

DEHYDRATING MUSTARD SEED EXTRACT

For Dr. Ina Popova

Team Spicy Extract: Leslie Hurtado & Sophia Bowen

Objective

- The project aims to reduce the water content of cold-pressed mustard seed extract by at least 50% using a flash evaporation system.



Value Proposition

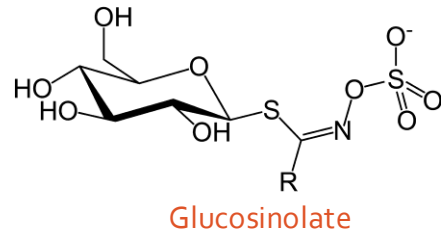
- The mustard seed meal byproduct contains a biopesticide compound
- Current freeze-drying method is a bottleneck
- Create a flash evaporator system to powderize and reduce water content of the mustard seed extract, increasing the viability of this biopesticide



Background & Requirements

Background

- Mustard plants produce many useful chemical products
 - Oils that can be processed into biodiesel and glucosinolates - they show promise on being used as biopesticides
- Drying methods available
 - Drum dry, freeze dry, and spray dry
 - Freeze drying currently takes three days for a 10-gallon batch

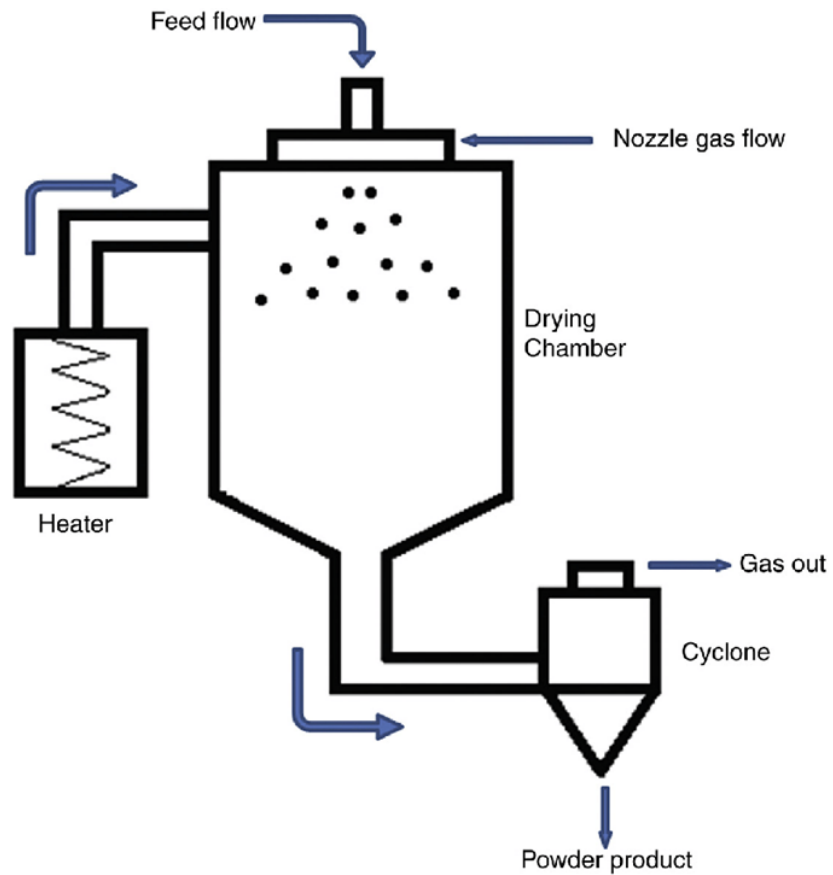


Requirements

- Get extract 50% dry
- Reduce drying time by at least half
- Make sure there is not a large drop in glucosinolate yields due to thermal degradation
- No use of chemicals that would prevent product from being used in organic farming



