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Introduction/Market

- Yogurt is a semisolid fermented product made from a standardized milk mixed by the activity of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* cultures
- Yogurt has become more and more popular in recent years due to its nutrition value and benefits of probiotics
- Compared with milk, yogurt is easier to digest and can be consumed by groups with low lactose tolerance
- The consumption of probiotics has been shown to have health benefits such as prevention and treatment of diarrhea and enterocolitis, and maintenance of general gut health
- The consumption of yogurt has reached record levels globally: 13 million metric tons were consumed in 2016 alone
- The problem for commercial yogurt products is the high content of sugar and artificial sweeteners
- Drying yogurt can save storage and transportation resources and produce a more shelf stable product
- Dried yogurt has been commercialized, and many yogurt drinks add heat treated dry yogurt powder
- Many drying processes which utilize heat input result in low probiotic levels in the dried product
- Freeze dried dairy is a premium product, commanding a premium price: "The growing consumer interest toward such high-value dairy is also expected to be a future trend for freeze-drying technique in the dairy industry" [1]

Objectives

- This project endeavors to design an optimal method to capitalize on a substantial commercial opportunity
- Plant design, ingredient chemistry, social and environmental implications, and processing effects on product quality were considered
- Alternative processing techniques and formulations were investigated
- These criteria were used to select an optimized set of process conditions

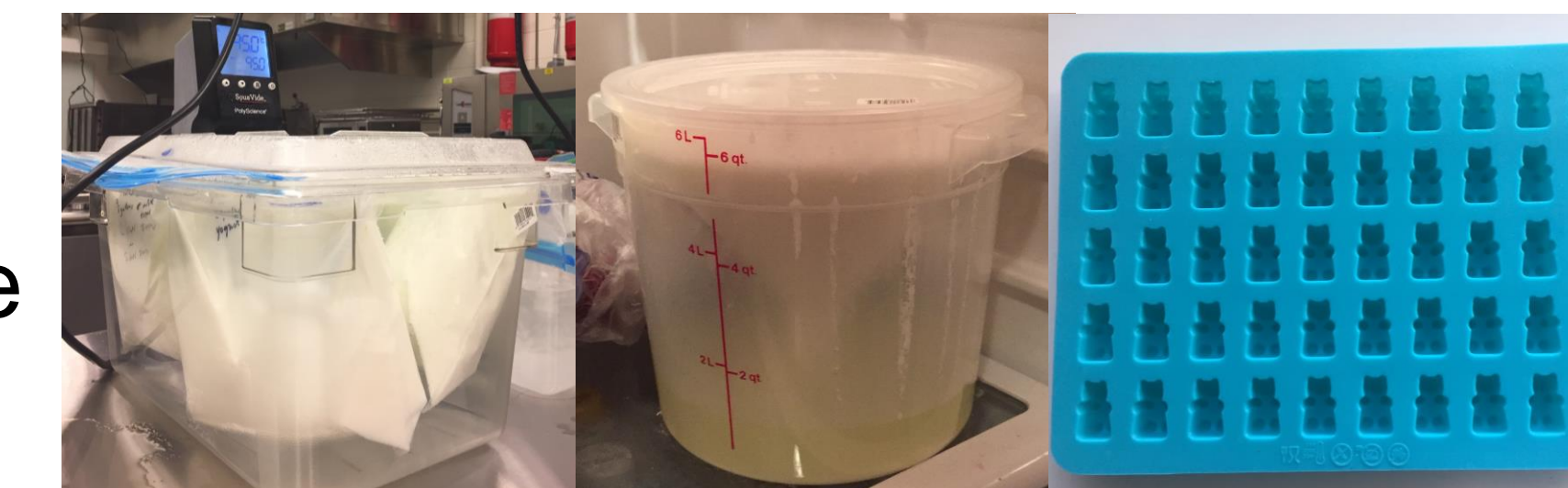
Experimental Design

Variables	Low	High
A: Milk Fat %	Skim	Whole
B: 85% Milk Protein Concentrate Powder	0%	4%
C: Dummy		
D: Pasteurization	No	Additional 95°C, 10 minutes
E: Incubation Temperature	37°C	43°C
F: Dummy		
G: Straining (Post-Fermentation)	No Straining	Strained

A Plackett-Burman experimental design was chosen to efficiently screen variables with the largest effects on quality and process efficiency in the manufacture of freeze dried yogurt. Yogurt batches were prepared, freeze-dried, and analyzed for variable effects on quality.

