SENIOR CAPSTONE/ SENIOR DESIGN EXPERIENCE

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Buckwheat Based GF Beer

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Objective

To design a large-scale manufacturing plant which will produce a buckwheat based, gluten-free Pale Ale beer (BGFPA)

Market Size & Trends

The total market size of gluten-free beer is estimated to be between $12.5 and $14 billion. The North American market accounts for $5 billion. Primary concerns with alternative beers are flavor and aroma. Highest preference was given to flavor.

Influencing Factors

Global: ISO Standards, Foreign markets

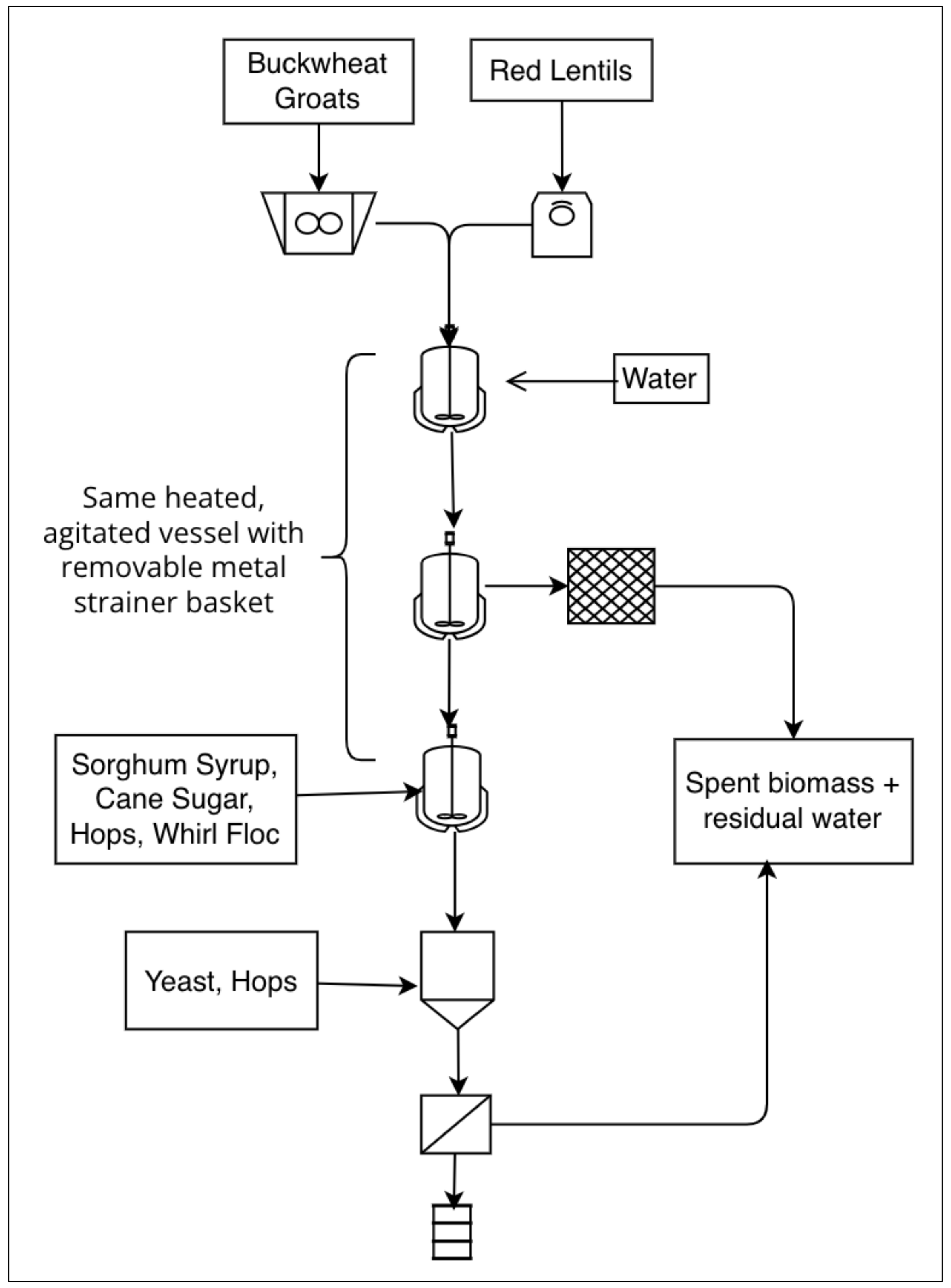
Social: Consumer preferences/Competition

Economic: Raw material costs, Plant operation costs, Inflation, Plant service life

Environmental: Extent of energy use and sourcing, Water use, Waste output

Literature Review

- Several literature reviews were performed to explore methods of fermentation for beer production, gluten-free alternatives, production process factors, and market size.
- A variety of production methods were explored to determine the optimal recipe and process for total revenue.
- Sustainability was a primary concern, with alternative distribution methods identified as a key avenue for carbon neutrality and reduced packaging costs.



