# 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 biopestcides
- 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

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

#### b) Heat gun source

- <u>Pro</u>: Provides additional air circulation
- <u>Con</u>: Requires additional adaptor

#### <u>c) Heated coils</u>

- <u>Pro</u>: Even heat distribution
- <u>Con</u>: Additional electrical control systems







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- 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/SAFTEY HAZARD UNEAVEN MISTING OR PRODUCT RESULTING IN UNEAVEN DRYING

#### Pump Test system in parts Heating Drying

# Validation



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



$$\begin{aligned} & \mathsf{Calculations of system} \\ & \mathsf{p} \text{ of air } @ 50^\circ \mathsf{C} = 1.09 \text{ kg/m}^3 \\ & \mathsf{Q} = 1050 \text{ in}^3/\text{min} * (1 \text{ min}/60 \text{ sec}) * [(1 \text{ m})^3/(39.37\text{ in})^3] \\ & = 2.87 \times 10^4 \text{ m}^3/\text{s} \\ & \mathsf{A} = \frac{\pi}{4} D^2 = \frac{\pi}{4} \left( 1 cm \left( \frac{1 m}{100 \text{ cm}} \right) \right)^2 = 7.85 \times 10^5 \text{ m}^2 \\ & \mathsf{Q} = \frac{q}{4} = \frac{2.87 \times 10^{-4} \frac{\text{m}^3}{\text{s}}}{7.85 \times 10^{-5} \text{ m}^2} \\ & \mathsf{Q} = \frac{q}{4} = \frac{2.87 \times 10^{-4} \frac{\text{m}^3}{\text{s}}}{7.85 \times 10^{-5} \text{ m}^2} \\ & \mathsf{Q} = \frac{q}{4} = \frac{2.87 \times 10^{-4} \frac{\text{m}^3}{\text{s}}}{7.85 \times 10^{-5} \text{ m}^2} \\ & \mathsf{Flow rate of humid air: F_{h,air} = VAp \\ & = Qp \\ & = (2.87 \times 10^4 \text{ m}^3/\text{s}) (1.09 \text{ kg/m}^3) \\ & \mathsf{p} > F_{h,air} = 3.13 \times 10^4 \text{ kg/s} = 1.125 \text{ kg/hr} \\ & \mathsf{Humidity of air in = H_{air,in} = 1 \text{ kg water/ kg air} \\ & \mathsf{Huss of water in air initial = M_{water,in} = \frac{F_{h,air}H_{air}}{1 + H_{air}} \\ & = \frac{\left(\frac{1.125kg}{hr}\right) \left(1 \frac{kg_{water}}{kg_{air}}\right)}{1 + \left(1 \frac{kg_{water}}{kg_{air}}\right)} = \frac{\left(\frac{1.125kg}{hr}\right)}{2} \\ & \mathsf{Humidity of air out = H_{air,out} = 0.5 \text{ kg water/ kg air} \\ \\ & \mathsf{Humidity of air out = H_{air,out} = 0.5 \text{ kg water/ kg air} \\ \\ & \mathsf{Mass of water in air final = M_{water,out} = \frac{F_{h,air}H_{air,out}}{1 + H_{air,out}} \\ & = \frac{\left(\frac{1.125kg}{hr}\right) \left(0.5 \frac{kg_{water}}{kg_{air}}\right)}{1 + \left(0.5 \frac{kg_{water}}{kg_{air}}\right)} = \frac{\left(\frac{0.5625kg}{hr}\right)}{1.5} \\ & = \mathsf{M}_{water,out} = 0.375 \frac{kg}{hr} \end{aligned}$$

$$\frac{1}{kg_{air}} \left(1 \frac{kg_{water}}{kg_{air}}\right) = \frac{\left(\frac{1.125kg}{hr}\right)}{2} \Rightarrow \mathbf{M}_{water,in} = \mathbf{0.5625} \frac{kg}{hr}$$
  
y of air out = H<sub>air,out</sub>=0.5 kg water/ kg air
  
water in air final = M<sub>water,out</sub>=  $\frac{F_{h,air}H_{air,out}}{1+H_{air,out}}$ 
  
 $\frac{1}{kg_{air}} = \frac{\left(\frac{0.5625kg}{hr}\right)}{1.5} \Rightarrow \mathbf{M}_{water,out} = \mathbf{0.375} \frac{kg}{hr}$ 

