MEASURING BOTANICAL SLURRY FLOW IN COMMERCIAL EXTRACTION

Final Design Report

Sponsor | Doehler North America
Sponsor Liaison | Dr. David Phinney
Advisors | Sean Carpenter, Holly Huellemeier, and Dr. Gonul Kaletunc
Senior Capstone Design FABENG 4910, Spring 2020
24 April 2020

Team members (from left to right): Christian Gerding, Caroline Weisgerber, Cody Dingess, Karissa Smith, and Christopher Waidelich

FABE
Department of Food, Agricultural and Biological Engineering

THE OHIO STATE UNIVERSITY

The Ohio State University

Department of Food, Agricultural, and Biological Engineering

24 April 2020

Doehler North America

400 High Point Dr SW

Unit 100

Cartersville, GA 30120

Dear Dr. David Phinney,

Attached is our report *Measuring Botanical Slurry Flow in Commercial Extraction*, which outlines the bench top particle analysis results, Guided User Interface, slurry ratio and volumetric flow rate relationship, and future detailed experimental design. This project highlights the following:

- Bench top particle analysis including calculations of the particle volume, bulk density, and particle density for black tea, green tea, and similar size coffee grounds
- An easy-to-use Guided User Interface (GUI) with user inputs of particle type, particle density, slurry density, desired slurry ratio, and desired water input generating a corresponding solids flow rate required
- The conclusion that slurry ratio and volumetric flow rate have a direct relationship and the explanation of that relationship
- Future detailed experimental design that includes physical testing set up, design variables, design procedure and model validation analysis

This has been a very challenging yet rewarding eight months. We greatly appreciate your involvement in our project and technical expertise provided during testing. We would also like to extend a special thanks to Dr. Gonul Kaletunc for her technical expertise, Holly Huellemeier for her technical expertise and providing us with her pump system for testing, and your colleagues at Doehler North America for going above and beyond both when we visited the plant and requested help and supplies for testing.

Sincerely,

Capstone Team Doehler

Caroline Weisgerber	weisgerber.21@osu.edu
Cody Dingess	dingess.27@osu.edu
Christian Gerding	gerding.42@osu.edu
Karissa Smith	smith.10523@osu.edu
Christopher Waidelich	waidelich.14@osu.edu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Executive Summary

Doehler, a global business to business conglomerate in the food and beverage industry, is seeking a method to determine the solid coffee and/or tea to slurry ratio as the mixture is brewed in a continuous flow system. The method must be automated so that the inputs of dry ingredient botanicals and water can be adjusted by the system to achieve the desired slurry concentration. Currently, Doehler's system is adjusted manually with a worker taking a bench-top sample measurement after brewing and adjusting the input parameters accordingly. By creating a method to determine the slurry ratio, Doehler looks to improve consistency, efficiency, and reduce overall waste. This project's objective was to determine the effect of particle properties of coffee, black tea, and green tea on slurry flow.

To better understand the physical properties of the botanicals used in brewing, particle analysis testing was performed to determine bulk density, particle density, and particle volume using image processing software, ImageJ, of coffee, black tea, and green tea. The particle analysis confirmed that there were no correlations between particle density and bulk density of particles of similar average volumes, leading to the conclusion that each botanical would affect slurry flow differently based upon its own properties. There was an inversely proportional correlation between bulk density and average particle volume, which would be considered when determining the amount of dry ingredient required. Particle analysis data and the application fluid dynamic equations were used to create a Graphical User Interface (GUI), within the software application MATLAB. This program became the interface with which Doehler employees can visually see the need to adjust the speed of the inputs required to obtain the desired concentration.

The combination of the particle analysis of the botanicals and the GUI help to create a procedure for further full-scale testing of three sensors, Coriolis mass, magnetic, and ultrasonic flow meters to determine the ratios of varying slurry concentrations of 5, 10, and 15%. The data collected in this future testing set up would be used to determine which of the three sensors in consideration would be the best option to implement in Doehler's system based upon accuracy, precision, and ability to physically handle the slurry concentration during data collection. The readings of these flow meters would be compared to rotary flow meters and as a result of the success metric of a detection of a 1% concentration change, a final sensor would be recommended for a final solution method. The final sensor chosen will then be added in-line of the continuous flow brewing process in use at Doehler's plant located in Cartersville, Georgia, and in other plants worldwide.

2.0 Introduction

Doehler is a privately held, German-based company that focuses on the manufacturing of natural ingredients, ingredient systems, and integrated solutions for the food and beverage industry. Within North America, Doehler has plants in Georgia and New Jersey, both of which focus on the production of coffee and tea. The process of coffee and tea manufacturing involves the mixing of the dry ingredients with water to create a slurry. After a slurry is created, it undergoes various processing steps including mixing, heating, pumping through hold tubes, and filtering of the solids from the liquid product. This liquid product concentration is affected by the amount of dry ingredient present in the slurry. Doehler is currently seeking a method to determine the slurry ratio as it moves through a continuous piping process after mixing. The method needs to be fully automated so that the system can adjust the input of dry ingredients and water to achieve the desired slurry ratio without the supervision of an employee. By solving this problem, Doehler hopes to improve the consistency and efficiency of their current production process as well as reduce overall waste.

This Final Design Report serves as a summary of progress made to date. This report includes the defined scope of the project, research topics that gave a deeper background of the industrial processes,

preliminary prototyping performed, development and initial evaluation of potential solution concepts, and the steps that should be taken in the continuation of the project.

Doehler needs an automated system measurement of the product slurry ratio to improve their current continuous flow system in order to improve efficiency, throughput volume, and reduce overall waste. Primary research compiled for this project includes discussion with stakeholders, technical advisors, and experts in the areas of electrical sensors and continuous flow piping loops, a root-cause analysis using a fishbone chart, and a needs assessment conducted by the capstone team.

3.0 Background

The current system that Doehler uses for producing tea and coffee is a continuous flow system. A simplified version of the production process is shown in Figure 1. The production process can be broken down into several phases. The first phase includes the inflow of dry ingredient and the second phase includes the inflow of water. These two phases occur simultaneously as both materials flow into the hydration tank, which is the third phase of the overall continuous flow process.
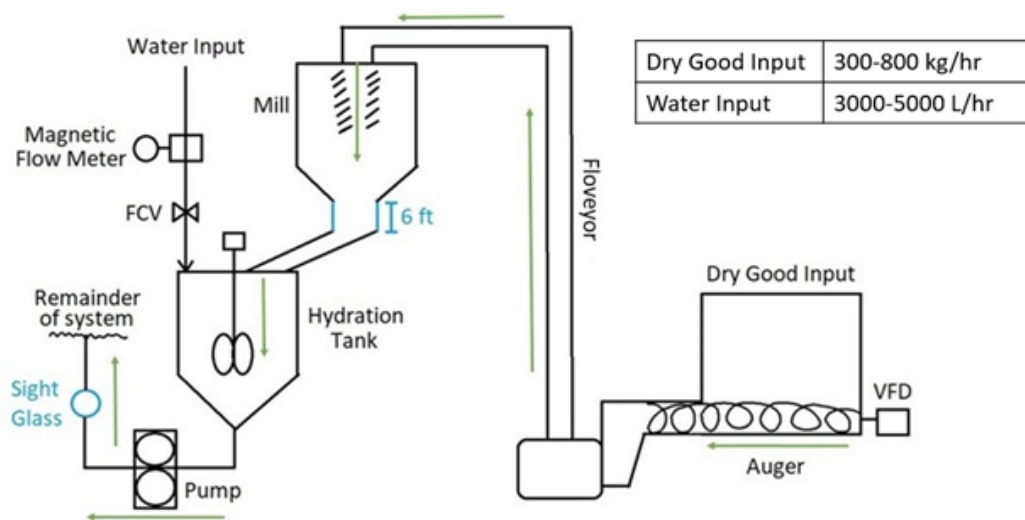
Figure 1: A reproduction of the sketch produced during the meeting with Dr. Phinney on Oct. 25th, 2019 displaying the current system in use at Doehler. Blue highlighted areas are available for sensor instrumentation placement and green arrows display the direction of production flow with the ranges of dry and water input rates provided.

Phase one encompasses the addition of dry ingredient into the system. First, the dry ingredient is fed into a hopper above the screw auger. The screw auger is controlled by a variable frequency drive, which is adjusted manually by a plant employee. The screw auger feeds dry ingredient into a Flowveyor vertical lift conveyor and delivers the ingredient into a mill. The ingredient then exits into a mill, where it is ground if necessary. The dry ingredient is fed at a rate of 300-800 kilograms per hour by the screw auger. Phase two involves the addition of water into the system. Cold water is pumped directly into the hydration tank. The flow rate is measured using a magnetic flow meter and controlled using a butterfly flow control valve. The water input is adjusted manually by a plant employee and varies between 3000-5000 liters per hour. Phase three describes the hydration of the solids within the hydration tank. The solid and liquid feeds are mixed by an agitator resulting in a slurry. The slurry is pumped through a sight glass and to the next stages of production using a lobe positive displacement pump. The mixture is pumped through the piping to the next production stages including thermal processing and solid/liquid separation. A sight glass, shown in Figure 2, is currently used to ensure that the mixture of ingredients is generally occurring, and the slurry is flowing properly.

