PURDUE UNIVERSITY

CAPSTONE/SENIOR DESIGN EXPERIENCE 2019

Dark Chocolate Production

Agricultural & Biological ENGINEERING

Rebecca Carr (B.S. BE), Meredith Roush (B.S. BE), and Kylie Snyder (B.S. BE)

OBJECTIVE AND BACKGROUND

Objective: To design and develop a plan to mass produce artisan-style dark chocolate bars, appealing to customers in a local market, with optimal quality in a zero-discharge plant. To emphasize sustainability and propose a profitable enterprise.

Background:

- Chocolate is a popular snack, dessert, and holiday item with a global consumer base
- Dark chocolate has nutritional benefits that attract consumers

IMPACT AND SUSTAINABILITY

- Fairtrade focus to ensure farmer wellbeing and sustainability of growing practices
- Cocoa farming provides jobs for 5-6 million farmers worldwide
- Antioxidants within chocolate reduce risk of cardiovascular disease and inflammation

MARKET ANALYSIS

- Globally, the chocolate market is valued at $103 billion with a projected growth rate of 7% in the next 6 years
- ~ 67% of adults and 90% of youths purchase chocolate regularly
- Target market is the population of Indianapolis, especially those looking to shop locally

UNIT FUNCTION

FUNCTIONAL ANALYSIS

Unit Operation	Function	Relation To Goal
Roasting	Decrease moisture and develop flavor	Dry bean and promote flavor profile
Kibbling and Winnowing	Remove shells and break beans	Eliminate waste and create nibs
Refining	Decrease particle size	Improve texture
Melting	Liquify butter	Prep ingredients
Conching	Decrease size and remove volatiles	Improve flavor and viscosity
Tempering	Crystallize cocoa butter	Gloss, snap, anti-bloom
Molding, Cool, and Package	Mold, cool, and wrap bars	Form final product

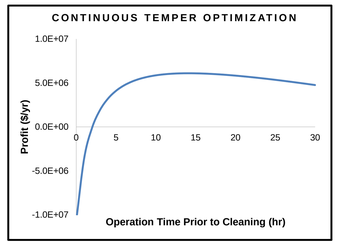
OPTIMIZATION

Criteria:
Minimize overall cost by altering equipment specification or production time.

Constraints:

- Cost-seeking to minimize production expenses
- Quality-particle size, flavor, texture
- Feasibility-availability of equipment and materials
- Market-appeal to consumers

UNIT OPERATION	OPTIMIZATION VARIABLE
Roast	Insulation thickness: 1.5 - 2 cm
Conche	Agitator diameter: 0.55 - 0.7 m
Temper	Tempering capacity: 62 kg Operation Time: 14 hours



ECONOMIC ANALYSIS

CASH FLOW ANALYSIS

Year	Production %Max	Cash Flow $/yr	Net Present Worth $/yr
1	30%	$180,607	$149,139
2	50%	$232,945	$158,842
3	80%	$311,451	$175,371
4	100%	$363,789	$169,150
5	100%	$363,789	$139,678
6	100%	$363,789	$115,341
7	100%	$363,789	$95,245
8	100%	$363,789	$78,650
9	100%	$363,789	$64,946
10	100%	$363,789	$53,630
Total Net Present Worth			**$1,199,992**

Estimated Internal ROI = 21.1%

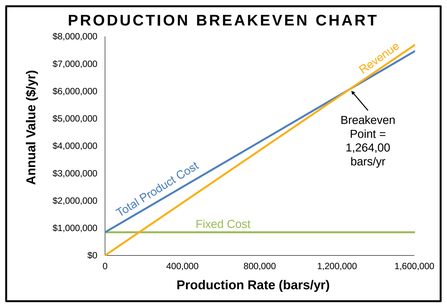
INVESTMENT ESTIMATION

Cost Description		Cost
Direct Costs	*Equipment*	$238,554
	Installation, systems, facilities	$481,879
	Total	**$720,433**
Indirect Costs	*Engineering and supervision*	$76,337
	Construction, contractors	$126,434
	Legal expenses, contingency	$97,807
	Total	**$300,578**
Fixed Capital Investment (FCI)		**$1,021,011**
Working Capital (WC)		**$178,916**
Total Capital Investment (TCI)		**$1,199,927**

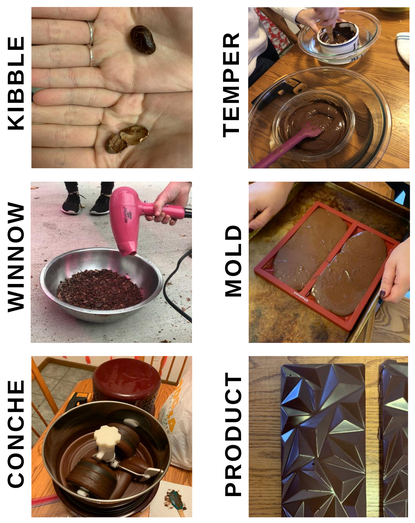
- Analysis based on annual production rate of **1,570,750 bars per year**
- Proposed selling price = **$4.80/bar**

