Mission Statement

“Partnering with others to help them reach their goal”

Who we are

Triad Enterprises is 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 will be designing, building and testing a cocoa bean winnower that meets the following specifications:

- Affordable for bean-to-bar chocolate producers
- Able to fabricate winnower at US Roaster Corp facilities
- Incorporates competitive features
  - Unsupervised operation
  - Easily adjustable
  - PLC interface*
General Overview of Project

- Researched the physical properties of cocoa beans
- Design of hoppers based on physical properties of cocoa beans
- Design of cracking methods based on physical properties of cocoa beans
- Design of separation methods for nibs and hulls
What is a winnower?

- A winnower is any apparatus that separates out the undesired portion from the desired portion of a material.
Why is winnowing important?

• A cocoa bean winnower is essential to:
  • Separate hull from inner portion, called the nib, before processing
  • Hull is bitter and too much will ruin final product
    • Industry standard is <2% hull left in nibs
  • Hull contains heavy metals, pesticides, and mycotoxins

(1) http://www.sciencedirect.com/science/article/pii/S0168160508002225
(2) https://www.sciencenews.org/blog/food-thought/leaden-chocolates
Engineering Specifications

- Winnow at a rate of 100 lbs/hr
- Winnow at an efficiency >95%
- Not allow greater than 2% shell in the final nib output
- Retail price near $3000
- Be powered by either 120V or 240V AC
- Not exceed 90 dB of sound
- *minimize moving parts (simplify), cleanibility, aesthetics, stainless steel frame, division of work
Overview of Cocoa Bean Process up to Winnowing

There are two key steps to winnowing:

- The cracking of the bean
- The separation of the hull and nib

The variability of cocoa beans depends on previous processes.
Physical Properties of Cocoa Beans

Three Main Varieties of Cacao:

**Criollo**
- Considered to be high quality & only used in luxury chocolates
- Consists of around 3% of the global consumption of cocoa

**Forastero**
- Used in most bulk chocolate operations
- Consists of around 85% of the global consumption of cocoa

**Trinitario**
- Is a hybrid of Criollo & Forastero beans
- Consists of around 12% of the global consumption of cocoa
Physical Properties of Cocoa Beans

The Fermentation & Drying Process

Fermentation
• Critical for the development of the flavors of cocoa
• The fermentation process depends on the bean type

Drying
• Necessary to prevent microbial spoilage
• Bulk of the moisture of the bean is removed
Physical Properties of Cocoa Beans

Moisture Content Before Roasting
• 18-22%
• Varies depending on fermentation and drying processes

Moisture Content After Roasting
• 6-8%
Physical Properties of Cocoa Beans

<table>
<thead>
<tr>
<th>Physical Properties of Cocoa Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
</tr>
<tr>
<td>Average Weight (g)</td>
</tr>
<tr>
<td>Max Weight (g)</td>
</tr>
<tr>
<td>Min. Weight (g)</td>
</tr>
<tr>
<td>Average Sphericity</td>
</tr>
<tr>
<td>Max Diameter (mm)</td>
</tr>
<tr>
<td>Min Diameter (mm)</td>
</tr>
</tbody>
</table>
Physical Properties of Cocoa Beans

Fat content could affect the process:

- Crushing could press fats out of the nib
- Fat residues may accumulate on the machinery
- Increases biological hazard
Physical Properties of Cocoa Beans

Comparison of roasted coffee and cocoa

**Coffee**
- Fat Content: 10%
- Hull Type*: Similar to parchment

**Cocoa**
- Fat Content: 54%
- Hull Type: Thin & brittle
Freshman Group 1

- Tasked with determining viable air velocity range to separate hull from nib
- Utilized air velocity separator in BAE lab to determine range
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 determine price of the hopper
Freshman Group 2

- Group determined that rectangular hopper would have the least surface area

- The two materials that they looked at for the design are stainless steel & aluminum

- Stainless steel was $118.40 for a sheet, and aluminum is $40.96 per sheet.
Technical Analysis - Winnowers in the Industry

**Vortex Winnower by Brooklyn Cocoa**
- 88 lbs/hr
- Nib loss = 0.25%
- Shell content in nibs = 0.20%
- $34,000

**Aether Winnower**
- 70-80 lbs/hr
- Nib loss = 0.5%
- Shell content in nibs = 0.5%
- $1,800*

*Price does not include Champion Juicer or Shop Vac. Also, blades and housing must be replaced regularly at a cost of ~$1800/yr
Technical Analysis—Winnowers in the Industry

Pros: Vortex Winnower
- Aesthetically pleasing
- Sorts hulls and nibs well

Cons: Vortex Winnower
- High upfront cost
- Requires external vacuum
- Requires cocoa beans to be pre-cracked
Technical Analysis-Winnowers in the Industry

Pros: Aether Winnower

- Lower upfront cost
- Compact

Cons: Aether Winnower

- Continual costs from blade and housing ($1800/year)
- Requires external vacuum
Technical Analysis—Winnowers in the Industry

**Bear Winnower**
Type BWI
- 1100-6600 lbs/hr
- Nib content in shells = 0.25%
- Shell content in nibs = 1.75%

**Delani CAC-101-WIN**
- 441 lbs/hr
- Weight = 231.5 lbs
- Shell content in nibs = 1%
Semi-Theoretical Analyses on Mechanical Performance of Flexible-Belt Shearing Extrusion Walnut Shell Crushing

