PURDUE UNIVERSITY

CAPSTONE EXPERIENCE 2014

Agricultural & Biological ENGINEERING

Micro Malt House Process & Design

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Introduction

- A locally processed malt product can fill two market niches by:
  - Providing local product for brewers and consumers
  - Providing infrastructure to connect local farmers and brewers in a sustainable economic relationship
  - Decreasing environmental impact
- Increasing demand for craft brews:
  - Requires local material sourcing
  - Requires growth of craft brewing by ~18% per annum
- Increasing demand for local products and environmental sustainability by:
  - Decreasing CO2 emission & pollution
  - Decreasing landfill use
  - Increasing reinvestment into local community
  - Increasing community involvement and pride

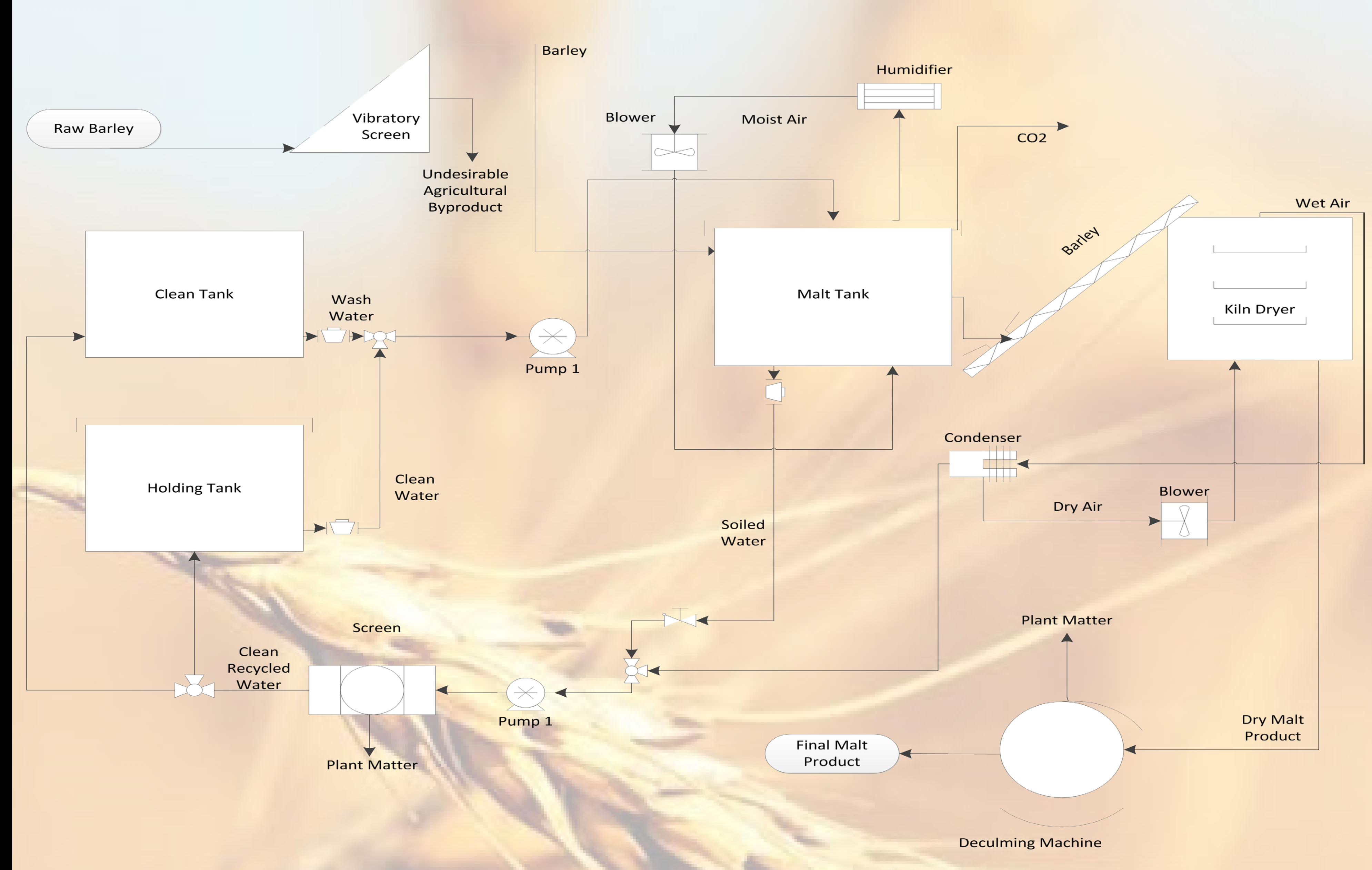
Objectives

- Create a process to produce high quality malt
- Perform experiments to identify key variables in production to obtain a consistent and saleable product
- Perform scale-up to meet malt demand for 1% of Indiana Malt Market (110,00 lbs. per year) at a competitive price
- Provide useful information to Mr. Jim Mosely to create full scale operation

Background

- Practice that dates back to ancient times
  - Process remains same
- Current market is dominated by macro-malters
  - 20 companies own 70% of Market
