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BACKGROUND & PROBLEM STATEMENT

Background

Demand for fermented products, niche ice cream products, and craft alcohol have been growing in recent years. By creating an alcoholic ice cream through the fermentation of lactose, this product will satisfy demand in all of these categories. Another unique aspect of this product is the fermentation of lactose will make this product available for consumption to those who are lactose intolerant.



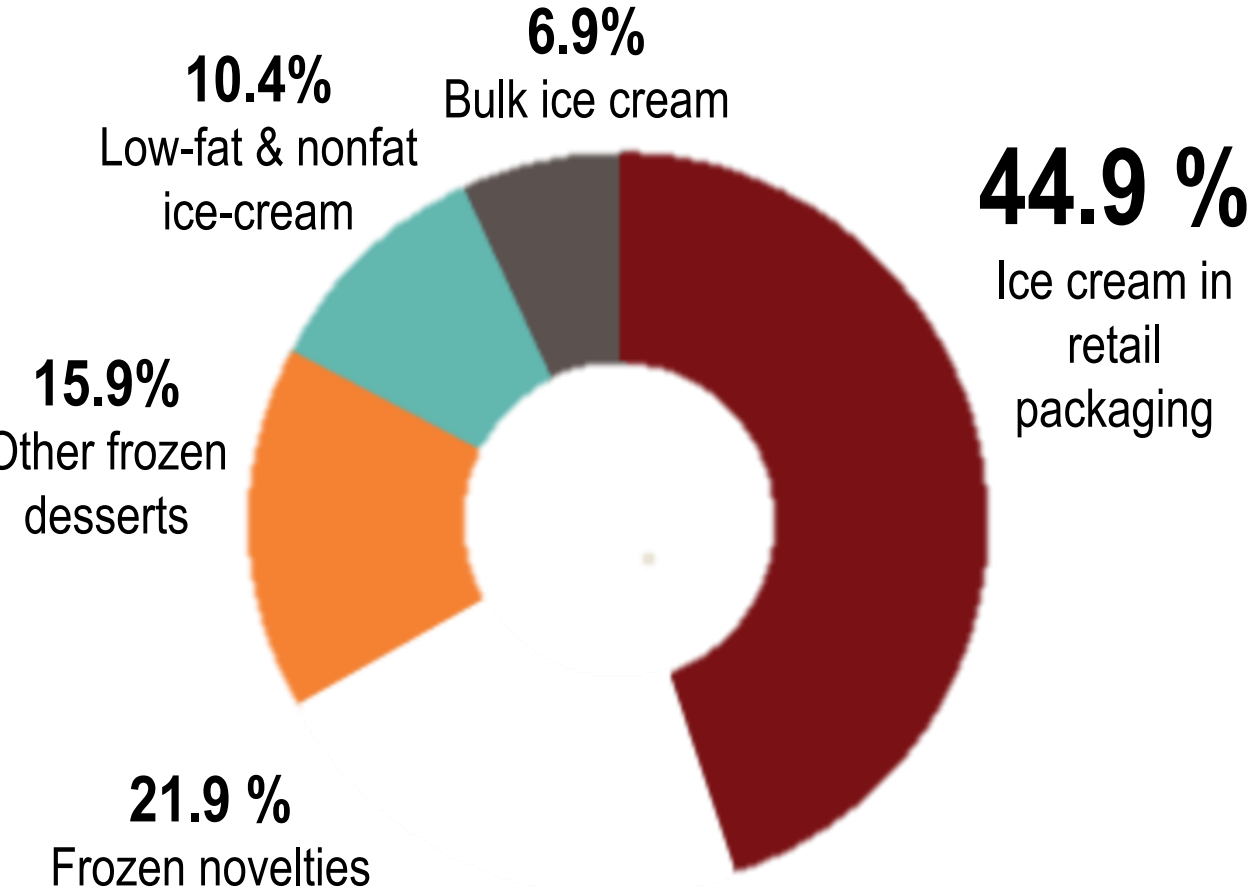
Problem statement

The objective of this project was to formulate and process steps for an alcoholic ice cream derived from the fermentation of lactose in milk. Additionally, the design for an industrial scale facility for processing was created, which was optimized.