Simplified Process Flow Diagram for producing BGFPA

Operations Design

Size Reduction
- Mill Type: Roller Grinder
- Quality Indicators: Clear separation between particles, no discoloration, metal detection

Fermentation
- 3 batch reactors
- Utilize staggered schedule to allow for cleaning during operation

Filtration
- Membrane filter to be selected based on clarity of product, time required for filtration

Experimentation

Size Reduction
- The densities of wort produced from buckwheat of varying grind sizes were evaluated. Analysis suggests that milling may decrease the amount of buckwheat required for producing BGFPA

Grind sizes tested. From left to right: whole groats, #20 sieve, #40 sieve, #60 sieve.

Fermentation
- Fermentations will be run at various lengths.
- Hypothesis: longer brewing provides greater flavor but slows productions

Filtration
- Various filtration materials will be compared. Clarity of samples will be analyzed via spectrophotometer. Time to process will also be taken into account

Optimization & Process Control

Size Reduction
- Optimum: Maximum roller gap setting that still removes material from particles
- PID control systems to adjust roller mill gap and power outputted to mill machine

Fermentation
- Optimum: Fermenter volume and operation time were optimized to minimize costs
- PID designed to maintain consistent oxygen concentration and flow

Filtration
- Optimum: Maximize clarity while minimizing heat and energy losses
- PID systems for controlling the rate at which liquid passes through filter system

Final Design

Scheduling

Stage 1	Stage 2	Stage 3
Toasting Lentils	Cleaning FG	Refilling
Milling Buckwheat	Shipping Kegs	Waste Disposal
Kegging	Wort heating	
Dry Hopping other FGs		

Scheduling for daily plant objectives

	FG 1	FG 2	FG3	FG4	FG5	FG6	FG7	FG8
Preproduction 0	filled, T = 0							
Preproduction 1	filled, T=1	filled, T = 0						
Preproduction 2	filled, T=2	filled, T=1	filled, T = 0					
Preproduction 3	filled, T=3	filled, T=2	filled, T=1	filled, T = 0				
Preproduction 4	filled, T=4	filled, T=3	filled, T=2	filled, T=1	filled, T = 0			
Preproduction 5	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	filled, T = 0		
Preproduction 6	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	filled, T = 0	
Preproduction 7	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	filled, T = 0
Day 1	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1
Day 2	filled, T=1	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2
Day 3	filled, T=2	filled, T=1	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3
Day 4	filled, T=3	filled, T=2	filled, T=1	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5	filled, T=4
Day 5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5
Day 6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	SHIP/REFILL	filled, T=7	filled, T=6
Day 7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	SHIP/REFILL	filled, T=7
Day 8	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1	SHIP/REFILL
Day 9	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2	filled, T=1
Day 10	filled, T=1	SHIP/REFILL	filled, T=7	filled, T=6	filled, T=5	filled, T=4	filled, T=3	filled, T=2

Scheduling for fermenter groups

Economic Analysis
- Total production costs are estimated at approximately $45,000
- Profits should be comparable with similar size plants that are new to market
- Initial plant startup costs were estimated to be approximately $4 million.

Plant Systems

	Original Recipe	Scaled Up
Final Vol (gal)	**5.5000**	**12413.0000**
Sorghum Syrup (lbs)	7.0000	15798.3636
Lentils (lbs)	1.5000	3385.3636
Buckwheat (lbs)	1.1250	2539.0227
Cane Sugar (lbs)	0.6875	1551.6250
Cascade Hops (lbs)	0.2500	564.2273
Whirl Floc (gal)	0.0026	5.8774
Yeast (gal)	0.0029	6.5533
Water (gal)	6.2500	14105.6818

Ingredient quantities for the final recipe

Future Work & Improvements

- **Quantify methods for transporting materials throughout the manufacturing plant**
- **Determine economically feasible range for implementing keg-exchange program**

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