Treatment	Variables						
	A	B	C	D	E	F	G
1	+	+	-	+	+	-	-
2	-	+	+	-	+	+	-
3	-	-	+	+	-	+	+
4	+	-	-	+	+	-	+
5	+	+	-	-	+	+	-
6	-	+	+	-	-	+	+
7	+	-	+	+	-	-	+
8	-	-	-	-	-	-	-

Pasteurization, Straining, & Freezer Molding

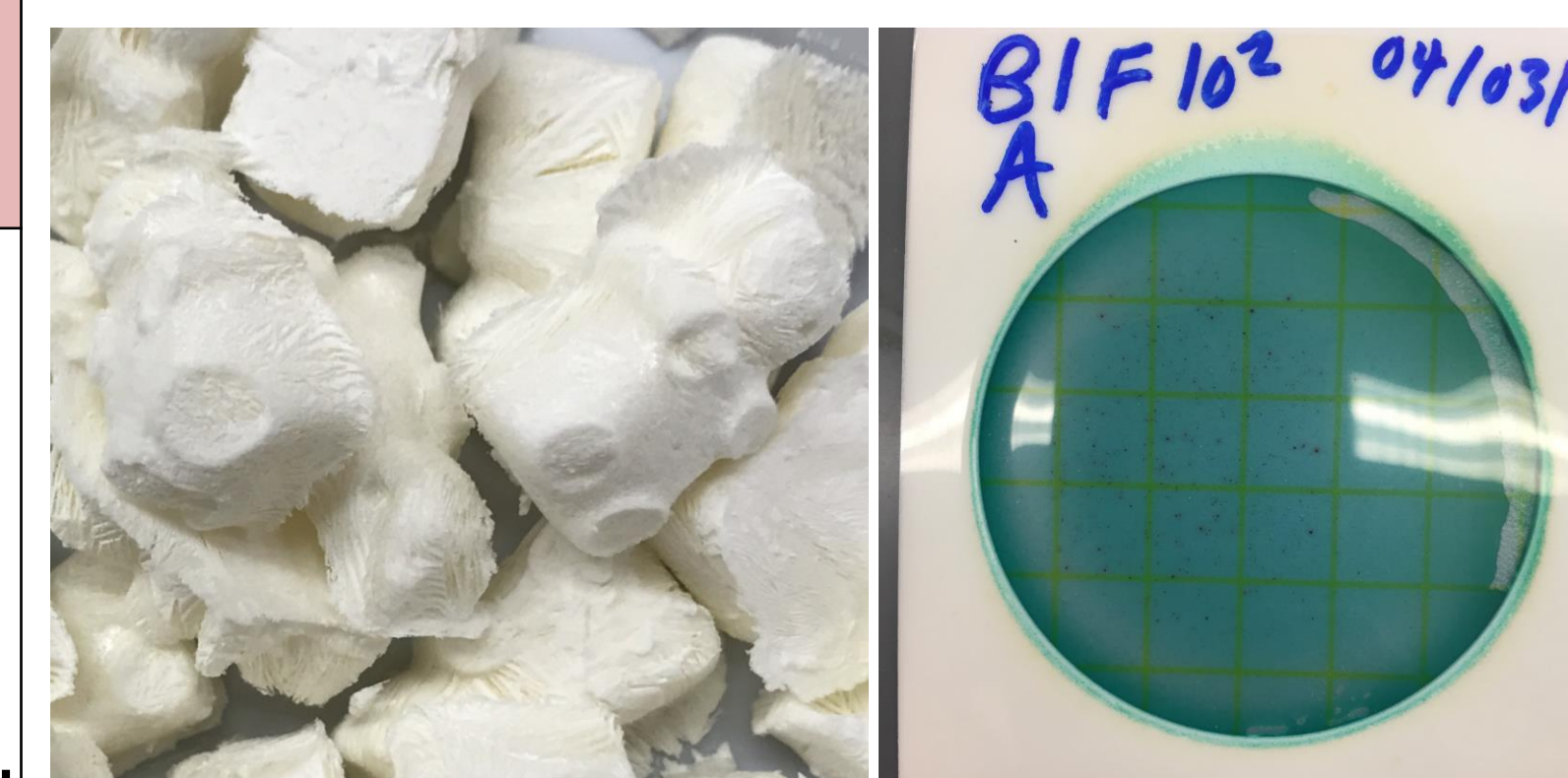


Results

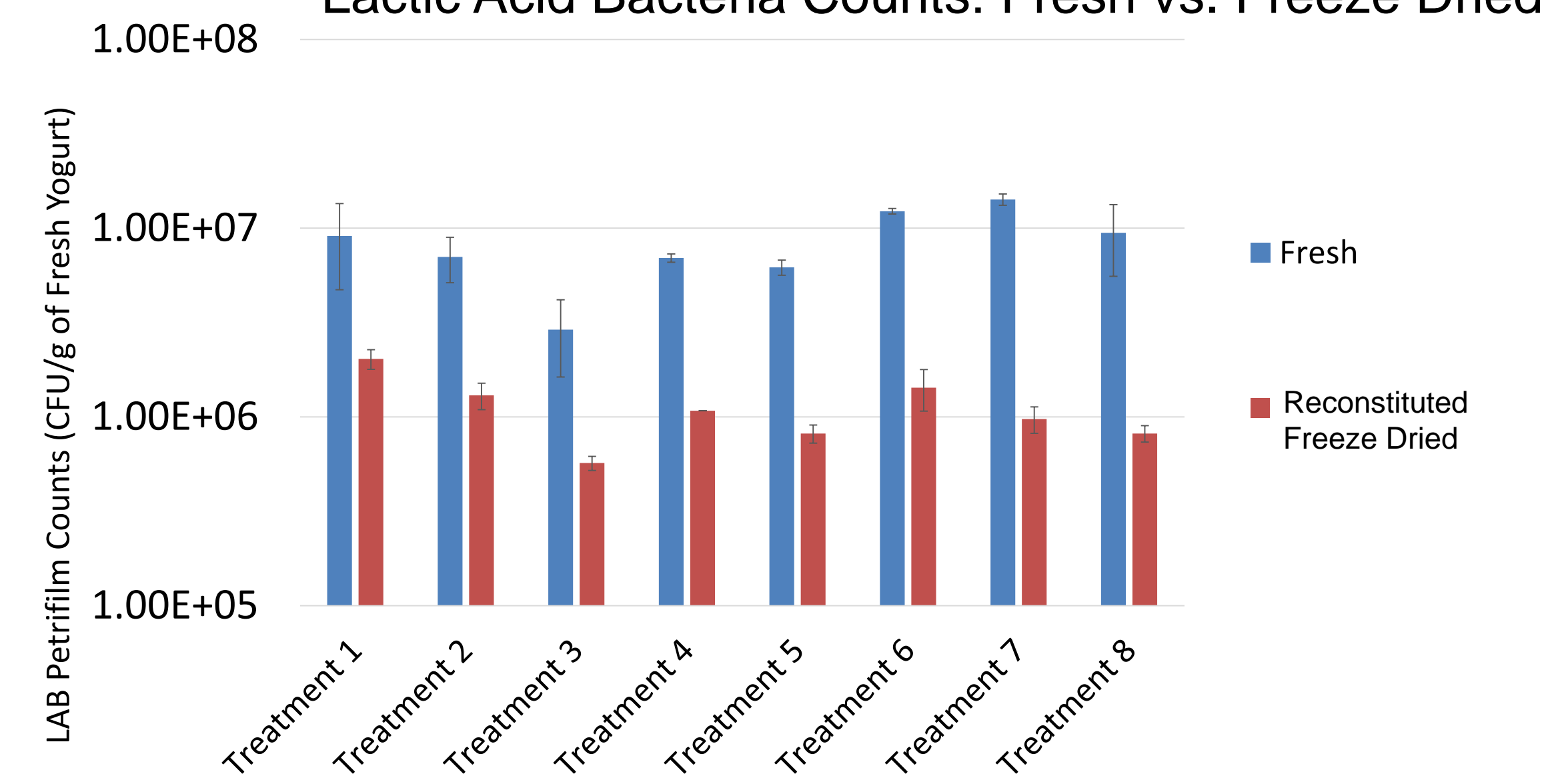
	Freeze Dryer Yield (%w/w)	Water Activity	Moisture (%w/w)	Probiotic Count (CFU/g)	Reconstitutibility