MARKET ANALYSIS AND IMPACT

Ice cream market Products and services segmentation (2018)

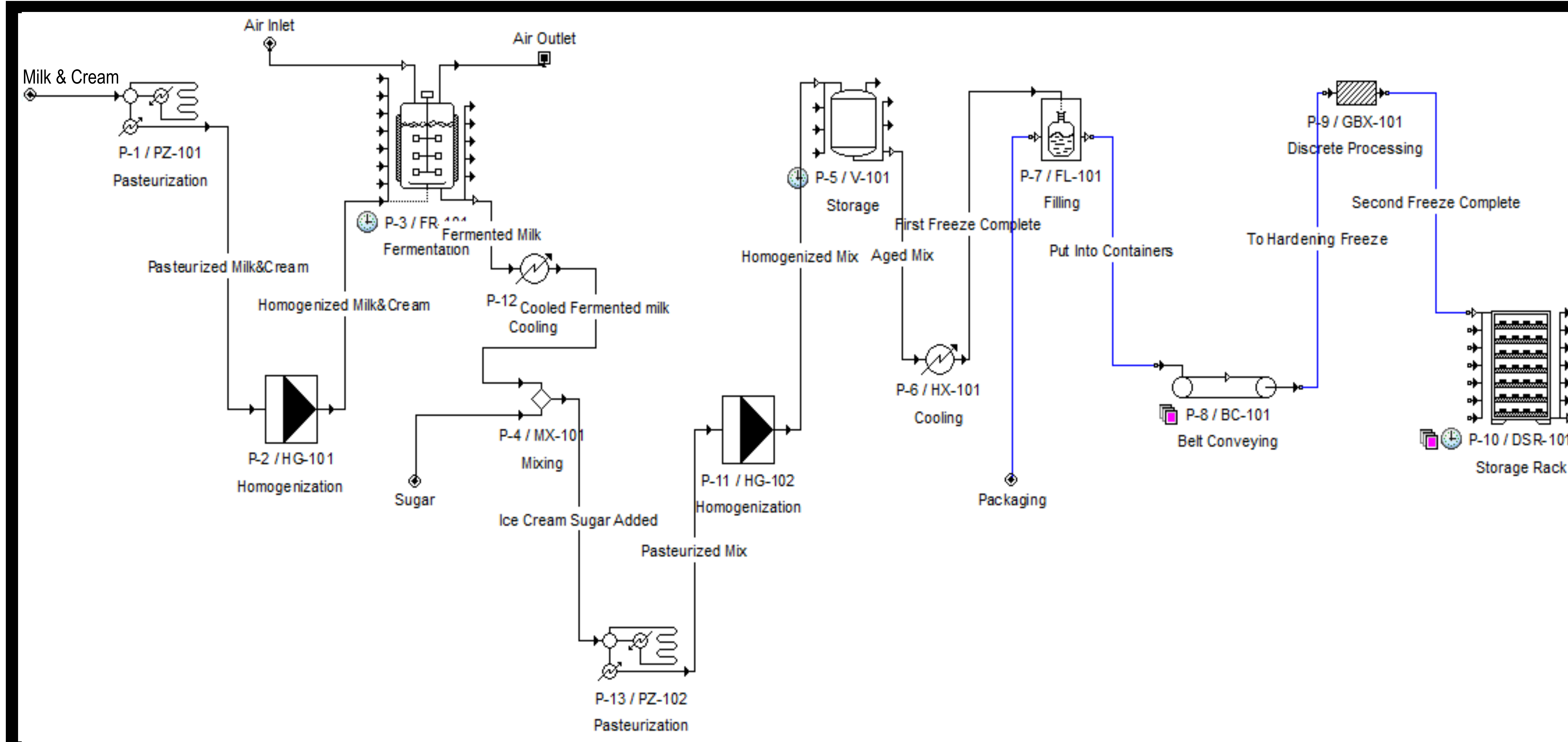
- 8.6 billion dollar industry with growth rate 1.6% annually (2018)
- ~1.54 billion gal produced in the US (2015)