Currently, the plant employee bases the water and dry feed adjustments on the near final product after the solid/liquid separation phase. Measurements are made using a brix refractometer which is used to estimate the extraction concentration of the product. If a higher concentration is needed, then the water input is reduced and/or dry good input is increased. The brix factor and profitability of a slurry can be maximized by increasing the slurry ratio of dry ingredient to water. However, the optimal ratio of dry ingredient to water is limited at 10% solid volume ratio because of the decanting process. Exceeding this limit causes machinery failure and stoppage. A large amount of down time is used to remediate this issue as the pipeline and decanter need to be pulled apart and cleaned with additional costs due to lost product. The goal of this design solution is to maximize the slurry ratio without running the risk of clogging the decanter.
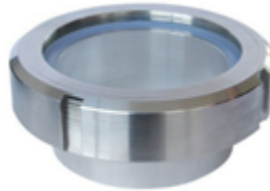
Figure 2: A sanitary union type sight glass similar to that used in Doehler's piping system. It is typically used with piping in dairy plants processes (Source: http://www.harshsteel.com/sanitary-union-type-sight-glass.html)

Definitions of industry terms:

Slurry – A nonhomogeneous mixing of solid and liquid. In this case, the solids are tea and coffee.

Brix – An industry standard relating to coffee and tea measurement for dissolved solids. It is measured as a percent or fraction and is related to TDS.

TDS or "Total Dissolved Solids" – A measurement of solids that have dissolved within a mixture. It is calculated by percent mass of dissolved solids divided by mass of liquid.

Guayusa – A highly caffeinated type of tea leaf, the dry good is leaf fragments of approximately 0.25 cm² or smaller in area.

Coarse grind – The standard grind used for French press coffee, has larger pieces and has a slower extraction rate.

Regular grind – The standard grind used for drip coffee.

Fine grind – The standard grind used for espresso, is a somewhat powdery solid mixture with a faster extraction rate.

Slurry ratio – The ratio of the mass of solid ingredient to the total mass of slurry (water and solid ingredient combined).

Flowveyor – Conveyor belt-like tool that brings the solid from the screw auger to the top of system to be fed into the mill.

4.0 Detailed Design Description

4.1 Application of a Particle Analysis to the System

In order to investigate how the various dry ingredients behaved in Doehler's system, several procedures were developed to determine properties of their physical characteristics. The properties that were critical in the system included particle volume, bulk density, and particle density. The bulk density of the particles was important because it affected the dry volumetric flow rate of the ingredients through the auger. The particle volume and particle density were important because they affected the density and

flow rate of the slurry. One of the key considerations of the ingredients is whether different ingredients with similar particle volumes have the same particle density. If different ingredients with similar particle volumes have the same particle density, then the slurry density and flow rate will be the same regardless of the type of dry ingredient. However, if ingredients of similar volumes have varying particle densities, their effect on slurry flow in the system will call for adjustments of inflow rates when changing between ingredients.

4.2 Use of ImageJ in the Particle Analysis

An image processing software, ImageJ, was utilized for calculating the particle volume of each of the dry ingredients. ImageJ was chosen for this analysis for its ease of use, accuracy through the elimination of human error, availability to the team, and ability to analyze many particles within a short period of time. The calculation involved a thresholding technique where the contrast of an image of the particles was adjusted so that only the particles to be analyzed appeared. After setting a scale for the software to use as a reference, the average particle area was automatically calculated using a built-in function within ImageJ. A similar procedure was performed for the thickness of the average particle and these two measurements were used to calculate the average particle volume for each type of dry ingredient the team tested.

4.3 Creation of the Guided User Interface with Integrated Particle Data

After the particle analysis experiments were performed and data was collected by the team, the relationships between properties were analyzed. By determining the average values of particle density, particle volume, and bulk density, a program was created to determine ideal input parameters to obtain the desired slurry concentration. In combination with fluid dynamics equations, the application of particle analysis data could be compiled to create an easy-to-use interface with which an employee at Doehler's plant could manually select the parameters of the system to determine which changes need to be made. The easy-to-use interface was essential to the success of the implementation and application of the program created. In order to maximize efficiency of the plant and reduce time lost, a graphical user interface (GUI), shown in Figure 3, was created using MATLAB software.
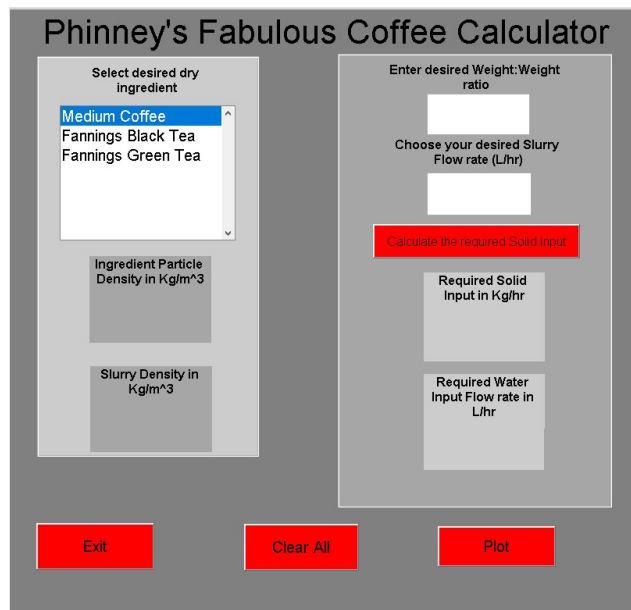

Figure 3: GUI input screen with which the Doehler employees will interact to adjust the water and dry ingredient inputs via drop down menus

4.4 Application of Graphical User Interface to the System

The GUI is an essential program which will be applied to the current system in order to create the feedback loop portion of the team's final design. By using a program which outputs the exact parameters required of the system to obtain the desired slurry ratio, human error of the brewing process can be eliminated. Due to the program containing the parameters of the current system at Doehler, the user simply selects the inputs, ingredient type, desired slurry ratio, and slurry flow rate, and based upon mathematical modeling of the flow, the GUI will populate the input of dry ingredient required. The ranges of inputs from which the parameters are selected are defined by Doehler's current system – dry good input between 300-800 kilograms per hour and water input between 3,000-8,000 liters per hour. The slurry flow is selected to match a flow rate based upon a desired brewing time further down line of the system. The slurry ratios used within the code range from 2-22%. These ranges are calculated based upon the ranges of inputs provided by the sponsor. The smallest end of the ranges, with the minimum amount of solid and minimum amount of water creates a 2% concentration slurry and the opposite combination creates a 20% concentration.

5.0 Design Evaluation

5.1 Particle Analysis

Particle analysis included calculations of the particle volume, bulk density, and particle density. The following were repeated for each of the three ingredients – coffee at a medium grind, green tea, and black tea – which were provided to the team by Doehler.

5.1.1 Particle Volume Methods

Average particle volumes were calculated using images (see example in Figure 4) taken of the top view of the ingredient particles against a white background to find the average area in square millimeters. A second image (seen in Figure 5) of the same ingredients was taken from the side to find the average thickness of the particles in millimeters. These values were retrieved using the image processing software, ImageJ. For the average area calculation, a thresholding technique was utilized to calculate the values. Particles less than 0.1 square millimeter were neglected due to an unrealistically small average area calculation when they were included. For the average thickness values, a straight line was traced from the top to the bottom of each particle. Finally, the average particle volume in cubic millimeters was calculated using the average area value multiplied by the average thickness value. Sample values from testing can be seen in Table 1.

Figure 4: Example of Top View of Ingredient Particles (Black Tea)
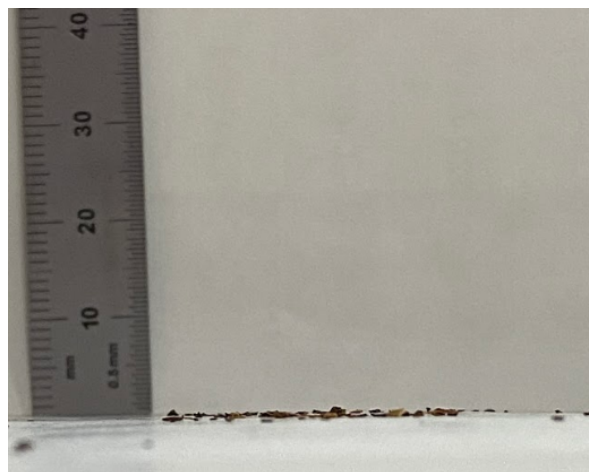
Figure 5: Example of Side View of Ingredient Particles (Black Tea)

5.1.2 Bulk Density Methods

Average bulk density was found by filling a container of known volume with each of the dry ingredients and finding the mass of the dry ingredient (shown in Figure 6). The volume of the container was determined using water and measuring the amount which fit into the container used. The bulk density value was calculated by dividing the mass value by the volume value. Sample values from testing can be seen in   .

