Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

BE 487 - Spring 2024
Biosystems Design Projects

Curd Feed Rate Optimization for Improved Cheese Consistency and Operational Efficiency (Under NDA)

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Client: Tillamook Faculty Advisors: Dr. Bahar Aliakbarian and Dr. Jiyoon Yi

Background

The key chemical attributes that characterize cheese quality are pH, salt, and moisture. Maintaining these attributes within an optimal range is essential to product consistency. Challenges at the Tillamook Boardman plant exist in the pump over operation that causes inconsistencies in curd feed rates leading to varying bed heights. Ideally, the bed height would be a single value with minimal variability.

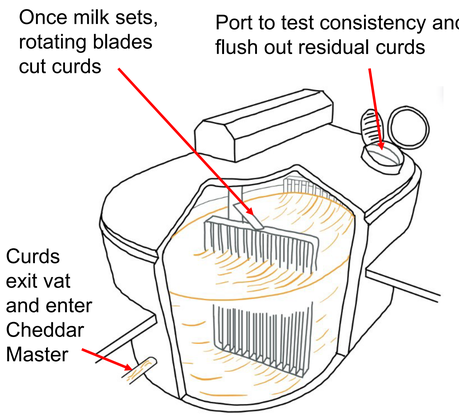

Figure 1: One of eight vats that pumps over curds to the Cheddar Master

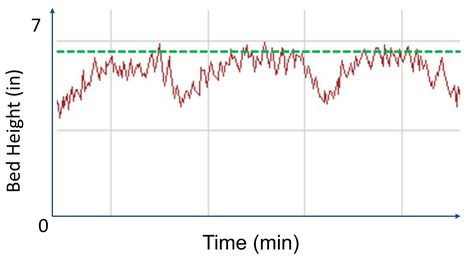

Figure 2: Curd bed height over time with ideal bed height (-)

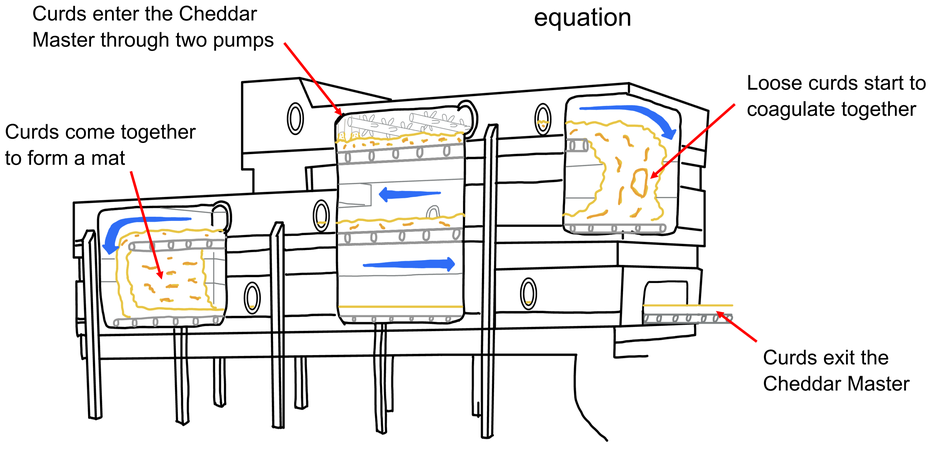

Figure 3: The Cheddar Master, a three-tiered conveyor system that separates curds and whey

Objectives

- Propose equation for vat sequencing
- Determine performance improvements
- Optimize cheese throughput
- Produce cheese yield per vat, 11-13%

Constraints

Category	Requirements
Budget	< $500,000
Curd Bed Height	6 – 7.5 inches
Vat Fill Time	33 – 35 minutes
Cheese Making Process	No change
Labor	No additional
Maintenance	No additional

Design Alternatives

New Equation:

- Two new equations for each phase
- Fit new models to data
- Accounts for different ratios of curds and whey during a vat

Double Feedback Loop:

- Use the weight and bed height sensors in tandem
- Two inputs communicate to ensure a stable bed height

Vat Overlap & Stepwise Equation:

- Overlap start and ends
- Pump vats in sequential order
- Cuts transition time between vats
- Paired with a stepwise pump speed equation

