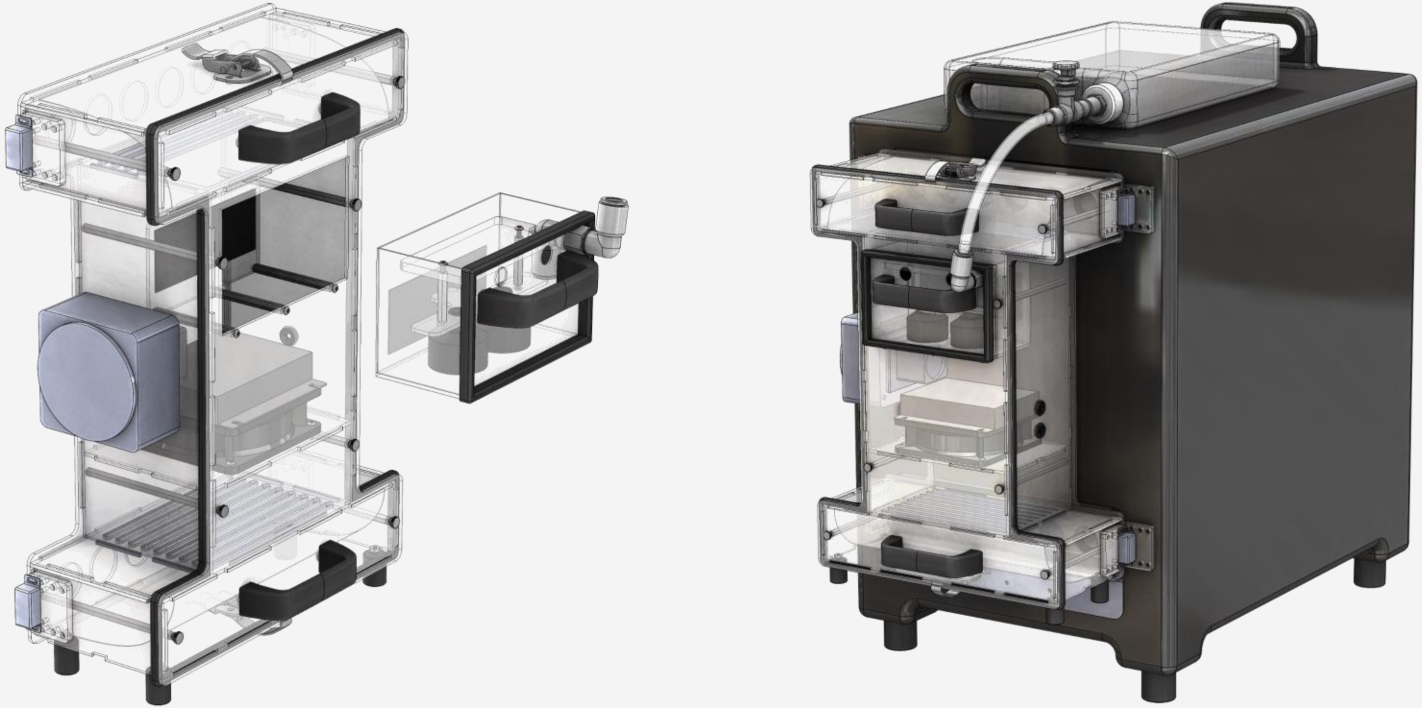

Fermentabot (2018-2019)

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

Sponsored by the Basque Culinary Center

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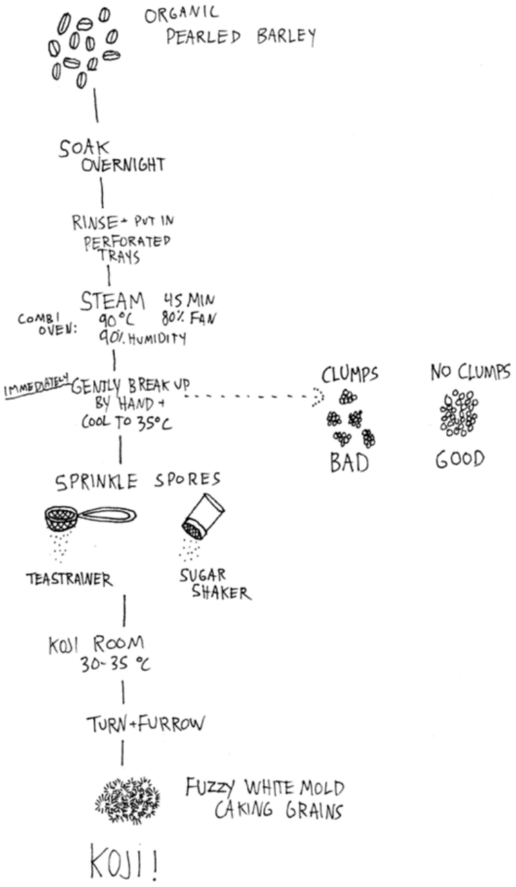
Agenda

