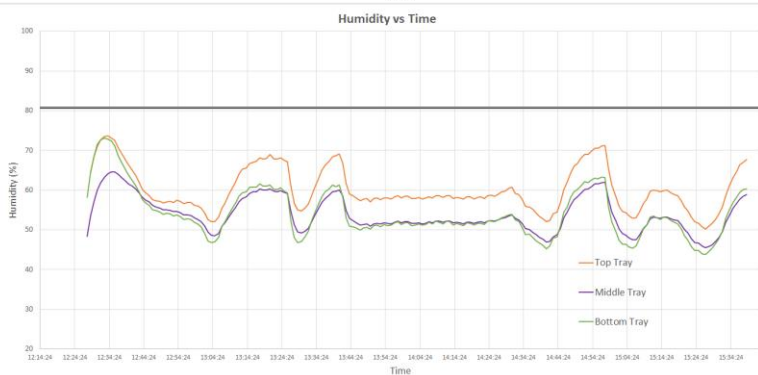
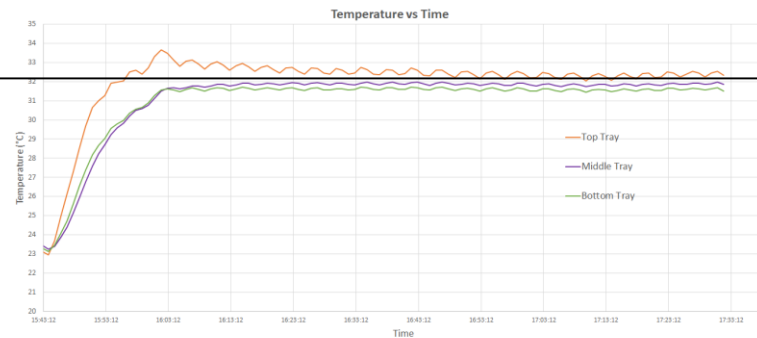


Humidification Testing and Prototyping

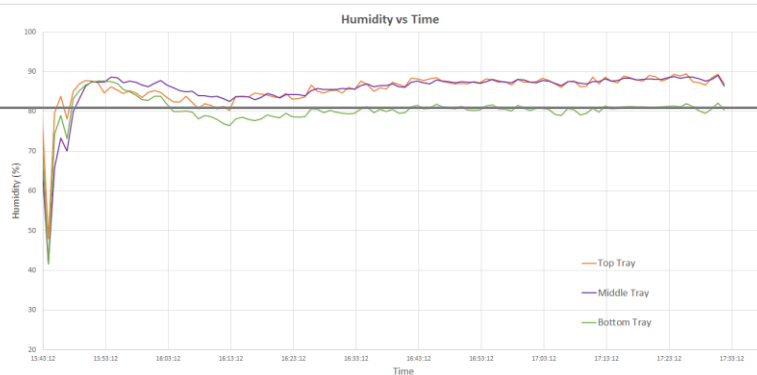
- **Humidifier Unit** was integrated into **Environmental Chamber** so that it could be removed for maintenance and refilled based on the rate of water usage
- Designed for easy handling, cleaning, and maintenance
- Water use approximates 1 mL/min, or 2.2 L over the course of a 36 hour fermentation, due to condensation inside the Food Carrier and positive pressure inside the Environmental Chamber pushing humidity out through leaks in the system



