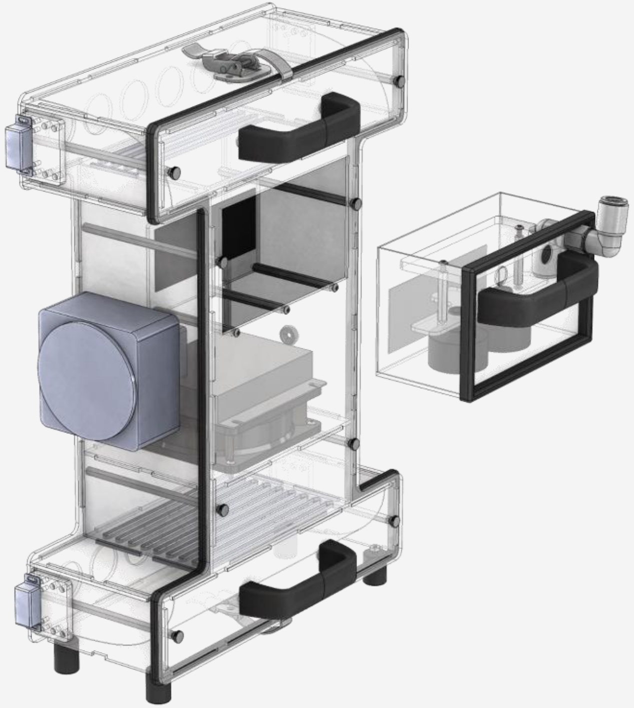

Fermentabot (2018-2019)

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

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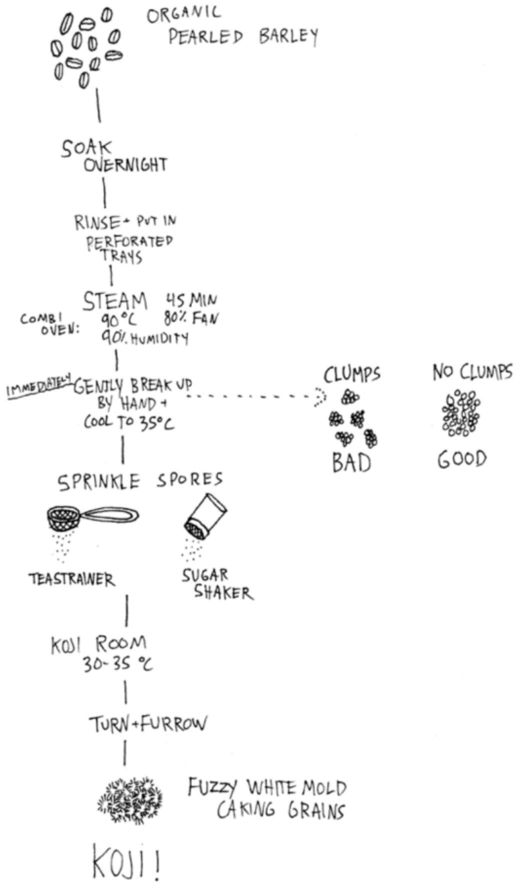
Agenda

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) **Budget and Next Steps**
8) **Options for Further Development**



