SENIOR CAPSTONE/
SENIOR DESIGN EXPERIENCE
2025

Sleepy-time Probiotic Soda

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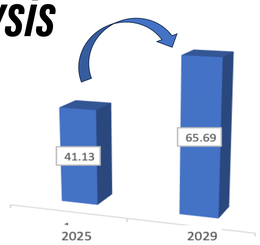
Objective

To create a probiotic soda that would improve sleep while being uniquely non-dairy. This product utilizes water kefir grains, tart cherry juice and magnesium powder to achieve these goals.

Market Analysis

Projected market size growth for probiotic drinks (billions $):



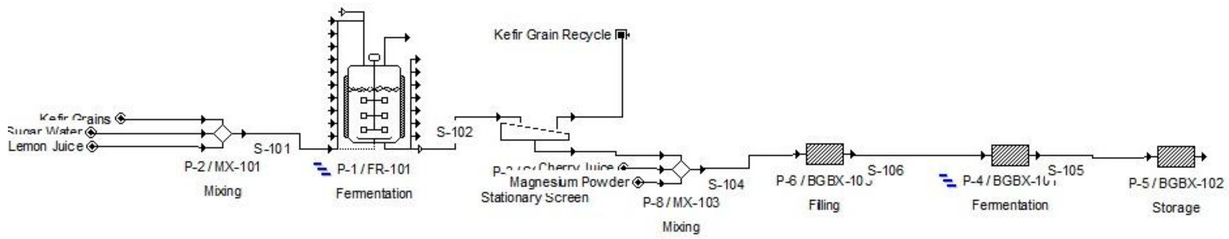
Well known competitors:

- 54% of consumers are willing to pay more for sustainable products.[2]
- 44% of Americans are lactose intolerant.[3]
- 80% of adults want to improve their sleep.[4]

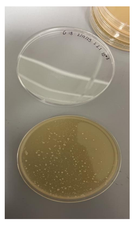
External Factors

- **Enviromental impact**
  - Reduce dairy farming, less greenhouse gases
- **Social impact**
  - Alcohol free mocktail option
  - Encouraging gut health

Process Design



	Mixing	Fermentation	Separation
Optimization	Diameter: 1.1 m Vessel Volume: 2.09 m^3 Power Required: 3.54 kW	Diameter: 1.2 m Vessel Volume: 2.6 m^3	Filter Area: 100 m^2 Flow Rate: 3.19x10^{-4} m^3/s Pressure Drop: 270kPa Plate and Frame Filter, Centrifugal Pump
Alternatives	Motionless Mixer	Horizontal vessel Type of substrate	Continuous Rotary Filter Centrifugal Filtration
Controls	Level Sensor: monitor flow turbulence Power Sensor: monitor power usage of agitator	Turbidity sensor: monitor cell concentration	Flow controllers: centrifugal pump to filter, output filter flow Pressure controller: across filter
Design	$V = \pi H(\frac{D_k}{2})^2$ $N_p = \frac{P}{D_{imp}^5 N^3 \rho}$	$\frac{dX}{dt} = x\mu$ $\frac{dS}{dt} = -\frac{1}{Y_{xs}}\frac{dX}{dt}$	$Q = \frac{2A*(-\Delta P)}{\mu(\alpha C_s v + 2R_m)}$ $Power = \frac{Q*\Delta P}{\eta * 1000}$

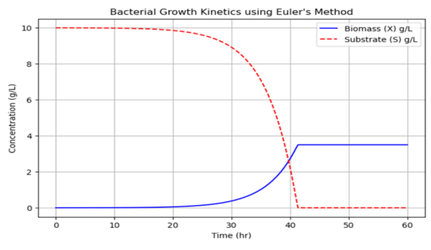


Experimental Results and DOE

12 samples created to vary:

- Kefir mass (5, 10, 15g)
- Fermentation time (24, 48, 72hr)
- Magnesium mass (400, 600, 800mg)

Growth Kinetics



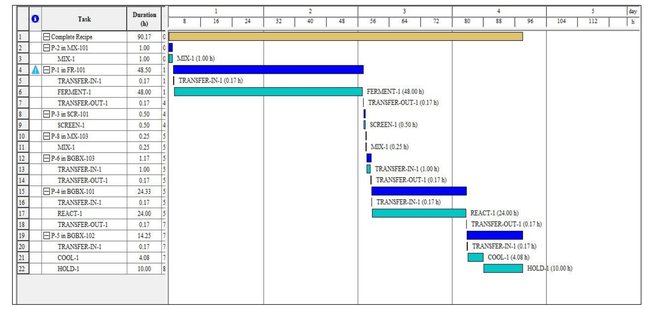
10g of Kefir grains fermented for 48 hours resulted in highest CFU concentration of 6.6x10^6. 600mg of magnesium for best flavor profile.

Economic Analysis

Total Capital Investment [1]	**$2,134,128**
Total Product Cost	**$1,195,409**
Break Even Production Rate	**185,992 kg/yr**

After 10 Years of Production

Sales/kg	**$3.56/kg**
Annual Sales	**$1,610,000**
DCF	**$11,307,966.28**



Plant System

- Minimize Carbon Footprint
  - CO_2 absorption/ recapture post-fermentation (solid/liquid media absorption, membrane separation)
- Plant Sanitization
  - CIP: rotary spray balls, chemical cleanings
- Kefir grain recycle
  - Retrieval during filtration
  - Storage in sugar water medium, reintroduced for future batches
- Quality Assurance
  - Imaging sensors (mixing), sensory and composition analysis (fermentation), filter integrity and turbidity testing (separation)

Future Work

- **Further automation**: quality assurance, filter cleaning
- **Culture alternatives**: test kefir grain variations
- **Probiotic strength**: improve bacterial survival

Instructors: Martin Okos & Daniel Hauersperger

Acknowledgements to Agricultural and Biological Engineering Undergraduate Program

Sources:

1. **Peters, M. S., Timmerhaus, K. D., & West, R. E. (2006).** ***Plant design and economics for chemical engineers*****. Mcgraw-Hill.**
2. Monteiro, M. (2024, September 10). *3 Innovative Beverage Trends | GrowinCo*. GrowinCo.
3. GI Alliance. (2024). *Lactose intolerance in United States*. Lactose Intolerance .
4. Team, S. (2025, February 5). *How much sleep does the average American get?*. The Checkup.