Mission Statement

"Partnering with others to help them reach their goal"

Who we are

Triad Enterprises is a small local firm supplying various services including, but not limited to, engineering consultation and small scale manufacturing.
Background

• Located in Oklahoma City, OK
• Founded by Dan Jolliff
• Has served the roasting industry for over 33 years
• Specializes in new roaster fabrication and rebuilding older roasters
• Provides wide range of roasters, from 3 oz to 300 kg
A few examples of US Roaster Corp coffee roasters
Problem Statement
Triad Enterprises is to design, build and test a cocoa bean winnower that meets the following specifications:

- Affordable for bean-to-bar chocolate producers
- Able to fabricate at US Roaster Corp facilities
- Incorporates competitive features:
  - Unsupervised operation
  - Easily adjustable
  - Quiet and fast
What is a winnower?

• A winnower is an apparatus that separates out the undesired portion from the desired portion of a material.
Engineering Specifications Goals

• Winnow at a rate of 100 lbs/hr

• Winnow at an efficiency >95%

• Not allow greater than 2% chaff in the final nib output

• Retail price between $4,000-$6,000

• Minimize moving parts

• Be easily cleaned
General Overview of Project

- Beans
  - Researched the physical properties of cocoa beans
- Cracking
  - Designed cracking methods based on physical properties of cocoa beans
- Sorting
  - Designed sorting methods based on output of cracker
- Separating
  - Designed separation methods for nibs and chaff
Winnowers in Industry

**Bear Winnower**

*Type BWI*

- 1100-6600 lbs/hr
- Nib content in chaff = 0.25%
- Chaff content in nibs = 1.75%

**Vortex Winnower**

*by Brooklyn Cocoa*

- 88 lbs/hr
- Nib content in chaff = 0.25%
- Chaff content in nibs = 0.20%
- $34,000
Freshman Group 1

- Tasked with determining viable air velocity range to separate chaff from nib
- Utilized air velocity separator in BAE lab to determine range

Determined air velocity of 5.15 m/s was best for separating nib from chaff. Viable range was from 5-6 m/s for this apparatus.
Freshman Group 2

- Tasked with designing hopper that meets specifications:
  - Must hold 100 lbs of roasted cocoa beans
  - Must determine appropriate foodgrade material
  - Must not exceed loading height of 5 ft
- Make a model of hopper utilizing CAD software
- Contact material suppliers and estimate a price for the hopper
Visit to Izard Chocolate

• Bean-to-bar chocolate company in Little Rock, AR
• Founded in 2014
• Introduced us to chocolate process and issues related to current winnower
# Fall - Testing

<table>
<thead>
<tr>
<th>Physical Properties of Cocoa Beans</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>122</td>
</tr>
<tr>
<td>Average Weight (g)</td>
<td>1.19</td>
</tr>
<tr>
<td>Max Weight (g)</td>
<td>2</td>
</tr>
<tr>
<td>Min. Weight (g)</td>
<td>0.5</td>
</tr>
<tr>
<td>Average Sphericity</td>
<td>0.61</td>
</tr>
<tr>
<td>Max Diameter (mm)</td>
<td>28.97</td>
</tr>
<tr>
<td>Min Diameter (mm)</td>
<td>5.01</td>
</tr>
</tbody>
</table>
Fall - High Risk Suggested Design

- The main cracking method is impact with the paddles on a wheel traveling with high angular velocity
Fall - Low Risk Suggested Design

- Conceptually common design utilizing a two stage roller-cracker design which standardizes the crushed bean size
Spring Testing

- Varied gap distance between the rollers to study crushing effect
- Able to increase/decrease speed with VFD
Spring Testing

- Used Ro-Tap machine to sieve the nibs and chaff into quantifiable categories
- Utilized data to assist in designing the separation aspect of the winnower
Spring Testing

- Varying speed with single roller

### Single Roller Speed Comparison 7 mm

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Single Roller (7 slow)</th>
<th>Single Roller (7 fast)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>20.3</td>
<td>21.8</td>
</tr>
<tr>
<td>5</td>
<td>20.0</td>
<td>17.2</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>21.3</td>
</tr>
<tr>
<td>7</td>
<td>12.9</td>
<td>12.5</td>
</tr>
<tr>
<td>10</td>
<td>11.4</td>
<td>11.5</td>
</tr>
<tr>
<td>Dust</td>
<td>15.8</td>
<td>15.8</td>
</tr>
</tbody>
</table>

### Single Roller Speed Comparison 9 mm

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Single Roller (9 slow)</th>
<th>Single Roller (9 fast)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>67.9</td>
<td>67.8</td>
</tr>
<tr>
<td>5</td>
<td>14.4</td>
<td>13.6</td>
</tr>
<tr>
<td>6</td>
<td>13.6</td>
<td>12.5</td>
</tr>
<tr>
<td>7</td>
<td>7.9</td>
<td>8.5</td>
</tr>
<tr>
<td>10</td>
<td>3.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Dust</td>
<td>4.6</td>
<td>4.4</td>
</tr>
</tbody>
</table>
Spring Testing

- Single roller comparison

![Single Rollers Diameter Comparison Chart]