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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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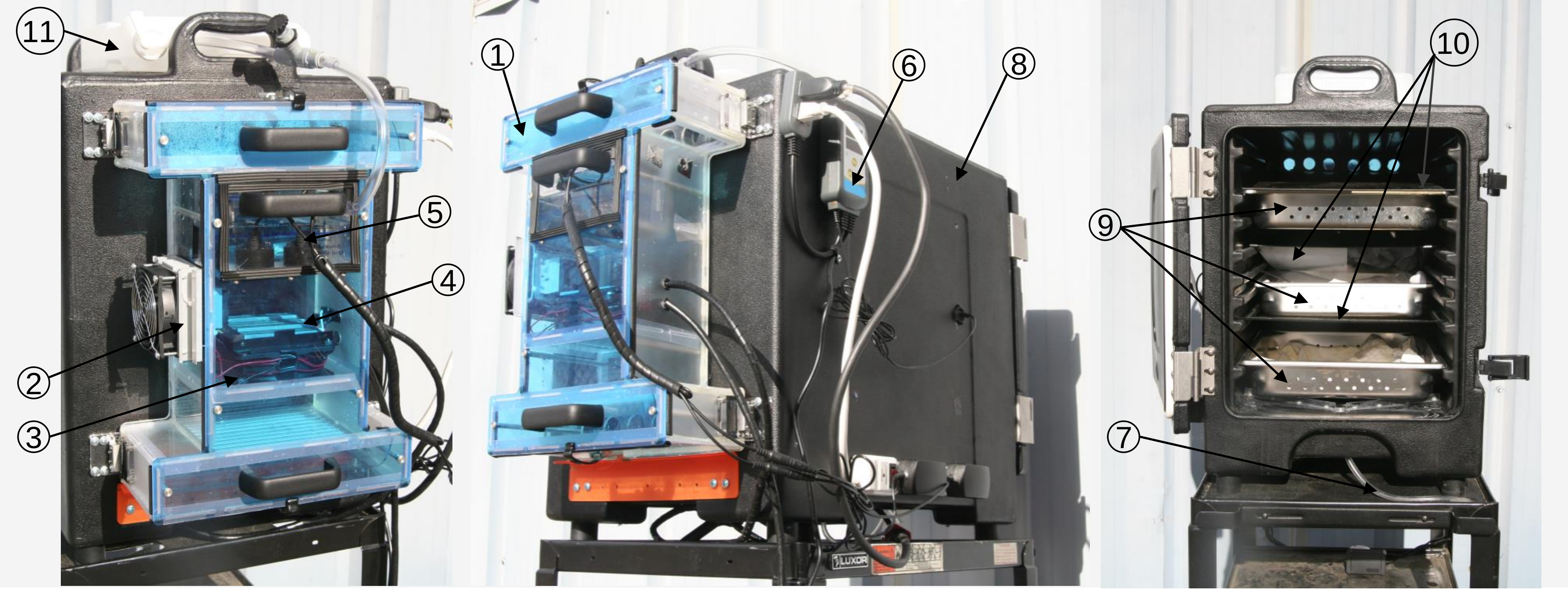

Fermentabot 2.0 Project Overview

1. Environmental Chamber
2. Thermoelectric Peltier Cooling Unit
3. 12V Computer 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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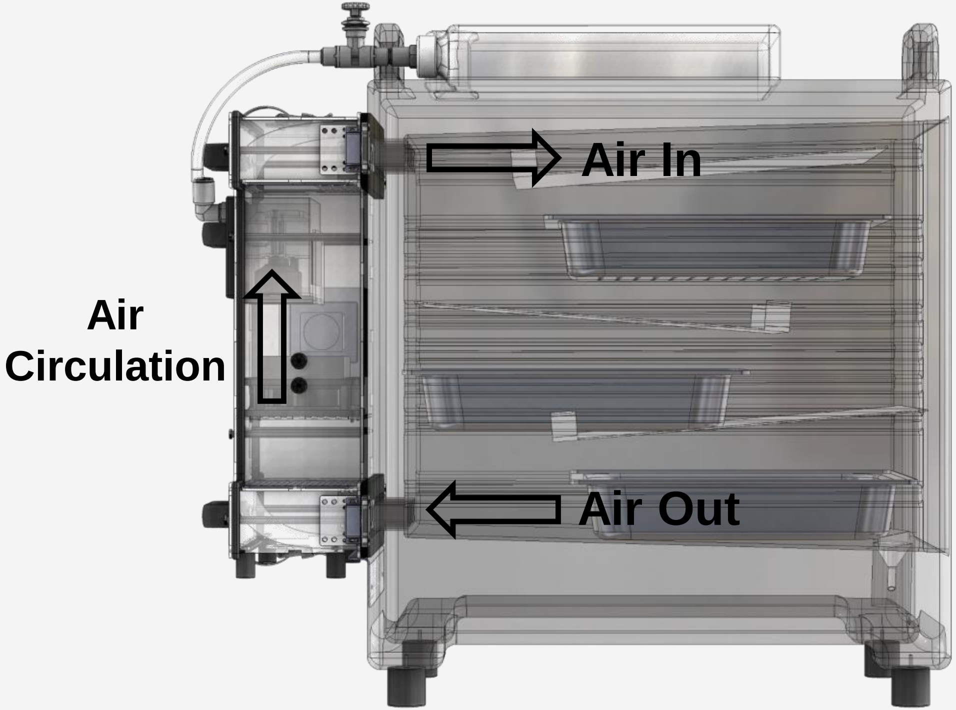
Notable Features

