Formulation and Stability Analysis of Erythritol-Based Ice Cream

UCONN SCHOOL OF ENGINEERING

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1. Introduction and Motivation

Due to the rising rate of obesity, the UCONN Creamery has expressed interest in adding a reduced-sugar ice cream to their product catalog. After conducting a survey of the UCONN community, it was determined that natural sweeteners were favored over artificial, and thus erythritol was chose to replace sucrose.

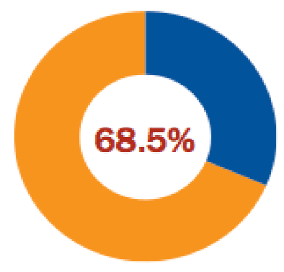


Figure 1. Nearly 70% of adults in America were overweight or obese in the years 2011 to 2012.[1]

Goal: Formulate an erythritol ice cream for the UCONN Creamery, model the stability of the product during storage, and ensure feasibility of production.

2. Project Constraints

- Formula must have no more than 10 wt. % erythritol, in accordance with Food and Drug Administration regulations[2]
- Fixed production process at UCONN Creamery
- Product meets UCONN Creamery's high quality standard in taste and texture
- Projected erythritol ice cream demand of 180 gallons per year, and thus must be stable for one year

3. Technical Analysis

3.1 Freezing Curves

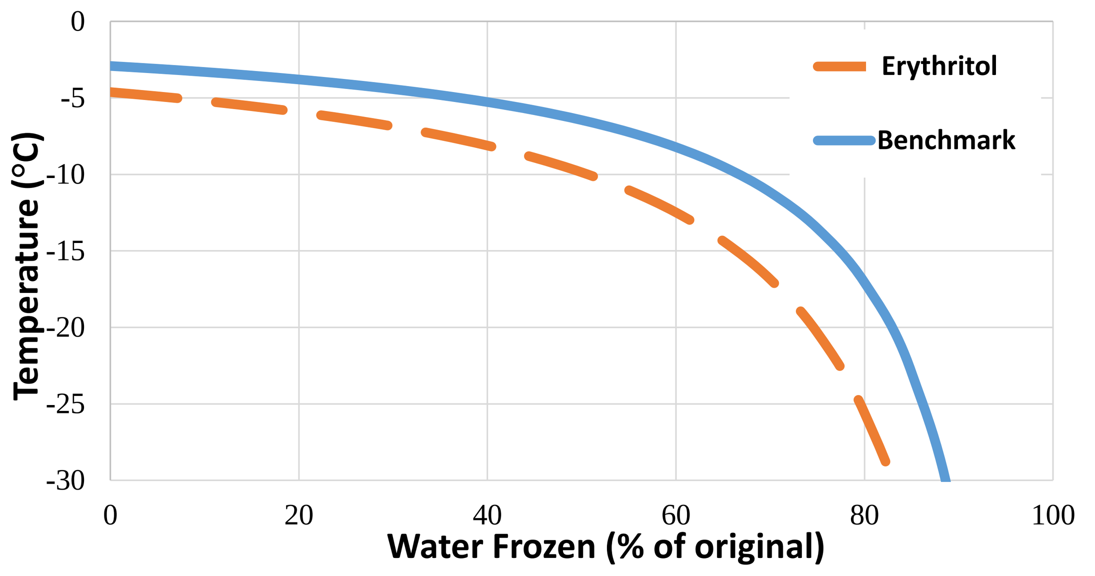


Figure 2. Predictive freezing curves of formulas with differing ingredient percentages. Curves generated via freezing point calculation.

3.2 Formulation

Table 1. Comparison of the benchmark and erythritol formulation ingredient weight percentages, with respective calories per ½ cup serving.

	Benchmark [wt.%]	**Erythritol** [wt.%]
Milk (3.27 wt. % Fat)	46.2	42.5
Cream (34 wt. % Fat)	31.2	37.1
Non-Fat Fairy Milk	3.3	11.5
Sucrose	16.1	0.0
Corn Syrup Solids	2.9	0.0
Erythritol (70% as sweet)	0.0	8.6
Stabilizer & Emulsifier	0.3	0.3
Calories per serving	**122**	**93**