PRODUCT COST ESTIMATION

Cost Description		Cost $/Yr
Manufacturing Cost	*Raw Materials*	$674,067.22
	Operating Labor	$1,074,864
	Supervisory and Clerical Labor	$161,230
	Utilities	$1,074,864
	Maintenance and Repairs	$51,051
	Operating Supplies	$5,105
	*Depreciation (10yr Straight Line)***	$102,101
	*Local Taxes****	$20,420
	*Insurance****	$7,147
	*Plant Overhead Cost****	$716,576
General Expenses	*Administrative Costs*	$214,973
	Distribution and Marketing	$2,866,304
	Research and Development	$358,288
Total Product Cost (TPC)		**$7,165,760/yr $4.56/bar**



EXPERIMENTATION



Ingredients:

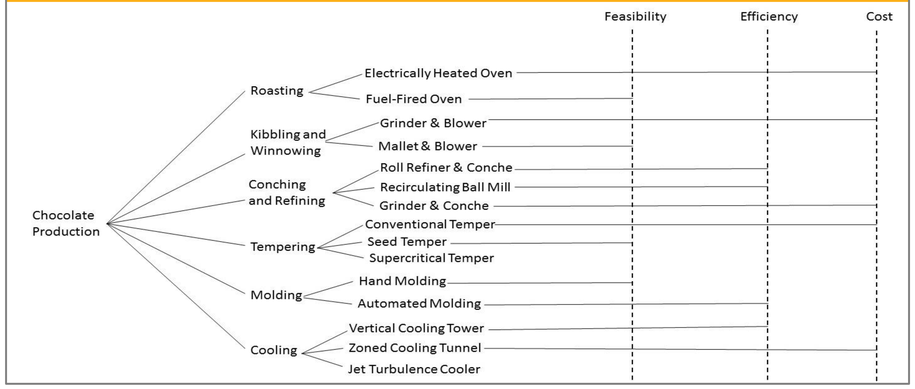
1. Raw cacao beans
2. Cocoa butter
3. Granulated sugar
4. Soy lecithin powder

Experimental Design Variables:

- Recipe (% Cacao)
- Roasting Time
- Roasting Temperature
- Kibbling Time (Particle Size)
- Conching Time
- Tempering Temperatures
- Cooling Temperatures
- Cooling Time

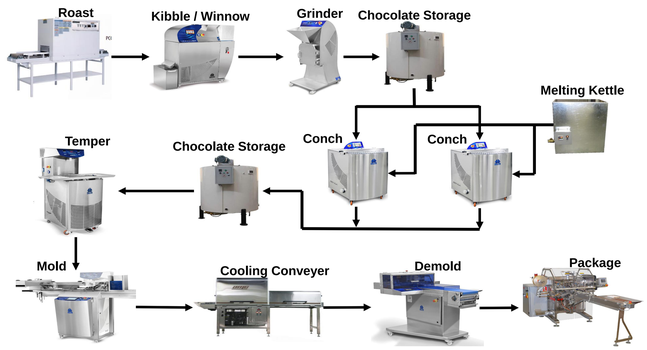
Quality Testing:
Temperature reading, moisture content, power requirement, sensory analysis

ALTERNATIVES



PROCESS DESIGN

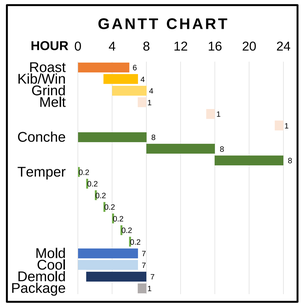
INDUSTRIAL FLOW DIAGRAM



PID CONTROL
Oven Temperature
Conche Speed
Temperer Temperature

EMISSION	UNITS/ BATCH*
Water	6.85 kg
Air	13.6 m^3

**Predicted by SuperPro*



Processing schedule for semi-continuous production

OPERATION	INPUT INGREDIENT	MASS LOAD (kg/day)	TEMPERATURE (°C)	POWER (kWh)/day
Roast	Unroasted Cocoa Beans	189.07	120	72
Kibble & Winnow	Roasted Cocoa Beans	183.43	25	8
Grind	Cocoa Nibs	160.58	25	16
Melt	Cocoa Butter	39.82	65	4.65
	Soy Lecithin	1.81		
Conche	Sugar	161.1	65	84
	Ground Cocoa Nibs	160.58		
	Cocoa Butter & Lecithin	41.63		
Temper	Untempered Chocolate	362.1	30-35	4.9
Mold	Tempered Chocolate	362.1	30	5
Cool	Melted Chocolate	362.1	22	10.5
Demold	Chocolate	362.1	25	10.5
Packager	Chocolate Bars	362.1	25	5

FUTURE WORK

- **QUALITY CONTROL**
  - Increase Automation
  - Sensory Testing
  - PID Sensors
- **COST**
  - Decrease TPC
  - Fairtrade & Ingredient Sourcing
- **MARKETABILITY**
  - Customized orders
  - Flavors: White, Fruit, Nut

Technical Advisor and Instructor:
Dr. Martin Okos

Acknowledgements:
Special thanks to Yvonne Hardebeck and Carol Weaver

PURDUE AGRICULTURE
PURDUE UNIVERSITY

PURDUE ENGINEERING
Think impact.