- 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

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

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Notable Features - 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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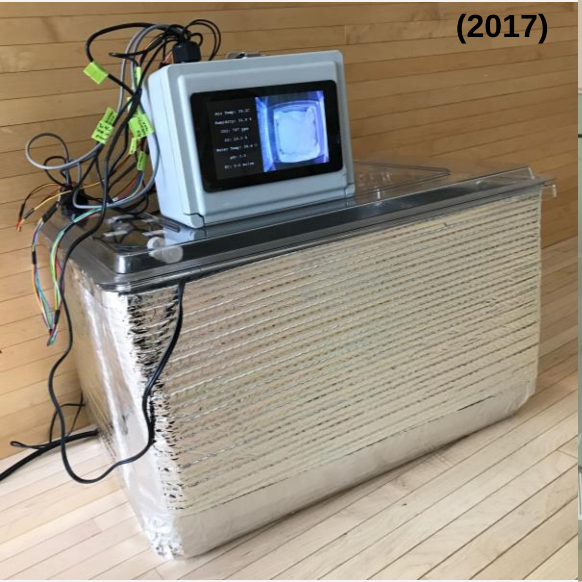
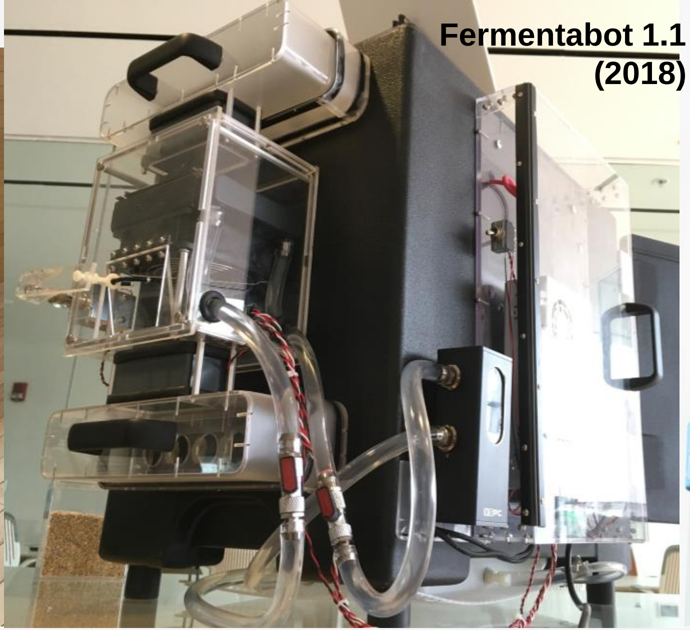
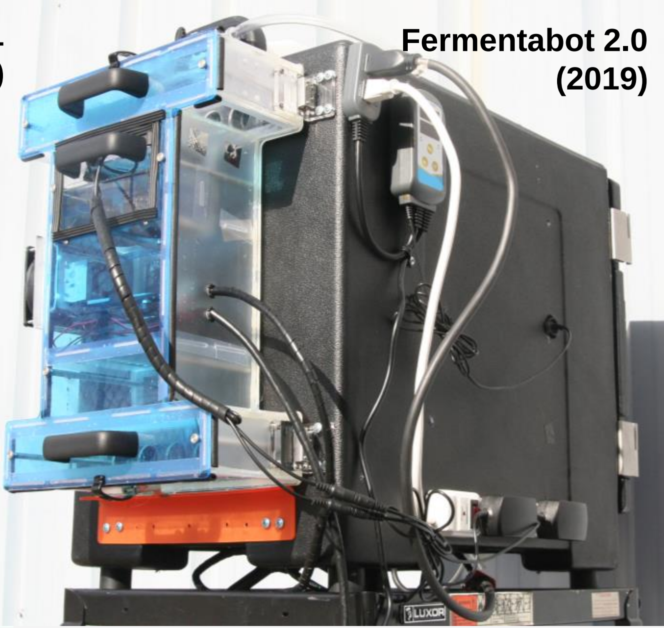


Fermentabot 1.0 (2017)



