

Powdered Yogurt Drink

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Problem Statement:

- According to USDA, annual consumption of yogurt is approximately 7.5 lb/person (2002)
- Consumption increases more rapidly than other Dairy Class II products, such as sour cream, light and heavy cream and half&half.
- Increase in yogurt popularity due to the nutritional benefits.
- However, yogurt commonly needs cold storage thus resulting in inconvenience and short shelf life.



Culture found in yogurt!

Objective:

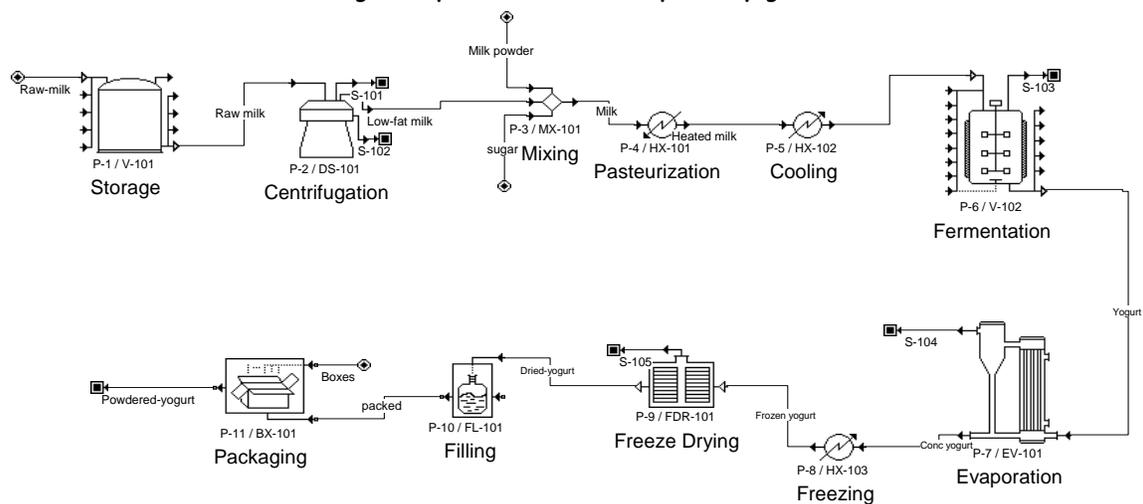
To design an economically competitive process to produce a premium quality yogurt powder drink mix

- To produce shelf stable powder yogurt.
- To achieve yogurt drink texture upon re-hydration of powder yogurt.
- To investigate operational processes and economic efficiency.

So, why make such a product?

- Product can be used under your own convenience
- Numerous health benefits
- No need to worry about spoilage for a year or so
- No refrigeration needed!
- Dairy substitute for lactose intolerance people
- Can be used in cooking, baking and confectionaries (coating, filing)

Fig. 1: Operation scheme for powder yogurt



Fermentation

- Purpose: Monod model is investigated based on our process.
- Batch process
- Time: ~4 hours
- Temperature: 45°C
- Monod's Equation
$$\mu = \frac{\mu_m C_i}{C_i + K_i}$$

- Results: Comparison of pH

| | |
|---------------------------|--------|
| Dannon brand plain yogurt | : 4.18 |
| Our yogurt | : 4.16 |



Lets make some yogurt!

Concentration of yogurt

- Purpose: Excess water is removed (to reduce drying costs)
- Conventional oven is used.
- Drying time: 6 hours
- Temperature: 70°C
- Moisture content is reduced to 70%

Rate of water removal:

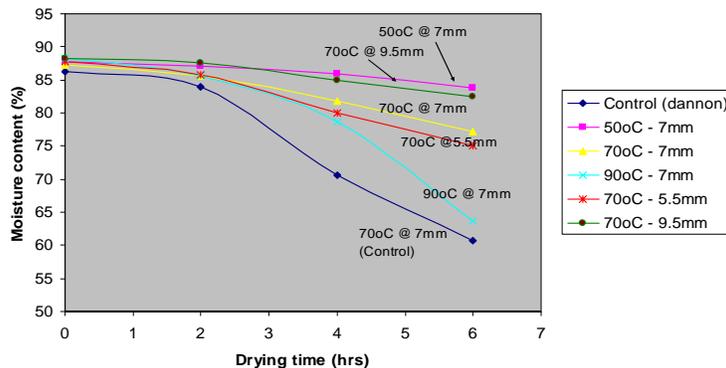
$$-\frac{dw}{dt} = A\rho(m_i - m_f)\frac{dx}{dt}$$

- Result: Shown in Fig. 2



Concentration of yogurt in force draft oven.