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

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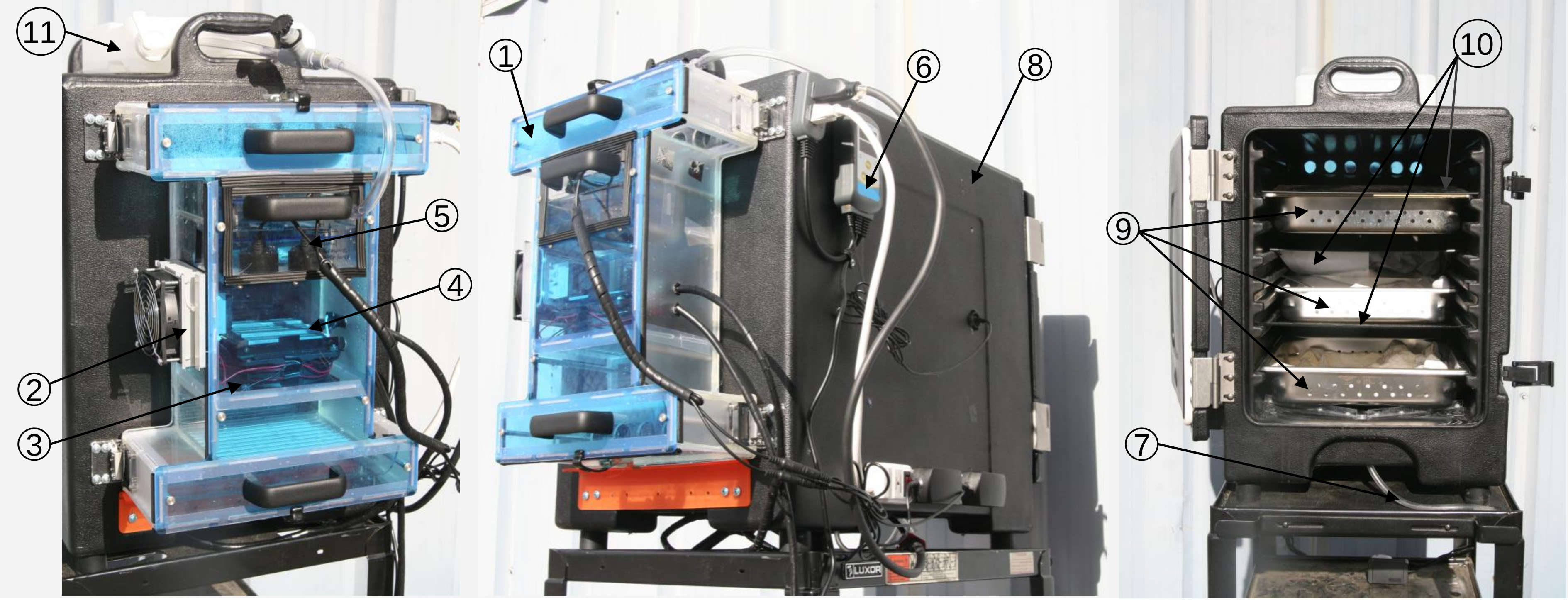

Fermentabot 2.0 Project Overview

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

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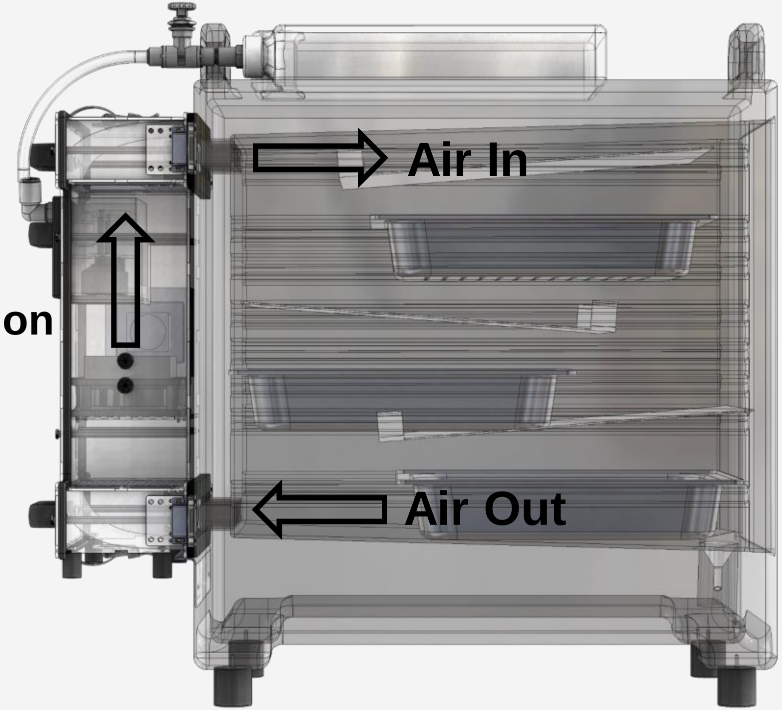
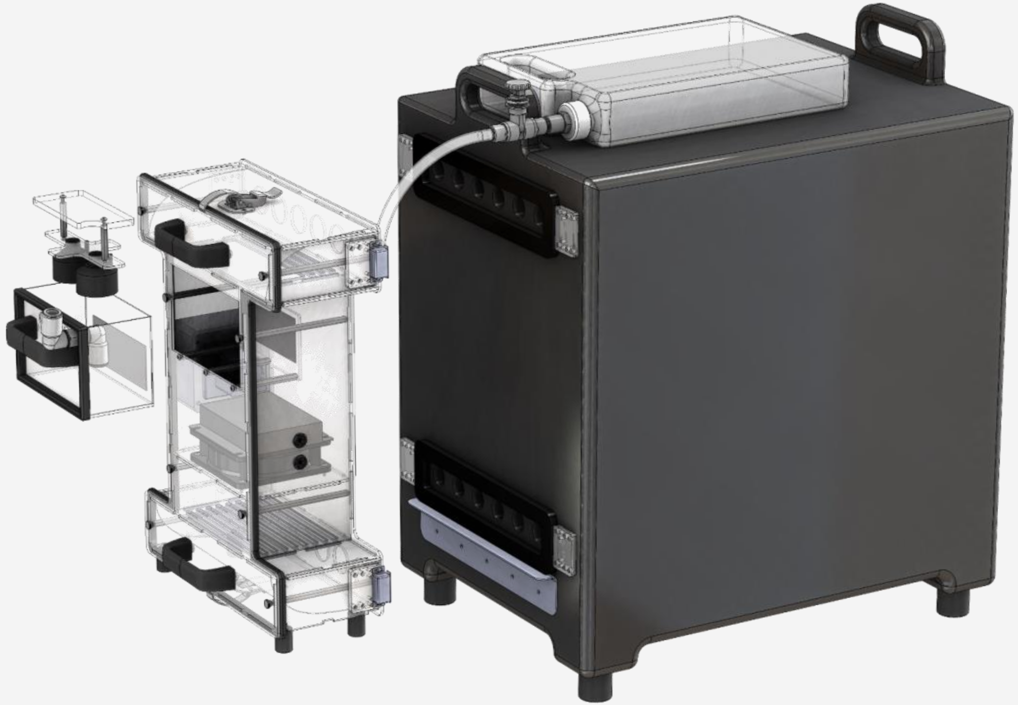


