PURDUE UNIVERSITY

CAPSTONE/SENIOR DESIGN EXPERIENCE 2017

Designing a Whiskey Distillation Facility

Agricultural & Biological ENGINEERING

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Introduction

What is whiskey?

- A grain-based, distilled alcohol product that obtains a signature aroma, body, and flavor profile from prolonged interaction with an oak barrel. Whiskey is traditionally between 40% to 50% ABV.

How is whiskey made?

- **Mashing:** The process of combining the grain bill with water and heating the mixture in order to allow enzymes in the malt to break down starches into simple sugars.
- **Fermentation:** The process of adding yeast to the wort such to promote the conversion of sugars into alcohol and carbon dioxide. A simple fermentation reaction is shown below.

  glucose + water → alcohol + carbon dioxide
- **Distillation:** The process of separating ethanol from water and condensing the alcohol vapors into a high proof product.
- **Aging:** The chemical reactions that take place between the distilled alcohol product and the oak barrel, resulting in the characteristic flavor associated with traditional whiskey.

Goals & Objectives

How is our whiskey unique?

- Small-batch whiskey sold in liter-sized oak barrels
- Consumer chooses how long to age the whiskey

Motivation:

- Provide consumers with a quality product in the rapidly-expanding whiskey market
- Invest profits towards pursuing research on whiskey maturation and rapid-aging

Goals and Objectives:

- Design a zero-waste facility that collects/sells valuable byproducts
  - Carbon dioxide, fusel oils, and spent grains
- Penetrate expanding whiskey market
- Become a profitable distillery

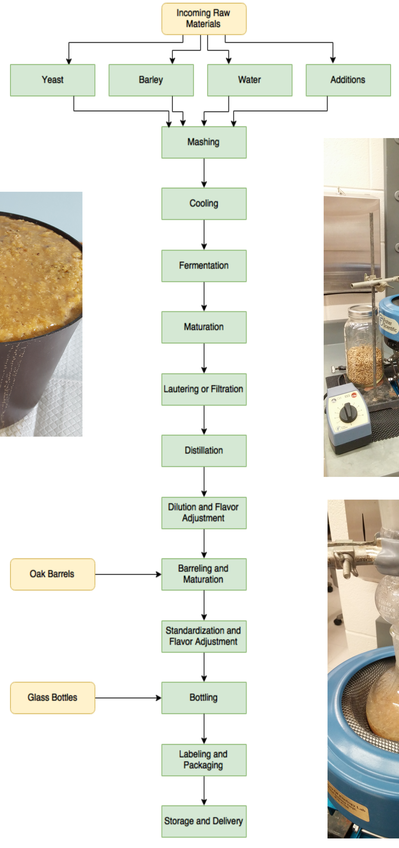
Societal & Global Impact

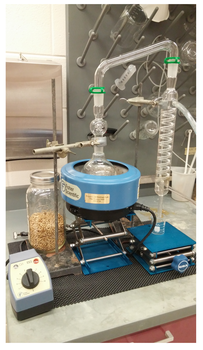
- **Cultural Identity:** Ireland, Scotland, and Kentucky
- **Booming Market:** 6% annual yearly growth rate from 2010 to 2016
- **Consumer Experience:** Relaxation, socialization, and leisure
- **Ethical Concerns:** Alcohol abuse and excessive consumption

Whiskey Formulation

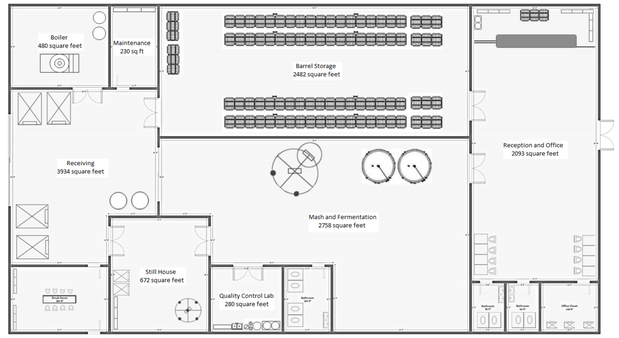
Ingredient	Function	Mass Percent
Water	Liquid medium	72.8%
Corn	Carbohydrate source (80%)	21.5%
6-row malted barley	Carbohydrate source (20%)	5.4%
Gypsum	Improve water quality	< 0.1%
Citric acid	pH adjustment	< 0.1%
Amylase	Break down starches into sugars	< 0.1%
Yeast	Initiate fermentation	0.25%

Process Flow Chart





Plant Layout Design

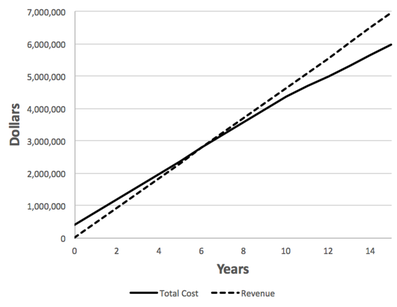


Economics

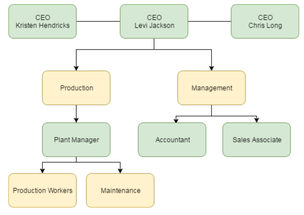
Equipment	Size	Purchase Cost
Mash Tun	0.76 m^3	$15,000
Fermentation Tanks	1.30 m^3	$65,000
Distillation	6.62 m^3	$60,000
Total Equipment Cost		$140,000

Type of Cost	Cost Estimate
Total Capital Investment	$836,000
Annual Operating Cost	$318,000
Net Revenue	$900,000
Net Income	$91,000
Return on Investment	10.8%

Breakeven Analysis



Organizational Chart



Future Endeavors

- Move towards a zero-waste operation by recycling heat and water
- Convert additional byproducts into marketable products
- Expand the whiskey production capacity to sell different size barrels
- Invest into research on whiskey characterization to discover new whiskey maturation and production methods

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