Figure 6: Example of Bulk Density Method (Coffee)

5.1.3 Particle Density Methods

Particle density was determined using a displacement method (shown in Figure 7) with water in a graduated cylinder containing a pre-weighed amount of the dry ingredient. In order to account for any porousness within the particles and to get a cleaner reading at the meniscus, particles could sink before reading the volume change. The mass of dry ingredients was divided by the volume change to calculate the particle density values. Sample values from testing can be seen in   .
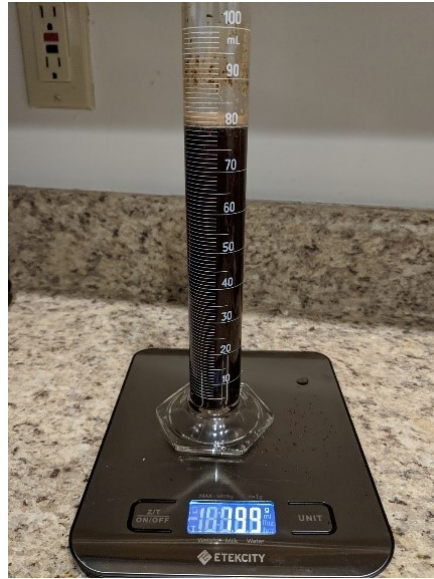
Figure 7: Example of Particle Density Method (Coffee)

5.1.4 Data and Calculations

Table 1: Example of Particle Analysis Data (Black Tea)		
Particle Area (mm²)	**Particle Thickness (mm)**	**Particle Volume (mm³)**
0.727	0.322	0.234
Mass (g)	**Volume (mL)**	**Bulk Density (g/L)**
40.16	114.38	351.11
Mass (g)	**Volume (mL)**	**Particle Density (g/L)**
5	7	714.29

$$Particle\ volume\ (mm^3) = particle\ area\ (mm^2)\ x\ particle\ thickness\ (mm)\ \ [1]$$

$$Bulk\ density\ \left(\frac{g}{L}\right) = \frac{mass\ (g)}{volume\ (mL)} * \frac{1000\ mL}{1\ L} [2]$$

$$Particle\ density\ \left(\frac{g}{L}\right) = \frac{mass\ (g)}{volume\ (mL)} * \frac{1000\ mL}{1\ L}\ \ \ \ [3]$$

Table 2: Average Values from Particle Analysis			
	Avg Particle Volume (mm³)	Avg Bulk Density (g/L)	Avg Particle Density (g/L)
Coffee	0.249	277.78	2331.17
Black Tea	0.202	348.23	912.00
Green Tea	0.299	315.44	1260.24

5.2 GUI (Graphical User Interface) and Calculations

$$Density_{Slurry} = \frac{Density_{liquid}}{1 - \left[\left(\frac{Density_{solid} - Density_{liquid}}{Density_{solid}}\right) * SlurryRatio\right]} \quad [4]$$

$$Flowrate_{solid} = \frac{SlurryRatio * Flowrate_{liquid}}{1 - SlurryRatio} \quad [5]$$

$$Volumetric\ Flowrate_{slurry} = \frac{Flowrate_{Solid} + Flowrate_{liquid}}{Density_{Slurry}} \quad [6]$$

Figure 8: GUI with selected values for black tea, displaying sample inputs for desired slurry ratio and water input to display the populated output information.

As can be seen in Figure 8, when the desired parameters are combined with equations [4], [5] and [6] that are incorporated within the code, the required solid and water inputs can be calculated as well as all the ranges of slurry ratios and corresponding volumetric flow rates [3,6]. The ranges of flow rates and slurry ratios are based on the required water input and all possible solid inputs that make up the range of slurry ratios. A graph of these calculations clearly defines the desired slurry flow rate and how the slurry flow rates change based on the changing slurry ratio. This graph can be seen in Figure 9.

As confirmed by the particle analysis, it is necessary to account for the varying particle densities of the different ingredients. To do this, the GUI allows the user to select the ingredient from the list and uses its respective particle density to calculate the slurry density as seen in equation [4] with all further calculations accounting for the ingredient's particle density as well [3]. In future applications this list can be expanded to include any botanical ingredient desired permitted the particle density is known.

6.0 Results

6.1 Results from GUI
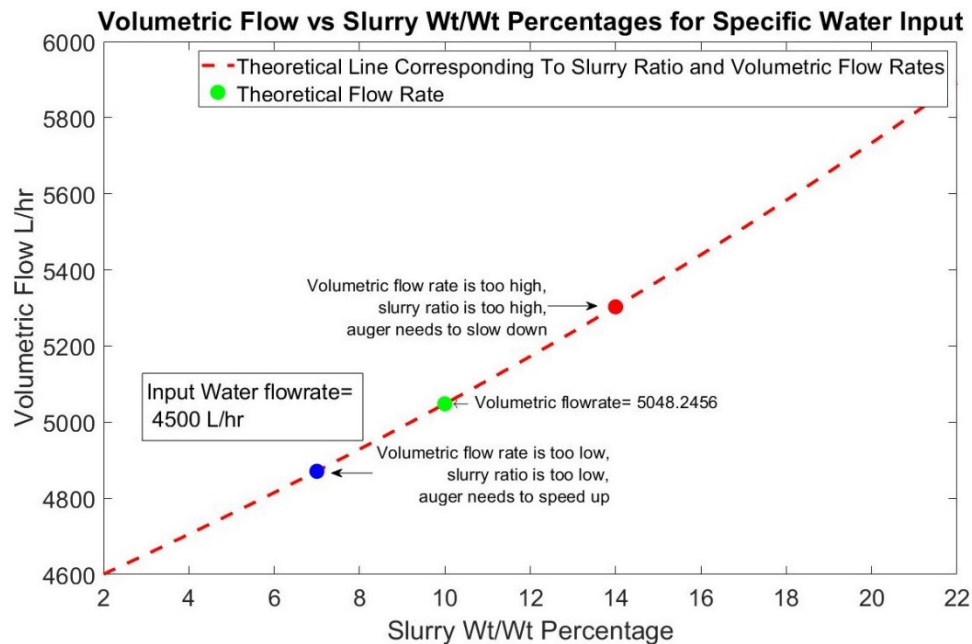
Figure 9: Graph produced by GUI based on user inputs

Results from the GUI are plotted as a graph in Figure 9. The GUI allows the user to input the volumetric flow rate of the slurry and then calculate the required inflow rates for the water and solid inputs. This desired volumetric flow is then graphed versus the inputted slurry ratio. Based off the calculated required water flow rate, the GUI creates a theoretical line that shows all the theoretical volumetric flow rates versus their corresponding slurry ratios.

Readings from a meter by the sight glass in the post mixing spot (highlighted in Figure 1) will be plotted on the same graph as the input and the theoretical line allows the user to see what slurry ratio is actually being supplied by the auger and water input. If the actual volumetric flow is higher than the theoretical value then the slurry ratio is too high, and the auger needs to slow down. If the volumetric flow rate is lower than the theoretical value than the slurry ratio is too low, and the auger needs to speed

up to add dry ingredient to the mixture. If this GUI and the calculations were to be incorporated into a PID loop it is also possible to automate this process.