3.3 Heat Transfer Modeling Equations

Governing Equations

$$\alpha \frac{\partial^2 T}{\partial r^2} + \alpha \frac{1}{r}\frac{\partial T}{\partial r} + \alpha \frac{\partial^2 T}{\partial z^2} + \frac{\dot{q}}{\rho C_P} = \frac{\partial T}{\partial t}$$

$$\alpha = \frac{k}{\rho C_P} \qquad \dot{q} = L_f(T_f)\frac{dX_{ice}}{dt}\rho$$

Initial Condition

$$T = -5\,°C \quad for\ t = 0$$

Boundary Conditions

$$\frac{\partial T}{\partial r} = 0 \quad for\ r = 0$$

$$k_C \frac{\partial T_S}{\partial r} = -h_0(T_S - T_{amb}) \quad for\ r = R\ and\ t > 0$$

$$k_C \frac{\partial T_S}{\partial z} = -h_0(T_S - T_{amb}) \quad for\ z = 0, H\ and\ t > 0$$

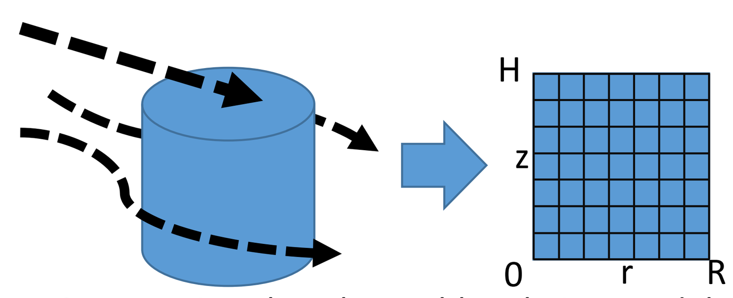


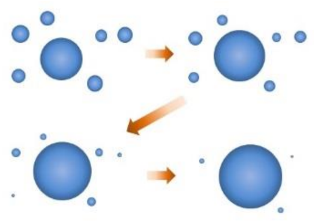
Figure 3. Assuming that the problem being modeled was axis-symmetric. The model studied a cross-sectional plane.

3.4 Ostwald Ripening Recrystallization

Rate Kinetics

$$L = k_R \cdot t^{\frac{1}{3}}$$

Where k_R is a function of temperature[3]



Crystals greater than 55 μm create sandy texture[4]

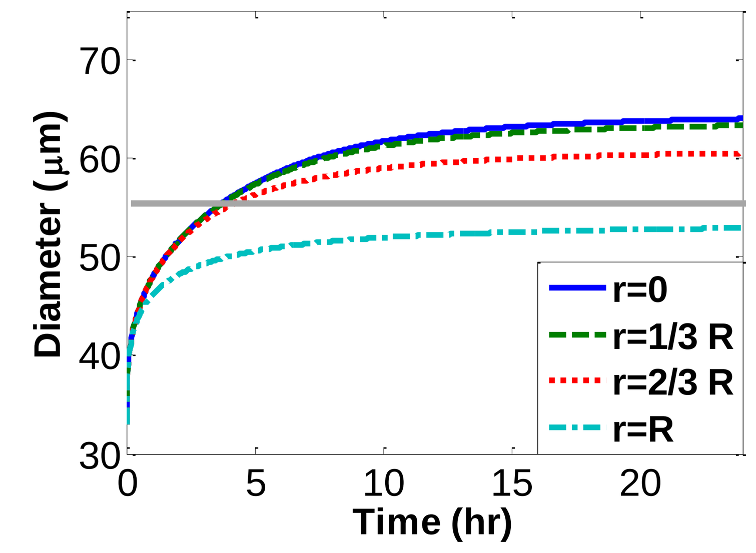


Figure 4. Ice crystal growth of erythritol ice cream during hardening.

Table 2. Predicted ice crystal sizes for benchmark and erythritol ice cream in ½ gallon HDPE container with 70 % overrun, at T_{amb} = -30 °C .

Step	Location	Benchmark [μm]	Erythritol [μm]
Hardening *24 hours* *Air velocity: 8.9 m/s*	0	62.6 ± 11.7	64.0 ± 12.3
	R	52.0 ± 11.4	52.9 ± 12.0
	Average	**59.2 ± 3.8**	**60.5 ± 4.0**
Storage *12 months* *Air velocity: 3.3 m/s*	0	69.6 ± 12.3	71.5 ± 13.2
	R	58.5 ± 12.1	59.6 ± 12.9
	Average	**66.0 ± 4.0**	**67.6 ± 4.3**

The stability of the erythritol product is similar to that of the benchmark.