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

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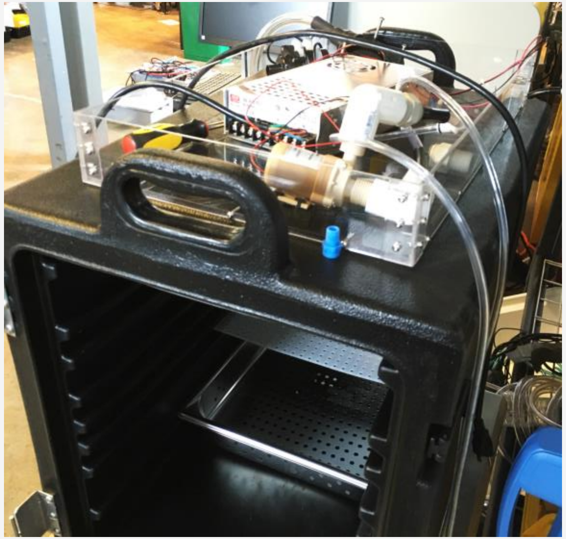

Design Progress – Early Stage

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

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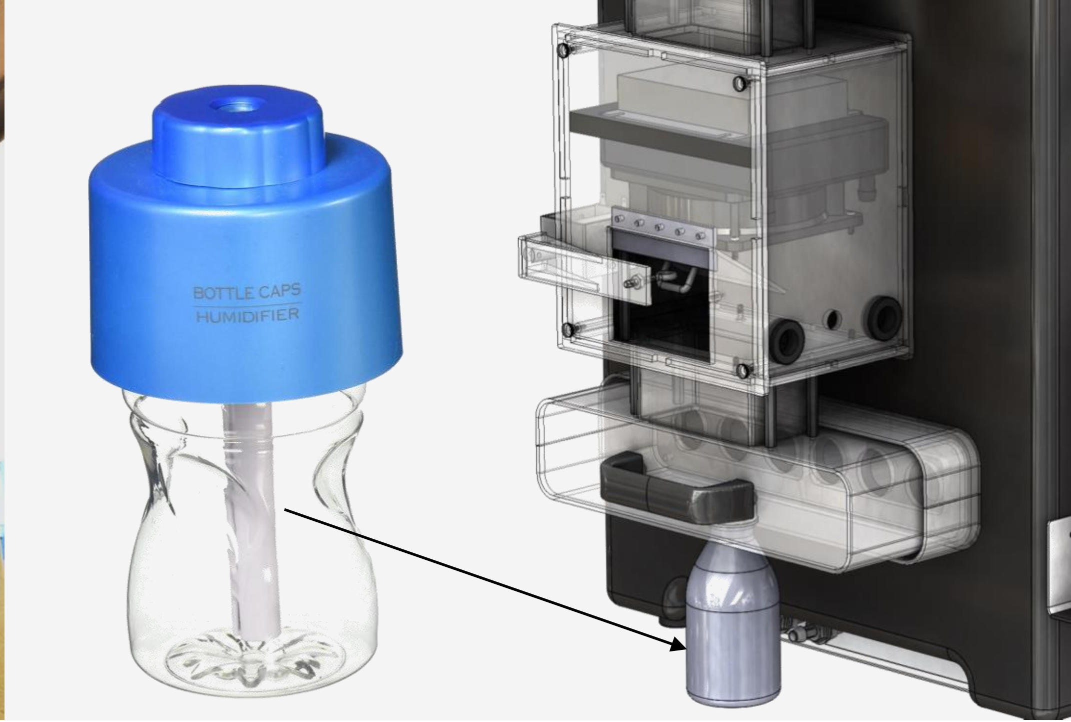

Humidification Testing and Prototyping – Early Stage

- 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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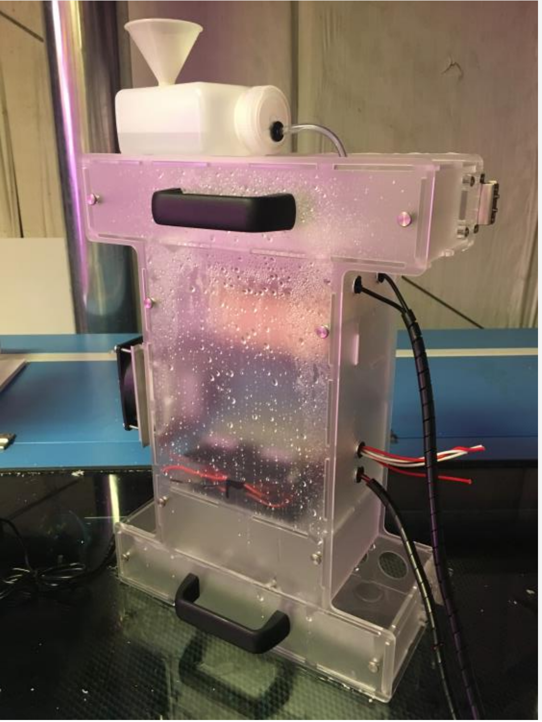