Conceptual Development

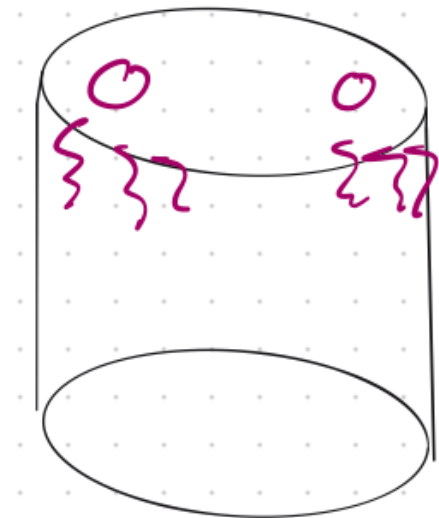


- Conceptual designs based off this initial spray evaporation diagram provided by Dr. Popova

Choosing a heating element

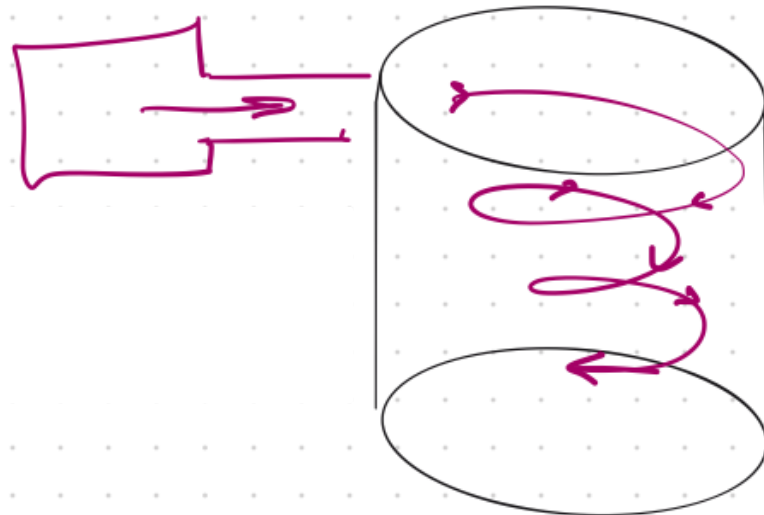
a) Radiant Heat Source

- Pro: Simple. Provides a temperature gradient
- Con: May require multiple heat sources to maintain temperature