Selected Design

Part 1: Vat Resequencing

- Currently vats pumped over one side at a time
- Team proposes vats running sequentially
- Modifications to the system are required to do this

Part 2: Vat Overlap

- Periods where there are no curds being pumped
- Resequencing allows for vats to be overlapped
- Next vat is started before the previous vat ends (Fig 5)
- Results in reduction of dead period and therefore ideal bed height

Part 3: Stepwise Equation

- Current process uses a continuous curve modeled for physiochemical properties
- A stepwise function was needed to control the vat sequence overlap
- An average pump speed was taken every 3 minutes

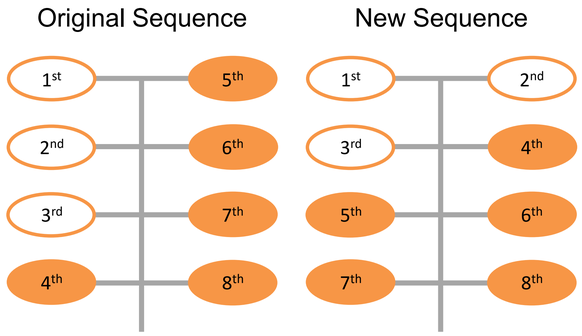

Figure 4: Vat sequencings

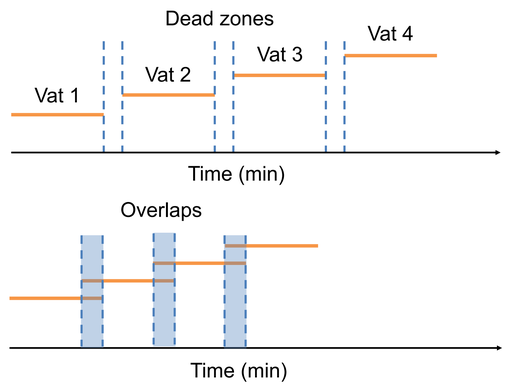

Figure 5: Vat overlap timeline

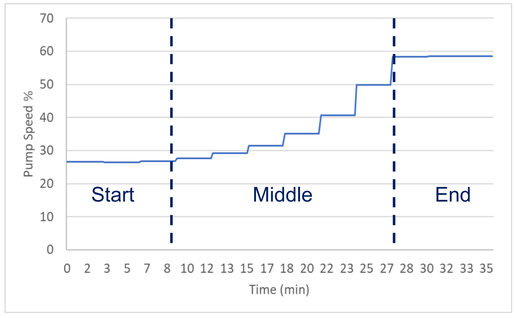

Figure 6: Pump speed stepwise graph

Density Calculation

Belt #	Mass (lb)	Volume (in^3)	Density ($\frac{lb}{in^3}$)
1	2,200	63,000	0.037
2	7,100	206,640	0.036
3	7,300	201,600	0.038

Mass Flow Calculation

Projected mass flow:

$$\frac{\sum \text{Volume “n” belt} \times \text{Density "n" belt}}{\text{Vats in CM}}$$

= 4% increase

Performance Improvements

Assumptions:

- Curd bed height is 7 inches
- 0.2% increase in moisture content in curds

$$\text{Current Cheese Yield} = 78{,}000{,}000 \ \frac{lb}{yr}$$

$$\text{Performance Increase Yield} = 81{,}000{,}000 \ \frac{lb}{yr}$$

$$\text{Total New Yield} = 81{,}162{,}000 \ \frac{lb}{yr}$$

$$\text{Total Yield Increase} = \mathbf{3{,}162{,}000 \ \frac{lb}{yr}}$$

ROI

- $0.03 saved per every extra pound of cheese produced
- Lower bound budget of $300,000
- Upper bound budget of $500,000

$$\text{Total Money Saved} = 3{,}162{,}000 \frac{lb}{yr} \times \frac{\$0.03}{lb}$$

≈ $100,000 per year

Payback Period = 3 − 5 years

Next Steps

Based off the ROI evaluation, the team can confidently recommend moving forward with the selected solution including: vat resequencing, vat overlap, and a stepwise equation. Further optimization is recommended for the stepwise function including quality testing and a trial production run.

Takeaways

- Total Cheese Yield Increase of 4%
- Payback Period of 3-5 years
- Team recommends solution
- Optimization recommended for stepwise equation

Acknowledgements

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Standards References

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