Notable Features

- 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

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Notable Features – Interim Temperature/Humidification Control System

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

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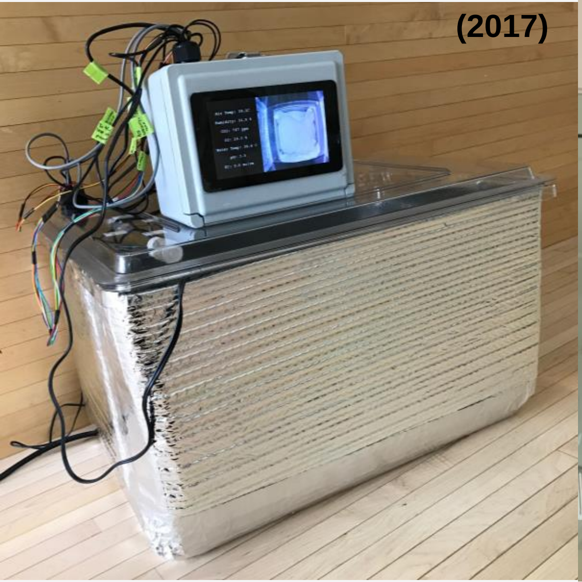

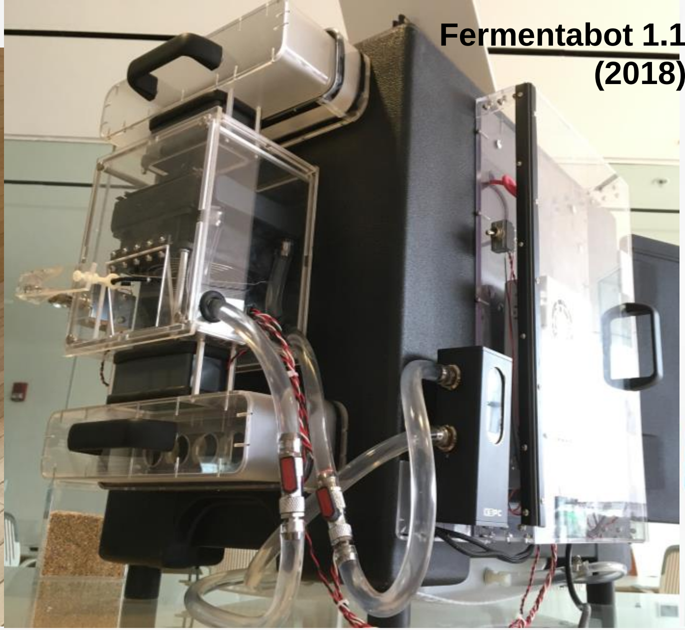

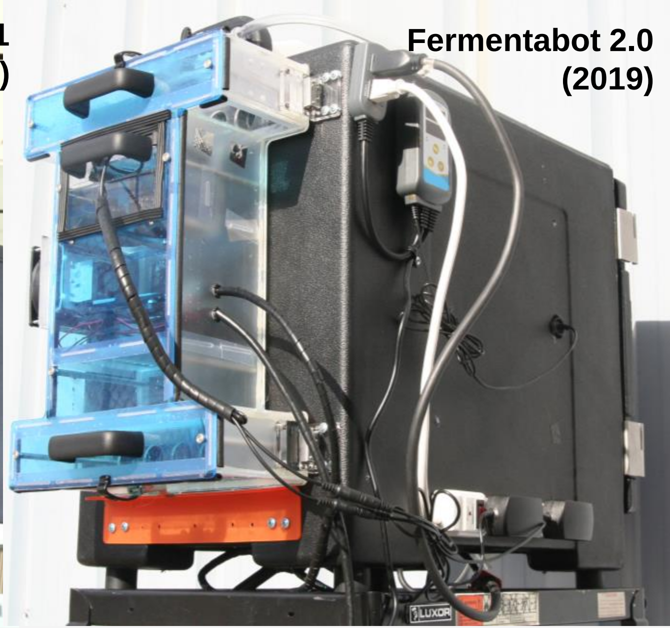

Design Progress - Overview

- 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

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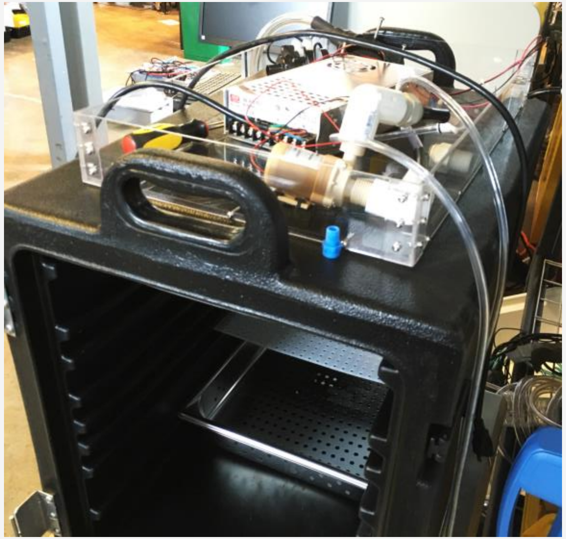