32°C

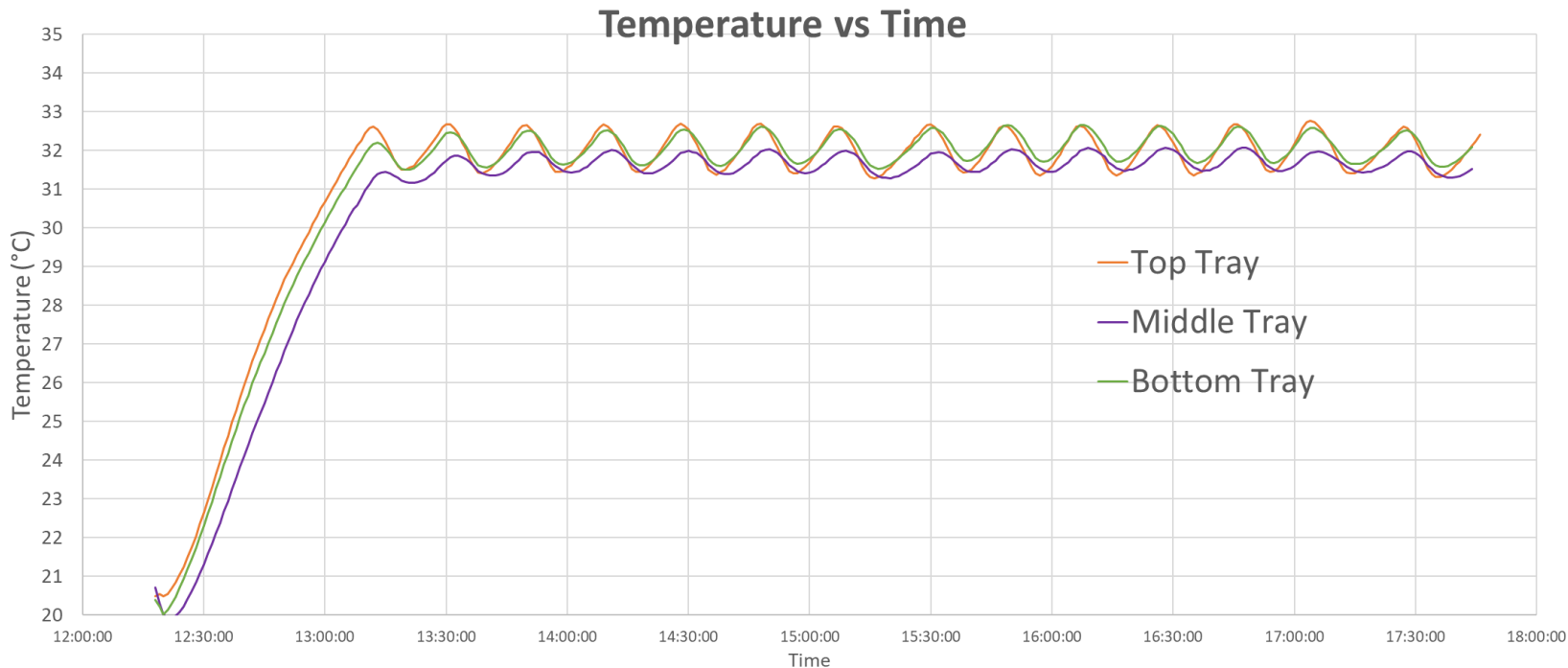


80% RH



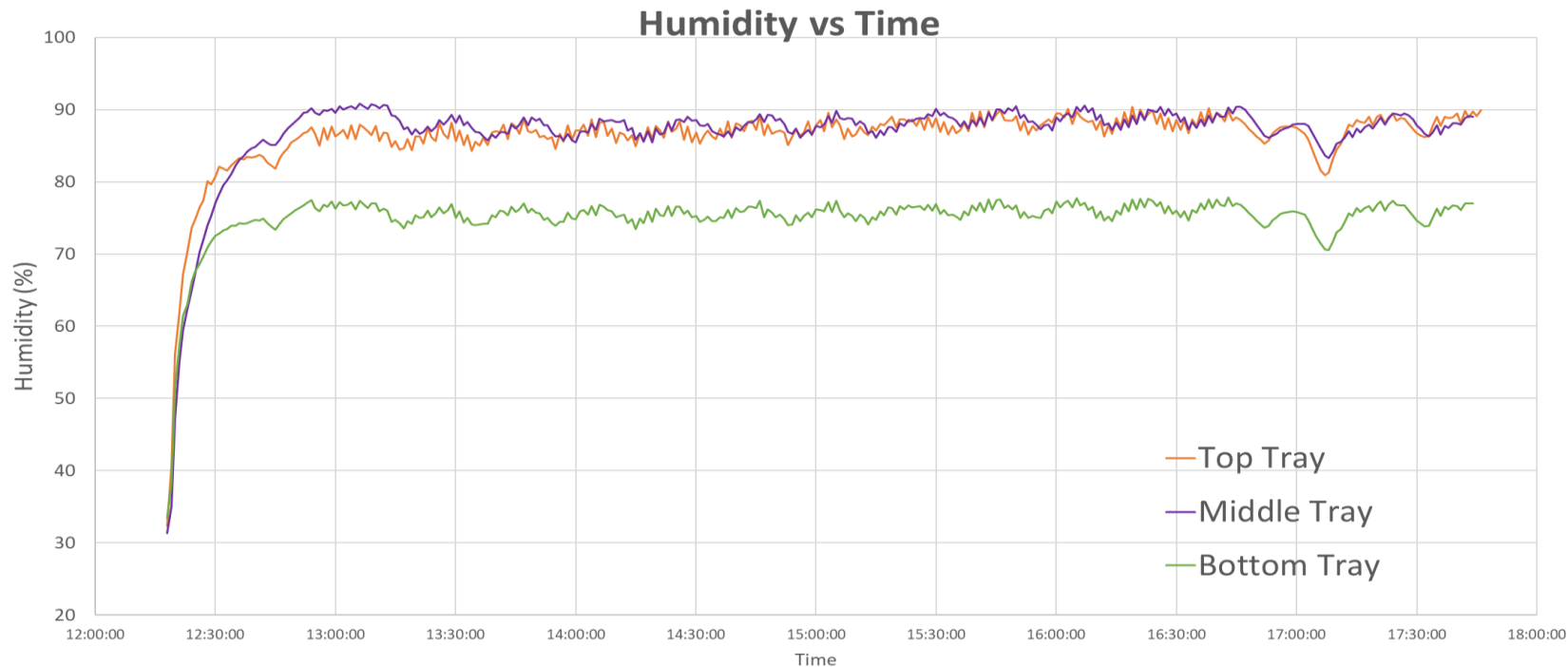
Testing Results - Introduction

- Two hour burn-in tests helped in characterizing the sensitivity of the environmental controls