$$\begin{split} \boldsymbol{\epsilon}_{air,in} &= E_{air,in} F_{dry,air} \\ &= [T_{air,in}(1.01+1.89H_{air,in})+2500H_{air,in}] \left(\frac{V_{air,out}A_{out}\rho}{1+H_{out}}\right) \\ &= [50 \ ^{\circ}C \ (1.01+1.89\left(1\frac{kg \ water}{kg \ air}\right))+2500\left(1\frac{kg \ water}{kg \ air}\right)] \\ &\left(0.75\frac{kg}{hr}\right) \\ &= 1983.8\frac{kJ}{hr} \\ \boldsymbol{\epsilon}_{water,in} &= M_{water,in}Cp_{water}T_{water,in} \\ &= \left(0.5625\frac{kg}{hr}\right)\left(4.18\frac{kJ}{\cdot C \ kg}\right)\left(50^{\circ}C\right) = 117.6\frac{kJ}{hr} \\ \boldsymbol{\epsilon}_{total,in} &= \boldsymbol{\epsilon}_{air,in} + \boldsymbol{\epsilon}_{water,in} \\ &= 1983.8\frac{kJ}{hr} + 117.6\frac{kJ}{hr} \\ \boldsymbol{\epsilon}_{total,in} &= 2101.4\frac{kJ}{hr} \\ \boldsymbol{\epsilon}_{total,out} &= \boldsymbol{\epsilon}_{air,out} + \boldsymbol{\epsilon}_{water,out} \\ &= [T_{air,out}(1.01+1.89H_{air,out})+2500H_{air,out}]\left(\frac{V_{air,out}A_{out}\rho}{1+H_{out}}\right) \\ &+ M_{water,out}Cp_{water}T_{water,out} \\ &= [150 \ ^{\circ}C(1.01+1.89\left(0.5\frac{kg \ water}{kg \ air}\right))+2500 \\ &\left(0.5\frac{kg \ water}{kg \ air}\right)]\left(0.75\frac{kg}{hr}\right) + \\ &\left(0.375\frac{kg}{hr}\right)\left(4.18\frac{kJ}{\cdot C \ kg}\right)(150^{\circ}C) \\ &=> \boldsymbol{\epsilon}_{total,out} = 1392.6\frac{kJ}{hr} \end{split}$$

# Project Schedule

- Stage 1.a: Determine pump and nozzles to use
- Stage 1.b: Develop electrical monitoring system
- Stage 2: Create Heating Chamber
- Stage 3: Run drying experiments

Capstone Project Schedule - Fa	11-																																						
		Project:	Dehy	drating	g Must	tard Se	ed Ext	ract																															
	Las	t Updated:	11/12	2/20																																			
		Year						2020													2021																		
		Month	Sept Oct			Oct Nov				Dec			Jan				Feb				Mar				Apr					May									
Task Description	n Duration	Assigned	9/4	9/11 9	9/18 9	/25 10	/2 10/	9 10/1	6 10/23	3 10/30	11/6	11/13	11/20	11/27	12/4	12/11	12/18	12/25	1/1	1/8	1/15	1/22	1/29	2/5	2/12 2	/19 2/	26 3/	/5 3/1	2 3/1	9 3/26	4/2	4/9	4/16	4/23	4/30	5/7	5/14	5/21	5/28
Budget		Leslie					_	_	_																			_		_	_	<u> </u>							ا <del>اا</del>
Poster		Sophia						_	_																				_	_	_					$ \rightarrow $			i li
Personal Logbook		all																																					$ \longrightarrow $
Project Portfolio		all																																					
Wikipage																												3	<mark>/9</mark>										
Prototype - Create design																																							
Prototype - Order parts																																							
Prototype - Build																																							
Prototype - Testing & Analysis																																							
Snapshot Days							10/1	13							12/4																								
Design expo																																							
Project Final deliverables												0																											

### 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

# Budget

<b>Capstone Project Budge</b>	t Template	- Fall/Spri	ing										
Project	: Dehydrating	Mustard Ex	tract										
Last Updated	11/11/20												
			1	Ye	ar					Item			
Expense Items	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr		Total			
Equipment/Tools:									\$	-			
			1						\$	-			
			1						\$	-			
			1										
Travel:			1										
									\$	-			
									\$	-			
Supplies / Parts / Services:													
Bulk Line - Plastic Fastener			\$ 0.59						\$	0.59			
V Tube - Plastic Tubing (3 ft)			\$ 1.96						\$	1.96			
Bulls Eye Brass Nozzle			\$ 9.99						\$	9.99			
Brass Coupler			\$ 7.99						\$	7.99			
Brass Adapter			\$ 3.49						\$	3.49			
Thread Seal Tape			\$ 1.39						\$	1.39			
55 Gal. Steel Drum (ULINE)			1		\$ 104				\$	104.00			
Different Nozzles (potentially)			1		\$ 18.00				\$	18.00			
Heat Gun			1		\$ 35.00				\$	35.00			
Pump			- I		\$ 220.91				\$	220.91			
Control system					\$ 50				\$	50.00			
Jacket Insulation (SpeedTech)					\$ 56.12				\$	56.12			
Storage Chamber (Cvault)					\$ 40.99				\$	40.99			
									\$	-			
									\$	-			Expenses
											\$	550.43	Subtotal
Shop Usage (est. Hrs):									_	Hours			
Welding/Cutting			1			8				8			
			1							-			
						Gr	aduate Stude	ent Support	Ś	-	inclu	ding fringe	
							Sho	p Overhead	Ś	-			
							University Overhead			27.52	5% o	fall expen	ses
								Totals	Ś	577.95	Ś	1.000.00	\$ 422.05
									Ť		E	ludget	Excess

# Thank you

- to Dr. Brian He for providing project guidance
- to Bishal Batterai for assistance in the workshop and with calculations
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