Design Progress – Early Stage

- 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

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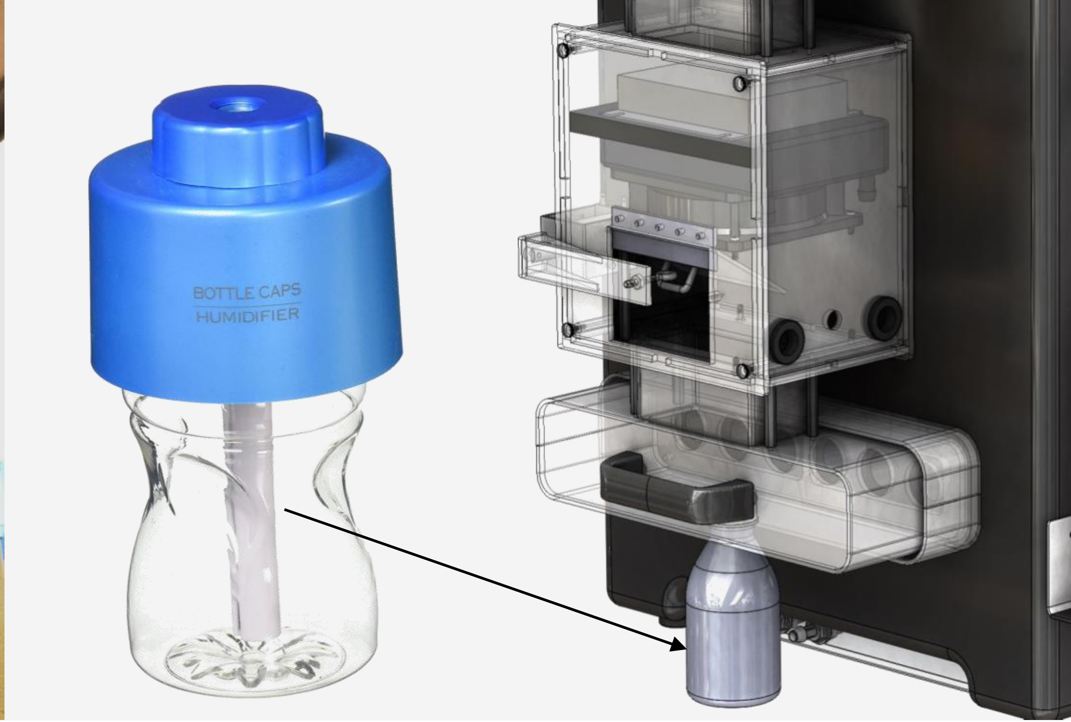

Humidification Testing and Prototyping – Early Stage

- 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

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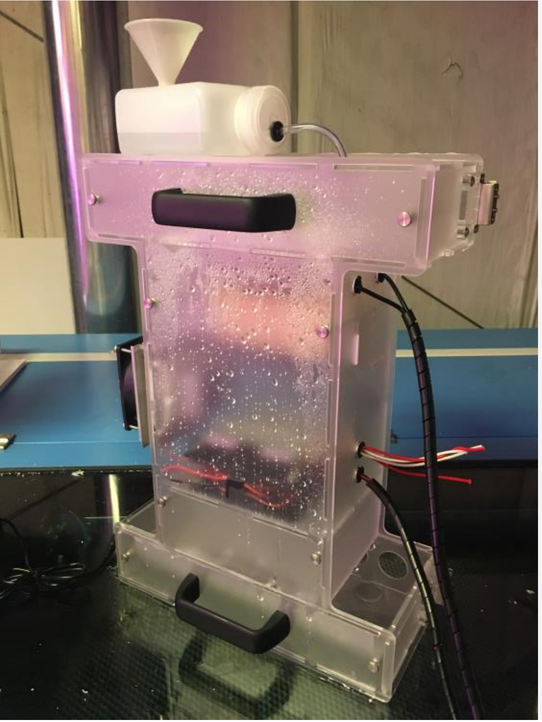
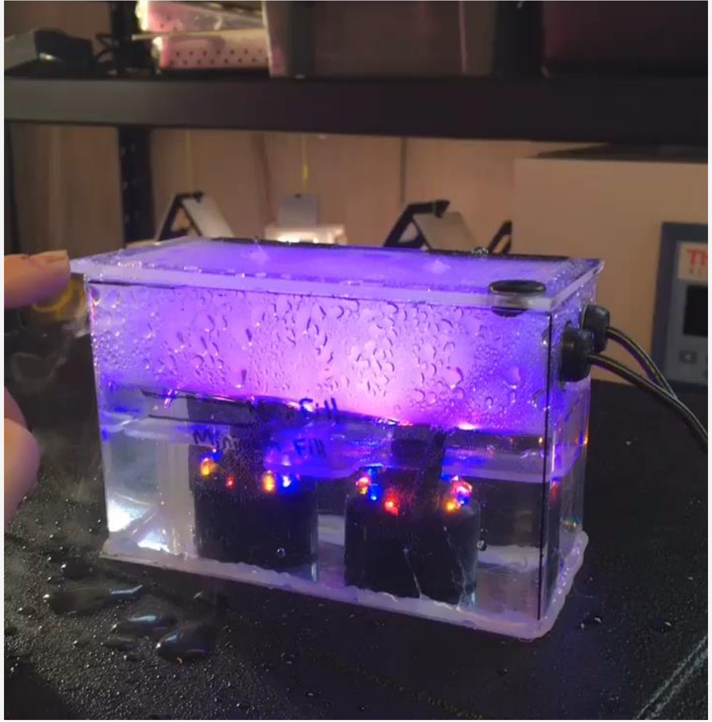