- Location of temperature sensor affected the temp/humidity of each tray
- Data collected with off-the-shelf **Omega OM-92** sensors, transferred manually into Excel



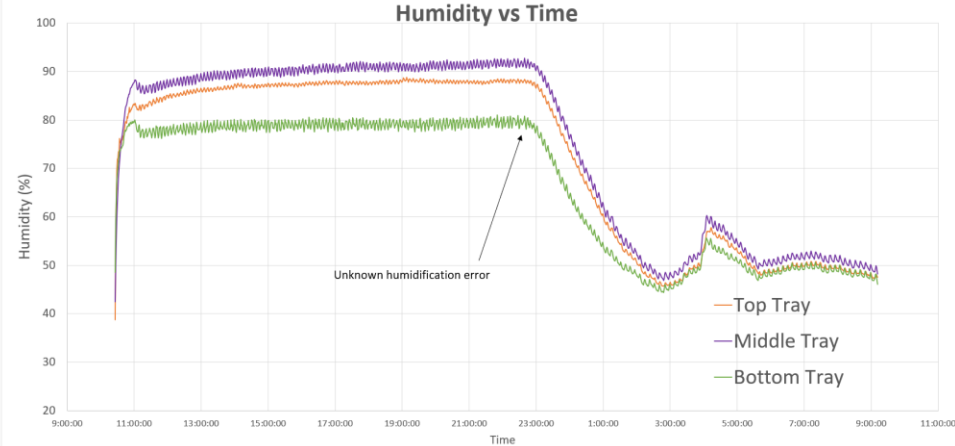
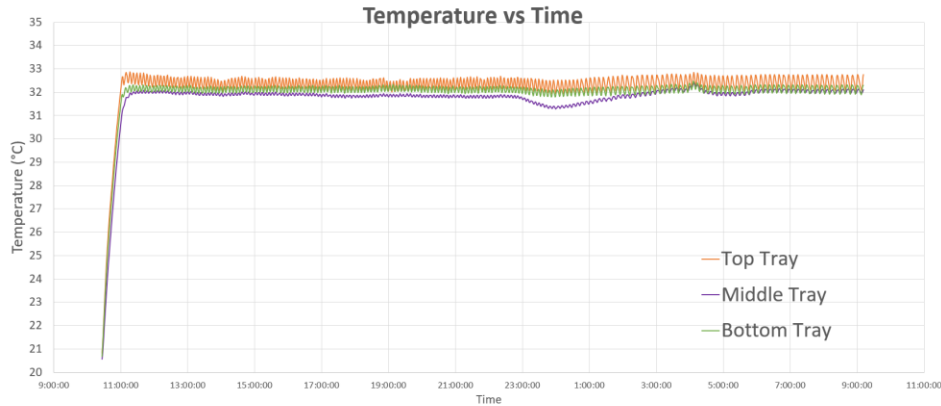
Testing Results – 5 Hour Burn-in

