SENIOR CAPSTONE/
SENIOR DESIGN EXPERIENCE
2024

Yogurt Whey Utilization

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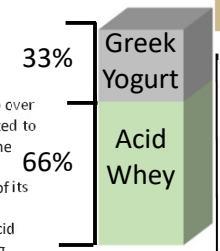
Background



Greek yogurt has grown from a niche product to over half the market in the last 15 years and is expected to double in size over the next decade. However, the acid whey byproduct from Greek yogurt production can't be easily disposed of because of its high biological oxygen demand and can't be processed the same as sweet whey as its high acid and salt concentration lead to equipment fouling.

Objective

Develop sustainable, scalable manufacturing processes that effectively transform excess acid whey into value-added products, whey protein tablets and an alcoholic beverage.

Ethics and Competitors

Ethical Considerations:

- **Social:** Our whey alcoholic beverage is a product that meets at the intersection of consumer trends for increased desire for environmentally friendly products and opting for more affordable products.
- **Global:** Whey protein tablets could provide a different dosage form to the growing masses that want supplemental protein, as well as to the approximately 12% of people worldwide who's diets are deficient.
- **Environment:** Acid whey processed through our design can go from an environmental burden to consumable products.
- ***Key Competitors:***
  - Ready to Drink Cocktails ($850M with 13.4% projected growth)
  - Whey Protein Supplements ($5.1B with 4.2% projected growth)

Experimental Design

Preprocessing Procedure

- Separate acid whey into 5 metal bowls, each containing 200 mL
- Mix in 0.2 g of baking soda into 2 of the bowls to adjust pH
- Place 1 bowl and surround with 200 mL of water inside the pressure cooker
- Cook for 15 minutes at desired pressure (2 on High and 2 on Low)
- Transfer cooked whey into 50 mL centrifuge tubes
- Spin at 3000 times gravity for 5 minutes
- Decant the supernatant, collect and dry the pellet of separated protein

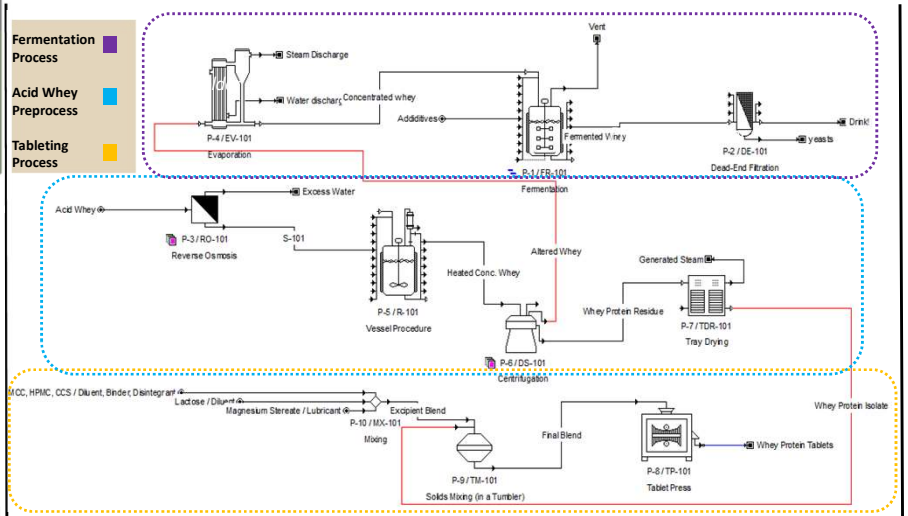
Fermentation Procedure

- Adjust lactose concentration and pH
- Sterilize acid whey
- Cool to 90 degrees Fahrenheit and add lactase
- Measure specific gravity
- Add yeast
- Allow to ferment in dark area
- Test specific gravity to calculate % ABV
- Filter yeast out and refrigerate
- Add flavoring and carbonate if needed
- Varied pH, lactose concentration, and yeast concentration

Tableting Procedure

- Mass all materials
- Pre-blend ingredients without magnesium stearate
- 10 minutes at 33 RPM
- Blend with magnesium stearate
- Blend another 2.5 minutes
- Analyze powder characteristics
- Flow and compressibility
- Compress tablets using rotary tablet press
- Dial press target weight to 600mg
- Develop compaction curve to identify target compression force
- 22.67 kN
- Analyze tablets characteristics