6.2 Results from Particle Analysis

Relationship Between Average Particle Volume and Average Bulk Density
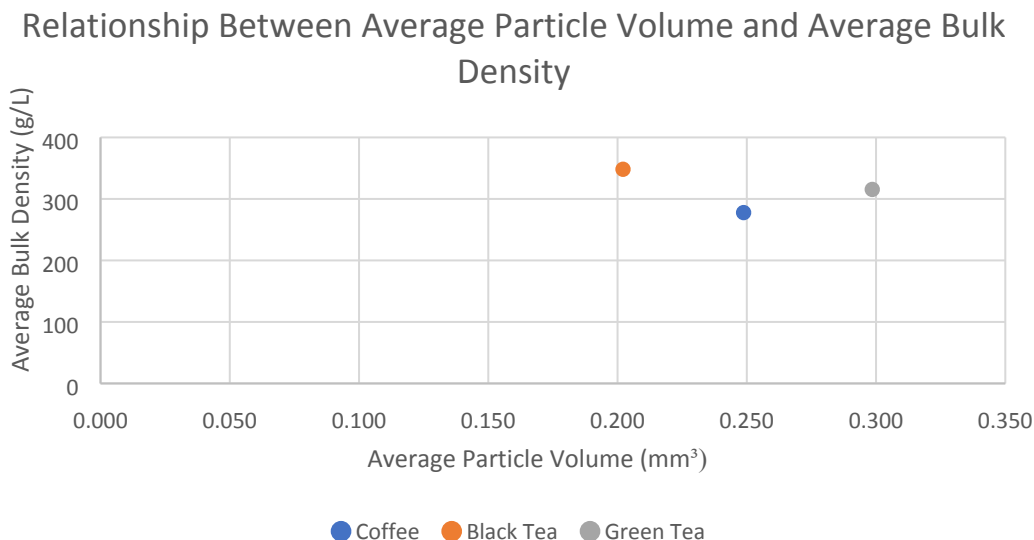
Figure 10: Relation between Average Particle Volume and Average Bulk Density

Results from particle analysis can be seen in   for the three different ingredients. A comparison of the particle volume compared to bulk density for each ingredient can be seen in Figure 10. This figure shows that there is no correlation between bulk density when particle volume for the ingredients is very similar. This is significant because it means that even if the particle volume is similar for the ingredients used at Doehler, it cannot be assumed they will have similar dry flow rates from the auger due to differing bulk densities. This means each ingredient need to have its own input flow rate and their individual particle densities will have to be utilized for the theoretical calculations. The GUI design helps overcome this limitation because it lets a user select their ingredient and then will automatically incorporate the ingredients' particle densities from the particle analysis into its calculations.

7.0 Cost Analysis

To verify the accuracy of the meters and the GUI, small scale testing needs to be performed. The pumping system, tested meters, and water will be provided by Ohio State and Doehler. Rotary flow meters with their respective connectors and a level sensor for the hydration tank will need to be purchased to perform testing.

Figure 11: Proteus Series 6000 Rotary Flow Meter used in Physical Testing [5]

Based on the cost and pump specifications and slurry flow rate calculations, a Proteus 6000 series (displayed in Figure 11) should be used. With a range of 0.95-9.5 liters per minute, each meter will cost approximately $200 [5] plus an additional $110 for their respective connectors (based on quote from Sanitary Fittings). A capacitance level sensor, selected for its ability to handle slurries, will cost roughly $300.[3] This brings the total cost of small-scale testing to $810. Labor cost is excluded for this experiment, as it will be performed by students.

After small scale testing is completed, a final meter will be selected for implementation in Doehler's system. The following meters were selected for their performance when measuring slurries and their ability to be used in hygienic applications: magnetic, ultrasonic, and Coriolis mass flow meters. Exact costs for each meter vary with precision, flow range, and pipe size. However, approximate costs can be compared between flow meters as shown in Table 3.

Table 3: Comparative Cost of Meters[2]		
Flow Meters	Initial Cost	Maintenance Cost
Magnetic	High	Low
Ultrasonic	High	Very Low
Mass	Medium	Low

8.0 Further Design Considerations

Additional considerations for this project include sustainability, manufacturability, health and safety, and limitations in application. The GUI was created with editability and flexibility in mind. Doehler plans to run a variety of coffees, teas, and botanicals on their product line and the GUI is made to be updated to meet the needs for every dry ingredient. Additionally, each proposed meter has no moving parts so interference in the system is minimized. Furthermore, the low upkeep costs make it easy to sustain the project for years to come. For manufacturability, the mass flow meter is the only in-line sensor recommended and requires scheduled installation. However, the ultrasonic and magnetic flow meters are out-of-line sensors and can be installed during pre-scheduled downtime of the system. Moreover, the GUI can be connected to the flow meters and auger during pre-scheduled downtime.

The health and safety of the floor workers will be improved after the installation of the feedback loop. Less manual adjustments of the system will be made so less workers on the plant floor during operation will be required. Finally, the limit for the slurry ratio of Doehler's system is 17% which causes flow rate to slow to a near stop and can result in pipe and pump clogging. The GUI can calculate all flow rates within and beyond this range, so the limitations of the design exceed the limitations of the system.

9.0 Conclusions and Recommendations

9.1 Conclusions

From particle analysis, it was found that green tea obtained the largest particle volume of 0.299 mm³, black tea had the largest average bulk density of 348.23 g/L, and coffee was the largest average particle density of 2331.17 g/L. The particle analysis found no direct correlation between particle volume and bulk density. However, the fact that the bulk density was not the same for similar particle volumes is significant because it means that each dry ingredient will have a different effect on volumetric flow rate. A Graphical User (GUI) was constructed to pair with the particle analysis data collected. The GUI allows

a user to input parameters such as particle type, particle density, slurry density, desired slurry ratio, and desired water input. These inputs generate a corresponding volumetric flow rate. This volumetric flow rate is then graphed with the GUI versus the inputted slurry ratio. This creates a theoretical line that shows all the theoretical volumetric flow rates versus their corresponding slurry ratios. Ultimately the user can input their desired slurry ratio and the GUI will output the required flow ratio based on the input value. At the Doehler NA Atlanta facility, as described in Figure 1, this GUI can be used in tandem with in line meters to automate the water and solid ingredient input rates to achieve the desired slurry ratio. After detailed design and evaluation, it can firmly be stated that particle analysis directly impacts flow rate calculations. Simply stating that slurry concentration and volumetric flow rate have a direct relationship. Both the GUI and particle analysis data for green tea, black tea and coffee will be presented to Doehler. These deliverables will be used in applications from fluid dynamics to extraction kinetics in their Atlanta facility and other Doehler systems worldwide.

9.2 Recommendations

Further physical testing is recommended utilizing a system similar to the proposed small-scale testing design in Figure 12. This model will potentially validate our theoretical predictions from the Graphical User Interface. After validation from the model, automation of the design can take place. The particle analysis data should be used in tandem with the GUI and chosen in-line flow meter to incorporate everything into a PID response loop between the solids feed auger, water input flow meter and slurry flow meter. Our detailed future experimental design model is discussed in the next section.

10.0 Detailed Future Experimental Design-Model Validation

10.1 Possible Solution Implementation Locations

The sponsor has provided two sections of the system that could be altered to add sensors (highlighted in blue in Figure 1). One of which is below the mill in a 6ft section, after the Flowveyor. At this location, there is potential for a solids feed instrumentation to be added. The other section is near the sight glass where a flow meter could be added. These options were explored independently to create a wide range of solutions and compare the best of each.

10.2 Post-Milling Sensor

A solids feed instrumentation would be the most direct way to measure the mass of dry material entering the line. A slurry ratio could be easily calculated when paired with the water mass flow measurements from the magnetic flow meter alrighty present in the line after the positive displacement pump in the current system. Additionally, having a sensor close to the auger input would create a better reactivity adjustment for the output to the auger. However, the dry material and water input enter a hydration tank before continuing into the system, so the slurry ratio would be an estimated average of what continues into the pipes.

10.3 Post-Mixing Sensor

Several types of flow meters including a magnetic flow meter, ultrasonic flow meter, and Coriolis mass flow meter were considered for the sight glass area. The meters themselves must be able to handle the potential physical impact on any probe due to a slurry, have increased sensitivity to detect minimal changes in the input of dry ingredient into the slurry, give a continuous and accurate reading to allow for immediate feedback to the screw auger causing any adjustments in ingredient amount needed, as well as be able to fit into the allotted stretch of piping indicated by the team's sponsor near the sight glass.

10.4 Final Concept Implementation Locations

After research was performed by the team on the variety of sensors and instrumentation which could be implemented in Doehler's current system at the two locations indicated, the team shifted focus on the location near the sight-glass or at the post-mixing section. This decision was a result of sponsor preference as well as cost and accessibility for testing by the team. While the post-milling sensor has been seen to be successfully used in other industrial applications, it was ultimately not chosen through a series of decision matrices performed by the team.