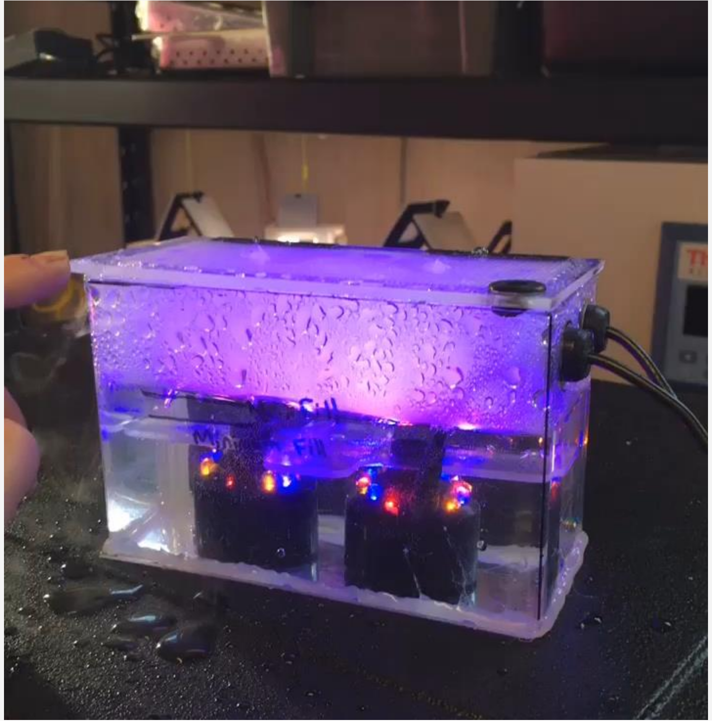

Humidification Testing and Prototyping

- 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

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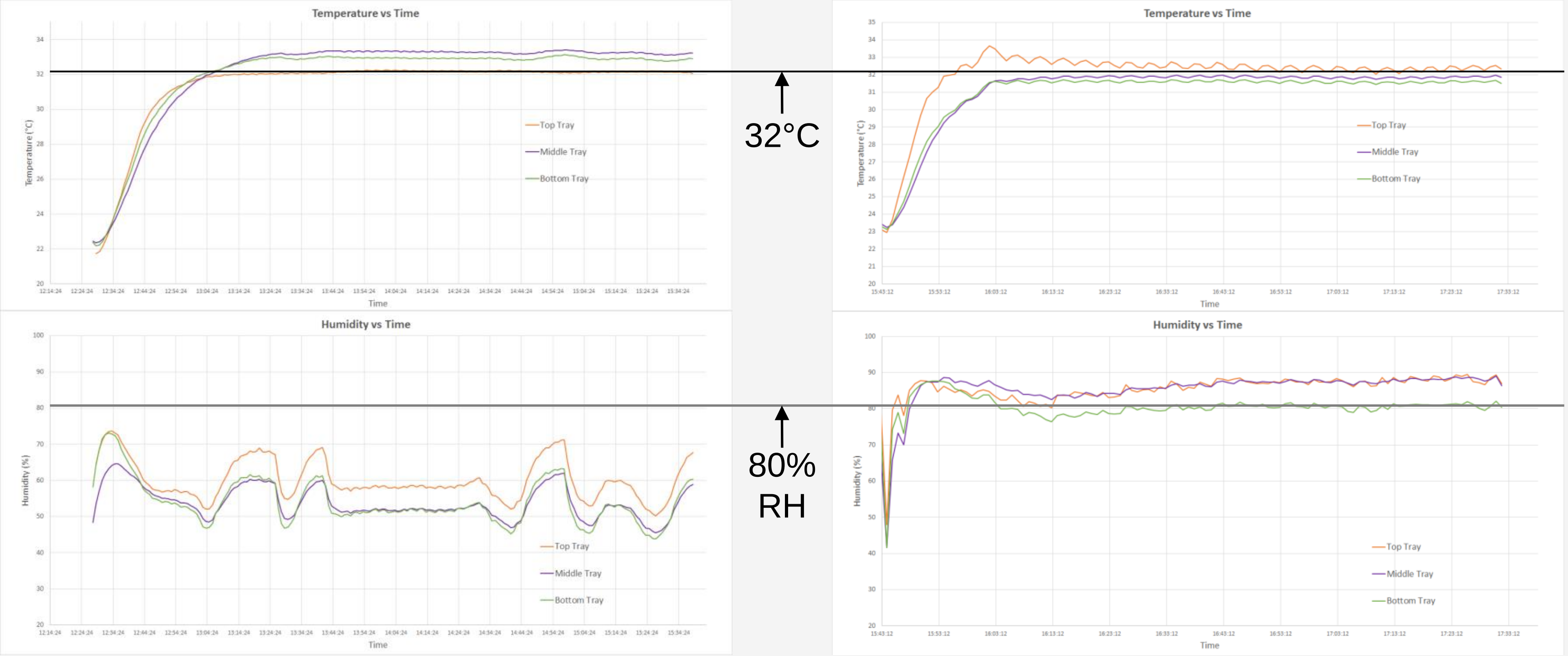