- Macro-malters hold a majority of patents
  - Equipment oriented
  - Macro-malting equipment/process is dissimilar to micro-malting
- Malt is derived from the highest quality barley
  - Barley quality varies based on environmental conditions
  - Comes in varieties of 2 row and 6 row
- Malt can be made from other materials such as:
  - Sorghum, millet, corn, wheat, and rice

Final Plant Design



	Percent Material Inflow at Each Stage	
	Barley	Water
Vibrational Clean	100 (12% MC)	0
Clean	43(12% MC)	57
Steeping/ Germination	62.5 (12% MC)	37.5
Kilning	100 (45% MC)	0
Deculming	100 (4% MC)	0

	Percent Material Outflow at Each Stage			
	Barley	Plant Matter	Water	Carbon Dioxide
Vibrational Clean	95 (12% MC)	5	0	0
Clean	43(12% MC)	0	57	0
Steeping/ Germination	94.5 (45% MC)	4	0	1.5
Kilning	59 (4% MC)	0	41	0
Deculming	95 (4% MC)	5	0	0

Scheduling

- 1 day steeping
- 4 day germination
- 6.26 days per batch
- 67.4 batches per year
- 52 available weeks per year
- 48 operating weeks per year

Economic Analysis

- Raw material cost:
  - \$0.065 per lbs. feed barley
  - \$0.095 per lbs. malt barley
- Break even price: \$0.20 per lbs.
  - \$0.80-\$0.90 for bulk purchase
- Price for ROI of 20%: \$0.83 per lbs.
- Scaling up to 5x production yield ROI of 29%

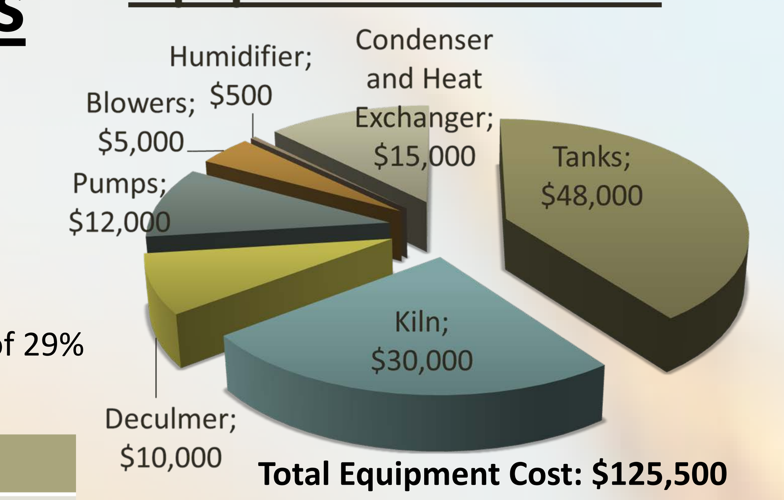
Annual Expenses

Costs (Annual)	Amount
Total Direct	\$11,130
Operating	\$5,686
Raw Materials	\$5,330
Total:	\$22,146