10.5 Small-Scale Physical Testing

The next step of testing will include the closed loop skid in the Parker Pilot Plant including an ultrasonic, a Coriolis mass flow, a Magnetic flow meters, as well as two rotary flow meters shown in Figure 11. The two rotary flow meters will be placed in line ahead of the other flow meters which will be tested. Rotary flow meters, per the recommendation of the team industrial sponsor, Dr. Phinney, will be used due to their consistency, accuracy, and precision. These two rotary meters will be used to validate the real values of the water inlet flow and the dry ingredient feed flow. The difference between the two rotary flow meters will be used as the true value of the slurry flow which will then be used to compare the workings of the mass and magnetic flow meters further down the line. Rotary meters, while reliable for testing, are not hygienic and thus not under consideration for a final solution but are simply being used for testing of a product in trial runs which will not be consumed. Three concentrations of slurries will be tested to obtain experimental volumetric flow values for 5%, 10%, and 15% slurry ratios for one grind of coffee, one fanning cut of black and green teas, the parameters for which are laid out in Table 4*: Flow Rates for Various Botanical Slurries at Different* . Particle analysis must be performed before this portion of testing to ensure that the grind of coffee and tea fanning are comparable in particle volume to further reduce any discrepancies variables within testing.
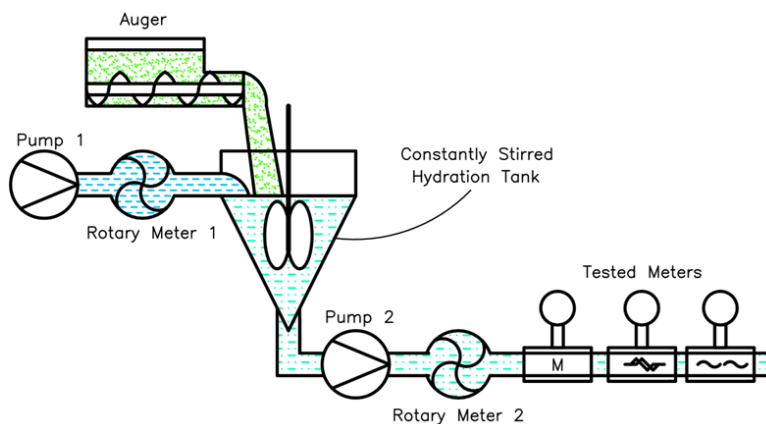
Figure 12: Small scale set up with dots representing solid, dash representing liquid, and dash-dot representing slurry

Experimental data will be collected for three tests of slurry flow through the loop piping for each of the three dry ingredients: coffee, black tea, and green tea. This experimental data will be collected and analyzed to help determine which of the sensors will have the more accurate and precise readings continuously so that one may be recommended to Doehler to implement in their industrial line. Collected data will be statistically analyzed to allow easy comparison and reduce work required to display the scale up process when implementation occurs at the end of the semester. Finally, the experimental data with the completed particle analysis will be combined so that a bulk density and desired slurry ratio inputs can be utilized in a feedback loop for Doehler between the final concept to the screw auger currently in place.

Independent Variables

- Type of solid ingredient:
    - Green tea, black tea, coffee
- Ingredient particle volume
- Slurry ratio:
    - 5%, 10%, 15%
- Solids feed rate
- Pump 1 frequency
- Processing time
- Number of trials

Dependent Variables

- Rotary meter 1 volumetric flow rate
- Rotary meter 2 volumetric flow rate
- Tested meters flow rates
- Pump 2 frequency

Table 4: Flow Rates for Various Botanical Slurries at Different Ratios						
Percent Slurry Concentration	Coffee Slurry		Black Tea Slurry		Green Tea Slurry	
	Dry (kg/hr)	Water (gpm)	Dry (kg/hr)	Water (gpm)	Dry (kg/hr)	Water (gpm)
5%	52.57	4.40	56.10	4.69	47.88	4.01
10%	52.57	2.08	56.10	2.22	47.88	1.90
15%	52.57	1.31	56.10	1.40	47.88	1.20

Procedure:

1. Start water input from Parker Pilot Plant.
2. Start pump 1 set at frequency determined from Table 4: *Flow Rates for Various Botanical Slurries at Different* .
3. Start pump 2 at the same set frequency as pump 1.
4. Begin solids feed auger into hydration tank and begin agitator.
5. Adjust pump 2 frequency to obtain constant level in hydration tank.
6. Record frequencies from pumps 1 & 2, flow rates from rotary flow meters 1 & 2, and the tested meters flow rates on the digital displays all at consistent intervals for the desired processing time.
7. Repeat this process three times for each type of solid ingredient and slurry ratio.

Figure 13: Basic block diagram of flow through the system for physical testing

Figure 13 represents the basic block diagram of the detailed future experimental small-scale design. Following the procedure listed above, this design will generate the needed data to make the correct correlations of volumetric flow rates to slurry ratio. This procedure will be run a total of 27 times

to produce this data for black tea, green tea, and coffee. After analyzing this small-scale design data of the three proposed meters, a final flow meter with the lowest margin of error will ultimately be recommended to Doehler to use in their Atlanta facility.

11.0 References

[1] "Bulk Solid Materials." Flexicon Corporation, Flexicon, http://www.flexicon.com/Articles/Case-Histories/article.aspx?ID=Q-0950A.

[2] "Comparing Flowmeters." *Engineering ToolBox*, www.engineeringtoolbox.com/flowmeter-selection-d_526.html.

[3] "Measuring the Percent Solids of a Slurry with the AccuPyc 1330 Pycnometer ." *Application Note*, Micromeritics, www.micromeritics.com/Repository/Files/ap77.pdf.

[4] "Omega Engineering." *LVC152 Series | Economical Capacitance Level Switch | Omega Engineering*, www.omega.com/en-us/process-switches/level-switches/capacitance-and-conductivity-switches/lvc152/p/LVC-152-R.

[5] "Proteus 6000 Series Flow Meter Product - Proteus Industries Inc." *Proteus Industries*, proteusind.com/product/6000-series-flow-meter.

[6] "Slurry Calculator Help." *Paterson & Cooke*, 30 June 2018, www.patersoncooke.com/slurry-calculator-help/.

[7] "Ultrasonic Analyzers and Sensors." Process Measurement and Analysis, https://www.pma.uk.com/ultrasonic-analysers-sensors-instruments/

12.0 Appendices

12.1 Appendix A: Qualifications of Personnel

12.1.1 Caroline Weisgerber

Caroline Weisgerber

Weisgerber.21@osu.edu | 513-307-6043| https://u.osu.edu/carolineweisgerber/

OBJECTIVE
Aiming to leverage my research, academic, leadership, communication, and teamwork skills in the food, pharmaceutical, or medical sciences industry.

EDUCATION
The Ohio State University, College of Engineering – Columbus, Ohio   (August 2015 – May 2020)
Bachelor of Science in Food, Agricultural, and Biological Engineering   (Major GPA: 3.4)
Specialization: Biological Systems Engineering

RELEVANT EXPERIENCE
Laboratory Assistant Intern   (June 2018 – April 2020)
Medpace Reference Laboratories – Cincinnati, Ohio
- Support daily departmental operational activities including logistics, inventory, lab cleanliness in conjunction with safety protocols, organize and prepare sample testing using QA software Clin-Trak, and conduct daily maintenance on lab equipment
- Provide ad hoc assistance to Laboratory Technicians as requested
- Maintain database and spreadsheets as necessary to facilitate tracking and documentation of departmental activities
- Conduct quality control reviews of outbound clinical kits to ensure proper fulfillment for study trial patients

Undergraduate Research Assistant   (August 2019 – April 2020)
 Dr. Richard Bruno Nutrition Laboratory – The Ohio State University
- Conduct experimentation to distinguish effects of green tea extract on digestion health of study patients
- Prepare weekly glucose, triglyceride, and HDL standards used for spectrophotometry of trial patient samples to be used in analysis of samples
- Assign and organize sample collection vials in efficient manner to expedite collection process

Senior Capstone Design Project   (August 2019 – May 2020)
Doehler North America – The Ohio State University
- Conduct research and preliminary prototyping to test and validate concepts to determine optimal solution to proposed engineering problem in Doehler's production facility
- Designed and tested an automated sensor to measure the weight to weight slurry ratio in a continuous flow system
- Lead and collaborate with a small team to develop, document, and presented ideal solution for use at Doehler
- Correspond with advisors and sponsor in a professional and efficient manner while following design process steps to satisfy sponsor organization requirements
- Continuing research to further test proposed solution during live operation

SKILLS AND QUALIFICATIONS
Software: SolidWorks, MATLAB, C++ coding, Microsoft Office, Microsoft Project, ChemDraw, LoggerPro, COMSOL, AutoCAD, Clin-Trak
Writing, Communication and Organization: Written laboratory notebook maintenance and formal reports, public speaking (classroom and to business audiences via Capstone), proficient in Spanish, teamwork in presentations, distribution of work in a timely manner

LEADERSHIP AND SERVICE
BuckeyeThon Cancer Fundraiser at Ohio State University -Team Member/Volunteer   (August 2015 – May 2019)
Project Impact at Ohio State University - President   (March 2018 – May 2019)
- Voted into various leadership positions including Vice President, Treasurer, and logistics Committee

Relay for Life - Planning Committee Member and Team Captain   (August 2011 – May 2017)

Christian D. Gerding

gerding.42@osu.edu | 2239 Neil Ave, Columbus, OH 43201 | (330) 416-1150

EDUCATION

The Ohio State University, Columbus, OH   Overall GPA (4.0 scale): 3.861
B.S. Food Engineering, May 2021
Science, Engineering, and Public Policy Minor
Green Engineering Scholars Program