Milk Fat %	+0.58% (p = 0.026)	-0.0075 (p = 0.007)	-0.19% (p = 0.146)	+6.27e4 (p = 0.419)	-0.156 (p = 0.0031)
Straining	+0.54% (p = 0.029)	-0.0158 (p = 0.002)	-0.20% (p = 0.140)	-2.85e4 (p = 0.463)	+0.344 (p = 0.00064)
Pasteurization	+0.35% (p = 0.061)	-0.0136 (p = 0.002)	-0.18% (p = 0.158)	+9.03e3 (p = 0.488)	+0.25 (p = 0.0012)
Incubation Temp.	+0.08% (p = 0.303)	0 (p = 0.4954)	-0.13% (p = 0.219)	+4.48e4 (p = 0.442)	-0.219 (p = 0.0016)
MPC Addition	-0.06% (p = 0.349)	-0.0031 (p = 0.037)	-0.17% (p = 0.171)	+6.67e4 (p = 0.414)	-0.0938 (p = 0.0085)
Highest Quality Conditions:	Whole Milk, Strained, & Pasteurized at 95 °C for 10 minutes	Whole Milk, Strained, Pasteurized at 95 °C for 10 minutes, MPC added	Any	Any	Skim Milk, Strained, Pasteurized at 95°C for 10 minutes, Incubated at 37°C, No MPC addition