Testing Results

- 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

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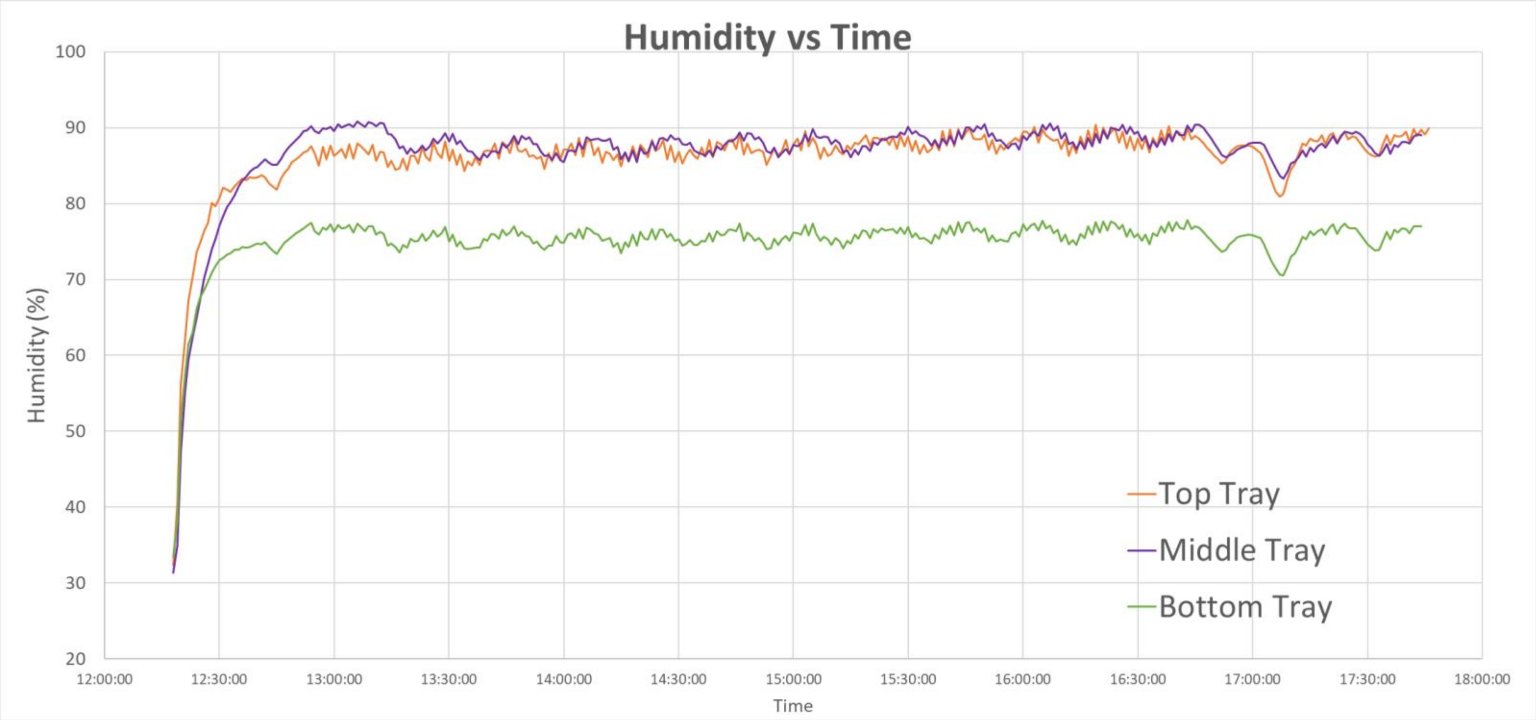