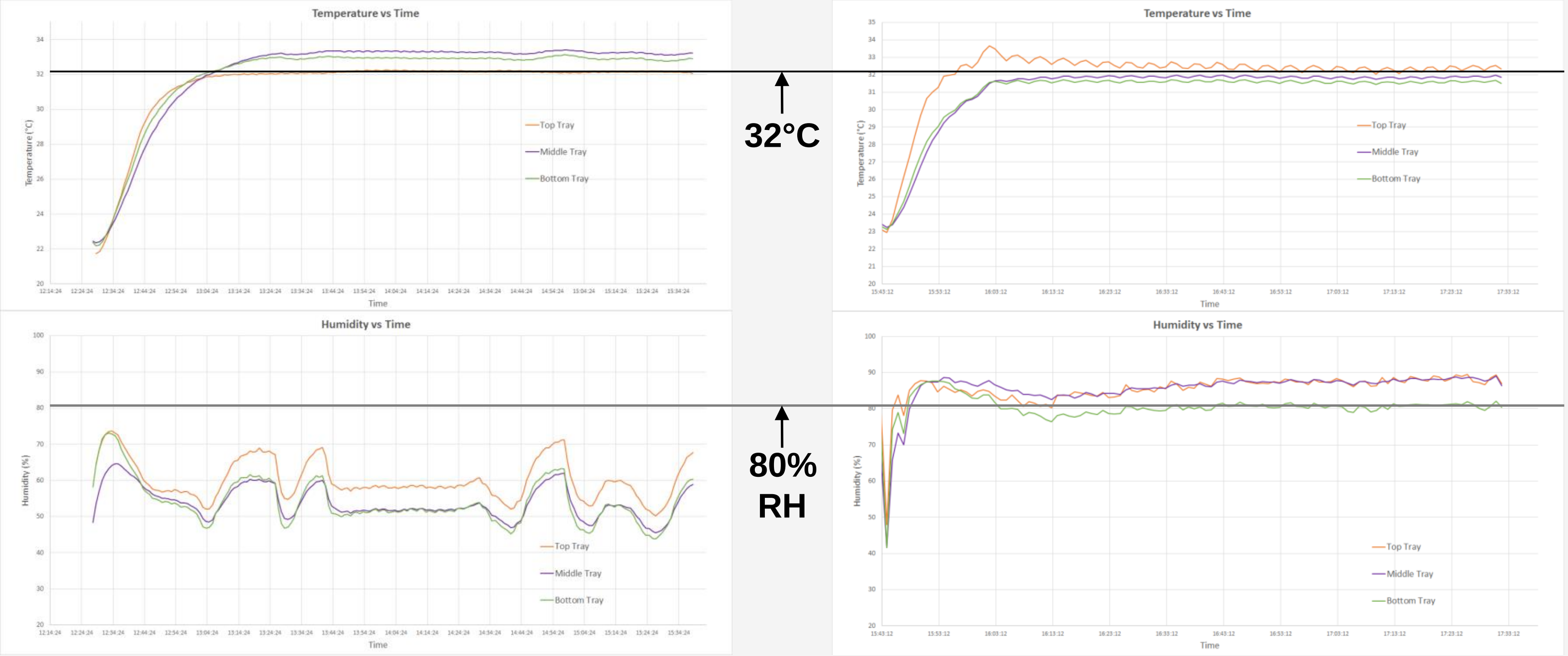


Humidification Testing and Prototyping

- 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

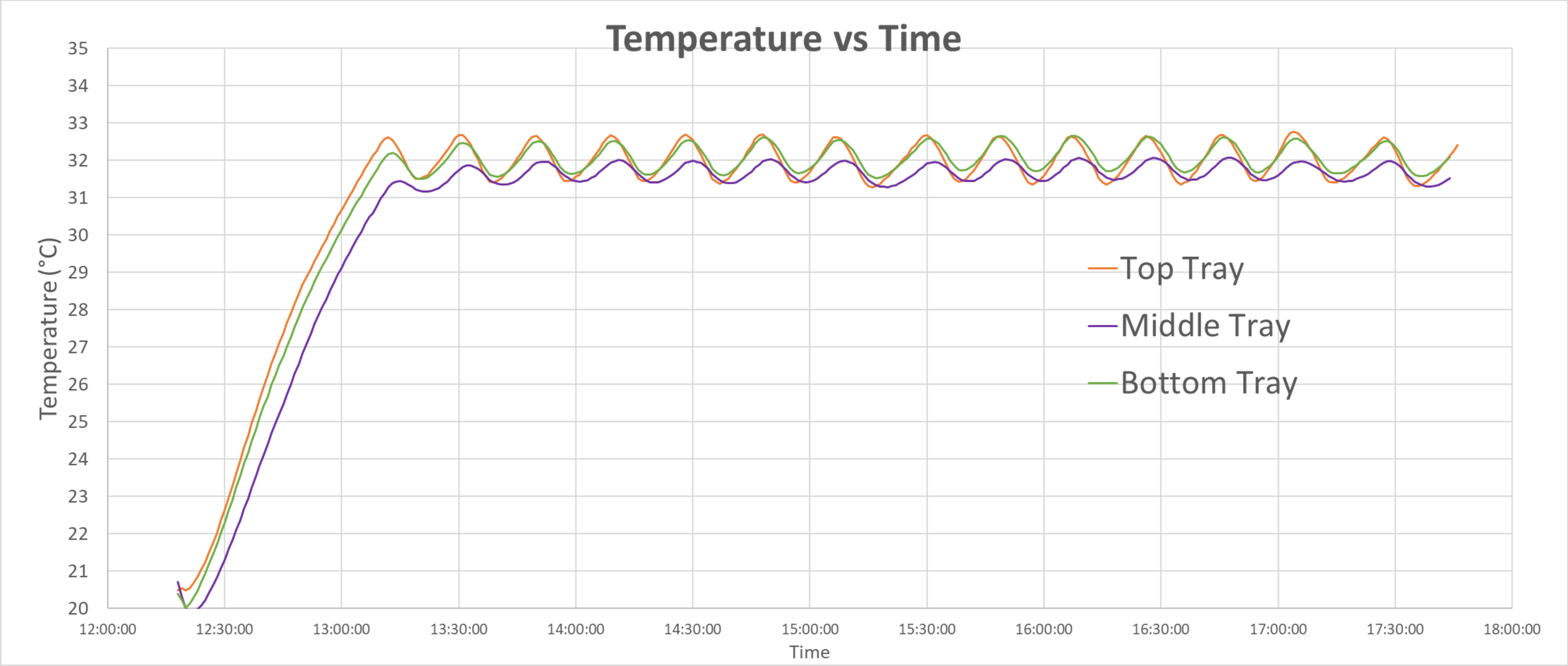
Humidification Testing and Prototyping

- **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



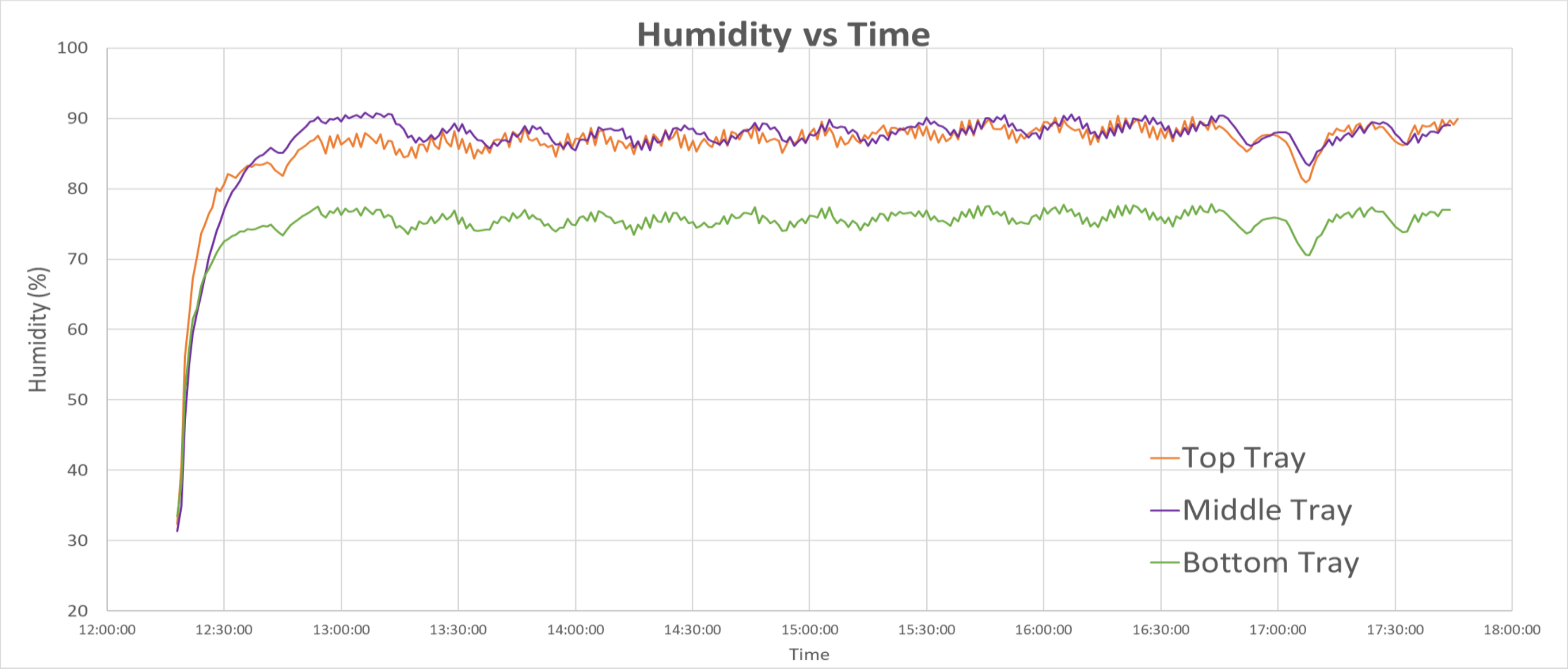
Testing Results - Introduction