Freeze Drying Program

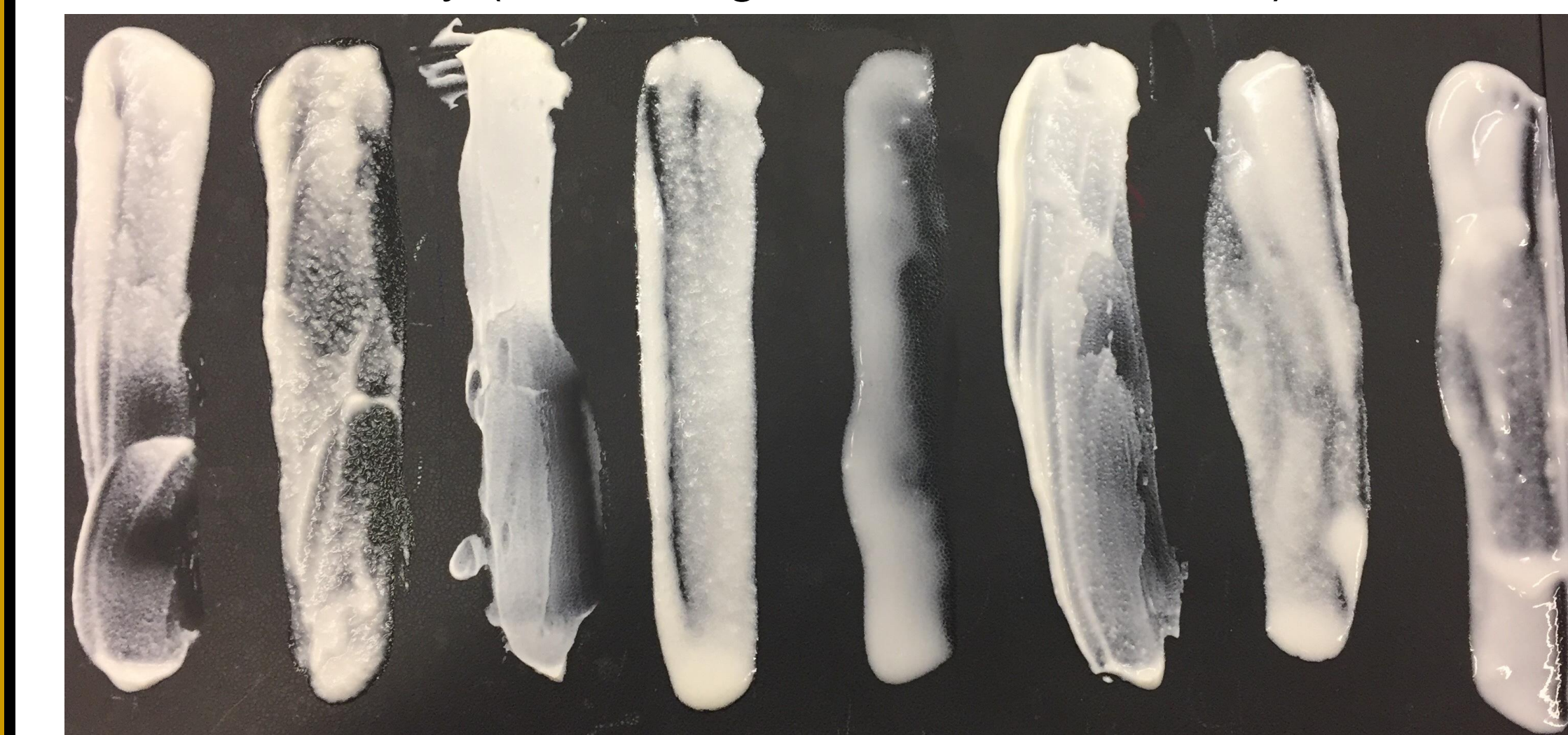
Step	Temperature (°C)	Vacuum (mTorr)	Time (min)
Thermal	1	-40	330
Drying	1	-25	300
	2	-20	300
	3	-15	300
	4	-10	300
	5	-5	300
	6	0	300
	7	5	300
	8	10	300
	9	20	300
Post Heat	1	30	120