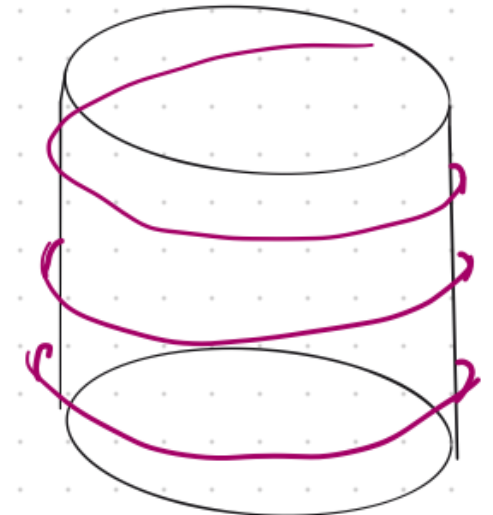
b) Heat gun source

- Pro: Provides additional air circulation
- Con: Requires additional adaptor

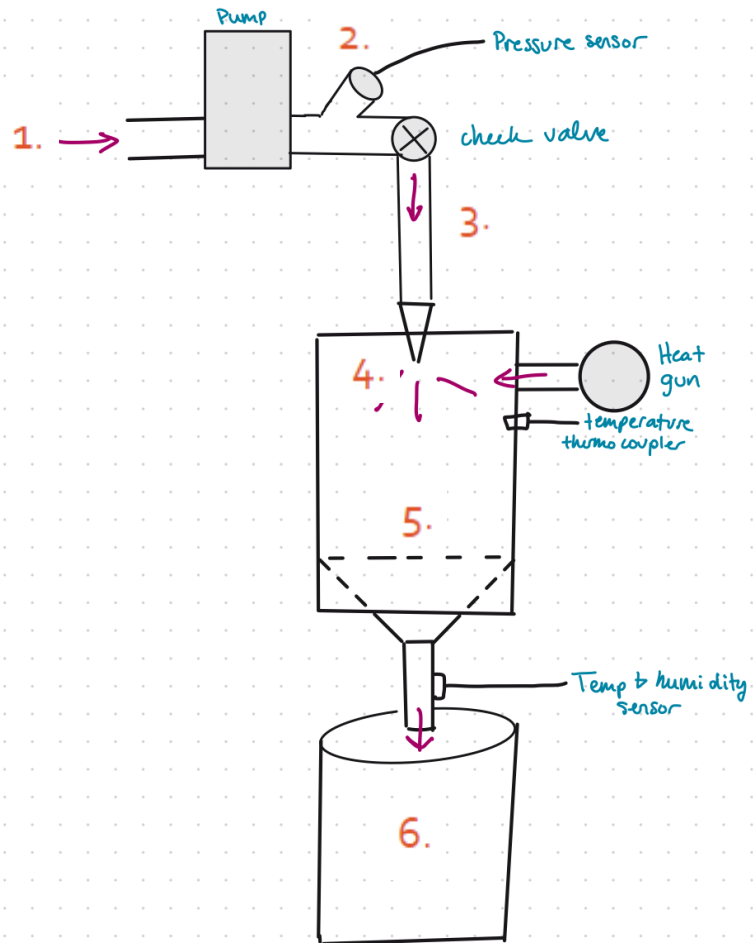


c) Heated coils

- Pro: Even heat distribution
- Con: Additional electrical control systems

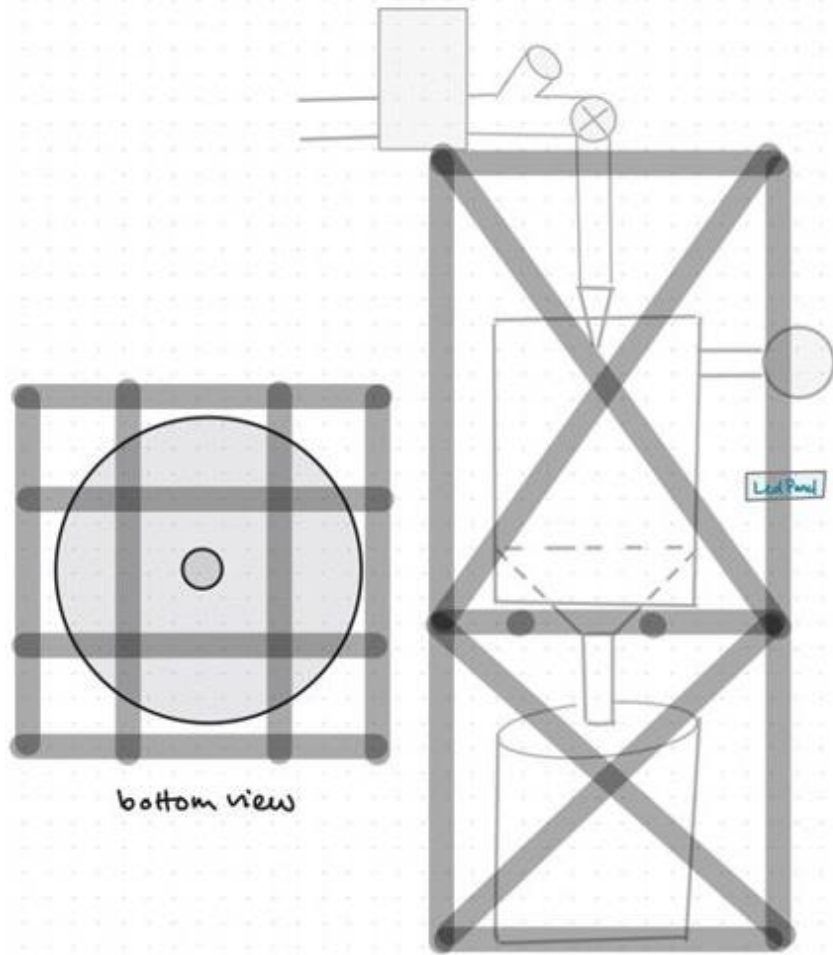


Prototype Design



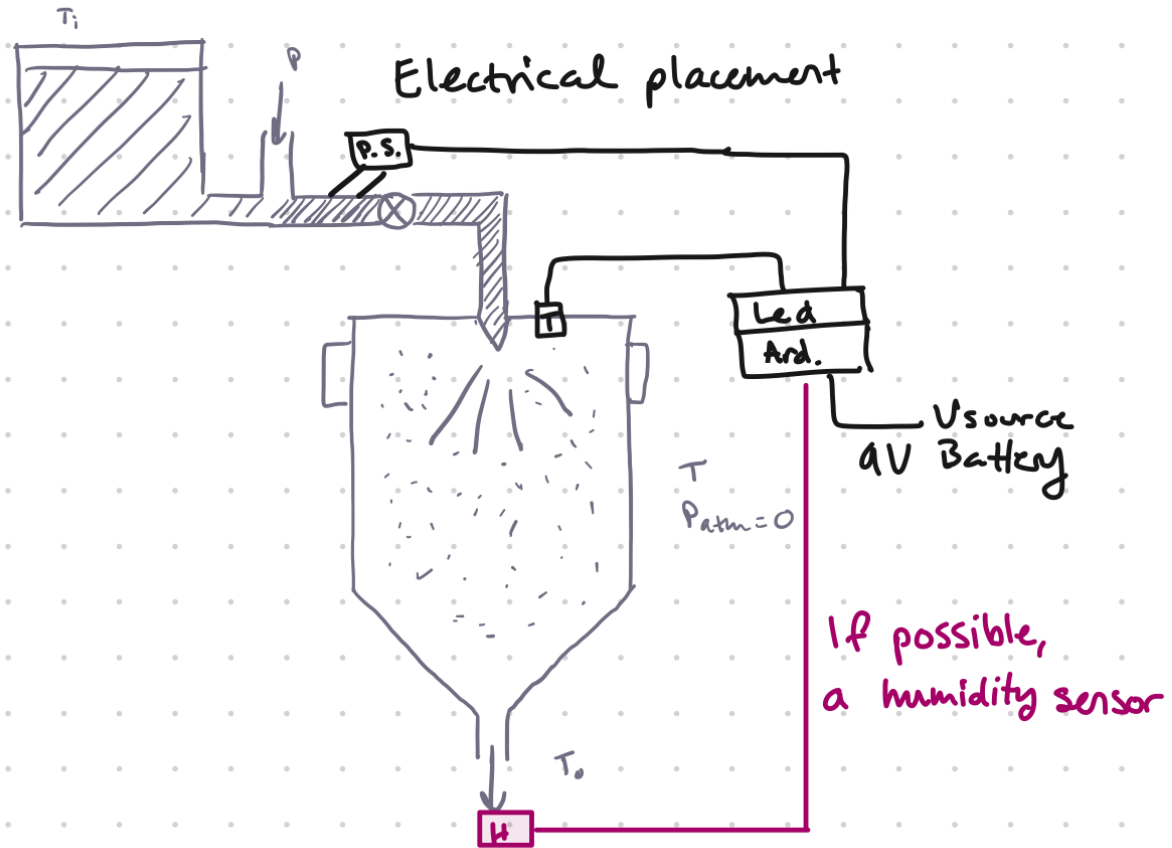
1. Exit product storage tank through pump
2. Pump pressurizes product
3. Pressurized product exits past check valve
4. Product is misted into heating chamber
5. Product is dried in heating chamber
6. Dried product exits heating chamber into collection bin.

Prototype Design



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Electrical system planning



- Create an electrical monitoring system using an Arduino nano
- Use a small LED screen to display the inflow pressure, the heating chamber temperature, and the outflow humidity.