- Paper analyzes specific walnut cracking process
- Uses belts and rollers to shear the walnuts enough to crack the shell but protect the walnut meat
- Process could be modified to better suit cocoa bean winnowing
Technical Analysis-Applicable Patents

Method and apparatus for separating lighter and heavier portions of threshed tobacco
- Separates by creating two adjacent vortices that circulate in opposing directions
- Turbulence causes separation by combining to form a rising column of high-velocity air
- Lighter portions rise while heavier portions drop down
- Could use a similar approach to separate lighter hulls from heavier nibs
Technical Analysis - Applicable Patents

**Method for producing fat and/or solids from cocoa beans**

- Goes deeper into the cocoa manufacturing process than project requires
- Discusses a method of processing cocoa beans for producing solids from fat-containing products
- Discusses cocoa bean process as a whole, helpful to keep whole process in mind
- Includes parts of winnowing process
Technical Analysis - Technical Literature

Chocolate Alchemy Winnowing Forums

- Online database of everything related to the chocolate making process
- 39 different forums related to cracking and winnowing process
- Knowledge and experience will be of assistance throughout the project
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
Completed Testing

• Impact testing
  • Made an apparatus to test effectiveness of impact on cocoa beans under various conditions
  • Used dry cocoa beans, wet cocoa beans, dry cocoa beans frozen in liquid nitrogen, and wet cocoa beans frozen in liquid nitrogen
  • Determined that freezing made little effect on final particle size after impacting
  • Determined that cocoa beans become soaked rapidly, no matter how long they are left in water
Conceptual Designs-Hopper Feed

- We anticipate clogging at the base of the hopper, as observed during our visit to Izzard Chocolate, so a simple roller to agitate the clogged area was conceived.
Concern of the bean’s tendency to slide on the simple roller led us to rethink the base of the hopper.

- A paddled wheel was conceived that would not only prevent clogging of the beans, but also allow adjustable and predictable delivery rate of the beans from the hopper.
Conceptual Designs-Hopper Feed

- A more common and possibly cheaper method is an auger, typically vertical in orientation.
- A horizontal orientation would not only be easier to drive, but help keep overall height to a minimum.
Conceptual Design - Cracking

- Much like US Roaster Corp’s roller grinders, this would be a simple and achievable design
- To mitigate the beans from not passing through the round rollers, lobed rollers were thought of as an alternative
Conceptual Design - Cracking

- Upon observation, quick impact was seen as an effective way of cracking the beans, which would also be independent of individual bean size.

- To ensure consistent contact velocity, it was thought to feed the beans down in parallel with the rotating axis.
High Risk Suggested Design

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

Pros

• Indiscriminant of bean size
• Velocity adjustable to vary impact force
• Simple design and construction
High Risk Suggested Design

Cons

- Un-proven design
- Loss of contact with bean
- Requires metered feed
Low Risk Suggested Design

- Conceptually common design utilizing a two stage roller-cracker design which standardizes the crushed bean size
Low Risk Suggested Design

Pros

• Robust and adjustable
• Guarantees beans that have passed will be cracked/crushed
• Self-metering flow of beans
Low Risk Suggested Design

Cons

• Tolerance and part intensive
• Potentially less differentiable qualities between nib and hull
• Finer particles will require a more thorough separation process
## Materials for Suggested Design

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopper</td>
<td>Stainless Steel</td>
</tr>
<tr>
<td>Impact Wheel</td>
<td>Stainless Steel</td>
</tr>
<tr>
<td>Rollers</td>
<td>Hardened Steel</td>
</tr>
<tr>
<td></td>
<td>Delrin</td>
</tr>
<tr>
<td></td>
<td>Knurled Stainless</td>
</tr>
<tr>
<td>Support Frame</td>
<td>Mild Steel</td>
</tr>
<tr>
<td>Sieves</td>
<td>Stainless Steel</td>
</tr>
<tr>
<td>Drive belt(s)</td>
<td>Urethane</td>
</tr>
<tr>
<td>Separation Chutes</td>
<td>Stainless Steel</td>
</tr>
</tbody>
</table>
Spring Semester Testing

- Test velocity range and efficiency of impact cracking
- Effectiveness and speed of hopper auger
- Air sort implementation and design
- Sieving sizes and effectiveness/need
Spring Semester Plan of Action

- Complete Testing for Conceptual Designs
- Finalize Cracking Design
- Finalize Separation Design
- Fabricate a Prototype
- Troubleshoot Prototype
Spring Semester

- January 27th – Complete testing on conceptual cocoa bean cracking methods
- February 3rd – Complete testing on conceptual nib sorting methods
- February 10th – Complete control systems design
- February 17th – Complete power/utility requirements for winnower design
Spring Semester

• February 22\textsuperscript{nd} – Complete expected prototype cost analysis

• *March 1\textsuperscript{st} – Finalize winnower design and receive client approval

• *March 8\textsuperscript{th} – Draft all necessary parts diagrams

• *March 10\textsuperscript{th} – Order all necessary materials and components for prototype

*a month too late
Spring Semester

• March 13\textsuperscript{th}-17\textsuperscript{th} – Spring Break

• \textbf{March 20\textsuperscript{th}} – Begin fabrication/assembly of prototype

• March 31\textsuperscript{st} – Complete prototype assembly

• April 12\textsuperscript{th} – Complete prototype troubleshooting
Spring Semester

- April 19th – Complete spring final report draft
- May 3rd – Complete final presentation
- May 1st – Complete final spring design report
- May 5th – Final Senior design presentation
Questions?