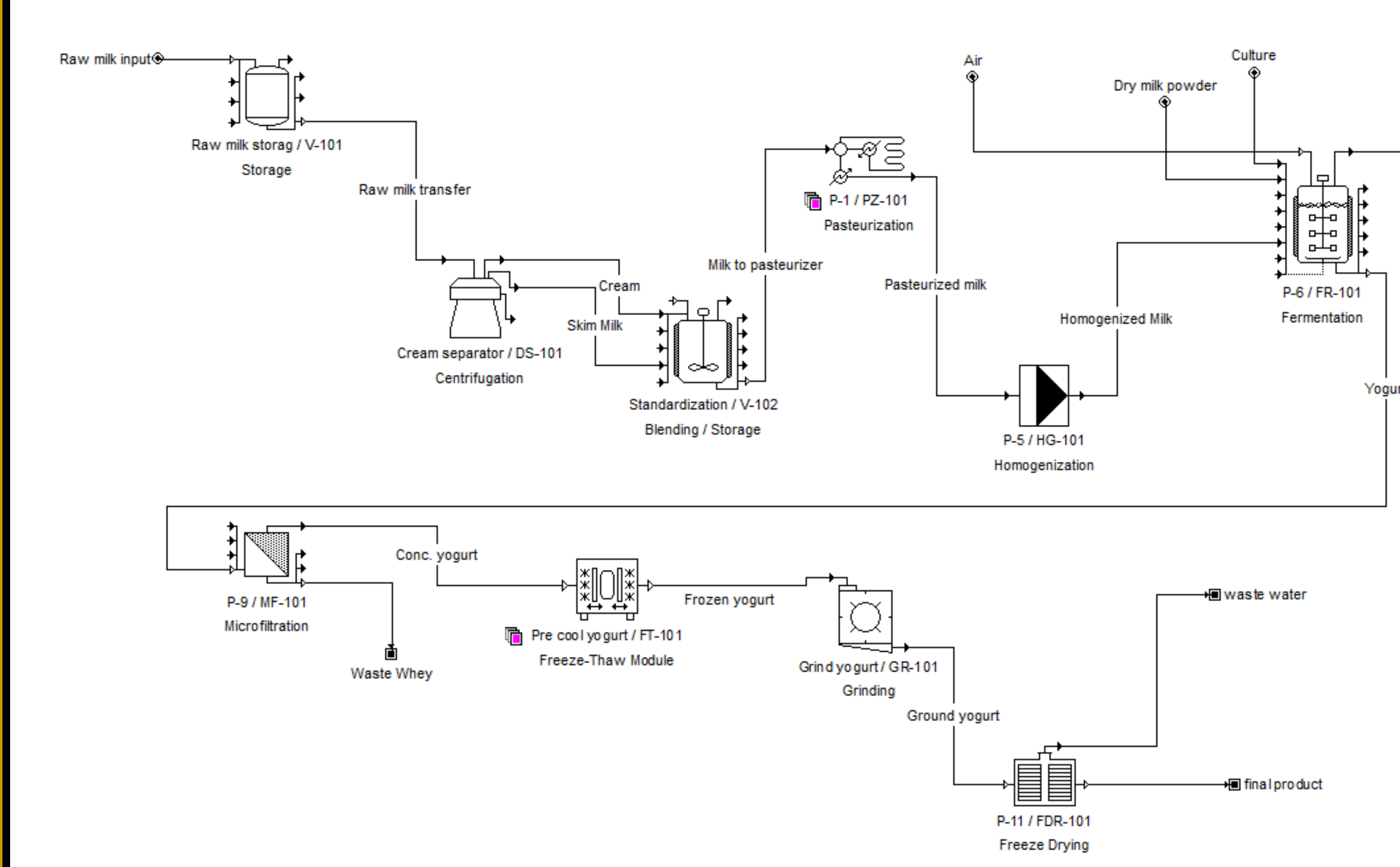
Lactic Acid Bacteria Counts: Fresh vs. Freeze Dried



Reconstitutibility (Left to Right: Treatments 1 to 8)