QUALIFICATIONS

Technical Skills: Trained on Rotational Rheometer and Differential Scanning Calorimeter, Experience with MATLAB and SolidWorks, Knowledge of AutoCAD, DraftSight, and Arduino, Proficient in Microsoft Office

Languages: Five years of experience with Mandarin Chinese (reading, writing, and speaking)

ACADEMIC ENGINEERING PROJECTS

Senior Capstone Design Project – Doehler North America, Aug 2019 – Present
- Developed a solution for measuring the solids concentration of a slurry in a continuous flow system
- Communicated with company sponsors and technical advisors throughout a year-long design process

Automatic Irrigation System – MakeOHI/O, March 2017
- Designed a self-watering system for a small plant as a part of a four-person team
- Utilized Arduino programming and a circuit board to program a motor powered by solar panels

Advanced Energy Vehicle – Fundamentals of Engineering Program, Jan 2017 – Apr 2017
- Created and programmed a vehicle with three teammates to perform an automated run on a rail system
- Collected and analyzed experimental data and design modifications to maximize the vehicle's efficiency

WORK EXPERIENCE

Undergraduate Researcher in Food Engineering – The Ohio State University, Columbus, OH   Apr 2019-Present
Performed characterization experiments of soy/pea protein mixtures for use in 3-D printing

Materials Science & Engineering Intern – Newport News Shipbuilding, Newport News, VA   May 2018-Jul 2018
Investigated surface preparation methods with cost savings of up to $22 million per carrier

Industrial Engineering Intern – Anchor Manufacturing Group, Cleveland, OH   May 2017-Aug 2017
Performed 5S monthly audits, cost and efficiency analyses, and time studies

Sandwich Artist – Subway, Medina, OH   Jun 2014-Feb 2015
Responsible for the service of as many as 300 customers and over $2,000 per shift

LEADERSHIP, INVOLVEMENT, AND COMMUNITY OUTREACH

Chi Chapter of Theta Xi Fraternity – Elected as Vice President, Scholarship Chairman,   Mar 2017-Present
Public Relations Chairman, Fundraising Chairman, and Bylaws Chairman

Ohio State Welcome Leader (OWL) Move-In Program – Student Volunteer   Aug 2016-Aug 2019

Ohio State AROUSE Student Radio – Radio Show Co-host   Aug 2018-Aug 2019

Ohio State GrOSU Sustainability Club – General Body Member   Aug 2017-Aug 2018

Ohio State Second-Year Transformational Experience Program (STEP)   Aug 2017-May 2018

Ohio State Materials Science Department – Undergraduate Laboratory Volunteer   Jan 2018-Feb 2018

Christopher W. Waidelich

1810 Rhoda Ave, Columbus, OH 43212 | 740.477.6220 | waidelich.14@osu.edu

OBJECTIVE
> A proven leader seeking to obtain a full-time position leveraging my industry experiences, academic learnings, and leadership qualities to become a valuable asset to an industry leading company.

EDUCATION
The Ohio State University, Columbus, OH   **Expected Graduation May 2020**
Bachelor of Science in Food, Agriculture, and Biological Engineering (Food Engineering Specialization)
Projects, Research and Related Skills
> - <u>Academic Projects:</u> **Advanced Energy Vehicle**: *Designer and Team Manager;* **Buckeye Poppers Food Product Development**: *Prototype Design;* **Doehler Blending Capstone Project**: *Team Sponsor Liaison*
> - <u>Technical Skills:</u> MATLAB, SolidWorks, AutoCad, Microsoft, Fluid Mechanics, Thermodynamics, Food Science & Processing, Food Plant Management, Measurement & Instrumentation, System Dynamics, Kinetics and Reactor Design

EXPERIENCE
Capstone Project Engineer, Doehler North America, Cartersville, GA   **Aug. 2019 – May 2020**
> - Developed a technical proposal for a continuous improvement, process engineering problem for coffee/tea slurry applications
> - Conduct research and prototyping to test and evaluate top concepts determined
> - Designed automated instrumentation to measure weight to weight slurry ratio in a continuous flow beverage system
> - Developed a project work scope cost analysis, as well as technical and financial justification consistent with sponsor needs
> - Reported on project results in interim and final reports using both written and oral communications methods

Food Defense Intern, Ingredion Incorporated, Bridgewater, NJ   **May 2019 – Aug. 2019**
> - Development and implementation of the facility Food Defense Plan with accordance to FDA FSMA-IA Rule requirements
> - Completed Food Defense Qualified Individual training
> - Developed site specific mitigation strategies at processing steps to prevent intentional adulteration
> - Created FSMA compliance process flow diagrams for all processing areas
> - Developed training modules for Food Defense Awareness and site Specific mitigation strategies
> - Developed Lot Coding Traceability System for ingredient receiving and finished prototypes

Process Engineering Intern, Ingredion Incorporated, Indianapolis, IN   **May 2018 – Aug. 2018**
> - Coordinated with contractors and vendors to develop solutions for cost saving and continuous improvement projects
> - Completed 9 corn wet milling processing projects resulting in $78,000 annual savings
> - Developed and maintained a working budget of $98,000 for a process improvement project
> - Programmed and troubleshot DeltaV and Aspen controls software for current operational systems

Pilot Plant Intern, Ingredion Incorporated, Bridgewater, NJ   **May 2017 – Aug. 2017**
> - Maintained a clean, safe work environment following established guidelines for GMPs, SOPs and Safety
> - Managed 3 Technical Service projects, working both independently and collaboratively, to meet project timelines
> - Conducted experimental production in the food pilot plant to advance projects with the Dairy and Bakery applications teams
> - Analyzed data, results, and scientific literature to progress R&D projects related to reduced sugar dairy products
> - Worked with Technical Service team and other colleagues cross functionally to obtain more clientele
> - Presented prototypes, project statuses, updates and outcomes in interim and final reports to team and stakeholders

ACCOLADES/ACTIVITIES
Mount Leadership Society Scholars, The Ohio State University   **Aug. 2014 – Present**
General Member/ Graduate/ Legacy Week Team Member
> - Developed leadership skills by mentoring first-year students transitioning into college life
> - Organized and facilitated volunteer events in Columbus, OH as part of our monthly service to the community

Undergraduate Student Government (USG), The Ohio State University   **Nov. 2014 – Sep. 2017**
Campaign Senate Slate Coordinator (2014)/ Interns Coordinator (2016-2017)/ North Campus Senator (2014-2016)
> - Collaborated with other team members weekly to organize events for ten day student body presidential campaign
> - Provided voice in the General Assembly for 14,000 students by communicating and writing legislation on current student issues on campus

Club Baseball, The Ohio State University   **Aug. 2014 – Sep. 2017**
Captain and Team Member
> - Actively participated in team service events, monthly team meetings and a 40-game season schedule

Delta Tau Delta Fraternity, The Ohio State University   **Jan. 2016 – Aug. 2018**
Peter R Peirce Memorial Scholarship (2018)
> - Given to a student in engineering or related fields recognizing their campus involvement and student leadership

Karissa Smith

614-264-6822 | smith.10523@osu.edu

Objective

I am a motivated undergraduate student seeking a summer/fall internship, co-op or full-time job in biological engineering. I work well on project teams and solo projects and hope to utilize my chemistry background in the food industry.

Education

BACHELOR OF SCIENCE | MAY 2020 | OHIO STATE UNIVERSITY

· Majors: Bioengineering and Chemistry
· Recipient of Provost Scholarship
· Recipient of OSU-Honda Math Medal Award

Skills & Abilities

· Proficient in Microsoft Office and Excel
· Intermediate C/C++ and Matlab skills
· Proficient, patient and precise in a chemistry lab
· Intermediate chemistry instrumentation skills
· Proficient data and statistical analyzation skills

· Intermediate AutoCAD and Solidworks skills
· Work well in groups and on independent projects
· Proficient and practiced in technical writing
· Quick and eager learner

Experience

DOEHLER BLENDING CAPSTONE| OSU FOOD, AGRICULTURE, BIOLOGICAL ENGINEERING DEPARTMENT| 8/2019 TO CURRENT

· Researched flow meters and dry-feed system as potential solutions for Doehler's continuous flow system
· Coordinated with FABE department experts and out of state company sponsor to discuss project specifications, direction and potential solutions

NASA HUMAN EXPLORATION TEAM MEMBER| OSU WELDING ENGINEERING| 01/2016 TO CURRENT| SECRATARY 01/2019 TO CURRENT

· Created new concept for wheel design, gained experience in shop safety and tools for metal parts assembly
· Planned trip for competition and oversaw group safety and professionalism
· Coordinated with small project teams to ensure completion of designs and fabrication on schedule