Testing Results – 5 Hour Burn-in

- Humidity from 50-60% RH (ambient) to 80-90%RH in approximately 10 minutes
- ~10%RH variance between the top and bottom tray, based on air flow clearance inside
- Humidity set to 80.5%RH +/- 1%
- Bottom tray feels least amount of humidity, most likely due to bottom-most Condensation Shield (more testing necessary for optimization)

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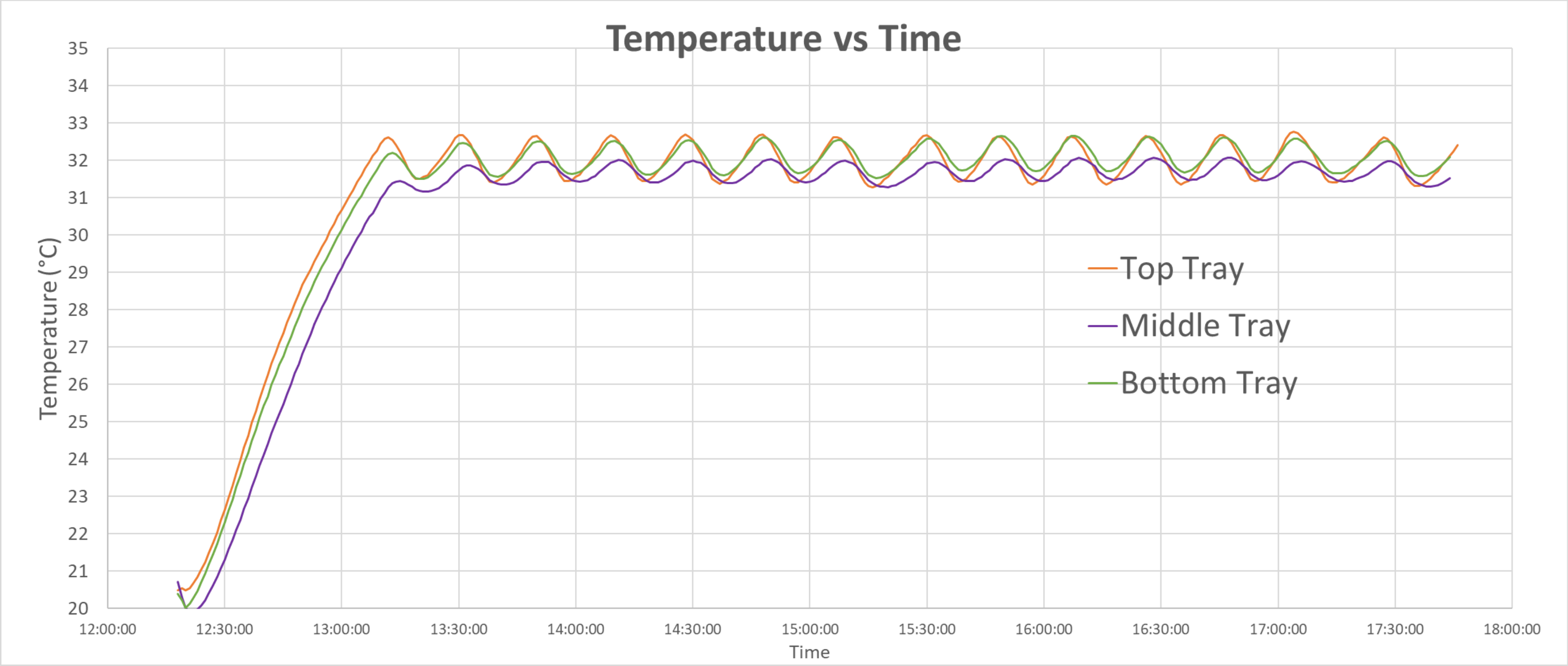

Testing Results – 5 Hour Burn-in

- Temperature from 25°C (ambient) to 32°C in approximately 20 minutes
- ~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