Potential Risks



CLOGGING OF THE PUMP OR
NOZZLE



HEAT SOURCE AND CHAMBER
BEING A POTENTIAL
FIRE/SAFETY HAZARD



UNEVEN MISTING OR
PRODUCT RESULTING IN
UNEVEN DRYING

Validation



Test system in parts

Pump
Nozzle
Heating
Drying

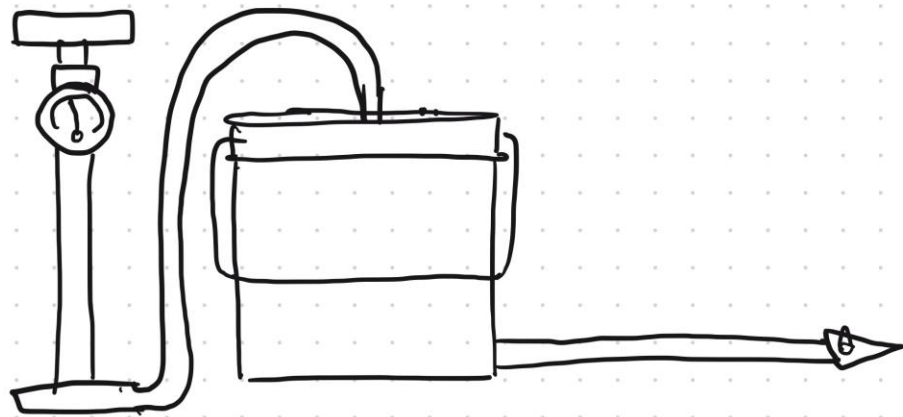


Estimate calculations vs measurements

Testing of pumps & nozzles

- Idea for testing

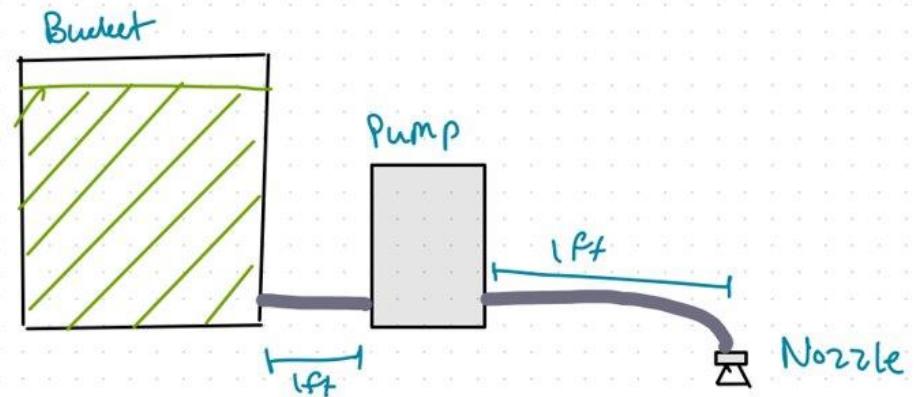
Measure the pressure needed to evaluate flow for the nozzle



- Prototype build

Conclusion: Pumps available are not functional. Nozzle may be suitable under proper pressure

Next step: Buy a new pump



Calculations of system

$$\rho \text{ of air @ } 50^{\circ}\text{C} = 1.09 \text{ kg/m}^3$$

$$Q = 1050 \text{ in}^3/\text{min} * (1 \text{ min}/60 \text{ sec}) * [(1 \text{ m})^3/(39.37\text{in})^3] \\ = 2.87 \times 10^{-4} \text{ m}^3/\text{s}$$

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \left(1 \text{ cm} \left(\frac{1 \text{ m}}{100 \text{ cm}} \right) \right)^2 = 7.85 \times 10^{-5} \text{ m}^2$$

$$V = \frac{Q}{A} = \frac{2.87 \times 10^{-4} \frac{\text{m}^3}{\text{s}}}{7.85 \times 10^{-5} \text{ m}^2} = 3.65 \frac{\text{m}}{\text{s}}$$

$$\begin{aligned} \text{Flow rate of humid air: } F_{h,\text{air}} &= VA\rho \\ &= Q\rho \\ &= (2.87 \times 10^{-4} \text{ m}^3/\text{s}) (1.09 \text{ kg/m}^3) \\ \Rightarrow F_{h,\text{air}} &= 3.13 \times 10^{-4} \text{ kg/s} = 1.125 \text{ kg/hr} \end{aligned}$$

$$\text{Humidity of air in} = H_{\text{air,in}} = 1 \text{ kg water/kg air}$$

$$\begin{aligned} \text{Mass of water in air initial} &= M_{\text{water,in}} = \frac{F_{h,\text{air}} H_{\text{air}}}{1 + H_{\text{air}}} \\ &= \frac{\left(\frac{1.125 \text{ kg}}{\text{hr}} \right) \left(1 \frac{\text{kg water}}{\text{kg air}} \right)}{1 + \left(1 \frac{\text{kg water}}{\text{kg air}} \right)} = \frac{\left(\frac{1.125 \text{ kg}}{\text{hr}} \right)}{2} \Rightarrow M_{\text{water,in}} = 0.5625 \frac{\text{kg}}{\text{hr}} \end{aligned}$$