- 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



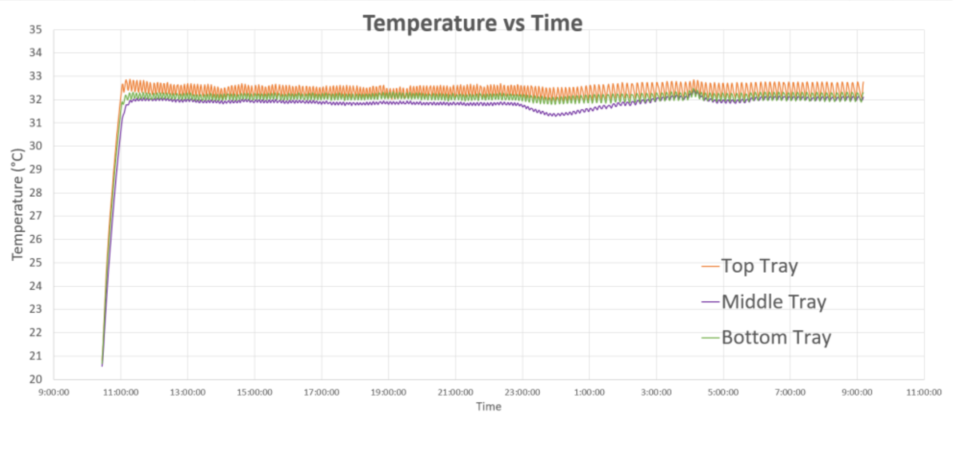
Testing Results – 5 Hour Burn-in

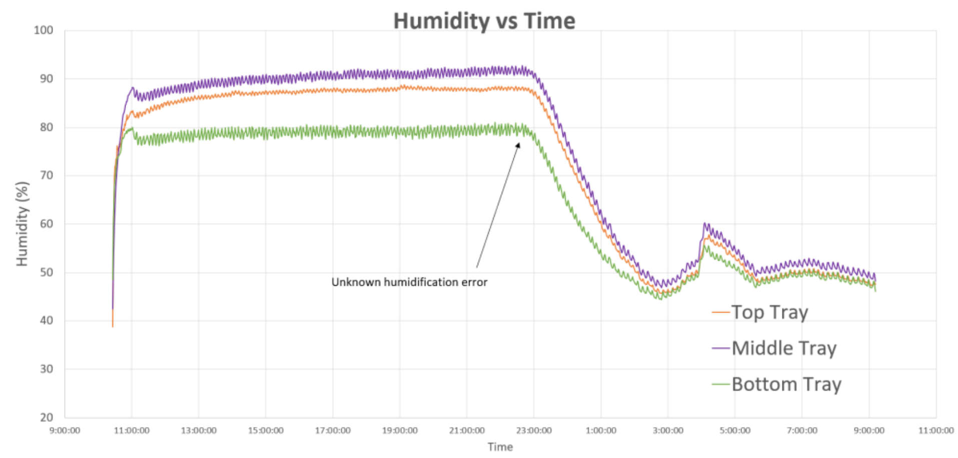
- Temperature from 20°C (ambient) to 32°C in approximately 30 minutes (heating rate of 24°C/hr)
- ~0.5°C difference between each tray, based on air flow clearance inside
- Temperature set to 32°C with bounds at +/-1°C