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>7 mm</th>
<th>8 mm</th>
<th>9 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>20.3</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20.0</td>
<td>16.7</td>
<td>14.4</td>
</tr>
<tr>
<td>6</td>
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</tr>
<tr>
<td>10</td>
<td>14.8</td>
<td>17.0</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Percentage of Total (%)
Spring Testing

- Double roller results and comparison
Model – Complete Model

- Robust roller design
- High process rate
- Simple and easy to fabricate frame design
- Easy operation
- Manageable floor footprint
- Easy access to rollers for cleaning
Model – Rollers and Housing

- 0.5” Steel plate housing
- 12”x7” diameter rollers with grooved surface
- Food grade flange mounted bearings
- Schedule 40 chain drive sprockets
- Infinite linkage roller gap adjustment
Model – Motor and VFD

Where
θ = 90°
F= 75 lbs
R= 5”

\[ T = F \cdot R \cdot \sin(\theta) \]

\[ HP = \frac{RPM \cdot T}{5252} \]

This was divided by the test roller length, to get a torque requirement per in. of roller length.

This equation was used to verify the motor that was specified would be suitable.

- 0.37 to 11 kW/0.5 to 15 hp 200V
- 0.37 to 22 kW/0.5 to 30 hp 400V
- IP20 enclosure
- Embedded Modbus EIA-485 interface
Model – Trommel and Frame

- Simple, low maintenance design
- Would utilize three screen sizes
  - 0.187”, 0.111”, and 0.073”
- Sort cracked beans to allow more specific air velocities for better separation

* Specified but not fabricated
Model – Seperation

Piping
• 2” Diameter PVC input
• 3” Diameter PVC plenum chamber/outlet
• Two discriminator valves for separation velocity adjustment

Vacuum
• 170 CFM of airflow
• 6.5 Peak HP

Cyclone
• 14” Cyclone
• 10 Gallon waste storage
Prototype - Assembly
Prototype – Rollers and Housing
Finalized Prototype
Testing-Rollers

Bean Cracking

- At VFD setting $f=30$ hz nearly all beans were cracked
- Consistent cracking at this frequency
- Lower than 30 hz caused jamming issues
- If overloaded the rollers would jam
- Spring tension on the adjustment feature was insufficient to keep the rollers in place
Testing - Winnower

- Max measured inlet air velocity was capable of picking up whole beans
- Large volumes of cocoa beans at once reduced winnowing efficiency
- Trommel would help address this issue
- Manual slow feeding was required to achieve proper sort
Testing - Video
Testing - results

- Winnowing rate with manual feed was 1.6 lb/min
- Winnowing efficiency was around 98%
- 1%-1.7% chaff in the winnowed cocoa nib
Prototype Financial Breakdown—What We Built

- Overall budget of $3,000
- Material cost of the project is $1,741.82
- Cost of the control system is $289.94
- Labor was not included
- Direct donation of material to the project from McElroy Mfg. valued at $348
- **Total Cost of Prototype $2,031.78**
Final Design Financial Breakdown

- Target production cost is $3,000-$4,000
- Materials cost $3,485
- Control cost $579
- Labor $4,800
- Estimated production cost of the winnower is $8,285.
### Operator Safety

- Hopper Clogging

### Roller Movement During Cracking

- Cracker Rollers Getting Stuck
  - Cracker Roller Motor Failure
    - Cracker Roller Movement

### Food Contamination

- Cocoa Bean Cracking
  - Sorting Cracked Cocoa Beans
    - Winnowing
      - Winnower Air Velocity Tuning
      - Vacuum Failure
    - Safety
      - Winnower Falling Over
      - Operator Injuries
      - Sanitation
        - Food Contamination
Recommendations

Operator Safety

• Add chain guards
• Add emergency shutoff controls when moving parts are accessed
• On subsequent iterations, make winnower shorter to ease loading of beans and make maintenance easier
• Reduce weight of machine and add warning labels

Roller Movement

• Increase spring tension and add spring guide to decrease or eliminate roller movement

Food Contamination

• Upgrade all materials to food grade materials, such as stainless steel or UHMW
• Make all components easier to disassemble to assist in cleaning
<table>
<thead>
<tr>
<th>Objective</th>
<th>Obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Winnowing rate of 100 lb/hr</td>
<td>• Winnowing rate of at least 100 lb/hr</td>
</tr>
<tr>
<td>• Efficiency of 95%</td>
<td>• Efficiency of 95%-98%</td>
</tr>
<tr>
<td>• No more than 2% chaff in the product stream</td>
<td>• 1%-1.7% chaff in the product stream</td>
</tr>
<tr>
<td>• Production cost of $3,000-$4,000</td>
<td>• Production cost estimate of $8,285</td>
</tr>
<tr>
<td>• Easy to clean</td>
<td>• Ease of cleaning needs improvement</td>
</tr>
<tr>
<td>• Minimal moving parts</td>
<td>• Only moving parts are in the cracker</td>
</tr>
</tbody>
</table>
Lessons Learned

- Organization
- Communication
- Prioritization
Questions?

Acknowledgments

Dan Jolliff - US Roaster Corp
Mr. Wayne Kiner
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Dr. Niels Maness