- Temperature from 20°C (ambient) to 32°C in approximately 30 minutes (heating rate of 24°C/hr)
- ~0.5°C difference between each tray, based on air flow clearance inside
- Temperature set to 32°C with bounds at +/-1°C
- More testing necessary to understand discrepancy between middle and top/bottom tray temperature profiles



Testing Results – 5 Hour Burn-in

- Humidity from 30-40% RH (ambient) to 80-90%RH in approximately 15 minutes
- ~10%RH variance between the top and bottom tray, based on air flow clearance inside
- Humidity set to 80.5%RH with bounds at +/- 1%
- Bottom tray experienced least amount of humidity when **Condensation Protectors** were used



Testing Results – 24 Hour Burn-in

- Longer burn-in data trend reflects short-term burn-in results
- 10% difference in RH between top and bottom tray remains steady (even without **Condensation Protectors**)



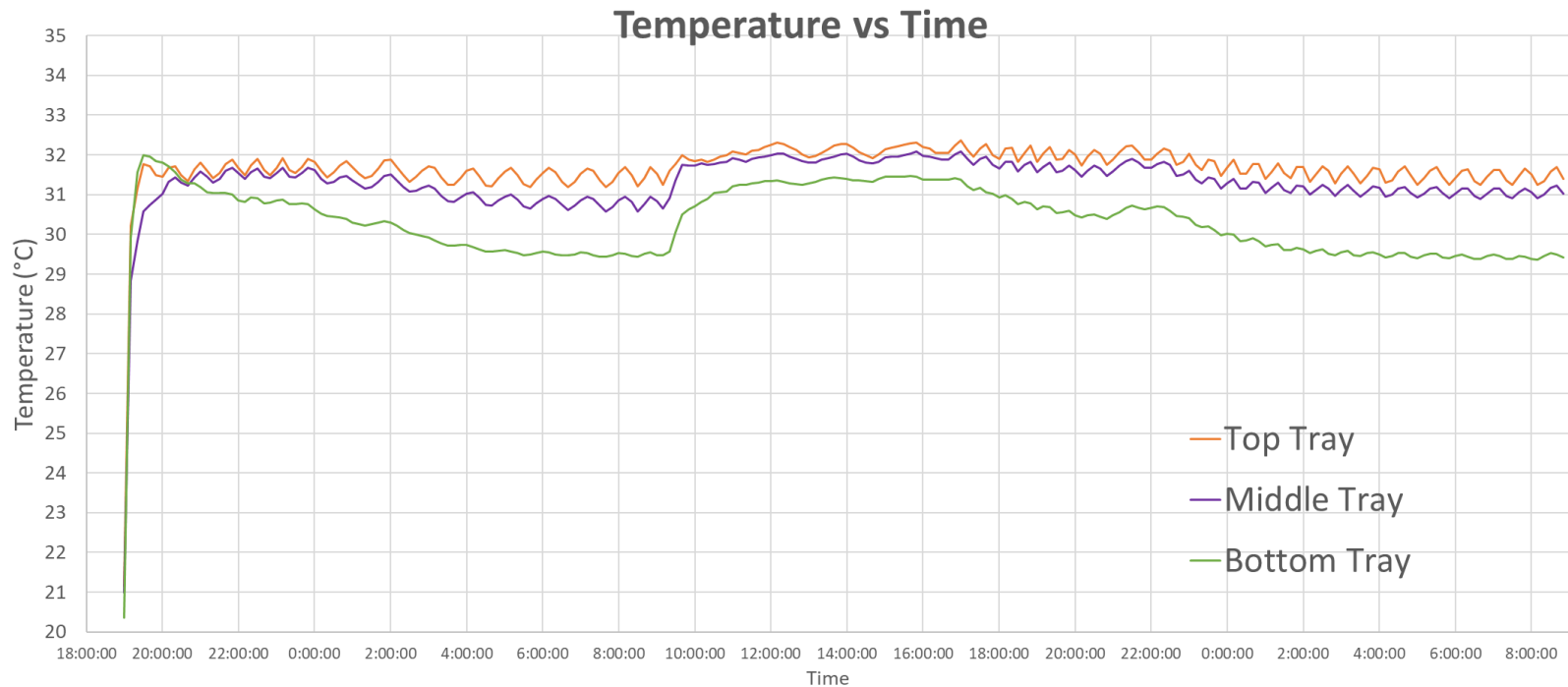
Testing Results – First Batch

- Koji grown successfully on jasmine rice in a single tray at 32°C and 80% RH for 36 hours (with the help of Rich Shih)
- Control system used for this batch was unreliable, so only one batch was grown until a better control system could be integrated



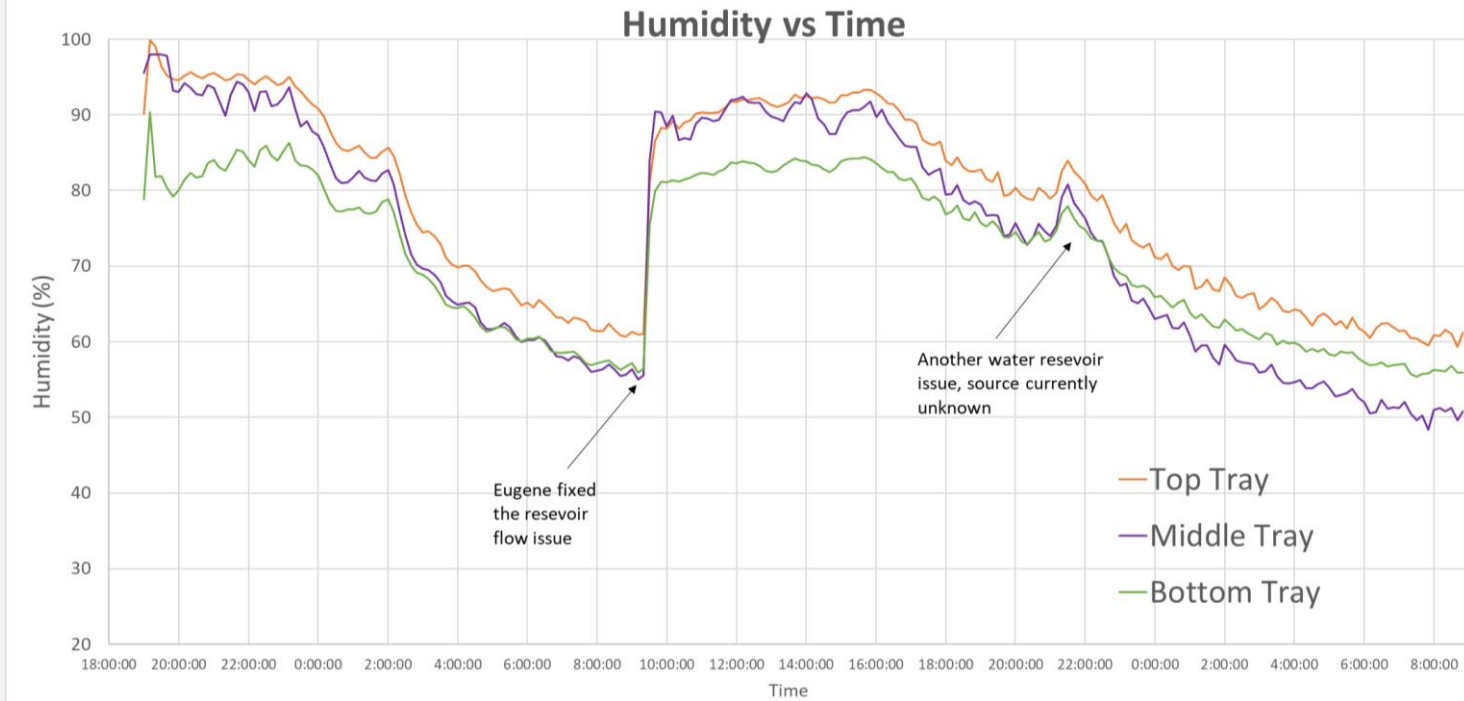
Testing Results – Second Batch

- Koji grown successfully on jasmine rice on all three trays at 32°C and 80% RH for 36
- Control system used was the interim IHC-230 Plug-n-Play Humidity and Temperature Controller