- More testing necessary to understand discrepancy between middle and top/bottom tray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

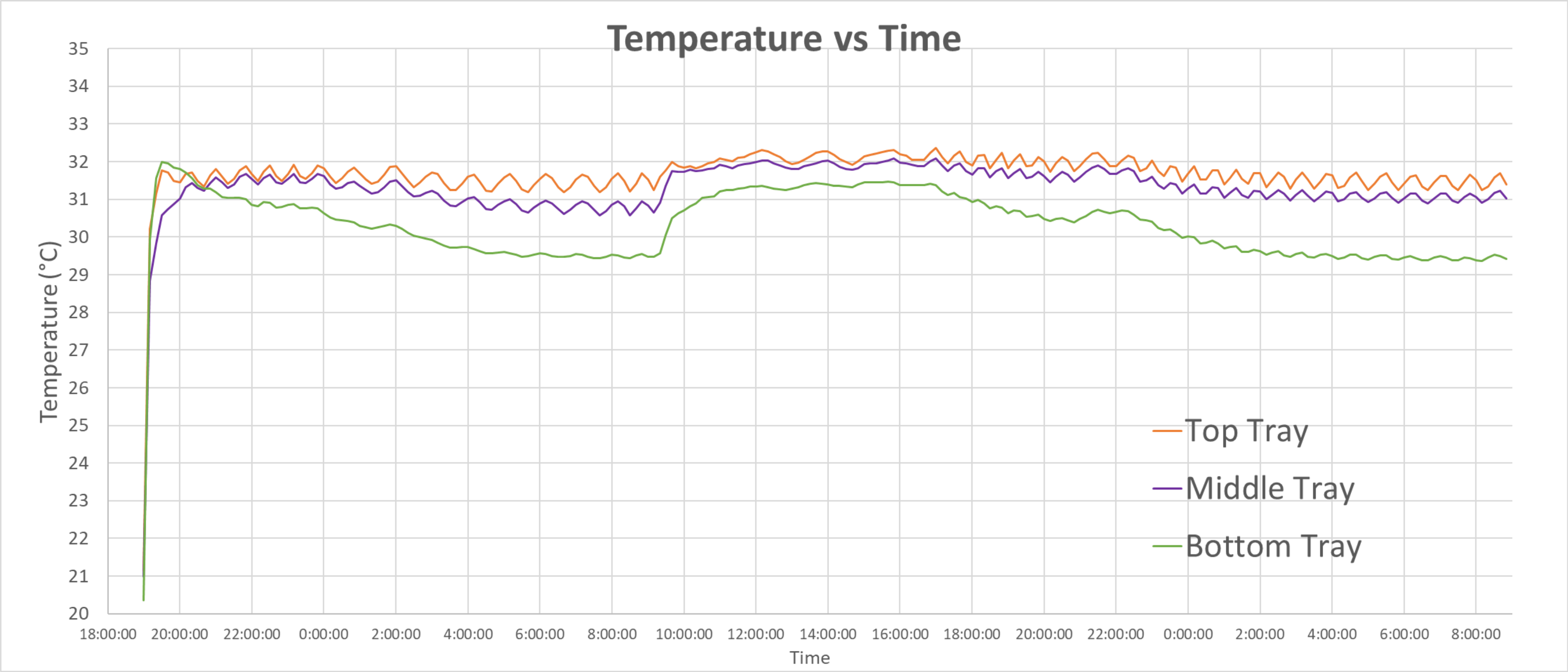
- Longer burn-in data trend reflects short-term burn-in results
- 10% difference in RH between top and bottom tray remains steady (even without **Condensation Protectors**)