Plant Design



Economics

Retail price equivalent for yogurt products

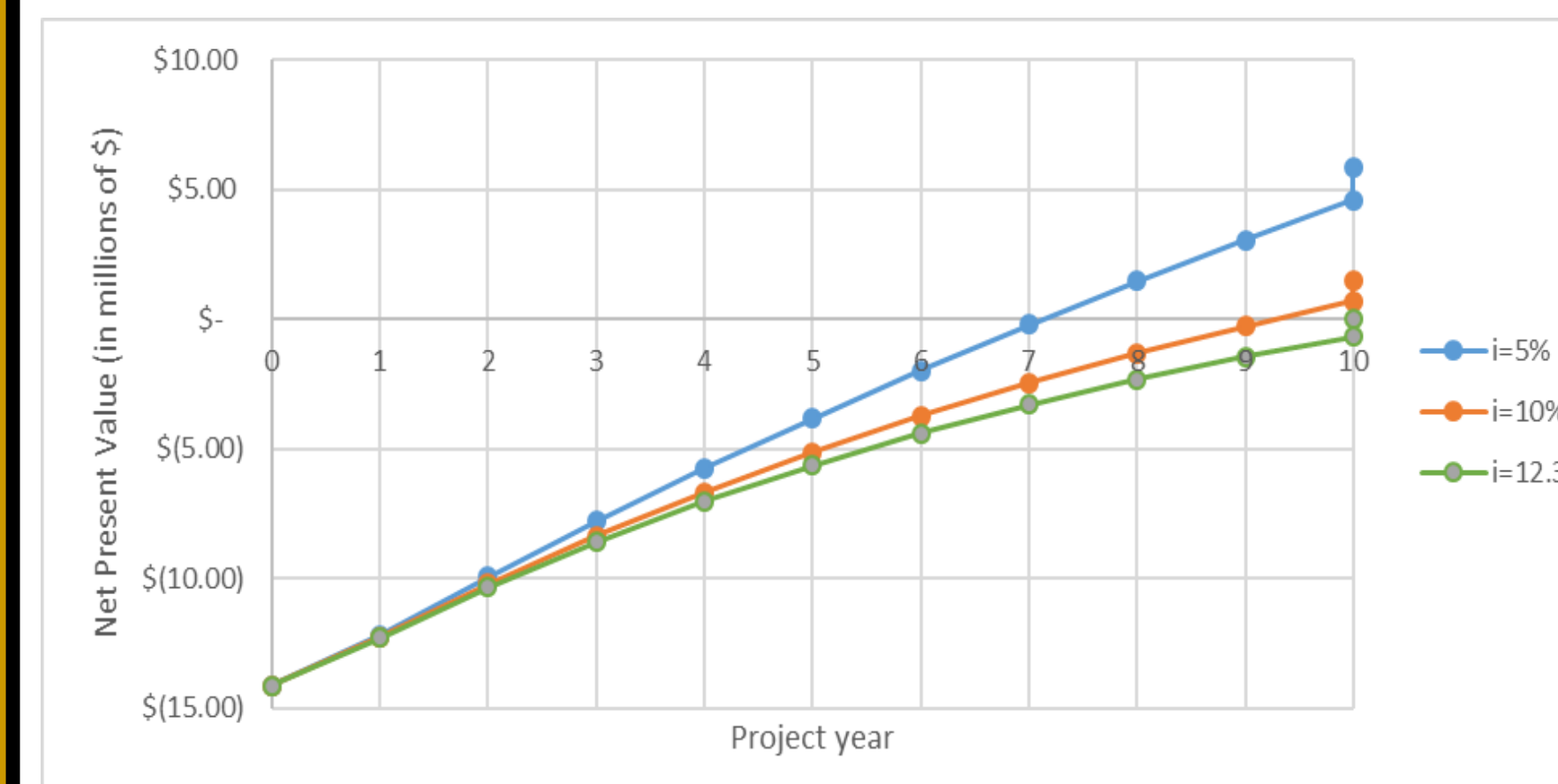
	Traditional Yogurt	Freeze Dried Yogurt
Weight	100 oz	15.4 oz
Unit Price	\$.09/oz [2]	\$2.73/oz [3]
Total Value	\$9.00	\$42.04