4. Environmental Analysis

Table 3. Environmental impact of producing benchmark (44,000 gal/yr) and erythritol (180 gal/yr) ice cream.

	Benchmark	**Erythritol**
Dairy Pollution	1,800 kg NO_x/yr	7.3 kg NO_x/yr
Power Consumption	3 metric tons CO_2e/yr	12 kg CO_2e /yr
Water Consumption	1.2 million gal/yr	4,700 gal/yr

0.5% increase in production results in minimal environmental impact

5. Economic Analysis

Goal: Estimate sale price of erythritol-base to minimize profit loss

Method: Compare cost of 180 gallon batch production for benchmark and erythritol

Table 4. Sale price of benchmark and erythritol ice cream.

	Benchmark	**Erythritol**
Sale Price ($/gal)	11	16

Table 5. Cost analysis for production of 180 gallons for each respective formula to achieve the same profit margin.

	Benchmark	**Erythritol**
Production Cost	$3,100	$3,100
Ingredient Cost	$1,150	$2,050
Revenue	$1,980	$2,880
Profit Margin	-$2,270	-$2,270

6. Health and Safety Analysis

Formulation and production abides by Food and Drug Administration guidelines

- Erythritol has no adverse health effects[5]
- Operators must wear hair nets, gloves, and aprons to prevent contamination
- Controller implementation will improve worker safety and reduce error

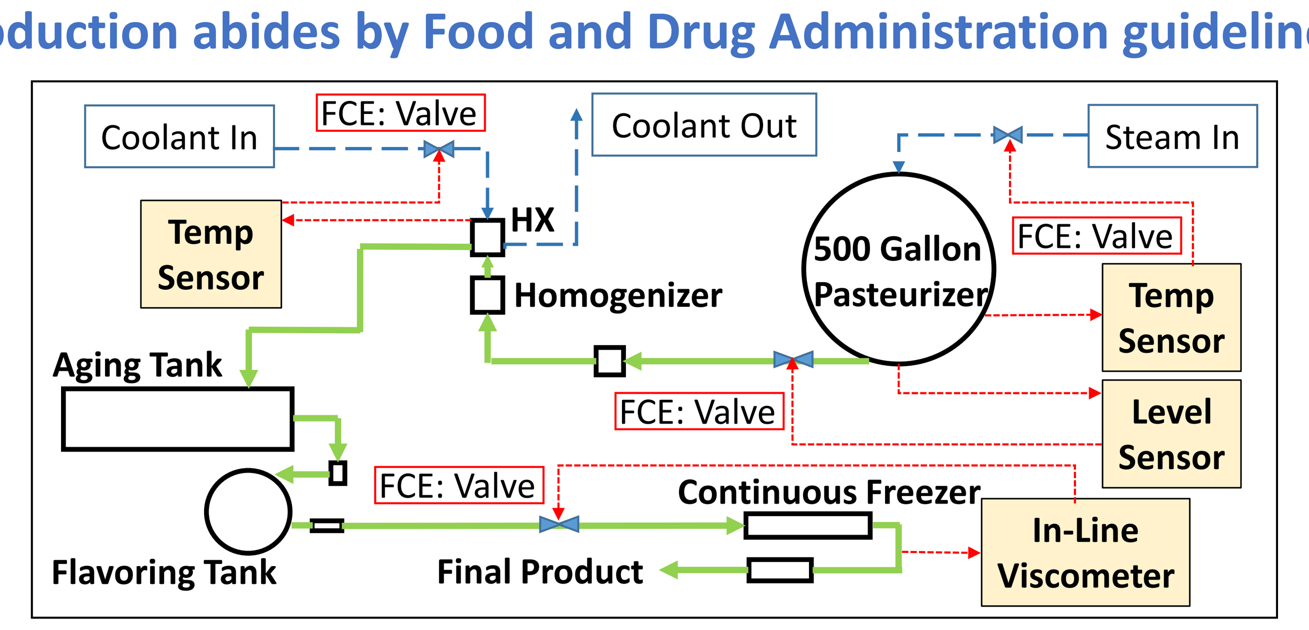


Figure 5. Schematic of current Creamery production process with proposed controller implementation.

7. Future Work

- Test additional flavors
- Validate recrystallization model through long-term experimental studies
- Produce product at full-scale
- Integrate into Dairy Bar product catalog

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[2] McColl, Diane B. "Notice of GRAS Exemption for Erythritol." (2001): n. pag. Food and Drug Administration. Web.
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