Testing Results – Second Batch Data

- **Condensation Protectors** were not used for this batch of Koji
- Top and Middle trays expressed similar temperature profiles to shorter test
- Bottom tray fell to 1.5°C lower



Testing Results – Second Batch Data

- **Condensation Protectors** were not used for this batch of Koji
- A flow issue with the 4L water reservoir caused the humidity to fluctuate during the grow cycle

Next Steps for Development

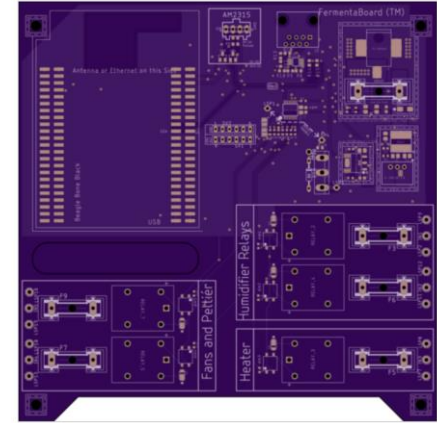
1) Next development steps include

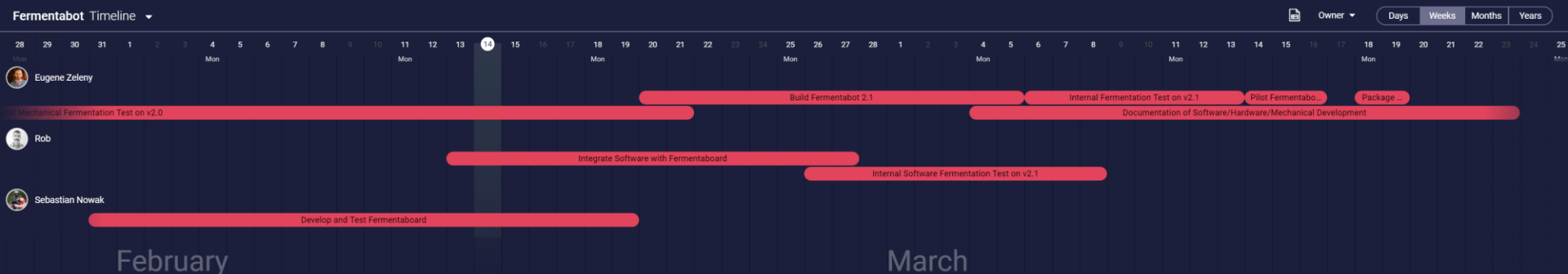
1) Mechanical Development

- 1) Improving mechanical seals on Environmental Chamber
- 2) Improving humidification unit water refill system

2) Software and hardware development

- 1) Creating, fabricating, and testing a circuit board:
“Fermentaboard.”
- 2) Creating an online user interface that can control the Fermentabot and collect data via wi-fi
- 3) Integrating the software/hardware development into the existing Fermentabot prototype





Timeline	Owner	Status	Due Date	Timeline	Link	
Build Fermentabot v2.0		Done	Jan-9	Dec-4 - Jan-8		
Internal Mechanical Fermentation Test on v2.0		Working on it	Feb-21	Jan-8 - Feb-21		
Develop and Test Fermentabot		Working on it	Feb-21	Jan-31 - Feb-19		
Integrate Software with Fermentabot		Waiting to Start	Mar-2	Feb-13 - 27		
Build Fermentabot 2.1		Waiting to Start	Mar-6	Feb-20 - Mar-5		
Internal Software Fermentation Test on v2.1		Waiting to Start	Mar-8	Feb-26 - Mar-8		
Internal Fermentation Test on v2.1		Waiting to Start	Mar-14	Mar-6 - 13		
Documentation of Software/Hardware/Mechanical Development		Waiting to Start	Mar-28	Mar-4 - 23		
Pilot Fermentabot w/Diego		Waiting to Start	Mar-16	Mar-14 - 16		
Package & Ship Fermentabot to Diego		Waiting to Start	Mar-16	Mar-18 - 19		

Timeline Breakdown

- Estimated completion of Fermentabot 2.1 (with integrated software/hardware) for Diego's visit: March 12-15th

Thank You.