ROBOT TEAM| FUNDAMENTALS OF ENGINEERING HONORS COURSE| 01/2016 TO 4/2016

· Lead for documentation, assisted in construction of robot
· Oversaw testing, completion of project goals and group assignments
· Top 16 out of 76 teams in competition, awarded 3rd place in most consistent

  https://u.osu.edu/feh16e3/   Password: FEH2016

UNDERGRADUATE RESEARCH| OHIO STATE BEE LAB| 06/2018 TO CURRENT

· Completed an individual project to study Nosema Ceranae in honeybees and screen for viable treatments and potential infection accelerants
· Assisted in data collection and bee yard upkeep
· Performed talks and poster presentations at Ohio State, Ohio South Beekeepers Assoc. conference and plan on speaking at American Beekeeping Federation Conference in 2020

SOCCER REFEREE| OHIO SOUTH YOUTH SOCCER ASSOCIATION| 04/2009 TO CURRENT

· Officiate games to maintain standards of play and to ensure that game rules are observed
· Inspect sporting equipment and examine participants to ensure compliance with event and safety regulations
· Communicate with other officials to call infractions or to otherwise regulate play or competition
· Complete yearly certification and stay updated on rule additions and changes

Cody P. Dingess

Dingess.27@osu.edu   10225 State Route 665 London, OH 43140 740-412-9706

OBJECTIVE

Positive and motivated biological engineering student. Plan to get a master's degree and then a Medical Degree where I hope to become an Oncologist. I'm passionate about helping others and one day saving lives. I'm also excited about the future possibilities that biological engineering can bring to the world in both our environment and in medicine and one day want to be on the forefront of that future

SKILLS & CERTIFICATIONS

- **Coursework**: basic and advanced topics in Calculus, Physics, Chemistry, Biology, programming, and applied differential equations to real world systems
- **Operating Systems**: knowledge of: Macintosh, Windows
- **Programming**: proficient in MATLAB and AutoCAD
- **Software Applications**: advanced knowledge of Word, PowerPoint, Excel,
- **Other applicable skills:** effective interpersonal communication and teamwork skills, confidence in my ability to solve a problem and a hard work ethic to make sure that problem gets solved

EDUCATION

The Ohio State University, Columbus, OH

- B.S., Biological Engineer with a Minor in Biomedical Engineering, August 2015-May 2020
- Member of the Varsity Wrestling Team, and scholar athlete recipient, August 2015- May 2018
  - Approximately 40 hours a week spent on wrestling practice and meetings while on team

ACADEMIC PROJECTS

Doehler Continuous In-Line coffee/tea blending - August 2019-May 2020

- Doehler, a worldwide food and beverage supplier to companies like Coke and Keurig, needed a design for a continuous feedback system to improve their botanical blending process, operational efficiency and testing accuracy
- Utilized MATLAB, fluid dynamics, and particle analysis in order to calculate botanical slurry flow and slurry ratio and create a design that calculates slurry flow rate based of user inputs and compare to measured inputs

MidOhio Foodbank design – August 2018-December 2018

- Create a design and complementary presentation poster to develop a design that could keep food cold in the summer during MidOhio foodbank food drives
- Applied fundamentals of Thermodynamics and engineering design process in a team setting to determine the best theoretical design and create a presentation to concisely explain the design

EXPERIENCE

PACKAGE LOADING ● FEDEX ● SUMMER OF 2016

- Loaded packages on the Semi-trailers in orderly fashion in order to maximize space.
- Learn to work efficiency in working in a way that was fast, but also safe and space efficient.
- Learned how to maintain a calm and efficient work pace in the chaotic and crazy work environment of a factory

BUSSER ● WEDGEWOOD COUNTRY CLUB DINNING ● JULY 2017- CURRENT

- Learned to positively interact with coworkers in order to create a positive and efficient work environment.
- Learned to interact with members and other customers in a way to positively improve their dining experience at Wedgewood.
- Help servers with cleaning, serving and setting of the tables in order improve their workflow and improve problem prioritizing

VOLUNTEER WORK

Cypress Wesleyan Church – summer 2016-present

- Volunteer as a youth group leader for middle school and high school students
  - Work with fellow youth group leaders to run small groups as well as games and activities for the kids
  - Chaperone for camps and retreats for the kids