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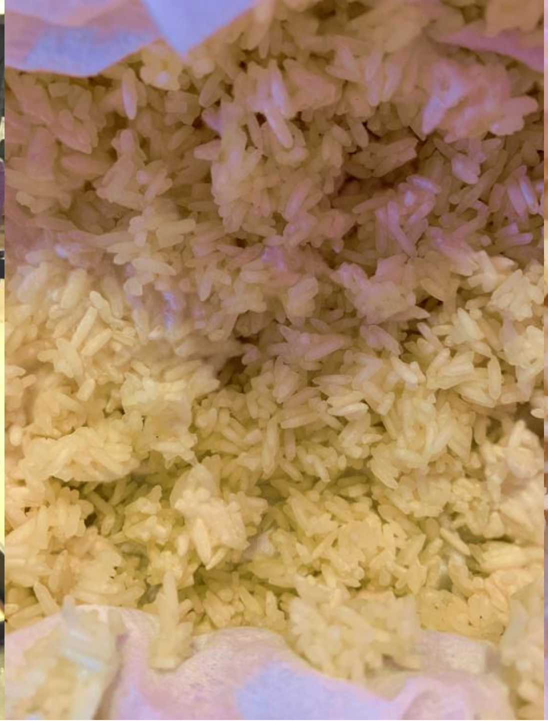


Testing Results

- Koji grown successfully on jasmine rice 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
- (Next batch to be grown in early February)

Budget and Next Steps

1) Approximately 25% of the Fermentabot Project budget has been spent 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) Next development steps include
    1) Improving mechanical seals on Environmental Chamber
    2) Improving humidification unit water refill system
    3) Software and hardware development
        1) Creating, fabricating, and testing a circuit board
        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**

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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 following 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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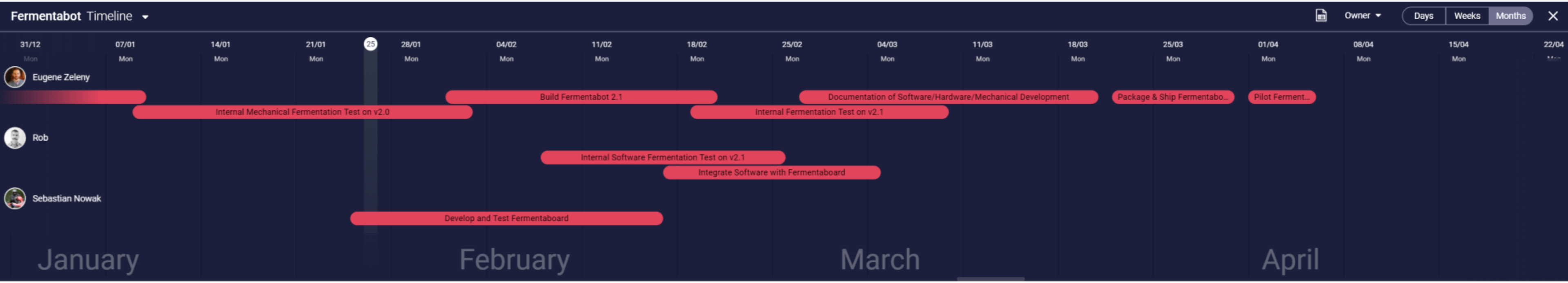

Timeline

Task	Owner	Status	Due Date	Timeline	Link
Develop and Test Fermentaboard		Working on it	Feb 16	Jan 24 - Feb 15	
Build Fermentabot v2.0		Done	~~Jan 9~~	Dec 4 - Jan 8	
Internal Mechanical Fermentation Test on v2.0		Working on it	Jan 31	Jan 8 - Feb 1	
Documentation of Software/Hardware/Mechanical Development		Waiting to Start	Mar 5	Feb 26 - Mar 19	
Build Fermentabot 2.1		Waiting to Start	Feb 15	Jan 31 - Feb 19	
Internal Fermentation Test on v2.1		Waiting to Start	Feb 28	Feb 18 - Mar 8	
Internal Software Fermentation Test on v2.1		Waiting to Start	Feb 19	Feb 7 - 24	
Package & Ship Fermentabot to Diego		Waiting to Start	Mar 15	Mar 21 - 29	
Pilot Fermentabot w/Diego		Waiting to Start	Mar 26	Mar 31 - Apr 4	
Integrate Software with Fermentaboard		Waiting to Start	Mar 2	Feb 16 - Mar 3	

Timeline Breakdown

- Estimated delivery of Fermentabot 2.1 (with integrated software/hardware) at the beginning of April
- Earlier delivery possible based on Basque's feedback

Thank You.

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