Summary of capital investment

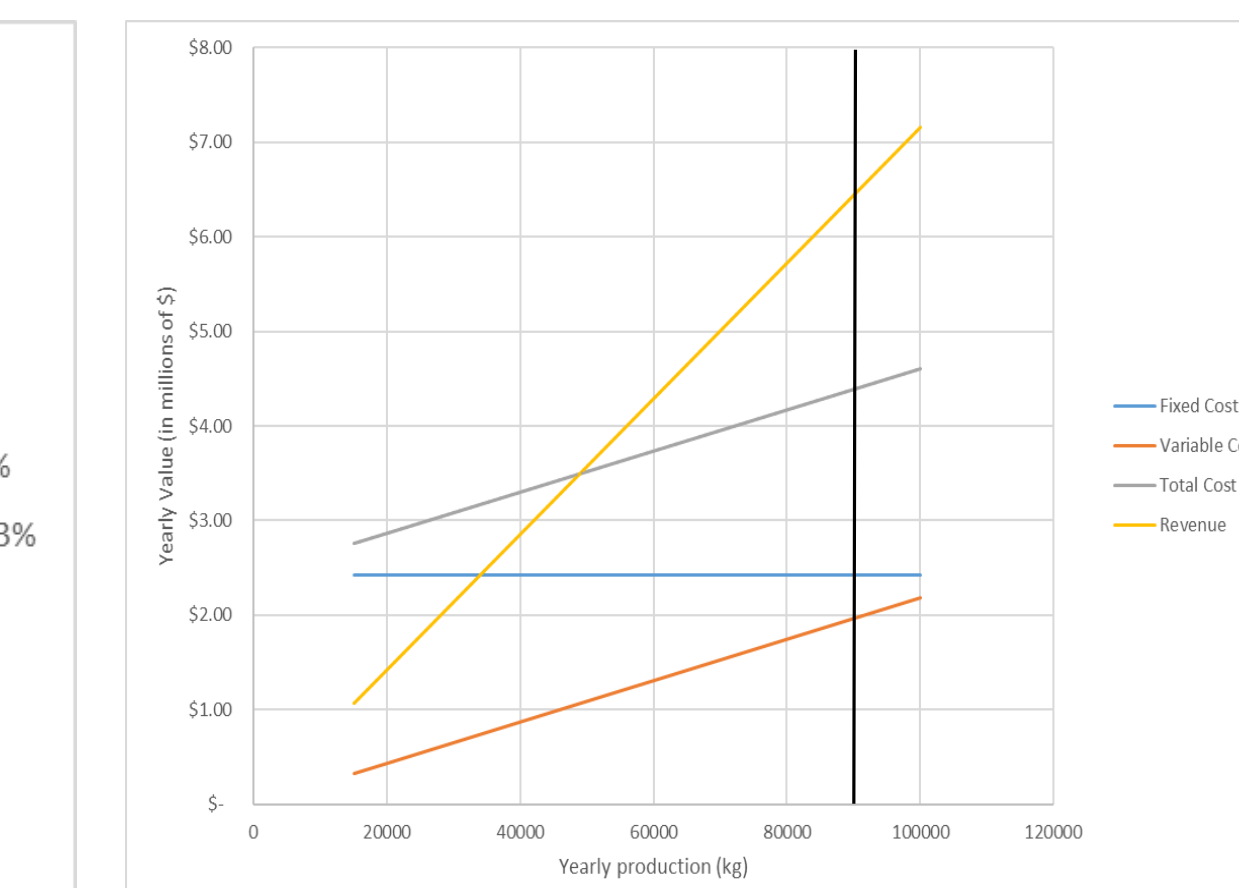
Direct Costs	\$ 8,486,200.00
Indirect Costs	\$ 3,540,600.00
FCI	\$ 12,026,800.00
Working Capital	\$ 2,107,500.00
Total Capital Investment	\$ 14,134,300.00

Summary of expenses and income

Direct Production Costs	\$ 1,920,798.70
Fixed Charges	\$ 1,731,859.20
Plant Overhead Costs	\$ 217,579.38
General Expenses	\$ 477,808.87
Total Product Cost	\$ 4,348,046.15
Income	
Yearly Production	88150 kg
Value of Final Product	\$71.52 per kg
Yearly Income	\$ 6,304,742.52
Gross Earnings	\$ 1,956,696.37



Discounted cash flow analysis



Break-even analysis

Sources:

- [1] Yogurt Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2017-2022" 2017)
- [2] Dannon® Classic Nonfat Yogurt. Retrieved March 10, 2017, from https://www.walmart.com/ip/Dannon-Plain-All-Natural-Lowfat-Yogurt-32-oz/10291169
- [3] Gerber® Graduates® Yogurt Melts® Strawberry. Retrieved March 10, 2017, from https://www.walmart.com/ip/Gerber-Graduates-Yogurt-Melts-Freeze-Dried-Yogurt-and-Fruit-Snacks-Strawberry-Naturally-Flavored-with-Other-Natural-Flavors-1-ounce-1-count/10294897

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