Impact

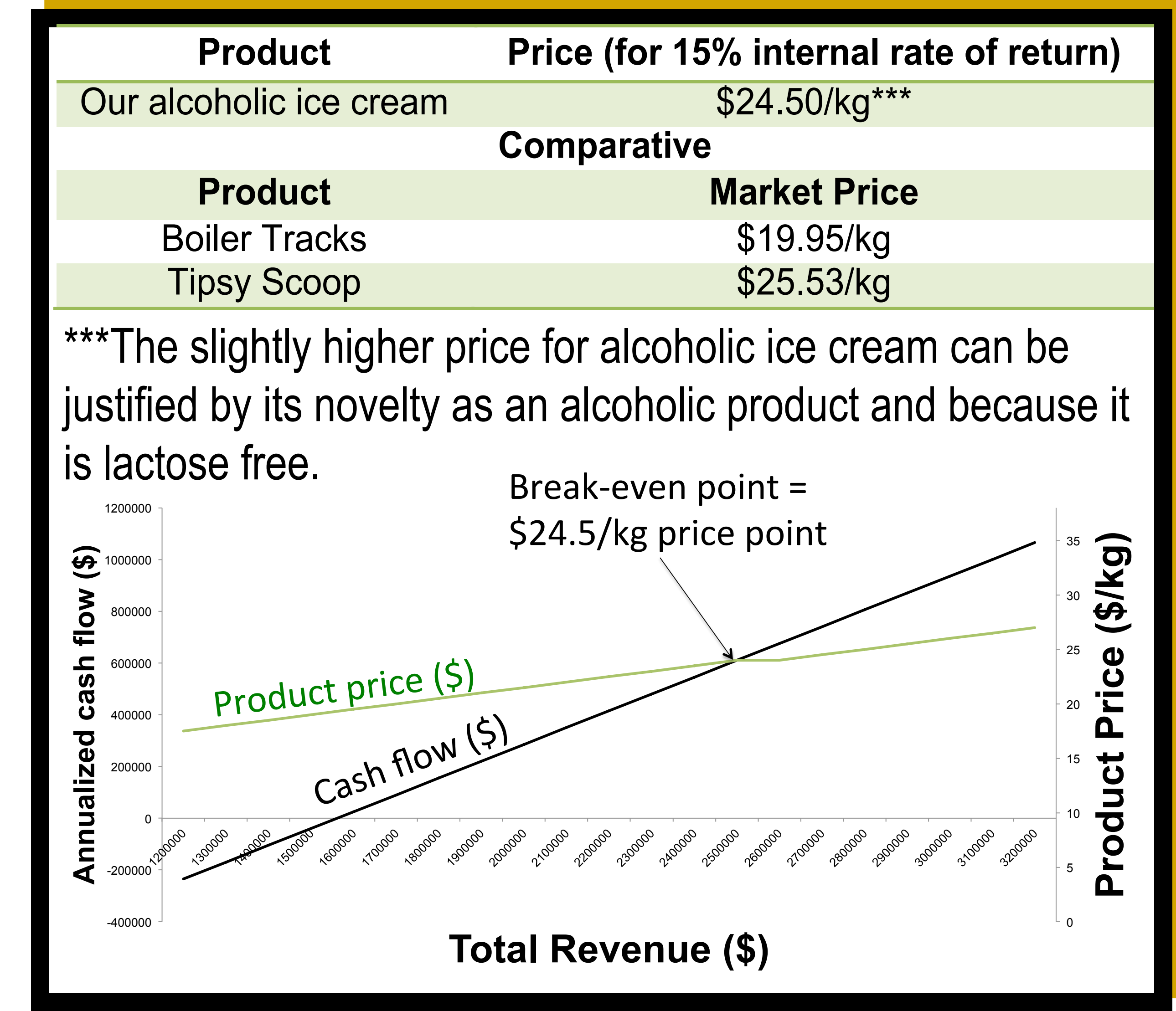
- The ice cream industry has met a golden era
- Ice cream ingredient trends are leaning towards new flavors & healthier formulations
- Our ice cream will transform all the lactose in the milk into alcohol
- This would provide customers with unique and healthy product