$$\text{Humidity of air out} = H_{\text{air,out}} = 0.5 \text{ kg water/kg air}$$

$$\begin{aligned} \text{Mass of water in air final} &= M_{\text{water,out}} = \frac{F_{h,\text{air}} H_{\text{air,out}}}{1 + H_{\text{air,out}}} \\ &= \frac{\left(\frac{1.125 \text{ kg}}{\text{hr}} \right) \left(0.5 \frac{\text{kg water}}{\text{kg air}} \right)}{1 + \left(0.5 \frac{\text{kg water}}{\text{kg air}} \right)} = \frac{\left(\frac{0.5625 \text{ kg}}{\text{hr}} \right)}{1.5} \Rightarrow M_{\text{water,out}} = 0.375 \frac{\text{kg}}{\text{hr}} \end{aligned}$$

$$\begin{aligned} \epsilon_{\text{air,in}} &= \epsilon_{\text{air,in}} F_{\text{dry,air}} \\ &= [T_{\text{air,in}} (1.01 + 1.89 H_{\text{air,in}}) + 2500 H_{\text{air,in}}] \left(\frac{V_{\text{air,out}} A_{\text{out}} \rho}{1 + H_{\text{out}}} \right) \\ &= [50^{\circ}\text{C} (1.01 + 1.89 \left(1 \frac{\text{kg water}}{\text{kg air}} \right)) + 2500 \left(1 \frac{\text{kg water}}{\text{kg air}} \right)] \\ &\quad \left(0.75 \frac{\text{kg}}{\text{hr}} \right) \\ &= 1983.8 \frac{\text{kJ}}{\text{hr}} \end{aligned}$$

$$\begin{aligned} \epsilon_{\text{water,in}} &= M_{\text{water,in}} C_{p,\text{water}} T_{\text{water,in}} \\ &= \left(0.5625 \frac{\text{kg}}{\text{hr}} \right) \left(4.18 \frac{\text{kJ}}{^{\circ}\text{C kg}} \right) (50^{\circ}\text{C}) = 117.6 \frac{\text{kJ}}{\text{hr}} \end{aligned}$$

$$\begin{aligned} \epsilon_{\text{total,in}} &= \epsilon_{\text{air,in}} + \epsilon_{\text{water,in}} \\ &= 1983.8 \frac{\text{kJ}}{\text{hr}} + 117.6 \frac{\text{kJ}}{\text{hr}} \\ \Rightarrow \epsilon_{\text{total,in}} &= 2101.4 \frac{\text{kJ}}{\text{hr}} \end{aligned}$$

$$\begin{aligned} \epsilon_{\text{total,out}} &= \epsilon_{\text{air,out}} + \epsilon_{\text{water,out}} \\ &= [T_{\text{air,out}} (1.01 + 1.89 H_{\text{air,out}}) + 2500 H_{\text{air,out}}] \left(\frac{V_{\text{air,out}} A_{\text{out}} \rho}{1 + H_{\text{out}}} \right) \end{aligned}$$

$$\begin{aligned} &+ M_{\text{water,out}} C_{p,\text{water}} T_{\text{water,out}} \\ &= [150^{\circ}\text{C} (1.01 + 1.89 \left(0.5 \frac{\text{kg water}}{\text{kg air}} \right)) + 2500 \\ &\quad \left(0.5 \frac{\text{kg water}}{\text{kg air}} \right)] \left(0.75 \frac{\text{kg}}{\text{hr}} \right) + \\ &\quad \left(0.375 \frac{\text{kg}}{\text{hr}} \right) \left(4.18 \frac{\text{kJ}}{^{\circ}\text{C kg}} \right) (150^{\circ}\text{C}) \\ \Rightarrow \epsilon_{\text{total,out}} &= 1392.6 \frac{\text{kJ}}{\text{hr}} \end{aligned}$$

Milestones

By end of
December

Order remaining parts for
the pressure system

- Build pressure System

Finish electrical system
design and programming

Order electrical components

For January

Have heating chamber parts
ordered and ready to build

Build heating chamber and
connect to pressure system

By February

Have system built and ready
for testing

Attach electrical system

Thank you

- to Dr. Brian He for providing project guidance
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