12.2 Appendix B: Graphical User Interface Code

```
%%%%%%%%BELOW IS THE CODE FOR A GRAPHICAL USER INTERFACE DESIGNED TO
INCORPORATE%%%%%%%%%
 %%%%%%%%%FLUID DYNAMICS AND THE SPECIFIC SYSTEM PARAMETERS OF DOEHLERS
CONTINIOUS%%%%%
 %%%%%%%%%%%%%%%%%%%%%%%%%%BOTANICAL SLURRY FLOW EXTRACTION
PROCESS%%%%%%%%%%%%

 %%%% THE CODE IS DESIGNED TO ALLOW A USER TO SELECT THEIR DESIRE SLURRY
 %%%% RATIO AND DESIRED SLURRY FLOW RATE, AND FROM THERE CALCULATE THE
 %%%% SYSTEMS REQUIRED INPUT PARAMETERS
 %%%% THE CODE THEN SERVES TO GRAPH THEIR DESIRED SLURRY FLOW RATE AND
 %%%% SLURRY RATIO AND COMPARE IT TO A THEORETICAL LINE THAT IS THE
 %%%% CALCUALTED SLURRY FLOW RATE FOR EACH POSSIBLE SLURRY RATIO
 %%%% IF USED IN DOEHLER SYSTEM THIS CAN BE MODIFIED TO ALSO GRAPH AND
 %%%% READING FROM A SENSOR OR OTHER MEASURING TOOL AND COMPARE THE
 %%%% MEASURED SLURRY FLOW RATE TO THE THEORETICAL FLOW RATE
 %%%% WHERE THE MEASURED SLURRY FLOW RATE PLOTS ON THE GRAPH TELLS A USER
 %%%% WHAT THEIR ACTUALY SLURRY RATIO IS CURRENTLY AT AND THUS THE INPUT OF
 %%%% THE SOLID INGREDIENT CAN BE ADJUSTED BY THE AUGER TO SHIFT THE
 %%%% MEASURED SLURRY FLOW RATE TO MATCH THE DESRIED THEORETICAL SLURRY
 %%%% FLOWRATE, THUS KEEPING THE SLURRY RATIO CONSTANT AND IMPROVING THE
 %%%% EFFIECIENY AND ACURRACY OF THE CONCETRATION OF THE BOTANTICAL BEING
BREWED

 %%%%%% FUTURE WORK WITH THIS CODE AND GUI CAN ALLOW THIS TO BE INCORPORATED
 %%%%%% INTO A PI&D LOOP TO AUTONOMOUSLY RUN THE READINGS, CALCULATIONS, AND
 %%%%%% ADJUSTMENTS TO THE SOLID INPUT, THUS IMPROVING THE SYSTEM EVEN
 %%%%%% MORE AND DECREAING POSSIBLE HUMAN ERROR

function varargout = CapstoneGui(varargin)
% CAPSTONEGUI MATLAB code for CapstoneGui.fig
%      CAPSTONEGUI, by itself, creates a new CAPSTONEGUI or raises the
existing
%      singleton*.
%
%      H = CAPSTONEGUI returns the handle to a new CAPSTONEGUI or the handle
to
%      the existing singleton*.
%
%      CAPSTONEGUI('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in CAPSTONEGUI.M with the given input
arguments.
%
%      CAPSTONEGUI('Property','Value',...) creates a new CAPSTONEGUI or
raises the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before CapstoneGui_OpeningFcn gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to CapstoneGui_OpeningFcn via varargin.
%
%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
```

```matlab
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help CapstoneGui

% Last Modified by GUIDE v2.5 23-Apr-2020 12:04:27

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @CapstoneGui_OpeningFcn, ...
                   'gui_OutputFcn',  @CapstoneGui_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before CapstoneGui is made visible.
function CapstoneGui_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to CapstoneGui (see VARARGIN)

% Choose default command line output for CapstoneGui
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

% UIWAIT makes CapstoneGui wait for user response (see UIRESUME)
% uiwait(handles.figure1);


% --- Outputs from this function are returned to the command line.
function varargout = CapstoneGui_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;
```

```matlab
function wtwtin_Callback(hObject, eventdata, handles)
% hObject    handle to wtwtin (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of wtwtin as text
%        str2double(get(hObject,'String')) returns contents of wtwtin as a
double


% --- Executes during object creation, after setting all properties.
function wtwtin_CreateFcn(hObject, eventdata, handles)
% hObject    handle to wtwtin (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');


end




% --- Executes on button press in waterselectionpush.
function waterselectionpush_Callback(hObject, eventdata, handles)
% hObject    handle to waterselectionpush (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

    %                   &&&&& NOTE &&&&
    % Water selection push button isnt actually for water anymore
    % Code was changed where instead slurry flow rate is inputted but the
call
    % back name was kept the same
    % Once waterselctionpush button is pushed is activate the equations below


    % Below here is a calculation of the range of slurry percents being used
and
    % applied to the final plot. The range of wtwtpercentage can always be
    % adjusted as well as the value it increase by
    % for usage now the slurries range from 2 percent to 22 percent and
```

```matlab
    % increases by 0.5 percent

global wtwtpercent
global Slurrypercent
wtwtpercent=2:.5:22;
Slurrypercent = wtwtpercent/100';

    % Now would like to establish a Density of slurry for range of slurry
ratios
    % the calculations bellow calculated the density of the slurry again
taking
    % in the ingredeint density and density of water
    % this calculation serves to calculate the

global Density_Slurry_all
global CoffeeDensity
    global DensL
    DensL=1000;
Density_Slurry_all=(DensL./(1-(((CoffeeDensity-
DensL)/CoffeeDensity).*Slurrypercent)));


    % callback that gets the Voluemtric Slurry Flow rate as desired by the
user
    % and sets it as a variable

global inputSlurryRate
inputSlurryRate=str2num(get(handles.SlurryFlow, 'String'));

    % call back that gets the slurry ratio as desired by the user and set it
as
    % a variable

global inputwtwtratioper
 inputwtwtratioper = str2num(get(handles.wtwtin, 'string'));
    inputwtwtratio=inputwtwtratioper/100;
    global CoffeeDensity
    global DensL
    DensL=1000;

    % Below the code proceeds to calculate the Density of the slurry based on
    %Density of selected ingredeint (CoffeeDensity) and density of water
(DensL)
    %Also incorporates the desired slurry ratio (inputwtwtratio) to
determined
    %the density of the slurry

Density_Slurry_req=(DensL/(1-(((CoffeeDensity-
DensL)/CoffeeDensity)*inputwtwtratio)));

    % required Solid input in kg/hr is calculate below using the values of
the user's
    % inputted slurry flow rate, the inputted slurry ratio and the density of
    % the slurry
```

```matlab
requiredSolidIn=
((inputSlurryRate/1000)*Density_Slurry_req)*(inputwtwtratio);

    % Once the requiredSolidIn is calculated the require water input in L/hr
    % can be calculated using the solid in and the inputted slurry ratio

global ReqWaterFlow

ReqWaterFlow=(requiredSolidIn/inputwtwtratio)-requiredSolidIn;


    % In order to create the theoretical line of all possible Slurry flow
rates
    % for each slurry ratio for a singular water input the calculated below
are
    % utilized
    % the range Slurry percents established above as well as all the possible
    % densities of the slurry calculated above are used to establish all the
    % possible solid inputs for the one required water input as calculated
above
    % and then combining the one water input with the range of possible solid
    % inputs we get the range of possible total masses in kg/hr (defined as
    % variable AllTotalMass

global Slurrypercent
global Density_Slurry_all
AllSolidIn = (Slurrypercent*ReqWaterFlow)./(1-Slurrypercent);
AllTotalMass=ReqWaterFlow+AllSolidIn;

    % Once the range of possible total masses is calculated it is now
possible
    % to calculated all the possible theoretical Volmetric Flow rates of the
    % Slurry across all the possible slurry ratios
    %This is calculated bellow incorporating the ranges of slurry densities
    %calulated above
    %the units are in L/Hr

global VolFlowRateAll
VolFlowRateAll=(AllTotalMass./Density_Slurry_all)*1000;

    % These call functions serve to set the calculated values of required
Solid
    % in, require water in, and density of the slurry back into the GUI
    % interface so values can be easily read and understood

set(handles.requiredsolid, 'string', num2str(requiredSolidIn));
set(handles.requiredflowrate, 'string', num2str(ReqWaterFlow));
set(handles.SlurryDensity, 'string' , num2str(Density_Slurry_req));
```

```matlab
% --- Executes during object creation, after setting all properties.
function ingredientselection_CreateFcn(hObject, eventdata, handles)
% hObject    handle to ingredientselection (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: listbox controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end




% --- If Enable == 'on', executes on mouse press in 5 pixel border.
% --- Otherwise, executes on mouse press in 5 pixel border or over
waterflowlist.
function waterflowlist_ButtonDownFcn(hObject, eventdata, handles)
% hObject    handle to waterflowlist (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)




function SlurryFlow_Callback(hObject, eventdata, handles)
% hObject    handle to SlurryFlow (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of SlurryFlow as text
%        str2double(get(hObject,'String')) returns contents of SlurryFlow as
a double




% --- Executes during object creation, after setting all properties.
function SlurryFlow_CreateFcn(hObject, ~, handles)
% hObject    handle to SlurryFlow (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```matlab
% --- Executes on button press in exitbutton.
function exitbutton_Callback(hObject, eventdata, handles)
% hObject    handle to exitbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close all




% --- Executes on button press in plotbutton9.
function plotbutton9_Callback(hObject, eventdata, handles)
% hObject    handle to plotbutton9 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

    %The plot button serves to take the values calculated above and plot them
    %to a graph
    %the graph can be utilized to see desired volumetric flow rate of the
    %slurry and its desired corresponding slurry ratio as a line of al the
    %theoretical slurry flow rates for the range of slurry ratios

global wtwtpercent
global inputwtwtratioper
global inputSlurryRate

global ReqWaterFlow


global VolFlowRateAll
VolFlowRateAll=VolFlowRateAll';
wtwtpercent=wtwtpercent';

figure(1)
set(gcf, 'Units', 'Normalized', 'OuterPosition', [0, 0.04, 1, 0.96]);
plot(wtwtpercent,VolFlowRateAll,'r--
',inputwtwtratioper,inputSlurryRate,'g*');
xlabel('Slurry Wt/Wt Percentage');
ylabel('Volumetric Flow L/hr');
title('Volumetric Flow vs Slurry Wt/Wt Percentages for Specific Water In');
legend('Theoretical Line Corresponding To Slurry Ratio and Volumetric Flow
Rates','Theoretical Flow Rate')

%the two text functions below serve to clearly list the volumetric flow
%rate of the slurry at its point on the graph, as well as the required
%input of the water flow so that it shows that water flkow rate stays the
%same and only solid flow rate changes as the slurry ratio increases or
%decreases
```

```matlab
text(inputwtwtratioper,inputSlurryRate,['\leftarrow Volumetric flowrate=
',num2str(inputSlurryRate)])
text(3,inputSlurryRate+300, ['Input Water flowrate= ',num2str(ReqWaterFlow),
' L/hr'])




% --- Executes on button press in Clearallbutton.
function Clearallbutton_Callback(hObject, eventdata, handles)
% hObject    handle to Clearallbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

    % theses call backs serve to change all the values to zero on the GUI
code
    % and interface
    % if the user so desires

set(handles.DryDensity, 'string','default');
set(handles.wtwtin, 'string','default');
set(handles.SlurryDensity, 'string','default');
set(handles.requiredsolid, 'string','default');
set(handles.requiredflowrate, 'string','default');
set(handles.SlurryFlow, 'string','default');

% --- Executes on selection change in ingredientselect.
function ingredientselect_Callback(hObject, eventdata, handles)
% hObject    handle to ingredientselect (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = cellstr(get(hObject,'String')) returns ingredientselect
contents as cell array
%        contents{get(hObject,'Value')} returns selected item from
ingredientselect




% --- Executes on selection change in listbox4.
function listbox4_Callback(hObject, eventdata, handles)
% hObject    handle to listbox4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = cellstr(get(hObject,'String')) returns listbox4 contents
as cell array
%        contents{get(hObject,'Value')} returns selected item from listbox4

    %This list box serves to list the possible ingredients a user can select
    %from
    %once the user select and ingredient the calculations for slurry density
    %will henceforth use the values establish below for each ingredients
    %particle density as the CoffeeDensity variable in the calculations
```

```matlab
 contents = cellstr(get(hObject, 'String'));
popChoice= contents(get(hObject, 'Value'));

    if (strcmp(popChoice, 'Medium Coffee'))
    popVal= 2331.169;
    elseif (strcmp(popChoice, 'Fannings Black Tea'))
    popVal= 912;

    elseif (strcmp(popChoice, 'Fannings Green Tea'))
    popVal= 1260.244;


end
assignin('base','popVal',popVal)

    % this call back sets the ingredients dry particle density into a box so
    % that the user can clearly see what the particle density is of the
    % ingredient that each selected

set(handles.DryDensity, 'string', num2str(popVal))
global CoffeeDensity
CoffeeDensity=popVal;


% --- Executes during object creation, after setting all properties.
function listbox4_CreateFcn(hObject, eventdata, handles)
% hObject    handle to listbox4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: listbox controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');

end
```