PROCESS FLOW ANALYSIS WITH FINAL COMPOSITIONS



Component	Flowrate (kg/hr)	Mass Composition (%)	Concentration (g/L)
Ethyl Alcohol	1.77	5.66	58.97
Fats	6.71	21.45	223.44
Proteins	1.74	5.57	58.05
Sucrose	6.67	21.30	221.97
Water	14.40	46.02	479.45

ECONOMIC ANALYSIS



OPTIMIZATION CRITERIA & CONTROL

Unit operation	Equipment	Minimized parameters	Optimal parameter
Pasteurization	Plate heat exchanger	Energy and cost	Length of pasteurizer = 2.75 m Diameter of pipe = 0.6 m
Homogenization	2-stage homogenizer	Energy and cost	Diameter of pipe = 0.269 m
Fermentation	Fermenter	Energy and cost	Air flow rate of 2.8 m/s gives 87 C of inlet medium flow
Freezing	Swept surface heat exchanger	Energy and cost	Length of heat exchanger = 1m

FINAL SOLUTION & FUTURE WORK

Through lab-scale experimentation, alcoholic ice cream with 4.62% [EtOH] was produced.

Each unit operation was judged against alternatives and optimized for efficiency in regards to industry production.

In our economic analysis, product cost was determined to be \$24.50/kg for optimal internal rate of return & cash flow.

Considering the value of lactose-free, niche market ice cream, the cost is justified through market analysis.

Future work would involve improving texture & taste by introducing flavorings & additives. Additionally, scale-up experiments would take place before the product meets industry requirements and production.

FUNCTIONAL ANALYSIS & ALTERNATIVES

Unit Operation/Step	Relation to production goal	Equipment Alternatives	Process Alternatives
Pasteurizer	Reduce microbial load and prevent foodborne illness	HTST plate heat exchanger was chosen based on cost, feasibility and efficiency	Pasteurization has a few controversial alternatives but all aim to reduce microbial growth
Homogenizer	Homogenize the distribution of sizes of fat globules to maximize the freezing effect	Steel pipe is used to meet the high temperature (up to 85 C) and other operation requirement	HPH is preferred among ultrasonic and rotor-stator homogenization
Incubator	Convert the lactose to alcohol	Half-pipe jacketed batch was used among other types of batches to meet energy and cost efficiency	<i>Kluyveromyces marxianus</i> was used instead of <i>kefir</i> grain to increase the alcohol production
Refrigeration unit	Ammonia used for freezing	A hardening tunnel was chosen over the faster cryogenic freezing to maximize quality of ice cream	Freon, ethane, and butane were all cooling agents being considered. Ultimately ammonia was chosen for its low toxicity
Heat exchanger	Initial freezing step		
Hardening Tunnel	Secondary freezing step		

EXPERIMENTAL RESULTS

Pasteurized milk was inoculated with the bacteria *Kluyveromyces marxianus*

1st fermentation: 24 hrs (@ 37 °C) & yielded .23% [EtOH]

20% of start culture was inoculated to fresh milk and heavy cream mix

2nd fermentation: 24 hrs (@ 37 °C) & yielded 4.96% [EtOH]

End product yielded 4.62% [EtOH]. Taste & texture are desirable

Technical Advisor and Instructor:
Thank you Dr. Okos for all your support!

References:
Does lactose intolerance imply to consume lactose-free food? (2018, April 06). Retrieved from <https://www.yogurtinnutrition.com/does-lactose-intolerance-imply-to-consume-lactose-free-food/>

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Industry Reports. (n.d.). Retrieved from <https://clients1.ibisworld.com/splashindustryprocurement>