Fig. 2: Concentration profile as a function of Temperature and Thickness



Freeze Dryer.

Freeze Drying

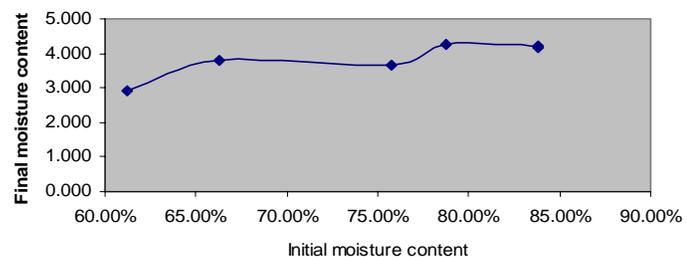
- Purpose: further dehydration of frozen concentrated yogurt under minimal damage
- Extensive browning is avoided
- Drying time: 40 hours
- Moisture content is reduced to 3-4%

Freeze-drying time:

$$t_d = \frac{L^2 \rho (m_i - m_f) \Delta H_s}{8k_d (T_s - T_i)}$$

- Result: shown in Fig 3

Fig. 3: Initial moisture content vs. Final moisture content of freeze dried yogurt



Cost Estimation

- Powdered-yogurt produced = 2,000 kg/day
- Yogurt produced = 20,000 kg/day (solid content of non-dried yogurt is 10%)
- Total Capital investment = \$7.3 million
- Direct production cost = \$18/kg
- Selling price = \$40/kg
- Annual net profit after tax = \$1.75 millions (assume 70% products sold)
- ROI = 24%



Comparison of Our Yogurt with spray-dried commercialized powdered yogurt

Equipment cost and size

- Storage tank (Vertical, medium, carbon steel)
 - Cost: \$33,500 (need ~2)
 - Size: 20,000 gal (88,000L)
- Centrifugal separator bottom driven (carbon steel)
 - Cost: \$20,400 (need ~4)
 - Size: 48" diameter (1,000L)
 - Time: 30-45 min (batch)
- Mixing/Blender Rotary Twin shell (Carbon steel)
 - Cost: \$23,900 (need ~1)
 - Size: 140ft³ (4,000L)
 - Time: 30-45 min (batch)
- Shell/Tube Heat Exchanger (Carbon steel)
 - Cost: \$13,000 (need ~1)
 - Size: 300ft²
 - Continuous process
- Jacketed-agitated Fermentor (Carbon Steel)
 - Cost: \$49,800 (need ~1)
 - Size: 3,200 gal (12,000L)
 - Time: 4 hr (batch)
- Falling film evaporator (Carbon Steel)
 - Cost: \$43,100 (need ~1)
 - Size: 250ft²
 - Continuous process
- Refrigeration at 0°F
 - Cost: \$50,000
 - Size: 0.1 million Btu/hr
 - Time: 5 hr (using Plank Eq)
- Freeze Dryer
 - Cost: \$275,000 (need ~5)
 - Size: 220ft² (400L)
 - Time: 10-12 hours

Total Purchased Equipment cost = ~\$1.7 million

■ Source: www.matche.com (cost based on 2003)

Comparison with Spray-dried commercialized powdered yogurt (combine)

| | <u>OUR Yogurt</u> | <u>Heartland Yogurt</u> | <u>Commercialized yogurt drink</u> |
|------------------|-----------------------------|---------------------------|------------------------------------|
| ■ Color | white | yellowish | depends on the flavor |
| ■ Smell | more like yogurt | more like milk | excellent |
| ■ Price | ~\$40/kg (\$1.2/300mL) | ~\$40/kg (\$1.2/300mL) | ~\$1.5/300mL |
| ■ Size of powder | uneven distribution of size | fine | N/A |
| ■ Texture | better | gummy like | smooth (more yogurt like) |
| ■ Refrigeration | no | no | yes |
| ■ Shelf-life | ~1 year | ~1 year | ~1 month |

Conclusion : Our Yogurt has better quality because it is dried under minimal damage in freeze dryer. However, more improvements needed for the freeze dried yogurt, such as adding the additives (flavoring, sugar, gum, acid, etc) Also, our yogurt has a more yogurt smell that would be more appealing for the consumer.

Conclusion and alternatives

- Freeze drying of yogurt is feasible
- Use of falling-film evaporator to concentrate yogurt (reduce time and cost)
- Replace freeze drying with other drying alternatives such as spray drying however with lower quality tolerance.
- Add flavoring to enhance the taste such as blueberry.
- Add additives, such as gums, sugars to enhance the texture of yogurt.