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

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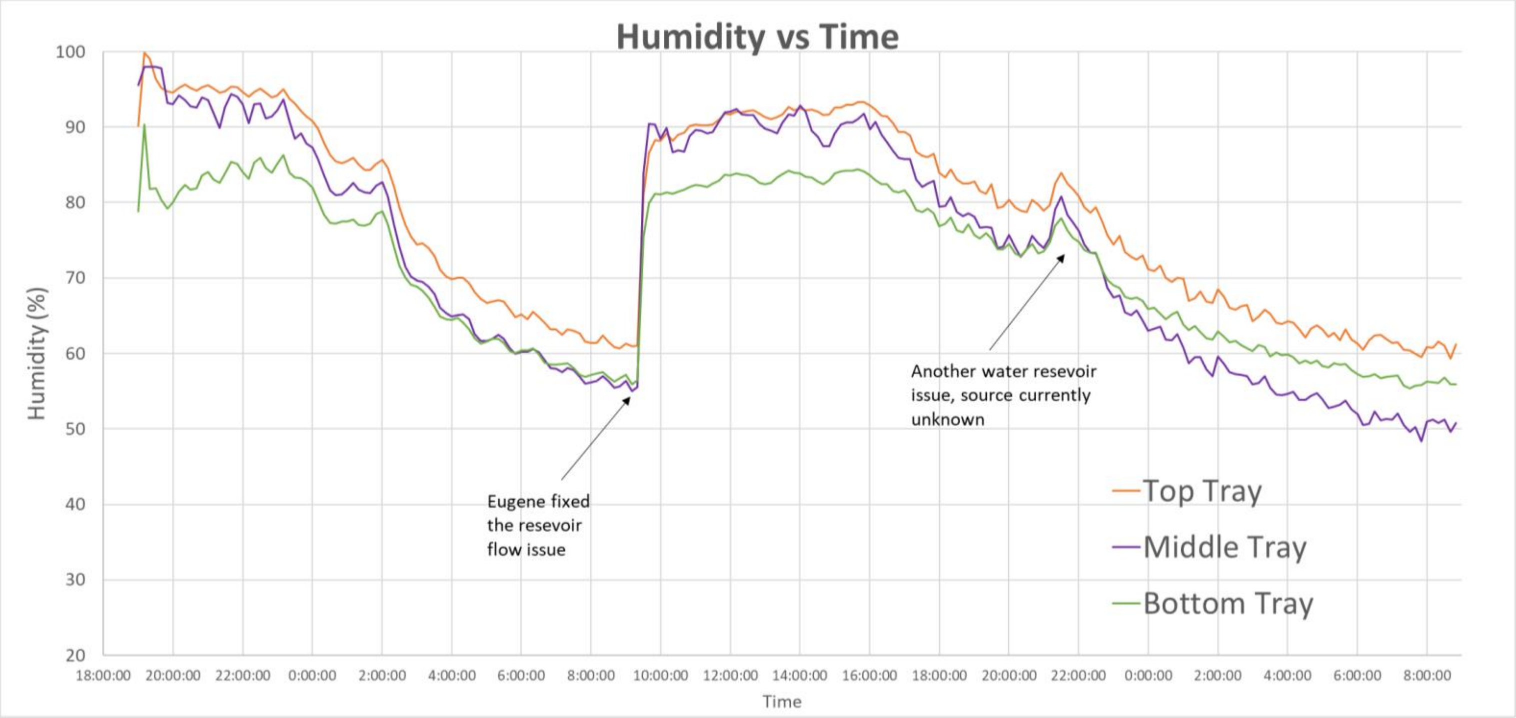


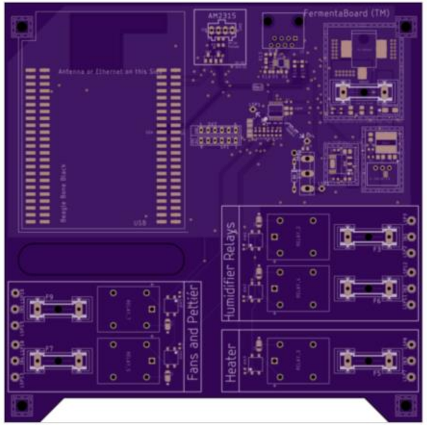
Testing Results – Second Batch Data

- **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



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Timeline

Task	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 Fermentaboard		Working on it	Feb 21	Jan 31 - Feb 19	
Integrate Software with Fermentaboard		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.

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ARCHIVED SLIDES

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Options for Further Development

1) **No software integration:**
    1) The Fermentabot 2.0 prototype is a plug-and-play device – if you plug it into the wall, it will run a single recipe (e.g. 32°C, 80%RH), until you unplug it. Temp/humidity can be programed with the InkBird control system, and can't change mid-recipe automatically. Also no integrated data collection.
    2) Copies of this prototype can be fabricated and sent to Diego ahead of the current timeline

2) **Software integration:**
    1) Creating the PCB, online user interface, and software for running the Fermentabot will give users more control over recipe creation and data collection.
    2) Timeline will reflect the following Gantt Chart

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Mechanical Budget and Next Steps

1) **Approximately 25% of the Fermentabot Project budget has been spent *mechanically* developing a fully functioning prototype**
    1) This includes 3D modeling and database creation, documentation, fabrication, assembly, and mechanical testing of two prototype Fermentabot units (1.1 and 2.0)
    2) This budget was spent between **July 2018-Februrary 2019**

2) **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

TOTAL MATERIAL PURCHASES:	$ 2,161.00
Hours Worked (Eugene) (approx. 4.7 full time weeks)	187
TOTAL LABOR:	$ 5,610.00
TOTAL BUDGET SPENT ON FERMENTABOT MECHANICAL DEVELOPMENT:	**$ 7,771.00**