Equipment Energy Use

Equipment	Energy Use per Year (kJ)
Humidifier	1.6×10^7
Condenser and Heat Exchanger	4.4×10^5
Kiln	4.7×10^7
Blowers	2.0×10^8
Deculmer	2.6×10^5
Pumps	4.6×10^6
Total	2.7×10^8

Equipment Breakdown



Total Equipment Cost: \$125,500

Capital Investment

Direct Costs	Amount
Purchased Equipment delivered	\$125,500
Equipment Installation	\$56,475
Instrumentation and Controls (installed)	\$22,590
Piping (installed)	\$20,080
Electrical Systems (installed)	\$12,550
Building (including services)	\$31,375
Yard Improvements	\$18,825
Service Facilities (installed)	\$50,200
Total Direct Plant Cost	\$337,595
Working capital (15%)	\$87,850
Total Capital Investment	\$425,445

Optimization

- Water recycled from Clean and Steeping decreases waste. Water is also recovered from wet barley as the kiln dries them.
- Plant matter is recycled as a high protein animal feed.
- Equipment sizing and batch size have been selected to decrease operating costs and optimize revenue.
- Equipment sizing allows for five times scale up with minimal additional equipment costs.

Experimental Design

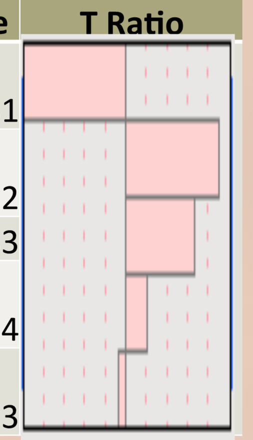
Trial	Steep Temperature	Germination Time	Germination Temperature	Kilning Temperature
1	0	1	0	1
2	0	0	1	1
3	0	0	0	0
4	0	0	1	0
5	0	0	0	1
6	0	1	1	0
7	1	1	0	1
8	1	1	1	1
9	1	1	0	0
10	1	0	1	0
11	1	0	0	1

Method

Clean: Used a series of sieves to remove dirt and chaff.
Steep: Performed 3 immersion cycles of 8/4 hours submerged and couching respectively. Changed moisture content (MC) from 8% to 45%. Temperature set at 20 or 25° C. Aeration performed every 4 hours.
Germinate: Sprayed with water and mixed every 4 hours to maintain 45% MC and keep oxygen levels and water content high. Conditions held over a 2-4 day period while temperature was set at 20 or 25° C.
Kiln: A fluidized bed dryer was used to decrease MC to 4% with 40 or 60° C, 1.5 m/s air.
Testing: Hulls of seeds milled and submerged in 65° C water to stimulate release of sugars. Measured sugar content in Brix over 30 minutes. Final results adjusted for weight of malt and water used.

Results

Effect	P Value	T Ratio
Steeping Temperature	0.0881	
Germination Time	0.1132	
Trial	0.2183	
Kilning Temperature	0.6754	
Germination Temperature	0.8813	



Trial	Sugar Content
1	11.6
2	5.8
3	4.0
4	8.1
5	6.9
6	11.8
7	6.1
8	9.8
9	8.5
10	4.6
11	5.3
Pills	12.0
Pale	9.7

Analysis

Steeping temperature and germination time had the most significant effect on the final sugar content. The germination and kilning temperature had less effect than trial number. However, none are significant within a 95% confidence interval.

- Problems
  - Several trials experienced contamination from the lack of an HTST cleaning cycle
  - Actual germination times deviated from planned schedule
  - Rootlet to seed length exceeded desired ratio

Design Alternatives

- **Clean:**
  - Steam: High cost to purchase, storing tank would be more expensive due to pressure requirements, heating requirements offset by pumping requirements to maintain pressure
  - Cleaning agents: Lack recyclability, more costly than water
- **Germination:**
  - Floor germination: Difficult to maintain moisture content and environmental control
- **Kiln:**
  - Floor kiln: Increase difficulty in recapturing water
  - Single vessel: Increase in equipment cost for a unified design, careful scheduling can mimic benefits
- **Tank Design:**
  - Single tank for cleaning and holding water: Increase in heating and cooling costs

Acknowledgements

Dr. Martin Okos (ABE)
Mr. Jim Mosely
People's Brewery

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