Production Processes



Fermentation Process

- 10 35,394 L Fermenters
- 1 45.17 m^2 Multi Effect Evaporator
- 1 120 m^2 Dead-End Filter
- 20-hour Anaerobic Fermentation

Alternate Processing methods

- Continuous Fermentation
- Lactose Fermenting yeast

288,000 L/day Produced
114,000 L/day Water Produced
25,500 kg/day CO2 Produced

Acid Whey Preprocess

- 1 RO Filtration System (105,000 L per Batch)
- 1 Jacketed Heating Vessel (32,000 L Capacity)
- 5 Disk Centrifuges (6,000 L per hour Capacity)
- 1 Vacuum Dryer (500 Kg per hour Capacity)

Alternate Processing Methods:

- Continuous Heating with Direct Steam Injection

2.5M L/day Preprocessed
1.91M L/day Water Filtered Out
64,100 Kg/day Steam Used

Optimization Conditions and Economic Results

	Acid Whey Preprocess	Fermentation Process	Tableting Process
Equipment Optimized	Jacketed Heating Vessel	Fermentation Tank	Blender
Optimal Parameters	• 30-minute Heating Time • 4:1 Vessel Height to Diameter Ratio • 31,100 L Vessel Volume	• 10, 35,394 L fermenters • 307.2 g/L Lactose	• 2 blenders • 12 tablet presses • 20 batches/day • 29,261.01 kg tablets/day
Optimized For	Minimized Annualized Cost	Maximum Annualized Cash Flow	Maximum Annualized Cash Flow
Optimal Results	$241,890.30	$12,031,560	$91,756,384

Tableting Process

- 2 Blenders
- 12 Tablet Presses
- 0.51-hour batch time

Alternate Processing Methods:

- Diffusion blending
- Shear blending
- Encapsulation

29,261 kg tablets/day
6.8 MWh/day

Future Recommendations

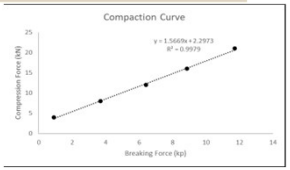
- Consider fermenting for fuel ethanol as well
- Using lactose fermenting yeast such as kluyveromyces, or modified saccharomyces
- Using wastewater to cool fermentation and for CIP

- Apply a cascading heat exchanger to recover wasted heat during jacket cooling process.
- Recycle the approximate 1.9M L water filtered out in preprocessing for process water or for various equipment CIP systems.

- Formulation development work to increase protein concentration
- Tablet and powder characterization, excipient stability studies
- Develop a continuous manufacturing process with PAT technology

Experimental Results

Fermentation Parameters	
Specification	Value
pH	4.2
Lactose Concentration (g/L)	300
Yeast Concentration (g/L)	.13



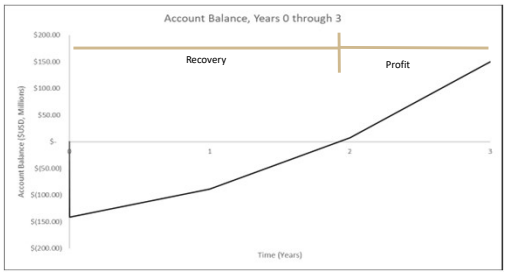
Acid Whey Preprocess Bench Scale			
Trial	pH	Pressure Mode	Yield (g)*
Control	4.7	-	-
1	4.7	Low (~110°C)	-
2	4.7	High (~121°C)	-
3	5.8	Low	0.18
4	5.85	High	0.416

*Theoretical Yield for 200 mL Acid Whey = 0.542g

Whey Protein Powder Characterization		
Specification	Value	Reference (if applicable)
Sample Weight (g)	27.5	-
Apparent Volume (mL)	56.6	-
Bulk Density (g/mL)	0.486	-
Tapped Volume (mL)	43.8	-
Tapped Density (g/mL)	0.629	-
Carr's Index	22.6%	Passable
Hausner Ratio	1.29	Passable

Economic Analysis

Specification	Tablets	Beverage
Sale Price	$25/kg	$0.50/kg
Direct Product Cost	$6.46/kg	$0.24/kg
DCFRR	73%	44%
Break-Even Production	15.8 Million kg/year, 22%	2.27 Million kg/year, 22%



Acknowledgements: Dr. Okos, Daniel Hauersperger, Dr. Li, Dr. Wade, Dishan Shah, Shawn Hawkins and Amanda Limiac